ISAAA
INTERNATIONAL SERVICE FOR THE ACQUISITION OF AGRI-BIOTECH APPLICATIONS

**ISAAA Briefs**

**BRIEF 46**

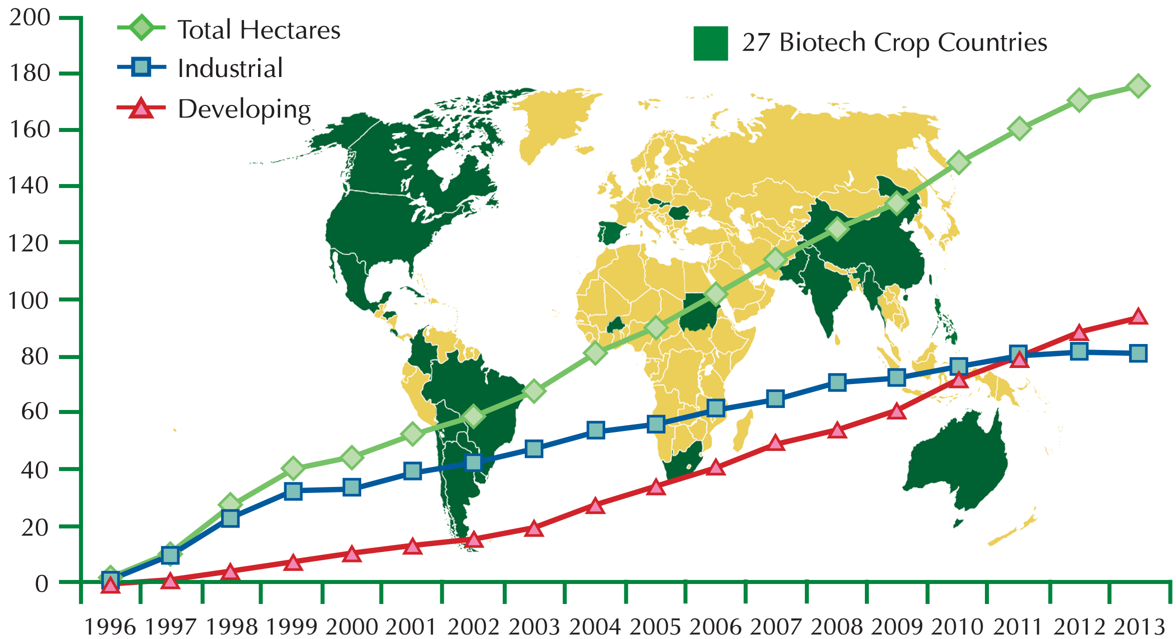
# Global Status of Commercialized Biotech/GM Crops: 2013

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 (1996-2013)**




*A record 18 million farmers, in 27 countries, planted 175.2 million hectares (433 million acres) in 2013, a sustained increase of 3% or 5 million hectares (12 million acres) over 2012.*

Source: Clive James, 2013.

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**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 2013 information for Argentina, Brazil, Australia, South Africa, and Uruguay is hectares usually planted in the last quarter of 2013 and harvested in the first quarter of 2014 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 2013 and more intensively through January and February 2014 is classified as a 2013 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. Details of the references listed in the Executive Summary are found in the full Brief 46.

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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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**Global Status of Commercialized Biotech/GM Crops: 2013**

**By Clive James, Founder and Emeritus Chair, ISAAA**

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

## TOP TEN FACTS about Biotech/GM Crops in 2013

**FACT # 1. 2013 was the 18th year of successful commercialization of biotech crops.** Biotech crops were first commercialized in 1996. Hectarage of biotech crops increased every single year between 1996 to 2013, with 12 years of double-digit growth rates, reflecting the confidence and trust of millions of risk-averse farmers around the world, in both developing and industrial countries. Remarkably, since the first plantings in 1996, an unprecedented cumulative hectarage of more than 1.5 billion hectares have been successfully cultivated, an area that is 50% more than the total land mass of China or the United States.

**FACT # 2. Biotech crop hectares increased by more than 100-fold from 1.7 million hectares in 1996, to over 175 million hectares in 2013.** This makes biotech crops the fastest adopted crop technology in recent times – the reason – they deliver benefits. In 2013, hectarage of biotech crops grew by 5 million hectares, at an annual growth rate of 3%. It is important to note that more modest annual gains, and continued plateauing, are predicted for the next few years due to the already optimal (between 90% and 100%) adoption rates for the principal biotech crops, leaving little or no room for expansion.

**FACT # 3. Number of countries growing biotech crops and stacked traits.** Of the 27 countries which planted biotech crops in 2013, 19 were developing and 8 were industrial countries. Stacked traits occupied 47.1 million hectares, or 27%.

**FACT # 4. For the second consecutive year, in 2013, developing countries planted more hectares than industrial countries.** Notably, developing countries grew more, 54% (94 million hectares) of global biotech crops in 2013 than industrial countries at 46% (81 million hectares). Successful public/private partnerships were established by several countries including Brazil, Bangladesh and Indonesia.

**FACT # 5. Number of farmers growing biotech crops.** In 2013, a record 18 million farmers, up 0.7 million from 2012, grew biotech crops – remarkably over 90%, or over 16.5 million, were small resource-poor farmers in developing countries. Farmers are the masters of risk-aversion and improve productivity through **sustainable intensification** (confining cultivation to the 1.5 billion hectares of cropland and thereby saving the forests and biodiversity). In 2013, a record 7.5 million small farmers in China and another 7.3 million in India, elected to plant more than 15 million hectares of Bt cotton, because of the significant benefits it offers. In 2013, almost 400,000 small farmers in the Philippines benefited from biotech maize.

**FACT # 6. The top 5 countries planting biotech crops – deployment of the first drought tolerant maize and stacked HT/IR soybean.** The US continued to be the lead country with 70.1 million hectares, with an average ~90% adoption across all crops. Importantly, the first biotech drought tolerant maize was planted by 2,000 US farmers on 50,000 hectares. Brazil was ranked second, and for the fifth consecutive year, was the engine of growth globally, increasing its hectarage of biotech crops more than any other country – an impressive record increase of 3.7 million hectares, up 10% from 2012, reaching 40.3 million hectares. Brazil also planted the first stacked HT/IR soybean in a record-breaking 2.2 million hectare launch, and its home-grown virus-resistant biotech bean is ready for commercialization. Argentina retained its third place with 24.4 million hectares. India, which displaced Canada for the fourth place had a record 11 million hectares of Bt cotton with an adoption rate of 95%. Canada was fifth at 10.8 million hectares with decreased plantings of canola but maintained a high adoption rate of 96%. In 2013, each of the top 5 countries planted more than 10 million hectares providing a broad, solid foundation for future growth.

**FACT # 7. Status of biotech crops in Africa.** The continent continued to make progress with South Africa benefiting from biotech crops for more than a decade. Both Burkina Faso and Sudan increased their Bt cotton hectarage by an impressive 50% and 300%, respectively, in 2013. Seven countries (Cameroon, Egypt, Ghana, Kenya, Malawi, Nigeria and Uganda) conducted field trials, the penultimate step prior to approval for commercialization. Importantly, the WEMA project is scheduled to deliver the first biotech drought tolerant maize to Africa in 2017. The lack of appropriate, science-based and cost/time-effective regulatory systems continues to be the major constraint to adoption. Responsible, rigorous but not onerous, regulation is needed, particularly for small and poor developing countries.

**FACT # 8. Status of biotech crops in the EU.** Five EU countries planted a record 148,013 hectares of biotech Bt maize, up 15% from 2012. Spain led the EU with 136,962 hectares of Bt maize, up 18% from 2012 with a record 31% adoption rate in 2013.

**FACT # 9. Benefits offered by biotech crops.** From 1996 to 2012, biotech crops contributed to Food Security, Sustainability and the Environment/Climate Change by: increasing crop production valued at US$116.9 billion; providing a better environment, by saving 497 million kg a.i. of pesticides; in 2012 alone reducing $CO_2$ emissions by 26.7 billion kg, equivalent to taking 11.8 million cars off the road for one year; conserving biodiversity by saving 123 million hectares of land from 1996-2012; and helped alleviate poverty for >16.5 million small farmers and their families totalling >65 million people, who are some of the poorest people in the world. Biotech crops are essential but are not a panacea and adherence to good farming practices such as rotations and resistance management, are a must for biotech crops as they are for conventional crops.

**FACT # 10. Future Prospects.** Cautiously optimistic with more modest annual gains expected due to the already high rates of adoption (90% or more) in the principal biotech crops in mature markets in both developing and industrial countries. Bangladesh, Indonesia and Panama approved biotech crop planting in 2013 with plans for commercialization in 2014.

# Global Status of Commercialized Biotech/GM Crops: 2013

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## Introduction

This Brief focuses on the global biotech crop highlights in 2013. 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.

2013 marks the 18th anniversary of the commercialization, 1996-2013, 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 17 years of commercialization, 1996 to 2012, 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 17 years of commercialization, 1996 to 2012, 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 2012, developing and industrial countries contributed to a record 100-fold increase in the global area of biotech crops from 1.7 million hectares in 1996 to 170 million hectares in 2012. Adoption rates for biotech crops during the period 1996 to 2012 were unprecedented and, by recent agricultural industry standards, they represent the highest adoption rates for improved crops, for example, higher than the adoption of hybrid maize in its heyday in the mid-west of the USA. High adoption rates reflect farmer satisfaction with the products that offer substantial benefits ranging from more convenient and flexible crop management, lower cost of production, higher productivity and/or net returns per hectare, health and social benefits, and a cleaner environment through decreased use of conventional pesticides, which collectively contribute to a more sustainable agriculture. There is a growing body of consistent evidence across years, countries, crops and traits generated by public sector institutions that clearly demonstrate the benefits from biotech crops. These benefits include improved weed and insect pest control with biotech herbicide tolerant and insect resistant Bt crops, that also benefit from lower input and production costs; biotech crops also offer substantial economic advantages to farmers compared with corresponding conventional crops. The severity of weeds, insect pests and diseases varies from year-to-year and country to country, and hence location will directly impact pest control costs and the economic advantages of biotech crops in any given time or place.

Despite the continuing debate on biotech crops, particularly in countries of the European Union (EU), millions of large and small farmers in both industrial and developing countries have continued to increase their plantings of biotech crops by double-digit adoption growth rates in 12 years since 1996, because of the significant multiple benefits that biotech crops offer. This high rate of adoption is a strong vote of confidence in biotech crops, reflecting farmer satisfaction in both industrial and developing countries. There were 17.3 million farmers in 28 countries who grew biotech crops in 2012 and derived multiple benefits that included significant agronomic, environmental, health, social and economic advantages. ISAAA's 2012 Global Review (James, 2012) predicted that the global area of biotech crops, would probably grow more modestly in 2013. Global population was approximately 6.5 billion in 2006 and is expected to reach approximately up to 9.3 billion by 2050, when around 90% of the global population will reside in Asia, Africa, and Latin America. The latest projection by the UN Population (United Nations, 2011 World Population Prospects: The 2010 Revision) is that the population will continue to increase until the end of this century when it will plateau at 10.1 billion. In 2011, ~1 billion people in the developing countries suffered from hunger, malnutrition and poverty. Biotech crops represent promising technologies that can make a vital contribution, but are not a panacea, to global food, feed and fiber security. Biotech crops can also make a critically important contribution to the alleviation of poverty, the most formidable challenge facing global society which has made the commitment to the Millennium Development Goals (MDG) to cut poverty, hunger and malnutrition by half by 2015; this is also the year that marks the completion of the second decade of commercialization of biotech crops, 2006-2015.

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

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

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

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

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

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

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

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

A 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.

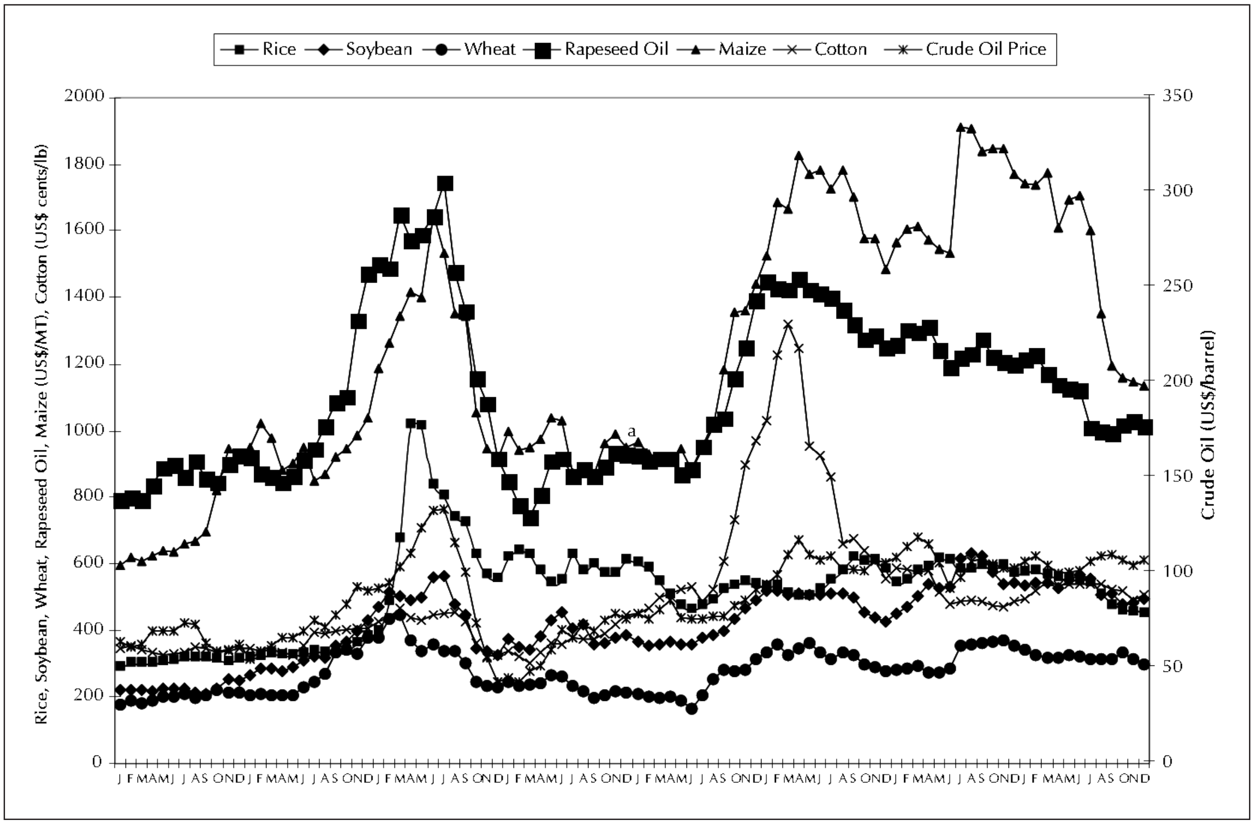
The author has published global reviews of biotech crops annually since 1996 as ISAAA Briefs: James, 2012; James 2011; James, 2010a; James, 2009; James, 2008; James, 2007; James, 2006; James, 2005; James, 2004; James, 2003; James, 2002; James, 2001; James, 2000; James, 1999; James, 1998; James, 1997; 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 2013 and the changes that have occurred between 2012 and 2013 are highlighted. The global adoption trends during the last 18 years from 1996 to 2013 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 46, 2013) is the eighteenth in an annual series. It documents the global database on the adoption and distribution of biotech crops in 2013 and in the Appendix there are five sections: 1) a table with global status of crop protection in 2012, 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 27 planting countries in 2100; and 6) 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 2013 information for Argentina, Brazil, Australia, South Africa, and Uruguay is hectares usually planted in the last quarter of 2013 and harvested in the first quarter of 2014, 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 2013 and more intensively through January and February 2014, is classified as a 2013 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 legal 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 18 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 18 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 are the trends of adoption over time, for example the increasing dominance of developing countries which is clearly evident.

Figure 1. International Prices of Crop Commodities and a Barrel of Crude Oil, 2006 to December 2013




Source: International Monetary Fund, 2013.

## Global Area of Biotech Crops in 2013

International prices of maize and soybean (IMF data in Figure 1) have not retraced the high prices of 2008 and 2011/12. The price of cotton has been low from early 2011 which resulted in a significant decrease in hectarage of biotech cotton globally. Farmers in several countries have favored soybean over maize because soybean has lower production costs and is an easier crop to grow. Some observers are predicting increases in the price of food and feed products. Generally speaking, the prices of maize (from US$8 per bushel to US$4) and canola have dropped significantly in 2013 but have continued to provide incentives for farmers worldwide, resulting in increased hectarages of the principal crops and more investments in improved technologies, including biotech crops.

Thus, in 2013, a record 175.2 million hectares of biotech crops were planted by 18 million farmers in 27 countries, compared with 170.3 million hectares grown by 17.3 million farmers in 28 countries in 2012 (Table 1). Of the total number of 27 countries planting biotech crops in 2013, 19 were developing countries and 8 industrial countries (Figure 4). Bangladesh approved a biotech crop for the first time whilst Egypt did not plant. It is notable that 5.0 million hectares more were planted in 2013 by 18 million farmers in the 18th year of commercialization at a growth rate of 3% equivalent. The highest increase in any country, in absolute hectarage growth, was Brazil with 3.7 million hectares followed by the US at 0.7 million, and Argentina at 0.5 million hectares; high percentage increases were reported for both Sudan and Burkina Faso where Bt cotton is delivering benefits at the farm level. Modest decreases in biotech crops were recorded in Canada where farmers planted more wheat in the canola rotation which is a good practice – however adoption of herbicide tolerant canola in Canada remains very high at 96%. India narrowly displaced Canada for fourth place in 2013. Australia biotech acreage decreased because cotton plantings were down due to lack of rain but where adoption and commitment to biotech cotton was still very high at a 99%

**Table 1. Global Area of Biotech Crops, the First 18 Years, 1996 to 2013**

| 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 |
| **Total** | **1,603.4** | **3,962.1** |

**Increase of 3%, 5.0 million hectares (12 million acres) between 2012 and 2013.**
Source: Clive James, 2013.

adoption (Table 3). From some points of view the biotech crop highlight of 2013 was in Bangladesh, one of the poorest countries in the world, approving Bt eggplant, an important food/vegetable crop in the country. This is clear evidence that through innovative philanthropic public/private sector partnerships very poor countries can access biotech crops provided there is the political will to support scientific innovation using science-based methodology. The Bangladesh experience can serve as a very important model for other small and poor countries to follow. Another important and growing feature witnessed in 2013 is the development and approval of home-grown biotech products by developing countries. Brazil has developed a biotech virus resistant bean which has been approved for commercialization; Bangladesh will be benefiting from a home-grown biotech product developed through a public private partnership. Indonesia has also developed a home-grown biotech sugarcane that has already been recommended for commercialization approval by the regulation agencies in the country.

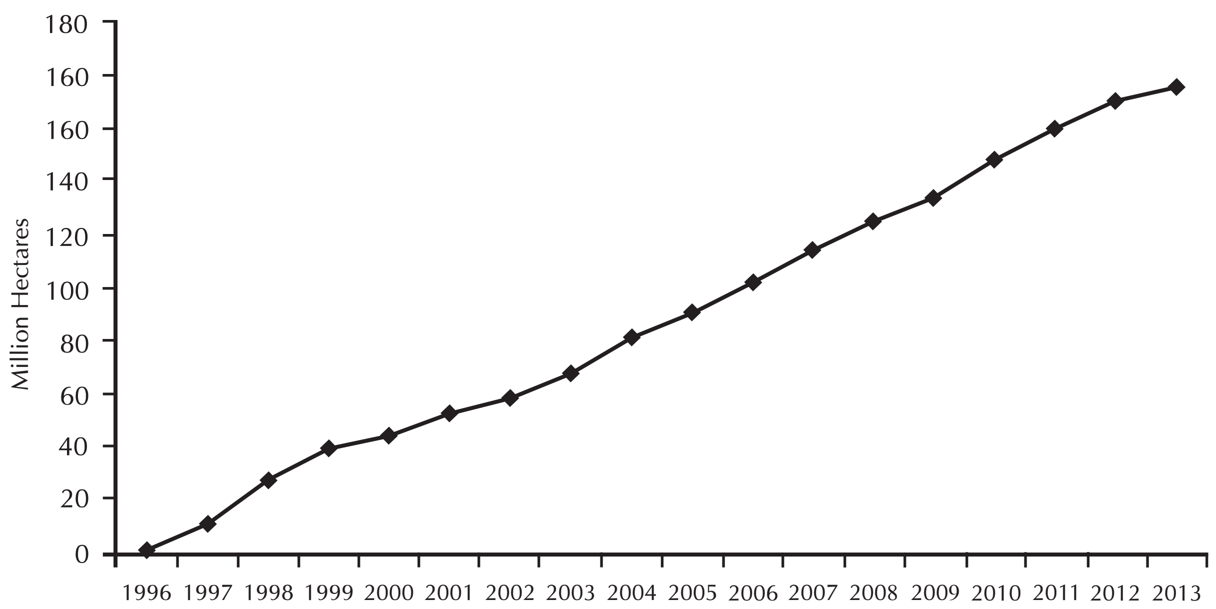
Continuing progress in 2013 in paving the way for approval of Golden Rice and commercialization in two to three years is encouraging. This is a very important development and hopefully the progress in 2013 will provide a foundation for an early as possible approval to benefit the millions of malnourished children facing a life threatening future – for more details see the section on Golden Rice in this Brief.

It is noteworthy that thanks to the leadership of Spain, hectarage of Bt maize in the EU still continues to grow despite all the obstructions placed by the EU to approval and adoption of biotech crops. Five EU countries grew a record hectarage of 148,013 hectares compared with 129,071 hectares in 2012, a significant 15% increase of biotech crops in 2013. Spain plants over 90% 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 2013 global area of biotech crops into context, 175 million hectares of biotech crops is equivalent to close to 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 2012 and 2013 of 3% is equivalent to 5 million hectares or 12 million acres (Table 1).

During the eighteen years of commercialization 1996 to 2013, the global area of biotech crops increased more than 100-fold, from 1.7 million hectares in 1996 to 175.2 million hectares in 2013 (Figure 2). This rate of adoption is the highest rate of crop technology adoption for any crop technology and reflects the continuing and growing acceptance of biotech crops by farmers in both

**Figure 2. Global Area of Biotech Crops, 1996 to 2013 (Million Hectares)**




Source: Compiled by Clive James, 2013.

large as well as small and resource-poor farmers in industrial and developing countries. In the same period, the number of countries growing biotech crops more than quadrupled, increasing from 6 in 1996 to 12 countries in 1999, 17 in 2004, 21 countries in 2005, 25 in 2009, 28 in 2012 and 27 in 2013. 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: 27 countries (developing and industrial) already planting biotech crops in 2013, with a strong indication that several new countries will join in the near term; notable and significant continuing progress in Africa with three African countries (South Africa, Burkina Faso, and Sudan), collectively planting over 3.3 million hectares in 2013. Africa is the continent with the greatest challenge; significant increases in hectarage of "new" biotech crops such as biotech maize in Brazil opens up significant additional potential hectarage for biotech crops; recently approved biotech crop products, such as the IR/HT soybean approved for Brazil; the biotech drought-tolerant maize planted for the first time in the US in 2013; high demand of RR®alfalfa for planting in the US – alfalfa is the fourth largest crop in the US (8 million hectares) after maize, soybean and wheat; approval of the virus resistant bean in Brazil; continuing growth in stacked traits in cotton and maize, increasingly deployed by 13 countries worldwide ten of which are developing countries; and a new second generation of events with quality traits such as Golden Rice enriched with vitamin A, and soybean with healthier omega-3 oil.

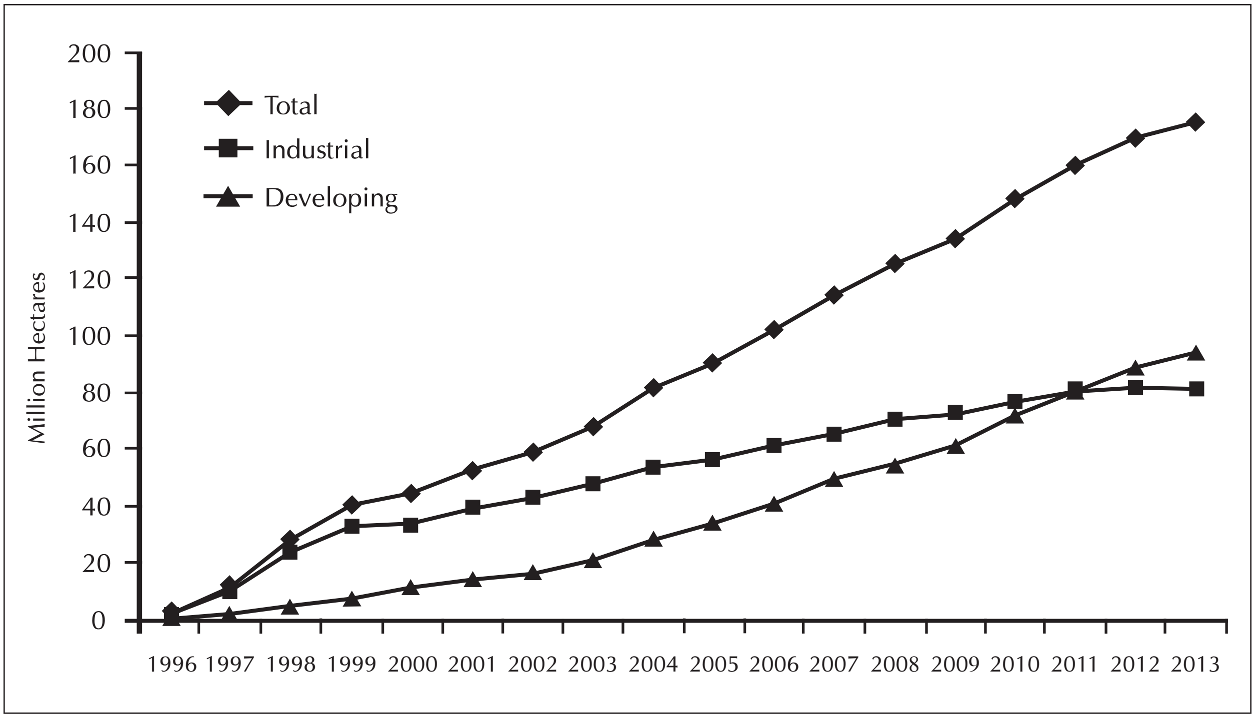
This new wave of adoption is providing a seamless interface with the first wave of adoption, resulting in continued and broad-based strong and stable growth in global hectarage of biotech crops. In 2013, the accumulated hectarage (planted since 1996) surged to 1.6 billion hectares or 4.0 billion acres. Developing countries continued to out-perform industrial countries by 12.9 million hectares and for the second consecutive year, developing countries grew more than half (54%) of the global biotech crop hectarage of over 175 million hectares. 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 year, when global society has pledged to cut poverty and hunger in half – a vital humanitarian goal that biotech crops can contribute to, in an appropriate and significant way in developing countries. The MDG provides global society and the scientific community with a one-time opportunity to urgently set explicit humanitarian goals, more specifically the imperative priority of food security and reducing hunger and poverty by 50% by 2015, to which biotech crops can make a significant contribution.

In summary, during the first eighteen years of commercialization 1996 to 2013, an accumulated total of 1.6 billion hectares, equivalent to 4.0 billion acres of biotech crops, have been successfully grown as a result of ~100 million independent decisions by farmers to plant biotech crops (Table 1). Farmers have signaled their strong vote of confidence in crop biotechnology by consistently 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 27 in the same 18-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 2013. It illustrates that in 2013 for the second time, developing countries planted more than half of the 175.2 million hectares of global biotech crops. In 2013, developing countries, planted 54% (compared with 52% in 2012) equivalent to 94.1 million hectares. Industrial countries planted only 46% (compared with 48% in 2012) equivalent to 81.1 million hectares in 2013 (Table 2). Figure 3 illustrates that prior to 2013, 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 2013, more than half of the global biotech crop area of 175.2 million hectares, equivalent to 94.1 million hectares was grown in 19 developing countries where growth continued to be strong, compared with the 8 industrial countries growing 81.1 million hectares of biotech crops equivalent to 46% (Table 2). The increase in hectarage between 2012 and 2013

**Figure 3. Global Area of Biotech Crops, 1996 to 2013: Industrial and Developing Countries (Million Hectares)**




Source: Clive James, 2013.

**Table 2. Global Area of Biotech Crops, 2012 and 2013: Industrial and Developing Countries (Million Hectares)**

| | 2012 | % | 2013 | % | +/- | % |
|---|---|---|---|---|---|---|
| Industrial countries | 81.8 | 48 | 81.1 | 46 | -0.6 | -0.7 |
| Developing countries | 88.5 | 52 | 94.1 | 54 | 5.6 | +6.3 |
| **Total** | **170.3** | **100** | **175.2** | **100** | **5.0** | **+3** |

Source: Clive James, 2013.

for developing countries was 5.6 million hectares or 6.3% versus 0.6 million hectares or –0.7% in industrial countries. Thus, growth was significantly faster in developing countries compared with industrial countries, whether measured in absolute hectares or in percentage growth. The strong trend for higher growth in developing countries versus industrial countries is highly likely to continue in the near, mid and long-term, as more countries from the South adopt biotech crops and crops such as rice, 90% of which is grown in developing countries, are deployed as new biotech crops.

## Distribution of Biotech Crops, by Country

A total of 27 countries, 19 developing and 8 industrial countries, planted biotech crops in 2013. The top ten countries, each of which grew over 1 million hectares in 2013, are listed by hectarage in Table 3 and Figure 4, led by the USA which grew 70.1 million hectares (40% of global total), Brazil with 40.3 million hectares (23%), Argentina with 24.4 million hectares (14%), India with 11.0 million hectares (6%), Canada with 10.8 million hectares (6%), China with 4.2 million hectares (2%), Paraguay with 3.6 million hectares (2%), South Africa 2.9 million hectares (2%), Pakistan 2.8 million hectares (2%), and Uruguay with 1.5 million hectares or 1% of global biotech hectarage. An additional 17 countries grew a total of approximately 3.6 million hectares in 2013 (Table 3 and Figure 4). It should be noted that of the top ten countries, each growing 1.0 million hectares or more of biotech crops, the majority (8 out of 10) are developing countries, viz Brazil, Argentina, India, China, Paraguay, South Africa, Pakistan, and Uruguay compared with only two industrial countries, USA and Canada. The number of biotech mega-countries (countries which grew 50,000 hectares, or more, of biotech crops) was 19 compared to 18 in 2012. 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 2013, 19 out of 27 equivalent to 70% 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 18 years.

It is noteworthy, that in absolute hectares, the largest year-over-year growth, by far, was Brazil at 3.7 million hectares, followed by the US at 0.7 million hectares and Argentina at 0.5 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 14%.

Bt brinjal was approved for planting in Bangladesh in October 2013 and is expected to be cultivated in 2014. Brinjal (eggplant/aubergine) is a very important vegetable in Bangladesh, where it is

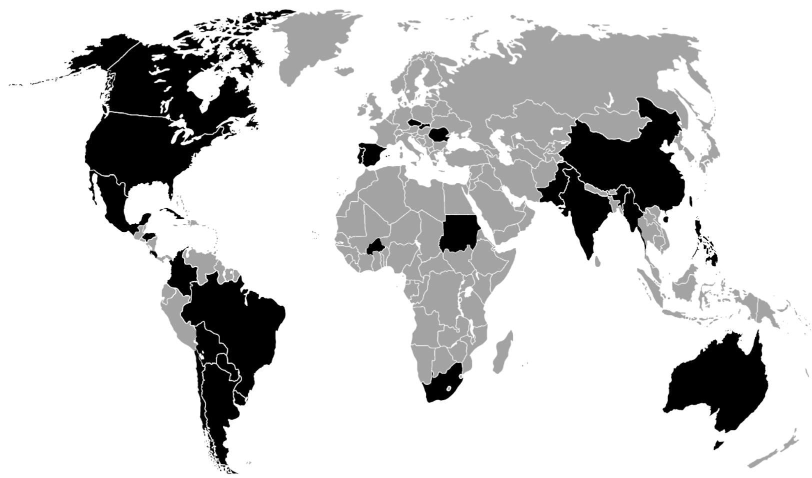
Table 3. Global Area of Biotech Crops in 2012 and 2013: by Country (Million Hectares**)

| | Country | 2012 | % | 2013 | % | +/- | % |
|---|---|---|---|---|---|---|---|
| 1 | USA* | 69.5 | 41 | 70.1 | 40 | +0.7 | +1 |
| 2 | Brazil* | 36.6 | 21 | 40.3 | 23 | +3.7 | +10 |
| 3 | Argentina* | 23.9 | 14 | 24.4 | 14 | +0.5 | +2 |
| 4 | India* | 10.8 | 6 | 11.0 | 6 | +0.2 | +2 |
| 5 | Canada* | 11.6 | 7 | 10.8 | 6 | -0.8 | -7 |
| 6 | China* | 4.0 | 2 | 4.2 | 2 | +0.2 | +5 |
| 7 | Paraguay* | 3.4 | 2 | 3.6 | 2 | +0.2 | +6 |
| 8 | South Africa* | 2.9 | 2 | 2.9 | 2 | 0 | 0 |
| 9 | Pakistan* | 2.8 | 2 | 2.8 | 2 | 0 | 0 |
| 10 | Uruguay* | 1.4 | 1 | 1.5 | 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* | 0.7 | <1 | 0.6 | <1 | -0.1 | – – |
| 14 | Burkina Faso* | 0.3 | <1 | 0.5 | <1 | +0.2 | – – |
| 15 | Myanmar* | 0.3 | <1 | 0.3 | <1 | <0.1 | – – |
| 16 | Spain* | 0.1 | <1 | 0.1 | <1 | <0.1 | – – |
| 17 | Mexico* | 0.2 | <1 | 0.1 | <1 | -0.1 | – – |
| 18 | Colombia* | <0.1 | <1 | 0.1 | <1 | <0.1 | – – |
| 19 | Sudan* | <0.1 | <1 | 0.1 | <1 | <0.1 | – – |
| 20 | Chile | <0.1 | <1 | <0.1 | <1 | <0.1 | – – |
| 21 | Honduras | <0.1 | <1 | <0.1 | <1 | <0.1 | – – |
| 22 | Portugal | <0.1 | <1 | <0.1 | <1 | <0.1 | – – |
| 23 | Cuba | <0.1 | <1 | <0.1 | <1 | <0.1 | – – |
| 24 | Czech Republic | <0.1 | <1 | <0.1 | <1 | <0.1 | – – |
| 25 | Costa Rica | <0.1 | <1 | <0.1 | <1 | <0.1 | – – |
| 26 | Romania | <0.1 | <1 | <0.1 | <1 | <0.1 | – – |
| 27 | Slovakia | <0.1 | <1 | <0.1 | <1 | <0.1 | – – |
| | **Total** | **170.3** | **100** | **175.2** | **100** | **+5.0** | **+3** |

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

Source: Clive James, 2013.

## Figure 4. Global Area (Million Hectares) of Biotech Crops, 1996 to 2013, by Country, Mega-Countries, and for the Top Ten Countries



**Biotech Mega-Countries**

**50,000 hectares, or more**

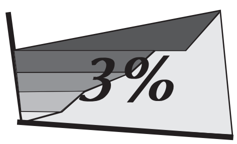
| | | |
|---|---|---|
| 1. | USA | 70.1 million |
| *2.* | *Brazil** | 40.3 million |
| *3.* | *Argentina** | 24.4 million |
| *4.* | *India** | 11.0 million |
| 5. | Canada | 10.8 million |
| *6.* | *China** | 4.2 million |
| *7.* | *Paraguay** | 3.6 million |
| *8.* | *South Africa** | 2.8 million |
| *9.* | *Pakistan** | 2.8 million |
| *10.* | *Uruguay** | 1.5 million |
| *11.* | *Bolivia** | 1.0 million |
| 12. | *Philippines** | 0.8 million |
| *13.* | Australia | 0.6 million |
| *14.* | *Burkina Faso** | 0.5 million |
| *15.* | *Myanmar** | 0.3 million |
| 16. | Spain | 0.1 million |
| *17.* | *Mexico** | 0.1 million |
| *18.* | *Colombia** | 0.1 million |
| *19.* | *Sudan** | 0.1 million |

**Less than 50,000 hectares**

| | |
|---|---|
| *Chile** | Czech Republic |
| *Honduras** | *Costa Rica** |
| Portugal | Romania |
| *Cuba** | Slovakia |

** Developing countries*

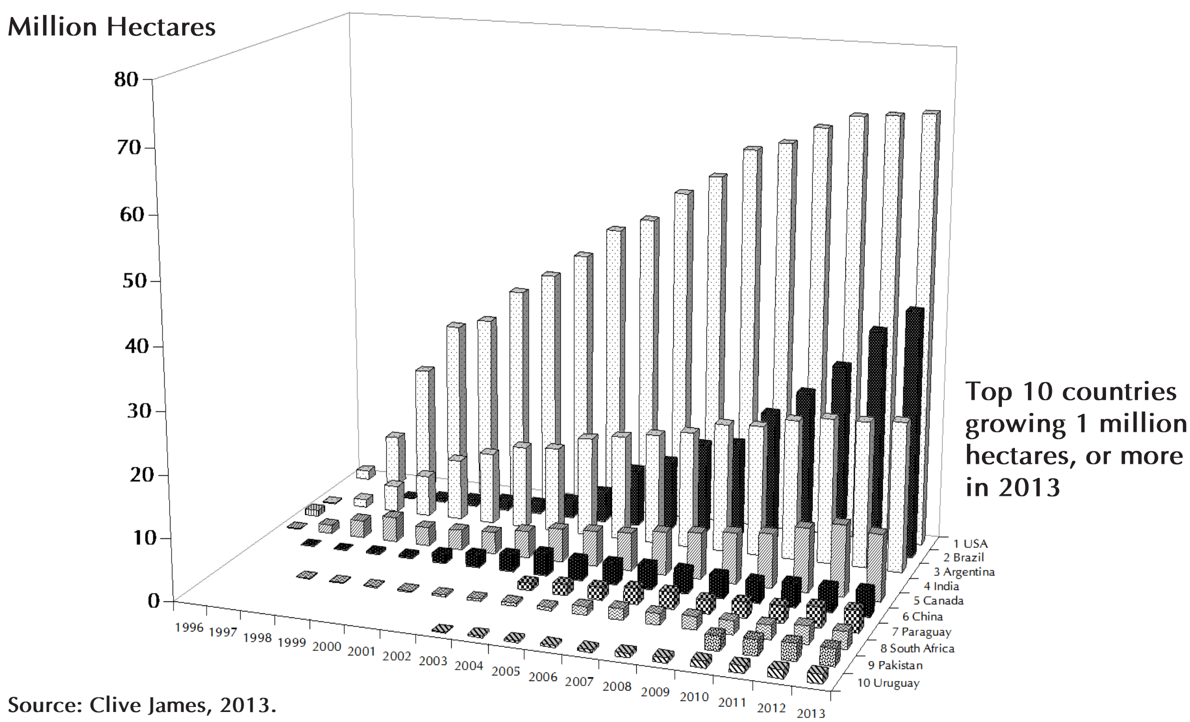
*Increase over 2012*




■ 27 countries which have adopted biotech crops

In 2013, global area of biotech crops was 175.2 million hectares, representing an increase of 3% over 2012, equivalent to 5 million hectares.

Source: Clive James, 2013.




Source: Clive James, 2013.

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 implications for producers, consumers and the environment. On 30 October 2013, in a historic decision, Bangladesh approved the official release of four biotech varieties of insect resistant Bt brinjal for seed production and initial commercialization, for planting in 2014. 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 fourth year, a commercial biotech flower, the “blue rose” in 2013. 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 2013, five EU countries continued to plant MON 810 Bt maize with an increase in hectarage of 148,013 hectares compared to 129,071 hectares in 2012. Bt maize hectarage increased significantly by 20,665 hectares in Spain. Portugal, decreased by 1,107 hectares, Romania was the same and hectarage decreased marginally in Czechia and Slovakia. These decreases were associated with several factors, including disincentives for some farmers due to bureaucratic and onerous reporting of intended plantings of Bt maize, and a limited seed supply.

**Economic benefits of biotech crops**

The six principal countries that have gained the most economically from biotech crops, during the first 17 years of commercialization of biotech crops, 1996 to 2012 are, in descending order of magnitude, the USA (US$53.1 billion), Argentina (US$15.6 billion), China (US$15.3 billion), India

(US$14.6 billion), Brazil (US$8.4 billion), Canada (US$4.9 billion), and others (US$5.0 billion) for a total of US$116.9 billion.

In 2012 alone, economic benefits globally were US$18.7 billion of which US$8.6 billion was for developing and US$10.1 billion was for industrial countries. The six countries that gained the most economically from biotech crops in 2012 were, in descending order of magnitude, the USA (US$9.1 billion), India (US$2.1 billion), China (US$2.2 billion), Argentina (US$1.6 billion), Brazil (US$1.7 billion), and Canada (US$0.72 billion), and others (US$1.28 billion) for a total of US$18.7 billion (Brookes and Barfoot, 2014, Forthcoming).

## Country Chapters

### USA

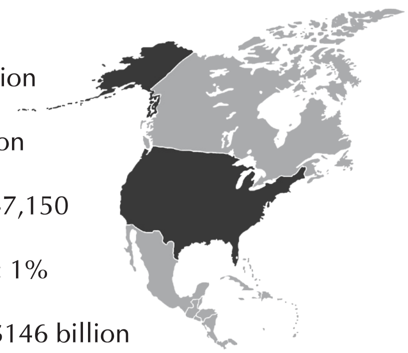
**In 2013, the USA continued to be the largest producer of biotech crops in the world, with a global market share of ~40%. The USA planted a record hectarage of 70.1 million hectares featuring eight biotech crops (maize, soybean, cotton, canola, sugar beet, alfalfa, papaya and squash) in 2013, up from the 69.5 million hectares in 2012. The country also leads the world in the deployment of stacked traits; in maize, 71% of total maize plantings were stacked and in cotton, 67% – these offer farmers multiple and significant benefits. 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 high adoption rates for the principal biotech crops in the USA are: soybean 93%, maize 90% and cotton 90% – these are close to, or at optimal with a very high average of ~90%. 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. It is estimated that the USA has enhanced farm income from biotech crops by US$53.1 billion in the first seventeen years of commercialization of biotech crops, 1996 to 2012. This represents 45% of global benefits for the same period; the benefits for 2012 alone were estimated at US$9.1 billion (representing 48% of global benefits in 2012). These are the largest economic gains for any biotech crop country. It is noteworthy that in October 2013 the World Food Prize was awarded to three biotechnologists for their internationally-recognized contributions, they were Dr. Marc Van Montagu from Belgium, and Dr. Mary-Dell Chilton and Dr. Robb Fraley from the Unites States.**

The USA is the leader of the six "founder biotech crop countries", having spear-headed the commercialization of biotech crops in 1996, the first year of global commercialization of biotech crops. The USA continued to be the lead biotech country in 2013 with 70.1 million hectares of biotech crops. USDA estimates (USDA NASS, 2013) indicate that the percentage adoption of the three principal biotech crops were at, or close to, optimal adoption – biotech maize at 90% adoption, soybean 93%, and upland cotton at 90% in 2013; total hectares of upland cotton plantings decreased by 17% in 2013 to 4.1 million hectares, because of low international prices for cotton and competition from other crops. The total hectarage planted to biotech maize, soybean, cotton, canola, sugar beets, alfalfa, papaya and squash was 70.1 million hectares compared with 69.5 million hectares in 2012. In the USA, the three principal major biotech crops of soybean, maize and cotton are now at, or close to, optimal levels with an average of ~90%; biotech sugar beets are at 98% adoption and canola at 93%.

The discovery of a few biotech wheat plants in Oregon in 2013 (the cause of which is still unclear) resulted in a temporary turmoil in the US$7 billion wheat export market.

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 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.

## USA



Population: 317.6 million

GDP: US$14,587 billion

GDP per Capita: US$47,150

Agriculture as % GDP: 1%

Agricultural GDP: US$146 billion

% employed in agriculture: 2%

Arable Land (AL): 166 million hectares

Ratio of AL/Population*: 2.4

Major crops:

| | | |
|---|---|---|
| • Maize | • Soybean | • Cotton |
| • Sugarcane | • Sugarbeet | • Alfalfa |
| • Wheat | • Canola | |

Commercialized Biotech Crops:

| | | |
|---|---|---|
| • HT/Bt/HT-Bt Maize | • HT Soybean | • HT Canola |
| • Bt/HT/Bt-HT Cotton | • VR Squash | • VR Papaya |
| • Bt/HT Potato | • Sugarbeet | • HT Alfalfa |

Total area under biotech crops and (%) increase in 2013:
70.5 Million Hectares (+1%)

Farm income gain from biotech, 1996-2012: $53.1 billion

*Ratio: % global arable land / % global population

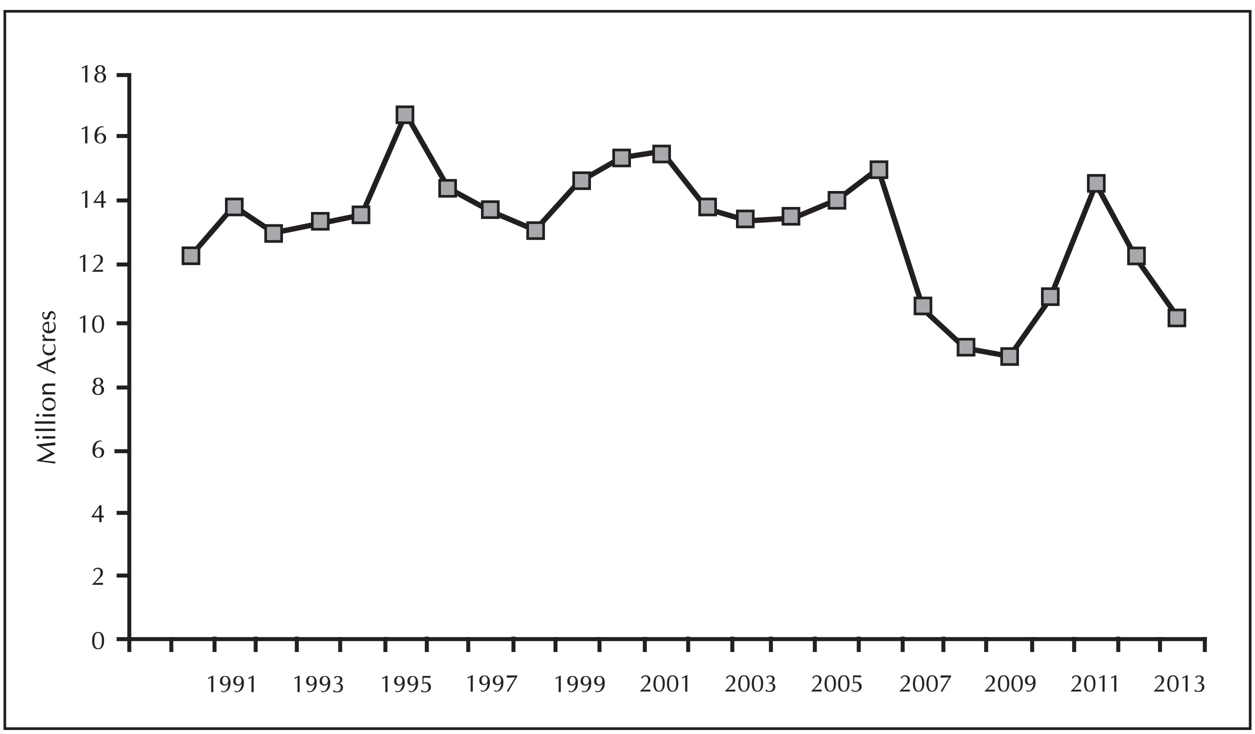
Source: The Economist, supplemented with Data from the World Bank, FAO and UNCTAD when necessary.

Total plantings of maize in the USA in 2013 were 39.4 million hectares, up slightly from 2012 (NASS USDA Crop, 2013) and was the same as the maize crop of 1937 when a record 39.4 million hectares of maize were planted. **The US hybrid maize seed market is valued at US$12 billion annually** and biotech maize continued to be attractive in the USA in 2012 because of increasing global demand for feed, ethanol and strong export sales. The US exports more than 40% of world exports of maize. Total plantings of soybean in the US in 2013 were slightly up at 31.4 million hectares.

USDA (2013) estimated that total plantings of upland cotton at 4.1 million hectares in 2013, was down a significant 17%, compared to 2012 (Figure 5). This is due to several factors, primarily the at-planting price ratio of cotton compared with the rotational crops, corn and soybeans, encouraged their planting where feasible. Another key factor was the large world carryover of upland cotton supplies that creates uncertainty for future price stability. China, the world's largest importer of cotton bales, is estimated to hold ~50 million bales in their reserve; compared with an annual consumption of ~36 million bales. As a result, the world stocks to use ratio exceeds 80% – a historically high level. A third cause of upland cotton planting decline is the continual climb in variable production costs for cotton (Figure 5a).

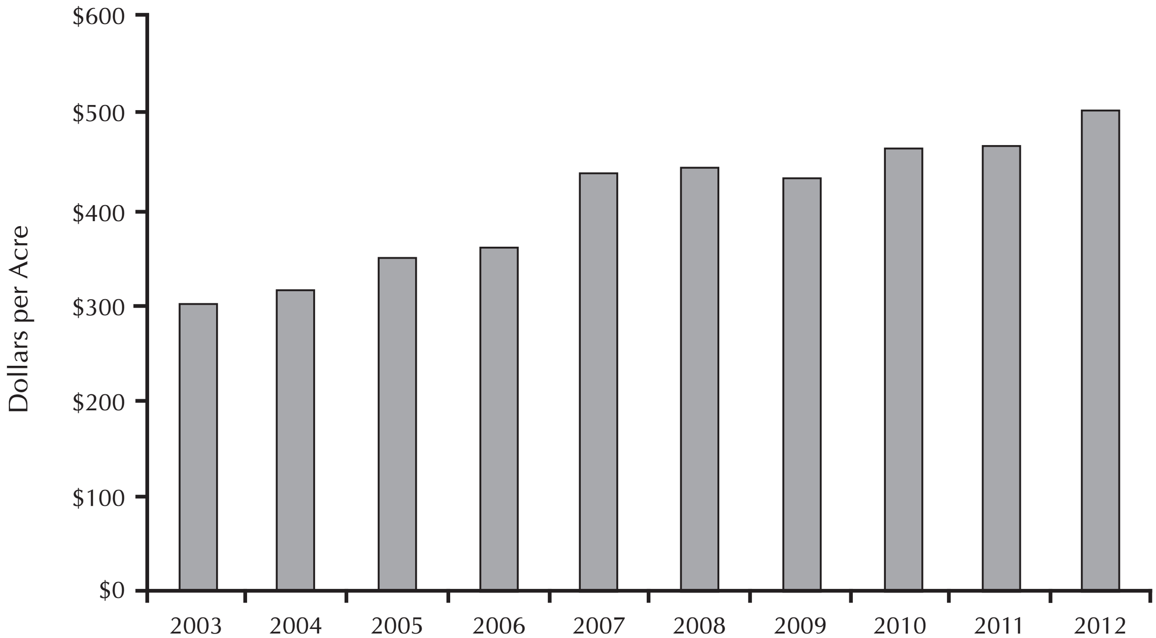
Canola hectarage in the USA in 2013 was 528,000 hectares down significantly from 661,000 hectares in 2012. Total hectarage of sugar beet in 2013 was similar at ~500,000 hectares in 2012. Estimates of alfalfa seedings for 2013 will not be available from USDA until the first quarter of 2014. However, they are not likely to be very different from 2012 seedings at approximately 1.3

**Figure 5. Cotton Planting Trend in the US, 1991-2013**




Source: USDA, 2013

**Figure 5a. Variable Production Cost per Acre of US Cotton, 2003-2012**




Source: USDA, 2013

million hectares – this includes alfalfa harvested as hay and alfalfa haylage and green chop. Alfalfa is planted as a forage crop and grazed or harvested and fed to animals, and seeded in the spring and the fall. Alfalfa is the fourth largest crop in the US at up to 8 million hectares.

In 2013, the USA continued to grow more biotech crops (70.1 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 90% or more, the gain of 0.5 million hectares in 2013 was expected. This is consistent with steady increases in the percentage adoption for the major crops which are now close to optimal with biotech soybean at 93%, cotton at 90% adoption, maize at 90% adoption, canola at 93% and sugar beet at 98%.

Stacked biotech maize and cotton continued to be the dominant trait in the two crops. 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 2013, in descending order of hectarage were: Brazil, Argentina, Canada, South Africa, Australia, the Philippines, Mexico, Uruguay, Chile, Honduras, Paraguay, and Colombia.

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 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 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 2013, the total hectarage of sugar beet was the same at approximately 485,000 hectares, of which 95% in 2011, 97% in 2012 and 98% were biotech in 2013. Canadian growers planted approximately 15,000 hectares of biotech varieties in 2009, representing nearly 96% of the nation's sugar beet crop, and in 2013, the adoption of biotech was at about the same level, 15,000, and close to 100% adoption. 2013 was the fifth year of commercial planting in Eastern Canada and the fifth year of commercial production in Western Canada. This very high adoption rate in the US of 98% in five years makes RR®sugar beet the fastest ever adopted biotech crop since biotech crops were first commercialized in 1996, eighteen years ago. 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, led by Brazil (9 million hectares), India (4 million) and China (2 million). Developing countries grow sugarcane for food and ethanol production and biotech cane is likely to be available in the near term.

The very high level of satisfaction and demand by US and Canadian farmers for RR®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, said ***"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 RR®alfalfa was first approved for commercialization in the USA in June 2005. The first pre-commercial plantings (20,000 hectares) were sown in the fall of 2005, followed by larger plantings in 2006/2007 that brought the total to approximately 100,000 hectares. A court order (not based on safety reasons) filed by critics, stopped planting in 2007, pending completion of an environmental impact statement (EIS) by USDA. Farmers who had planted the 100,000 hectares of RR®alfalfa were not required to uproot the RR®alfalfa already planted which has remained in the ground for up to 6 years, due to the perennial nature of alfalfa which is normally ploughed at up to six years. On 21 June 2010, the Supreme Court overturned the ban, and on 16 December, USDA announced that the EIS was completed, and on 27 January it declared that planting of RR®alfalfa could be resumed on 2 February 2011 – the first planting since 2007. Farmer demand has been significant and it is estimated that the total hectarage of this perennial crop planted in 2011, 2012 and 2013 could be up to ~750,000 hectares. Approximately one-third (113 out of 381) of alfalfa farmers surveyed in 2011 reported seeding RR®alfalfa, and a remarkably high 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 and 2013 was strong, because of the significant benefits it offers.

Benefits of RR®alfalfa include improved and more convenient weed control resulting in significant increases in quantity and quality of forage alfalfa as well as the crop and feed safety advantages that the product offers. Gene flow has been studied and 300 meters provides adequate isolation between conventional and biotech alfalfa and 500 meters for seed crops. RR®alfalfa plants were first produced in 1997 and field trials were initiated in 1999, followed with multiple location trials to determine the best performing varieties. Import approvals have already been secured for RR®alfalfa in major US export markets for alfalfa hay including Mexico, Canada, Japan, the Philippines and Australia – these countries represent greater than 90% of the US alfalfa hay export market. Japan is the major market for alfalfa hay exports, mainly from California and the west coast states. The USA is a major producer of alfalfa hay which occupies approximately 8 to 9 million hectares with an average yield of 7.59 metric tons per hectare of dry hay valued conservatively at US$105 per ton, worth US$7 billion per year. In addition, there is approximately 2 million hectares of alfalfa used for haylage/green chop with a yield of approximately 14.19 metric tons per hectare. The crop is sown in both the spring and the fall, with 1 to 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. Monsanto developed the biotech RR alfalfa in partnership with Forage Genetics International, a new biotech alfalfa with about a 12% lower level of lignin is currently under consideration for approval.

The following three major biotech crops: biotech soybean, maize, and cotton were grown globally, and in the US in 2013. In addition to these three major crops the following biotech crops were grown in the US in 2013; biotech alfalfa, canola, sugar beet, sweet corn, virus resistant squash and virus resistant papaya. **In a landmark decision, Japan approved the import of biotech papaya from the US in 2011, for consumption as fresh fruit/food.** The biotech papaya resistant to the papaya ring spot virus was commercialized in Hawaii, and was approved and has been available in the US since 1997, sixteen years ago. The Japanese approval was granted and officially announced by Japan's Ministry of Agriculture, Forestry and Fisheries responsible for GM processed food quality labeling, Article 7 Clause 1 on GM fresh food quality labeling was amended on 31 August 2011 to include papaya as Japan's 8th GM imported food; the notification was effective 1 December 2011 (www.caa.go.jp/jas/hyoji/pdf/kijun_03.pdf). The list of approved biotech plant products in Japan now includes the following eight GM products: soybean, maize, potato, rape seed, cotton seed, alfalfa, sugar beet and papaya.

Wal-Mart decided to market Bt and Bt/HT sweet corn in the US in 2013 because of the merits of the biotech crop over conventional; less insecticides, less insect damage and a higher quality product that contributes to sustainability. Dr. Tony Shelton entomologist at Cornell University reported that ***"One of the most spectacular examples occurred in New York plots in 2010: The Bt sweet corn had 99 to 100 percent marketable ears without any sprays, and even with eight conventional insecticide sprays, the non-Bt corn had only 18 percent marketable ears. This wasn't much better than the 6 percent marketable ears produced in the plots that received no sprays at all"*** (Cornell Chronicle, 7 October 2013).

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.

Managing resistance in insect pests will always be a challenge but recent work 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.

### Decline of US Wheat Hectarage

Stake holders in the US wheat industry are concerned that wheat is not competitive with biotech maize and soybean and as a result the hectarage of wheat has declined sharply from 1996 (when the first biotech maize and soy were planted) to 2013. In 1996, 28 million hectares of wheat were planted in the US and last year this had declined by 18%. While critics argue about potential drawbacks of biotech, wheat's loss of hectares to maize and soybean is well documented. Maize hectares increased by 10 million to reach 39 million between 1996 and 2012, whilst soy increased by 6 million to reach 31 million hectares. In the same period, wheat hectarage shrank from 28 million hectares to 22 million hectares (Capitalpress.com. 2013). Wheat farmers reported that the decline is due to its non-competitiveness compared with biotech maize and soy. 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 very worried about wheat losing market share to biotech maize and soy 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."*** Traits being developed in biotech wheat include herbicide tolerance, disease (Fusarium) 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.

### Benefits from Biotech Crops in the USA

In the most recent global study on the benefits from biotech crops, Brookes and Barfoot (2014, Forthcoming) estimated that USA has enhanced farm income from biotech crops by US$53.1 billion in the first seventeen years of commercialization of biotech crops 1996 to 2012. This represents 45% of global benefits for the same period, and the benefits for 2012 alone are estimated at US$9.1 billion (representing 48% of global benefits in 2012). These are the largest gains for any biotech crop country.

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

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

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

**In the US study, the economic benefits of this area-wide pest suppression was estimated at US$6.9 billion over the 14 year period 1996 to 2009 for the 5-state region, comprising Minnesota, Illinois and Wisconsin, Iowa and Nebraska. Of the US$6.9 billion, it is noteworthy that non-Bt corn hectares accounted for US$4.3 billion (62 percent, or almost two-thirds, of the total benefit).** The principal benefit of Bt maize is due to reduced yield losses, resulting from the deployment of Bt maize for which farmers have paid Bt maize technology fees. However, what is noteworthy is that as a result of area-wide pest suppression, farmers planting non-Bt hectares also experienced yield increases without the cost of Bt technology fees; in fact non-Bt hectares benefited from more than half (62%) of the total benefits of growing Bt maize in the 5 contiguous states.

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

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

An independent study published by the US National Research Council (2010) (an organization related to the National US Academy of Sciences) in April 2010 is entitled ***"The impact of genetically engineered (GE) crops on farm sustainability in the United States."*** The study concluded that

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

**Biotech/GM American Chestnut Trees**

Four billion magnificent American chestnut trees used to grace Americas forests until the invasive fungus *Cryphon ectria parasitica*, inadvertently imported from Asia started to colonize and kill them in the late 19$^{th}$ century – now there are only a few colonies left. The fungus killed the chestnut tree by secreting oxalic acid but this can be detoxified by an enzyme, oxalate oxidase, found in wheat. Genetic engineering was used to transfer the gene from wheat to confer resistance in the American chestnuts to the deadly fungus. In addition, genes from Chinese chestnuts, which are resistant to the fungus, were also transferred to the American chestnut. Field trials are now underway to test 800 GM chestnuts with various combinations of the 6 genes from Chinese chestnuts and the gene from wheat to determine whether resistance to the fungus has been conferred. 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. 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).

**Political Will and Support for Biotech Crops in the US**

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

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

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

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

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

- There is no evidence that unique hazards exist either in the use of rDNA techniques or in the

movement of genes between unrelated organisms;
- The risks associated with the introduction of rDNA-engineered organisms are the same in kind as those associated with the introduction of unmodified organisms and organisms modified by other methods;
- Assessment of the risk of introducing rDNA-engineered organisms into the environment should be based on the nature of the organism and the environment into which it is introduced, not on the method by which it was produced.

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

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 this year. 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).

**Regulation is the Biggest Constraint to Adoption**

On 5 November 2013 Washington State's Initiative 522 to require labelling of GM products was convincingly defeated by a vote of 54.8 percent against versus only 45.2% for labelling (Crop Biotech Update, 13 November 2013). The referendum follows a similar outcome in California late last year. California's Proposition 37 or the GMO labeling initiative appeared on voter ballots for the November 6 elections. Those opposed to the law believe that the poll was a tactic to scare consumers of the safety of GM products. Biotech labeling, which has been adopted in more than 40 countries, has never been endorsed by the FDA. The agency says crops engineered to tolerate herbicides or produce insecticide pose no greater health risks than conventional foods (Bloomberg, 2 May 2012).

A study by Alston and Sumner (Reuters, 16 September 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.

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

**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"** (http://www.aphis.usda.gov/newsroom/2011/11/ge_petition_process.shtml).

***Farmer Experience***

**A US farmer's view on biotech crops**

A Nebraska farmer, and chairman of the American Soybean Association Steve Wellman recently shared his views of Biotech crops. He 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."***
- More recently biotech drought tolerant maize trials on his farm demonstrated the opportunity to conserve moisture leading to higher 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."***
- He referred to a 2009 report by the Council for Agricultural Science and Technology (CAST) that concluded ***"today's commercialized biotechnology-derived soybean crops yield significant environmental benefits primarily by supporting conservation tillage on more fields than previously implemented."*** He agreed with the findings of the CAST report which concluded that ***"biotechnology use results in a 93 percent decrease in soil erosion, the preservation of 1 billion tons of topsoil, 70 percent reduction of herbicide and pesticide runoff, 148 million kilogram reduction in carbon dioxide emissions, 80 percent reduction in phosphorous contamination of surface water, annual soil evaporation loss reduction and 50 percent less fuel usage."***
- His message on sustainability was that with biotechnology you can produce more with less resources, and that ***"biotechnology is the driver to reach the goals that we have of sustainable agriculture production."***
- Referring to a 2012 study conducted by Stanford University he observed that advances in high-yield agriculture have prevented massive amounts of greenhouse gas from entering the atmosphere, the equivalent of 590 billion tons of carbon dioxide.
- Yield intensification has lessened the pressure to clear land, and even in the US there is a limit on land availability and if the US has to compete internationally with production make better use of the land is necessary:
- Improvement of crop yields should be prominent among portfolio strategies to reduce global greenhouse gas emissions.
- Wellman believes that biotechnology does contribute to sustainable production but is concerned about the portfolio of traits on hold awaiting approval in the EU and the effect of this delay in terms of reduced production and returns for US farmers. The delay of approvals in the EU leads to significant losses for US farmers who have to wait for up to six years for approval.
- He expressed regret that USDA is going to require a full environmental impact study which will delay the approval of the 2,4-D and dicamba resistance traits for at least two years. He said that ***"As farmers deal with some weed resistance of herbicides, glyphosate, in particular, those two tools are going to be very advantageous for U.S. producers. It comes at a bad time."*** Weed resistance to herbicides was evident long before biotechnology, so it's not

a biotech problem – on the contrary biotechnology offers a tool to manage weed resistance.

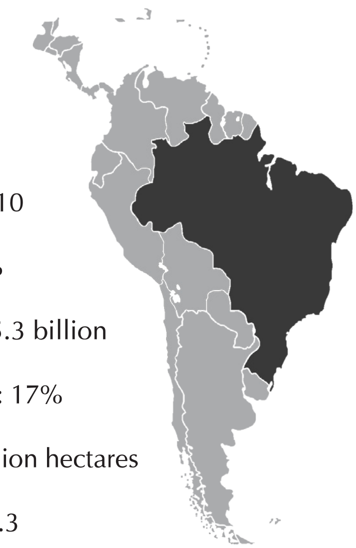
- The effort to sustainably increase production on only current land is necessary to meet increasing global demand due to a growing population and increased income. More specifically on corn, between 2000 and 2030 it is predicted that demand will increase 76% and 125% for soybeans and that will be another 70 to 80 million metric tons of soybeans required per year for the next decade.
- In conclusion 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."***

## *BRAZIL*

**In 2013, for the fifth consecutive year, Brazil recorded the largest increase of biotech/GM crops hectares of any country in the world. The total biotech crop hectares of biotech soybean, corn and cotton was estimated at ~40.3 million hectares in 2013, compared with 36.6 million in 2012, an increase of ~3.7 million hectares , or ~10%. The total biotech crop hectares of 40.3 million include 26.9 million hectares of soybean, 12.9 million hectares of corn (summer and winter corn) and 0.5 million hectares of cotton. The total planted area of these three crops in Brazil was estimated at ~46.2 million hectares of which ~40.3 million hectares or ~87% was biotech. In 2013, Brazil maintained its #2 world ranking after the USA which is #1 globally with a biotech crop hectarage of 70.0 million hectares. Brazil accounted for ~23% (up from 21% in 2012) of the global biotech crop hectarage of 175.2 million hectares of biotech crops globally. Biotech soybean is by far the most important biotech crop increasing by ~3.1 million hectares or 13% from 2012. Brazilian biotech soybean occupied 92% of the 29.5 million hectares of the national soybean crop grown in 2013/14. Biotech corn was the second most important biotech crop in Brazil with a total of 12.9 million hectares (summer 5.2 million hectares and winter 7.7 million hectares), an increase of ~6.5% from 2012. The last biotech crop in Brazil was cotton, planted on 1.07 million hectares in 2013/14 of which ~0.5 million hectares or 47.0% was biotech cotton. Biotech cotton decreased 15% in 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 approved for import by China in mid-2013, and Brazilian farmers planted it on a substantial area of ~2.2 million hectares. The home-grown virus-resistant bean, approved in 2011, is completing variety certification**

**trials and is expected to be commercialized in early 2015. Brazil is quickly emerging as the engine of biotech crop growth in the world, with a potential to increase hectarage, but, more importantly a significant potential to increase productivity. The economic benefits to Brazil from biotech crops for the sixteen year period (1996/97 to 2011/12) is US$18.8 billion and US$6.7 billion for 2012 alone (Celeres). Another annual global study of benefits from biotech crops covering a different period, concluded that Brazil gained US$8.4 billion during the nine year period 2003 to 2012 and US$1.7 for 2012 alone (Brookes and Barfoot 2014, Forthcoming)**

**<u>BRAZIL</u>**



Population: 195.4 million

GDP: US$2,088 billion

GDP per Capita: US$10,710

Agriculture as % GDP: 6%

Agricultural GDP: US$125.3 billion

% employed in agriculture: 17%

Arable Land (AL): 61.3 million hectares

Ratio of AL/Population*: 1.3

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

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

Total area under biotech crops and (%) increase in 2013:
40.3 Million Hectares (+10%)

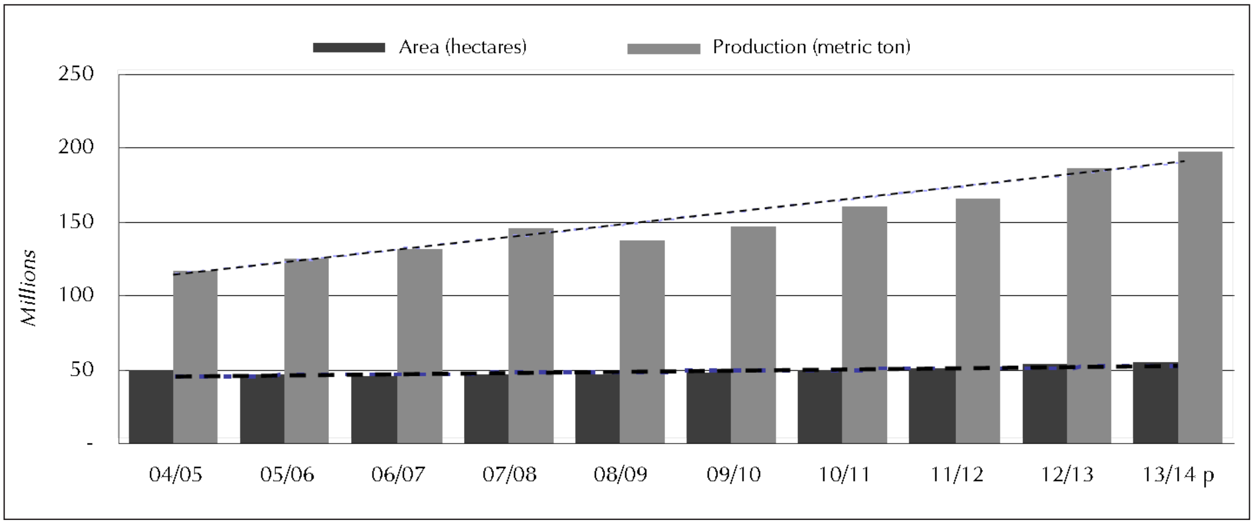
Farm income gain from biotech, 2003-2012: US$8.4 billion

*Ratio: % global arable land / % global population

The first crop estimate for 2013 (2013/2014/ by CONAB (the Brazilian agency for crop surveys), projects an increase of grain planted to a record area of 55.3 million hectares; an increase of 4.1% in planted area over 2012/2013.

Brazilian farmers are expanding their planted area, but, the most important development is in yield projections. CONAB predicts that total grain production will reach 197.5 million tons, an increase of 5.4%, compared to the great 2012/13 crop season (Figure 6). Between 2004/05 and 2013/14, harvested crop area in Brazil increased from 49.1 million hectares to 55.3 million hectares, an annual growth of 1.2%. At the same time, crop yield increased, at an annual growth of 4.2% with biotech crops making a substantial contribution. Biotech crops will also contribute to more sustainable production on crop land, and the conservation of natural resources, for future generations. During this ten year period, the crops that occupied the biggest increase in hectarage were soybean (+6.0 million ha), and winter corn (+5.5 million ha) which are normally cultivated in a soybean/corn cropping system: soybean crop in the summer season and corn in the winter season as a cover

**Figure 6. Grain Production in Brazil**




Source: CONAB | Elaboration: CÉLERES®, 2013.

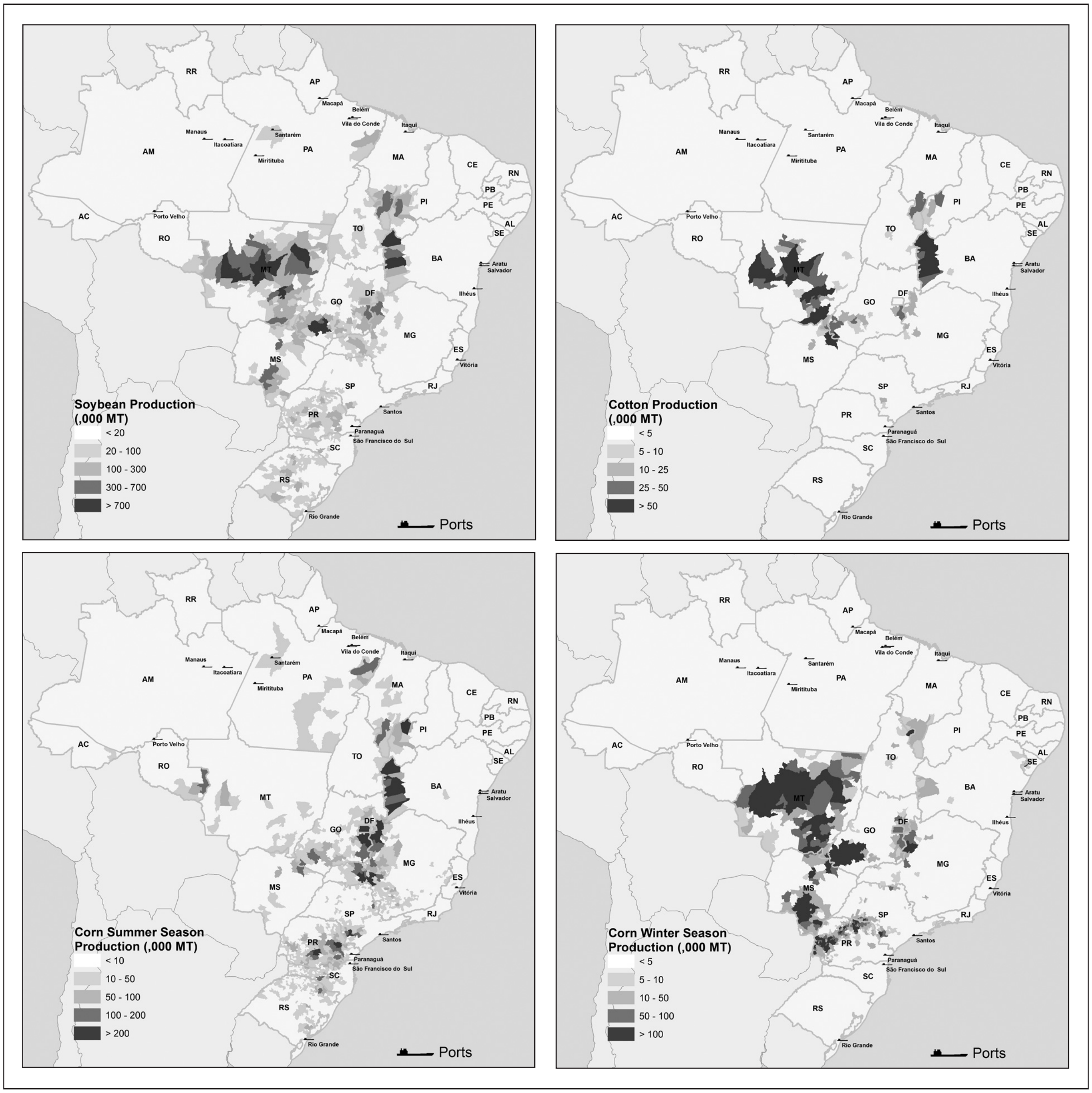
crop. The crops that suffered a decrease in hectarage during the same period were summer corn at -2.0 million ha, biotech rice (-1.53 million hectares) and edible beans (-0.82 million ha) – the latter decreased due to the high cost of crop protection which the new virus resistant bean should control.

As a result of consistent gains in yield and crop management improvement, total grain production between 2004/05 and 2013/14 increased from 116.7 million tons to 197.5 million tons, an annual growth rate of 5.4%. These gains in yield have made important contributions to Brazilian agriculture which has been one of the most dynamic sectors in the Brazilian economy, and one of the principal drivers of the thriving Brazilian economy, including significant export earnings. Agriculture and more specifically improved crop production have also protected the domestic economy from the global financial crises during the last couple of years.

According to Figure 7, the most important soybean production region in Brazil is Midwest and South. Also, Northeast and North regions are deemed to be the new agricultural frontier, such as BAMAPITO (the region comprising western Bahia, south of Maranhão and Piauí, and east of Tocantins). In the case of summer corn, the production is distributed among different regions, but Southeast and South are the highest technology usage, in contrast with North and Northeast, lowest technology usage regions. Winter corn is produced mainly in Midwest and South (only Paraná state), planted after the soybean crop (cover crop practice is common in these regions).

The most important regions of cotton production in Brazil are Midwest and Northeast (Bahia state), using high technologies for both conventional and GM production. Analyzing all the regional

## Figure 7. Geographical Distribution of Selected Grain Production in Brazil




Source: CÉLERES® based on 2012/13 crop season differences among grain production in Brazil, as a huge dimensional country, there are many specific climates and soil conditions. Therefore, constant development of new technologies is required, for both conventional and biotech crops. In fact, farmers are constantly searching for innovative technologies, especially biotech crops. In the past, most of the biotech varieties were less productive than conventional because they were not adapted to the climate and soil differences in different regions. For example, Midwest farmers, in the beginning of biotech soybean adoption, used to sow varieties adapted for South region conditions; as a result biotech soybean yield was lower than conventional, because non-biotech varieties were already adapted to Midwest conditions. Nowadays, biotech crop growers have adapted varieties and hybrids adapted to diverse climate conditions, due to the constant improvement of both technologies, for the different regions in Brazil, including the new agricultural frontier, BAMAPITO (the region comprising western Bahia, south of Maranhão and Piauí, and east of Tocantins).

In 2013 (2013/2014), Brazil for the fifth consecutive year, recorded the largest year-to-year increase of biotech crops hectares in any country in the world. Brazilian farmers planted ~40.3 million hectares of biotech crops, including soybean, corn and cotton, an increase of ~3.7 million hectares or ~10% compared with 2012/13. The total planted area of these three crops in Brazil in 2013 could reach ~46.2 million hectares of which ~40.3 million hectares or ~87% was biotech. Brazil retains its number 2 world ranking after the (US with 70.0 million hectares). Biotech soybean was by far the most important biotech crop which increased by 3.1 million hectares or 12.8% compared with 23.8 million hectares in 2012. Brazilian biotech soybean occupied 92.4% of the 29.5 million hectares of the national soybean crop grown, of which 85% is HT and 8% is IR/HT and the balance of 7% conventional (Table 4). The highest adoption rate, by region, was the South region with 94% (within which Rio Grande do Sul was the highest at 99% adoption) followed by the Southeast at 94% (São Paulo state was the highest adoption, 95%) and Midwest at 93% (Goiás state was the highest adoption, 99%).

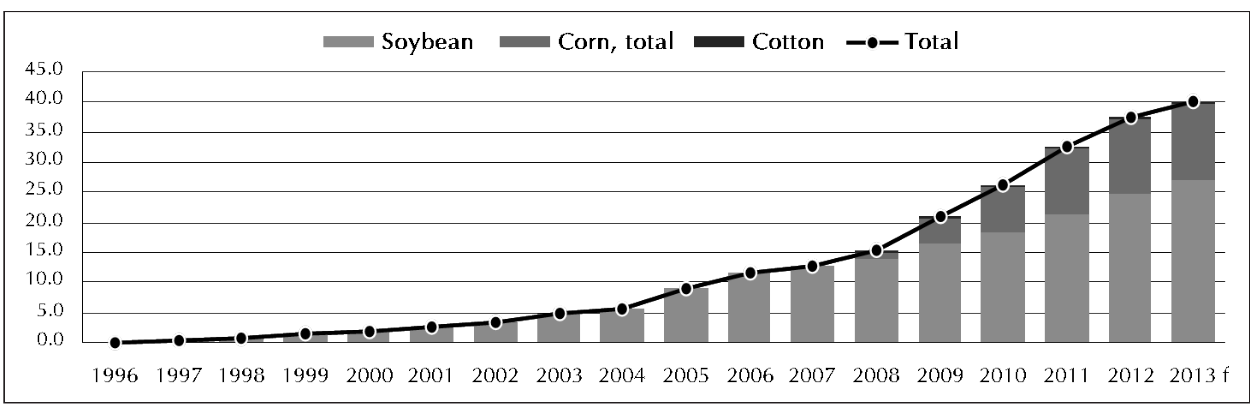
The second most important crop in Brazil is biotech corn, with a total of 12.9 million hectares (Table 5) for both summer (5.2 million hectares, Table 6) and winter (7.7 million hectares, Table 7), an increase of ~6.5% from 2012 (12.10 million hectares). In Brazil, summer and winter corn crops are discussed 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 6 and 7. Of the 7.31 million hectares of summer corn, 72% are biotech, of which 41% is IR, 28% is the IR/HT stack, and 3% is HT alone. The highest adoption, by region, is in the Southeast at 92% (São Paulo state was the first position on adoption rate, 94%), South at 89% (Paraná state was the highest adoption, 90%) and Midwest at 89% (Distrito Federal was the highest at 92% adoption). On the other hand, winter corn (also referred to as "second season corn crop") occupies a bigger hectarage than summer corn at 8.5 million hectares, and biotech winter corn is responsible for 7.7 million hectares or 90%, of which 45% is the stacked product IR/HT, 41% is IR and 5% as herbicide tolerance alone. The highest adoption, by region is in the South (only Paraná state) at 95%, followed by Midwest at 91% (Mato Grosso state – 92%) and Southeast (Minas Gerais and São Paulo states – 86%).

The last important crop in Brazil is biotech cotton, which was planted on 0.5 million hectares or 47% of 1 million total cotton hectares in 2013/14 (Table 8). This season, GM cotton decreased 15% in comparison with 2012 (0.55 million hectares). Of these 0.5 million hectares of biotech cotton, 23% is IR, 14 is HT and 10% is the stacked trait, IR/HT. The highest adoption, by region is in the Southeast at 59%, followed by the Northeast and North at 50%. Cotton prices and favorable exchange rates have been buoyant in the latter part of 2013 and have enticed more Brazilian cotton farmers to plant a larger hectarage in 2013/2014 by up to 20% particularly in the Midwest in states ranging from Mato Grosso to Goiás.

In 2013/14, 92.4% of the area grown with soybeans, 89.9% of the area with corn (winter season crop), 71.5% of the area with corn (summer season crop) and 47.0% of cotton, will be planted with biotech traits (Figure 8).

Herbicide tolerance (HT) is still the most adopted trait in 2013, with 25.4 million hectares, the stacked gene technologies (IR/HT) with 8.2 million hectares and lastly, followed by insect resistance (IR) with 6.7 million hectares (Table 9). The high rate of biotech corn adoption is impressive and it is important to note that Brazil is only in its sixth planting season and 2013 will only be the fourth year with an abundant supply of stacked traits for corn and cotton. Even so, it is already evident that usage of the single trait technology is decreasing fast in favor of the stacked traits. For example, stacked genes (IR/HT) increased by almost 49%, from 5.5 million hectares in 2012 to 8.2 million

**Figure 8. Biotech Crop Adoption in Brazil, by Crop. Values in Million Hectares**




Source: CÉLERES®, 2013.

**Table 4. Biotech Soybean Adoption in Brazil**

| | Planted Area (,000ha) | Yield (t/ha) | Production (,000 t) | Adoption rate (% of total area) | | | | Biotech Area (,000 ha) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | IR | HT | IR/HT | Total | IR | HT | IR/HT | Total |
| **NORTH** | **1.06** | **3.08** | **3.25** | – | **63.4%** | **7.3%** | **70.8%** | – | **0.67** | **0.08** | **0.75** |
| **NORTHEAST** | **2.73** | **2.94** | **8.05** | – | **79.6%** | **9.0%** | **88.6%** | – | **2.18** | **0.25** | **2.42** |
| Maranhão | 0.74 | 3.06 | 2.27 | – | 73.4% | 10.0% | 83.4% | – | 0.54 | 0.07 | 0.62 |
| Piauí | 0.65 | 2.76 | 1.79 | – | 69.9% | 8.4% | 78.3% | – | 0.45 | 0.05 | 0.51 |
| Bahia | 1.34 | 2.97 | 3.99 | – | 87.7% | 8.6% | 96.4% | – | 1.18 | 0.12 | 1.29 |
| **SOUTHEAST** | **1.86** | **3.01** | **5.59** | – | **85.0%** | **8.7%** | **93.7%** | – | **1.58** | **0.16** | **1.74** |
| Minas Gerais | 1.21 | 3.14 | 3.80 | – | 84.1% | 8.8% | 92.9% | – | 1.02 | 0.11 | 1.12 |
| São Paulo | 0.65 | 2.76 | 1.80 | – | 86.8% | 8.4% | 95.2% | – | 0.56 | 0.05 | 0.62 |
| **SOUTH** | **10.02** | **2.71** | **27.18** | – | **86.4%** | **7.7%** | **94.1%** | – | **8.66** | **0.77** | **9.43** |
| Paraná | 4.82 | 3.02 | 14.56 | – | 79.0% | 9.7% | 88.7% | – | 3.81 | 0.47 | 4.27 |
| Santa Catarina | 0.50 | 2.95 | 1.48 | – | 91.6% | 7.3% | 98.9% | – | 0.46 | 0.04 | 0.50 |
| Rio Grande do Sul | 4.70 | 2.37 | 11.14 | – | 93.5% | 5.7% | 99.1% | – | 4.39 | 0.27 | 4.66 |
| **MIDWEST** | **13.51** | **3.04** | **41.11** | – | **85.9%** | **7.4%** | **93.3%** | – | **11.60** | **1.00** | **12.61** |
| Mato Grosso | 8.31 | 3.09 | 25.70 | – | 83.9% | 7.1% | 91.0% | – | 6.97 | 0.59 | 7.56 |
| Mato Grosso do Sul | 2.13 | 2.73 | 5.81 | – | 86.8% | 7.7% | 94.5% | – | 1.84 | 0.16 | 2.01 |
| Goiás | 3.01 | 3.12 | 9.39 | – | 90.9% | 7.9% | 98.8% | – | 2.73 | 0.24 | 2.97 |
| Distrito Federal | 0.06 | 3.38 | 0.21 | – | 85.1% | 14.6% | 99.7% | – | 0.05 | 0.01 | 0.06 |
| **N/NE** | **3.79** | **2.98** | **11.30** | – | **75.1%** | **8.5%** | **83.6%** | – | **2.85** | **0.32** | **3.17** |
| **C-SOUTH** | **25.39** | **2.91** | **73.89** | – | **86.0%** | **7.6%** | **93.7%** | – | **21.84** | **1.94** | **23.78** |
| **BRAZIL** | **29.18** | **2.92** | **85.19** | – | **84.6%** | **7.7%** | **92.4%** | – | **24.69** | **2.26** | **26.95** |

Source: CÉLERES®. *Updated in: 2 August 2013

**Table 5. Biotech Corn Adoption in Brazil. Summer + Winter Seasons.**

| | Planted Area (,000ha) | Yield (t/ha) | Production (,000 t) | Adoption rate (% of total area) | | | | Biotech Area (,000 ha) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | IR | HT | IR/HT | Total | IR | HT | IR/HT | Total |
| **NORTH** | **0.56** | **2.66** | **1.48** | **7.1%** | **0.9%** | **6.6%** | **14.6%** | **0.04** | **0.01** | **0.04** | **0.08** |
| **NORTHEAST** | **2.48** | **2.18** | **5.40** | **24.6%** | **1.5%** | **20.1%** | **46.2%** | **0.61** | **0.04** | **0.50** | **1.15** |
| Maranhão | 0.56 | 2.27 | 1.26 | 36.5% | 1.8% | 29.4% | 67.7% | 0.20 | 0.01 | 0.16 | 0.38 |
| Piauí | 0.40 | 2.09 | 0.84 | 34.4% | 2.2% | 28.9% | 65.6% | 0.14 | 0.01 | 0.12 | 0.26 |
| Bahia | 0.60 | 3.48 | 2.10 | 40.9% | 2.6% | 33.4% | 76.9% | 0.25 | 0.02 | 0.20 | 0.46 |
| **SOUTHEAST** | **2.26** | **6.35** | **14.32** | **51.8%** | **4.1%** | **34.8%** | **90.7%** | **1.17** | **0.09** | **0.79** | **2.05** |
| Minas Gerais | 1.31 | 6.76 | 8.85 | 53.2% | 3.5% | 33.8% | 90.5% | 0.70 | 0.05 | 0.44 | 1.18 |
| São Paulo | 0.91 | 5.87 | 5.36 | 49.7% | 4.9% | 36.2% | 90.8% | 0.45 | 0.04 | 0.33 | 0.83 |
| **SOUTH** | **4.66** | **6.23** | **29.01** | **48.0%** | **3.9%** | **39.9%** | **91.9%** | **2.24** | **0.18** | **1.86** | **4.28** |
| Paraná | 3.08 | 6.58 | 20.26 | 47.0% | 4.4% | 42.2% | 93.7% | 1.45 | 0.14 | 1.30 | 2.88 |
| Santa Catarina | 0.51 | 6.87 | 3.52 | 48.6% | 3.4% | 36.7% | 88.7% | 0.25 | 0.02 | 0.19 | 0.45 |
| Rio Grande do Sul | 1.07 | 4.92 | 5.23 | 50.6% | 2.6% | 35.0% | 88.1% | 0.54 | 0.03 | 0.37 | 0.94 |
| **MIDWEST** | **5.88** | **5.94** | **34.91** | **40.6%** | **4.7%** | **45.6%** | **90.8%** | **2.38** | **0.27** | **2.68** | **5.34** |
| Mato Grosso | 3.19 | 6.22 | 19.85 | 40.0% | 4.8% | 46.8% | 91.6% | 1.28 | 0.15 | 1.49 | 2.92 |
| Mato Grosso do Sul | 1.44 | 4.45 | 6.41 | 40.1% | 4.8% | 45.0% | 89.8% | 0.58 | 0.07 | 0.65 | 1.29 |
| Goiás | 1.19 | 6.85 | 8.18 | 42.4% | 4.3% | 43.1% | 89.8% | 0.51 | 0.05 | 0.51 | 1.07 |
| Distrito Federal | 0.05 | 9.19 | 0.47 | 44.9% | 3.6% | 43.3% | 91.9% | 0.02 | 0.00 | 0.02 | 0.05 |
| **N/NE** | **3.04** | **2.26** | **6.88** | **21.4%** | **1.4%** | **17.6%** | **40.4%** | **0.65** | **0.04** | **0.53** | **1.23** |
| **C-SOUTH** | **12.79** | **6.12** | **78.24** | **45.3%** | **4.3%** | **41.6%** | **91.2%** | **5.79** | **0.55** | **5.32** | **11.66** |
| **BRAZIL** | **15.83** | **5.38** | **85.12** | **40.7%** | **3.7%** | **37.0%** | **81.4%** | **6.44** | **0.59** | **5.86** | **12.89** |

Source: CÉLERES®. *Updated in: 2 August 2013

**Table 6. Biotech Corn Adoption in Brazil. Summer Season.**

| | Planted Area (,000ha) | Yield (t/ha) | Production (,000 t) | Adoption rate (% of total area) | | | | Biotech Area (,000 ha) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | IR | HT | IR/HT | Total | IR | HT | IR/HT | Total |
| **NORTH** | **0.43** | **2.58** | **1.10** | **6.0%** | **0.8%** | **3.9%** | **10.7%** | **0.03** | **0.00** | **0.02** | **0.05** |
| **NORTHEAST** | **2.12** | **2.14** | **4.54** | **23.3%** | **1.6%** | **17.5%** | **42.4%** | **0.50** | **0.03** | **0.37** | **0.90** |
| Maranhão | 0.40 | 1.88 | 0.75 | 36.1% | 2.5% | 26.2% | 64.7% | 0.14 | 0.01 | 0.10 | 0.26 |
| Piauí | 0.38 | 1.94 | 0.73 | 34.2% | 2.4% | 28.3% | 64.9% | 0.13 | 0.01 | 0.11 | 0.24 |
| Bahia | 0.43 | 4.33 | 1.86 | 46.5% | 2.6% | 33.6% | 82.6% | 0.20 | 0.01 | 0.14 | 0.36 |
| **SOUTHEAST** | **1.78** | **6.75** | **11.98** | **56.2%** | **3.5%** | **32.2%** | **91.9%** | **1.00** | **0.06** | **0.57** | **1.63** |
| Minas Gerais | 1.17 | 6.78 | 7.90 | 55.4% | 3.1% | 32.5% | 91.1% | 0.65 | 0.04 | 0.38 | 1.06 |
| São Paulo | 0.58 | 6.91 | 3.97 | 58.1% | 4.0% | 31.5% | 93.6% | 0.33 | 0.02 | 0.18 | 0.54 |
| **SOUTH** | **2.41** | **6.73** | **16.24** | **50.0%** | **2.7%** | **36.1%** | **88.9%** | **1.21** | **0.07** | **0.87** | **2.15** |
| Paraná | 0.84 | 8.95 | 7.49 | 50.2% | 2.6% | 37.3% | 90.1% | 0.42 | 0.02 | 0.31 | 0.75 |
| Santa Catarina | 0.51 | 6.87 | 3.52 | 48.6% | 3.4% | 36.7% | 88.7% | 0.25 | 0.02 | 0.19 | 0.45 |
| Rio Grande do Sul | 1.07 | 4.92 | 5.23 | 50.6% | 2.6% | 35.0% | 88.1% | 0.54 | 0.03 | 0.37 | 0.94 |
| **MIDWEST** | **0.57** | **8.06** | **4.56** | **44.9%** | **3.3%** | **40.3%** | **88.5%** | **0.25** | **0.02** | **0.23** | **0.50** |
| Mato Grosso | 0.08 | 6.69 | 0.50 | 36.7% | 3.5% | 34.6% | 74.8% | 0.03 | 0.00 | 0.03 | 0.06 |
| Mato Grosso do Sul | 0.05 | 8.34 | 0.42 | 38.8% | 3.4% | 40.9% | 83.1% | 0.02 | 0.00 | 0.02 | 0.04 |
| Goiás | 0.41 | 8.10 | 3.28 | 47.0% | 3.2% | 41.1% | 91.3% | 0.19 | 0.01 | 0.17 | 0.37 |
| Distrito Federal | 0.04 | 10.10 | 0.36 | 47.0% | 3.1% | 42.2% | 92.3% | 0.02 | 0.00 | 0.02 | 0.03 |
| **N/NE** | **2.55** | **2.21** | **5.64** | **20.4%** | **1.4%** | **15.2%** | **37.1%** | **0.52** | **0.04** | **0.39** | **0.95** |
| **C-SOUTH** | **4.76** | **6.89** | **32.78** | **51.7%** | **3.1%** | **35.2%** | **90.0%** | **2.46** | **0.15** | **1.67** | **4.28** |
| **BRAZIL** | **7.31** | **5.26** | **38.42** | **40.8%** | **2.5%** | **28.2%** | **71.5%** | **2.98** | **0.18** | **2.06** | **5.23** |

Source: CÉLERES®. *Updated in: 2 August 2013

**Table 7. Biotech Corn Adoption in Brazil. Winter Season.**

| | Planted Area (,000ha) | Yield (t/ha) | Production (,000 t) | Adoption rate (% of total area) | | | | Biotech Area (,000 ha) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | IR | HT | IR/HT | Total | IR | HT | IR/HT | Total |
| **NORTH** | **0.13** | **2.92** | **0.38** | **10.9%** | **1.2%** | **15.2%** | **27.3%** | **0.01** | **0.00** | **0.02** | **0.04** |
| **NORTHEAST** | **0.36** | **2.41** | **0.86** | **32.4%** | **1.3%** | **35.4%** | **69.2%** | **0.12** | **0.00** | **0.13** | **0.25** |
| Maranhão | 0.16 | 3.23 | 0.51 | 37.5% | 0.00% | 37.7% | 75.2% | 0.06 | 0.00 | 0.06 | 0.12 |
| Piauí | 0.03 | 4.15 | 0.12 | 37.5% | 0.00% | 37.7% | 75.2% | 0.01 | 0.00 | 0.01 | 0.02 |
| Bahia | 0.17 | 1.37 | 0.23 | 27.0% | 2.8% | 32.9% | 62.6% | 0.05 | 0.00 | 0.06 | 0.11 |
| **SOUTHEAST** | **0.48** | **4.86** | **2.34** | **35.4%** | **6.4%** | **44.3%** | **86.1%** | **0.17** | **0.03** | **0.21** | **0.41** |
| Minas Gerais | 0.14 | 6.62 | 0.95 | 35.4% | 6.4% | 44.3% | 86.1% | 0.05 | 0.01 | 0.06 | 0.12 |
| São Paulo | 0.34 | 4.11 | 1.39 | 35.4% | 6.4% | 44.3% | 86.1% | 0.12 | 0.02 | 0.15 | 0.29 |
| **SOUTH** | **2.24** | **5.69** | **12.77** | **45.8%** | **5.1%** | **44.0%** | **95.0%** | **1.03** | **0.12** | **0.99** | **2.13** |
| Paraná | 2.24 | 5.69 | 12.77 | 45.8% | 5.1% | 44.0% | 95.0% | 1.03 | 0.12 | 0.99 | 2.13 |
| Santa Catarina | 0.00 | 0.00 | 0.00 | 0.00% | 0.00% | 0.0% | 0.0% | 0.00 | 0.00 | 0.00 | 0.00 |
| Rio Grande do Sul | 0.00 | 0.00 | 0.00 | 0.00% | 0.00% | 0.0% | 0.0% | 0.00 | 0.00 | 0.00 | 0.00 |
| **MIDWEST** | **5.31** | **5.71** | **30.35** | **40.1%** | **4.8%** | **46.1%** | **91.1%** | **2.13** | **0.26** | **2.45** | **4.84** |
| Mato Grosso | 3.12 | 6.21 | 19.35 | 40.1% | 4.8% | 47.1% | 92.0% | 1.25 | 0.15 | 1.47 | 2.87 |
| Mato Grosso do Sul | 1.39 | 4.31 | 5.99 | 40.1% | 4.8% | 45.1% | 90.0% | 0.56 | 0.07 | 0.63 | 1.25 |
| Goiás | 0.79 | 6.21 | 4.90 | 40.1% | 4.8% | 44.1% | 89.0% | 0.32 | 0.04 | 0.35 | 0.70 |
| Distrito Federal | 0.02 | 7.04 | 0.11 | 40.1% | 4.8% | 46.1% | 91.0% | 0.01 | 0.00 | 0.01 | 0.01 |
| **N/NE** | **0.49** | **2.55** | **1.24** | **26.7%** | **1.3%** | **30.0%** | **58.0%** | **0.13** | **0.01** | **0.15** | **0.28** |
| **C-SOUTH** | **8.03** | **5.66** | **45.45** | **41.4%** | **5.0%** | **45.4%** | **91.9%** | **3.33** | **0.40** | **3.65** | **7.38** |
| **BRAZIL** | **8.52** | **5.48** | **46.70** | **40.6%** | **4.8%** | **44.6%** | **89.9%** | **3.46** | **0.41** | **3.80** | **7.66** |

Source: CÉLERES®. *Updated in: 2 August 2013

**Table 8. Biotech Cotton Adoption in Brazil**

| | Planted Area (,000ha) | Yield (t/ha) | Production (,000 t) | Adoption rate (% of total area) | | | | Biotech Area (,000 ha) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | IR | HT | IR/HT | Total | IR | HT | IR/HT | Total |
| **NORTH** | **0.01** | **1.40** | **0.01** | **22.2%** | **14.3%** | **13.0%** | **49.5%** | **0.00** | **0.00** | **0.00** | **0.00** |
| **NORTHEAST** | **0.33** | **1.50** | **0.54** | **22.2%** | **14.3%** | **13.0%** | **49.5%** | **0.07** | **0.05** | **0.04** | **0.16** |
| Maranhão | 0.03 | 1.49 | 0.04 | 22.2% | 14.3% | 13.0% | 49.5% | 0.01 | 0.00 | 0.00 | 0.01 |
| Piauí | 0.02 | 1.32 | 0.02 | 22.2% | 14.3% | 13.0% | 49.5% | 0.00 | 0.00 | 0.00 | 0.01 |
| Bahia | 0.29 | 1.56 | 0.48 | 22.2% | 14.3% | 13.0% | 49.5% | 0.06 | 0.04 | 0.04 | 0.14 |
| **SOUTHEAST** | **0.03** | **1.43** | **0.05** | **30.7%** | **14.3%** | **13.8%** | **58.8%** | **0.01** | **0.00** | **0.00** | **0.02** |
| Minas Gerais | 0.02 | 1.46 | 0.04 | 30.7% | 14.3% | 13.8% | 58.8% | 0.01 | 0.00 | 0.00 | 0.01 |
| São Paulo | 0.01 | 1.33 | 0.01 | 30.7% | 14.3% | 13.8% | 58.8% | 0.00 | 0.00 | 0.00 | 0.00 |
| **SOUTH** | **0.00** | **0.79** | **0.00** | **9.5%** | **14.3%** | **9.9%** | **33.7%** | **0.00** | **0.00** | **0.00** | **0.00** |
| Paraná | 0.00 | 0.79 | 0.00 | 9.5% | 14.3% | 9.9% | 33.7% | 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** | **0.63** | **1.33** | **0.98** | **22.9%** | **14.3%** | **8.0%** | **45.2%** | **0.14** | **0.09** | **0.05** | **0.29** |
| Mato Grosso | 0.52 | 1.28 | 0.79 | 22.3% | 14.3% | 7.0% | 43.6% | 0.12 | 0.07 | 0.04 | 0.23 |
| Mato Grosso do Sul | 0.05 | 1.46 | 0.09 | 17.9% | 14.3% | 13.2% | 45.4% | 0.01 | 0.01 | 0.01 | 0.02 |
| Goiás | 0.06 | 1.57 | 0.10 | 32.8% | 14.3% | 11.7% | 58.8% | 0.02 | 0.01 | 0.01 | 0.03 |
| Distrito Federal | 0.00 | 1.29 | 0.00 | 32.8% | 14.3% | 11.7% | 58.8% | 0.00 | 0.00 | 0.00 | 0.00 |
| **N/NE** | **0.34** | **1.50** | **0.55** | **22.2%** | **14.3%** | **13.0%** | **49.5%** | **0.07** | **0.05** | **0.04** | **0.17** |
| **C-SOUTH** | **0.66** | **1.33** | **1.03** | **23.2%** | **14.3%** | **8.2%** | **45.7%** | **0.15** | **0.09** | **0.05** | **0.30** |
| **BRAZIL** | **1.00** | **1.39** | **1.58** | **22.9%** | **14.3%** | **9.8%** | **47.0%** | **0.23** | **0.14** | **0.10** | **0.47** |

Source: CÉLERES®. *Updated in: 2 August 2013

**Table 9. Biotech Crop Adoption in Brazil**

| | Planted Area (,000ha) | Adoption rate (% of total area) | | | | Biotech Area (,000 ha) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | IR | HT | IR/HT | Total | IR | HT | IR/HT | Total |
| **NORTH** | **1.62** | **2.5%** | **41.8%** | **7.1%** | **51.4%** | **0.04** | **0.68** | **0.11** | **0.83** |
| **NORTHEAST** | **5.55** | **12.3%** | **40.8%** | **14.2%** | **67.3%** | **0.68** | **2.26** | **0.79** | **3.73** |
| Maranhão | 1.32 | 15.8% | 42.0% | 18.3% | 76.1% | 0.21 | 0.56 | 0.24 | 1.01 |
| Piauí | 1.07 | 13.3% | 43.5% | 16.2% | 73.1% | 0.14 | 0.47 | 0.17 | 0.78 |
| Bahia | 2.23 | 13.9% | 55.4% | 15.9% | 85.1% | 0.31 | 1.24 | 0.35 | 1.90 |
| **SOUTHEAST** | **4.15** | **28.4%** | **40.5%** | **22.9%** | **91.8%** | **1.18** | **1.68** | **0.95** | **3.81** |
| Minas Gerais | 2.54 | 27.7% | 42.0% | 21.7% | 91.4% | 0.70 | 1.07 | 0.55 | 2.32 |
| São Paulo | 1.57 | 29.0% | 38.9% | 24.6% | 92.5% | 0.46 | 0.61 | 0.39 | 1.45 |
| **SOUTH** | **14.68** | **15.2%** | **60.2%** | **17.9%** | **93.4%** | **2.24** | **8.84** | **2.63** | **13.71** |
| Paraná | 7.90 | 18.3% | 49.9% | 22.4% | 90.7% | 1.45 | 3.94 | 1.77 | 7.16 |
| Santa Catarina | 1.01 | 24.6% | 47.0% | 22.1% | 93.8% | 0.25 | 0.48 | 0.22 | 0.95 |
| Rio Grande do Sul | 5.77 | 9.4% | 76.7% | 11.1% | 97.1% | 0.54 | 4.42 | 0.64 | 5.60 |
| **MIDWEST** | **20.01** | **12.6%** | **59.8%** | **18.6%** | **91.1%** | **2.53** | **11.97** | **3.73** | **18.23** |
| Mato Grosso | 12.02 | 11.6% | 59.9% | 17.6% | 89.1% | 1.39 | 7.20 | 2.12 | 10.72 |
| Mato Grosso do Sul | 3.62 | 16.2% | 53.1% | 22.6% | 91.9% | 0.59 | 1.92 | 0.82 | 3.33 |
| Goiás | 4.26 | 12.3% | 65.6% | 17.8% | 95.8% | 0.53 | 2.79 | 0.76 | 4.08 |
| Distrito Federal | 0.12 | 20.4% | 47.9% | 27.3% | 95.6% | 0.02 | 0.06 | 0.03 | 0.11 |
| **N/NE** | **7.16** | **10.1%** | **41.0%** | **12.6%** | **63.7%** | **0.73** | **2.94** | **0.90** | **4.56** |
| **C-SOUTH** | **38.84** | **15.3%** | **57.9%** | **18.8%** | **92.0%** | **5.94** | **22.49** | **7.31** | **35.74** |
| **BRAZIL** | **46.00** | **14.5%** | **55.3%** | **17.9%** | **87.6%** | **6.67** | **25.42** | **8.21** | **40.31** |

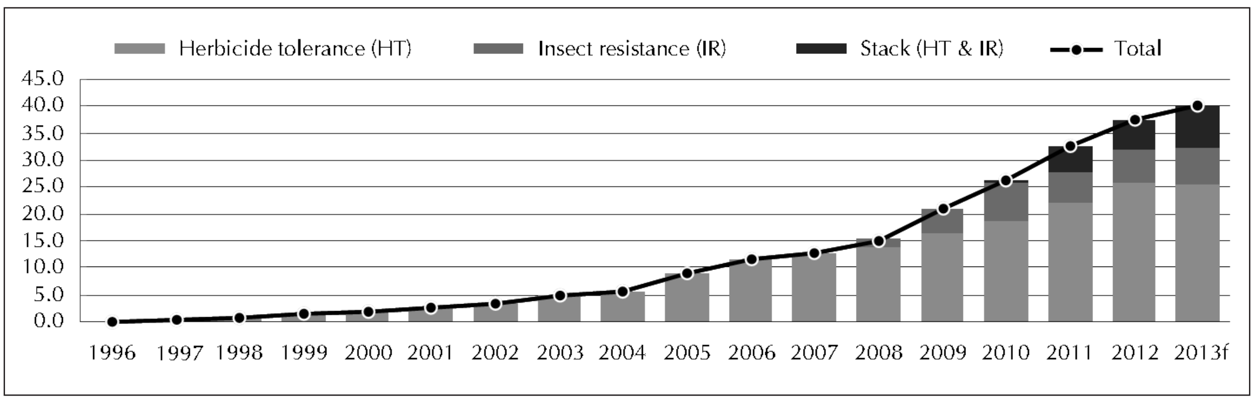
Source: CÉLERES®. *Updated in: 2 August 2013

in 2013. Thus, stacked gene technology is deployed in the three biotech crops, including the last approval of soybean, Intacta RR2®, which is estimated to be planted on a substantial 2.3 million hectares in 2013/14. Consistent with experience in other countries such as the United States and Canada, Brazilian farmers have indicated a clear preference for the stacked traits over the single traits (Figure 9).

The evolution of biotech adoption rate in the three crops: cotton, corn and soybean from the year approved for planting is presented in Figure 10.

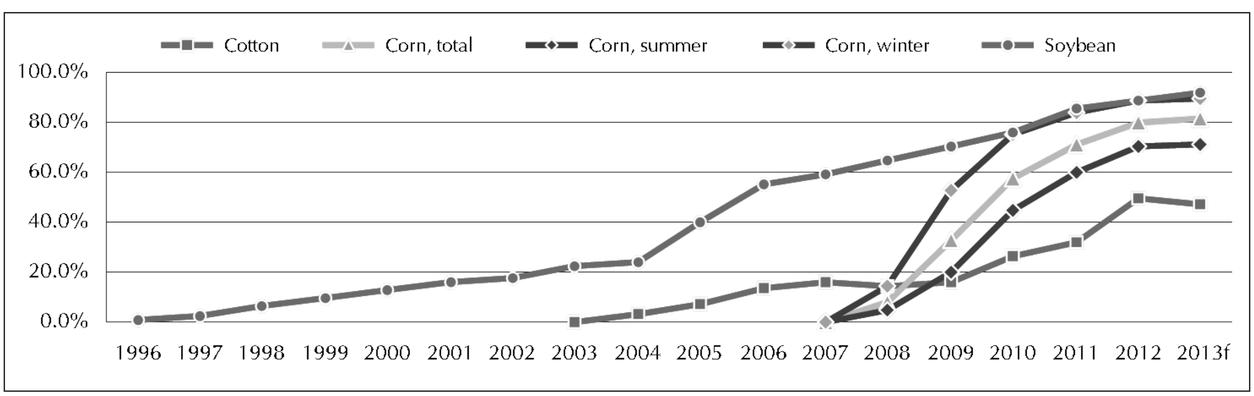
In as much as the technology developers were able to develop biotech varieties and hybrids adapted to the different farming regions in Brazil, a continuous migration of biotech crops was witnessed with adoption progressing from one end of the country to the other. Thus, in the analysis of biotech

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




Source: CÉLERES®, 2013.

**Figure 10. Evolution of Biotech Adoption Rate in Brazil, by Crop, as % of Total Acreage**



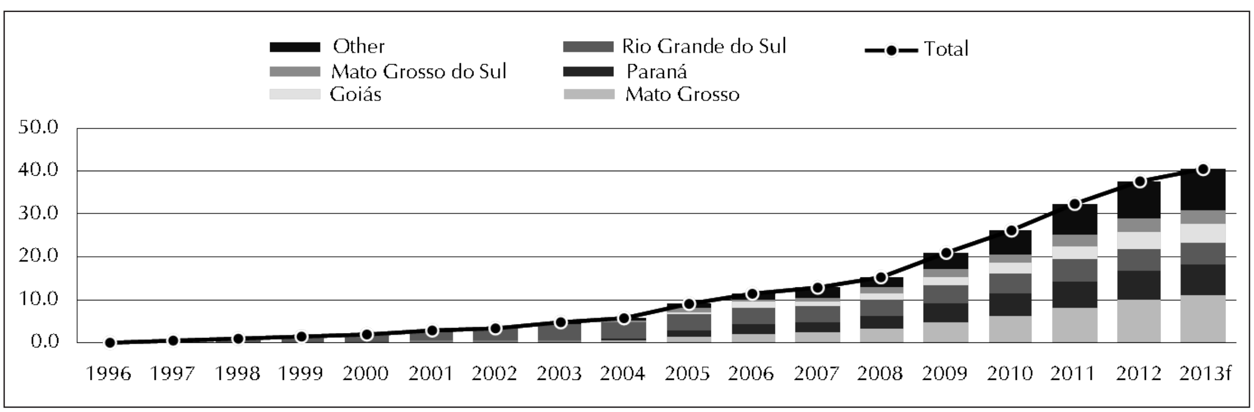

Source: CÉLERES®, 2013.

crop adoption in Brazil (Figure 11), Mato Grosso is the largest state for biotech crops, with 10.7 million hectares (7.6 million hectares of GM soybean, 2.9 million of GM winter corn, 0.2 million hectares of GM cotton and only 0.1 million hectares of GM summer corn). Paraná is an important state where biotech adoption is large, 7.2 million hectares (4.3 million hectares of GM soybean, 2.1 million hectares of GM winter corn and 0.8 million of GM summer corn). Also, GM cotton is cultivated in Paraná state, but in small farms. Rio Grande do Sul, where GM adoption began in Brazil in 1996/97, is in the third place of biotech crop adoption, with 5.6 million hectares (4.7 million hectares of GM soybean and 0.9 million hectares of GM summer corn).

Subsequent to early judicial difficulties with biosafety in Brazil, CTNBio (Brazilian National Technical Commission on Biosafety) seems to be one of the most effective commissions worldwide, with a clear federal biotech regulatory framework and functional approval processes. Thus, Brazil has accelerated the approvals of biotech events and the farmers have, currently, 37 biotech approved traits in the country for planting, five traits for soybeans, 19 for corn, 12 for cotton and one for an edible virus resistant bean (Figure 12).

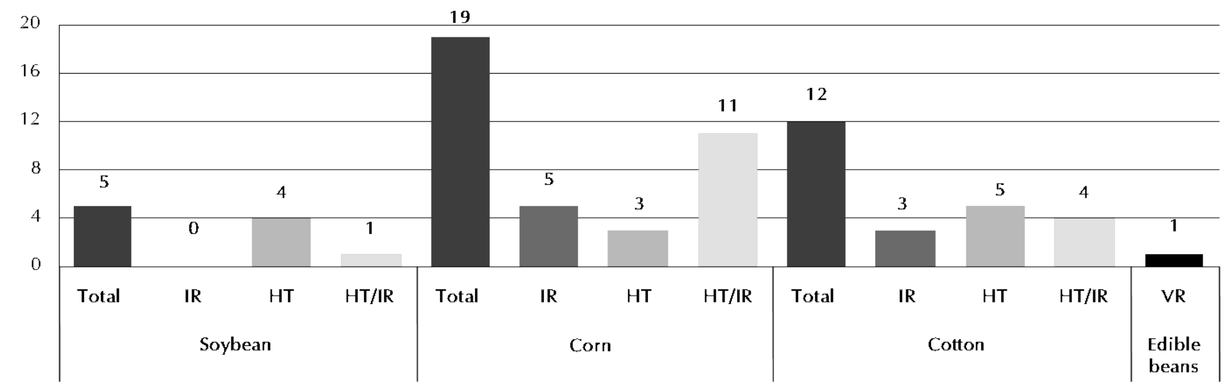
High adoption rates are an important feature of biotech crops in Brazil. Analyzing the individual results for each crop (Figure 13), a high profit level for farmers that use biotech seeds is observed, during the three years considered, except for cotton in 2011/12, due to the low prices realized in the market, there was a negative profit margin, US$1.30 for every US$1 invested in the purchase of biotech seeds. In this case, it is important to stress the fact that the international cotton prices underwent a steep downturn in the 2011/12 crop year, as a result of its abundant supply and lower demand caused by the international economic crisis. That is, the benefits achieved through biotech crops were not sufficient for the farmers to obtain an operating margin, due to the low prices paid

**Figure 11. Biotech Crop Adoption in Brazil, by State, Values in Million Hectares**




Source: CÉLERES®, 2013.

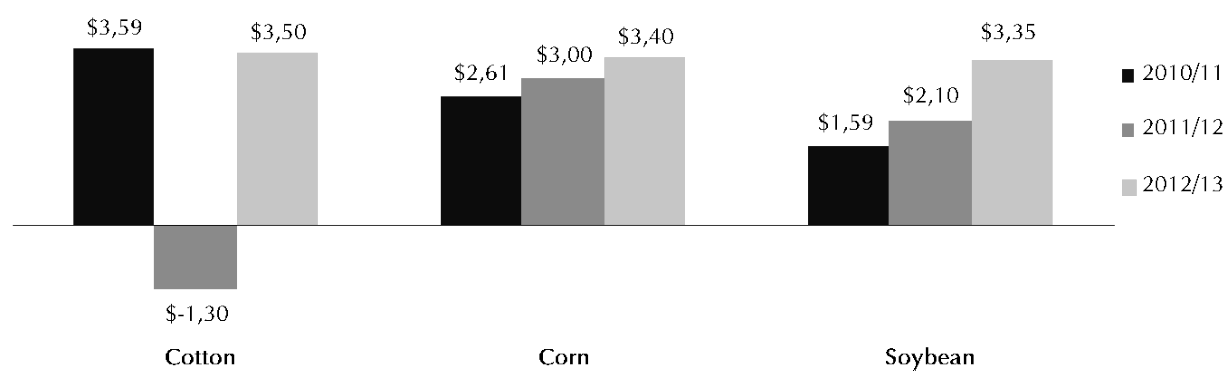
**Figure 12. Number of Approved Traits in Brazil, by Crop and Traits**




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

Source: CTNBio | Elaboration: CÉLERES®, 2013.

**Figure 13. Profit Margin Analysis Resulting from the Use of GM Seeds, Season 2010/2011 to 2012/2013. Values in US$/Hectare**




Source: CÉLERES®, 2013.

for their products. However, in the other seasons, the profit margin was much higher than well-performing crops (US$3.59 in 2010/11 and US$3.50 in 2012/13), such as corn and soybean.

For those two crops, there was an excellent profit margin level from adopting biotech crops, during the time considered. For corn, already taking into consideration the weighted average of the summer and winter harvests, in the season 2012/13 for example, this margin reached US$3.40 for every US$1 invested. And for soybeans, in the same season, the profit margin reached US$3.35 for every US$1 invested (Figure 13).

According to data from the Ministry of Agriculture (MAPA/SNRC), from 2004 to 2013, Brazil registered 755 new varieties of soybeans, of which 560 (74%) were biotech and only 195 (26%) were conventional varieties. In the past few years, a predominance of biotech crops was clearly evident versus conventional varieties, for example, in 2012, a record 90% of registered varieties were biotech/GM (Figure 14).

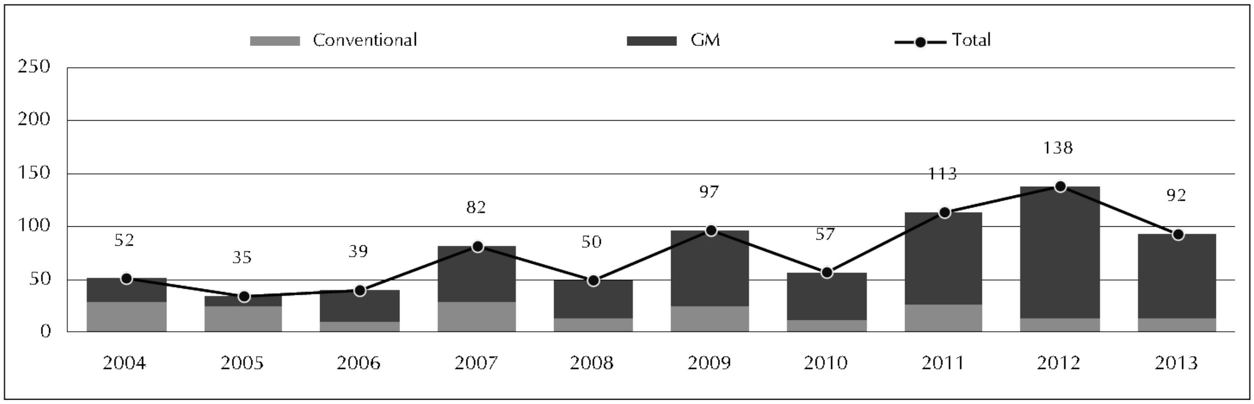
The deployment of biotech corn in Brazil is in its sixth year, following its approval by CTNBio. During this period, biotech corn developers have successfully delivered a significant number of hybrids with biotech traits. According to Brazil's Ministry of Agriculture (MAPA/SNRC), from 2004 to 2013, Brazil registered 1,109 corn hybrids, out of which 609 (~55%) were biotech hybrids – this is a significant achievement given that registration of biotech events has only been in effect for only six years (Figure 15).

Substantial gains in yield and easier management, over the last six years, are responsible for the high adoption of biotech corn, even in different producing states (Tables 5 to 7). Brazil is a huge dimensional country, with enormous differences amongst Brazil's crop mega-environments, particularly when considering the differences between summer and winter corn which require quite different technologies and management.

In the winter corn crop season, the adoption of biotech crops by farmers is greater and more consistent than is the case for the summer corn. Practically, all of the winter corn is produced by farmers who also grow soybeans in the previous summer and who are therefore familiar with high-tech biotech crops including biotech soybean. Thus, as expected, biotech corn adoption rate in the winter crop season is higher; reaching a projected 90% in the 2013/14 crop season, whilst summer corn reached a projected 72%.

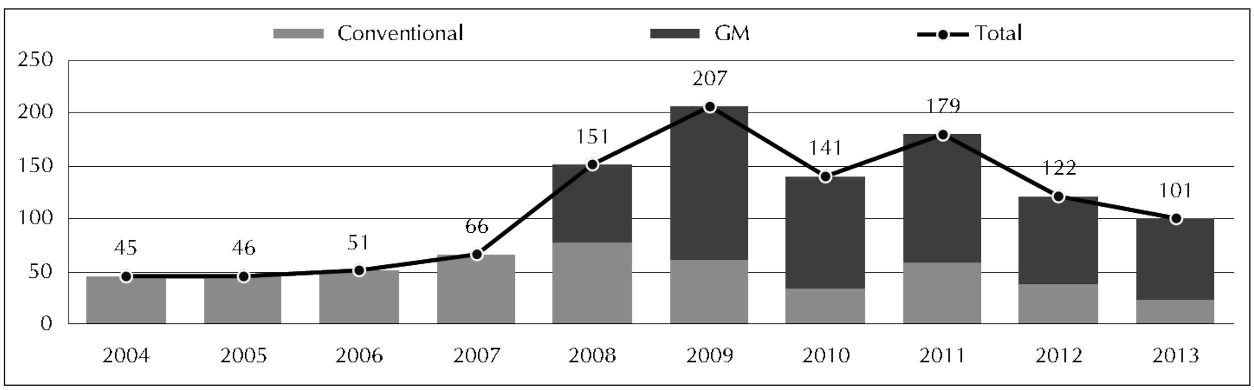
In the case of cotton, the technology developers have been delivering new biotech cotton varieties to the market but at a much slower rate than the corresponding technologies for soybean and corn; the number of registered varieties is considered small by farmers and industry. According to data published by the Ministry of Agriculture (MAPA/SNRC), Brazil registered a total (biotech and conventional) of 71 new cotton cultivars since 2004. Of this number, 30 varieties were biotech (42% of the total). In 2012 and 2013, a record number of biotech cotton was registered mostly with HT traits (Figure 16). Another important attribute of biotech cotton is that a good share of the hectares planted to biotech cotton is done with seeds produced by the farmers themselves; this is a disincentive to companies that need to be assured of a return on investment when developing new biotech cotton varieties. Farmer saved seeds is allowed by Brazilian legislation, but has resulted in disincentives for investors in research and development of biotech cotton, which is clearly indicated by low number of registered varieties in comparison with soybean and corn.

**Figure 14. Register of Soybean Varieties in Brazil**



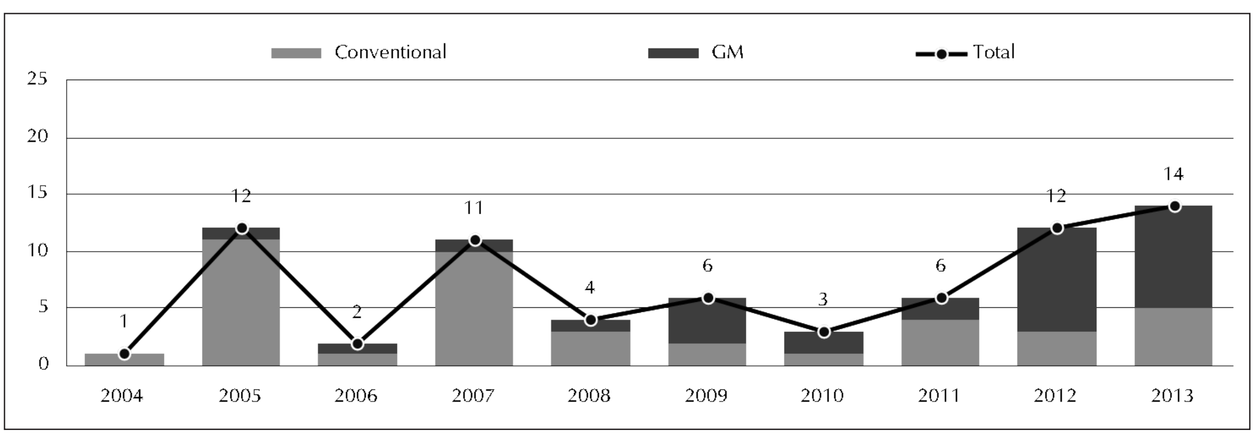

Source: MAPA/SNRC | Elaboration: CÉLERES® | Note: 2013 as of October 22nd, 2013.

**Figure 15. Register of Corn Hybrids in Brazil**




Source: MAPA/SNRC | Elaboration: CÉLERES® | Note: 2013 as of October 22nd, 2013.

**Figure 16. Register of Cotton Varieties in Brazil**




Source: MAPA/SNRC | Elaboration: CÉLERES® | Note: 2013 as of October 22nd, 2013.

The following paragraph was contributed by Dr. A. M. Shelton, Professor of Entomology, Cornell University:

> According to a new report (Czepak et al. 2013), a polyphagous insect that has caused damage on many crops in many parts of the world, but had not yet established a presence in the Americas, was recently found in soybeans and cotton in Brazil. A major pest in Asia, Africa and Australia, but rarely seen in South America, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) got a foothold in northeastern Brazil amid drier conditions over the last two seasons, proliferating extremely quickly during a recent six-week drought and causing farmers to make repeated insecticide sprays
>
> Often confused with a similar looking species (*Helicoverpa zea*), the Brazilian state-run research organization EMBRAPA estimates that the losses caused by this new pest are already over US$1 billion (http://www.agrosouth-news.com/?p=78). Prior to its occurrence in Brazil, according to a report in 2007 (Lammers and MacLeod), the estimated annual costs for controlling this pest globally, along with its yield losses, was US$5 billion. Managing this new insect in Brazil will undoubtedly increase grower costs in soybean, cotton and the many other crops it attacks.
>
> Several factors make *H. armigera* a particularly difficult insect pest to control, including its high reproductive capacity, long distance migration, wide host range and tolerance to many insecticides. Efforts are underway to identify and contain newly established populations, but past history suggests that it is likely to become a perennial pest of many crops as it spreads through the Americas over time. The arrival of this new pest in Brazil warrants the rapid replacement of Bollgard, the single gene Bt cotton, with Bollgard II which features two Bt genes and greatly enhances the durability of Bt cotton. This rapid replacement strategy has proven effective in Australia which manages a very strict and effective resistance management strategy.

As a result of the new insect pest in Brazil, described above the adoption of biotech cotton decreased in 2013/14, in the expectation of lower yields in cotton and soybean, mainly in Bahia state, an important cotton producer. Farmers are starting to plant conventional varieties, due to cheaper cost of seeds and higher yields.

It is noteworthy that the decision to plant cotton in Brazil can be delayed until the end of December and, in certain regions, until mid-January of 2013. Thus, there is still the possibility for the biotech cotton hectarage to change after this Brief goes to press. The situation is confounded for cotton due to the fact that cotton is subject to more volatility in prices than other crops and this adds to the uncertainty about the future markets.

### 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, 2013. 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. For the virus-resistant dry bean, 12 field trials are required for two years in four regions; currently the second year trials are in progress. They are due for completion by January 2014 culminating with initial seed production, prior to commercial seed production by seed companies to supply farmers with commercial seed in early 2015.

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 which recently reached a high of US$5.40 per kilo – equivalent to ~ four times the low price of a year ago.

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 will be grown in Brazil this year, 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

An annual study of benefits from biotech crops concluded that Brazil gained US$18.8 billion during the sixteen year period 1996/97 to 2011/12 and US$6.7 billion in 2012 alone (Céleres, 2013). Brazil maintains its #2 ranking globally for  biotech crop hectarage (US is the leader) and, in 2013, it further enhanced its status by consolidating its position and decreasing the gap between it and the US, especially with soybean and corn.

Another annual global study of benefits from biotech crops covering a different period (2003 to 2012) concluded that Brazil gained US$8.4 billion during the nine year period 2003 to 2012 and US$1.7 billion for 2012 alone (Brookes and Barfoot, 2014 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 corn and deploying biotech cotton. Brazil is also developing other biotech crops, like 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 (until October), 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.

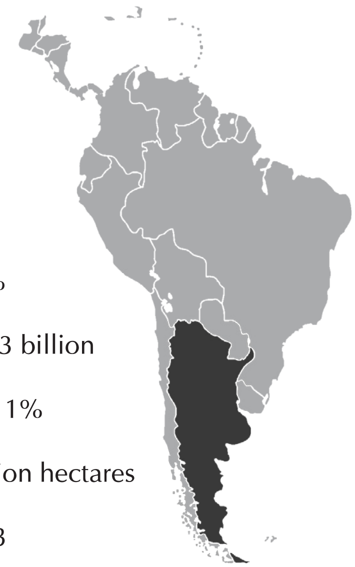
## *ARGENTINA*

**Total biotech crop hectares in Argentina in 2013 were estimated at an all time record of 24.4 million hectares. Argentina maintained its ranking as the third largest producer of biotech crops in the world in 2013 occupying 14% of global hectarage. In 2013, the 24.4 million hectares is ~0.5 million hectares up from the 2012 planting at 23.9 million hectares. The 24.4 million hectares comprise 20.8 million hectares of biotech soybean, ~3.2 million hectares of biotech maize and ~0.5 million hectares of biotech cotton. Farmers substituted soybean for maize because of the higher prices and margins from biotech soybean. Positive trade discussions between Argentina and China to export Argentinean biotech maize to China has provided a great incentive and boost for biotech maize in the longer term in Argentina. Argentina has achieved a marked improvement in its promotion of biotech crops and has pursued their timely regulation aggressively. Brookes and Barfoot estimated benefits from biotech crops in Argentina from 1996-2012 that amounted to US$15.6 billion while US$1.6 billion for 2012 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 2013 were estimated at an all time record of 24.4 million hectares. Argentina is one of the six "founder biotech crop countries", having commercialized RR®soybean and Bt cotton in 1996, the first year of global commercialization of biotech crops. After retaining the second ranking position in the world for biotech crops area for 13 years, Argentina was narrowly displaced from being the second largest producer of biotech crops in the world in 2009, by Brazil. The 30 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. It is noteworthy that a significant number of 5 new biotech crop events were approved in 2012 and 3 in 2013.

In 2013, the year-over-year increase, compared with 2012, was 0.5 million hectares. Of the 24.4 million hectares of biotech crops in Argentina, 20.8 million hectares were expected to be planted to biotech soybean, up by ~0.5 million hectares over 2012. The 20.8 million hectares of biotech soybean is equivalent to 100% of the planting of 20.8 million hectares of the national soybean crop. The increase in soybean plantings in 2013 over 2012 is mainly due to farmers planting significantly more soybean in 2013 than 2012, and less maize.

**ARGENTINA**



Population: 40.7 million

GDP: US$1,443 billion

GDP per Capita: US$9,120

Agriculture as % GDP: 10%

Agricultural GDP: US$144.3 billion

% employed in agriculture: 1%

Arable Land (AL): 31.3 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-HTMaize

Total area under biotech crops and (%) increase in 2013:
24.4 Million Hectares (+2%)

Farm income gain from biotech, 1996-2012: US$15.6 billion

*Ratio: % global arable land / % global population

Of the total maize hectarage in 2013 about 3.2 million hectares were biotech composed of 3.1 million hectares planted to the stacked product Bt/HT, less than 5,000 hectares to the single Bt product, and ~20,000 hectares to herbicide tolerant maize. Thus, the stacked gene Bt/HT maize product occupied about ~95% of the biotech maize and is expected to retain this premier position in the future. Successful talks between Argentina and China to export the first Argentinean biotech maize to China in 2011/12 provided a great incentive and boost for the long term view on biotech maize in Argentina.

In 2013, Argentina reported a total planted area of 450,000 hectares of cotton of which 100% is biotech comprising 350,000 hectares of Bt/HT stacked product, about 95,000 hectares of herbicide

**Table 10. Commercial Approvals for Planting, Food and Feed in Argentina, 1996 to 2013**

| Crop | Trait | Event | Year |
|---|---|---|---|
| Soybean | Herbicide tolerance | 40-3-2 | 1996 |
| Maize | Insect resistance | 176 | 1998 |
| Maize | Herbicide tolerance | T25 | 1998 |
| Cotton | Insect resistance | MON531 | 1998 |
| Maize | Insect resistance | MON810 | 1998 |
| Cotton | Herbicide tolerance | MON 1445 | 2001 |
| Maize | Insect resistance | Bt11 | 2001 |
| Maize | Herbicide tolerance | NK603 | 2004 |
| Maize | Herbicide tolerance × Insect resistance | TC1507 | 2005 |
| Maize | Herbicide tolerance | GA21 | 2005 |
| Maize | Herbicide tolerance × Insect resistance | NK603 × MON810 | 2007 |
| Maize | Herbicide tolerance × Insect resistance | TC 1507 × NK603 | 2008 |
| Cotton | Herbicide tolerance × Insect resistance | MON1445 × MON531 | 2009 |
| Maize | Herbicide tolerance × Insect resistance | GA21 × Bt11 | 2009 |
| Maize | Insect resistance | MON89034 | 2010 |
| Maize | Herbicide tolerance × Insect resistance | MON88017 | 2010 |
| Maize | Herbicide tolerance × Insect resistance | MON89034 × MON88017 | 2010 |
| Maize | Insect resistance | MIR 162 | 2011 |
| Soybean | Herbicide tolerance | A2704-12 | 2011 |
| Soybean | Herbicide tolerance | A5547-127 | 2011 |
| Maize | Herbicide tolerance × Insect resistance | Bt11 × GA21 × MIR162 | 2011 |
| Maize | Herbicide tolerance | DP-098140-6 | 2011 |
| Maize | Insect resistance | MIR604 | 2012 |
| Maize | Herbicide tolerance × Insect resistance | Bt11 × MIR162 × MIR604 × GA21 | 2012 |
| Maize | Herbicide tolerance × Insect resistance | MON89034 × TC1507 × NK603 | 2012 |
| Maize | Herbicide tolerance × Insect resistance | MON89034 × NK603 | 2012 |
| Soybean | Herbicide tolerance × Insect resistance | MON89788 × MON87701 | 2012 |
| Maize | Herbicide tolerance × insect resistance | TC1507 × MON 810 | 2013 |
| Maize | Herbicide tolerance × insect resistance | TC1507 × MON 810 × NK603 | 2013 |
| Soybean | Herbicide tolerance | BPS-CV127-9 | 2013 |

Source: ArgenBio, 2013 (G. Levitus, Personal Communication) tolerant (HT), and 5,000 hectares Bt. It is noteworthy that farmer-saved seed, which is prevalent in Argentina, can lead to problems with Bt cotton if the purity drops to a point where larvae can establish on non-Bt cotton plants and start an infestation which can compromise insect resistant management strategies. There has been a shift towards more cotton grown on larger farms due to the damage caused by boll weevil which is more easily controlled by larger farmers than smaller farmers.

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

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

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

- CONABIA is currently evaluating two other sugarcane products – RR®sugarcane and Bt sugarcane – the RR®sugarcane could be approved for commercialization as early as 2014 – note that Indonesia has already approved a drought tolerant sugarcane for commercial release in 2014.

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

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

- Industry investments in Argentina in 2012 have increased significantly with Monsanto investing

US$355 million in a new maize production facility, and Syngenta with US$175 million in a seed production facility.

- A private agreement between farmers and Monsanto came into effect to deal with payment for the use of RR®2Y soybean and RR®2YBt (stacked). This agreement involves 8,000 farmers, representing 11 million hectares of soybean, which is equivalent to 60% of the total area of soybean in Argentina.

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

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

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

**Economic benefits, by crop**

- In the case of glyphosate-tolerant soybean, the benefits mounted to 65,153 million US dollars, 3,231 million attributable to a reduction in production costs (mainly due to less tillage and reduced applications of selective herbicides required by conventional varieties) and 61,917 million due to the expansion of the planted area. Regarding the distribution of the total benefits, 72.3% went to farmers, 21.3% to the National Government – collected through export tax and other taxes – and 6.5% to technology providers (seeds and herbicides) (Table 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).

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.

**More benefits**

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

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

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

**Future benefits.**

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

**Argentina must remain a leader so as not to miss opportunities**

***"One of the characteristics of the adoption process of GM crops in Argentina is the fact that***

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

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

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

In the most recent global study on the benefits from biotech crops (Brookes and Barfoot, 2014, Forthcoming) estimates that Argentina has enhanced farm income from biotech crops by US$15.6 billion in the first seventeen years of commercialization of biotech crops 1996 to 2012, and the benefits for 2012 alone were estimated at US$1.6 billion.

***Farmer Experience***

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

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

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

## *INDIA*

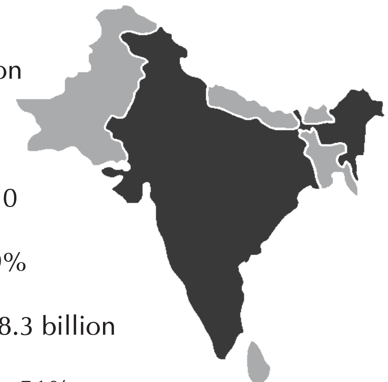
**In 2013, India achieved a landmark 11 million hectares of Bt cotton showing an upward trend in the twelfth year of cultivation of Bt cotton. Most of the cotton growing States have already achieved a near optimal adoption of 93% of Bt cotton in 2012. In the last twelve years, India reached a cumulative hectarage of 70 million hectares, which is more than twice the total global cotton area. The unprecedented 11 million hectares of Bt cotton in India is equivalent to 95% of total cotton area of 11.6 million hectares in 2013, slightly lower than the total cotton area in 2012. The number of Bt cotton farmers increased marginally to 7.34 million in 2013 from 7.2 million in 2012. The adoption of Bt cotton at 95% in India is a benchmark for the adoption among 27 countries planting GM crops for eighteen consecutive years from 1996 to 2013.**

**Notably, the year 2013 has been a year of cotton in the country. India produced a record 37 million bales of cotton, much higher than the previous record of 35.3 million bales achieved in 2012. The country has also surpassed the yield barrier of 500 kg lint per hectare and set a new cotton yield benchmark of 550 kg lint per hectare at national level. Notably, the States of Punjab, Haryana and Gujarat have crossed the average yield of 700 kg lint per hectare at the State level, which is higher than the average world cotton yield. In 2013, the modest growth of Bt cotton was driven primarily by the adequate availability of Bt cotton hybrid seeds and timely sowing of cotton due to**

early and widespread monsoon rain in the *Kharif* 2013 across the cotton growing area of the country.

The OECD/FAO Global Agricultural Outlook 2013-2023 report projected that India will become the world's largest cotton producing country by 2017/2018. The report estimates that China's cotton production is to decline by 17% while production in India is to increase by 25% mainly due to increasing yields, positioning India as the world's largest cotton producer.

**INDIA**



Population: 1,214.5 million

GDP: US$1,727 billion

GDP per Capita: US$1,410

Agriculture as % GDP: 19%

Agricultural GDP: US$328.3 billion

% employed in agriculture: 51%

Arable Land (AL): 174.5 million hectares

Ratio of AL/Population*: .66

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

Commercialized Biotech Crop: Bt Cotton

Total area under biotech crops and (%) increase in 2013:
11.0 Million Hectares (+2%)

Farm income gain from biotech, 2002-2012: US$14.6 billion

*Ratio: % global arable land / % global population

Ending the controversy surrounding Bt cotton cultivation, the Indian Minister of Agriculture Mr. Pawar eloquently briefed the concerns of the members of the Parliament of India on the benefits of Bt cotton cultivation by clearly showing how farmers themselves have opted for Bt cotton, which last year earned Rs 21,000 crore from exports alone. *"I honestly feel that the farmer of this country is wiser than me. He understands what crops should be taken and 93 per cent of cotton growers are using this seed, I think, they are the sensible people and they are for the larger interests of the country. Therefore, it is not proper to say that Bt cotton is not useful."*

In 2012 Kharif season, the Indian Society for Cotton Improvement (ISCI) conducted the largest and most comprehensive survey on Bt cotton covering 2,400 farmers across three agro-ecologically distinct States focusing on rainfed, semi-irrigated and fully irrigated cotton area. The survey confirmed the wide-spread planting of Bt cotton in both rainfed and irrigated areas over a long period of time and observed several key trends in cotton cultivation in India. It confirms that, "Bt technology has decreased

**pesticide usages, increased cotton productivity and increased farmers' income, and contributed significantly to poverty alleviation. The survey study launched knowledge centric campaign called *"An Alert Farmer is An Affluent Farmer".***

**Finally, the increase from 50,000 hectares of Bt cotton in 2002, (when Bt cotton was first commercialized) to 11 million hectares in 2013 represents an unprecedented 220-fold increase in the twelve years. Brookes and Barfoot estimates that India enhanced farm income from Bt cotton by US$14.6 billion in the eleven year period 2002 to 2012 and US$2.1 billion in 2012 alone compared with US$3.2 billion in 2011.**

From 2002 to 2013, ISAAA has been reporting major changes in cotton sector in India of which key developments are discussed in this section and underscore the game changing effects of Bt technology in cotton cultivation and production in the country (James, 2011; 2012). Table 12 compiles the trend in measurable parameters indicating the adoption, commercial release and impact of Bt cotton in the first twelve years from 2002-03 to 2012-13. India has registered a significant increase in cotton area from 7.7 million hectares in 2002-03 to 11.6 million hectares in 2012-13 with highest cotton area of 12.1 million hectares in 2011-12. Similarly, the number of small holder cotton farmers increased significantly from 5 million small and resource poor cotton farmers in 2002-03 to 8 million cotton farmers in 2012-13 with 7.2 million Bt cotton farmers representing approximately 88% of total cotton farmers in 2012-13 who planted and benefited significantly from Bt cotton hybrids.

## Twelve Years of Bt Cotton in India, 2002 to 2013, Continued Growth in Twelfth Year

2013 was the twelfth successful year of the commercialization of Bt cotton in India. Millions of small holder cotton farmers continue to reap enormous benefits offered by Bt cotton technology that effectively imparts the control on *Helicoverpa armigera* infestation that, in the past, caused havoc to cotton crop. For the twelve successive years, Bt cotton suppressed the occurrence of bollworm infestation – a cyclic nature of bollworm incidence occurred in 1987, 1994, 1997 and the last one in 2001 prior to the introduction of Bt cotton in 2002.

In 2013, an estimated 140,000 additional farmers than 2012, totalling 7.34 million planted Bt cotton on 11 million hectare equivalent to 95% of the total cotton area of 11.6 million hectare in 2013. In spite of a slight decrease in total cotton area, an additional 200,000 hectares was planted with Bt cotton in 2013, for one simple reason – because of farmers experience with Bt cotton has confirmed that it consistently delivers significant and multiple benefits to cotton farmers in India. Notably, during the twelve year period, around 45 million farmers planted 70 million hectares of Bt cotton in the country, which reflects the trust and confidence of millions of small holder farmers in Bt technology over a long period of time.

Table 12. Summary of Twelve Years of Adoption and Commercial Release of Bt Cotton in India, 2002 to 2013

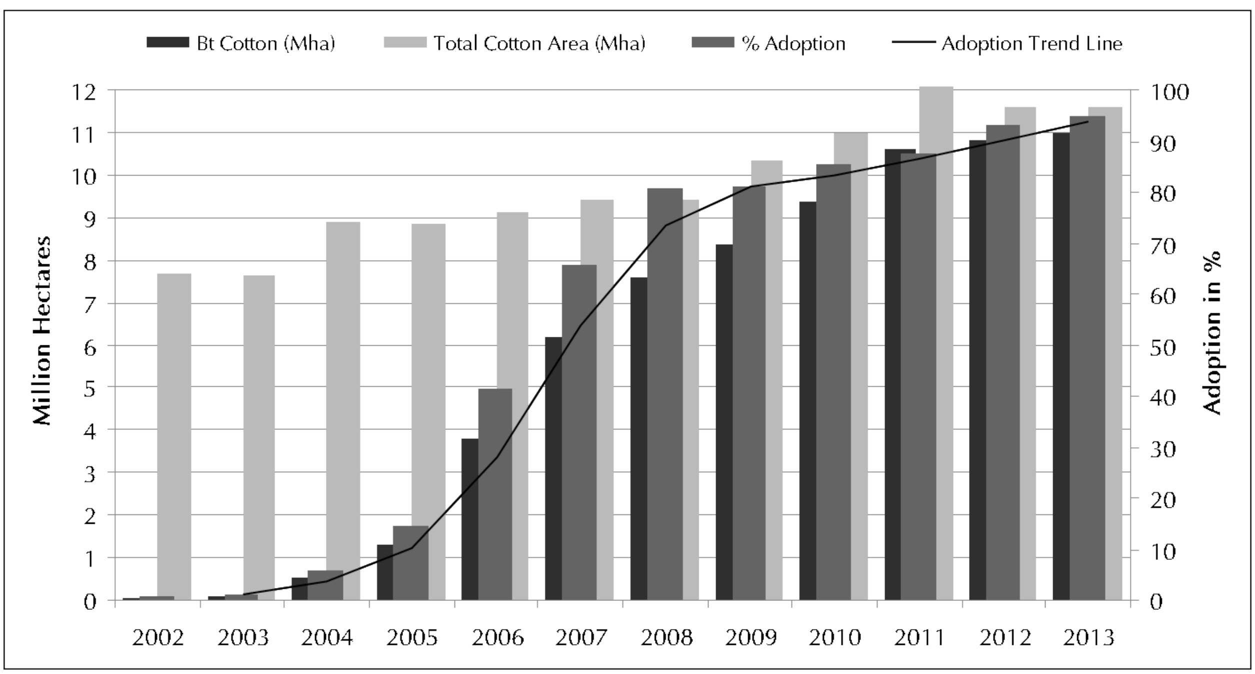
| Year | # of Bt Cotton Events | # of Bt Cotton Hybrids | # of Seed Companies Selling Bt Cotton | Adoption of Bt Cotton (Mha) | Total Cotton Area (Mha) | % Bt Cotton Area | # of Bt Cotton Farmers (Million) | % of Single Gene Bt Cotton | % of Double Gene Bt Cotton | Cotton Production (M Bales) | Cotton Yield (Kg/ha) | Total Insecticides to Control Bollworms (Metric tons) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2002-03 | 1 | 3 | 1 | 0.05 | 7.7 | 1 | 0.05 | 100 | - | 13.6 | 302 | 4,470 |
| 2003-04 | 1 | 3 | 1 | 0.1 | 7.6 | 1 | 0.08 | 100 | - | 17.9 | 399 | 6,599 |
| 2004-05 | 1 | 4 | 1 | 0.5 | 8.9 | 6 | 0.3 | 100 | - | 24.3 | 463 | 6,454 |
| 2005-06 | 1 | 30 | 3 | 1.3 | 8.9 | 15 | 1.0 | 100 | - | 24.4 | 467 | 2,923 |
| 2006-07 | 4 | 62 | 15 | 3.8 | 9.2 | 42 | 2.3 | 96 | 4 | 28 | 521 | 1,874 |
| 2007-08 | 4 | 131 | 24 | 6.2 | 9.4 | 66 | 3.8 | 92 | 8 | 31.5 | 567 | 1,201 |
| 2008-09 | 5 | 274 | 30 | 7.6 | 9.4 | 81 | 5.0 | 73 | 27 | 29 | 525 | 652 |
| 2009-10 | 6 | 522 | 35 | 8.4 | 10.3 | 81 | 5.6 | 43 | 57 | 30.5 | 503 | 500 |
| 2010-11 | 6 | 780 | 35 | 9.4 | 11.0 | 85 | 6.2 | 30 | 70 | 31.2 | 475 | 249 |
| 2011-12 | 6 | 884 | 40 | 10.6 | 12.2 | 88 | 7.0 | 18 | 82 | 35.3 | 493 | 222 |
| 2012-13 | 6 | 1,097 | 44 | 10.8 | 11.6 | 93 | 7.2 | 10 | 90 | 33.4 | 489 | - |

Source: Compiled by ISAAA, 2013.

Bt cotton, which confers resistance to important insect pests of cotton, was first adopted in India as hybrids in 2002. There were 54,000 farmers who grew approximately 50,000 hectares of officially approved Bt cotton hybrids for the first time in 2002 which doubled to approximately 100,000 hectares in 2003 (Figure 17). In 2013, the twelfth year of planting, Bt cotton area continued to increase by 200,000 hectares to 11 million hectares equivalent to 95% of total cotton area of 11.6 million hectares in 2013. Additional 1.34 million farmers totalling 7.34 million planted Bt cotton in 2013. Notably, the modest increase in Bt cotton area in the twelfth year of adoption indicates the deep penetration of Bt cotton to the smallest cotton farmers of the country.

Table 13 shows the adoption and distribution of Bt cotton in the major growing states from 2002 to 2013. The major states growing Bt cotton in 2013, listed in order of hectarage, were Maharashtra (3,860 thousand hectares) representing 35% of all Bt cotton in India, followed by Gujarat (2,130 thousand hectares or 19.4%), Andhra Pradesh (2,100 thousand hectares or 19%), Northern Zone (1,365 thousand hectares or 12.4%), Madhya Pradesh (620 thousand hectares), and the balance of 920 thousand hectares in Karnataka, Tamil Nadu and other cotton growing States including Odisha. In the twelfth year period, the adoption of Bt cotton has evenly spread across all the cotton growing States in the country. The high percentage adoption of Bt cotton by farmers across the different States reflects the priority of controlling the menace of the American bollworm complex, a group of

**Figure 17. Twelve Years of Adoption of Bt Cotton Hybrids in India, 2002 to 2013**




Source: Compiled by ISAAA, 2013.

**Table 13. Twelve Years of Adoption of Bt Cotton in India, by Major States*, 2002 to 2013 (Thousand Hectares)**

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

* Northern Region includes States of Punjab, Haryana and Rajasthan
Source: Compiled by ISAAA, 2012.

deadly borer insects that caused heavy damage to cotton crop in the past. In 2013, 95% of the total cotton area was planted with Bt cotton, irrespective of the size, location and land holdings. The 95% adoption rate for Bt cotton in India in 2013 is the highest ever recorded in the country and compares favorably with 99.5% adoption for biotech cotton in Australia, 90% in the USA and in China.

Over the years, there has been an increasing trend to adopt double gene Bt cotton hybrids by cotton farmers in India (Table 14). The first two-gene event MON15985, commonly known as Bollgard®II (BG®II) was developed by Mahyco and sourced from Monsanto, featured the two genes cry1Ac and cry2Ab, and was approved for sale for the first time in 2006 – four years after the approval of the single gene event MON531 Bt cotton hybrids in 2002-03. In the first year 2006-07, the double gene Bt cotton hybrids were planted on 0.15 million hectares whilst single gene Bt cotton hybrids occupied 3.65 million hectares equivalent to 96% of all the Bt cotton planted. In 2012, the double gene Bt cotton hybrid almost replaced the single gene Bt cotton hybrid with more than 90% of the area under double gene Bt cotton hybrids. The double gene Bt cotton hybrids would soon replace single gene Bt cotton hybrids, which in 2013 is at the ratio of 94:6. It is noteworthy to mention that the double gene Bt cotton hybrids provide additional protection to *Spodoptera* (a leaf eating tobacco caterpillar) while it provides protection to both American bollworm, Pink bollworm and Spotted bollworm. It is reported that double gene Bt cotton farmers earn higher profit through cost savings associated with fewer sprays for *Spodoptera* control as well as increasing yield by 8-10% over single gene Bt cotton hybrids.

## Approval of Events and Bt Cotton Hybrids in India, 2002 to 2013

India is the only country that grows cotton hybrids for many years. Of the estimated 11.6 million hectares of cotton in India in 2013, 95% or 11 million hectares were Bt cotton hybrids – a remarkably high proportion of Bt cotton in a fairly short period of twelve years. This is equivalent to

**Table 14. Adoption of Single and Double Gene Bt Cotton Hybrids in India, 2006 to 2013 (Millions Hectares and Percentage)**

| Number of Genes | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|
| Double | - | 0.15 (4%) | 0.46 (8%) | 2.04 (27%) | 4.82 (57%) | 6.60 (70%) | 8.70 (82%) | 9.7 (90%) | 10.4 (94%) |
| Single | 1.3 (100%) | 3.65 (96%) | 5.74 (92%) | 5.56 (73%) | 3.58 (43%) | 2.80 (30%) | 1.90 (18%) | 1.1 (10%) | 0.6 (6%) |
| **Total** | 1.3 (100%) | 3.80 (100%) | 6.20 (100%) | 7.60 (100%) | 8.40 (100%) | 9.40 (100%) | 10.6 (100%) | 10.8 (100%) | 11 (11%) |

Source: Compiled by ISAAA, 2013.

an unprecedented 220-fold increase from 2002 to 2013, and is more than double the 45% cotton hybrid area occupied in 2011. The remaining 5% cotton area was planted either with non-Bt cotton hybrids or varietal cotton seeds.

Of the 11 million hectares of Bt cotton hybrids, 35% was under irrigation and 65% rainfed. A total of 1097 introductions (1095 hybrids with the discontinuation of a hybrid and a variety of Event BNLA-601 since 2010) were approved for planting in 2012 and 2013 compared with 884 Bt cotton hybrids in 2011. Over the last twelve years, India has greatly diversified deployment of Bt genes and genotypes, which are well-adapted to the different agro-ecological zones to ensure equitable distribution to small and resource-poor cotton farmers. The significant increase in area under hybrid cotton cultivation is credited to the introduction of Bt technology which spurred the hybridization of cotton from 3 Bt cotton hybrids in 2002-03 to 1095 Bt cotton hybrids in 2012 and at the same time, the area of cotton hybrids increased significantly to 95% in 2013 from 45% in 2001 (Table 15).

The number of events as well as the number of Bt cotton hybrids and companies marketing approved hybrids have all increased significantly from 2002, the first year of commercialization of Bt cotton in India. The Genetic Engineering Appraisal Committee (GEAC) of the Ministry of Environment and Forest (MOEF) approved six events of Bt cotton incorporating single and double genes in the eleven year period from 2002 to 2013. These events included MON531 harboring *cry1Ac* gene, followed by first two-gene event MON15985 (*cry1Ac* and *cry2Ab2*), Event-1 (*cry1Ac*), GFM event (fused

**Table 15. Deployment of Approved Bt Cotton Events/Hybrids/Variety by Region in India in 2013**

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

*Bt cotton variety
**Event BNLA-601 discontinued since 2010
[1,2] Mahyco [3] JK Seeds [4] Nath Seeds [5] CICR (ICAR) and [6] Metahelix
Source: Compiled by ISAAA, 2013.

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. Table 16 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 and 44 (James, 2011 and 2012) provides detailed information about each of the six events approved for commercial cultivation in the country.

## Savings of Insecticides due to Bt Cotton, 2001 to 2011

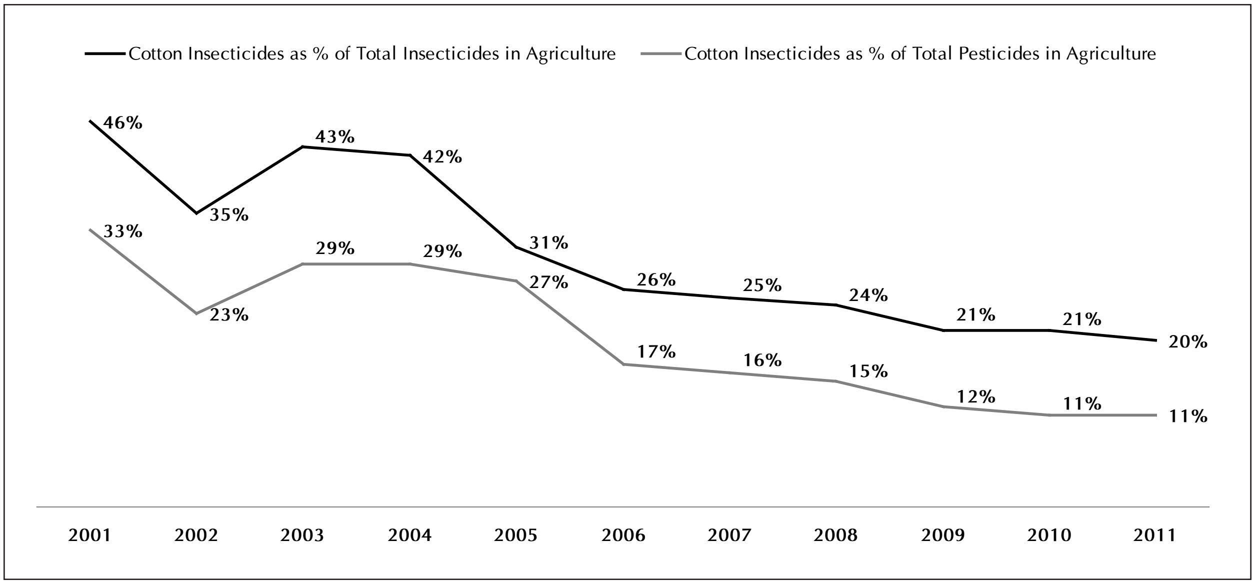
Traditionally, cotton consumed more insecticides than any other crop in India and was a significant proportion of the total pesticide (insecticides, fungicides and herbicides) market for all crops. For example, of the total pesticide market in India in 2001 valued at US$713 million (Figure 18 and Table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

**Table 16. Commercial Release of Different Bt Cotton Events in India, 2002 to 2013**

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

*Bt cotton hybrid; ** A hybrid and a variety of Event BNLA-601 discontinued since 2010
Source: Compiled by ISAAA, 2013.

**Figure 18. Percentage Reduction of Insecticides on Cotton Relative to Total Insecticides/ Pesticides Used in Agriculture in India, 2001 to 2011**




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

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

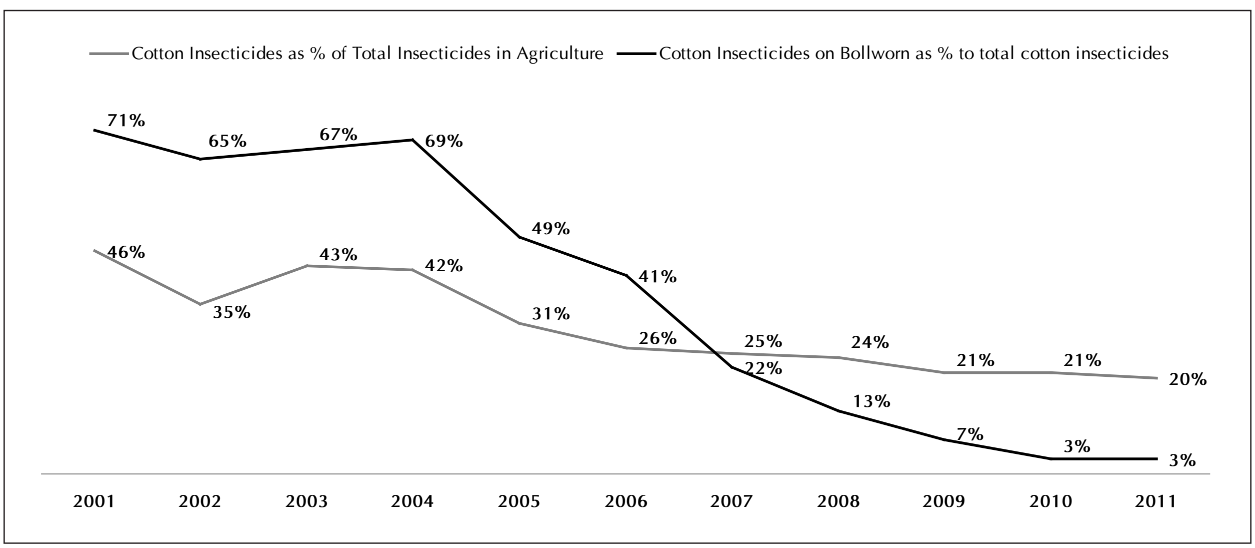
| Item/Year | 2001 | 2006 | 2010 |
|---|---|---|---|
| Total pesticide market (in million US$) | US$713 million | US$748 million | US$1,707 million |
| Cotton insecticides as % of total pesticide market | 33% | 17% | 11% |
| Total insecticide market (in million US$) | US$504 million | US$404 million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

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

percentage of cotton insecticides to the total pesticides market in India registered a steep decline from 33% in 2001 to 11% in 2011 at the time when total pesticides market in the country more than doubled from US$713 million in 2001 to more than US$1,707 million in 2011.

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

**Figure 19. Percentage Reduction of Insecticides on Cotton Bollworm Relative to Total Insecticides Used in Cotton in India, 2001 to 2011**




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

This saving in insecticides between 2004 and 2010 coincided with the large scale adoption of Bt cotton from half a million hectares in 2004 to 10.6 million hectares in 2011-12, equivalent to 88% of the total cotton crop in 2011-12. More specifically, the sharpest decline in insecticides occurred in the bollworm market in cotton in terms of value, which declined from US$160 million in 2004 to US$25 million in 2010 – an 85% decrease, equivalent to a saving of US$135 million. Similarly, the quantity of insecticides used to control bollworm reduced by 96% from 5748 metric tons of active ingredients in 2001 to as low as 222 metric tons of active ingredients in 2011. Thus, insecticide use for the control of bollworm dropped significantly at the same time when approximately 88% of the cotton area in 2011 (10.6 million hectares) was benefiting from controlling bollworm with Bt cotton.

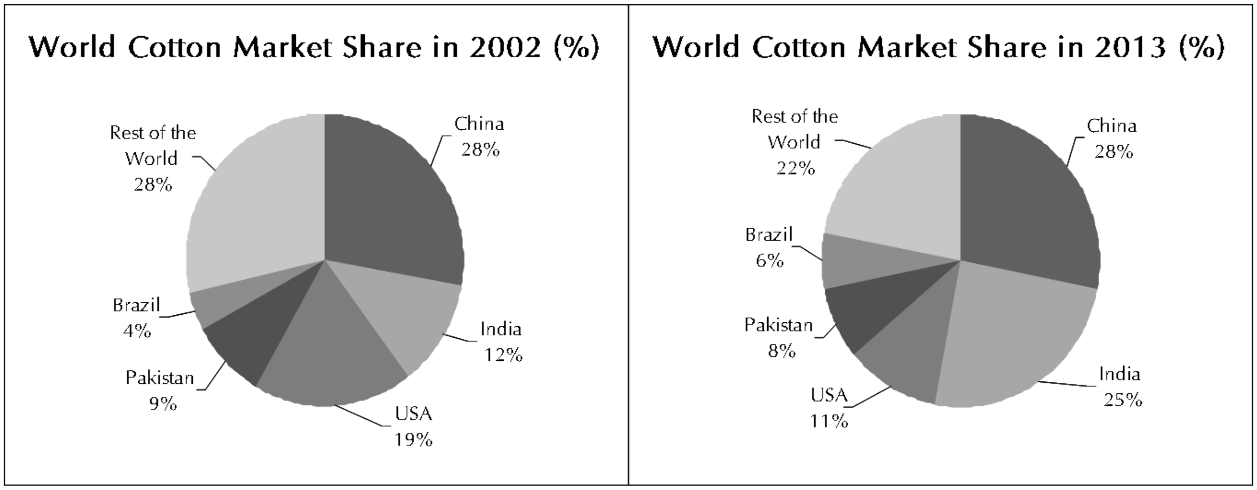
**Transformation of Cotton Since Bt Cotton Introduction in 2002**

In 2013, India was estimated to produce a record 37 million bales of cotton, compared to 35 million bales achieved in 2012. The country has also surpassed the yield barrier of 500 kg lint per hectare and set a new cotton yield benchmark of 550 kg lint per hectare. Notably, the States of Punjab, Haryana and Gujarat have crossed the average yield of 700 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 remarkable hike in cotton yield in 2013 up to 360 kg lint per hectare in 2013 in Maharashtra and 570 kg lint per hectare in Andhra Pradesh, to name a few. The modest growth of Bt cotton was driven primarily by the adequate availability of Bt cotton hybrid seeds and timely sowing of cotton due to early and widespread monsoon rain in the *Kharif* 2013 across the cotton growing area of the country.

Corroborating the year-on-year spike in cotton production, the OECD/FAO Global Agricultural Outlook 2013-2023 report projected India to become the world largest cotton producing country by 2017/2018. The report estimates that China's cotton production will decline by 17% while production in India will increase by 25% mainly due to increasing yields, resulting in the positioning of India as the world's largest cotton producer (OCED/FAO, 2013). In 2006-07, ISAAA reported for the first time the climbing of India to second position by displacing the USA to the third position in the cotton production (USDA/FAS, 2007). Notably, over the twelve year period, India has doubled the market share to the global cotton production from 12% in 2002 to 25% in 2013, representing a quarter of total cotton production. India is inching closer to replace China as the largest cotton producer in the world with the market share of 28% in 2013. The distribution of market share of cotton by top five cotton producing countries in 2002 and 2013 are shown in Figure 20.

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 2013, the average

**Figure 20. Distribution of World Cotton Market Share by Top Five Countries, 2002 and 2013**



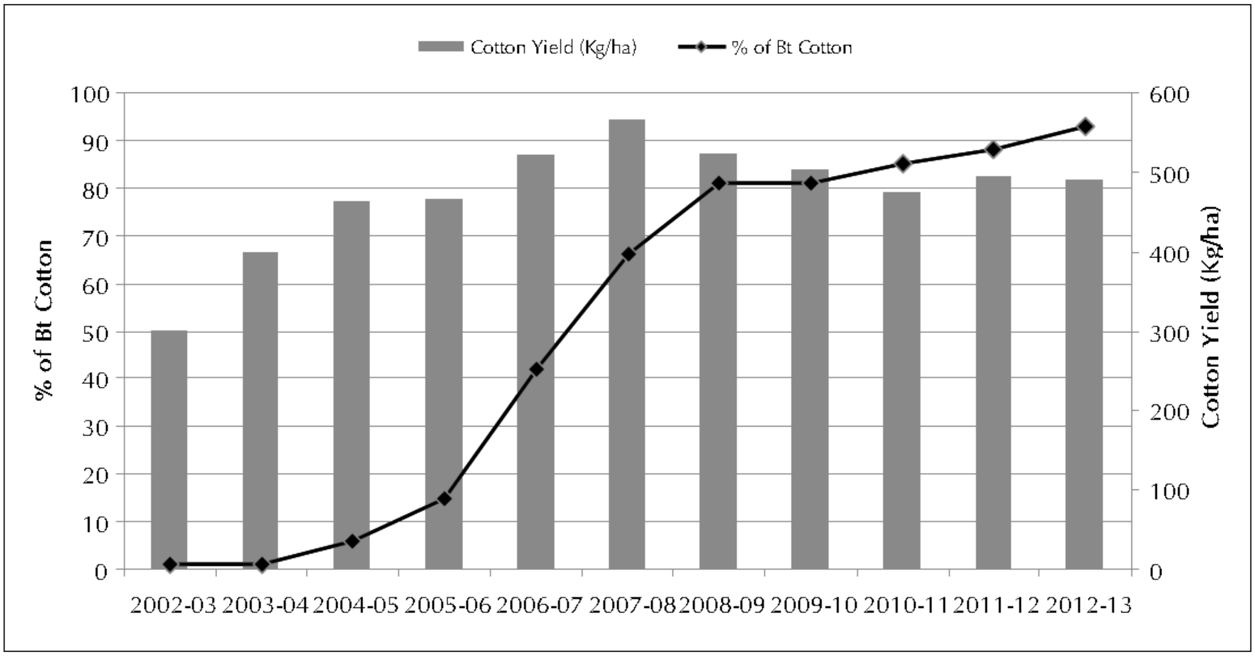

Source: USDA, 2013; Compiled by ISAAA, 2013.

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 550 kg per hectare in 2013-14. Cotton production increased from 13.6 million bales in 2002-03 to 37 million bales in 2013-14, which was a record cotton crop for India. At the same time, the country was transformed from a net importer of raw cotton until 2002-03 to net exporter of cotton. Figure 21 shows the upward trend in cotton yield which remained stagnant at 300 kg per hectare until the introduction of Bt technology in 2002-03.

In 2013-14, the Cotton Advisory Board reported that the country produced the largest ever cotton crop of 37 million bales substantially higher than previous record of 35.3 million bales in 2011-12 (CAB, 2013b). This quantum leap in cotton production since 2002-03 has been due to improved seeds particularly the ever-increasing hectarage of improved Bt cotton hybrids in the ten cotton-growing states. The first phase of substantial gains were realized with the large scale adoption of the single gene Bt cotton hybrids from 2002-03 to 2006-07 (Figure 22). Recognizing the remarkable progress achieved in cotton production in the last twelve years, India's Ministry of Agriculture has invested in R&D, infrastructure and human resource development in order to harness the full potential of biotechnology in agriculture in the coming years.

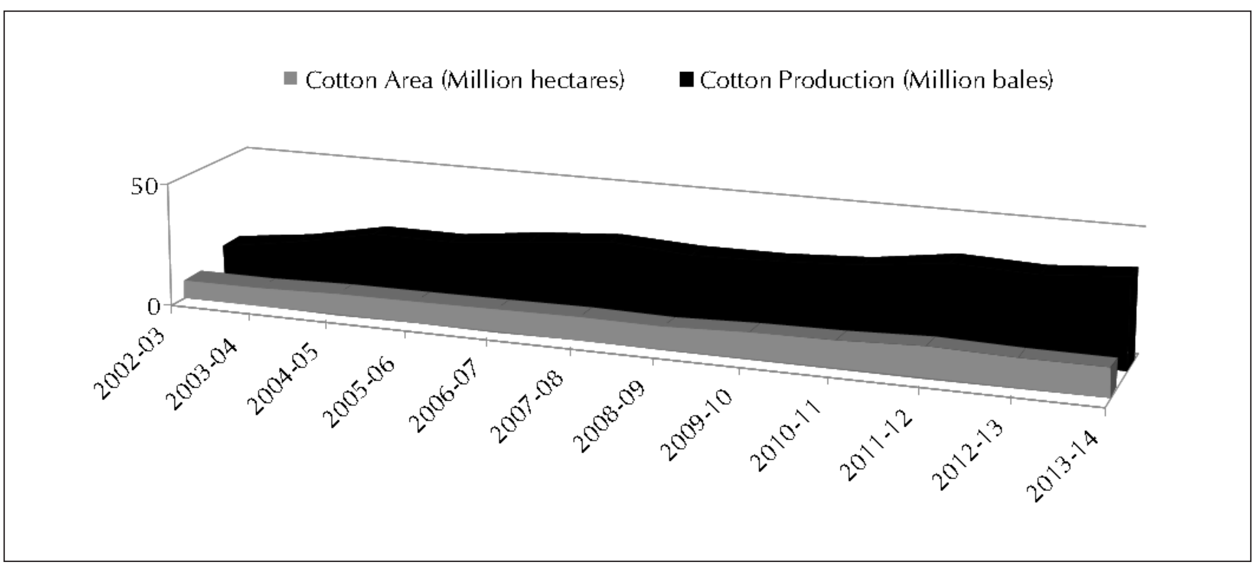
With the boom in cotton production in the last twelve years, India is transformed from a net importer to a net exporter of cotton. Exports of cotton have registered a sharp increase from a meager 0.05

**Figure 21. Impact of Adoption of Bt Cotton on Cotton Yield in India, 2002 to 2013**




Source: CAB, 2013; Compiled by ISAAA, 2013.

**Figure 22. Cotton Hectarage and Production in India, 2002 to 2013**



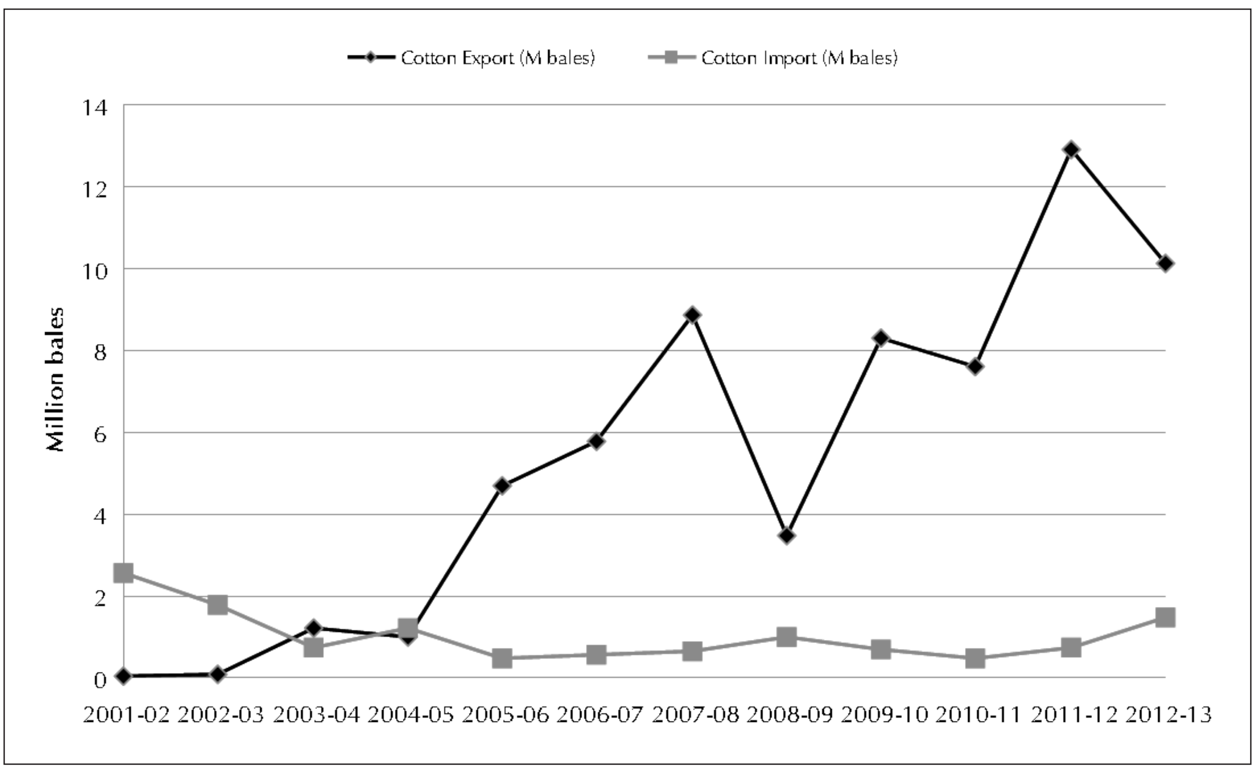

1 Bale =170kg
Source: CAB, 2013 and 2013b; Compiled by ISAAA, 2013.

million bales in 2001-02 to 8.8 million bales in 2007-08 (PIB, 2007). As per the latest Cotton Advisory Board (CAB) report, the raw cotton export rebounded from 7.6 million bales in 2010-11, marginally down from its previous year to the highest recorded raw cotton export of 12.9 million bales in 2011-12 falling again to 10.1 million bales in 2012-13 amidst unpredictable policy environment on export of raw cotton in the country. 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 23) (PIB, 2013a). 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 at setting up a new system of realistic assessment of the distribution and consumption of raw cotton in the country (Ministry of Textile, 2013; CAB, 2013b).

### Regulatory Status of Pending Biotech/GM Crop Projects in India

The regulatory approvals both for field trials and commercial release of different hybrids of Bt cotton and other GM crops have been at stand still since the last meeting of the Genetic Engineering

**Figure 23. Export and Import of Cotton in India, 2001 to 2013**




Source: CAB, 2013 and 2013b; Compiled by ISAAA, 2013

Appraisal Committee (GEAC) of the Ministry of Environment and Forests held on 11 April 2012. A year later, GEAC reconvened its meeting on 22 March 2013 with an intention to renew the extension of the Standing committee on Bt cotton and consider the evaluation of the piled backlog of GM projects without any concrete outcome. As of October 2013, the 79 applications covering 11 crops namely cotton, rice, castor, maize, wheat, sugarcane, brinjal, potato, chickpea, mustard and sorghum were pending for approval with the GEAC of the Ministry of Environment and Forests (MOEF). Out of the 79 applications, 24 were awaiting the no objection certificate (NOC) from the State Governments and the remaining 55 were yet to be considered by the GEAC (Lok Sabha, 2013a). In view of the objections received from some of the State Governments regarding GM crop field trials in their State, the GEAC in its meeting held on 6 July 2011 decided to direct the applicants to obtain NOC from the State Government in the first instance before issuance of the approval letter from the GEAC for the conduct of field trials of GM crops in the country.

In 2013, only two crops: Bt/HT maize and Bt/RRF cotton were field tested in two States: Haryana and Punjab for which the field trial permission were accorded by GEAC on 11 April 2013 and subsequently received NOC from respective States in early 2013 for conducting field trials in Kharif 2013. In 2013, there were no approvals accorded either by GEAC or Standing Committee on Bt Cotton for the approval of different Bt cotton hybrids suitable for various agro-climatic zones. In the past, the GEAC and the Standing Committee have regularly accorded approvals of different Bt cotton hybrids every year since the commercial release of Bt cotton in 2002 resulting in 1097 introductions (1095 hybrids with the discontinuation of a hybrid and a variety of Event BNLA-601 since 2010) for planting in 2012 and 2013, compared with 884 Bt cotton hybrids in 2011, 780 in 2010, 522 in 2009, 274 in 2008, 131 in 2007, 62 in 2006, 20 in 2005, 4 hybrids in 2004 and only 3 Bt cotton hybrids in 2002. Table 18 shows the status of biotech/GM crops pending approval for field trials and commercial release in India in 2013. Thus, in 2013, three GM crops were at the penultimate stage of environmental release and commercial approvals which include in chronological order, Bt/HT cotton, hybrid mustard and Bt/HT maize. More than a dozen of other GM crops with different events were at various stages of regulatory approvals including event selection stage, contained and confined field trials stage.

Amidst the regulatory uncertainty fuelled by the litigation on GM crops in the Supreme Court of India, the Technical Expert Committee (TEC) appointed by the Supreme Court of India has submitted two separate reports in mid 2013 for which the final stage of hearing would take place by end of 2013. At the same time, the Ministry of Science and Technology (MOST) of the Government of India has also introduced the Biotechnology Regulatory Authority of India (BRAI) bill in the Lok Sabha, the Lower House of the Parliament of India on 22 April 2013. The BRAI seeks to create a statutory independent regulator for biotech sector that would replace the existing regulatory system of the EPA Rules 1989. BRAI would provide a single window platform for the scientific risk assessment of

**Table 18. Status of Biotech/GM Crops Pending Approval for Field Trials and Commercial Release in India**

| Crop | Organization | Event/Trait | Pending Status |
|---|---|---|---|
| Brinjal | IARI, New Delhi | *cry1Aabc*/IR | - |
| | Sungro Seeds, New Delhi | *cry1Ac*/IR | - |
| | Mahyco, Jalna | *cry1Ac*/IR | - |
| | TNAU, Coimbatore | *cry1Ac*/IR | - |
| | UAS, Dharwad | *cry1Ac*/IR | - |
| | IIVR, Varanasi | *cry1Ac*/IR | - |
| | Bejo Sheetal, Jalna | *cry1Fa1*/IR | - |
| | Ankur Seeds | *cry1Fa1*/IR | Event Selection |
| | Rasi Seeds Pvt.Ltd. | *cry1Fa1*/IR | Event Selection |
| Cabbage | Nunhems, Gurgaon | *cry1Ba* and *cry1Ca*/IR | - |
| | Sungro Seeds, New Delhi | *cry1Ac*/IR | - |
| Castor | Directorate of Oilseeds Research, Hyderabad | cry1Ec and cry1Aa | Event Selection |
| Cauliflower | Sungro Seeds, New Delhi | *cry1Ac*/IR | - |
| | Nunhems, Gurgaon | *cry1Ba* and *cry1Ca*/IR | |
| Chickpea | Sungro Seeds Ltd., New Delhi | *cry2Aa*/IR | BRL-1 Trials |
| Cotton | Mahyco, Jalna | *cry1Ac* and *cry2Ab*/IR&HT | ***Final stage*** |
| | Mahyco, Mumbai | MAH-11501 – MAH-5512/NUE | Event Selection |
| | Dow Agro Sciences, Mumbai | *cry1Ac* and *cry1F*/IR | ***Final stage*** |
| | JK Agri-Genetics, Hyderabad | *cry1Ac* and *cry 1Ec* /IR | BRL-2 Trial |
| | Metahelix, Bangalore | *cry1C*/IR | - |
| | CICR, Nagpur and UAS, Dharwad | *cry1Ac*/IR | BRL-1 Trial |
| | CICR, Nagpur | *cry1Ac*/IR | Event Selection |
| | | *cry1F*/IR | Event Selection |
| | UAS, Dharwad | Event D1Ac to D7Ac (*cry1Ac*/IR) | Event Selection |
| | | Event SB1Ac to SB12 Ac (*cry1Ac*/IR) | Event Selection |
| | | Event J1Ac to J24 Ac (*cry1Ac*/IR) | Event Selection |
| | | Event BNAcF(*cry1Ac* x *cry1F*/IR) | Event Selection |
| | Bayer BioScience Pvt. Ltd., Gurgaon | GHB119 x T304-40/IR | BRL-1 Trials |
| | | GHB 614/HT | BRL-1 Trials |
| | Monsanto Holdings Privat Ltd., Mumbai | COT 102/IR<br>MON 15985 x COT102 (BGIII)/HTIR)<br>MON 15985 x COT 102 x MON 88913 (BG 113 RRF)/HT&IR&HT | BRL-1 Trials |

**Table 18. Status of Biotech/GM Crops Pending Approval for Field Trials and Commercial Release in India**

| Crop | Organization | Event/Trait | Pending Status |
|---|---|---|---|
| Groundnut | ICRISAT, Hyderabad | Rice *chit* and *DREB*/FR, DST | - |
| Maize | Monsanto, Mumbai | *cry2Ab2* & *cryA.105* and *CP4EPSPS* / IR&HT | ***Final Stage*** |
| | Pioneer/Dupont, Hyderabad | *cry1F* and *CP4EPSPS* / IR&HT | BRL-2 Trial |
| | Dow Agro Sciences, Mumbai | *cry1F*/IR | BRL-1 Trial |
| | Pioneer Overseas Corporation, Hyderabad | Event DP-32138-1 | BRL-1 Trials |
| | Syngenta Biosciences Pvt. Ltd., Pune | *cry1Ab* and *mepsps*/IR/HT | BRL-1 Trials |
| Mustard | Delhi University, New Delhi | *bar, barnase, barstar*/AP | Final stage |
| Okra | Mahyco, Mumbai | *cry1Ac*/IR | - |
| | Sungro Seeds, Delhi | *cry1Ac*/IR | |
| | Bejo Sheetal, Jalna | *cry1Ac*/IR | |
| | Arya Seeds, Gurgaon | *CP-AV1*/IR | |
| Potato | CPRI, Shimla | *RB, GA20 Oxidase 1* gene/DR | - |
| | NIPGR, Delhi | *ama1*/NE | |
| Rice | IARI, New Delhi | *cry1Aabc, DREB, GR-1 & GR-2 (Golden Rice)*/NE | - |
| | TNAU, Coimbatore | *chi11*/FR | - |
| | MSSRF, Chennai | *MnSOD*/DST | - |
| | DRR, Hyderabad | *cry1Ac*/IR | - |
| | Mahyco, Mumbai | *cry1Ac, cry2Ab*/IR | - |
| | | Event OS_A17314/HT | BRL-1 Trials |
| | | *AlaAt* gene | Event Selection |
| | | *OSnhx1* gene | Event Selection |
| | Bayer CropScience, Hyderabad | *cry1Ab* and *cry1Ca*/IR | Event Selection |
| | Avesthagen | *NAD9*/NE | - |
| | JK Agri Genetics Ltd., Hyderabad | JKOsE081 x E016/IR | BRL-1 Trials |
| | BASF India Ltd., New Delhi | | Event Selection |
| | Devgen Seeds and Crop Technology Pvt. Ltd., Secunderabad | OSLR-01/IR<br>OSLR-04/IR | BRL-1 Trials |
| | | OSHT-01/HT<br>OSHT-02/HT | BRL-1 Trials |

**Table 18. Status of Biotech/GM Crops Pending Approval for Field Trials and Commercial Release in India**

| Crop | Organization | Event/Trait | Pending Status |
|---|---|---|---|
| Rice | Dupont India Pvt. Ltd., Hyderabad | IR | Event Selection |
| | | HT | Event Selection |
| | Bioseed Research India Pvt. Ltd., Hyderabad | glyI and glyII genes/DST | BRL-1 Trials |
| | | T1-3,T1-5 and dreb gene/DST | BRL-1 Trials |
| | BASF India Ltd., New Delhi | - | Event Selection |
| | Pioneer Overseas Corporation, Hyderabad | *cry1Ab+cry2Ad* | Event Selection |
| | Metahelix Life Sciences Ltd., Bangalore | *cry1Ab*/IR | Event Selection |
| Sorghum | NRCS, Hyderabad | *cry 1B*/IR | |
| Sugarcane | Sugarcane Research Institute, UP | *cry1Ac* | Event Selection |
| Tomato | IARI, New Delhi | *antisense replicase, ACC Synthase gene, osmotin, DREB*/IR, DR, FR, NE, DST | - |
| | Mahyco, Mumbai | *cry1Ac*/IR | - |
| | Avesthagen | *NAD9*/NE | |

Legend: AP: Agronomic Performance, BR: Bacterial Resistance, DR: Disease Resistance, DST: Drought and Salinity Tolerance, FR: Fungal resistance, IR: Insect Resistance, HT: Herbicide Tolerance, NE: Nutritional Enhancement.

Abbreviation: TNAU- Tamil Nadu Agricultural University; IIVR- Indian Institute of Vegetable Research; UAS-University of Agricultural Sciences; CICR-Central Institute of Cotton Research; ICRISAT-International Crop Research Institute for Semi-Arid Tropics; CPRI-Central Potato Research Institute; NIPGR-National Institute of Plant Genome Research; IARI-Indian Agricultural Research Institute; MSSRF-MS Swaminathan Research Foundation; DRR-Directorate of Rice Research; NRCS-National Research Center on Sorghum.

Source: Indian GMO Research Information System (IGMORIS), 2013, Compiled by ISAAA, 2013.

all biotech products including agriculture, health, environment and industrial sector. The authority would supervise and regulate field trials of genetically modified crops and, the research, transport, import, manufacture and the use of organisms and products of modern biotechnology in the country. It aims to help India keep pace in regulatory measures with the rapid technology advancement in biotechnology and at the same time ensure safety to human and animal health and environment (Lok Sabha, 2013b).

**Socio-economic Benefits and Impact of Bt cotton in India.**

In 2013, 7.34 million small holder cotton farmers having an average land holding of less than 1.5 benefited from Bt cotton. Remarkably, a cumulative ~46 million small holder cotton farmers planted Bt cotton in the twelve-year period showing a plausibly high repeat decision of planting of Bt cotton between 2002-03 to 2013-14.

Of the fourteen peer-reviewed research studies 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). These studies as referenced chronologically in Table 19, have been covered in detail in previous Briefs.

In 2013, Qaim and Kouser, researchers at the Georg-August-University of Goettingen, Germany published a research study Genetically Modified Crops and Food Security in PLOS One. The study concludes that ***"the adoption of GM cotton has significantly improved calorie consumption and dietary quality, resulting from increased family incomes. This technology has reduced food insecurity by 15–20% among cotton-producing households."*** The survey study was divided into four rounds covering 1,431 farm households sampled in India between 2002 and 2008. The study focuses on the interrelation between Bt technology, income generation and food security. In terms of calorie consumption in Bt cotton area, the study reported that ***"each hectare of Bt cotton has increased total calorie consumption by 74 kcal per AE per day. For the average adopting household, the net effect is 145 kcal per AE, implying a 5% increase over mean calorie consumption in non-adopting households."*** The study noted that most of the calories consumed in rural India stem from cereals that are rich in carbohydrates but less nutritious in terms of protein and micronutrients. Yet the results show that Bt adoption has significantly increased the consumption of calories from more nutritious foods, thus also contributing to improved dietary quality. Figure 24 shows the net effects of Bt adoption on household calorie consumption.

**Adoption and Uptake Pathways of Biotech Cotton in India**

In 2012 Kharif season, the Indian Society for Cotton Improvement (ISCI) – a premier registered society of the cotton researchers in India, conducted the largest and most comprehensive survey covering 2,400 sample of Bt cotton farmers across three agro-ecologically distinct cotton growing States focusing on 1000 farmers of rainfed cotton in Maharashtra in Central zone, 1,000 farmers of semi-irrigated cotton in Andhra Pradesh in Southern zone and 400 farmers of fully irrigated cotton area of Punjab in Northern cotton growing zone of the country.

The survey *Adoption and uptake pathways of biotech cotton among farmers in selected cotton growing villages of Maharashtra, Andhra Pradesh and Punjab in India* conducted by ISCI in collaboration with grass-root NGOs in respective States were part of the global project *Adoption and uptake pathways of biotech crops among farmers in India, China and the Philippines* supported by John

**Table 19. Fourteen Studies Conducted by Public Institutes on the Benefits of Bt Cotton in India for the Years, 1998 to 2013**

| Publication | [1]Naik 2001 | [2]ICAR field trials 2002 | [3]Qaim 2006 | [4]Bennet 2006 | [5]IIMA 2006 | [6]ICAR FLD 2006 | [7]Andhra University 2006 | [8]CESS 2007 | [9]Subramanian & Qaim 2009 | [10]Sadashivappa & Qaim 2009 | [11]Qaim *et. al* 2009 | [12]Subramanian & Qaim 2010 | [13]Kathage & Qaim 2012 | [14]Mayee & Choudhary |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period studied | 1998-99 & 00-01 | 2001 | 2001-2002 | 2002 & 2003 | 2004 | 2005 | 2006 | 2004-05 | 2004-05 | 2006-07 | 1998-06 | 2006-07 | 2002-08 | 2012 |
| Yield increase | 38% | 60-90% | 34% | 45-63% | 31% | 30.9% | 46% | 32% | 30-40% | 43% | 37% | 43% | 24% | 98% |
| Reduction in no. of spray | 4 to 1 (75%) | 5-6 to 1 spray (70%) | 6.8 to 4.2 (50%) | 3 to 1 | 39% | – | 55% | 25% | 50% | 21% | 41% | 21% | | 82.8% |
| Increased profit | 77% | 68% | 69% | 50% or more gross margins | 88% | – | 110% | 83% | – | 70% | 89% | 134% | 50% | - |
| Average increase in profit/ hectare | $76 to $236/ hectare | $96 to $210/ hectare | $118/ hectare | – | $250/ hectare | – | $223/ hectare | $225/ hectare | $156/ hectare or more | $148 / hectare or more | $131/ hectare or more | $161/ hectare or more | $107-213/ acre | $453/ hectare |

Sources:

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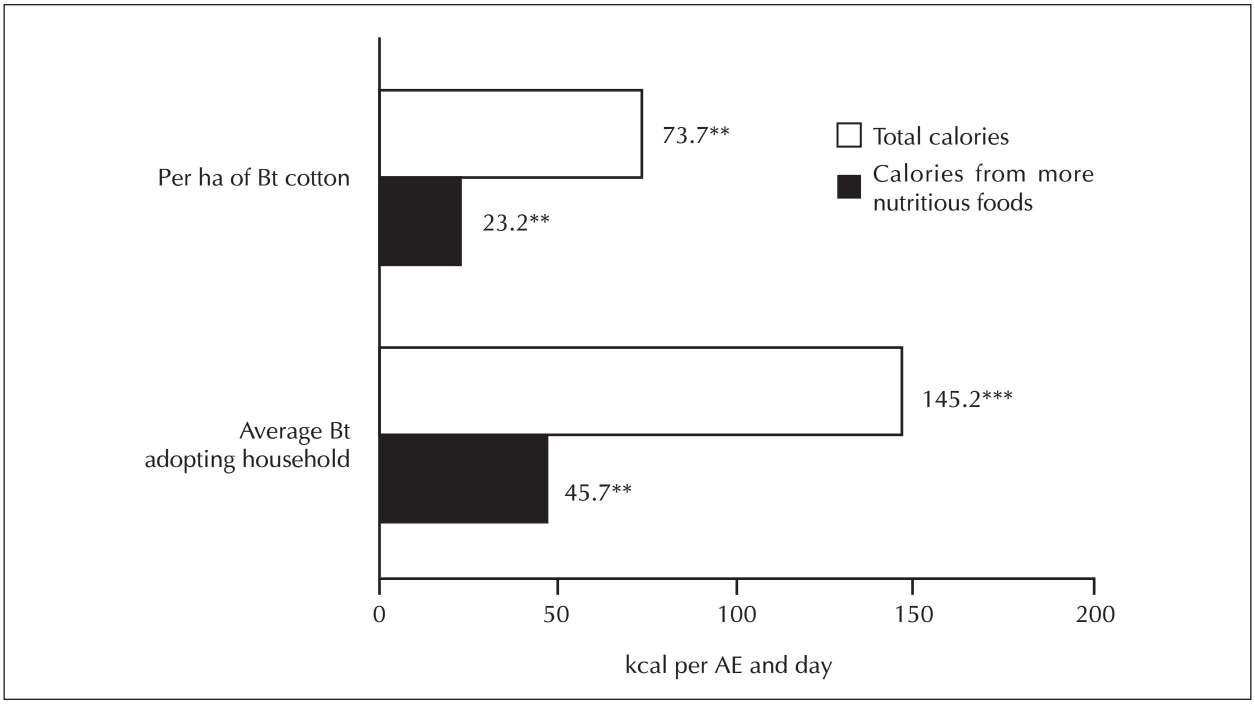
**Figure 24. Net Effects of Bt Adoption on Household Calorie Consumption**




Source: Adopted from Qaim and Kouser, 2013

Templeton Foundation. The ISCI published the survey report as the society's publication in October 2013 (Mayee and Choudhary, 2013). The survey confirmed the wide-spread planting of Bt cotton in both rainfed and irrigated areas over a long period of time and observed the following key trends in cotton cultivation in India:

1. The adoption of Bt cotton has been widespread across rainfed, semi-irrigated and irrigated areas of surveyed villages in the intensive cotton growing States of Maharashtra, Andhra Pradesh and Punjab. Most of the farmers interviewed admitted growing Bt cotton over a long period of time, in most cases 8-9 years in Maharashtra and Andhra Pradesh and 6-7 years in Punjab. The adoption rate of Bt cotton was more than 95% across surveyed villages in both rainfed and irrigated conditions. The adoption pattern of Bt cotton at village level was in conformity with the information on Bt cotton adoption at national level tabled in the Lok Sabha of the Parliament of India, which reported the adoption of Bt cotton to be more than 93% in 2012, the surveyed year.

2. Irrespective of farm and family size and demographic profile in surveyed villages, the adopters of Bt cotton included 50% or more small holder cotton farmers from other backward class (OBC) category in Maharashtra, whereas, similar percentage were from general category in Andhra Pradesh and Punjab. The categorization of Bt cotton farmers by social structure revealed

an overwhelming number of farmers especially from lower strata including OBC and SC/ST category who were active in farming adopted Bt technology at par with general category farmers. The survey confirmed that Bt cotton is a scale neutral technology that offers similar level of protection to dreaded bollworm irrespective of who cultivates Bt cotton.

3. There is gender bias in decision making in overall farming operation of cotton by male farmers across cotton growing areas in the country. However, majority of the respondents acknowledged a family-wide involvement in Bt cotton farming operation with distribution of work depending on the severity of the farm operation. Male farmer undertakes tough task of farm operation including land preparation and spraying, whereas, female farmer and children are involved in weeding, picking and cleaning operation. Notably, the survey observed an overall amicable work distribution among rural farm families resulting in happy family life, social satisfaction and community wide acceptance.

4. The Bt cotton technology has attracted young farmers to cotton farming across the surveyed States. More than 50% of respondent Bt cotton farmers were from the lower middle age group ranging from 21 to 40 years with mean average age of all respondents was 42 years in three States.

5. The doubling of cotton yield at farm level in both irrigated and rainfed condition was demonstrated. On an average, Bt cotton hybrids increased cotton yield from 4-5 quintals per hectare to 8-10 quintals per hectare in rainfed condition whereas cotton yield showed a steep increase from 10-12 quintals per hectares to 22-24 quintals per hectares in irrigated conditions. The yield increases were attributed to multiple factors driven by the large scale adoption of Bt technology resulting in saving of losses caused by bollworm, high vigour cotton genotypes, improved cropping practices and enhanced extension services to Bt cotton growers across three States. Notably, the country has witnessed a shift in average national yield from less than 300 kg lint per hectare which lasted for decades to 500 kg lint per hectare within 10 years of the large scale adoption of Bt cotton hybrids. The survey reported almost doubling of cotton yield in Vidharbha area of Maharashtra from an average yield of 150 kg lint per hectare to more than 300 kg lint per hectare in 2011-12. The progressive farmers of Punjab, Maharashtra and Andhra Pradesh reported the maximum cotton yield of 14-15 quintals per hectare in rainfed condition and 25-28 quintals per hectare in irrigated conditions.

6. There is a noticeable decrease in chemical sprays to control insect pests in cotton field across the three States. Two important observations related to chemical sprays on Bt cotton include an average 82.8% reduction in insecticide sprays while imparting 99.3% control to American bollworms in the surveyed States. Farmers in Maharashtra reported 78% reduction in insecticide sprays, 82% in Andhra Pradesh and 98% in Punjab. In some cases, farmers reported increased

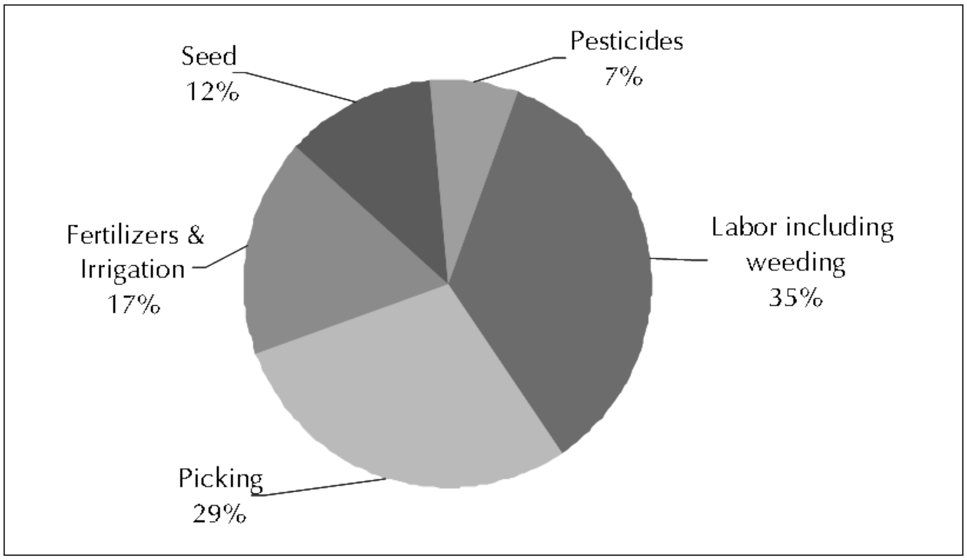
use of chemical sprays to control sucking pests which ranges from 2-3 sprays primarily in irrigated cotton areas of Punjab. The overall trend of insecticide usage to control bollworm decreased drastically from an annual insecticide usage of 9410 metric tons of active ingredient in 2001-02 to 222 metric tons of active ingredient in 2011 – a 40-fold decrease. Similarly, the Central Institute of Cotton Research (CICR) reported an annual saving of Rupees 651.3 crore on insecticides sprays to control cotton bollworm in 2011 alone.

7. Bt cotton reduced and changed the composition of the cost of cultivation of cotton across three States. In the post-Bt cotton period, the total cost of production was around Rs. 35,000 per hectare and the variation in inputs cost was observed marginal among states. On an average, Bt cotton farmers spent around 64% of total inputs cost on labor including farm operation, weeding and picking as shown in Figure 25. Fertilizers and irrigation accounted for 17% of total input costs followed by 12% on Bt cotton seeds and 7% on pesticides. The cost of pesticides which used to be the highest input cost prior to Bt cotton was reduced significantly and now ranges from 5.9% in rainfed area and 8.3% in irrigated area, which is reported to be the lowest of all input cost. The investment on Bt cotton seeds ranged from 10% in rainfed area to 15.2% in irrigated area due to variation in seed rates, gap filling and plant population.

8. Bt cotton farmers confirmed that more than 90% of farmers did not use non-Bt cotton packet for refuge plantings across three States. It was shocking to note that most of the cotton farmers either discarded non-Bt cotton packet or sold it at a cheap price to local retailers. The remaining 10% of farmers used non-Bt cotton refuge bag for gap filling and a very few percentage of them actually planted refuge around Bt cotton field. The unwillingness of farmers to plant non-Bt cotton refuge is a violation of the regulatory requirements of Bt cotton cultivation. It was observed that farmers who received pigeonpea as refuge bag planted it along with Bt cotton particularly in Maharashtra state. Many farmers also complained about low quality of non-Bt cotton refuge bag and didn't use it fearing it would attract insect pests and would not produce desirable cotton yield. It is important to note that refuge bag is supplied as a non-Bt counterpart of 120gm packaged separately in the Bt cotton hybrid seed bag.

9. There was no reported visual presence of American bollworm in Bt cotton field since the cultivation of Bt cotton in their respective fields. Farmers also reported that they staved off insecticides sprays, which used to require about 15 sprays for the control of American bollworm. Bt cotton continues to provide effective protection against targeted insect pests bollworm and there was no field level resistance development of the insect pests to Bt cotton. The observations on resistance management is in line with the reports of the Central Institute for Cotton Research (CICR) that has been implementing one of the most comprehensive resistance management program on Bt cotton in the world. Another finding of the survey is that majority of farmers (77.8%) across three States were growing double gene Bt cotton, the more durable Bt cotton hybrids providing effective protection to insect pests.

**Figure 25. Distribution of Cost of Cotton Cultivation Post Bt Cotton Era**




Source: Adopted from Mayee and Choudhary, 2013

10. In spite of large numbers of Bt cotton hybrids approved between 2002 to 2012, cotton farmers across three States reported that they were selective in cultivating a few popular Bt cotton hybrids. There was area-wise dominance of a few common Bt cotton hybrids planted across irrigated and rainfed conditions. Around 90% of the surveyed farmers were aware of denomination of Bt cotton hybrid and shared information about the brand name and seed company to which it belonged. The survey also showed a relatively quick turnaround of Bt cotton hybrids driven by farmers' preferences based on the quality and performance of Bt cotton hybrids in the field. Punjab farmers showed a high degree of preference for new Bt cotton hybrids belonging to different seed companies such as Rasi seeds, Vibha seeds, Nuziveedu seeds, Bioseeds, Ankur seeds to Mahyco hybrid seeds. In addition, many farmers reported the unavailability of the preferred Bt cotton hybrids and in some cases they had to compromise planting of non-preferred Bt cotton hybrids in absence of pre-booked Bt hybrids with local retailers.

11. Farmers reported a substantial increase in net income of Bt cotton farmers. However, farmers noted an annual fluctuation in net income of Bt cotton due to volatile market cotton prices, which fortunately remained above the Minimum Support Price (MSP) during the last couple of years giving higher return to Bt cotton farmers. The overall economics of Bt cotton cultivation was favorable to cotton farmers across three States. In 2011 Kharif season, the survey reported an average net income of Rs. 41,837 per hectare at national level which was reported to be highest

in Punjab at Rs. 53,139 per hectare followed by Rs. 39,786 in Andhra Pradesh and Rs. 32,885 per hectare in Maharashtra. Ironically, Maharashtra reported highest cost of cultivation whereas the reported yield was highest in Punjab and Andhra Pradesh (Table 20).

12. Replete with the experience of growing Bt cotton, farmers across the three States showed great interest and enthusiasm about the new technological breakthroughs in cotton in the future. Throughout the survey, the farmers repeatedly raised the question "when would we get new 'Bt type" cotton? Farmers also raised concerns about the unavailability and raising cost of labour not only for land preparation but also for weeding and picking operation throughout the cotton season. Farmers also reported that labor was becoming very expensive for farming as laborers often preferred to take advantage of NAREGA (National Rural Employment Guarantee Act), which is much more convenient than working for 8 hours in cotton farms.

13. There was an absence of involvement of KVKs and State agricultural departments in identifying and popularizing Bt cotton hybrids suitable for different areas in three surveyed States. However, farmers expressed satisfaction over handling of complaints and extension activities on Bt cotton by government agencies in recent years.

14. Most of the surveyed farmers acknowledged the contribution of progressive farmers who were the first to adopt and demonstrate the usefulness of Bt cotton hybrids before widespread adoption of Bt cotton by fellow farmers in respective three States.

15. Farmers also reported various communication and outreach activities on Bt cotton at village level by multiple stakeholders including private seed companies, dealers and retailers, media campaigns, advertisements, pamphlets distributions and pasting of stickers about different Bt cotton hybrids across cotton villages.

16. Farmers and farm community were the key driving force behind the quick and large scale adoption of Bt cotton across surveyed villages. The salient feature of the large scale adoption

**Table 20. Economics of Bt Cotton Cultivation in Maharashtra, Andhra Pradesh and Punjab**

| Items | Maharashtra | Andhra Pradesh | Punjab | Average in 3 States |
|---|---|---|---|---|
| Seed cotton yield (Kg/ha) | 1,640 | 1,875 | 2,086 | 1,867 |
| Gross income (Rs/ha) | 69,405 | 75,000 | 88,581 | 77,562 |
| Cost of cultivation (Rs/ha) | 36,520 | 35,214 | 35,442 | 35,725 |
| Net income (Rs/ha) | 32,885 | 39,786 | 53,139 | 41,837 |

Source: Adopted from Mayee and Choudhary, 2013 was the two-way communication channel among farmers at multiple levels including family level, friend's level, choupal (rural farmers) level, community level, village level and between fellow farmers across different villages in the surveyed States.

17. There is a growing understanding and interest among farmers and farm community about Bt cotton hybrids. Farmers acknowledged sharing of information about every aspect of cotton value chain, suitability and unsuitability of Bt cotton hybrids, shared learning about new farm practices and products in agriculture and most importantly access to the correct information about market price resulting in higher income. Similarly, in recent years farmers showed keen interest in different private companies selling Bt cotton hybrids and do keep track of new offering from news reports, advertisements in news papers, posters at community centre and local bazaar and often visited nearby KVKs to gain insight on new offering in agriculture.

18. Farmers across surveyed villages realized for the first time the true value of technology only after they commenced plantings of Bt cotton and were convinced that technological breakthroughs can improve agriculture at farm levels. Farmers voiced their support for "Bt type" technologies in agriculture and believed that technologies will play a key role in farming in the future.

19. Farmers reported high expectation in increase in cotton yield year-after-year after, as they realized a bountiful harvest due to Bt cotton hybrids over last couple of years. However, they were concerned for not being able to increase cotton yield to a higher level due to lack of new high yielding cotton hybrids.

Finally, farmers across three States echoed the same sentiments about welfare benefits of growing Bt cotton in terms of spending less time in the field, more time for family and doing other productive work, less exposure to pesticides & reaped more income and were no longer worried about the possibilities of big losses of cotton by insect pests.

Recognizing the importance of knowledge sharing as a critical component of technology adoption and dissemination in rural areas, the survey reinforced the age old practice of field demonstration and an active role of risk taking farmers as a most effective tool of wider dissemination of Bt cotton in the country. The survey's key message that "Bt technology has decreased pesticide usage, increased cotton productivity and increased farmer's income and contributed significantly to poverty alleviation" will be used to call on the governments in developing countries to empower farmers with a knowledge centric campaign called *"An Alert Farmer is An Affluent Farmer"*.

***Farmer Experiences***

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.

Prabhu of Andhra Pradesh, India
When we used non-Bt cotton seeds we did not get much yield. By using Bt cotton on my five acre land, I can get yields of 8 quintals (800 kg ) per acre. We used so much insecticides before but now life is fine.

Vijay Atmaram Ingle of Chitalwadi, Ta, Telhara, Akola, Maharashtra, India
I am a third generation cotton farmer who was not able to finish studies because my family did not have enough resources to send me to college. In 1976, I inherited a cotton farm of 14 acres (5.67 ha) where I was just harvesting 2.5 quintals (0.25 ton) of cotton per acre. In 1997-1999, I was one of the first farmers to conduct Mahyco's Bt cotton field trials. Today, my annual income from planting Bt cotton alone is about Rs. 12,60,000 (US$23,386.61). I was able to send my children to college. My son is currently studying agricultural biotechnology while my daughter has a degree in education. Being one of the first adopters of Bt cotton, my farm received wide publicity from media, including local newspapers and farm magazines. Among the benefits I gained from Bt cotton cultivation are the increase in my income which has tripled in the last ten years; improvement of my social status; ability to afford higher education for my children; acquisition of additional 8 acres of land in 2010; establishment of a dairy farm with 100 animals and other businesses; and building a Pucca (cement) house.

Venkatayya of Hussainpur, Sankarapalli Mandal, Andhra Pradesh, India
We used to plant conventional cotton varieties but yield was poor. We used insecticides every other day or once every two days. Yet we got only 3-4 quintals (300-400 kg) yield per acre. But after using Bt cotton seeds we now yield 1 ton. We are using less insecticide and the crop quality is good. Before we had debts because we spent a lot on insecticides. We are clearing those debts now with the profits from Bt cotton.

Sudhakar Vasudevrao Bhamkar of Khanapur, Vardha, Maharastra, India
For the last 25-30 years, I have been planting cotton referred to as white gold. Farmers need to adopt new scientific technology to improve production as well as earn more money. Growing Bt cotton helps farmers to save more by reducing labor cost otherwise spent for pesticide spraying. There is no need to spray pesticide on Bt cotton. I hope that agricultural research institutes can also focus their research to control other insect pests and diseases which infect Bt cotton.

Mohamad Habibbudin of Hussainpur, Mandal Shankarpali, Andhra Pradesh, India
I have been growing Bt cotton in the last five to six years. Previously I was growing conventional

cotton but I suffered a huge loss in yield due to bollworm infestation. Since Bt cotton was introduced, my yield has increased to 10-12 quintals (1,000 to 1,200 kg) per acre. Planting non Bt cotton used to yield only 400 to 500 kg/acre. Previously we were spraying pesticides 10-12 times on non Bt cotton. Now we are spraying only 2-3 times.

Ramu Dasrat Khoth of Nandora, Maharastra, India
My father used to grow traditional cotton varieties. Due to help from the government, we are now growing Bt cotton. Bt cotton technology helped increase yield. Previously, yield of non-Bt cotton was 6-7 quintals (600 to 700 kg) per acre but now we get up to 8-9 quintals (800 to 900 kg) per acre with very less expenses.

Srinivasa Reddy of Andhra Pradesh, India
Four years ago I used conventional seeds which yielded only 4 quintals (400 kg) per acre. In the last four years when I shifted to Bt cotton, I have been getting a yield of 8-9 quintals (800-900 kg) per acre which translates to a profit of INR50,000-70,000 (US$825-1,154). I have been able to study for a college degree while working on the farm as well.

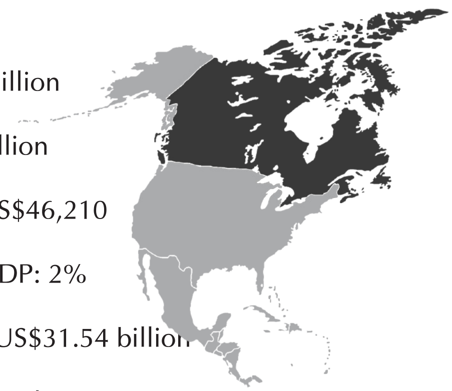
Narasimhulu of Masanigude, Sankarapalli Mandal, Rangareddy, Andhra Pradesh, India
I did not make money when we were planting conventional cotton varieties. Most of our money went to pesticides. Today I am growing Bt cotton on five acres of land. We are using less insecticides. This means more profits for us.

## *CANADA*

**In 2013, Canada retained its fourth place in world ranking of biotech crops with biotech crop hectarage at 10.8 million hectares compared with 11.6 in 2012 – a 7% decrease. The reason for the decrease was farmers electing to plant more cereals to rotate with canola which is a sound and welcome practice. The four biotech crops grown in Canada in 2013 were canola, maize, soybean and sugar beet. Biotech hectares for soybean were slightly higher than in 2012; biotech maize and biotech sugar beet hectarage similar to that in 2012, with the latter at ~15,000 hectares. Canada is estimated to have enhanced farm income from biotech canola, maize and soybean by US$4.9 billion in the period 1996 to 2012 and the benefits for 2012 alone is estimated at US$715.6 million.**

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 2013, Canada retained its fourth place in world ranking of biotech crops with an area of 10.81 million hectares, down by about 7% from 2012 when a record 11.6 million hectares were planted. The principal reason for the decrease is that 8% less canola was sown in 2013, with farmers planting more cereals to achieve better rotation which is to be applauded. The four biotech crops grown in Canada in 2013 were similar to last year; viz canola, maize, soybean and sugar beet, with canola being the major biotech crop at 7.5 million hectares and a high 96% adoption rate, with more growth in soybean, and about the same area for maize and sugar beet.

## CANADA



Population: 33.9 million

GDP: US$1,577 billion

GDP per Capita: US$46,210

Agriculture as % GDP: 2%

Agricultural GDP: US$31.54 billion

% employed in agriculture: 2%

Arable Land (AL): 49.7 million hectares

Ratio of AL/Population*: 6.0

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

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

Total area under biotech crops and (%) increase in 2013:
10.8 Million Hectares (-7%)

Farm income gain from biotech, 1996-2012: US$4.9 billion

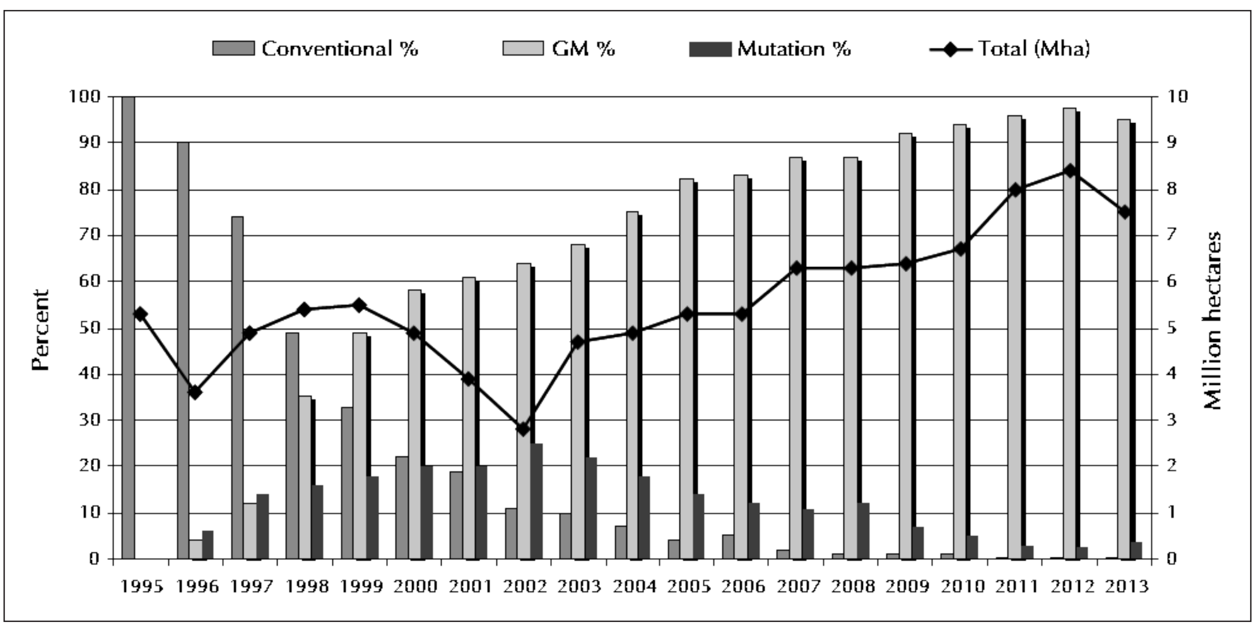
*Ratio: % global arable land / % global population

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 96%. The total land area planted to canola in Canada in 2013 was 8.0 million hectares, down 7% from the 8.6 million hectares in 2012. In 2013, the national adoption rate for biotech canola was 96%, down slightly from 97.5% in 2012, compared with 96% in 2011, 94% in 2010, 93% in 2009, 86% in both 2008 and 2007, 84% in 2006 and 82% in 2005 (Figure 26). In 2013, biotech herbicide tolerant canola was grown on approximately 7.5 million hectares, compared with 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 2006. Thus, in Canada there has been an impressive, steady and significant increase both in the total land area planted to canola in the absolute hectares and in the percentage planted to herbicide tolerant biotech canola, which reached a record high national adoption rate of 97.5% in 2012. In 2013, biotech canola was estimated at 96% of the biotech hectarage, mutation based canola at 3.8% and conventional at 0.2% (Personal Communication Canola Council of Canada 2013).

In Ontario and Quebec, the major provinces for maize and soybean, total plantings of maize for all purposes in 2013 were 1.7 million hectares and 1.8 million hectares for soybean. In 2013, the area of biotech maize, was 1.66 million hectares (97.6% adoption), up slightly from last year. 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 2013, only 20% contained a single gene, compared with 21% in 2012, and 68% in 2008. In 2013, 80% contained 2 or 3 stacked genes compared with 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. In 2013, of the total soybean hectarage of 1.8 million hectares, the biotech soybean hectarage was 1.6 million hectares (89.8% adoption).

Biotech RR®sugar beet was planted in Canada in 2013 after being launched in 2008. It is estimated that in 2013, 96% (same as 2012) of the sugar beet in Canada, equivalent to approximately 15,000 hectares were RR®sugar beet. This was the sixth year of planting in Ontario in Eastern Canada,

**Figure 26. Percentage of Conventional, Biotech and Mutation-based Herbicide Tolerant (HT) Canola Planted in Canada, 1995 to 2013 (Million Hectares)**




Source: Canola Council of Canada (Personal Communication, 2013) (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 in Canada.

It is estimated that approximately 2% of the Canada canola production will be used for biofuel by 2013. Canada is a major producer of wheat and several of the current principal wheat varieties have been developed through mutagenesis – there is increased interest in biotech wheat. Maize with higher levels of lysine is undergoing field tests. The RR®alfalfa from the USA has also been approved for import to Canada.

## Benefits from Biotech Crops in Canada

Canada is estimated to have enhanced farm income from biotech canola, maize and soybean by US$4.9 billion in the period 1996 to 2012 and the benefits for 2012 alone is estimated at US$715.6 million (Brookes and Barfoot, 2014, Forthcoming).

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

- More cost effective weed management was the most important advantage attributed by farmers to herbicide tolerant canola with herbicide cost 40% lower for biotech canola (saving of 1,500 MT of herbicide in 2000) compared with conventional canola.
- A 10% yield advantage for biotech canola over conventional and the dockage was only 3.87% for biotech canola compared with 5.14% for conventional.
- Less tillage and summer fallow required for biotech canola which required less labor and tractor fuel (saving of 31.2 million liters in 2000 alone) and facilitated conservation of soil structure and moisture and easy "over the top" spraying for weeds after crop establishment.
- Increased grower revenue of US$14.36 per hectare and a profit of US$26.23 per hectare for

biotech canola over conventional.

- At a national level the direct value to growers from 1997 to 2000 was in the range of US$144 to US$249 million.
- The indirect value to industry of biotech canola was up to US$215 million for the same period 1997 to 2000.
- The total direct and indirect value to industry and growers for the period 1997 to 2000 was US$464 million.
- Extrapolating from the period 1997 to 2000 when 8,090,000 hectares of biotech canola were grown for a gain of US$464 million and the additional 19,809,000 hectares grown during the period 2001 to 2007, the total direct and indirect value to industry and growers for the period 1997 to 2007 is of the order of US$1.6 billion.

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 21). 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.

A report called *The Economic Impact of Canola on the Canadian Economy* was released in 11 October 2013 by Canola Council of Canada (CCC) (2013). The report highlights the tremendous growth in canola's contribution to the Canadian economy, which now equates to Ca$19.3 billion, which also directly or indirectly accounts for 249,000 Canadian jobs.

**Table 21. 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.

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 22). Wages linked to the industry's impact have more than tripled during the same period.

## Canadian Wheat Alliance to Develop New Varieties

The Governments of Canada, and Saskatchewan, and the University of Saskatchewan created the Canadian Wheat Alliance (CWA), a new 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 will invest 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).

**Table 22. 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

*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."

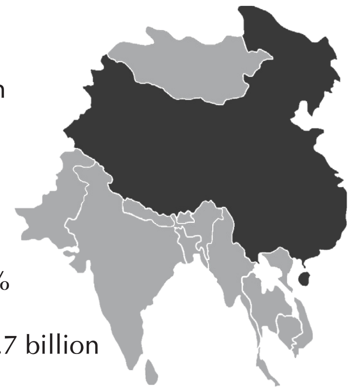
Lady Farmer Cherilyn Nagel farms in Saskatchewan, talks about life on the farm, her passion for agriculture, the value of modern technology and the safety of food produced on Canadian farms. "Through the use of biotech seeds, I was able to increase my yield 20 to 50% higher than before, I do not worry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

## *CHINA*

**In China in 2013, 7.5 million small farmers (0.5 to 0.6 hectare/farm) successfully grew ~4.2 million hectares of Bt cotton at a 90% adoption rate; an additional ~5,800 hectares of virus resistant papaya were planted in Guangdong province and Hainan Island; plus ~543 hectares of Bt poplar. Economic gains at the farmer level from Bt cotton for the period 1997 to 2012 was US$15.3 billion and US$2.2 billion for 2012 alone. Research in northern China indicates that there maybe up to an additional 10 million beneficiary farmers cultivating 22 million hectares of crops other than cotton, which also host cotton bollworm, but where infestations have decreased up to ten-fold, because of lower infestations due to Bt cotton. Thus, the actual number of beneficiary farmers of biotech Bt cotton in China alone may well exceed 17.5 million.**

Whereas rice is the most important food crop in China, maize is the most important feed crop, and the home-grown biotech phytase maize has been assigned high priority for commercialization by the Government of China. About 35 million hectares of maize is grown in China by an estimated 100 million maize-growing households (~400 million potential beneficiaries). Phytase maize, which confers increased phosphate uptake by animals is reported to increase the efficiency of meat production. This is an important new and growing need, as China becomes more prosperous and consumes more meat which requires more expensive imports of maize. China has 500 million pigs (~50% of the global swine herd) and 13 billion chickens, ducks and other poultry which need feed. Given the significant increased demand for maize and rising imports, it is likely that biotech maize, will be the first biotech feed crop to be commercialized by China. A group of over 60 senior scientists in China recently reiterated the strategic importance of commercializing biotech crops to the country and its commitment to ensure safe testing of the products before deployment. Biotech phytase maize and Bt rice approved for biosafety on 27 November 2009, are undergoing extensive and rigorous field trials that all new improved crops, conventional and biotech, must undergo prior to commercial approval.

**CHINA**



Population: 1,354.1 million

GDP: US$5,927 billion

GDP per Capita: US$4,430

Agriculture as % GDP: 10%

Agricultural GDP: US$592.7 billion

% employed in agriculture: 40%

Arable Land (AL): 112.8 million hectares

Ratio of AL/Population*: 0.35

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 2013:
4.2 Million Hectares (+5%)

Increased farm income for 1997-2012: US$15.3 billion

*Ratio: % global arable land / % global population

Biotech maize and rice offer significant benefits and have momentous implications for China, Asia and the world in the near, mid and long term, because rice is

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

**China has also approved and successfully grown biotech papaya, a fruit food crop for seven years, since 2007. In 2013, Guangdong province and Hainan Island grew a total of 5,800 00 hectares of virus resistant papaya. It is noteworthy that Japan also approved biotech papaya for import and marketing as a fresh fruit/food from the US in 2011. In addition, plantations of Bt poplar in China, with improved insect resistance, continued to be successfully grown on 543 hectares, a similar hectarage to that reported for 2012.**

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

In November 2009, China completed its chronological approval of a troika of key biotech crops – fiber (Bt cotton already approved in 1997), feed (phytase maize) and food (Bt rice). China's Ministry of Agriculture (MOA) granted three biosafety certificates on the same day. Two biosafety certificates were issued for biotech rice, one for a rice variety (Huahui-1) a restorer line, and the other for a hybrid rice line (Bt Shanyou-63), both of which expressed *cry1Ab/cry1Ac* and developed at Huazhong Agricultural University (James, 2009a). The approval of Bt rice is extremely important because rice is the most important food crop in the world that feeds 3 billion people or almost half of humanity; furthermore and importantly, rice is also the most important food crop of the poor. The third certificate was for biotech phytase maize, an important trait for maize, the principal animal feed crop in the world. It is important to note that all three products are all home-grown. The phytase maize was developed by the Chinese Academy of Agricultural Sciences (CAAS) and licensed to Origin Agritech Limited after 7 years of study at CAAS. **The three certificates of approval have momentous positive implications for biotech crops in China, Asia and the whole world in the near, mid and long term.** It is important to note that the MOA conducted a very careful due diligence study, prior to issuing the three certificates for full commercialization, pending completion of the standard registration field trials which applies to all new conventional and biotech crops. In addition, all three approved biotech crops, Bt cotton, Bt phytase maize, and Bt rice were all developed using public resources in Chinese public sector institutions, and thus are home-grown products. It is noteworthy that China has now completed approval of a troika of the key biotech crops in an appropriate chronology – first was FIBER (cotton), followed by FEED (maize) and FOOD (rice). The potential benefits of these 3 crops for China are enormous and summarized below.

- **Bt cotton.** China has successfully planted Bt cotton since 1997 and in 2013, 7.5 million small farmers in China increased their income by approximately US$220 per hectare (equivalent to approximately US$1 billion nationally) due on average to a 10% increase in yield, and a 60% reduction in insecticides, both of which contribute to a more sustainable agriculture and the prosperity of small poor farmers. China is the largest producer of cotton in the world, with an estimated 90% of its 4.6 million hectares successfully planted with Bt cotton in 2013.

- **Phytase maize.** China, after the USA, is the second largest grower of maize in the world (35 million hectares grown by 100 million households); it is principally used for animal feed. Achieving self-sufficiency in maize and meeting the increased demand for more meat in a more prosperous China is an enormous challenge. For example, China's swine herd, the biggest in the world, increased 100-fold from 5 million in 1968 to over 500 million today. Phytase maize will allow pigs to digest more phosphorus, resulting in faster growth/ more efficient meat production, and coincidentally, a reduction of phosphate pollution from animal waste into soil and extensive bodies of water and aquifers. Maize is also used as feed for China's huge number of domesticated avian species – 13 billion chickens, ducks and other poultry, up from 12.3 million in 1968. Phytase maize will allow animal feed producers to eliminate the need to purchase a phytase supplement with savings in equipment, labor and added convenience. The significance of this maize approval is that China is the second largest grower of maize in the world with >30 million hectares (USA is the largest at 37 million hectares). As wealth is rapidly being created in China, more meat is being consumed which in turn requires significantly more animal feed of which maize is a principal source. China imports 5 million tons annually at a foreign exchange cost of over US$1 billion. It is noteworthy that phytase maize is China's first approved feed crop. The only country in Asia that has approved and already growing biotech maize is the Philippines where it was first deployed in 2003; Bt maize, herbicide tolerant (HT) maize and the stacked Bt/HT product were grown on approximately ~800,000 hectares in the Philippines in 2013. Biotech maize is likely to be commercialized in China well before Bt rice, given Government's priority for biotech maize and the significant increased demand currently being met by increased imports.

- **Bt rice** offers the potential to generate benefits of US$4 billion annually from an average yield increase of up to 8%, and an 80% decrease in insecticides, equivalent to 17 kg per hectare on China's major staple food crop, rice, which occupies 30 million hectares (Huang et al. 2005). It is estimated that 75% of all rice in China is infested with the rice 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 tons per hectare by 2030 when its population will be 1.6 billion** (Chen et al. 2010). T**hus, in 2030, China will need approximately 235 million tonnes of paddy annually, equivalent to one third of global production of approximately 750 million tonnes.**

The significant advantages that these products offer China also apply to other developing countries, particularly in Asia (but also elsewhere in the world), which have similar crop production constraints. Other Asian countries, which could benefit from biotech maize, include India (8 million hectares of maize), Indonesia (4 million hectares), Thailand, Vietnam and Pakistan, all three with approximately 1 million hectares each of maize. Asia grows and consumes 90% of production from the world's 150 million hectares of rice, and Bt rice will have enormous impact in Asia. Not only can Bt rice contribute to an increase in productivity and self-sufficiency but it can also make a substantive contribution to the alleviation of poverty of poor small farmers who represent 50% of the world's poor. Similarly, there are up to 50 million hectares of maize in Asia that could benefit from biotech maize. China's exertion of global leadership in approving biotech rice and maize in 2009 was a positive influence on acceptance and speed of adoption of biotech food and feed crops in Asia, and more generally globally, particularly in developing countries. This approval is exemplary for other countries in pursuit of "self-sufficiency" (optimizing productivity and production of home-grown food) as opposed to "food security" (enough food for all) – the distinction is important and the two goals are not mutually exclusive. China can serve as a model for other developing countries, particularly in Asia, which could have substantive implications for:

- a more timely and efficient approval process for biotech crops in developing countries;
- new modes of South-South technology transfer and sharing, including public/public and public/private sector partnerships;
- more orderly international trade in rice and reduction in probability of recurrence of 2008-type price hikes, which were devastating for the poor; and
- shift of more authority and responsibility to developing countries to optimize "self-sufficiency" and provide more incentive for their involvement to deliver their share of the 2015 Millennium Development Goals.

**Bt Cotton Adoption**

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 2013, at 4.6 million hectares was lower than that planted in 2012 at 4.9 million hectares, but the adoption rate increased to 90% in 2013, thus, offsetting the decrease in total area of cotton. The area planted to Bt cotton in 2013 of 4.2 million hectares was higher in 2013 when adoption rate was 80%. 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 7.5 million small and resource-poor farmers grew 4.2 million hectares of Bt cotton in China in 2013. An important paper in Science (Wu et al. 2008) suggested that the potential number of small farmers actually benefiting indirectly from Bt cotton in China might be as high as 10 million more. It is noteworthy that a paper by Hutchinson (2010) based on studies in the USA draws similar conclusions to Wu et al. (2008) – indeed it reports that the indirect benefits for conventional crops grown in the same area where biotech crops are deployed, are actually greater than the direct benefits from biotech crops. For more details see the Chapter on the USA in this Brief.

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

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

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

> "The cotton bollworm (*Helicoverpa armigera*) and pink bollworm (*Pectinophora gossypiella*) are the most devastating pests on cotton in China and are the key pests that Chinese cotton farmers have traditionally had difficulty in controlling, even with frequent insecticide spray programs. Bt cotton has changed this situation. The high adoption rate of Bt cotton in China has resulted in effective suppression of both species on cotton and also regional suppression of the polyphagous *H. armigera* on a number of other crops (e.g. peanuts, soybean and vegetables). This situation has resulted in dramatic reductions in the use of traditional, broad-spectrum insecticides which, in turn, have led to decreased environmental harm and fewer farmer poisonings. However, since Bt cotton only controls the caterpillar pests, in some cases other arthropod populations have increased. This includes cotton aphids (*Aphis gossypii, A. atrata, A. medicaginis,* and *Acyrthosiphon gossypii*), mirids (*Adelphocoris suturalis, A. lineolatus, A. fasciaticollis, Lygus lucorum,* and *L. pratensis*), spider mites (*Tetranychus cinnabarinus, T. truncates, T. turkestani,* and *T. dunhuangensis*), thrips (*Frankliniella intonsa, Thrips tabaci,* and *T. flavus*), and whiteflies (*Bemisia argentifolii* and *B. tabaci*).

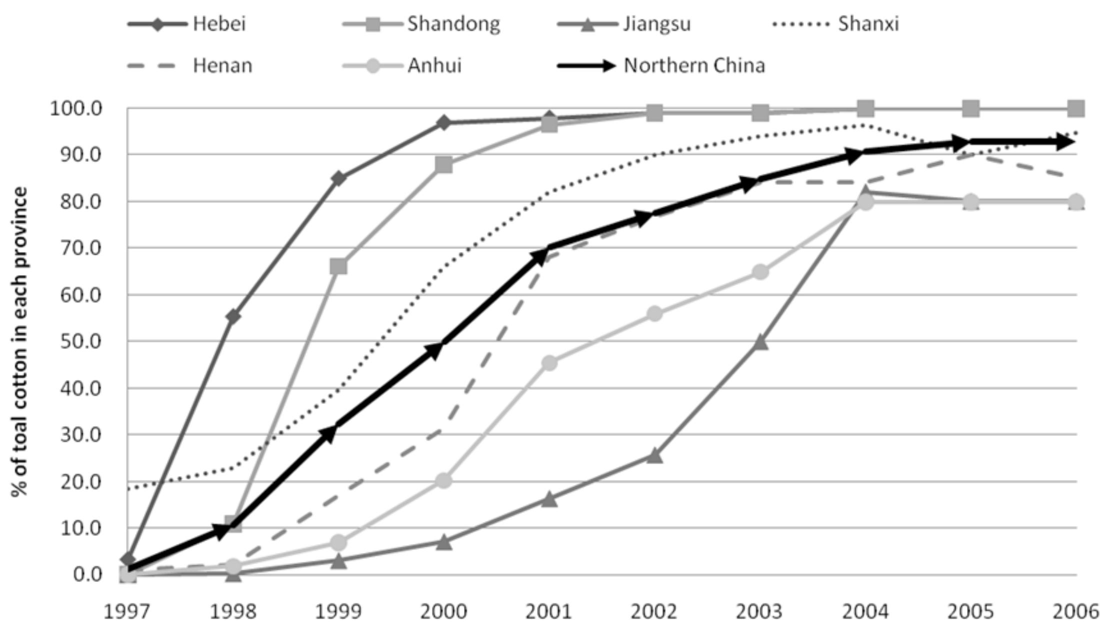
> Management programs for the insect complex not affected by Bt proteins need to be put into place and these include the use of some systemic insecticides which are far safer on the environment and natural enemies. From the pest management standpoint, conservation of such natural enemies, through the use of Bt plants and selective insecticides is key for managing the entire pest complex of cotton and is part of an overall integrated pest management (IPM) approach needed for sustainable cotton production. Such comprehensive IPM programs have proven effective for key and secondary arthropod pests in the US where Bt cotton adoption continues to climb and reached ~90% of all upland cotton production in the US in 2011. Chinese scientists are exploring strategies so that they can also obtain similar comprehensive IPM programs."

The field data from China's Ministry of Agriculture used in the same study by Wu et al. (2008) also clearly demonstrated the unusually high and rapid adoption of Bt cotton in each of the six provinces of northern China during the period 1997 to 2006 (Figure 27). It is noteworthy that adoption of Bt cotton was fastest in the two provinces of Hebei and Shangdong reaching over 95% in the short span of 5 years and 100% in 8 years. The adoption rates in the provinces of Jiangsu, Shanxi, Henan and Anhui were almost as fast, reaching 80 to 90% in 8 years or less (Figure 27). In northern China, as a region, more than 66% adoption of Bt cotton was reached in only 5 years. These adoption rates are remarkably high by any standard and reflect the vote of confidence and trust of farmers in Bt cotton, which has delivered multiple and significant economic, agronomic and socio-economic benefits consistently from 1997, the first year of commercialization, to the present.

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

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

**Figure 27. Adoption of Bt Cotton in Each Province of Northern China, as Percentage, 1997 to 2006**




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

hectares of Zhongzhi varieties and these are estimated to contribute US$2 billion per annum to the Chinese economy.

## 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 23). 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 4,000 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 50% of 4,000 hectares of biotech papaya was grown in 2013 for a national total of 5,800 hectares in China. The adoption rate in 2013 in Guangdong

**Table 23. Approval of Biotech Crops in China**

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

Source: Compiled by Clive James, 2013.

was estimated at 95%, the same level as in 2012, 2011 and 2010. (Personal Communication, Prof Li, South China Agricultural University). The percentage adoption of biotech papaya in Guangdong was 95% in 2013 and historically has consistently increased annually from 70% adoption (equivalent to 3,550 hectares) in 2007 when it was first commercialized, to 88% in 2008, and 90% in 2009.

**Insect Resistant Poplar**

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

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

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

About 91% of the 490 hectares in 2011 were Bt *Populus nigra* clones, and the balance of 9% was clone 741 featuring *cry1Aa* and API. A new clone under development, a hybrid white poplar clone 84K transformed with the *Bt886Cry3Aa* resistance gene, has already undergone testing in nurseries and the preliminary results are promising. Clone 84K with *Bt886Cry3Aa* is tolerant to the economically important Asian longhorn beetle, which attacks the trunks of poplars and can cause significant damage. Comparisons between Bt poplar and non-Bt checks, confirm that Bt poplars require no insect pest control in the first 6 years, compared with the checks, which required 2 to 3 insecticide sprays (Lu M-Z, 2010, Personal Communication). This is consistent with experimental data (Table 24) 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".

**Table 24. 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.

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.

**Chinese Private Sector Seed Companies and Public-Private Sector Partnerships**

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

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

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

There are a growing number of collaborative initiatives between Chinese institutions and foreign companies and institutions. For example, the China National Seed Group (China Seed) and Monsanto have agreed to extend their respective investments in their joint venture company, CNSGC-DEKALB Seed Company Ltd. (CNDK) – the agreement is pending approval by the Chinese Government. CNDK was formed in 2001 to market maize hybrids in China, the second largest market for maize hybrids in the world, after the USA. In November 2009, Monsanto announced the establishment of its Biotechnology Research Center in Zhongguancun, Beijing that will allow the company to strengthen its links with Chinese Research Institutions in plant biotechnology and genomics. In November 2008, Bayer 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.

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

In June 10, 2013, China's Ministry of Agriculture eventually approved three GM soybean products for importation as food, that include 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).

**Support for Biotech Crops in China**

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

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

Elsewhere in Asia, there are also significant R&D investments on biotech rice featuring agronomic and quality traits. For example, a team at the University of Tokyo, Japan has developed biotech rice that can tolerate iron deficiency, which is a very prevalent constraint in the rice growing countries of Asia (Takanori et al. 2008). Deployment of a rice, tolerant to iron deficiency, is one of many biotechnology applications, including pest and disease resistance and pro-Vitamin A enhanced Golden Rice (expected to be available in Asia in 2015) that could contribute to higher productivity and improved nutritional quality of rice. Rice is not only the most important food crop in the world but is also the most important food crop of the poor in the world. This is particularly true in Asia where 90% of the world's rice is produced and consumed and where rice has a very important cultural role. In Asia, rice is the staple of 600 million extremely poor rural people, mostly subsistence farmers and the rural landless who are completely dependent on agriculture for their livelihood. Hence, biotech rice with improved attributes can make an enormous contribution to the alleviation of poverty and hunger in Asia but also in Latin America and Africa where rice is important, particularly for the poorer in rural communities.

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

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

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

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

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

### Benefits from Biotech Crops in China

***Bt cotton*** – In 2013, Bt cotton was planted by 7.5 million small and resource-poor farmers on ~4.2 million hectares, which is 90% of the ~4.6 million hectares of all cotton planted in China in 2013. Based on studies conducted by the Center for Chinese Agricultural Policy (CCAP), it was concluded that, on average at the farm level, Bt cotton increases yield by 10%, reduces insecticide use by 60%, with positive implications for both the environment and the farmers' health, and generates a substantial US$220 per hectare increase in income which makes a significant contribution to their livelihood as the income of many cotton farmers can be as low as around US$1 per day (Jikun Huang, 2008, Personal Communication). At the national level, it is estimated that increased income from Bt cotton was approximately US$1 billion per year in 2011. **It is estimated that China has enhanced its farm income from biotech cotton by US$15.3 billion in the period 1997 to 2012 and by US$2.2 billion in 2012 alone (Brookes and Barfoot, 2014, Forthcoming).**

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

### Political Support for Biotech crops in China

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

***improve the quality, yield and disease resistance of agricultural products. He said that this will assure sustainable development and competitiveness of the nation's agricultural sector"*** (Hu, 2010).

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

**Dr. Dafang Huang**, former Director of the Biotechnology Research Institute under the Chinese Academy of Agricultural Sciences (CAAS), in an interview by the Xinhua News Agency said that, ***"We are technically advantageous in hybrid rice planting. The genetically modified technology could ensure China's superiority in food production."*** Supporting Dr. Huang's statement was **Dr. Wu Yongning**, a scientist at the Chinese Center for Disease Control and Prevention, ***"I am not ruling out all possible risks, but those risks of genetically-modified food are no greater than that of traditional ones, given the heavy use of pesticide in growing traditional food"*** (Huang, 2010).

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

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

During this year, 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 Time to modify our stance on GM food 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 points out that after two decades, hundreds of millions have eaten GM food, and that "***any opposition is ideological, nothing more"*** – he asks ***"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 contrast, he notes that there have been many genuine food scandals around the world including China's milk scandal in 2008 caused by Melamine; mad cow disease; the 2005 *E. coli* food outbreak in South Wales; salmonella-infected egg production in Britain; the euro cucumber scare, related to an *E. coli* outbreak, in Germany in 2011; and dioxin-tainted Irish pork in 2008, to name a few. He notes that some of the anger against GM has to do with the fight against corporate greed in large transnational, makes the opposition of anti-GM radicals even more counter productive. Small companies are deterred from entering the field. Effectively, sustained GM opposition helps create a high barrier to entry, making sure only a few well-funded corporations like Monsanto dominate the field. GM opposition is also dangerous. The European Union's punitive regulatory regimes against GM make it difficult for African countries with histories of famine and food crisis to use the technology. With drastic climate change and rising population, it is irresponsible to oppose such crop-improvement technology.

The following is a summary of an article in the China Daily (21 October 2013) on *Government requested to plant GM Crops*. 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 USA has been commercializing biotech crops since 1996 and China has benefited from these more affordable biotech soybean imports which now represent 75% of China's demand.
- The Chinese government subsidizes Chinese soya farmers heavily, but they only produce about 12 million tons of non-biotech soya every year, and their products are "uncompetitive."
- Dr. Dafang Huang, a researcher from the Biotechnology Research Institute at the Chinese

Academy of Agricultural Sciences noted that the only biotech crop grown commercially in China is cotton and that this poses a threat to food security in China, especially when international food prices begin to rise.

- 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, but the certificates will expire on August 17, 2014.
- In order to commercialize biotech crops in China, crops need two certificates: one for safety and the other for commercialization. The latter is still pending for the two biotech rice lines. Zhang said that ***"The Ministry of Agriculture didn't work out a way to commercialize our GM rice due to public objections to GM products. It's a great pity."***
- In September, the Ministry of Agriculture posted on its website an interview with Lin Min, a member of the nation's committee to evaluate the safety of biotech organisms, and stated that biotech food is as safe as non-biotech food.
- 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-wide.

A recent article appeared in the Wall Street Journal (23 October 2013) on *China pushing genetically modified food*. The article 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. Recently 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. (Author's note - China has already issued a biosafety certificate for a home-grown phytase feed maize developed by CAAS in November 2009). 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.

## Adoption and Uptake Pathways of Biotech Cotton in China

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, 2014. In Preparation).* A synthesis of the results in China is presented below:

> A study on the adoption and uptake pathways of Bt cotton by small-scale farmers in China and the changes these have brought to farmers' lives was conducted by the Center for Chinese Agricultural Policy.
>
> The research focused on Bt cotton as the crop of study since it is the most widely adopted GM crop in China. The locales of the study are the provinces of Hebei, Shandong, Anhui and Henan provinces where Bt cotton is widely cultivated. These provinces are also referred as China's Huang-Huai-Hai cotton production zone.
>
> The study revealed that the adoption rate of Bt cotton varies in four provinces. Bt cotton was commercialized in 1997 in the provinces of Hebei, Shandong, and Anhui. However, fast adoption rate only occurred in Hebei, with almost 100 percent adoption rate upon Bt cotton's commercialization; while farmers in the province of Anhui did not initially adopt the crop. Meanwhile, in one of the counties in Shandong, Bt cotton was cultivated in about one third of the cotton area; but the adoption rate was zero in the other counties. It also increased rapidly in other provinces but the growth rate of adoption is lower. In two counties (one in Anhui and the other in Henan provinces), the adoption rate only reached more than 90 percent in 2004. In Taikang county in Henan, the adoption rate varied between 80 percent and 95 percent in the early 2000s.

The most promising benefit that the farmers derived from Bt cotton adoption is the reduction of pesticide use. The trend was evident in all of the four provinces. In Hebei, the farmers now spray pesticide only four times compared to more than 25 times before adopting Bt cotton. Majority of farmers also reported that planting Bt cotton enabled them to use less labor input, but higher yield with good cotton quality. This reduced their farming cost compared to the conventional cotton. In terms of earning, farmers get net revenue for Bt cotton three times more (31.9 yuan/ha) than what they get from non Bt cotton (9.7 yuan/ha). The difference of total cost between Bt cotton and non-Bt cotton production is 5028.6 yuan/ha.

Using a participatory rural appraisal tool *Innovation Tree*, the researchers attempted to track how Bt cotton adoption started and spread among farming communities in China. In most cases, the seed technicians or the traders are the ones who introduce Bt cotton to the farmers. In some communities, farmers first learned Bt cotton from their fellow farmers in nearby villages who were evidently benefiting from Bt cotton cultivation. They usually visit their fellow farmers' field especially during pruning and harvest season to see how the crop performs. Some village officials are also influential for the farmers to adopt Bt cotton. The spread of the technology happens as the farmers influence their fellow farmers, neighbors, relatives, and even their wives' families outside their villages to plant Bt cotton. The farmers indicated their fellow farmers, seed technicians, seed suppliers, and others, including media and village officers, as their sources of information with regard to Bt cotton cultivation.

Recommendations for this study include training programs for older and female farmers on Bt cotton cultivation; further information dissemination on Bt cotton as some farmers are still not aware of the technology; allowing Bt cotton farmers to rent additional lands as most of them are interested to expand their Bt cotton farmlands; and encouragement for the village leaders to convince the farmers to plant Bt cotton as the village leaders are viewed as influential people in Chinese communities.

***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.

<u>Wang Yuping of Zhangzhai, Nancheng, Xiajin, Shandong, China</u>
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.

<u>Kaibo Wang of Jiguan, Wangjiang, Anhui, China</u>
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.

<u>Li Yizheng of Qinahuozhuang, Xinshengdian, Xiajin, Shandong, China</u>
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.

<u>Chen Jianbin of Da Lisi, Wangkou, Xinji City, Hebei Province, China</u>
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.

<u>Xu Derong of Zhangzhai, Xiajin, Shandong, China</u>
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.

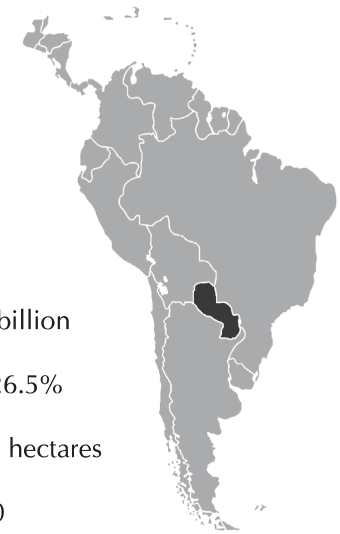
Li Wenjing of Da Lisi, Wangkou, Xinji City of Hebei, China
Bt cotton was recommended to us by a Chinese agricultural company. The village council also persuaded us to grow Bt cotton as they said that the variety has lots of benefits compared to the conventional cotton. Ever since I planted Bt cotton, 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 nine years since 2004. In 2013, Paraguay grew a total of 4.2 million hectares of soybean, cotton and maize, of which a record 3.6 million hectares were biotech, up ~200,000 hectares from 2012 and at a record 85% adoption rate. Of the 3.1 million hectares of soybean ~95% or 3.0 million hectares were biotech. Of the 1.1 million hectares of maize estimated for 2013/2014, over 50% were biotech and 50% of the 100,000 hectares of cotton were biotech. Intacta, a new stacked HT/IT soybean was authorized and launched in 2013. Economic gains over the period 2004 to 2012 is estimated at US$830 million and the benefits for 2012 alone at US$95.6 million.**

**PARAGUAY**



Population: 6.7 million

GDP: US$25.5 billion

GDP per Capita: US$3,183

Agriculture as % GDP: 16%

Agricultural GDP: US$4.08 billion

% employed in agriculture: 26.5%

Arable Land (AL): 3.8 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 2013:
3.6 Million Hectares (+6%)

Farm income gain from biotech, 2004-2012: US$0.83 billion

*Ratio: % global arable land / % global population

Paraguay is the world's number four exporter of soybeans. It grew biotech soybean unofficially for several years before it approved four herbicide tolerant soybean varieties in 2004. In 2013, Paraguay was expected to grow a total of 3.1 million hectares of soybean, of which a record 3.03 million hectares (approximately 95% adoption) was biotech herbicide tolerant soybean. This increase in 2013 was mainly due to more total plantings of soybean. Paraguay is one of the 11 countries that have successfully grown biotech soybeans; the eleven countries, listed in order of biotech soybean hectarage are the USA, Argentina, Brazil, Paraguay, Canada, Bolivia, Uruguay, South Africa, Mexico, Chile and Costa Rica.

In October 2011, Paraguay approved its second biotech crop, Bt cotton for commercial production. Four biotech maize events were officially approved in 2012 (Table 25). Its neighboring countries Argentina and Brazil have been growing biotech maize successfully for many years. In 2013, Paraguay was expected to grow a total of approximately 1.1 million hectares of maize of which over 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. The country approved biotech maize for the first time in September 24, 2012, that includes events MON810, Bt11, TC1507 and MON89034 x MON88017. Paraguay was expected to grow 60,000 hectares of cotton in 2013, of which 50% were biotech. Intacta, a new stacked HT/IR soybean was authorized and launched in 2013. Paraguay will benefit from biotech cotton also successfully grown in the neighboring countries of Argentina and Brazil.

**Table 25. Commercial Approvals for Planting in Paraguay (2004 to 2013)**

| Crop | Trait | Event | Year |
|---|---|---|---|
| Soybean | Herbicide tolerance (HT) | 40-3-2 | 2004 |
| | HT x IR | MON 87701 x MON89788 | 2013 |
| 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 |

Source: G. Levitus (Personal Communication), 2013.

## Benefits from Biotech Crops in Paraguay

Paraguay is estimated to have enhanced farm income from biotech soybean by US$830 million in the period 2004 to 2012 and the benefits for 2012 alone is estimated at US$95.6 million (Brookes and Barfoot, 2014, Forthcoming).

## Political Support to GM Crops in Latin America

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

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

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

## *SOUTH AFRICA*

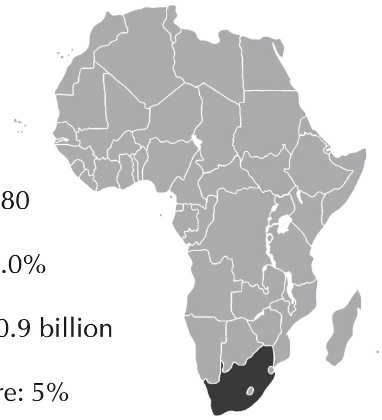
**Lack of adequate rain and more limited financing for farmers, resulted in total maize plantings being marginally less than last year, and this translates to slightly lower estimates for biotech maize. The total biotech crop area for maize, soybean and cotton in 2013 is estimated at 2.85 million hectares (rounded off to 2.9), similar to 2012. The total maize area is estimated at 2.73 million hectares in 2013 compared to 2.83 million hectares in 2012, largely due to drought conditions; biotech maize hectares is at 2.36 million hectares in 2013, compared with 2.42 in 2012. The total area planted to soybeans increased marginally from 500,000 hectares in 2012 to 520,000 in 2013, with an adoption rate of 92%, compared with 90% in 2012. This is equivalent to 478,000 hectares of herbicide tolerant soybean, compared with 450,000 hectares in 2012. Total cotton area is expected to decline marginally to 8,000 hectares (11,000 hectares in 2012) due to competition from maize and soybeans. Biotech cotton adoption rate remained at 100%, of which ~95% were stacked traits; herbicide tolerant cotton is used as a mandatory refuge for biotech cotton fields. It estimated that the economic gains from biotech crops for South Africa for the period 1998 to 2012 was US$1.15 billion and US$218.5 million for 2012 alone (Brookes and Barfoot, 2014, Forthcoming).**

The mandatory labeling of GM/GMO "goods", ingredients or components, as prescribed in Regulation 7 of the Consumer Protection Act of 2008 that should have entered into force in 2011, has elicited ongoing criticism from stakeholders in the food chain due to its ambiguity and complexity. There has been no effort from the side of the Department of Trade and Industry to proceed with this regulation that might be seen by trading partners as a technical barrier to trade.

It is estimated that a total of 2.73 million commercial hectares of maize will be planted in 2013, down marginally from 2.83 in 2012. Of the total maize area, 86.6% or 2.364 million hectares will be biotech. Of the 2.364 million hectares of biotech maize, 28.4% or 680,342 hectares were the single Bt gene, 18.2% or 409,032 hectares herbicide tolerant, and 53.4% or 1,274,790 hectares stacked Bt and herbicide tolerant genes. The white maize crop of 1.580 million hectares comprised 83.7% biotech or 1.322 million hectares with the single Bt gene accounting for 412,707 hectares, herbicide tolerance at 165,347 hectares and Bt-herbicide tolerance stacks at 744,725 hectares. The yellow maize area of 1.150 million hectares will be 90.5% biotech or 1.041 million hectares; the biotech share represented by 25.7% single Bt or 267,635 hectares, 23.4% or 243,684 hectares by single herbicide tolerance and 50.9% or 530,065 hectares stacked traits.

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

**SOUTH AFRICA**



Population: 50.5 million

GDP: US$364 billion

GDP per Capita: US$7,280

Agriculture as % GDP: 3.0%

Agricultural GDP: US$10.9 billion

% employed in agriculture: 5%

Arable Land (AL): 14.5 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 2013:
2.9 Million Hectares (0)

Farm income gain from biotech, 1998-2012: US$1.15 billion

*Ratio: % global arable land / % global population

Total soybean plantings are estimated to have grown from 500,000 hectares in 2012 to 520,000 hectares in 2013. HT soybean is estimated at 478,000 hectares or 92% of the total area planted. Thus, the total biotech hectarage for maize, soybean and cotton was 2.85 million hectares (rounded off to 2.9 million hectares).

Cotton production has continued to decline in recent years due to a movement away from risky dryland to irrigation where it has to compete with maize or soybeans. Area to be planted in 2013 is expected to decline marginally to 8,000 hectares compared with 11,000 hectares in 2012. All of the cotton is expected to be biotech with 95% stacked (Bt/Bt/HT) and 5% HT used in refugia. Two consignments of IR/IR/HT cotton seed for planting of 152 MT each were exported.

The GMO regulatory framework is based on a permit system. There were 348 GMO permits granted from January to 31 October 2012 of which maize accounted for 87%, soybeans for 5.2%, cotton for 6.0%, and GM vaccines for 1.2%. Maize seed import permits for 2013 (to 31 October) for commercial planting covered 2,930 MT and exports for 3,830 MT. South Africa has shifted its commodity GM maize grain exports to new markets in Europe, Latin America, Asia and some African states. Export permits granted in 2013 amounted to another 1.82 million MT from January to October. Permits were also granted for export of 55,000 MT of GM soybeans. Some 1,780 MT of soybean seed for planting were imported.

A number of biotech crops have been given approvals for field testing as indicated in Table 26.

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. 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 estimated that the economic gains from biotech crops for South Africa for the period 1998 to 2012 was US$1.15 billion and US$218.5 million for 2012 alone (Brookes and Barfoot, 2014, Forthcoming).

**Table 26. Trial Release Approvals for GM Crop Testing 2013 (Confined Field Trials)**

| Crop | Trait | Event Name |
|---|---|---|
| Maize | Drought tolerance | MON87460 |
| | Insect Resistance, including IR/IR | 59122 |
| | Insect Resistance/Herbicide tolerance | TC1507 x 59122 |
| | | MON89034 x TC1507 x NK603 |
| | | PHB36882 |
| | | TC1507 x NK603 |
| | | TC1507 x MON810 |
| | | TC1507 x MON810 x NK603 |
| | | PHB37046 |
| | | PHB37050 |
| | Male Sterility, Fertility Restoration, Visual Marker | DP32138-1 |
| Soybeans | Modified oils/HT | 305423-40-3-2 |
| | | 305423 |

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

Source: Compiled by Clive James, 2013.

### *Farmer Testimonies*

Farmers consider the main benefits of GM maize to be peace of mind, consistent increased yields, better grain quality, and excellent weed control. Mr. Hans van Rensburg of the farm Witklip, Bronkhorstspruit, Mpumalanga province, grows 1 700 hectares GM dry-land maize and 350 hectares under irrigation. ***"On average, with GM maize I get 5 tons/hectare dry-land which is 0.5 tons better than conventional maize and under irrigation 10 tons/hectare which is one ton better than conventional, equivalent to R2,000 (US$200) plus R60 for better quality per hectare,"*** Van Rensburg said.

Mr. Willie de Klerk plants 3,500 hectares of dry-land maize on his farm Driefontein, Hendrina, Mpumalanga province and gets some 7 tons/hectare and on some field 10 tons. He stated that the stacked insect resistance and herbicide tolerance traits give one ton per hectare extra yields and, less technology fee, amounts to R1, 600/hectare added that GM maize grain is safe to humans, animals and the environment.

Mr. Richard Hobson of the farm Nonen Ranch, Setlagole, North-West province stated that he had been farming GM maize for 15 years and, since 2007, planted stacked insect resistance and herbicide tolerant maize. He obtained an average of 5 tons/hectare on his 5,070 hectare maize fields, almost double that of previous conventional varieties used (H. Lombard in S A Grain, October 2013).

Mr. Anthony Evans, managing director of the Rhys-Evans family farming enterprise near Bothaville, Free State province, ascribed his success in crop production to biotechnology. He grows over 3,000 hectares of GM maize, as well as 340 hectares of soybeans.

Practical problems related to crop credit, signing of contracts to comply with planting of refugia, and enforcing refugia, have presented problems in marketing GM maize seed to smallholders (less than 2 hectares). However, in 2013 marketing GM seed in packets of 2 kg to 25 kg saw planting of 6,308 hectares of GM white maize (8% IR, 61% HT and 31% IR/HT), as well as 7,180 hectares of GM yellow maize (0.9% IR, 78% HT and 21% IR/HT). This successful smallholder adoption is expected to increase. Planting data for current season are awaited.

## ***PAKISTAN***

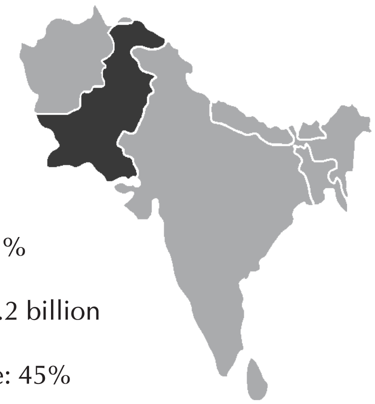
**2013 was the fourth year of commercialization of Bt cotton in Pakistan when ~700,000 small farmers planted 2.8 million hectares at an adoption rate of 86% of the total 3.2 million hectares of cotton. The level of adoption remained at 2.8 million hectares similar to 2012 despite the overall decrease in cotton area to 3.2 million hectares in 2013, thereby increasing percentage adoption from 82% to 86%. Bt cotton was first approved by the Punjab Seed Council (PSC) of Pakistan in 2010. In 2013, the Cotton Crop Assessment Committee (CCAC) of the Ministry of Commerce and Textile Industry has estimated cotton production ranging from 11.95 million bales to 13.22 million bales in 2013-14 Kharif season. Cotton production has suffered losses due to lack of proper supply of Bt cotton varieties, adverse weather conditions and infestation of the leaf curl virus in major cotton producing Punjab province. In 2013, farmer adoption increased despite the fact that the PSC declined to approve additional 15 Bt cotton varieties and permission for renewal of 8 provisionally approved Bt cotton varieties expiring in 2013. This is due to absence of environmental and biosafety clearance and commercialization license from National Biosafety Committee. Hence, all the approved 16 cotton varieties including 8 varieties which were provisionally approved between 2010 and 2012, are also awaiting formal environmental biosafety clearance and commercialization license from NBC. It estimated that the economic gains from**

**biotech crops for Pakistan for the period 2010 to 2012 was US$470 million and US$135.5 million for 2012 alone.**

### Change in Regulatory System

The federal Government of Pakistan has undergone a major change in the administration of various ministries in pursuant of the Constitution (18th Amendment) Act, 2010 enacted in April 2010. 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 fact, the subjects of agriculture and environment were devolved, 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 at 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 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). For the Technical Advisory Council and the National Biosafety Committee 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 an Act by the Parliament of Pakistan. This will also help the country to avert confusion at 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.

**PAKISTAN**



Population: 184.8 million

GDP: US$177 billion

GDP per Capita: US$990

Agriculture as % GDP: 21%

Agricultural GDP: US$37.2 billion

% employed in agriculture: 45%

Arable Land (AL): 21.3 million hectares

Ratio of AL/Population*: 0.5

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

Commercialized Biotech Crop: Bt Cotton

Total area under biotech crops and (%) increase in 2013:
2.8 Million Hectares (0)

Farm income gain from biotech, 2010-2012: US$470 million

*Ratio: % global arable land / % global population

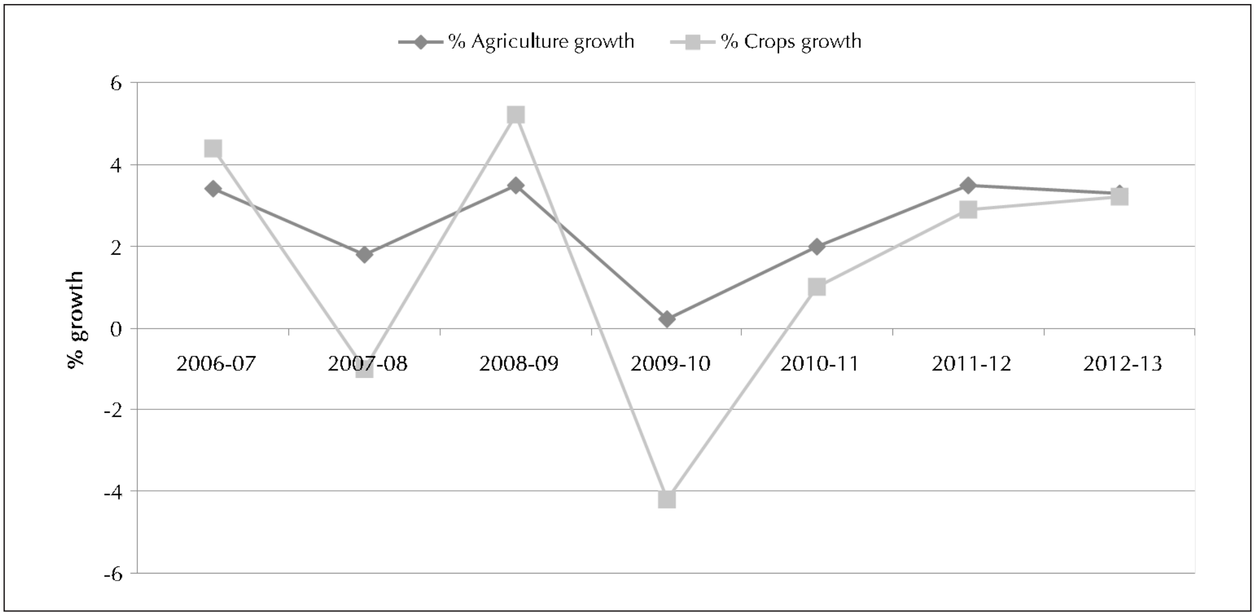
With the renewed mandate at federal level, the Ministry of National Food Security and Research (MNFS&R) embarks on a much needed path to consolidate the legislations related to agriculture, to coordinate programs with respective provinces, to establish the National Food Security Council, to announce the "National Food and Nutrition Security Policy" and to unveil the first "National Zero Hunger Action Plan". Two important legislations including "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). Similarly, the food security ministry has laid an emphasis by drafting the National Food and Nutrition Security Policy to be announced by end of 2013 (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 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).

## Agriculture in Pakistan

In 2013, the decelerating growth and rising food prices remain the most daunting challenges for agriculture that accounts for 21.4% to GDP and engages around 45% population of the country. In recent years, the country registered a declining trend in the overall growth of agriculture to 3.3% and particularly a high variability in growth of food crops due to unfavorable weather conditions (Figure 28). The country occupies large areas of rice, wheat, sugarcane, maize and cotton. These crops require intensive irrigation system and therefore the availability of water becomes a paramount importance in every Kharif season to achieve required food production. The monsoon continues to play an important role and dependency of agriculture production system of the country.

Cotton is one of the five most important crops grown mainly in Punjab, Sindh and Balochistan Provinces, which are divided into zones on the basis of rainfall and temperature (Soomro, 1996). Farmers plant cotton on 2.8 to 3.4 million hectares with an average farm holding of approximately 4 hectares. Thus there are up to 850,000 cotton farmers in the country (based on 3.4 million hectares and an average holding size of 4 hectares). Punjab is the largest cotton growing region occupying almost 80% of total cotton in Pakistan with the balance of cotton hectarage in the Sindh with less in Balochistan and North West Frontier Province (NWFP), now known as Khyber Pakhtunkhwa. Both Punjab and Sindh farmers mainly grow open pollinated varieties (OPVs) of cotton with almost 100% assured irrigation facility throughout the cotton season. Kharif (monsoon season) is the major season for cotton cultivation which begins in April-June and harvested in October-December. ISAAA Brief 43 and 44 (James, 2011 and 2012) provides a detailed overview of agriculture and cotton crop and also highlights the composition of value of major crops and distribution of cotton crop in four major cotton growing provinces in Pakistan.

**Figure 28. Trend in the Growth of Agriculture* in Pakistan, 2006 to 2013**




*Includes food crops, livestock, fisheries and forestry
Source: MOF, 2013; Compiled by ISAAA, 2013.

## Commercial Approval of Bt Cotton in Pakistan

The Punjab Seed Council (PSC) under the Ministry of Agriculture of the Punjab province, for the first time decided to officially approve the commercial cultivation of 8 insect resistant Bt cotton varieties and one Bt cotton hybrid at their 39th meeting held on 31 March 2010. 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 declined to approve 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 Protection Agency (Pak EPA), Ministry of Climate Change (MOCC) (Table 27). Hence, all the approved 16 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) (Table 28). 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 16 Bt cotton varieties provisionally approved by the PSC between 2010 and 2012 in the three intensive cotton growing provinces of Punjab, Sindh and Balochistan in Pakistan. The regulatory uncertainty caused by NBC led to delays in approval of additional 15 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 provincial government, Pakistan (Table 27).

**Table 27. Bt Cotton Varieties with MON 531 Event Pending Approval from PSC and NBC, 2013**

| Bt Cotton Variety | Developer |
|---|---|
| VH-259 | Cotton Research Station, Vehari |
| BH-178 | Cotton Research Station, Bahawalpur |
| CIM-599 | Central Cotton Research Institute, Multan |
| CIM-602 | Central Cotton Research Institute, Multan |
| FH-118 | Cotton Research Institute, Faisalabad |
| FH-142 | Cotton Research Institute, Faisalabad |
| IR-NIAB-824 | Nuclear Institute for Agricultural Biology (NIAB), Faisalabad |
| IUB-222 | College of Agri & Environmental Sciences, Islamia University, Bahawalpur |
| CEMB-33 | CEMB, University of the Punjab, Lahore |
| SAYBAN-201 | M/s Auriga Seed, Lahore |
| Sitara-11M | M/s Agri Farm Service, Multan |
| A-555 | M/s Weal AG, Multan |
| KZ-181 | M/s Kanzo Seeds, Multan |
| Tarzan-2 | M/s Four Brothers Seeds, Multan |
| CA-12 | M/s Ali Akbar Seeds, Lahore |

Source: Punjab Seed Council (PSC), 2013

## Table 28. Commercial Release of Different Bt Cotton Varieties and Hybrid in Pakistan between 2010 and 2013

**Punjab Seed Council (PSC) Approved on 31 March 2010**
**Federal Ministry for Food and Agriculture Approved on 15 April 2010**
**Not approved by NBC of Pak EPA in 2013**

| Event | Variety (*hybrid) | Developer | Status |
|---|---|---|---|
| *cry1Ac* gene (MON531 event) | IR-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 | GM-2085* | M/s Guard Agricultural Research Services, Lahore | Approved in 2010 (two year approval, DUS trial data to be submitted to FSC&RD) |
| **Punjab Seed Council (PSC) approval on 31 March 2010 and renewed on 16 Feb 2012** | | | |
| *cry1Ac* gene (MON531 event) | IR-1524 | NIBGE, Faisalabad | 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 | M/s. Neelum Seeds, Multan | Renewed in 2012 |
| *cry1Ac* gene (MON531 event) | FH-114 | Cotton Research Institute, AARI, Faisalabad | Approved in 2012 |
| *cry1Ac* gene (MON531 event) | CIM-598 | Central Cotton Research Institution (CCRI), Multan | Approved in 2012 |
| *cry1Ac* gene (MON531 event) | SITARA-009 | Sitara Seed Company | Approved in 2012 |
| *cry1Ac* gene (MON531 event) | A-ONE | M/s Weal-AG Seed | Approved in 2012 |
| *cry1Ac* gene (MON531 event) | TARZAN-1 | Four Brothers Seeds Corporation Pakistan Pvt. Ltd. | One year Approval in 2012 (Conditional approval for field performance/monitoring) |
| *cry1Ac* gene (MON531 event) | NS-141 | M/s Neelum Seeds, Multan | Same as above |
| *cry1Ac* gene (MON531 event) | IR-NIBGE-3 | NIBGE, Faisalabad | Same as above |

**Table 28. Commercial Release of Different Bt Cotton Varieties and Hybrid in Pakistan between 2010 and 2013**

**Punjab Seed Council (PSC) Approved on 31 March 2010**
**Federal Ministry for Food and Agriculture Approved on 15 April 2010**
**Not approved by NBC of Pak EPA in 2013**

| Event | Variety (*hybrid) | Developer | Status |
|---|---|---|---|
| *cry1Ac* gene (MON531 event) | MNH-886 | Central Cotton Research Institution (CCRI), Multan | Same as above |

Source: Punjab Seed Council (PSC), 2010 & 2012, Pakistan Today, 2011 & 2012; Ministry of Textile Industry, 2012; PSC, 2013.

Out of the 15 Bt cotton varieties pending for approval from PSC and NBC, 9 of them were developed by public sector research institutes of Federal and Provinces government in Pakistan including Cotton Research Station, Central Cotton Research Institute, Nuclear Institute for Agricultural Biology, Islamia University and Punjab University respectively. The remaining 6 Bt cotton varieties were developed by the private seed companies in Pakistan (Table 28). All approved Bt cotton varieties and a hybrid have undergone more than 5 to 6 years of field trials in accordance to the procedures implemented by the Pakistan Central Cotton Committee (PCCC).

Of the 16 approved Bt cotton varieties (including a hybrid), 15 contains the *cry1Ac* gene (MON531 event) which have been developed by public and private sector institutes, whereas the one Bt cotton hybrid GFM-2085, expressing fusion gene *cry1Ac* and *cry1A*, has been developed by a local private seed company (Table 28). Among these, 12 received unconditional approval and four received one year approval with the condition that developers must submit field performance and monitoring report to the Punjab Seed Council. In addition, Bt cotton hybrid GM-2085 received approval for two years in 2010 with the condition that the hybrid would be reconsidered by the PSC after fulfilling the requirement of the Federal Seed Certification and Registration Department (FSC&RD) in the distinctness, uniformity and stability (DUS) trials. 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.

## Adoption of Bt Cotton in Pakistan, 2010 to 2013

In 2010, Pakistan became the thirteenth country to officially plant Bt cotton along with the USA, China, India, Australia, South Africa, Brazil, Argentina, Columbia, Mexico, Costa Rica, Myanmar and Burkina Faso which 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 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 fourth year of commercialization, 2013, Bt cotton was planted by ~700,000 farmers on 2.8 million hectares, occupying a substantial 86% of the total 3.2 million hectares of cotton area planted in Pakistan; this compares with 2.8 million hectares of Bt cotton in 2012, 2.6 million hectares of Bt cotton in 2011, equivalent to 81% of the 3.2 million hectares cotton area planted nationally (Table 29). Therefore, in 2013, Pakistan planted 2.8 million hectares of biotech cotton which is over 10% of total biotech cotton area of the world.

## Cotton Yield and Production

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 2013-14. During the same period, cotton yields remained almost stagnant at 550 kg to 750 kg of lint per hectare (Figure 28). Annual cotton production stalled between 10 to 12 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 provinces (Hussain & Awan, 2011; PCGA, 2012).

In 2004-05 the country produced a record cotton crop of 14.5 million bales as a result of favorable climatic conditions. Pakistan was a net cotton exporter in the early 1990s but is now a major importer to meet the growing demand of the domestic cotton based industry. Over the last five years, Pakistan has been importing 3 to 5 million bales of cotton per year which costs the national

**Table 29. Adoption of Bt Cotton in Pakistan, 2010 to 2013**

| 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% |

Source: Compiled by ISAAA, 2013.

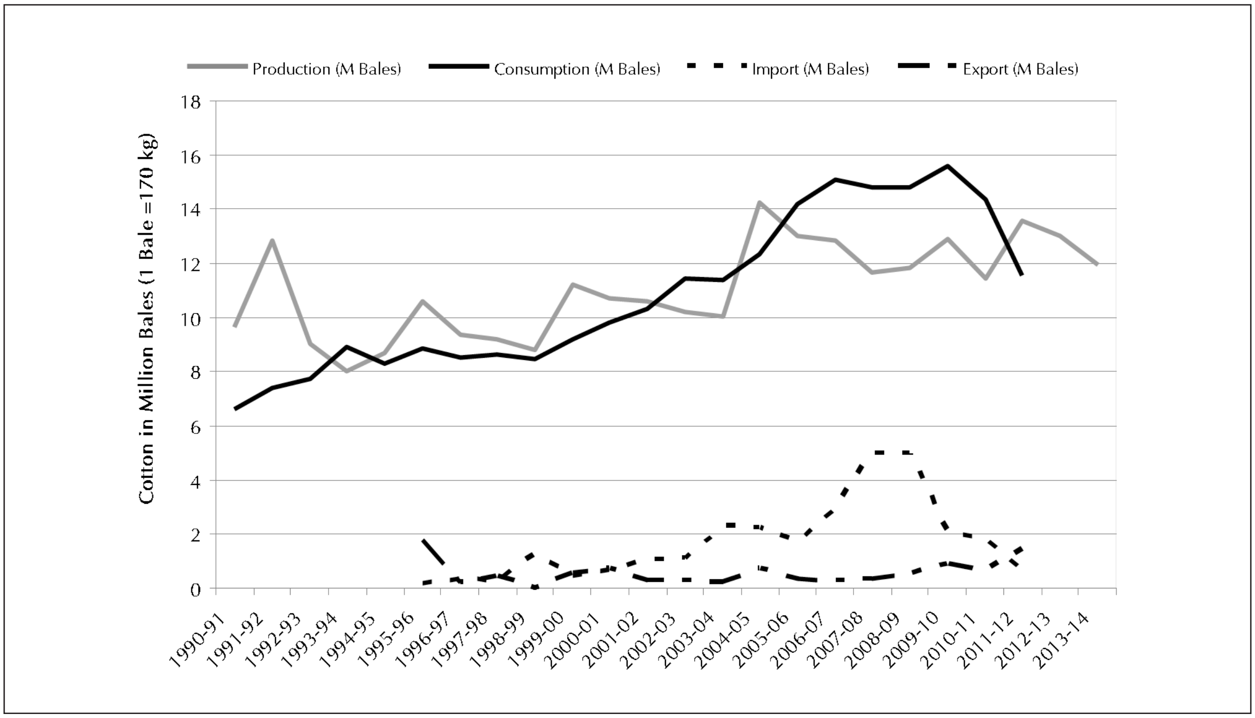
exchequer between US$3 to US$5 million per year, widening further the trade deficit to record levels. In 2010-11, a record cotton production of 14 million bales was expected, however, 2 to 2.5 million bales of cotton were lost due to severe floods, which destroyed 0.7 million hectares of cotton in the major cotton growing provinces of Punjab and Sindh, resulting in a significantly lowered production of only 12 million bales. However, the country produced a record cotton production of 13.59 million bales in 2011-12 due to the high adoption of Bt cotton, low incidence of CLCuV and favorable climatic conditions. In 2011-12, the cotton area was increased slightly from 3.1 million hectares in 2010-11 to 3.2 million hectares in 2011-12. In 2013-14, it is expected that the country would harvest slightly lower cotton production in the range of 11.95 million bales to 13.22 million bales (Figure 29) on the account of lower cotton area (Figure 30), flooding of cotton area and incidence of mealy bug and the leaf curl virus in cotton belt (PCCC, 2013).

In the fourth year of commercialization of Bt cotton in 2013-14, the Cotton Crop Assessment Committee (CCAC) of the Ministry of Textile has estimated cotton production ranging from 11.95 to 13.22 million bales lower than the record 13.59 million bales registered during 2011-12. 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 event 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 2013-14, the country has to import around 3 million bales of raw cotton to meet the demand of textile industry (Business Recorder, 2013b). In the contrary, the surplus production of raw cotton in 2011-12 due to timely availability of good quality Bt cotton varieties, the raw cotton export registered a substantial growth of 78% to 1.66 million bales in 2011-12 from 0.937 million bales in 2010-11, worth half a billion (~US$462 million) in 2011-12. 2011-12 was the first time the country has reported a significant export of raw cotton after meeting growing demand from domestic textile industry in the country (Ministry of Textile Industry, 2012; PCGA, 2012; Business Recorder, 2012b).

Based on preliminary field trials, and assuming deployment of biotech cotton at 90% with both insect and herbicide tolerance, there is a potential to substantially increase farmer income by up to US$280 per hectare (Pakistan Textile Journal, 2010; Kakakhel, 2010). In order to optimize the benefits from the new technologies, the province of Punjab organized a vigorous campaign from 2010 to 2012 to implement insect resistant management and effectively control whitefly, the vector of the lethal cotton leaf curl virus (CLCuV).

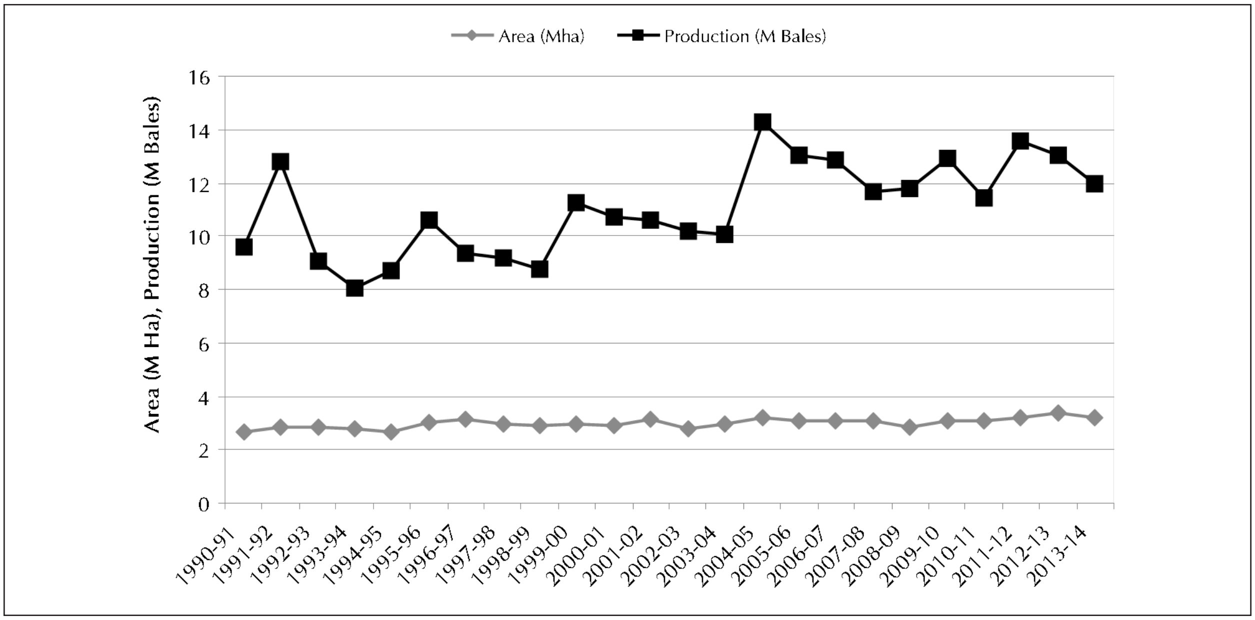
Over the recent years, the Government of Pakistan has been implementing the "Pak-US Cotton Productivity Enhancement Program" funded by USAID and implemented by ICARDA in collaboration with USDA and Ministry of National Food Security and Research, Pakistan. The Pak-US cotton program is a five-year (2010-2015) research & development project aims at developing cotton leaf curl virus (CLCuV) and disease resistant cotton varieties in Pakistan. Under this project, the

Figure 29. Cotton Production, Consumption, Export and Import in Pakistan, 1990 to 2013




Source: MNFS&R, 2013b; Compiled by ISAAA, 2013.

Figure 30. Area and Production of Cotton, 2013-14




Source: MNFS&R, 2013b; Compiled by ISAAA, 2013.

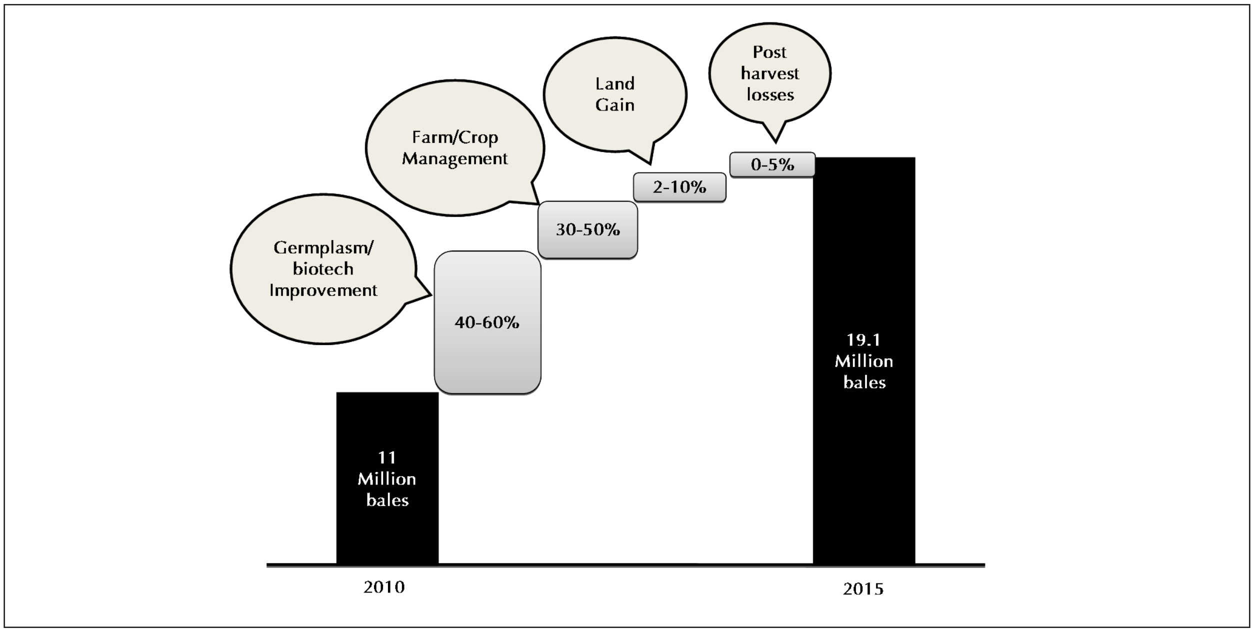
country has imported 3,200 cotton germplasm accessions from USDA collection under the project during 2011-13. The imported cotton germplasm is stored at the most sophisticated and scientific germplasm storage facility at the Central Cotton Research Institute (CCRI), Multan Pakistan, which is being utilized to identify and introgress the virus free material into the current and future breeding programs to develop high quality and stress resistant cotton varieties in Pakistan. In 2012-13, the Pak-US cotton program was successful in screening imported USDA cotton germplasms in Pakistan that resulted in the identification and selection of highly-tolerant cotton accession "Mac-07" against cotton leaf curl virus (CLCuV) disease. It is expected that the selection of cotton accession "Mac-07" would pave the way forward to breeding of CLCuV resistant cotton varieties in the country in the near future (MOC&TI, 2013). The Pak-US cotton program is a step forward to identify and breed cotton varieties resistant to the annual outbreak of severe cotton leaf curl virus (CLCuV).

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 to 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 (Figure 31). 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.

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

**Figure 31. Pakistan's Roadmap to Cotton Vision 2015**




Source: Adopted from PCCC, 2011.

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 the Punjab Seed Corporation (PSB) officially approved 8 Bt cotton varieties and one hybrid containing event MON531 and GFM event.

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 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 cotton which has been field tested in 2011/2012 offer Pakistan new opportunities for boosting cotton yields which have been almost stagnant for the last two decades.

It estimated that the economic gains from biotech crops for Pakistan for the period 2010 to 2012 was US$470 million and US$135.5 million for 2012 alone (Brookes and Barfoot, 2014, Forthcoming).

**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 chilli (Table 30). 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 2010, 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 in the country. Notably, between 2010 and 2013 there were approvals of second year large scale field

**Table 30. Crops under Genetic Transformation at Different Biotech Institutes in Pakistan**

| Institute/Department | Crops under transformation |
|---|---|
| National Institute for Biotechnology and Genetic Engineering (NIBGE), Faisalabad | Wheat, potato, cotton and sugarcane |
| National Institute for Genomics and Advanced Biotechnology (NIGAB), National Agricultural Research Centre (NARC), Islamabad | Rice, wheat, groundnut, chickpea, tomato, cotton, potato and sugarcane. |
| Department of Biosciences, COMSAT Institute of Information Technology (CIIT), Islamabad | Wheat and banana |
| Faculty of Biological Sciences, Quaid-i-Azam University, Islamabad | Soybean, maize, cotton and tomato |
| School of Biological Sciences (SBS), University of the Punjab, Lahore | Sugarcane |
| Centre of Excellence in Molecular Biology (CEMB), Lahore | Cotton, maize, potato and gladiolus |
| Institute of Agriculture Sciences (IAGS), Punjab University, Lahore | Cotton, tobacco and tomato |
| Institute of Biotechnology and Genetic Engineering (IBGE), Peshawar | Brassica |
| Department of Biotechnology, Foremen Christian College, Lahore | Wheat |
| Agriculture Biotechnology Research Institute (ABRI), Faisalabad | Wheat, sugarcane and brassica |
| Center for Agriculture Biochemistry and Biotechnology (CABB), Faisalabad | Wheat, sugarcane, rice and sheesham tree (*Dalbergia sissoo*) |
| International Center for Chemical and Biological Sciences (ICCBS), HEJ Research Institute, University of Karachi, Karachi | Tomato, potato and lettuce |
| Dr. A.Q. Khan Institute of Biotechnology and Genetic Engineering (KIBGE), Karachi University, Karachi | Brassica, Arabidopsis and sugarcane |

Source: Roberts, et al. 2012; Personal Communication with Dr. Iqbal Chaudhary; Compiled by ISAAA, 2013

trials of 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 (Table 31).

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.

**Table 31. The Status of Field-trial of Different GM Crops in Pakistan, 2013**

| 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: Compiled by ISAAA, 2013

## *URUGUAY*

**Uruguay increased its biotech plantings of soybean and maize to 1.47 million hectares in 2013, an increase of about 10% from 1.34 million hectares in 2012. Herbicide tolerant soybean now occupies 100% of the national soybean hectarage at more than 1.3 million hectares. Biotech maize occupied ~140,000 hectares in 2013 — the 10$^{th}$ year for Uruguay to plant biotech maize. Of the 140,000 hectares of biotech maize, 71% was the stacked Bt/HT product. Remarkably, Uruguay approved five events on the same day in early 2011. Uruguay has enhanced farm income from biotech soybean and maize of US$121 million in the period 2000 to 2012 and for 2012 alone at US$20.4 million.**

Uruguay, which introduced biotech soybean in 1996, followed by Bt maize in 2003 increased its total biotech crop area once again in 2013 to reach 1.47 million hectares. A significant increase was recorded in the hectarage of herbicide tolerant soybean which occupies 100% of the national soybean hectarage of 1.3 million hectares. Biotech maize was planted on 140,000 hectares in 2013 when it was planted for the tenth year; 71% of the biotech maize was the stacked Bt/HT product biotech maize which was first approved in Uruguay in 2003. Table 32 shows the biotech maize and soybean approvals from 2003 to 2013.

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.

**URUGUAY**

Population: 3.4 million

GDP: US$49.1 billion

GDP per Capita: US$14,449

Agriculture as % GDP: 8.2%

Agricultural GDP: US$4.03 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 2013:
1.5 Million Hectares (+7%)

Farm income gain from biotech, 2000 to 2012: US$121 million

*Ratio: % global arable land / % global population

## Benefits from Biotech Crops in Uruguay

Uruguay is estimated to have enhanced farm income from biotech soybean and maize of US$121 million in the period 2000 to 2012 and the benefits for 2012 alone is estimated at US$20.4 million (Brookes and Barfoot, 2014, Forthcoming).

**Table 32. Commercial Approvals for Planting, Food and Feed in Uruguay, 2003 to 2013**

| 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 |
| 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 |

Source: Cámara Uruguaya de Semillas, 2013

## *BOLIVIA*

**RR®soybean was grown on an estimated 1.0 million hectares in 2013 in Bolivia, similar to last year. The adoption rate of RR®soybean in 2013 was estimated at 91% of the total 1.1 million hectares, similar to 2012. In 2008, Bolivia became the tenth country to officially grow RR®soybean at 600,000 hectares. Thus, the growth rate between 2008 and 2013 has been significant with almost a doubling of RR®soybean hectares. It estimated that the economic gains from biotech crops for Bolivia for the period 2008 to 2012 was US$432 million and US$105.2 million for 2012 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. 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.

**BOLIVIA**

Population: 10.5 million

GDP: US$27 billion

GDP per Capita: US$2,576

Agriculture as % GDP: 10%

Agricultural GDP: US$2.7 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 2013:
1 Million Hectares (0)

Farm income gain from biotech, 2008 to 2012: US$432 million

*Ratio: % global arable land / % global population

**Certified Seed in Bolivia**

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

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

It is estimated that RR®soybean was grown on 91% or 1.0 million hectares of the estimated total hectarage of approximately 1.1 million hectares of soybean planted in Bolivia in 2013, similar to 2012.

According to the most recent estimates of global hectarage of soybean (FAO, 2012 data), Bolivia ranks eighth in the world with 1.1 million hectares, after the USA (31 million hectares), Brazil (25), Argentina (19.1), India (10.8), China (6.8), Paraguay (2.8), and Canada (1.7). Of the top eight soybean countries, six (USA, Argentina, Brazil, Paraguay, Bolivia and Canada) grow RR®soybean. Exports of soybean from Bolivia in 2011 were worth US$309 million – they were the most important agricultural export and the third largest of all Bolivian exports.

In 2008, Bolivia became the tenth soybean country to officially grow RR®soybean with 600,000 hectares planted, equivalent to 63% of the total national hectarage of 960,000 hectares. RR®soybean has been adopted on extensive hectarages in Bolivia's two neighboring countries of Brazil (currently at 26.9 million hectares of RR®soybean) and Paraguay (currently at 3.6 million hectares) for many years. It is not clear at this stage what the potential impact of the Bill "Law of the Productive Revolution" introduced on 26 June 2011 will have on future production of RR®soybean. The law prohibits the introduction of modified organisms into Bolivia, if the country is the centre of origin and diversity. This leaves open the option of introducing transgenic crops for which Bolivia is not the center of origin. Farmers are encouraging Government to introduce biotech varieties of crops such as cotton, rice, sugarcane, which are of interest to Bolivian farmers.

### Benefits from RR®soybean in Bolivia

Paz et al. (2008) noted that Bolivia is one of the few countries in Latin America where there are a significant number of small farmers producing soybeans. Soybeans are important, contributing 4.6% of GDP and 10% of total exports. Paz et al. (2008) noted that despite the lack of government incentive, RR®soybeans continue to expand because cost-benefit analysis favors RR®soybean over conventional. More specifically, the partial budget analysis (Table 33) 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 estimated that the economic gains from biotech crops for Bolivia for the period 2008 to 2012 was US$432 million and US$105.2 million for 2012 alone (Brookes and Barfoot, 2014, Forthcoming).

**Table 33. 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.

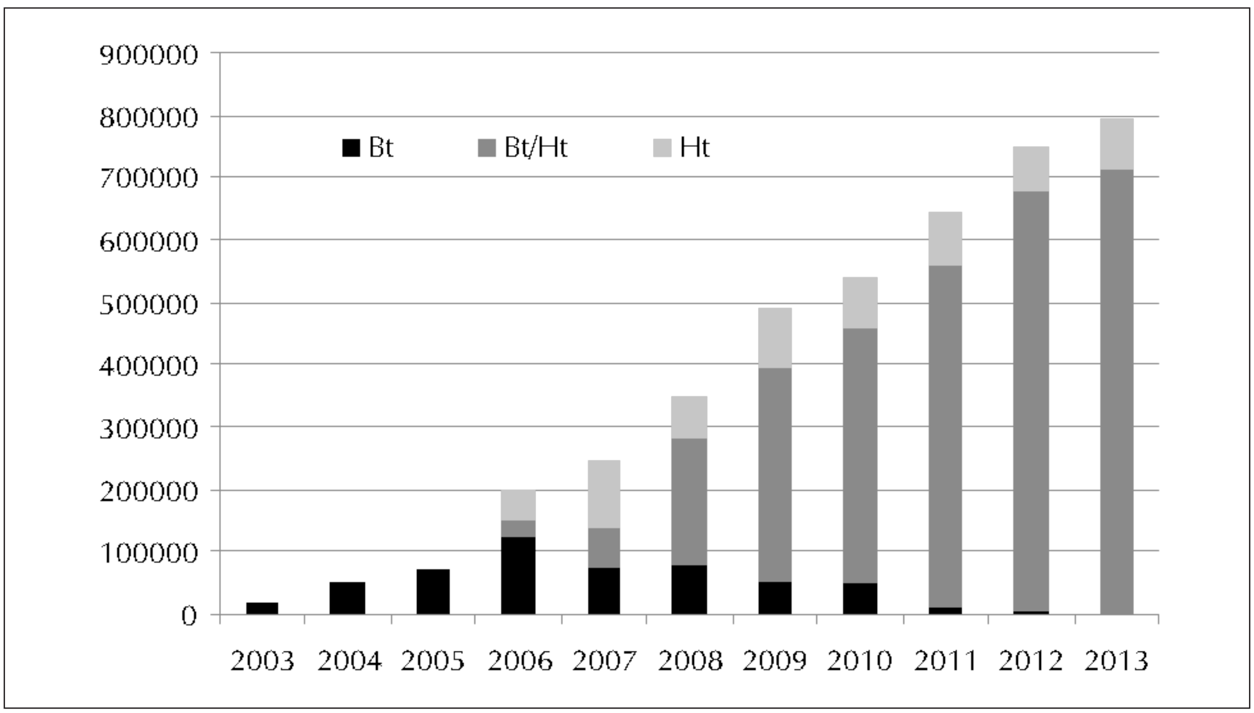
## ***PHILIPPINES***

**In 2013, the area planted to biotech maize in the Philippines is projected to increase to 795,000 hectares, up 6% from the estimated hectares of biotech maize in 2012 of**

**750,000. Notably, the area occupied in 2013 by the stacked traits of Bt/HT maize is 712,000 compared with only 675,000 hectares in 2012, with the stacked trait maize occupying 90% of total biotech maize hectares in 2013, reflecting the preference of farmers for stacked traits and the superior benefits they offer over a single trait. Farm level economic gains from biotech maize in the Philippines in the period 2003 to 2012 is estimated at US$378 million and for 2012 alone at US$92.6 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 2013 to reach 800,000 hectares, up 6.7% from the 750,000 hectares of biotech maize in 2012 (Figure 32). Notably, the area occupied by the stacked traits of Bt/HT maize has continuously increased every year reaching 721,000 hectares in 2012, compared with only 675,000 hectares in 2012, up by a substantial 11%, 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% between

**Figure 32. Increase in Hectarage of Biotech Maize in the Philippines and Proportion of Commercialized Traits, 2003 to 2013**

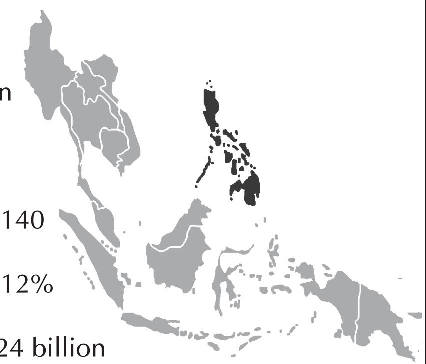



Source: Compiled by ISAAA, 2013.

2008 to 2009, to 76% in 2012, with a total of only 3,000 hectares, and in 2013, no single trait Bt maize has been planted. Single trait herbicide tolerant (HT) maize was planted on 82,300 hectares in 2013, which is only 10%, similar to last year's. 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 62% in 2013 (up from 59% 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.

The number of small resource-poor farmers, growing on average 2 hectares of biotech maize in the Philippines in 2013, was estimated at 397,500 up significantly by 22,500 from 375,000 in 2012.

**PHILIPPINES**



Population: 93.6 million

GDP: US$200 billion

GDP per Capita: US$2,140

Agriculture as % GDP: 12%

Agricultural GDP: US$24 billion

% employed in agriculture: 35%

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 2013:
0.795 Million Hectares (+6%)

Increased farm income for 2003-2012: US$378 million

*Ratio: % global arable land / % global population

A total of eight events of biotech maize are approved for commercial planting in the Philippines: MON810 for insect resistance (first approved in 2002 and the approval was renewed in 2007); NK603 for herbicide tolerance (first approved in 2005 and renewed in 2010); Bt11 for insect resistance (first approved in 2005 and renewed in 2010); GA21 for herbicide tolerance approved in 2009; the stacked gene product of MON810/NK603 (first approved in 2005 and renewed in 2010), the stacked trait Bt11/GA21 for insect resistance and herbicide tolerance approved in 2010, MON89034 which contains two Bt genes for resistance to fall armyworm, black cutworm, the ECB and the corn borer; and the stacked trait IR/HT, MON89034 x NK603 (Table 34). In addition, a total of 24 stacked trait maize and 3 stacked trait cotton products have been approved for importation for direct use as food, feed and for processing, from among a total of 67 biotech crops and products currently approved for direct use as food, feed and for processing.

Table 34. Approval of Biotech Maize Events in the Philippines, 2002 to 2011

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

IR: Insect resistance, HT: Herbicide Tolerance
Source: Compiled by ISAAA, 2013.

The future acceptance prospects for biotech crops in the Philippines continue to look promising with new biotech crop products also being developed by national and international institutes. Among these are Golden Rice (GR), biotech rice biofortified with the provitamin A betacarotene that is being developed by the Philippine Rice Research Institute (PhilRice) and the International Rice Research Institute (IRRI). The first generation Golden Rice (GR1) was first tested in advanced field trials in IRRI in 2008, and second generation of Golden Rice (GR2) introgressed into selected mega varieties were field tested in the wet season of 2010. At PhilRice, confined field 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. Most field and laboratory data have been collected and are now being compiled into a technical dossier for biosafety application. It is 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 is the third season of the multi location field trial and the project team is closely coordinating with the regulators to determine whether it would affect the timeline (IRRI, 2013a). Another research effort by the PhilRice scientists is to develop the '3-in-1' rice which incorporates resistance to tungro virus and to bacterial blight disease in Pro-Vitamin A-enriched lines (Antonio A. Alfonso, Personal Communications). More discussion on the Golden Rice can be found in the Global Overview of this Brief.

The fruit and shoot borer resistant eggplant being developed by the Institute of Plant Breeding, University of the Philippines Los Baños (IPB-UPLB) 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 are being 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.

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) against 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 who 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 will appeal the case to the Supreme Court. More discussion on Bt eggplant in the Philippines can be found in the Global Overview section of the Brief.

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 for the first time was tested in a confined field trial in 2010, has started multi location field trials in 2012, and in 2013, data to complete regulatory dossiers are being collected for commercialization purposes in two years' time. Initiatives in other crops include the development of a virus resistant sweet potato through collaborative activities between the Visayas State University (VSU) and IPB-UPLB and the initial efforts to generate transgenic lines of virus resistant abaca (*Musa textilis*) by the Fiber Industry Development Authority (FIDA) in collaboration with the University of the Philippines. The Philippine Department of Agriculture Biotechnology Program Office and the Department of Science and Technology have been very supportive of research and development activities on biotech crops and have been eager to support the products that will emerge from the R&D pipeline for commercialization in the near term.

It is important to note that the Philippines is the first country in the ASEAN region to implement a regulatory system for transgenic crops; the system has also served as a model for other countries in the region and other developing countries outside Asia. The Philippine biotechnology regulatory system was formalized with the issuance of Executive Order No. 430 in 1990 establishing the National Committee on Biosafety of the Philippines (NCBP). In 2002, the Department of Agriculture (DA) issued Administrative Order No. 8, which provided the basis for commercial release of biotech crops. Subsequently, in 2006, Executive Order 514 was issued further strengthening the NCBP and establishing the National Biosafety Framework. In 2008, the country launched its national biosafety clearinghouse, BCH Pilipinas, to serve as the Philippine node of the Biosafety Clearing House (BCH) mechanism established under the Cartagena Protocol on Biosafety (CPB). The Philippines, which grows approximately 2.5 million hectares of maize is still the only country in Asia to approve and grow a major biotech feed crop; moreover, the Philippines achieved a biotech mega-country status with biotech maize in 2004, i.e. 50,000 hectares or more. Asia grows 32% of the global 158 million hectares of maize with China itself growing 35 million hectares, plus significant production in India (8.4 million hectares), Indonesia (4), Philippines (2.6), Vietnam (1.1), Thailand (1) and Pakistan (900,000 hectares) (FAO, 2012).

## 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 2012 is estimated to have reached US$378 million. For 2012 alone, the net national impact of biotech maize on farm income was estimated at US$92.6 million (Brookes and Barfoot, 2014, 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$378 million from biotech maize in a short span of ten years, 2003 to 2012, and is advancing the adoption of the maize stacked traits, IR/HT. In 2013, 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 around 2016 (IRRI, 2013b).

**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. 2014, In Preparation).* 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).

Opinions on the Golden Rice Uprooting

On September 25, The National Academy of Science and Technology Philippines expressed in a press release that it deplores the disruption of the multilocational field experiment by anti-GMO elements who uprooted the month-old transplanted Golden Rice plants in Pili, Camarines Sur on 08 August 2013. According to NAST, the disruption is ***"an act of sabotage of a lawfully and responsibly-conducted scientific experiment."*** The trials are being conducted for scientific inquiry and thus the incident disregards the hard work devoted towards finding results (Crop Biotech Update, 26 September, 2013).

Philippine Department of Agriculture Secretary Proceso Alcala said that the government does not see any problem in allowing field trials of GM crops during a press briefing. ***"There's a program on Bt eggplant and Golden Rice that scientists study. For as long as testing is within contained environment, it's not right for us to stop it...At the end of the day, if we don't give them a chance to prove it, we're stopping development for the future. If we didn't allow scientists to produce Diatabs (Loperamide hydrochloride), it's like saying we should only use charcoal (to cure diarrhea),"*** said Alcala (Crop Biotech Update, 6 November 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.

<u>Aquino Gozun of Lacmit, Arayat, Pampanga, Philippines</u>
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.

<u>Aurea Raso of Macayug, San Jacinto Pangasinan, Philippines</u>
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.

<u>Corazon Cabasag of Sta. Rosa, Iguig, Cagayan, Philippines</u>
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.

<u>Faustino Astrero Jr. of Banga, South Cotabato, Philippines</u>
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.

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*__AUSTRALIA__*

**Australia grew 638,000 hectares of biotech crops in 2013, comprising 416,000 hectares of biotech cotton (down from 512,000 hectares in 2012) plus 222,000 hectares of biotech canola (up from 176,000 in 2012), more than five-fold increase from the 41,200 biotech canola hectares in 2009. Reduction in biotech cotton planting is due to lower total cotton hectarage brought by continuous drought, lower cotton prices and the shift to higher priced canola and other cereals. Biotech cotton adoption remains at 99% of all cotton grown in Australia with 95% of it featured the stacked traits (insect resistance and herbicide tolerance). The total biotech crop hectarage in 2013 represents a ~14-fold increase over the 48,000 hectares of biotech crops in 2007 during which Australia suffered a very severe drought which continued in 2008 and to a lesser degree in 2009 when the country was still recovering from the multi-year drought which is the worse on record in Australia. Enhanced farm income from biotech crops is estimated at US$766 million for the period 1996 to 2012 and the benefits for 2012 alone at US$129.2 million.**

**__AUSTRALIA__**

Population: 21.5 million

GDP: US$1,132 billion

GDP per Capita: US$50,750

Agriculture as % GDP: 2%

Agricultural GDP: US$22.6 billion

% employed in agriculture: 3%

Arable Land (AL): 46.9 million hectares

Ratio of AL/Population*: 10.0

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

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

Total area under biotech crops and (%) increase in 2013:
0.638 Million Hectares (-7%)

Farm income gain from biotech, 1996-2012: US$766 million

*Ratio: % global arable land / % global population

In 2013, Australia grew 638,000 hectares of biotech crops, (down 7% from 688,000 hectares planted in 2012) comprising 416,000 hectares of biotech cotton, (down 20% from 512,000 hectares in 2012), plus 222,000 hectares of biotech canola (up 26% from 176,000 in 2012). This compares with more than five-fold increase from the 41,200 biotech canola hectares in 2009. The decrease in biotech cotton was due to decreased cotton plantings and lower cotton prices. Farmers shifted to planting biotech canola and other cereals due to high prices. A remarkable 99% of all cotton grown in Australia in 2012 was biotech and 95% of it (395,000) featured the stacked genes for insect resistance and herbicide tolerance and 5% (21,400) are herbicide tolerant.

In 2013, Australia for the sixth year grew herbicide tolerant RR®canola in three states: New South Wales (NSW), Victoria and Western Australia. According to the Australian Oilseeds Federation (2013), an estimated total of 2.29 million hectares of canola were grown in Australia, of which 15.4% of 1.1 million hectares (169,232 hectares) biotech canola were grown in Western Australia, 5.7% of 550,000 hectares (31,165 hectares) were biotech in NSW, and 5.6% of 390,000 hectares (21,780 hectares) were biotech in Southern Australia. Biotech canola planting at 222,361 hectares is 9.7% adoption rate in 2013 compared to 9.1% in 2012. There is a potential 1.7 million hectares in Australia that can be planted to biotech canola for the benefit of the farmers and consumers in the country (Table 35).

The total biotech crop hectarage of 638,000 hectares in 2013 represents a ~14-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 33 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).

### *Drought Tolerant Wheat*

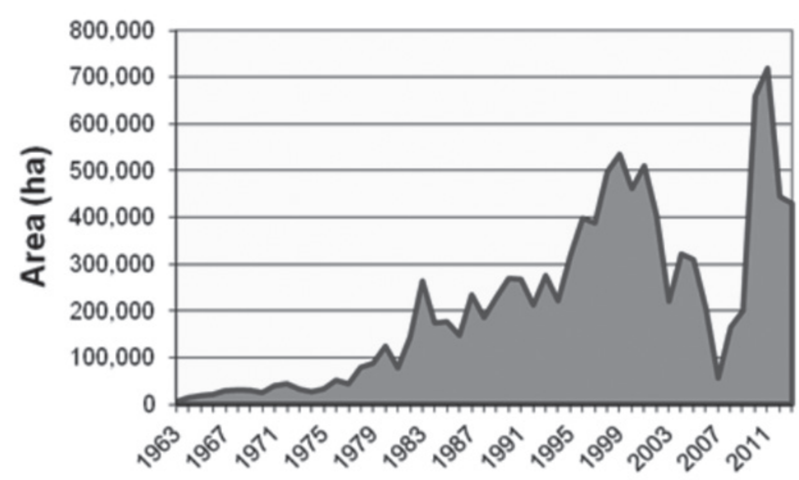
In Australia, the Office of the Gene Technology Regulator (OGTR) oversees and regulates the conduct of field trials. The office assesses individual field trial applications and once approved issues a license under which it can be conducted. Biotech researches on wheat gene technology are undertaken by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

Table 35. Hectares of Canola, Conventional and RR® Biotech Planted in Australia, by State, 2012 and 2013

| State | Total Canola (Ha) | | Biotech Canola (Ha) | | Biotech Canola (%) | | Non-Biotech |
|---|---|---|---|---|---|---|---|
| | 2012* | 2013* | 2012** | 2013** | 2012 | 2013 | 2013 |
| NSW | 390,000 | 550,000 | 40,324 | 31,165 | 10.3% | 5.7% | 404,540 |
| Victoria | 370,000 | 390,000 | 19,012 | 21,780 | 5.1% | 5.6% | 371,260 |
| South Australia | 255,000 | 250,000 | – | – | – | – | 250,000 |
| Western Australia | 800,000 | 1,100,000 | 121,694 | 169,232 | 15.2% | 15.4% | 744,760 |
| **Total** | **1,974,938** | **2,290,000** | **181,030** | **222,361** | **9.1%** | **9.7%** | **1,774,570** |

* Sourced from Industry Data
** Area estimate of Biotech canola based on seed sold using a 2.5kg/Ha seeding rate

Figure 33. Cultivated Area of Cotton in Australia as Affected by Rainfall Patterns




Source: CSIRO, Personal Communication

in heat/drought conditions and cope with climate change. For consumers, research is on altering grain composition such as developing foods that have the potential to address diabetes, heart disease and other illnesses.

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

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

***Biotech Sugarcane***

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

***Biotech Banana***

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

Simultaneously, Dr. Dale also received a support grant for the provitamin A-enriched banana from the Bill and Melinda Gates Foundation. A field testing for banana varieties Williams and Dwarf Cavendish, and LadyFinger hybrid with increased level of pro-vitamin A and/or iron and marker gene expression was approved in February 2011 and is being conducted in May 2011 to May 2013. 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).

## Benefits from Biotech Crops in Australia

Australia is estimated to have enhanced farm income from biotech cotton by US$766 million in the period 1996 to 2012 and the benefits for 2012 alone is estimated at US$129.2 million (Brookes and Barfoot 2014, 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.

## Scientists and Farmers Support Biotech Crops in Australia

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

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

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

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

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

***Views on Biotech Crops in Australia***

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

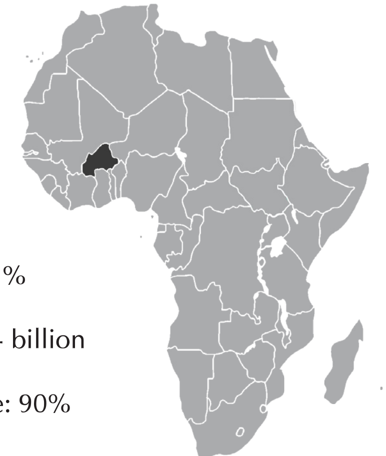
Mr. Roy Hamilton is a founding member of the Riverine Plains Grower Group, and a regular participant in Grain Research and Development Corporation (GRDC) Southern Grower Updates. Mr. Hamilton also sits on the SE Regional Advisory Committee and enjoys reflecting local farmer issues and priorities through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

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

*BURKINA FASO*

**2013 was the sixth year for farmers in Burkina Faso to benefit significantly from Bt cotton. Out of a total of 690,971 hectares planted to cotton in the country in 2013, 474,229 or 68.6% were planted to Bt cotton (BGII). Total cotton planted in 2013 was 690,971 hectares compared with 615,796 hectares in 2012, equivalent to a 12% increase. Expansion of Bt cotton planting led to a record hectarage increase of 51% in 2013 from 313,781 hectares in 2012 to 474,229 hectares. Based on an average cotton holding of 3.16 hectares the number of farmers growing Bt cotton in 2013 was approximately 150,072. The increase in total Bt cotton area of 160,448 hectares (a 51% increase) and 68% adoption rate was principally due to the success and benefits of planting Bt cotton that has provided the incentive for Burkina Faso farmers to increase plantings of Bt cotton. The latest data on benefits from Bt cotton in 2011 includes an average yield increase of almost 20% (19.7%), plus labor and insecticide savings (2 rather than 6 sprays), which resulted in a net gain of about US$95.35 per hectare compared with conventional cotton. 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 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. Enhanced farm income from biotech crops is estimated at US$187 million for the period 2008 to 2012 and the benefits for 2012 alone at US$90.2 million.**

## BURKINA FASO



Population: 16.5 million

GDP: US$10.4 billion

GDP per Capita: US$634

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*: 1.5

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

Commercialized Biotech Crops: Bt Cotton

Total area under biotech crops and (%) increase in 2013:
0.691 Million Hectares (+12%)

Farm income gain from biotech, 2008-2012: US$187 million

*Ratio: % global arable land / % global population

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

2013 was the sixth year for farmers in Burkina Faso to benefit significantly from Bt cotton. Out of a total of 690,971 hectares planted to cotton in the country in 2013, 474,229 hectares or 69% were planted to Bt cotton (BGII). Total cotton planted in 2013 was 690,971 hectares compared with 615,796 hectares in 2012, equivalent to a 12% increase over 2012. Expansion of Bt cotton planting led to a record hectarage increase of 51% in 2013: from 313,781 hectares in 2012 to 474,229 hectares in 2013. Based on an average cotton holding of 3.16 hectares, the number of farmers growing Bt cotton in 2013 was approximately 150,000 up from 100,000 in 2012. The increase in total Bt cotton area of 160,448 hectares (a 51% increase) at an adoption rate of 69% were principally due to the incentive provided by the success with Bt cotton and the substantial benefits that it offers for Burkina Faso farmers. The latest data on benefits from Bt cotton in 2011 includes an average yield increase of almost 20%, (19.7%) plus labor and insecticide savings (2 rather than 6 sprays), which resulted in a net gain of about US$95.35 per hectare compared with conventional cotton.

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.

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 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 trials for Bt cotton (Bollgard II) in six locations in the Northern part of the country bordering Burkina Faso. The decision was based on the recommendation of the Technical Advisory Committee, after analysing existing knowledge and experiences from among other countries, India and South Africa. This will expedite commercialization process in Ghana for the benefit of their cotton farmers. There has been heightened awareness and demand from farmers in neighboring countries such as Mali and Togo for Bt cotton and they 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 the safe use of modern biotechnology.

## Benefits of Biotech Crops in Burkina Faso

National benefits to Bt cotton farmers in 2012 were estimated at US$26 million representing 67% of total benefits with the balance accruing to the technology developers. Extrapolating from 2011 data, the national benefit from Bt cotton in 2012 was about US$30 million. This is a significant achievement for a country with a per capita GDP of ~US$500 per year. In 2011, the average increase in yield for Bt cotton was 19.7% over conventional and insecticide sprays were reduced from 6 to 2. Profit increased by 50% to an average of US$95.35 per hectare and benefits were consistent across farm types and geographical zones. Bt cotton farmers captured 53% of the total benefits in 2009, 66% in 2010 and 67% in 2011 and there is no reason to believe that subsequent years will be different.

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 the 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 in total seed cotton production, anticipated to reach 630,000 tons during 2012/13, a 52 percent increase from 2011/12. This large increase was due, in part 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 474,229 hectares in 2013.

Enhanced farm income from biotech crops is estimated at US$187 million for the period 2007 to 2012 and the benefits for 2012 alone at US$90.2 million (Brookes and Barfoot, 2014, Forthcoming).

## *Farmer Testimonials*

Mrs. Azèta Kinda a farmer from Bazèga Province, central Burkina Faso. The mother of five, obtained a one hectare farm from her husband and embarked on Bt cotton farming. For Mrs. Kinda, 2013 was her 4th year of cultivating Bt cotton. Despite the challenges of late rains and a dry spell after the onset of rains in September 2013, she still believes she will get a reasonable yield. ***"Four years ago,***

***I heard from cotton promoters that there were numerous advantages in cultivating cotton. I decided to follow their advice and I am very satisfied with the results. From the income from Bt cotton. I have been able to provide for my children and invested in cattle, in order to diversify my income sources. I will continue to grow Bt cotton because I have confirmed that indeed, the benefits are enormous not only in terms of profits but also relieving the burden of spraying and fetching water for the same. It also saves me time to grow food crops."***

Mr. Tasséré Ilboudo a cotton farmer from Bazèga Province, central Burkina Faso. A polygamous with 4 wives and father of 16 children, Mr. Ilboudo has been a cotton farmer for the last 14 years. He owns a 50 hectare plot where he has been farming cotton alongside other crops like maize, ground nuts and cowpea. He adopted Bt cotton 5 years ago and planted only Bt cotton in 2013, alongside 349 farmers of his cotton farmer group. Comparing Bt cotton with the conventional variety he says, ***"If one follows the prescribed technical instructions and chemical treatments, Bt cotton is more advantageous as it flowers earlier than conventional cotton and gives out many bolls in a record time, thus more yields. The reduction in the number of insecticide treatments from 6 or more for conventional cotton to 2 treatments only for Bt cotton has been a great relief. Our health is better than before because we are not exposed to pesticides as much as before."*** Talking about the income he gets from Bt cotton he confides ***"My profit is usually between 200,000 to 300,000 CFA Francs after paying all my debts. I take care of my family needs and I also invest in other businesses."*** Concerning the negative perceptions about Bt cotton Ilboudo regrets there is so much misinformation and manipulation by outsiders who don't even know the difference between conventional and Bt cotton. As for his group, he says they have no problem because they have already tasted the benefits.

## ***MYANMAR***

**2013 is the eighth consecutive year of cultivation of the long staple insect resistant Bt cotton variety named "Silver Sixth" or "Ngwe chi 6". In 2013, "Ngwe chi 6" was planted on 305,000 hectares by 435,000 small farmers (average of 0.7 hectare of cotton farm per farmer). This is equivalent to an adoption rate of 85% of all the cotton grown in Myanmar, and up from 300,000 hectares in 2012-13. "Ngwe chi 6" is a bollworm resistant and high yielding variety broadly adapted to different environments in Myanmar. It was developed, produced and distributed by the Myanmar Industrial Crops Development Enterprise (MICDE). In 2010, the National Seed Committee (NSC) of the Ministry of Agriculture & Irrigation officially registered "Ngwe chi 6"**

**for commercial cultivation, which had been used for the first time in 2006-07. "Ngwe chi 6" is very popular and has replaced all long staple cotton hectarage within the first 8 years of its commercial release. This variety has more than doubled the national cotton production from 271,069 MT in 2006-07 to 618,220 MT in 2012-13. Country yield of long staple cotton has risen steeply from 770 kg per hectare in 2006-07 (coincides with introduction of Bt cotton Ngwe chi 6) to 1,722 kg per hectare in 2012-13, an increase of 125% in a short period of seven years. 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. Enhanced farm income from biotech crops is estimated at US$222 million for the period 2006 to 2012 and the benefits for 2012 alone at US$48.7 million.**

**MYANMAR**

Population: 52.8 million

GDP: US$55.32 billion

GDP per Capita: US$1,144

Agriculture as % GDP: 38.8%

Agricultural GDP: US$21.5 billion

% employed in agriculture: 70%

Arable Land (AL): 9.7 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 2013:
0.305 Million Hectares (+1.7%)

Increased farm income for 2006-2012: US$222 million

*Ratio: % global arable land / % global population

## Agriculture and Cotton in Myanmar

Myanmar with a population of 50 million is predominantly an agricultural based economy. Agriculture contributes more than half (50.3%) of the national Gross Domestic Product (GDP) of US$26.5 billion or equivalent to US$635 per capita. Agriculture products contribute 17.5% of total export earnings for the country. Agriculture employs 61.2% of total population of the country which has two distinct agro-eco climates – the temperate North and tropical South. Approximately 4.5 million farm families cultivate various crops on an estimated arable land of 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 four principal crops – rice, pulses, cotton and sugarcane that ensure food self sufficiency and earn significant foreign exchange. Rice occupies 47% or 5.5 million hectares of the cultivated area and cotton occupies about 350,000 hectares (MCSE, 2001; UNEP GEF, 2006). Approximately half a million cotton farmers (an estimated 503,566) farming 368,000 hectares in 2007, cultivate an average 0.7 hectares of cotton per farm in the regions of Western Bago, Mandalay, Magwe and Sagaing (Tun, 2008). Traditionally, cotton farmers grew indigenously developed varieties of *Gossypium arboreum* (short staple) until the large scale commercial adoption of upland cotton varieties of *Gossypium hirsutum* (long staple) in the 1960s. In 2010, the National Seed Committee (NSC) of the Ministry of Agriculture and Irrigation registered the insect resistant Bt cotton variety "Ngwe chi 6" for commercial cultivation, that has become very popular and replaced all long staple cotton area within first 8 years of its commercial release. Remaining cotton area of approximately 55,000 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 (James, 2011 and 2012) provides a detailed overview of agriculture, R&D and cotton crop in Myanmar.

## Agriculture 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 from 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 7$^{th}$ January 2011, which came into force on 7$^{th}$ 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 36 shows the enactment of different legislative system to regulate and promote agriculture inputs including seeds, pesticides and fertilizer in Myanmar.

**Table 36. Legislative System to Regulate & Promote Agriculture Inputs by the MOAI in Myanmar, 2013**

| 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<br>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<br>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, 2013

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 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).

## Insect Resistant 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 and 305,000 hectares in 2013-14. Bt cotton was farmed by 435,000 farmers in 2013-14 compared to 428,000 farmers in 2012-13, 375,000 in 2010-11 with increasing adoption of 75% in 2010-11 to 84% of 359,000 of total cotton hectarage which increased by 6% from 283,000 hectares in 2011-12 and to 85% in 2013-14. The insect resistant Bt cotton now occupies the entire long staple cotton hectarage in the country (Table 37).

In 2013-14, approximately 55,000 hectares of cotton area that was planted with conventional 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 75% of the cotton grown in Myanmar is long staple cotton whilst the balance of 25% is short staple. The short staple cotton is planted in 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.

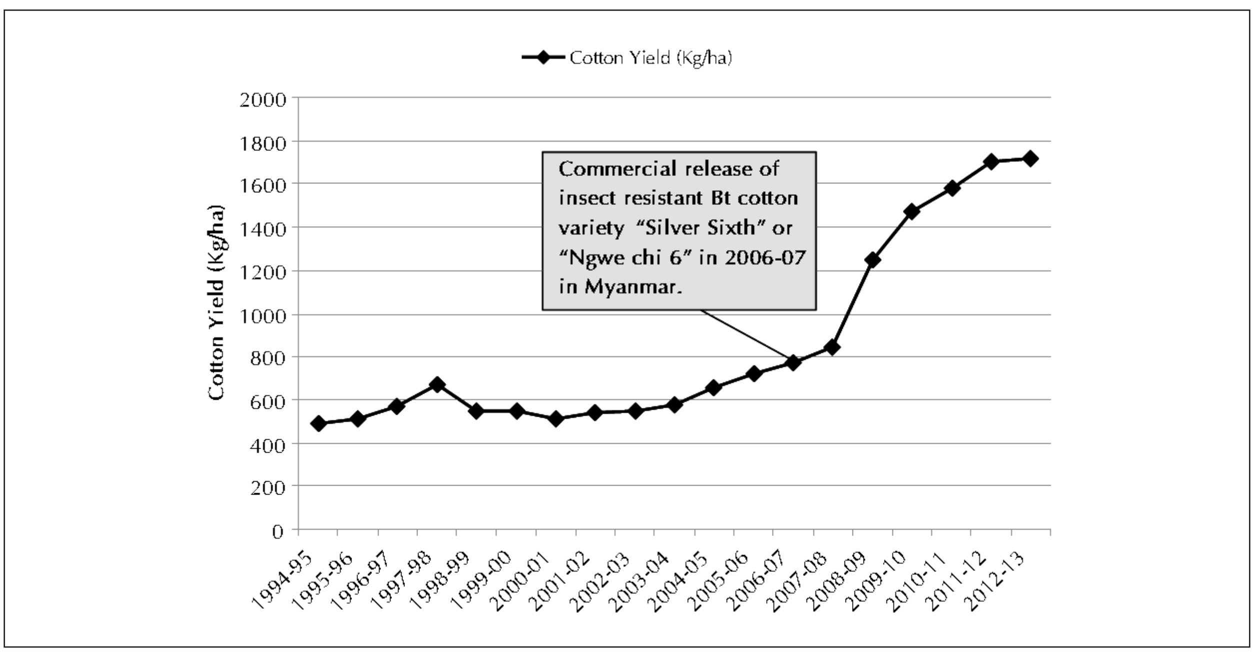
**Table 37. Adoption of Bt Cotton in Myanmar, 2006 to 2013**

| 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% |

Source: Compiled by ISAAA, 2013.

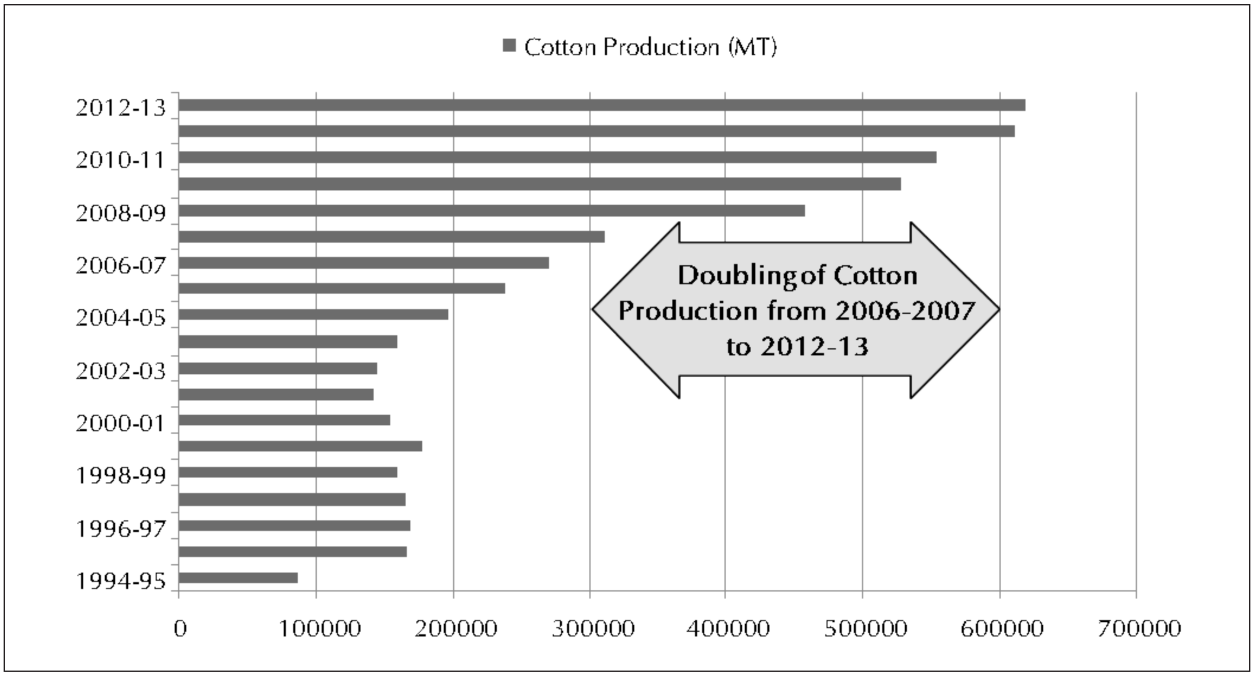
In 2009, Myanmar grew 360,000 hectares of cotton of which 270,000 hectares were long staple cotton producing 524,000 MT or 93 percent of total cotton production, whilst 68,000 hectares were short staple cotton producing only 38,000 MT or 7% of total cotton production (Figure 34). The yield of short staple 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 1722 kg per hectare in 2012-13, 125% increase in cotton yield in a short period of seven years as shown in Figure 34 (MICDE, 2012c; MOAI, 2012). Yield losses from bollworms such as American bollworm and pink bollworms were significant, ranging from 30 to 70 percent (Nu, 2011). Therefore, the commercial release of Bt cotton variety "Ngwe chi 6" has imparted a significant control to insect pests resulting to a significant reduction in yield losses and a major contribution to steep yield increases in the last few years in Myanmar. Similarly, cotton production more than doubled from 271,069 MT in 2006-07 to 618,220 MT in 2012-13, an increase of 130% from 2006-07 to 2012-13 (Figure 35). 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.

**Figure 34. Cotton Yield in Myanmar, 1995-96 to 2012-2013**




Source: MICDE, 2012c; Nu, 2011

**Figure 35. Cotton Production in Myanmar, 1995-96 to 2012-13**



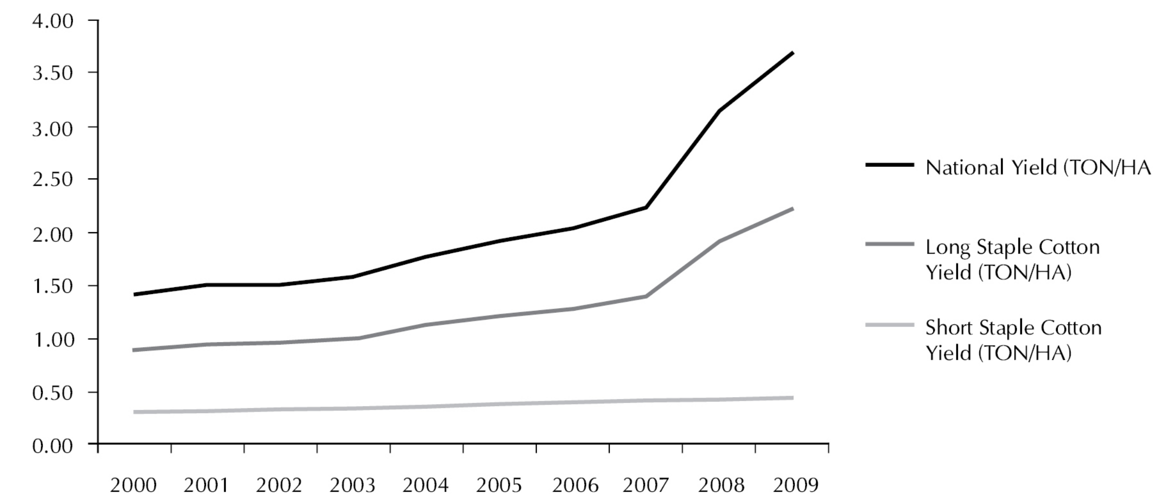

Source: MoAI, 2012; Compiled by ISAAA, 2013

## 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 36). 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.

Enhanced farm income from biotech crops is estimated at US$222 million for the period 2006 to 2012 and the benefits for 2012 alone at US$48.7 million (Brookes and Barfoot, 2014, Forthcoming).

**Figure 36. Comparing Yield of Long Staple Bt Cotton, Short Staple Cotton and National Average, 2000 to 2009**




Source: Adopted from GAIN, USDA FAS, 2010.

## *SPAIN*

**Spain is the lead biotech crop country in Europe, with 93% of a record 148,013 Bt maize hectares planted in Europe in 2013. Spain has successfully grown Bt maize for sixteen years, and grew a record 136,962 hectares of Bt maize hybrids in 2013. This compares with 116,307 hectares grown in Spain in 2012 equivalent to a substantial 18% increase. Total plantings of maize in Spain was 14% more in 2013 at 441,473 hectares compared with 387,422 hectares in 2012, leading to a record adoption of 31% in 2013 compared with 30% in 2012. Enhanced farm income from biotech Bt maize is estimated at US$176 million for the period 1998 to 2012 and for 2012 alone at US$37.2 million.**

Spain is the only country in the European Union to grow a substantial area of a biotech crop. In 2013, Spain grew 93% of all the 148,013 hectares of biotech maize in the EU. Note that the 2013 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 2013, the Bt maize area in Spain reached a record hectares of 136,962 in 2013 compared with 116,307 hectares in 2012. The adoption rate in 2013 was a record 31% – more than 20,000 hectare increase which is impressive. In 2013, total maize plantings at 441,473 hectares were 14% more than 2012 when the adoption rate was 30%. Thus, both absolute Bt maize hectares increased in 2013 by 18,942 hectares, as well as an increase in the adoption rate to 31% from 30%. The principal areas of Bt maize in Spain in 2013 were in the provinces of Aragon (54,451 hectares) where the adoption rate for Bt maize was 73% compared with 67% in 2012, followed by Cataluña (33,996) with the highest adoption rate of 82% for 2013, compared with 90% last year, with significantly more area of Bt maize in Extremadura (16,979), with an adoption rate of 25%; the balance of Bt maize was grown in eight other provinces in Spain in 2013 (Tables 38 and 39).

**SPAIN**

Population: 45.3 million

GDP: US$1,407 billion

GDP per Capita: US$30,550

Agriculture as % GDP: 3%

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
- Sugarbeet
- Maize
- Potato
- Wheat

Commercialized Biotech Crops: Bt maize

Total area under biotech crops and (%) increase in 2013: 0.148 Million Hectares (+18%)

Farm income gain from biotech, 1998-2012: US$176 million

*Ratio: % global arable land / % global population

Currently, more than 200 hybrids from about ten seed companies, all with the dominant event MON810 have been approved for commercial planting. Up until 2002, only the variety COMPA CB was grown with Bt-176 for insect resistance, and this variety was grown until the 2005 season. MON810 varieties for insect resistance were approved in 2003. There are about 200 registered hybrids of which 30 to 40 were estimated to have been planted in 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.

Table 38. Hectares of Biotech Bt Maize in the Autonomous Communities of Spain, 1998 to 2013

| Provinces | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| Valencia | 190 | 300 | 150 | 100 | 20 | 72 | 73 | 293 | 0 | 0 | 14 | 0 | 23 | 107 | 522 | 913 |
| Madrid | 660 | 1,560 | 1,970 | 1,940 | 780 | 1,034 | 1,385 | 155 | 80 | 193 | 381 | 130 | 340 | 418 | 421 | 531 |
| Islas Baleares | 2 | 2 | 26 | 0 | 30 | 6 | 29 | 29 | 0 | 3 | 3 | 92 | 75 | 52 | 154 | 174 |
| Castilla Y Leon | 200 | 360 | 270 | 0 | 0 | 74 | 0 | 12 | 0 | 13 | 28 | 19 | 0 | 6 | 8 | 6 |
| Murcia | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 0 | 0 | 24 | 0 | 0 | 0 | 0 | 4 | 52 |
| La Rioja | 25 | 30 | 30 | 0 | 0 | 0 | 35 | 41 | 122 | 4 | 11 | 8 | 5 | 21 | 0 | 2 |
| Cantabria | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 0 |
| Asturias | 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 |

Source: Ministry of Environment Rural Development and Fisheries, Spain, 2013. Avances Suopefices y Producciones Agricolas, September 2013.

**Table 39. Total Hectares of Maize Planted in Spain by Province, 2012 and 2013 Percentage Adoption of Bt Maize**

| Province | Total Hectares (2013) | Percent Bt Adoption (2013) |
|---|---|---|
| Castilla y Leon | 122,565 | <1 |
| Aragon | 75,022 | 73 |
| Extremadura | 68,100 | 25 |
| Castilla-Mancha | 39,773 | 22 |
| Andalucia | 43,356 | 33 |
| Catalunia | 41,686 | 82 |
| Galicia | 19,112 | 0 |
| Navarra | 21,198 | 33 |
| Madrid | 7,250 | 7 |
| Canarias | 646 | 0 |
| La Rioja | 750 | 0.3 |
| Pais Vasco | 320 | 0 |
| C. Valenciana | 716 | 13* |
| Cantabria | 325 | 0 |
| Balearas | 326 | 53.4 |
| Pais de Asturias | 200 | 0 |
| R de Murcia | 128 | 40.9 |
| **Total** | **441,473** | **31%** |

* Provisional data pending confirmation
Source: Ministry of Environment Rural Development and Fisheries, Spain, 2013. Avances Suopefices y Producciones Agricolas, September 2013

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

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

## Benefits from Biotech Crops in Spain

Spain is estimated to have enhanced farm income from biotech Bt maize by US$176 million in the period 1998 to 2012 and the benefits for 2012 alone is estimated at US$37.2 million (Brookes and Barfoot, 2014, Forthcoming).

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

### *Farmers' Views on Biotech Crops*

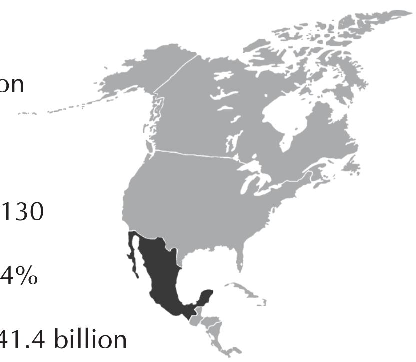
Farmers from Spain, Romania and Portugal presented to the members of the European parliament (MPs) and representatives of the European Commission in Brussels a manifesto stating that ***"Biotechnology, a tool for agro-food cannot be ignored. The text in the rejection of positions and decisions against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

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

## *MEXICO*

**In 2013, Mexico planted 114,000 hectares of biotech crops comprised of 102,000 biotech cotton and 12,000 biotech soybean. The reduction in total biotech crops from 160,000 hectares in 2012 is due to reduced total cotton planting from 157,000 hectares in 2012 to 113,000. Biotech cotton hectarage in 2013 decreased by one third or 102,000 hectares from 153,000 hectares in 2012, due to drought, and lower cotton prices. RR®soybean was grown in 12,000 hectares, compared with 7,000 hectares in 2012. Plans for large scale pilot field trials of biotech maize were submitted but to-date no response has been received – in the interim a restraining court order in September was issued, suspending the issue of permits for maize trials. Experts observe that this is a delay and not a final outcome and that Mexico will adopt a national,**

### MEXICO



Population: 110.6 million

GDP: US$1,036 billion

GDP per Capita: US$9,130

Agriculture as % GDP: 4%

Agricultural GDP: US$41.4 billion

% employed in agriculture: 13%

Arable Land (AL): 25.4 million hectares

Ratio of AL/Population*: 1.0

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

Commercialized Biotech Crops:
- Bt Cotton
- HT Soybean

Total area under biotech crops and (%) increase in 2013:
0.114 Million Hectares (-28%)

Farm income gain from biotech, 1996-2012: US$238 million

*Ratio: % global arable land / % global population

**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 estimated to have enhanced farm income from biotech cotton and soybean by US$238 million in the period 1996 to 2012 and the benefits for 2012 alone is US$57.8 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 2013, Mexico planted 102,000 hectares of biotech cotton, equivalent to 90% of the 113,000 hectares of the national cotton hectarage and approximately 12,000 hectares of biotech RR®soybean for a country total of 114,000 hectares of biotech crops, compared to 160,000 hectares in 2012. The major reason for the decrease was drought, in the absence of which, biotech cotton hectarage could have been approximately 200,000 hectares. Data in Table 40 shows that 88.5% of all cotton was planted to the stacked gene HT/IR product favored by farmers, 1.8% as HT and the balance of 9.7% as conventional.

Mexico planned to be self sufficient in cotton. This was evident in its productive discussions in 2012 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.

RR®soybean was grown in 12,000 hectares in 2013, a 71% increase compared with 7,000 hectares in 2012. There is an increase in adoption rate from 5% in 2012 to 9% in 2013.

**Table 40. Biotech Cotton in Mexico, 2013**

| Trait | Total Hectares | % Biotech cotton |
|---|---|---|
| Bt/HT | 100,000 | 88.5 |
| HT | 2,000 | 1.8 |
| Conventional | 11,000 | 9.7 |
| **TOTAL** | **113,000** | **100%** |

Source: Compiled by Clive James, 2013.

## Biotech Maize

Experimental field trials were conducted during 2011/2012 in the northern states of Mexico: Sonora, Sinaloa, Tamaulipas, Chihuahua and Coahuila which proved the effectiveness of maize biotech traits. Additional approvals were also granted for field evaluations under the aegis of the Pilot phase project (pre-commercial) in Sinaloa and Tamaulipas during 2012. These trials were planted in January 2012 and harvested in July 2012. The trials generated important information regarding the use of adequate bio-safety measures that will allow coexistence of biotech and conventional maize. The trials also generated data on economic and environmental benefits for farmers. After completion of the Pilot phase, regulatory agencies will analyze the data and utilize it in consideration of granting commercial approvals for plantings of biotech maize in Mexico.

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

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

Mexico cultivates about 7 million hectares of maize and is heavily dependent on about 10 million tons 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.

Plans for large scale pilot field trials of biotech maize were submitted for 2013 but to-date no response was received – in the interim a restraining court order was issued in September 2013. This class action lawsuit was presented by a group of people and associations against the Agriculture Ministry (SAGARPA), the Environment Ministry (SEMARNAT), and some of the agricultural biotechnology companies in Mexico. The plaintiffs argued that Mexicans have the right to a healthy environment, biodiversity, and the preservation of native maize. They also raised concerns over intellectual property rights and unintended commingling of conventional and biotech varieties. The plaintiffs did not provide any scientific evidence to support their claims.

A federal judge issued a provisional measure which is a temporary suspension to the issuance of new permits for field trials, pilot program and commercial release of biotech/GM maize. This suspension has been appealed already by SAGARPA, SEMARNAT and the companies involved. A higher court must resolve the issue in 2 or 3 months, which would be approximately at year-end 2013. It is important to note that the temporary measure issued by the court does not pre-judge the merits of the case. The judge has not ruled in favour of the plaintiffs and it only affects cultivation and does not involve imports or the consumption (feed, food or processing) of GM maize in Mexico.

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. The defendants are already reviewing the case and determining the appropriate legal response. 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.

Experts observe that the court ruling is a delay and not a final outcome and 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

Mexico is estimated to have enhanced farm income from biotech cotton and soybean by US$238 million in the period 1996 to 2012 and the benefits for 2012 alone is estimated at US$57.8 million (Brookes and Barfoot, 2014, Forthcoming).

## *COLOMBIA*

**In 2013, Colombia grew 24,000 hectares of biotech cotton and 85,000 hectares of biotech maize for a total of 109,000 hectares – in previous years, maize was grown under a special pre commercial project and was not included in this data base. In 2012, 28,172 hectares of biotech cotton was reported. In 2013, ~95% of the biotech cotton was the stacked product Bt/HT. About half of the biotech maize grown in 2013 was the stacked product Bt/HT. Colombia is estimated to have enhanced farm income from biotech cotton by US$62.7 million in the period 2002 to 2012 and the benefits for 2012 alone is estimated at US$22.8 million.**

In 2013, Colombia grew 24,000 hectares of biotech cotton and 85,000 hectares of biotech maize for a total of 109,000 hectares. 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 85,000 hectares of biotech maize in 2013 compared with 75,000 hectares in 2012. Of the ~85,000 approximately half were the stacked traits Bt and herbicide tolerance (Bt/HT), ~30,000 hectares were Bt maize (35%) and the balance of about 10% was herbicide tolerant. The 24,000 hectares of biotech cotton is almost entirely the 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 2013 planted an estimated 4 hectares in greenhouses.

**COLOMBIA**

Population: 46.3 million

GDP: US$289 billion

GDP per Capita: US$6,240

Agriculture as % GDP: 7%

Agricultural GDP: US$20.2 billion

% employed in agriculture: 18%

Arable Land (AL): 1.8 million hectares

Ratio of AL/Population*: 0.1

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

Commercialized Biotech Crops:
- Bt Maize
- Bt Cotton

Total area under biotech crops and (%) increase in 2012:
0.109 Million Hectares (+287%)

Farm income gain from biotech, 2002-2012: US$62.7 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$62.7 million in the period 2002 to 2012 and the benefits for 2012 alone is estimated at US$22.8 million (Brookes and Barfoot, 2014, 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 a conventional maize crops, he would spend about 500 thousand pesos (approximately US$250) per hectare during a farming season. However, by planting biotech seeds, he has been able to reduce that amount to just 70 thousand pesos (approximately, US$35) per hectare. The use of biotech seeds has enabled him to save 86 percent in costs per hectare."*** He added that, ***"which means I get to enjoy more free time! I can focus in other activities in my farm or… just rest!"***

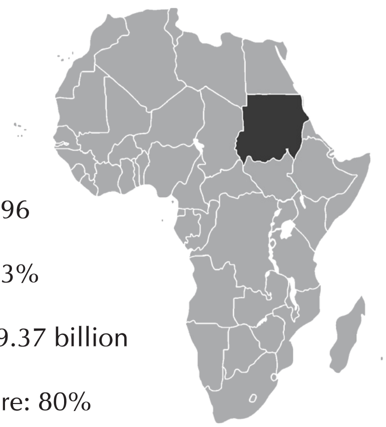
For all these benefits, he said, today ***"I do prefer biotechnology!"*** From now on he will continue to grow biotech crops in this region of Colombia, which has been catalogued as one of the most promising territories on agricultural development and production (Valencia, 2010).

## ***SUDAN***

**2013, was the second year of commercial planting of Bt cotton in Sudan. A total of 61,530 hectares of Bt cotton, up more than three-fold from 20,000 hectares in 2012, were planted in both rainfed and irrigated areas by ~27,000 farmers; this compares with 10,000 beneficiary farmers in 2012 who on average grew cotton on about 1 to 2.5 hectares of land. Of a total national cotton hectarage of 69,132 hectares in the Sudan in 2013, 61,530 hectares, equivalent to 89%, 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, 2012, 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 per feddan for Bt cotton. The net profit for a farmer planting Bt cotton, compared**

**with conventional cotton was US$170 per feddan or ~US$400 per hectare.**

## SUDAN



Population: 33 million

GDP: US$89 billion

GDP per Capita: US$2,496

Agriculture as % GDP: 33%

Agricultural GDP: US$29.37 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 2013:
0.062 Million Hectares (+208%)

*Ratio: % global arable land / % global population

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 188 million hectares and a population of 33 million, at a population growth rate of 2.5%. The Blue and the White Niles run from the South to the North, and to the east the Sudan borders the Red Sea. The irrigated areas around the Nile are fertile and today, cotton is cultivated on about 70,000 hectares in the districts/states shown in Table 41 with the largest area being 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 food crop. Other important crops include wheat, peanuts and sesame, grown for domestic consumption.

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. Prior to the South Sudan being granted independence, of the 203,000 hectares of cotton grown in the 2003/2004 season for example, 118,000 hectares (58%) were under the long-staple variety "Barakat", 77,000 (38%) under the medium-staple "Acala", and 8,000 ha (4%) under the short staple varieties "Nuba and Acarain". Over the past decade, the share of cotton in Sudan's foreign export earnings has declined relative to other crops like sesame and livestock; even so, cotton still plays a major role in the economy. Cotton is an important source of income for a large number (200,000) of growers and their families. Cotton crop residues

**Table 41. Actual Productive Areas of Cotton in Sudan, 2013/2014**

| District/State | Type | Areas (1,000 Feddans) | | % of Bt Cotton |
|---|---|---|---|---|
| | | Bt Cotton | Non Bt Cotton | |
| Gezira | Irrigated | 34.6 | 14.1 | 71 |
| Rahad | Irrigated | 29.5 | 2.2 | 93 |
| New Halfa | Irrigated | 34.7 | 1.8 | 95 |
| Suki | Irrigated | 23.7 | 0 | 100 |
| Blue Nile | Rainfed | 11 | 0 | 100 |
| North Kurdufan | Rainfed | 4.5 | 0 | 100 |
| Arab Company | Rainfed | 6.5 | 0 | 100 |
| Sudan-Egyptian Company | Rainfed | 2 | 0 | 100 |
| **Total** | | **146.5** (61,530 ha) | **18.1** (7,602 ha) | **89%** |

Note: 1 Feddan = 0.42ha

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.

2013, was the second year of commercial planting of Bt cotton in Sudan. A total of 61,530 hectares up from 20,000 hectares in 2012 were planted in both rainfed and irrigated areas by close to 27,000 farmers compared to the initial 10,000 farmer beneficiaries. The total hectarage of Bt cotton in 2013 was 61,530 hectares which 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 89% is equivalent to 61,530 hectares (Table 41).

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 against US$246 for Bt cotton. The net profit for a farmer planting Bt cotton was US$170 per feddan. 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. Important lesson learnt from the first season crop is that increase in cotton productivity and production depends on good farm management. Expanding the area under Bt cotton will thus require an agronomic package supported by an efficient extension service.

Most of Sudan's cotton is exported as lint. Major importers of Sudan's cotton are Egypt in Africa; Germany and Italy in Europe; and Thailand and Bangladesh in Asia. Compared with average export earnings of US$270 million during the 1970s, proceeds from cotton exports slumped to only US$42 million in 2001. In relative terms, local utilization of lint, mostly in textile industry, varies between 10% during the 1980s and 7% to 17% in recent years. However, in absolute terms, domestic lint consumption consistently declined from an average of 86 thousand bales during the 1980s to only 16 thousand bales in 2001 due to problems of the local textile industry.

Earnest efforts are now being made by the Sudanese government 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 in the global map as a major player in the world cotton trade.

The major outcomes from the first season of planting of 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. The threefold increase in hectarage of Bt cotton between 2012 and 2013 is clear evidence that the experience of farmers was positive in the first year of planting in 2012 and has provided the incentive for a large increase in adoption in 2013.

## *CHILE*

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

In 2013, Chile was projected to plant 20,000 hectares of biotech maize, 3,000 hectares of biotech canola and 1,000 hectares of biotech soybean for a total of 24,000 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 2011, with a value of US$380 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 42). 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; the hectarage for biotech canola was 3,000 hectares and 1,000 for biotech soybean for seed export. The number of biotech seed crops multiplied in Chile

**Table 42. 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| Canola | 110 | 140 | 746 | 628 | 444 | 2,500 | 4,200 | 1,200 | 3,500 | 15,000 | 15,000 | 3,000 |
| Soybean | 215 | 128 | 273 | 166 | 250 | 500 | 1,800 | 3,000 | 3,800 | 2,300 | 2,300 | 1,000 |
| **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** |

Source: Government of Chile statistics, SAG, 2013. *industry estimates 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 resistant to drought and tolerant to nitrogen deficiency, virus resistant potatoes, and *Pinus radiata* species that are resistant to shoot moth and also tolerant to glyphosate. The National Institute for Agricultural Research (INIA) is developing grapes that are resistant to Botrytis, and in a joint program with the University of Santo Tomas they are developing stone fruits (nectarines and peaches) with improved quality and shelf life. Fundacion Chile provides technical and financial support for some of these projects.

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

## *HONDURAS*

**Honduras grew 20,000 hectares of biotech maize in 2013 compared with 27,000 hectares in 2012. The marginal reduced planting reflects drought conditions in the maize planting areas of the country. In 2013, the 20,000 hectares of biotech maize comprised 18,000 hectares of Bt/HT maize and 2,000 hectares of HT maize. Honduras is estimated to have enhanced farm income from biotech maize by US$12.2 million in the period 2002 to 2012 and the benefits for 2012 alone is US$5.3 million.**

Honduras is a relatively poor country in Central America with a GDP per capita of US$1,966 – one of the poorest in the region. Both large and small farmers cultivate maize which is the major staple in the country. The average yield is 1.6 tons per hectare which is one of the lowest in the region; this low yield is due to several factors, including 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. Biotech maize is comprised of 18,000 hectares of Bt/HT maize and 2,000 hectares of HT maize. The national maize crop of Honduras is approximately 350,000 hectares.

**Benefits from Biotech Maize in Honduras**

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

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

It is estimated that Honduras has enhanced farm income from biotech maize by US$12.2 million in the period 2002 to 2012 and the benefits for 2012 alone is US$5.3 million (Brookes and Barfoot, 2014. Forthcoming).

## *PORTUGAL*

**In 2013, Portugal planted 8,171 hectares of Bt maize, compared with 9,278 hectares in 2012, a decrease of 1,107 hectares or 12%, which was not due to lack of interest of farmers in Bt maize, but due to a shortage of seed. In 2013, the 8,171 hectares of Bt maize, were grown in 5 regions by Portuguese farmers. They first grew Bt maize in 1999, resumed successful planting in 2005, and since then, they have elected to continue to plant Bt maize for nine years because of the benefits that it offers.**

Portugal resumed the planting of Bt maize in 2005 after a five-year gap having planted an introductory area of approximately 1,000 hectares in 1999 for one year. In 2013, Portugal planted 8,171 hectares of Bt maize, which was a Government estimate when this Brief went to Press. The 8,171 hectares in 2013 compares with 9,278 hectares in 2012, a decrease of 1,107 hectares or 12%, which was not due to lack of interest of farmers in Bt maize, but due to a shortage of seed. The major six regions for planting Bt maize in Portugal are listed in Table 43 in descending order of percent adoption and contribution to the total Bt maize national hectarage of 8,171 hectares in 2013. The region of Alentejo had the largest hectarage of Bt maize at 5,010 hectares or 61% of the national hectarage. Alentejo was followed by the Lisbon and Tejo Valley regions with 2,215 hectares of Bt maize or 27% of the national hectarage. The central region was the third region with 853 hectares of Bt maize or 10% of the national hectarage. Norte area was the fourth region with 85 hectares of Bt maize or 1% of the national hectarage of biotech maize. The Algarve region was 5th with 8 hectares or 0.1%. 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.

**Table 43. Major Regions Planting Bt Maize in Portugal, 2013**

| Region | Hectares | Percentage of National Bt Maize Hectares |
|---|---|---|
| Alentejo | 5,010 | 61 |
| Lisbon/de Tejo | 2,215 | 27 |
| Central | 853 | 10 |
| North | 85 | 1 |
| Algarve | 8 | 0.1 |
| **National** | **8,171** | **100** |

Source: Ministry of Agriculture, Rural Development, and Fisheries, Lisbon, Portugal, www.dgadr.pt, 13 September, 2013.

## 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."***

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## *CUBA*

**In 2013, Cuba is in its second year of planting biotech maize at 3,000 hectares, similar to 2012, when it first joined the group of countries planting biotech crops. Prior to expanding the current hectarage, activities related to biotech hybrid maize production are being prioritized and consolidated. Biotech maize is currently planted in a "regulated commercialization" initiative, in which farmers seek permission to grow biotech maize commercially. The initiative is part of an ecological sustainable pesticide-free program featuring biotech maize hybrids and mycorrhizal additives. The Bt maize, with resistance to the major pest, fall armyworm, was developed by the Havana-based Institute for Genetic Engineering and Biotechnology (CIGB).**

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

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

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

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

In the interim, an initiative for "regulated commercialization" has been underway in which farmers seek permission to grow biotech maize "commercially". In 2011, up to an estimated 5,000 hectares of Bt maize varieties were grown under "regulated commercialization". The regulated commercialization program in Cuba is similar to the situation in several EU countries where farmers seek permission to grow Bt maize. In 2013, the regulated commercialization program featured hybrid Bt maize covered up to 3,000 hectares, similar to 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 in the group of countries that were cultivating biotech crops in 2012.

The Bt maize being developed by Cuba is similar to that grown on over 50 million hectares in 16 countries in 2012 alone. Thus, Cuba has the advantage of benefiting from the extensive and more than 15 years of commercial experience of a large number of countries in all continents of the world, including several EU countries, which have been successfully growing and benefiting from Bt maize for more than a decade, and which also import large tonnages of biotech crops. The potential benefits of commercializing Bt maize in Cuba are significant. The latest published import information indicated that Cuba imported significant tonnages of maize ranging from 599,917 tons in 2006 valued at approximately US$86 million to approximately 700,000 tons in 2007 to 2009 valued at up to US$200 million (Table 44). Some of these imports could be substituted by domestic production, if the yield losses due to armyworm alone, which are up to 30%, are controlled, thus making the country substantially more self-sufficient in maize production. This is a very important benefit to Cuba because the alternative is to keep relying on maize imports, which are likely to become more expensive as prices of staples trend upwards in the future. Work is also underway in Cuba to develop biotech soybean, potatoes and tomato, but unlike Bt maize, these biotech crops are at the R&D stage.

**Table 44. 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

## *CZECH REPUBLIC*

**In 2013, the Czech Republic grew ~2,560 hectares, a minimal decrease from 3,080 hectares of Bt maize in 2012, and compared with 5,091 hectares in 2011. 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 2013, the Czech Republic grew 2,560 hectares of biotech maize, a minimal decrease from the 3,080 hectares of Bt maize in 2012, and a significant decrease from the 5,091 hectares in 2011. 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, and hence there is less incentive than growing maize for grain production where losses are higher than for silage. It is estimated that up to 30,000 to 50,000 hectares of maize are affected by the corn borer to a degree that would warrant the deployment of Bt maize planting, thus the potential for biotech maize expansion is significant. Coexistence rules apply with 70 meters between Bt maize and conventional maize (or alternatively 1 row of buffer is a substitute for every 2 meters of isolation) and 200 meters between Bt maize and organic maize (or alternatively 100 meters of isolation and 50 buffer rows).

### Benefits from Biotech Crops in Czechia

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

## *COSTA RICA*

**Costa Rica planted a small hectarage of biotech cotton and soybean for seed export for the first time in 2009, and continued to grow them in 2010, 2011, 2012 as well as biotech pineapple in 2013. Similar to Chile, Costa Rica plants commercial biotech crops exclusively for the seed export trade. In 2013, it planted a total of approximately 240 hectares of biotech crops comprising biotech cotton, (235 hectares), soybean (1 hectare) and pineapple (4 hectares) for a total of 240 hectares.**

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

Costa Rica was included for the first time in 2009 in the global list of countries officially planting biotech crops, because like Chile, it plants commercial biotech crops exclusively for the export seed trade. The only difference between Chile and Costa Rica, and the other twenty seven countries planting biotech crops in 2010, is that the current laws in Costa Rica and Chile allow only commercialization of biotech crops designated for "seed" export. The biosafety law was promulgated in Costa Rica in 1998 (www.cr.biosafetyclearinghouse.net). The volume of biotech seed production in Costa Rica is small compared with Chile but has potential for growth. In 2013, approximately 235 hectares of biotech cotton were planted commercially, as well as about 1 hectare of biotech soybean and 4 hectares of biotech pineapple 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.

## *ROMANIA*

**Romania planted 220 hectares Bt maize in 2013, a marginal increase from 217 hectares in 2012. Romania grew its first 350 hectares of Bt maize in 2007 which increased to 7,146 hectares in 2008. Following the severe economic recession (particularly the restricted access to credit), the biotech maize area in 2009 declined to 3,243 hectares, to 822 hectares in 2010, 588 hectares in 2011 and 217 hectares in 2012 and finally 220 hectares in 2013. There were several factors involved in the lower hectarage in 2013 particularly the onerous and bureaucratic reporting requirements for farmers regarding intended planting details exacerbated by a limited supply of biotech Bt maize seed, as companies understandably assign lower priorities in an environment that is hostile to biotech.**

**Up until 2006, Romania successfully grew over 100,000 hectares of RR®soybean, but on entry to the EU in January 2007, was forced to discontinue the use of an extremely cost-effective technology because RR®soybean is not approved for commercialized planting in the EU. This has been a great loss to both producers and consumers alike. It is noteworthy that because conventional soybeans yield substantially less (approximately up to 30% 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.**

Romania grew its first 350 hectares of Bt maize in 2007 which increased to 7,146 hectares in 2008. Following the severe economic recession (particularly 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 and a marginal 220 hectares in 2013. There were several factors involved in the lower hectarage such as onerous reporting requirements for farmers regarding intended planting details, and a limited and decreasing supply of biotech Bt maize seed.

Despite the need 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. 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 a derogation. First, if farmers are denied the right to plant RR®soybean they will not be able to achieve as cost-effective weed-control program, even with more expensive alternates, resulting in significant financial losses for farmers growing conventional soybeans, and less affordable soybeans for consumers. Second, given that use of RR®soybean also results in better weed control in the crops following it in the rotation, elimination of RR®soybean leads to higher cost of weed control and more use of herbicides for all other crops following it in the rotation. This will result in negative implications for the environment because of more applications of alternative herbicides, which will also erode profitability. Thirdly, preclusion of RR®soybean legal plantings in Romania has reduced national production of soybean by up to one third which illogically can only be compensated with imports of exactly the same product – RR®soybean that has been banned, which will have to be purchased with scarce foreign exchange – 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."***

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## *SLOVAKIA*

**In 2013, the hectarage of Bt maize in Slovakia was 100 compared with 189 hectares**

**in 2012 and 761 hectares in 2011. The decrease is entirely due to the requirement of laborious and onerous reporting which is 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 2013, the hectarage of biotech maize was 100 hectares compared with 189 in 2012, and 761 hectares in 2011. The decrease is entirely due to the requirement for laborious reporting and a disincentive for farmers seeking to plant Bt maize.

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

### Benefits from Biotech Crops in Slovakia

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

## *THE EUROPEAN UNION (EU 27)*

**Five EU countries continued to plant a record 148,013 hectares of biotech Bt maize in 2013, equivalent to a 15% increase over 2012 at 129,071 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 93% or a record 136,962 hectares of the total 148,013 hectares maize in the EU. Bt maize hectarage increased significantly by 20,655 hectares in the largest Bt maize country Spain and was up 220 hectares in Romania; decreases in Portugal, Czechia and Slovakia totaling**

**1,716 hectares. The decreases in Bt maize were associated with several factors, including disincentives for some farmers due to bureaucratic and onerous reporting of intended plantings of Bt maize, and a limited seed supply. Increasing political support from the EU was evident in 2013 with supportive pronouncements from DEFRA Minister Rt. Hon. Owen Patterson in the UK and the EU Science Advisor Dr. Anne Glover. Biotech crop perception by the consumers has improved especially in the UK, and farmers and other respective farming associations are pushing for the approval of new biotech crops for planting. The EU (excluding Spain) is estimated to have enhanced farm income from biotech maize by US$18.8 million in the period 2006 to 2012 and the benefits for 2012 alone is US$2.6 million.**

The European Union comprises 27 states, a population of almost 500 million (7% of global) with a GDP in 2010 of US$17 trillion, equivalent to over 22% of global GDP. Less than 6% of the EU's workforce is employed in agriculture and the principal major crops occupy just over 90 million hectares (versus 1.5 billion hectares globally) of which maize is 13 million hectares, about 10% of global hectarage. There are approximately 15 million farms in the EU; Romania has the largest number of farms (almost a third of the EU total, followed by Poland, Italy and Spain). Table 45 summarizes the planting of Bt maize in the countries of the European Union from 2006 to 2013.

Five EU countries continued to plant a record 148,013 hectares of biotech Bt maize in 2013, equivalent to a 15% increase over 2012. The five countries, in decreasing order of hectarage, were Spain, Portugal, Czechia, Romania and Slovakia. Spain was by far the largest Bt maize grower with 93% or a record 136,962 hectares of the total 148,013 Bt maize in the EU compared with the adoption rate of 92% in 2012. Bt maize hectarage increased significantly in Spain by 20,655 and marginally by 3 hectares in Romania. Hectarage decreased in Portugal by 1,107 hectares because of shortage of seed and decreased by 520 hectares in Czechia and 89 hectares in Slovakia. The decreases in Bt maize in Czechia and Slovakia were associated with several factors, including disincentives for some farmers due to bureaucratic and onerous reporting of intended plantings of Bt maize, and a limited seed supply. In summary in 2013, a record hectarage of 148,013 hectares were planted in the EU with a net increase of 18,942 hectares equivalent to a 15% year over increase.

All five EU countries which grew Bt maize commercially in 2013 provided benefits to farmers, to the environment and a more affordable feed source for animals, which in turn benefited consumers who eat meat.

## Slow Approval of GM Crops in the EU

In October 2011, the European biotech industry warned the EU Commission that slow approval

**Table 45. Hectares of Bt Maize Planted in EU Countries in 2006 to 2013***

| | Country | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | Change 2012/13 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Spain | 53,667 | 75,148 | 79,269 | 76,057 | 76,575 | 97,326 | 116,307 | 136,962 | 20,655 |
| 2 | Portugal | 1,250 | 4,263 | 4,851 | 5,094 | 4,868 | 7,724 | 9,278 | 8,171 | -1,107 |
| 3 | Czechia | 1,290 | 5,000 | 8,380 | 6,480 | 4,680 | 5,091 | 3,080 | 2,560 | -520 |
| 4 | Romania* | – – | 350 | 7,146 | 3,244 | 822 | 588 | 217 | 220 | +3 |
| 5 | Slovakia | 30 | 900 | 1,900 | 875 | 1,248 | 761 | 189 | 100 | -89 |
| 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** | **+18,942** |

* 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, 2013

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. 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). 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.

### 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 enhanced farm income from biotech maize by US$18.8 million in the period 2006 to 2012 and the benefits for 2012 alone is US$2.6 million.

**Opinions on GM Crop Policy in EU**

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

Mr. Gilbert Arap Bor who participated in the 2013 World Food prize, is a Kenyan framer who grows maize and vegetables and keeps dairy cows on his 25-acre farm near Kapseret, Kenya . He recently shared his views on biotech crops and the EU regulatory policy. ***"Thankfully, Kenya is beginning to take positive steps. Last year, our government approved the commercial planting of genetically modified crops, becoming the fourth African country to do so after Burkina Faso, Egypt and South Africa. This will give our farmers access to one of the world's most***

***important hunger-fighting tools. We can also draw upon tremendous resources in human capital, from the scientific expertise at the Kenya Agricultural Research Institute to the business know-how of the Kenya Seed Company…the billions in aid that Europe sends to Africa every year do nothing to encourage the use of agricultural technology, and often discourage or prevent it. Africa's farmers and their would-be customers are being held hostage by scientific illiterates whose well-paid jobs involve raising money by frightening people about biotechnology"*** (Bor, 2011).

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 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 abroad 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. Today the campus in Ghent is the second largest hub worldwide in plant biotechnology research which also hosts some of the R&D centers of the world's largest agbio companies.

- In 2009, the VIB lab secured a permit to initiate field trials with GM poplar trees, The VIB research group led by Wout Boerjan is an internationally recognized authority on the biosynthesis of lignin. It has generated poplar trees with less lignin that have a significantly higher conversion of biomass to energy than conventional poplars. The field trial will continue until 2016 and next year, a second GM poplar field trial is planned with trees that have an altered lignin composition (http://www.vib.be/en/news/Pages/VIB-applies-for-second-poplar-field-trial.aspx).

- In 2010, VIB started a GM potato field trial. The late blight resistant potatoes from Wageningen University were tested in field trials during the 2010-2011 and the 2011-2012 growing season. The trial was conducted to compare 26 different genetically modified (GM) potatoes compared with susceptible and conventionally-bred resistant late blight resistant potatoes. Results showed that the GM potatoes have multiple resistances to potato diseases and can contribute in a sustainable manner to the country's potato industry. The GM potato showed significantly reduced susceptibility to *Phytophthora infestans*, the causal organism of late blight which was responsible for the Irish famine of 1845. It is still the most important disease of potatoes today, 150 years later. Thus, conventional technology has failed to develop a solution to late blight during the last 150 years – scientists believe that biotech offers the best promise at this time, and should be tried (Crop Biotech Update, 16 January 2013). An informative video is available on YouTube http://www.youtube.com/watch?v=xgu3lH7G1kA and a manuscript describing the scientific results of the experiments are in preparation.

- In 2011, VIB started a field trial with GM maize with enhanced production of the plant hormone gibberellic acid. The GM maize lines were developed by the lab of Dirk Inzé (VIB) and were 40% taller than the non-GM control. For more information, see http://www.vib.be/en/news/Pages/VIB-corn-field-trial-Wetteren-Genetically-modified-corn-also-larger-in-the-field.aspx

## Biotech Endorsement by EU's Scientific Bodies

The EU's scientific advisory body, EFSA, conducts food, feed and environmental safety assessment of GM crops. EFSA was requested to review a publication by Séralini et al, 2012; the first review was published in 3 October, 2012 and the final concluding report published on 28 November 2012. EFSA determined that the conclusion drawn by the authors in the publication could not be supported by the data presented. According to EFSA's lead reviewer Per Bergman, ***"EFSA's analysis has shown that deficiencies in the Séralini et al. paper mean it is of insufficient scientific quality for risk assessment. In addition, several national organizations were independently mandated by Member States to assess this study. These reviews have demonstrated a consensus among a significant part of the EU risk assessment community that the conclusions of Séralini et al. are not supported by the data in the published paper. We believe the completion of this evaluation process has brought clarity to the issue"*** (EFSA, 2012). On 28 November, 2013, Elsevier, the publisher of the Journal of Food and Chemical Toxicology announced the article retraction of the Séralini paper (http://www.elsevier.com/about/press-releases/research-and-journals/elsevier-announces-article-retraction-from-journal-food-and-chemical-toxicology#sthash.J17mjDEy.dpuf).

In September 2013, the European Union Legislation demanded a 90-day feeding trial in rodents for every single transformation event and, in specific cases, for traits stacked through conventional breeding. EFSA however recommends that this type of experimentation can be done only under certain conditions. This was backed by scientists from the United Kingdom and the Netherlands who published a commentary in the *Plant Biotechnology Journal*. The scientists claimed that routine testing should not be required since, due to apparent weaknesses in the approach, it does not add to the current risk assessment of GM foods. The commentary added that far more sensitive analytical, bioinformatical, and specific toxicological methods exist to assess short-, medium- and long-term effects of GM foods. Moreover, the demand for routine testing using animals is in conflict with the EU Commission's efforts to reduce animal experimentation (Crop Biotech Update, 4 September 2013).

## Political Support to Biotech Crops in the EU

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

In September 2012, in a very important ruling by the highest court in Europe, The European Court of Justice (ECJ), ruled that EU member nations cannot ban the planting of biotech crops approved by the EU. This ruling is directed at countries like France, Germany, Italy and Poland which have illegally banned the planting of EU approved biotech crops (Crop Biotech Update, 12 September 2012).

In a recent development, the European Commission asks Council to agree on its proposal to grant

Member States more "subsidiarity" on cultivation. The EU General Court found that the Commission failed to act on a GMO cultivation request for GM maize TC1507 submitted in 2001. The Commission referred the request to the Council Ministers, and it is up to the Ministers to take a qualified majority vote on this request. EFSA had submitted a positive opinion on the request on five occasions (2005, 2006, 2008, 2011 and 2012). According to the Health Commissioner Tonio Borg, ***"The EU is duty bound to comply with the ruling of the Court, the Commission has decided today to send a draft decision of authorisation of the maize TC1507 to the Council: in the coming months, ministers will be invited to take a position on this authorisation request. The Court's decision on maize TC1507 confirms the urgency of reconciling strict and predictable European authorisation rules for GMO cultivation, with fair consideration of national contexts"*** (Europa EU Press Release, 26 September 2013).

**In July 2012, the EU Commission's Chief Scientific Advisor Dr. Anne Glover**, stated that genetically modified organisms (GMOs) are no riskier than their conventionally farmed equivalents (EurActiv, 24 July 2012). She further clarified that ***"there is no substantiated case of any adverse impact on human health, animal health or environmental health, so that's pretty robust evidence, and I would be confident in saying that there is no more risk in eating GMO food than eating conventionally farmed food,"*** – as a result she concluded that ***"the precautionary principle no longer applies."*** Dr. Glover emphasized that she was not promoting GMOs, and added that ***"eating food is risky – most of us forget that most plants are toxic, and it's only because we cook them, or the quantity that we eat them in, that makes them suitable."*** She called for countries impeding GMO use ***"to be put to proof."*** She opined that scientific evidence is needed to play a more prominent role in policymaking on GMOs, and concluded that ***"I think we could really get somewhere in Europe if when evidence is used partially, there were an obligation on people to say why they have rejected evidence."***

In addition, Dr. Anne Glover fully supported the report published by the European Academies Science Advisory Council (EASAC) in July (see above). She said, ***"The EASAC Report is a major contribution to this debate as it reflects the view of Europe's most eminent scientists."*** Dr. Glover added that, ***"In my view, consumers can believe in the overwhelming amount of evidence demonstrating that GM technology is not any riskier than conventional plant breeding technology."*** (Crop Biotech Update, 2 October 2013).

**UK Minister of Environment, Food, and Rural affairs Rt. Hon. Owen Paterson** has expressed on many occasions his confidence that biotechnology is one of the tools for meeting the global challenges of an increased population with diminishing resources. He has been pushing for reforms in the British agriculture, especially the one on biotechnology. In December 2013, Secretary Paterson said ***"Empathically, we should be looking at GM… I'm very clear it would be a good thing."*** He also stressed that consumers were already eating GM food for sometime, with 160 million hectares of GM crops being grown globally. And thus, GM food should be grown and sold widely in the UK. Concerns about the health implications of GM crops are "a complete nonsense" according to the UK environment secretary (Crop Biotech Update, 12 December 2012).

In Secretary Patterson's speech on 29 May 2013, at the British Irish Food Business Innovation Summit, the minister said that the food sector has an important role to play in helping unlock the potential of the UK and Irish economies. He emphasized that the success of the food industry can be attributed to its ability to embrace new technologies such as GM technology. ***"It's no secret that I think GM technology has the potential to be a crucial tool for helping us to tackle the global challenges of food security and the sustainable intensification of agriculture. 17 million farmers cultivated 170 million hectares of GM crops globally in 2012, that's over 12 per cent of the world's arable land. This represents a 100-fold increase since 1996."*** He also told the experience of Brazil, where 90 percent of soya grown in the country is GM because it is 30 percent more cost effective, in addition to its environmental benefit of reducing pesticide and diesel use. ***"The EU has the strongest and strictest safety-based regime for GMOs in the world and its right that products should be subject to such controls. But there is more the EU as a whole can do to facilitate fair market access for products which have been through that system. The EU is being left behind when it comes to GM, and I fear we'll regret it if we don't try and catch up,"*** he added (Crop Biotech Update, 5 June 2013).

Secretary Paterson in his speech at the Rothamstead Research Institute last June 20, addressed an audience of scientists on the benefits of GM crops and called on the government, industry, media, and the scientific and research community to convert the public and its widespread fear and skepticism towards GM. He said, ***"I want all those here today to play their part. I'll back you all the way."*** Secretary Paterson also said that the 170 million hectares of GM crops grown in 2012 – an area seven times the size of the UK – meant that farmers benefited from growing such crops. He praised the GM technology research being done at research facilities and universities in the UK, but expressed concern that Europe is falling behind its agricultural trading partners. ***"We cannot expect to feed tomorrow's population with yesterday's agriculture,"*** he said (Crop Biotech Update, 26 June 2013).

In an interview, by Skynews, Secretary Paterson again expressed his aversion towards the opponents of genetically modified crops that sabotaged the testing of Golden Rice, the vitamin A-enriched GM rice. ***"It's just disgusting that little children are allowed to go blind and die because of a hang-up by a small number of people about this technology,"*** he told the media during an interview. ***"I feel really strongly about it. I think what they do is absolutely wicked."*** Paterson believes that GM crops could improve the environment and save lives. He said that the severe regulation of their production could make them safer than conventional products. ***"There are 17 million farmers, farming 170 million hectares which is 12% of the world's arable area, seven times the surface area of the UK (with GM) and no one has ever brought me a single case of a health problem,"*** he added (Crop Biotech Update 16 October 2013).

**The UK government Minister for Science, David Willetts** has also called for a relaxation of EU laws for GM/biotech crops food, stating that ***"GM crops can help make agriculture more efficient and also, just as importantly, more sustainable by reducing the use of pesticides and the use of fossil fuels, for example. There are just too many 21st-century technologies that Europe is just being very slow to adopt... one productive way forward is to have this discussion as part of a wider need for Europe to remain innovative rather than a museum of 20th-century technology."*** The Minister added that ***"EU rules were holding back ground-breaking work in fields as diverse as medicine, agriculture and space exploration, and ministers were worried that Europe could lag behind"*** (Moses, 2013).

**Sir Mark Walport, the newly appointed chief scientific adviser of the United Kingdom government claimed that the rise of genetically modified (GM) crops is 'inexorable'** and more of these crops could be grown in Britain as the scientific case for their use becomes "stronger". Speaking publicly for the first time in the post, David Cameron's personal scientific adviser said evidence on the benefits of farming GM crops was becoming "stronger and stronger" as the technology started "showing its value". Sir Mark Walport added that GM technology is rapidly gaining influence after years of public hostility and despite fears about the so-called "Frankenstein foods" (Crop Biotech Update, 24 April 2013).

### Farmer Testimonies and Stakeholder Views

In a recent 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 set 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).

**Specter on GM crops**

Michael Specter, author of the book, *Denialism: How Irrational Thinking Hinders Scientific Progress and Harms the Planet and Threatens our Lives*, recently spoke out about his views on GM crops (Food Navigator, 24 October 2013). He said, ***"it was high time that we engaged in a rational debate about risk and reward when it comes to food production."*** In response to the question "Are GM crops 100% safe?" he responded ***"of course not, nothing is 100% safe"*** The article notes that the obsession with all things "natural" and non-GMO has diverted attention from the bigger issues associated with food security and the environmental issues facing the world. He noted that whereas technologies that improve yield and nutrients ***"will be a key part of the tool kit of the future"***. He went on to say that if people have concerns about the "control" exercised by biotech crop companies they ***"should address this concern through political channels and not by bashing GM technology per se."***

**Mark Lynas' Public Apology**

On 3 January 2013 at the important Oxford Farming Conference in England, Mark Lynas a historian/ journalist/environmentalist and a leading internationally-known critic of GMOs, offered an apology to the audience (Lynas, 2013a). He publicly apologized for his mis-guided past activities in fiercely criticizing and destroying GM crops; he then went on to declare his support for GM crops which he views to be important technologies that can contribute globally to food security and the environment. His statement took the audience and the international community involved with GM crops, by complete surprise. The declaration by Mark Lynas had already far reaching effects on the public debate about GM crops in the UK, EU and internationally. Lynas' declaration coincided with supportive statements on the potential role of GM crops in the UK from policy makers and politicians in the UK, including the Secretary of the Environment, Owen Patterson, and the new Chief Scientist Sir Mark Walport.

In a 29 April 2013 presentation at Cornell University USA, Lynas characterized the global campaign against GM crops as a "Conspiracy" that has generated fear and misunderstanding in the minds of millions or billions of people globally in both industrial and developing countries (Lynas, 2013b). In the latter this has delayed or denied poor and hungry people of a technology that can contribute to their food security. Lynas advocates the rejection of the anti-GMO conspiracy and calls on the public, scientists and policy makers to work together to undo the damage that has been done and build a science-based commitment for biotech crops. Lynas notes that "the key tenets of the anti-GM case were not just wrong in point of facts but in large parts the precise opposite of the truth." He concluded that "the anti-GMO denialist myth is an official EU policy today" and that this has implications for developing countries. He quoted Zambia's refusal to import GM maize during the 2002 famine, a policy supported by anti-GM NGOs, which resulted in the unnecessary deaths of thousands of Zambians. He is not an advocate of organic agriculture due to its lower productivity, compared with conventional crops, and he noted that it would require an additional 3 billion hectares (the size of 2 South Americas) to produce today's global crop production using only organic agriculture. He quoted H. G. Wells who opined that "civilization is a race between education and catastrophe" which the author of the book "Denialism", Michael Specter, modified to read "civilization is a race between innovation and catastrophe". Consistent with Bill Gates' philosophy, Lynas advocated innovation, synonymous with GM crops, as the critical element in achieving food security and predicted that rejecting innovation would lead to a catastrophe.

## Progress with Biotech Crops in Africa

In 2013, the growth momentum for GM/biotech crops in Africa was maintained as exemplified by increased acreage, additional multi-locational trials for important cash and food crops as well as policy pronouncements. Previously, commercialized biotech crops have already been reported in four countries – South Africa, Burkina Faso, Egypt and Sudan. For the first time, the Ghana National Biosafety Committee granted approval for confined field trials of GM crops in the country. They include: multi-location trials of Bt cotton (Bollgard II), Bt cowpea CFT by the Savannah Agricultural Research Institute, NUWEST rice (Nitrogen Use Efficient-Water Use Efficient and Salt Tolerant) by the Crops Research Institute and high-protein sweet potato. Nigeria also commenced multi-location trials for Bt cowpea to evaluate the efficacy of the podborer resistant cowpea lines under different ecological zones, having tested the same in confined field trials (CFT) in Zaria since 2010. The multi-location trials are being carried out by the Institute for Agricultural Research within its research farm stations in Samaru, Zaria; Talata Mafara in Zamfara state; and Minjibir in Kano state. In addition, Cameroon entered its second year of CFT on insect resistant and herbicide tolerant traits of GM cotton in three locations representative of Cameroon's growing conditions after successful completion of the 1st season CFT of 2012. The map of Africa (Figure 37) provides a self-explanatory summary of the countries that continued to grow biotech crops and ten (including the commercial countries) conducting field trials with biotech crops in 2013. These are: Egypt, Burkina Faso, Cameroon, Ghana, Kenya, Malawi, Nigeria, South Africa, Sudan and Uganda. The key crops at various stages of experimentation in both confined and open trials include banana, cassava, cotton, cowpea, maize, rice, sorghum, wheat, and sweet potato.

Importantly, most of 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 and an indication that Africa is progressively moving towards adopting important food security biotech crops. The research and field trial studies were conducted under the aegis of existing legislation or stand-alone biosafety structures.

A range of policy pronouncements in support of biotechnology and regulatory capacity development efforts intensified in 2013. The United Nations Educational, Scientific & Cultural Organization (UNESCO) called on African governments to commence popularization of biotechnology as the surest route to drive development in the continent. The recommendation came at an international seminar on biotechnology held in March 2013 to formally commission the International Centre for Biotechnology, UNESCO Category 2 at the University of Nigeria.

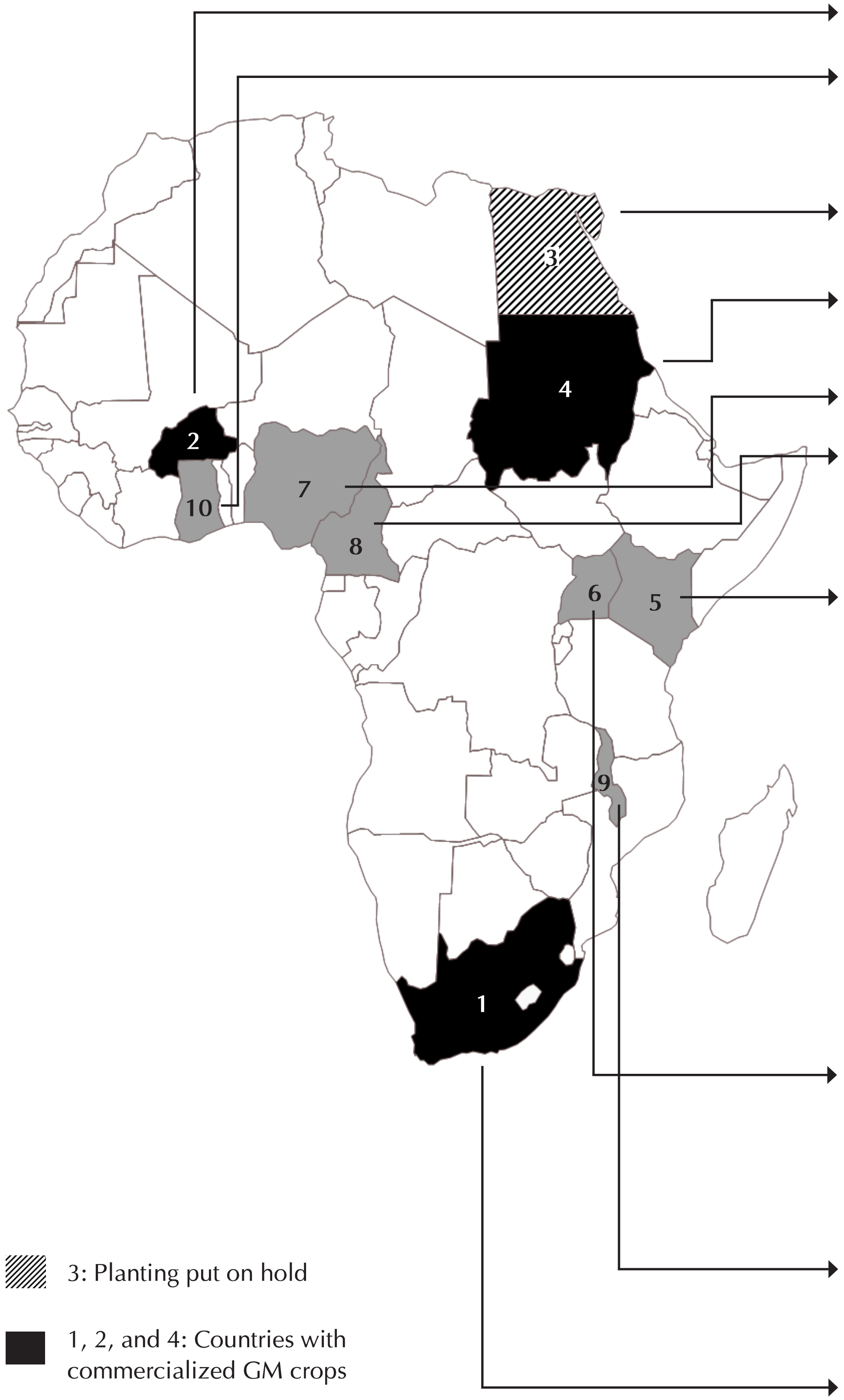
Tanzanian President, Jakaya Kikwete called for a change of negative mindset on Genetically Modified Organisms (GMOs) technology in the country. During a visit to the Mikocheni Agricultural Research Institute, he said ***"Scientists should conduct research to establish the practicality of the technology to enable the government to act accordingly. As long as there are no proven major negative impacts, there is no logic in opposing the application of the technology as the government embarks on various plans to modernize agriculture and farming methods".*** Speaking at the same meeting, the Minister for Agriculture, Food Security and Cooperatives, Eng. Christopher Chiza, said ***"Nothing could be achieved in agriculture without deploying biotechnology in the farming system."***

Ghana's Minister-designate for the Agricultural Committee, Clement Kofi Humado advocated for the utilization of genetically modified organisms (GMOs) in commercial farming to boost the country's food security. The Minister gave the proposal when he appeared before the Appointment Committee of Ghana's Parliament and said that farmers who can afford to cultivate GMO seed varieties should do so.

While presiding over the first ever launch of the global report on commercialized GM/Biotech crops in Benin, the Minister for Environment and Urbanization, Blaise Ahanhanzo-Glèlè called for increased engagement of different stakeholders on modern biotechnology. This, he said would inform the lifting of a long-standing moratorium on importation, marketing and use of GMOs that expired in March 2013.

In Kenya, a newly (March 2013) elected Governor under the new devolved governance structure, Benjamin Cheboi called for the highest possible priority to be accorded to this frontier area of Science and Technology by both the government and private sector. Acknowledging the great promise that biotechnology holds for all-round economic development of any nation, he said ***"Modern***

**Figure 37. Summary of Biotech Crop Commercialization and Field Trials in Africa, as of 15 November 2013**




3: Planting put on hold

1, 2, and 4: Countries with commercialized GM crops

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

| Africa CFTs Table – Status of Crop Biotechnology RD 2013 | | | |
|---|---|---|---|
| **Country** | **Crop** | **Trait** | **Stage as of November 2013** |
| **Burkina Faso**<br>Bt cotton commercialized in 2008 | Cowpea, *Vigna unguiculata* | Insect resistance | CFT - 4th season |
| **Ghana** | Bt Cotton (Bollgard II) | Insect resistance | Multi-locational trials in 6 sites |
| | NUWEST rice | Nitrogen Use Efficiency/Water Use Efficiency and Salt Tolerance | 1st CFT |
| | Bt Cowpea | Insect resistance | 1st CFT |
| **Egypt**<br><br>Bt maize approved for commercialization in 2008<br><br>Planting suspended in 2012 | Wheat, *Triticum durum* L. | Drought tolerant/salt tolerant | CFT approved by NBC in 2010 and updated in November 2013 |
| | | Fungal resistance | 3rd season approved by NBC in 2010 and updated in November 2013 |
| **Sudan**<br>1st year of commercialization of Bt cotton in 2012 | Cotton,<br>*Gossypium hirsutum* L. | Insect resistance | 2nd year Bt cotton commercialized |
| **Nigeria** | Cassava | Biofortified with increased level of beta-carotene, provitamin A | CFT 2nd season completed |
| | Cowpea | Insect resistant against Maruca pest | Multilocational trials in 3 sites |
| | Sorghum (ABS) | Biofortification | 3rd CFT and back crossing with preferred Nigerian varieties |
| **Cameroon** | Cotton | Insect resistance and Herbicide tolerant | 2nd season CFT in 3 sites |
| **Kenya**<br><br>Biosafety Act 2009<br><br>3 sets of Biosafety implementing regulations published in 2011<br><br>Labeling regulations published in 2012 | Maize, *Zea mays* L. | Drought Tolerance (WEMA) | CFT - 4th season completed. 5th season about to be planted. |
| | | Insect resistance | Approved by NBA. 1st season completed. 2nd season planted and about to be harvested. |
| | Cotton, *Gossypium hirsutum* L. | Insect resistance | CFTs completed; Awaiting submission of application for commercial release. |
| | Cassava, *Manihot esculenta Crantz* | Cassava mosaic disease | CFT - 1st season completed |
| | | Cassava Brown Streak Disease | 1st season CFT about to be harvested and second season plants being acclimatized in greenhouse about to be planted in CFT. |
| | | Vitamin A enriched | CFT - 1st season completed |
| | Sweetpotato, *Ipomoea batatas* | Sweetpotato virus disease | CFT - Mock trial completed. Application for CFT approved by IBC. |
| | Sorghum (ABS), *Sorghum bicolor Moench* | Enhanced Vit A levels, Bioavailable Zinc and Iron | Greenhouse trial completed<br>CFT - 1st, 2nd season completed |
| | Pigeon pea | Insect resistance | Lab and Greenhouse transformation approved by NBA in March 2011 |
| | Sweetpotato | Insect resistance | Lab and Greenhouse transformation approved by NBA in April 2011 |
| | Gypsophila flowers | Flower color | Application for CFT approved by IBC and submitted to NBA. |
| **Uganda** | Maize, *Zea mays L.* | Drought tolerance | CFT*, 5th season planted |
| | | Insect resistance | CFT*, 1st season planted |
| | Banana, *Musa spp.* | Bacterial wilt resistance | CFT - 1st trial of 60 lines harvested, repeat trial planted on 14th September with 10 selected lines |
| | | Nutrition enhancement (Fe and Pro-vitamin A) | Harvested (one ratoon), conducting 3rd season |
| | | Banana parasitic nematode resistance | CFT - Planted in August |
| | Cassava, *Manihot esculenta Crantz* | Virus resistance | CFT - 3rd season |
| | | Cassava brown streak virus (CBSV) resistance | Multi location CFT application submitted to IBC/NBC |
| | NUWEST Rice | Nitrogen Use Efficiency/Water Use Efficiency and Salt Tolerance | 1st CFT harvested in September, application for second planting submitted to NBC, planting expected in October |
| **Malawi** | Cotton, *Gossypium hirsutum L.* | Insect resistance (Bt) and Herbicide tolerance (Ht) | 1st season CFT harvested |
| **South Africa**<br><br>1st Commercialized 1998 | Maize, *Zea mays* L. | Drought tolerance | CFT 5th season |
| | | Sterility/Fertility | CFT 2nd season |
| | | Stacked Insect resistance | CFT 4th season |
| | | Stacked Insect resistance/Herbicide tolerance | CFT multiple repeats (2nd and 4th seasons) |
| | Cotton, *Gossypium hirsutum* L. | Stacked Insect resistance/Herbicide tolerance | CFT multiple repeats (2nd and 4th seasons) |
| | Soybean | Modified oils/HT | CFT approved |

***biotechnology has become crucial for sustainable development in every biological sector including agriculture, forestry, medicine and environment. It is my hope that the introduction of GM cotton (Bt cotton) will go a long way in addressing cotton production challenges in our country."***

In the area of biosafety legislation, the Burkina Faso parliament overruled proposals to include stringent clauses in the Biosafety Law, which would have stifled the gains made from commercialization of Bt cotton and others in the pipeline. The move is a positive development and likely to influence neighboring French-speaking countries struggling to review their laws to allow commercialization of Bt cotton and other food crops. In Uganda, the government endorsed the Biotechnology and Biosafety Bill 2012, which was tabled in parliament for ratification. The bill, whose object includes providing for development and general release of genetically modified organisms (GMOs) in the country also provides for a regulatory framework to facilitate safe development and application of modern biotechnology. The Bill further provides for a Competent Authority, whose functions will include approving the development, testing and use of GMO in Uganda as well as updating the national focal point on matters relating to biotechnology and biosafety.

African farmers continued accruing benefits from adoption of biotech crops. Burkina Faso's National Cotton Producers' Union (UNPCB) for example announced that the cotton output for 2012 (which included January 2013) increased by 57.5 percent due to higher number of farmers who adopted genetically modified (GM) cotton. Compared to its cotton output in the previous year (2011-2012) which accounted to 400,000 tonnes, the country's output for 2012-2013 rose sharply to 630,000 tonnes.

In Sudan, the first Bt cotton crop planted in 2012 for sensitization and awareness creation among farmers demonstrated benefits as reflected in reduction in production costs, increase in cotton productivity and maintaining the environmental balance. This led to reported expansion of acreage under Bt cotton threefold in 2013 from 20,000 ha to about 60,000 ha. The government recommended continuation of the adoption of producing Bt cotton for its endogenous control of boll worms together with reduction in the damage by sucking insects and improved cotton quality by reduction of stickiness.

The Zimbabwe Farmers Union and the Confederation of Zimbabwe Industries continued to push the government to end a ban on biotech crop production to achieve greater food security. They said: ***"We will continue pushing for the embracing of GMOs production using GMO technology for exports as a starting point"*** arguing that the nation would gain by adopting biotech food production. Similar sentiments were echoed by farmers across the continent as more and more interacted with their counterparts from adopting countries.

Progress was also reported on regional initiatives on harmonization of policies and regulatory frameworks to allow for cost-efficiency in the sharing of knowledge, expertise and resources. The fifth Joint meeting of the Ministers of Agriculture, Environment and Natural Resources held in Addis Ababa, September 19-20, 2013, adopted the COMESA policy on Biotechnology and Biosafety taking into account the sovereign right of each Member State. This follows nearly ten years of consultations on the policy guidelines among member states. The policy covers commercial planting, trade and access to emergency food aid with GM content.

At the international level, Argentina, which has been ranked 3$^{rd}$ in adoption of GM crops, extended its collaboration on agricultural technology transfer with nine sub-Saharan African countries in areas of special interest for each. Nine separate agreements were signed during the second meeting of sub-Saharan and Argentinean Agriculture Ministers in Argentina in August 2013. Representatives of Cameroon, Cape Verde, the Democratic Republic of Congo, Ghana, Guinea, Kenya, Senegal, Sudan and Zambia signed the agreements. Under the collaboration, Argentina will transfer technological knowledge and provide assistance, especially in the areas of rural development, biotechnology, seeding techniques, small-scale agriculture, plant and animal health, and rural extension programmes. New knowledge will hence be applied to agricultural practices through farmer education.

The aforementioned progress notwithstanding, a number of challenges were experienced in 2013 with a bearing on the political goodwill for biotech crops in Africa and require urgent attention. In Nigeria, for example, the anticipated presidential assent to the Biosafety Bill passed by parliament in 2011 is still on hold. A Kenyan cabinet decision to put on hold importation of GM foods in November 2012 has slowed down the stipulated timelines of getting Bt cotton commercialized by 2014. To date, the application for environmental release has not been submitted to the National Biosafety Authority for review. In addition, a devolved system of government in the country has split the national governance system into 47 county governments with new leadership, predominantly with little exposure to biotechnology. The majority of parliamentarians is new and will require intense engagement to bring them to the level of support received from the previous government.

In Uganda, biotech cotton trials were put on hold as the partners set out to review varietal choices and devise new technology transfer modalities, slowing down commercialization process as well. The temporary ban on GM maize in Egypt and the political unrest brought to a halt most biotech activities including planting of Bt maize for 2013. Increased activism against the technology is also putting unnecessary burden to the regulatory process. It is imperative that the issues are urgently addressed to avert further delay of safe and beneficial crop technologies to African farmers who need them most.

## Distribution of Biotech Crops, by Crop

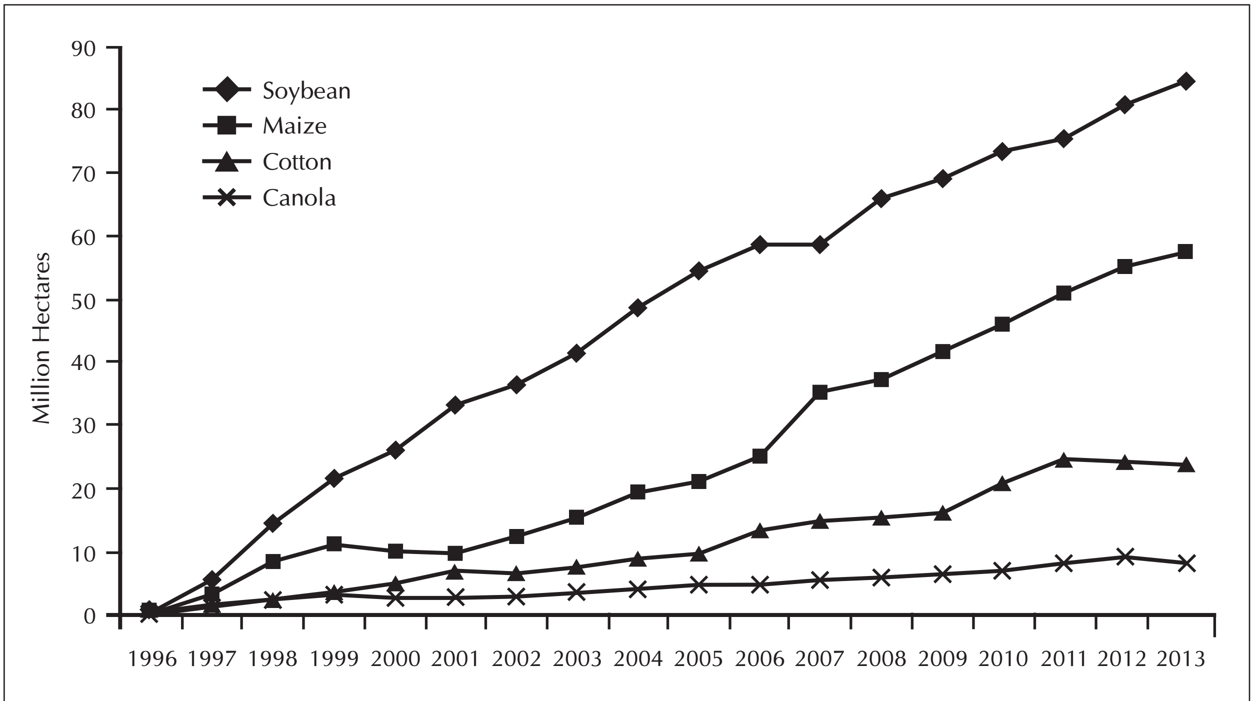
The distribution of the global biotech crop area for the four major crops is illustrated in Figure 38 and Table 46 for the period 1996 to 2013. It clearly shows the continuing dominance of biotech soybean occupying 48% of the global area of biotech crops in 2013; with the exception of about 2.5 million hectares of the stacked soybean (HT/Bt), the entire biotech soybean hectarage is herbicide tolerant. It is predicted that the stacked soybean product will penetrate deeply in 2014 in tropical regions in South America where maize is grown. Biotech soybean retained its position in 2013 as the biotech crop occupying the largest area globally, at 84.5 million hectares in 2013, 5% higher than 2012; biotech maize had the second largest area at 57.3 million hectares. Upland biotech cotton reached 23.9 million hectares in 2013 down from the 24.3 million hectares grown in 2012. Canola reached 8.2 million hectares in 2013, down 11% compared with 9.2 million hectares in 2012. Sugar beet is a relatively new biotech crop first commercialized in the USA and Canada in 2007, and quickly plateaued at a high adoption rate and peaked at a 98% adoption rate in 2013, approximately the same adoption rate as 2012 which was 97%. 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 10 to 15% of the 1.3 million hectares seeded in the USA in 2011. In 2012, another estimated 225,000 hectares were planted in 2012 for a total of 425,000 hectares, and the estimate for 2013 includes an additional 325,000 hectares seeded for a total of up to ~750,000 hectares of this perennial crop in the ground by year end 2013. This is about a 10% adoption rate for the 8 million hectares of alfalfa in the US in 2013. Small hectarages of biotech virus-resistant squash and papaya continued to be grown in the USA. China also grows about 6,000 hectares of PRSV resistant papaya and ~500 hectares of Bt poplar.

### *Biotech soybean*

In 2013, biotech soybean accounted for 48% 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 2013 was 84.5 million hectares, up by 3.8 million hectares, or 5% from 2012 at 80.7 million hectares. The increase resulted from intensified adoption in Brazil in particular. Modest increases were recorded in Canada, Paraguay and Uruguay. There were 11 countries which reported growing biotech soybean in 2013. The top three countries, growing by far the largest hectarage of herbicide tolerant soybean, were the USA (29.3 million hectares), Brazil (27.0 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 107 million hectares of soybean grown in 2013 (FAO 2013), an impressive 79% or 84.5 million hectares were RR®soybean and HT/IR soybean.

The increase in income benefits for farmers growing biotech soybean during the 17-year period

**Figure 38. Global Area of Biotech Crops, 1996 to 2013: by Crop (Million Hectares)**




Source: Clive James, 2013.

**Table 46. Global Area of Biotech Crops, 2012 and 2013: by Crop (Million Hectares)**

| Crop | 2012 | % | 2013 | % | +/- | % |
|---|---|---|---|---|---|---|
| Soybean | 80.7 | 47 | 84.5 | 48 | 3.8 | +5 |
| Maize | 55.1 | 32 | 57.3 | 33 | 2.3 | +4 |
| Cotton | 24.3 | 14 | 23.9 | 14 | -0.4 | - 2 |
| Canola | 9.2 | 5 | 8.2 | 5 | -1.0 | -11 |
| Sugar beet | 0.5 | <1 | 0.5 | >1 | -- | -- |
| Alfalfa | 0.4 | <1 | 0.8 | >1 | 0.4 | -- |
| Papaya | <0.1 | <1 | >0.1 | >1 | -- | -- |
| Others | <0.1 | <1 | >0.1 | >1 | -- | -- |
| **Total** | **170.3** | **100** | **175.2** | **100** | **+5.0** | **+3** |

Source: Clive James, 2013.

1996 to 2012 was US$37 billion and for 2012 alone, US$4.8 billion (Brookes and Barfoot, 2014, Forthcoming).

***Biotech maize***

In 2013, 57.3 million hectares of biotech maize were planted – this represents an increase of 4%, equivalent to a 2.3 million hectares. It is noteworthy that 17 countries grew biotech maize in 2013. There were five countries which grew more than 1 million hectares of biotech maize in 2013 in decreasing order of hectarage they were: USA (35.6 million hectares), Brazil (12.9 million), Argentina (3.2 million), South Africa (2.4 million) and Canada (1.7 million hectares). Modest increases were reported by several countries. Five EU countries continued to plant a record 148,013 hectares of biotech Bt maize in the EU in 2013, equivalent to a 15% increase over 2012 – this compares with 129,071 hectares in five countries in 2012. 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 177 million hectares (FAO, 2013) of maize grown in 17 countries in 2013, 32% or 57 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 40% to 50% of total maize hectarage in 2013.

The increase in income benefits for farmers growing biotech maize during the 17 years (1996 to 2012) was US$38.3 billion and US$7.9 billion for 2012 alone (Brookes and Barfoot, 2014, Forthcoming).

***Biotech cotton***

With lower global prices of cotton, the area planted to biotech cotton globally in 2013 was down compared with 2012. A total of 15 countries grew biotech cotton in 2013 and four grew more than 1.0 million hectares, in descending order of hectarage, they are: India (11.0 million hectares), China (4.2 million), USA (3.7 million hectares), and Pakistan (2.8 million hectares). Another 11 countries grew biotech cotton in 2013.

RR®Flex cotton was introduced in the USA and Australia for the first time in 2006 and was widely grown in 2013. In 2013, biotech hybrid cotton in India, the largest cotton growing country in the world, occupied 11.0 million hectares of approved Bt cotton despite almost optimal levels of adoption which reached 95% in 2013. The advantages of Bt cotton hybrid in India are significant and the increase in 2013 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, and a record 474,229 hectares in 2013 – an increase of 51% between 2012 and 2013. The top four biotech cotton countries are India at 11.0 million hectares, China (4.2 million hectares), USA (3.7 million hectares), and Pakistan (2.8 million hectares). Australia planted over 416,000 hectares of biotech cotton in 2013 (adoption rate of 99%) 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, a 99%+ biotech adoption rate was maintained irrespective of the absolute hectarage of cotton. Based on a global hectarage of 34 million hectares (FAO, 2013), 70% or 23.9 million hectares, were biotech cotton and grown in 15 of the 27 biotech crop countries worldwide.

The increase in income benefits for farmers growing biotech cotton during the 17-year period 1996 to 2012 was US$37.4 billion and US$5.4 billion for 2012 alone (Brookes and Barfoot, 2014, Forthcoming).

### *Biotech canola*

The global area of biotech canola is estimated to have decreased by a significant ~1 million hectares from 9.2 million hectares in 2012 to 8.2 million in 2013, with most of the decrease coming from Canada. The US was also down by about 100,000 hectares but Australia was up by about 50,000 hectares. Canada, by far, is the largest grower of canola globally, and the adoption rate in 2013 was a high 96%. 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 was used for biodiesel in 2008; this is expected to remain low at around 2% until new biodiesel plants come on stream.

Of the global hectarage of 34 million hectares of canola grown in 2013, 24%, or 8.2 million hectares were biotech canola grown in Canada, the USA, Australia and Chile.

The increase in income benefits for farmers growing biotech canola during the 17-year period 1996 to 2012 was US$3.7 billion and US$0.47 billion for 2011 alone (Brookes and Barfoot, 2014, 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 expected to be the first of several traits to be incorporated into this important forage crop. A court injunction in 2007 suspended further plantings of RR®alfalfa until a new dossier of information was submitted to the regulators for consideration. Before the injunction came into force, another 22,000 hectares were planted bringing the total RR®alfalfa in the USA in 2007 to 102,000 hectares. There are approximately 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 likely to be 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 will 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.

***Other biotech crops***

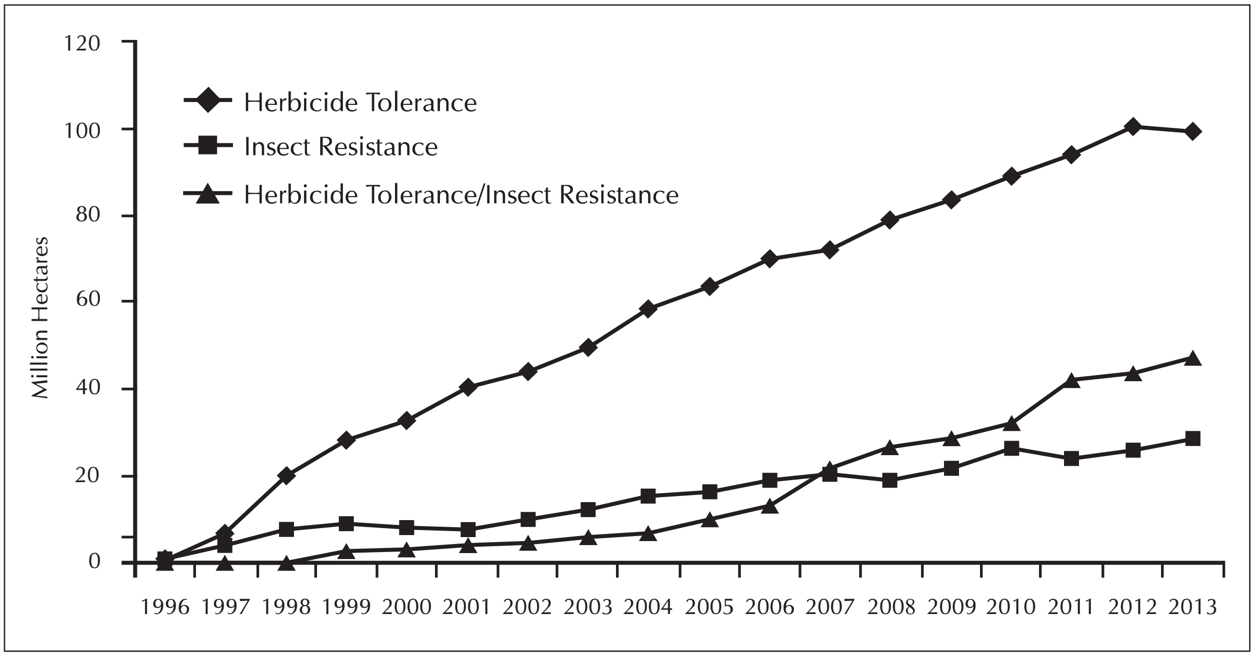
Biotech sweet corn is estimated to be at a minimal and nominal hectarage of 1,000 hectares of the sweet corn hectarage of 300,000 hectares. Small areas of biotech virus resistant squash (2,000 hectares) and PRSV resistant papaya in Hawaii (2,000 hectares with a 60% adoption) continued to be grown in the USA in 2013; the papaya industry in Hawaii was destroyed by PRSV and saved by the biotech papaya which is resistant to PRSV. In China in 2013, 6,275 hectares were planted to PRSV resistant papaya, and ~500 hectares of Bt poplars.

## Distribution of Biotech Crops, by Trait

During the 18 year period 1996 to 2013, herbicide tolerance has consistently been the dominant trait (Figure 39). In 2013, herbicide tolerance, deployed in soybean, maize, canola, cotton, sugar beet and alfalfa occupied 99.4 million hectares or 57% of the 175.2 million hectares of biotech crops planted globally (Table 47); this compares with 100.5 million hectares equivalent to 59% adoption of the total biotech hectarage in 2012. Thus, herbicide tolerance decreased by a net 1.1 million hectares from 100.5 million hectares in 2012 to 99.4 million hectares in 2013. Several events contributed to this reduction including: the displacement in Brazil of 2.2 million hectares of herbicide tolerant soybean by the stacked product; the reduction of close to 1 million hectares of HT canola in Canada; and a reduction of ~100,000 hectares of 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 43.7 million hectares in 2012 to 47.1 million hectares – an increase of 3.4 million hectares equivalent to an 8% increase from 2012 to 2013. Hectarage featuring insect resistance also increased from 26.1 million by 10% to 28.8 million hectares in 2013. Generally

**Figure 39. Global Area of Biotech Crops, 1996 to 2013: by Trait (Million Hectares)**




Source: Clive James, 2013.

**Table 47. Global Area of Biotech Crops, 2012 and 2013: by Trait (Million Hectares)**

| Trait | 2012 | % | 2013 | % | +/- | % |
|---|---|---|---|---|---|---|
| Herbicide tolerance | 100.5 | 59 | 99.4 | 57 | -1.1 | -1 |
| Stacked traits | 43.7 | 26 | 47.1 | 27 | +3.4 | +8 |
| Insect resistance (Bt) | 26.1 | 15 | 28.8 | 16 | +2.7 | +10 |
| Virus resistance/Other | <1 | <1 | <1 | <1 | <1 | -- |
| **Total** | **170.3** | **100** | **175.2** | **100** | **5.0** | **3** |

Source: Clive James, 2013.

the increases and decreases for various traits were mainly due to changes in the key countries of Brazil, US and Argentina and to a lesser extent to more modest gains in countries like Paraguay. 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 (Table 47). The Bt/Bt/IR stack refers to different Bt or other IR genes that code for different 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 the insect resistance trait at 10%, followed by stacked products at 8% with herbicide tolerance recording a marginal decrease of -1%.

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 66% of the 47.1 million hectares as "stacked traits" in 2013. 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. HT/Bt in Brazil and neighboring countries are expected to increase adoption very rapidly. In 2013, the other seven principal countries, of a total of 13, which deployed stacked traits in 2013 were: Brazil (8.2 million hectares), Argentina (3.6 million hectares), Canada (1.3 million hectares), South Africa (1.1 million hectares), Philippines (0.7 million hectares), Australia (0.4 million hectares), and Mexico (0.1 million hectares). Uruguay, Chile, Honduras, Paraguay, and Colombia planted less than 0.1 million hectares each. These countries will derive significant benefits from deploying stacked products because productivity constraints at the farmer level are related to multiple biotic stresses, and not to single biotic stress.

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 production of all crops) cotton and important 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 economic benefits at the farm level by trait, for the first sixteen years of commercialization of biotech crops 1996 to 2012 was as follows: all herbicide tolerant crops at US$47.7 billion and all insect resistant crops at US$68.9 billion, with the balance of US$0.26 billion for other minor biotech crops. For 2012 alone, the benefits were: all herbicide tolerant crops US$6.6 billion, and all insect resistant crops US$12 billion plus a balance of US$0.03 billion for the minor biotech crops for a total of ~US$18.7 billion (Brookes and Barfoot, 2014, 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 (2012) respective global areas of the four principal crops – soybean, cotton, maize and canola – in which biotechnology is utilized (Table 48 and Figure 40). The data indicate that in 2013, 79% (84.5 million hectares) of the 107 million hectares of soybean planted globally (FAO, 2013) were biotech. Of the 34 million hectares of global cotton, 70% or 23.9 million hectares were biotech in 2013. Of the 177 million hectares of global maize planted in 2013 (FAO, 2013), almost one-third (32%) or 57.3 million hectares were biotech maize. Finally, of the 34 million hectares of canola (FAO, 2013) grown globally in 2013, 24% were herbicide tolerant biotech canola, equivalent to 8.2 million hectares. If the global areas (conventional plus biotech) of these four crops are aggregated, the total area is 352 million hectares, of which half, 50%, or 175.2 million hectares, were biotech in 2013. Thus, 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 352 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

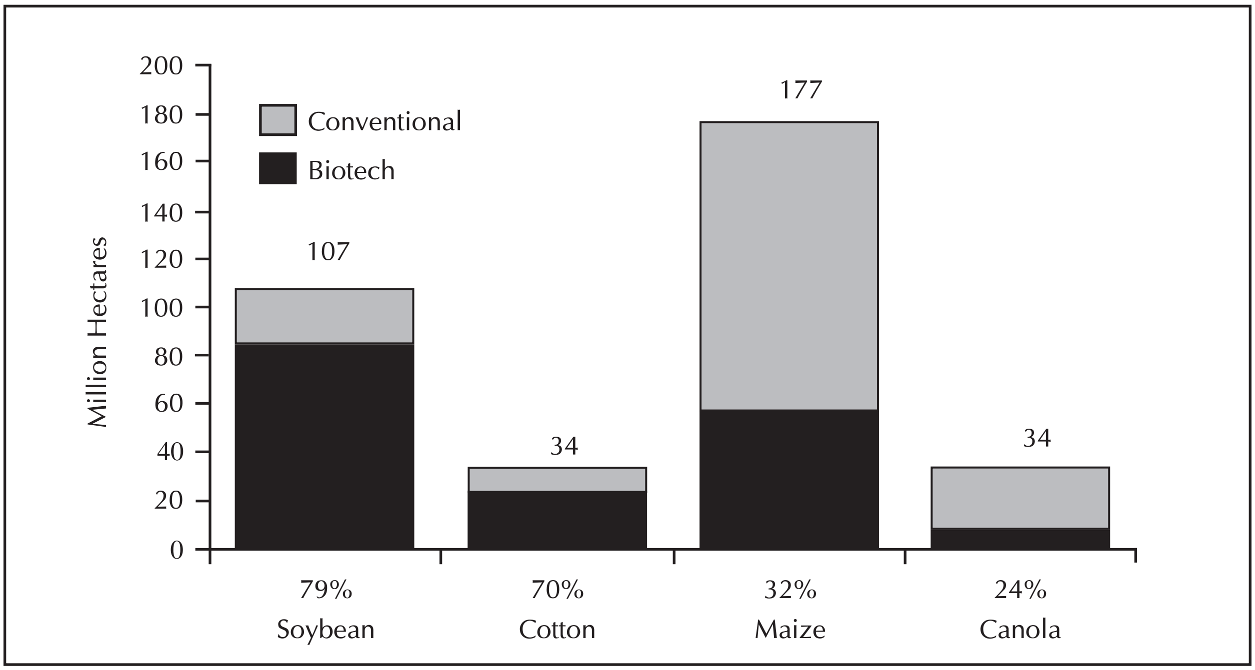
In 2013, a total of 6 Biotech/GM crops (canola, cotton, eggplant, maize, sugarcane, and soybean) and 77 biotech events have been approved for food/feed use and/or cultivation in 19 countries (as of November 30, 2013). A total of 70 GM events were approved for food and/or feed use; 25 biotech events were approved for cultivation. Eight countries, namely Argentina, Bangladesh,

**Table 48. Biotech Crop Area as Percent of Global Area of Principal Crops, 2013 (Million Hectares)**

| Crop | Global Area* | Biotech Crop Area | Biotech Area as % of Global Area |
|---|---|---|---|
| Soybean | 107 | 84.5 | 79 |
| Cotton | 34 | 23.9 | 70 |
| Maize | 177 | 57.3 | 32 |
| Canola | 34 | 8.2 | 24 |
| Others | -- | 1.3 | -- |
| **Total** | **352** | **175.2** | **50** |

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

**Figure 40. Global Adoption Rates (%) for Principal Biotech Crops, 2013 (Million Hectares)**




Global Hectarages Data for 2012 (FAO, 2013)
Source: Compiled by Clive James, 2013.

Brazil, Canada, Indonesia, Japan, Paraguay and United States of America, have issued approvals for cultivation. A country approves a biotech crop for food/feed use when it cannot produce the crop domestically but can allow import for subsequent food/feed use. Out of the 127 approvals issued in 2013, 27 are for cultivation and 100 are for food and/or feed use. Of the 100 food/feed approvals, 85 are for imported food/feed or processed products containing the event, and 15 are for direct use of cultivated biotech crop as food/feed.

Of the 77 events approved, 22 are single trait events and 55 are stacked trait events. Figures 41 and 42 show the distribution of approved events and global approvals, respectively, both by trait category (herbicide tolerance, insect resistance, stress tolerance, product quality, and combination of these traits). Stacked traits of herbicide tolerance and insect resistance dominate in terms of number of events or regulatory approvals issued globally. This is followed by single traits of herbicide tolerance and insect resistance. Six percent of the approved events have stress tolerance trait (drought tolerance) and 5% have product quality traits (modified oil, starch amylase).

New events of maize, soybean, eggplant (brinjal) and sugarcane were approved for cultivation for the first time in 2013. The maize stacked event 4114 (DuPont) expressing simultaneously 3 different Bt *cry* genes and the *pat* gene for glufosinate herbicide tolerance was approved for food/feed use and cultivation in Canada and the USA. The United States has approved for food/feed use and cultivation the glyphosate herbicide tolerant maize events HCEM485 (Stine Seed Farm, Inc.) and

**Figure 41. Distribution of Approved Events in 2013 by Trait Category**

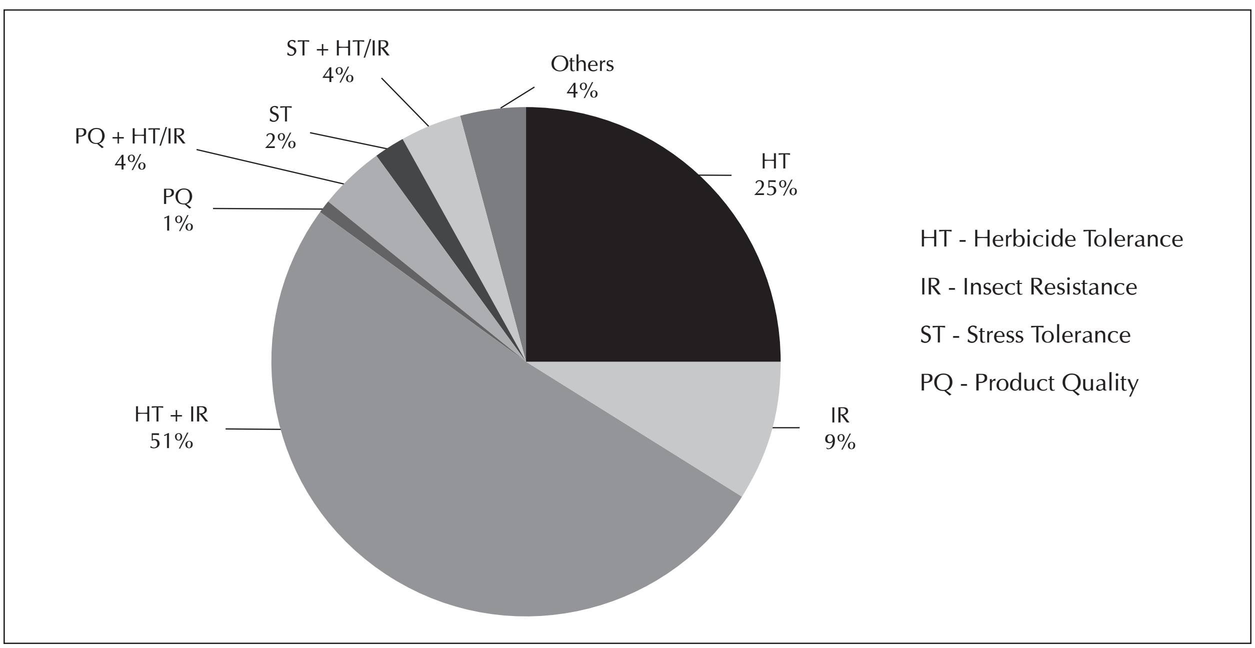
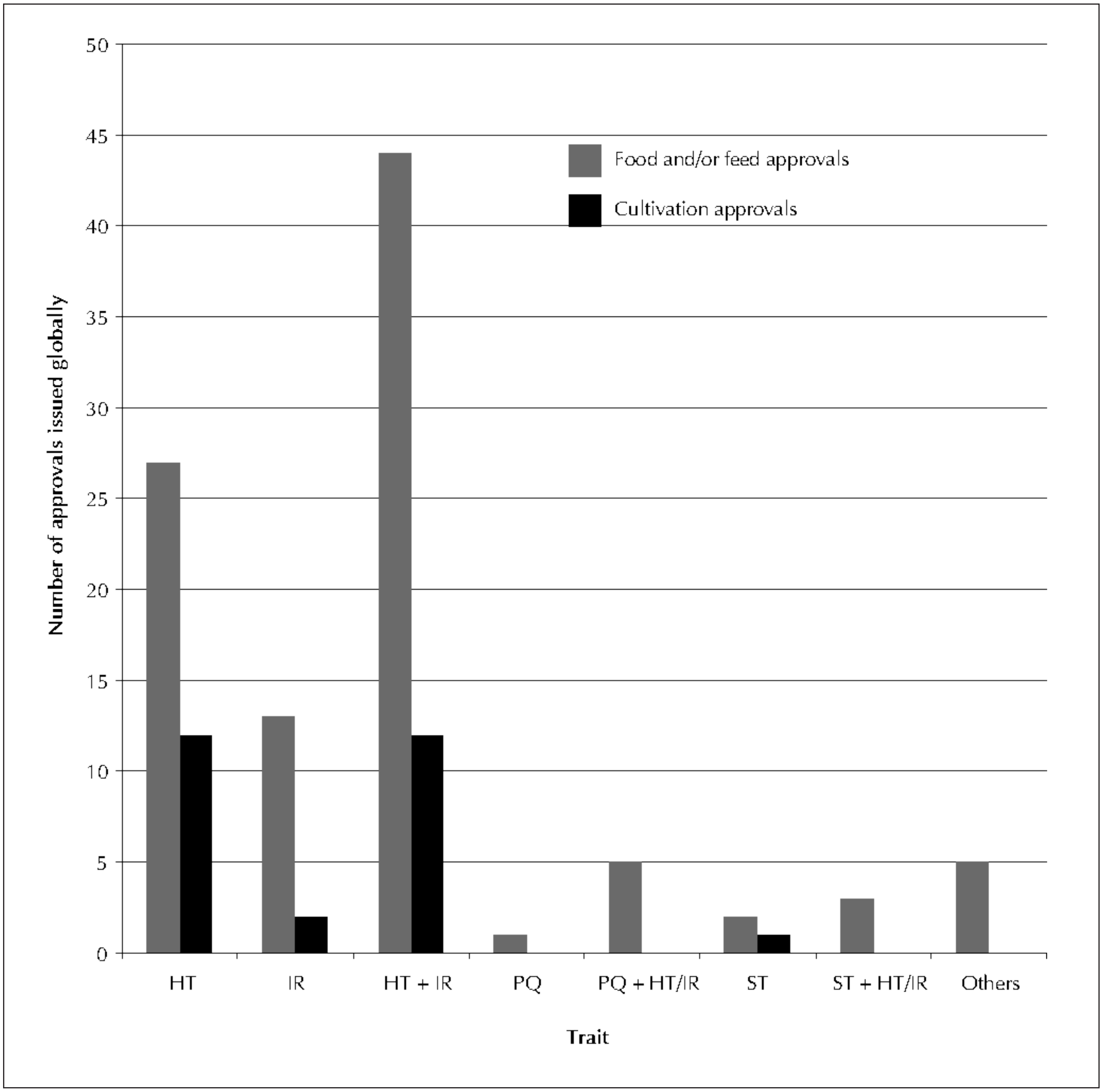


**Figure 42. Distribution of Approvals Issued in 2013 by Trait Category**




VCO-01981-5 (Genective S.A.) expressing modified *epsps* genes. The soybean event DAS44406 (Dow AgroSciences) expressing triple modes of herbicide tolerance (glyphosate, glufosinate and 2,4-D tolerance) was approved in Canada for food/feed use and cultivation. Australia, New Zealand and South Africa have also approved this event for import for food/feed use.

The USA has also approved for cultivation four new events, following Canada's approvals in 2012 - canola events 73496 and MON88302, maize event MON87427 and soybean event FG72.

Bangladesh and Indonesia have achieved major milestones with the approvals of two new biotech crops for environmental release.

The drought tolerant sugarcane event NXI-1T expressing a bacterial *betA* gene for the production of anti-water stress compound glycine betaine, was finally approved for cultivation in Indonesia by the Biosafety Commission for Genetically Engineered Product. The NXI-1T event, developed by a government-controlled corporation, was given food safety clearance in 2011.

In Bangladesh, the government has approved the release of four varieties of eggplant or brinjal expressing the Bt *cry1Ac* gene for commercial cultivation. The four Bt brinjal varieties are based on the Bt brinjal event EE1 originally developed by India-based Maharashtra Hybrid Seed Company (MAHYCO), which was later transferred to Bangladesh Agricultural Research Institute (BARI) through a public-private partnership agreement.

The new eggplant and sugarcane events add to the growing number of biotech crops developed through public-private partnership or by government institutions.

All approved biotech events with their descriptions and approval history are available online at the ISAAA GM Approval Database (http://www.isaaa.org/gmapprovaldatabase/default.asp).

## The Global Value of the Biotech Crop Market

### Global value of the biotech seed market alone was US$15.6 in 2013

In 2013, the global market value of biotech crops, estimated by Cropnosis, is US$15.6 billion, (up from US$14.6 billion in 2012); this represents 22.1% of the US$1.5 billion global crop protection market in 2013, and 35% of the ~US$45 billion global commercial seed market (Table 49). The US$15.6 billion biotech crop market comprised US$8.9 billion for biotech maize (equivalent to 55.4% of global biotech crop market, down from 56% in 2012), US$4.8 billion for biotech soybean (30.9%, down from 32% in 2012), US$1.29 billion for biotech cotton (9.4%), and US$0.4 billion for biotech canola (3%). Of the US$15.6 billion biotech crop market, US$11.4 billion (72%) was in the industrial countries and US$4.2 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 18 year period, since biotech crops were first commercialized in 1996, is estimated at US$117,851 million.

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 from GM drugs ('biologics') and GM industrial products (fuels, materials, enzymes),

**Table 49. The Global Value of the Biotech Crop Market, 1996 to 2013**

| 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** |
| **Total** | **117,851** |

Source: Cropnosis, 2013 (Personal Communication).

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).

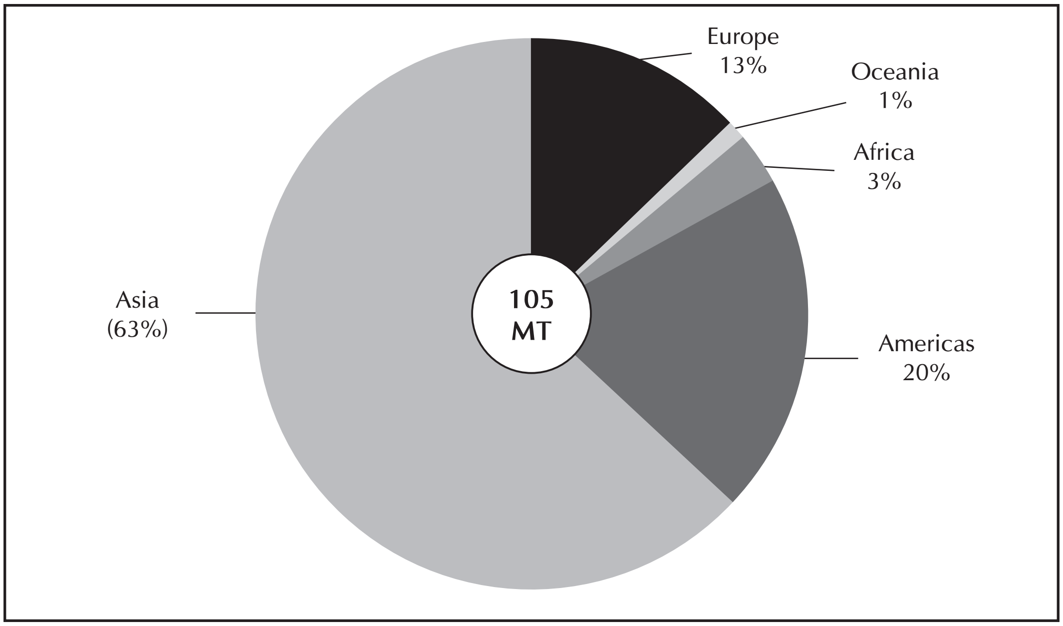
## Nitrogen Use Efficiency (NUE)

2013 marks the 100th anniversary of the invention of the Haber-Bosch process for synthetically fixing nitrogen that constitutes ~80% of the air we breathe. The process transformed farming and crop production and Fritz Haber was awarded a Nobel Prize in 1919 for his breakthrough. Haber's invention has fuelled significant annual increases in crop production globally over the last 100 years as a result of applying substantial amounts of urea or ammonium nitrate as crop fertilizers. Globally, over 100 million tons of nitrogen fertilizer (105 million tons in 2010) is consumed annually (Figure 43). The price of nitrogen fertilizers varies significantly from US$280 per tonne to over US$700 per tonne, but using an average cost of ~US$500 per ton, the global cost for nitrogen fertilizers is currently ~US$50 billion per year, growing at about 2% annually. By continent, Asia uses the most at 63% of global, followed by the Americas at 20%, Europe 13%, Africa 3% and Oceania 1% (Figure 43). By country, China is by far the biggest consumer of nitrogen fertilizer at 33% or one-third of global usage, compared with 16% in India, 11% in the USA, 3% each in Brazil, Pakistan and Indonesia, 2% each in France, Canada, Germany and Thailand, and the balance of ~23% distributed among the other countries in the rest of the world (Table 50 and Figure 44). World Bank (2013) data indicate that the average highest consumption of nitrogen per hectare in 2010 was in China at 504 kg/ha, followed by Pakistan at 217 kg/ha, Germany and Indonesia at 181 kg/ha each, India at 167 kg/ha, France 148 kg/ha, USA at 109 kg/ha and Canada the lowest at 61 kg/ha (Table 50). Global consumption by crop shows that maize, wheat, rice, and fruit/vegetables are the top users, each of which account for 16% to 17% and collectively responsible for about two-thirds of total nitrogen consumption globally (Figure 45). Figures 46 to 48 show the consumption of nitrogen, by crop in the top three countries that consume most nitrogen, with China at 35 million tons, India (17 million tons) and USA (11 million tons) in 2010.

In China, fruit and vegetables are by far the most important consumers of nitrogen at 30%, followed by rice at 18%, maize at 16% and wheat at 14% for a collective total of 78% for the top four crops (Figure 46). In India, the two top nitrogen consumers rice (30%) and wheat (21%) represent more than half (51%) of nitrogen used in India. In the USA, maize alone consumes almost half (48%) of total nitrogen use, followed by wheat at a distant 14% for a total of 62% of all nitrogen fertilizer.

Not only is nitrogen one of the three essential macro nutrients necessary for crop growth (the other two essential macro nutrients for crop growth are phosphorous and potassium) but nitrogen is a critical element in amino acids, proteins and genetic material such as DNA and RNA. Bacteria living on the roots of legumes, such as soybean and alfalfa, have the ability to fix nitrogen from the air, transforming ammonia into nitrates for uptake by plants. Popular legume crops such as alfalfa have been used traditionally to fix nitrogen and then incorporated in the soil as green cover/manure crops.

**Figure 43. Global Consumption of Nitrogen Fertilizers (N Total Nutrients) in 2010 by Continent, (Million Tons)**



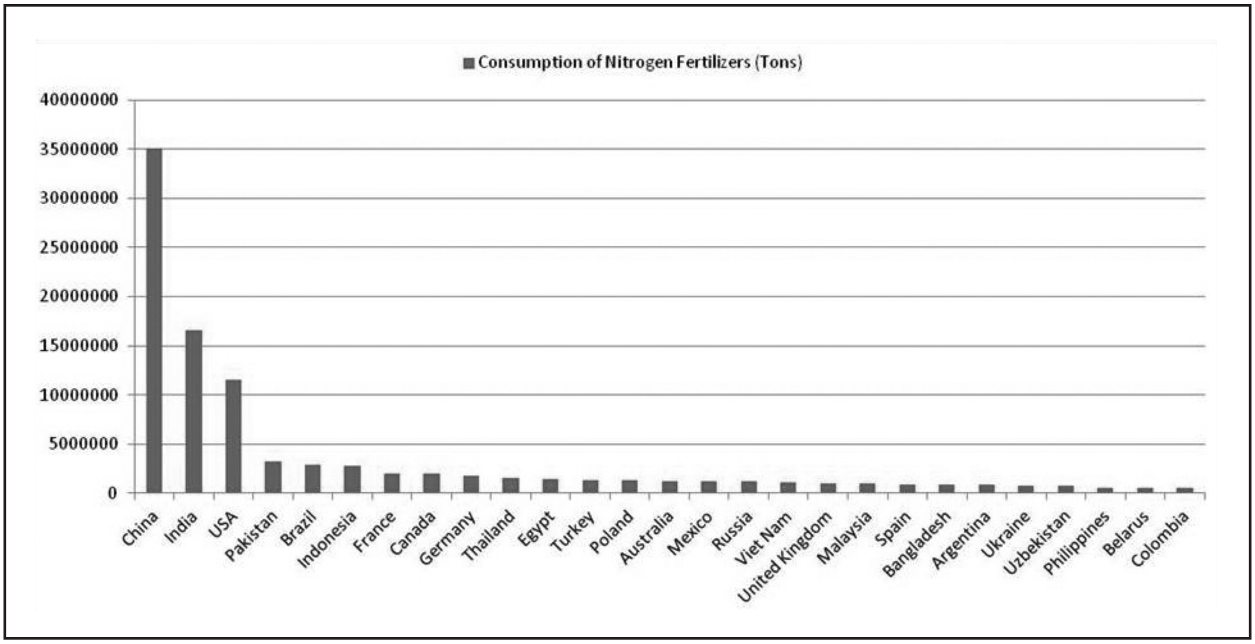

Source: FAO, 2013

**Table 50. Top Ten Nitrogen Fertilizers Consuming Countries, 2010**

| Countries | Consumption of Nitrogen Fertilizers ('000 tons) | % of Total Nitrogen Consumption | Fertilizers Consumption (Kg/ha of arable land) |
|---|---|---|---|
| China | 35,069 | 33% | 504 |
| India | 16,549 | 16% | 167 |
| USA | 11,488 | 11% | 109 |
| Pakistan | 3,270 | 3% | 217 |
| Brazil | 2,854 | 3% | 125 |
| Indonesia | 2,784 | 3% | 181 |
| France | 2,050 | 2% | 148 |
| Canada | 1,984 | 2% | 60 |
| Germany | 1,786 | 2% | 181 |
| Thailand | 1,584 | 2% | 119 |
| Rest of the World | 26,467 | 23% | - |

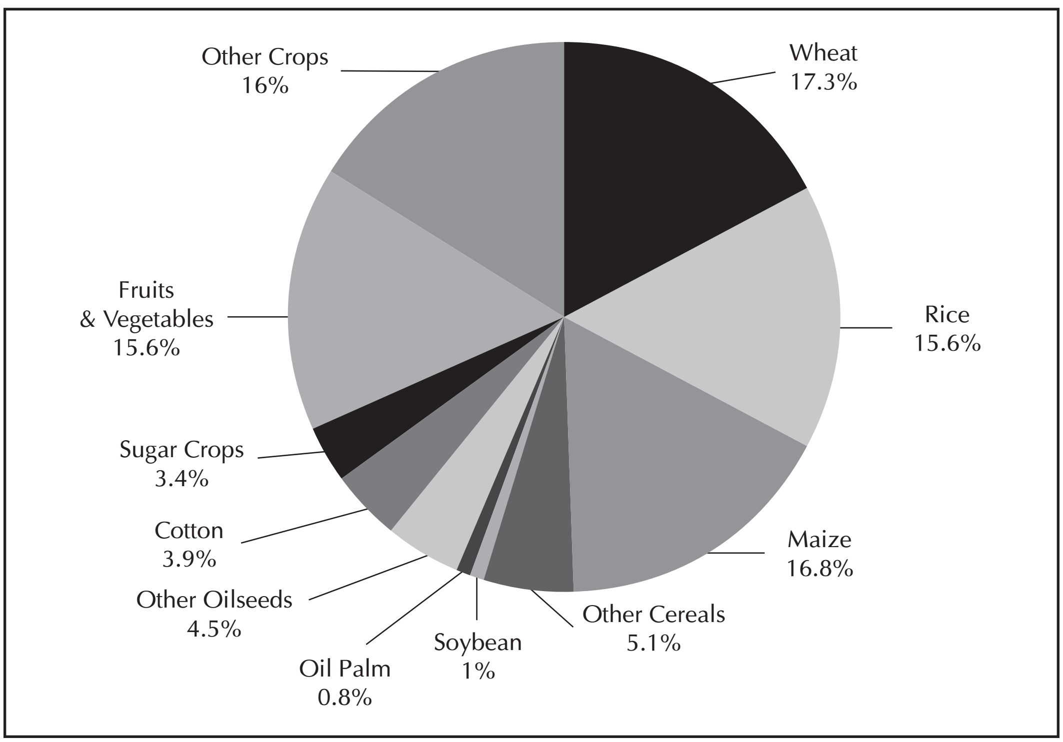
Source: FAO, 2013; World Bank, 2013

**Figure 44. Distribution of Nitrogen Fertilizer Consumption by Major Countries, 2010**



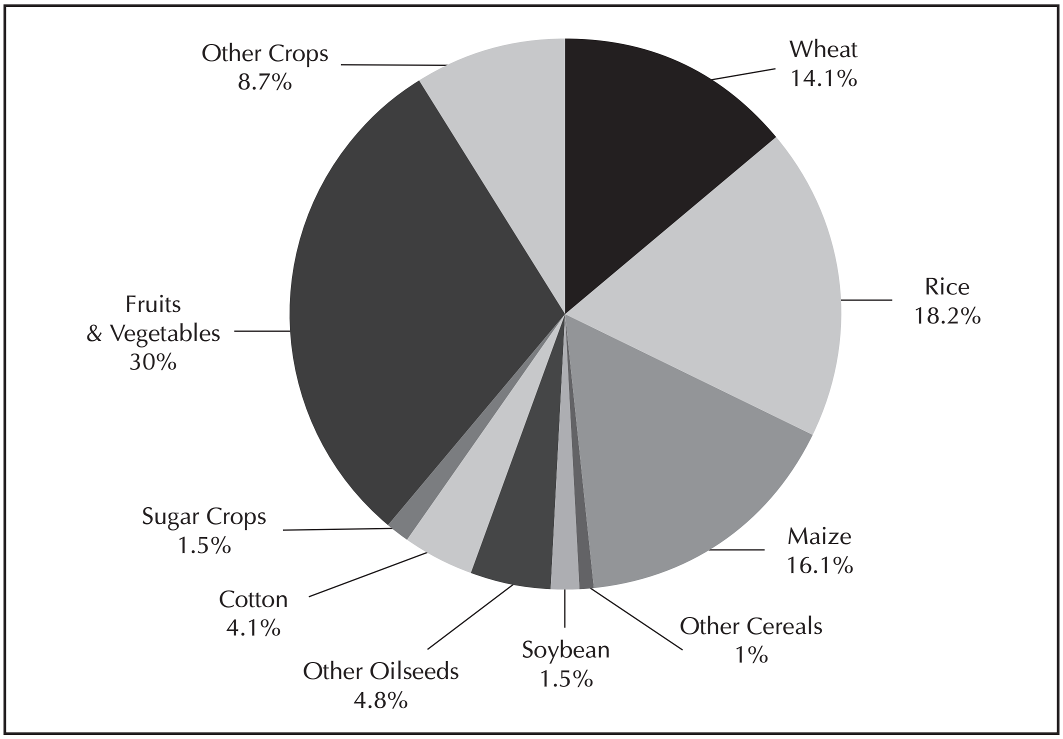

Source: FAO, 2013

**Figure 45. Global Consumption of Nitrogen Fertilizers, by Crop, (in %)**




Source: IFA, 2009

**Figure 46. Global Consumption of Nitrogen Fertilizers, by Crop, in China**

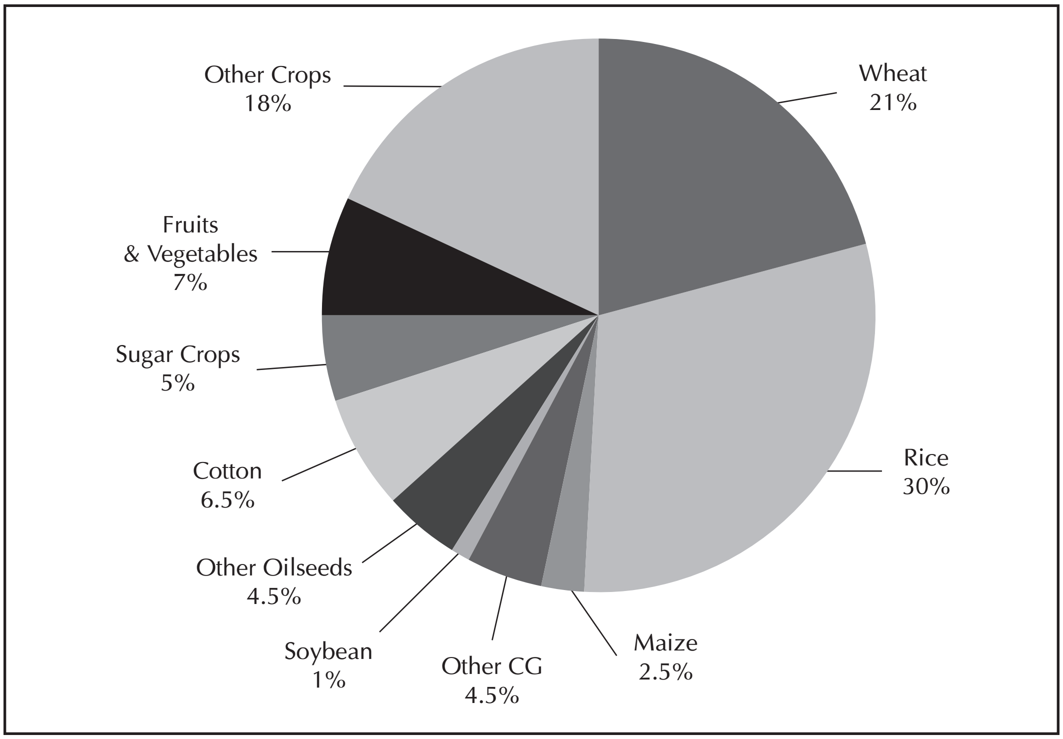



Source: IFA, 2009

Fifty years after the invention of the Haber-Bosch process, the "green revolutions" of wheat and rice of the 1960s were predominantly dependent on adequate nitrogen (as well as water through irrigation) to realize substantially higher yields. It was at this time that Norman Borlaug was awarded the Nobel Peace Prize in 1970 for his work on wheat that saved up to 1 billion people from hunger. It has been estimated that without nitrogen fertilizer the world could only support a population of 3.5 billion or half the current population of 7 billion; notably, it has been calculated that about half of the nitrogen in our bodies have probably been produced synthetically. Nitrogen fertilizers enable farmers to optimize productivity and global crop production to satisfy the demands of more than 7 billion people today. Global utilization of nitrogen fertilizer is expected to continue to increase significantly to meet the needs of a growing global population of 9 billion by 2050 unless nitrogen use efficiency (NUE) technology (with or without genetic modification or alternate) can be widely adopted to substantially reduce nitrogen fertilizer consumption (Pitman and Lauchli, 2002). The potential savings are significant, and of the order of one- third or more, depending on crop and other edaphic factors.

The following section describes different GM and non-GM projects that are aimed at developing cereals and non-legume crops which are efficient in utilization of nitrogen fertilizers. There are two

**Figure 47. Global Consumption of Nitrogen Fertilizers, by Crop, in India**



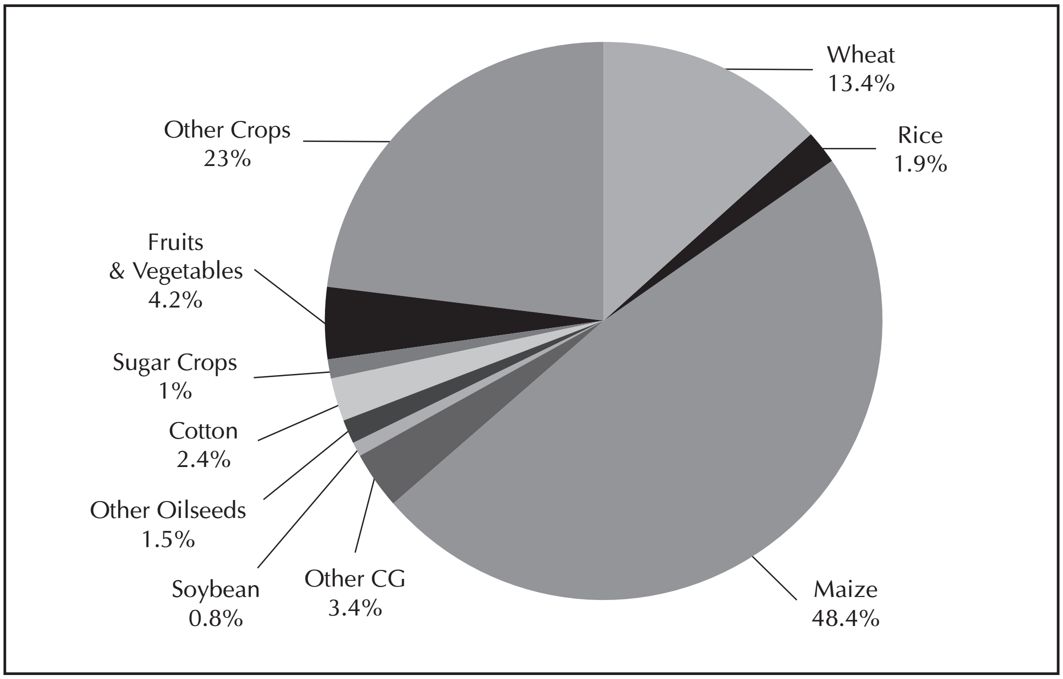

Source: IFA, 2009

sets of distinct projects that deploy technologies either by engineering the legume symbiosis into cereals or by engineering expression of nitrogenase in cereal crops. These projects include Arcadia Biosciences, Azotic Technologies of Nottingham University, John Innes Centre Nitrogen fertilizer project funded by the Bill Gates Foundation and N2 Africa funded jointly by Bill Gates Foundation and Howard G. Buffet Foundation. A brief summary of each project is featured in the following paragraphs:

**1. Arcadia Biosciences' NUE, Saline and Drought-Tolerant Rice**

Arcadia Biosciences reports that over five seasons of field trials, their NUE canola resulted in high yields using significantly less nitrogen compared to conventional canola. More specifically, Arcadia's NUE canola yielded 2,800 lbs per acre (3,144 kg per hectare) using two-thirds less nitrogen fertilizer than the conventional variety needed to generate the same yield (Arcadia Biosciences, 2013c). Arcadia's Nitrogen Use Efficiency (NUE) technology produces plants with yields that are equivalent to conventional varieties but which require significantly less nitrogen fertilizer because they use it more efficiently. This technology has the potential to reduce the amount of nitrogen fertilizer that is lost by farmers every year due to volatilization into the air

**Figure 48. Global Consumption of Nitrogen Fertilizers, by Crop, in USA**




Source: IFA, 2009

and leaching into soil and waterways and aquifers. Moreover in addition to environmental implications, cost for nitrogen is significant and is normally the highest cost of all inputs for crop production, and hence can significantly impact on profitability. Arcadia judges that farmers will have a strong incentive to use its NUE technology because it simply pays them to do so. In fact, NUE technology can be a win-win situation that will help farmers contribute to a better and more sustainable environment whilst simultaneously making their cropping operations more profitable. Arcadia reports that it has successfully transformed canola, Arabidopsis (model crop), tobacco (model crop), rice and wheat with their NUE technology and demonstrated significant yield improvements over conventional varieties using much less nitrogen fertilizer in field trials over five growing seasons.

As normally happens with any radical change in technology, new challenges arise from its adoption, and nitrogen fertilizer is no different. As a result of continuous and growing use of nitrogen fertilizers for 100 years it has contributed to air, water and soil pollution, with implications for human health, acidification of soils, and accelerated global warming. Whereas fertilizers are effective in significantly improving crop yields, they also result in negative effects. Given that most crops are only able to utilize less than one-half of the nitrogen fertilizer applied, the majority of the nitrogen fertilizer volatilizes into the air or leaches into the soil and water, and pollutes aquifers, waterways, rivers, lakes, and ultimately oceans. A significant amount of the unabsorbed nitrogen fertilizer volatilizes as nitrous oxide. After electrical and heat generation, which emit 31% of global $CO_2$ emissions making them the worst polluters, agriculture is the second most important industrial contributor to global greenhouse gases with 17% of global, followed by the transportation sector at 15%. The pivotal environmental review by Stern (2006) concluded that nitrogen fertilizer accounted for one-third of the 17% of global greenhouse gases produced by agriculture (produced during both the manufacture and application of nitrogen fertilizer).

The most evident symptom of overuse and the damaging effect of nitrogen fertilizers is the creation of "dead zones" in the world's lakes and oceans. "Dead zones" develop after the death and decomposition of massive algae blooms that are fed by excessive nutrient runoff. When the mass of algae grows to an unmanageable size, it dies and its natural decomposition depletes oxygen in the water. This in turn results in a condition called *"hypoxia"* that suffocates and kills fish and other aquatic fauna. A 2004 UNDP review identified *"dead zones"* as one of the most important environmental threats with a total of more than 145 dead zones worldwide ranging in size from one square kilometer to more than 70,000 sq km. One of the large "dead zones" is located in the Gulf of Mexico due to excessive run off of nitrogen fertilizers from farms in the Mississippi river valley; the *dead zone* in the Gulf of Mexico occupies a massive area of up to 17,353 sq km or 6,700 sq miles. Other areas that are badly polluted with nitrogen include locations in the Baltic Sea.

Similarly, nitrogen pollutes the air when nitrogen oxide volatilizes and contributes to "smog' which has respiratory health implications. It also pollutes the stratosphere where it causes damage by destroying the beneficial ozone layer which blocks us from damaging Ultra Violet rays (Mingle, 2013). Nitrogen fertilizers also stimulate the production by bacteria of nitrous oxide, a greenhouse gas that is 300 times more damaging than $CO_2$, and contributes to acid rain.

Many initiatives are now underway to address the overuse of nitrogen fertilizers, about half of which is not taken up by the crops and this results in excess runoff, acidification of soils and pollution of waterways. However, given the demonstrated principal role of nitrogen in determining yield, farmers are reluctant to decrease nitrogen application because of the risk of lower yields. It is noteworthy that 80% of the global increase in consumption of nitrogen in the decade 2000 to 2009 came from the lead developing countries of India and China, which are now using nitrogen liberally to boost yields in their quest for food, feed and fiber security, self-sufficiency and the alleviation of poverty for small, resource-poor farmers. Thus, the formidable challenge is to increase global food, feed and fiber productivity and production and at the same time increase the efficiency of nitrogen utilization so that yield is not penalized.

There has been a significant R&D investment in nitrogen utilization efficiency over the last 10 years by both private and public sectors. Arcadia Biosciences in California, USA has played a lead role in researching nitrogen use efficiency (NUE). The most advanced NUE application research by Arcadia is based on the *Alat* gene (Alanine gene aminotransferase) from barley (*Hordeum vulgare*), which it licensed from the University of Alberta. The *Alat* gene catalyzes a reversible transamination reaction in nitrogen assimilation (Arcadia Biosciences, 2013). Arcadia has many collaborative projects on NUE with private and public sector partners in both industrial and developing countries (Table 51). One of the first collaborations was initiated with Monsanto in 2005 focused on canola. In the last 5 years (2008 to 2013) ten collaborative programs have featured virtually most of the major crops, with some projects focusing on a single crop and others featuring multiple crops, for example, with Mahyco in India in 2008. Some of the activities include AID agencies such as the USAID project in 2008 whilst others, involve the donation of technology by Arcadia for use by small resource poor farmers in Africa such as the AATF agreement in 2008. The chronological listing below indicates the broad range of activities and partners involved in collaborative programs with Arcadia; note that it is not an exhaustive listing of the large number of collaborative projects operated by the company. The listing includes activities on the major staples of maize by DuPont in 2008, rice with AATF in 2008; wheat – Vilmorin and CSIRO/ACPFG in Australia in 2012; sugar beets with SES VanderHave in 2012. There is also collaboration on sugar cane with South Africa in 2011 and finally an agreement on Poplar and Eucalyptus with FuturaGene in 2013. It is noteworthy that Arcadia has been granted several patents on NUE technology in China. The company has also negotiated a clean development mechanism for their NUE technology with the UN that allows developing countries to earn carbon credits for the use of NUE that can be traded and sold to industrial countries.

In 2013, Arcadia and its partner institutions in Asia and Africa have announced the completion of green house trials of NUE rice in collaboration with Mahyco in India, and two years of field trials of NUE NERICA rice in collaboration with AATF and CIAT in Africa. In July 2013, Arcadia and Mahyco reported reaching a key milestone demonstrating that NUE technology significantly increased plant growth and yield in multiple rice lines developed by Mahyco in India. It noted that rice lines incorporating NUE technology showed double-digit increases in key plant performance and yield measurements. Commenting on the progress of NUE rice, Mr. Raju Barwale, Managing Director of Mahyco opined that ***"we are delighted to achieve this key milestone in NUE rice. We hope that our collaboration with Arcadia on NUE rice will help farmers achieve better yields and improve their livelihoods. Mahyco is committed to providing cutting-edge modern technologies to the farming community and this milestone marks a significant step in this direction"*** (Arcadia, 2013b). Arcadia and Mahyco signed a multi-crop, multi-technology licensing agreement in April 2008 aiming at delivering NUE rice and NUE cotton to Indian farmers who plant 44 million hectares of rice

**Table 51. A Selection of 10 Collaborative Projects on NUE Between Arcadia and Partners, 2008 to 2013**

| | Collaborative Projects |
|---|---|
| 1 | February, 2013. Arcadia and FuturaGene Enter Into Agreement to Develop Nitrogen Use Efficient and Water Use Efficient Eucalyptus and Poplar |
| 2 | June, 2012. SESVanderHave and Arcadia Biosciences Achieve Field Performance Milestone for Nitrogen Use Efficient Sugar Beets |
| 3 | May, 2012. Arcadia Biosciences Receives Key Chinese Patent for Nitrogen Use Efficiency Technology |
| 4 | May 2012. Arcadia NUE technology licensed by Vilmorin for Australian wheats in cooperation with CSIRO/ACPFG Australia which had licensed the technology from Arcadia earlier in 2007 |
| 5 | October 2011. Arcadia with South African Sugarcane Research Institute with focus on sugarcane |
| 6 | November, 2009. Arcadia Biosciences and Vilmorin Announce Strategic Alliance to Develop and Market Nitrogen Use Efficient Wheat |
| 7 | December, 2008. Arcadia Biosciences and the African Agricultural Technology Foundation Enter into Agreement for Development of Improved NUE and salt tolerant African Rice |
| 8 | December 2, 2008. Arcadia Biosciences Receives $3.6 Million USAID Grant to Develop Improved Crops in India |
| 9 | April, 2008. Arcadia Biosciences and MAHYCO Announce Multi-Crop, Multi-Technology Licensing Agreement |
| 10 | March 12, 2008. DuPont and Arcadia Biosciences Collaborate to Improve Nitrogen Use Efficiency in Corn |

Source: Arcadia Biosciences, 2013a

and 12 million hectare of cotton in the country. India is the second largest consumer of nitrogen fertilizer of 16.5 million tons of which 12 million is produced domestically and around 4.5 million tons imported annually (FAI, 2012).

Results of the two years field trials of nitrogen use efficient (NUE) rice in Africa look promising. In September 2013, Arcadia reported that in both years, African NERICA rice with Arcadia's NUE technology produced significant yield increases relative to conventional NERICA rice. Notably, at 50 percent of normally applied nitrogen fertilizer, NUE NERICA rice lines out-yielded the conventional NERICA control variety by 22 percent in the first year trial, and by 30 percent in the second year trial. ***"These results for NUE NERICA rice, combined with earlier results in Japonica rice and our recently announced commercial milestone for NUE Indica rice, clearly demonstrate the efficacy of NUE technology in all major types of rice,"*** said Eric Rey, president and CEO of Arcadia. In 2008, Arcadia donated key agricultural productivity technologies to the AATF for use in African NERICA type rice. Under the agreement, AATF received a cost-free license to Arcadia's NUE, water efficiency and salt tolerance technologies (Arcadia, 2013c).

Given the uncertainty associated with approval processes for biotech crops globally, it is not feasible at this time to determine which genetically modified NUE crop will be the first to be submitted for commercialization approval, and in which country. Speculation suggests that it maybe reasonable to expect commercialization between 2016 and 2025; by that time, global nitrogen fertilizer consumption could exceed 125 million tons per year with the possibility that global warming and climate change will have exacerbated the challenge of effectively and responsibly managing the application of nitrogen fertilizers globally.

## 2. Symbiotic Nitrogen Fixation in Cereals

There are on-going promising projects on NUE that deploy non-GM tools including the plant bacteria system to establish symbiotic nitrogen fixation in cereals. These projects aim at extending the symbiotic interaction of legumes with nitrogen fixing bacteria to a wider range of crops particularly to cereals and non-legumes crops. The discovery of N-fix technology by a team led by Professor Edward Cocking, Centre for Crop Nitrogen Fixation of the University of Nottingham is a milestone development in establishing symbiotic nitrogen fixation in cereals (Cocking, 2009). This breakthrough is related to the discovery of the intracellular colonization of cereals and other major non-legume crops by non-nodulating, nitrogen-fixing *Gluconacetobacter diazotrophicus* bacteria, including the formation of diazoplasts. The *Gluconacetobacter diazotrophicus* is a specific stain of nitrogen fixing bacteria found in sugarcane that can intracellularly colonize all major crop plants. This is a new generation seed treatment technique with bacterium, which enables every cell in the plant with the ability to fix atmospheric nitrogen.

***"Helping plants to naturally obtain the nitrogen they need is a key aspect of World Food Security. The world needs to unhook itself from its ever increasing reliance on synthetic nitrogen fertilizers produced from fossil fuels with its high economic costs, its pollution of the environment and its high energy costs,"*** said Prof. Cocking, an inventor of N-Fix technology (Azotic, 2013a).

The implications of N-Fix technology are enormous and it is hailed as a breakthrough that can be used in all cereals and non-leguminous crops and can provide much of the plant's nitrogen needs. In 2013, Azotic Technologies and the University of Nottingham have conducted field trials of wheat, oilseed rape, pasture and amenity grass and claimed to have generated very positive results. The field experiments have demonstrated that the inoculation of seed with N-Fix technology prior to sowing leads to: **successful colonization by the nitrogen-fixing bacteria in each of the field grown crops and a reduction of 25% to 50% of the amount of**

**nitrogen-based fertilizer required for each of the crops, thus, nitrogen application can be reduced by up to 50% without penalizing yield.** Azotic reported that the field results, based on measures of leaf chlorophyll and total leaf nitrogen content, and crop yield confirm laboratory findings that N-Fix technology can be used as a substitute for a significant amount of Nitrogen fertilizer use (Azotic, 2013b).

### 3. Fixing Nitrogen through Cereal Crops and Bacteria Symbiosis

In a landmark development in July 2012, the Bill & Melinda Gates Foundation announced that the John Innes Center (JIC) in Norwich, United Kingdom (in conjunction with research labs in the USA, Denmark, and France) was granted the lead role in a five year US$9.8 million international research project to investigate whether it is possible to initiate a symbiosis between cereal crops and bacteria to fix nitrogen from the air to improve yields. The project is designed to benefit small resource poor farmers, particularly in Africa (JIC Press, 2012).

**Professor Giles Oldroyd** from John Innes Center opined that ***"During the Green Revolution, nitrogen fertilizers helped triple cereal yields in some areas, but these chemicals are now unaffordable for small-scale farmers in the developing world. As a result, yields are 15 to 20 per cent of their potential. Nitrogen fertilizers also come with an environmental cost. Making and applying them contributes half the carbon footprint of agriculture and causes environmental pollution. A new method of nitrogen fertilisation is needed for the African Green Revolution. Delivering new technology within the seed of crops has many benefits for farmers as well as the environment, such as self-reliance and equity. The new research will investigate the possibility of engineering cereals to associate with nitrogen-fixing bacteria and of delivering this technology through the seed. If it is found to work, farmers would be able to share the technology by sharing seed. And the research opens the door to the use of grasses as rotational crops to enhance soil nitrogen."***

**Katherine Kahn**, senior program officer of Agricultural Development at the Bill & Melinda Gates Foundation observed that the **Foundation** ***"was excited about the long-term potential of this research to transform the lives of small farmers who depend on agriculture for their food and livelihoods. We need innovation for farmers to increase their productivity in a sustainable way so that they can lift themselves and their families out of poverty. Improving access to nitrogen could dramatically boost the crop yields of farmers in Africa."***

Prof. Oldryod added that, ***"the focus of the investigation will be maize, the most important staple crop for small-scale farmers in sub-Saharan Africa; maize is the major staple for***

***300 million Africans in Sub-Saharan Africa. Parallel studies in the wild grass Setaria viridis, which has a smaller genome and shorter life cycle, will speed up the rate of discovery. The discoveries in the project will be applicable to all cereal crops including wheat, barley and rice. The research will start by attempting to engineer in maize the ability to sense nitrogen-fixing soil bacteria. This may be enough to activate a symbiosis that provides some fixed nitrogen. Even slight increases could improve yields for farmers who do not have access to fertilizers."***

***"We have developed a pretty good understanding of how legumes such as peas and beans evolved the ability to recruit soil bacteria to access the nitrogen they need,"*** said Professor Oldroyd. ***"Even the most primitive symbiotic relationship with bacteria benefited the plant, and this is where we hope to start in cereals. In the most basic symbiosis, bacteria are housed in simple swellings on the root of the plant, providing the low oxygen environment needed. In more highly evolved legumes, the plant produces a specialised organ, the nodule, to house bacteria. Bacteria can infect the plant through cracks or through more complex tunnels built by the plant called infection threads. As the complexity of the interaction increases, so does the efficiency with which bacteria fix nitrogen for the plant."***

***"In the long term, we anticipate that the research will follow the evolutionary path, building up the level of complexity and improving the benefits to the plant,"*** said Professor Oldroyd. The project will also help highlight where more research is needed. It will run in parallel to on-going research funded by the Biotechnology and Biological Science Research Council into how nitrogen fixation works in legumes. It will also run in parallel to an existing Gates-funded project, N2Africa, to improve nitrogen management in African farming systems more immediately.

N2Africa is a large scale four year science research project focused on putting nitrogen fixation to work for smallholder farmers (N2Africa Website, 2013). N2Africa is funded by The Bill & Melinda Gates Foundation and The Howard G. Buffet Foundation' through a grant to Plant Production Systems, Wageningen University, in the Netherlands. It is led by Wageningen University together with CIAT-TSBF, IITA and has many partners in the Democratic Republic of Congo, Ghana, Kenya, Malawi, Mozambique, Nigeria, Rwanda and Zimbabwe. Currently, new partnerships are being established in Ethiopia, Uganda, Tanzania, Liberia and Sierra Leone. The 4-year project is designed to:

- identify niches for targeting nitrogen fixing legumes
- test multi-purpose legumes to provide food, animal feed, and improved soil fertility
- promote the adoption of improved legume varieties

- support the development of inoculum production capacity through collaboration with private sector partners
- develop and strengthen capacity for legumes research and technology dissemination
- deliver improved varieties of legumes and inoculant technologies to more than 225,000 smallholder farmers in eight countries of sub-Saharan Africa.

To close this brief overview of nitrogen utilization efficiency, readers interested in a more detailed in-depth analysis of the mechanisms of action of genes involved with NUE are referred to several recent reviews on NUE.

1. Liua et al. (2000) observes that crop production is the single largest cause of human alteration of global nitrogen. Liua categorizes N levels of countries on a per capita basis and observes that 80% of African countries suffer from nitrogen stress problems. Their assessment shows a global nitrogen recovery rate of 59% indicating that nearly 40% of nitrogen is lost in the ecosystems and causing environmental damage that needs to be rectified.

2. A 2011 comprehensive academic review of the subject by Hirel et al. (2011) which presents recent developments and future prospects for improving nitrogen use efficiency (NUE). These initiatives range from conventional plant breeding to the use of molecular markers and transgenic technologies as well as the use of no-till, cover crops and organic approaches. They conclude that a better understanding of the two step process of nitrogen uptake and utilization efficiencies is key to the future successful development of transgenic crops that utilize nitrogen more efficiently. They indicate that for abiotic stresses NUE is the second priority after drought, with significant R&D investments made by the private and public sector in both industrial and developing countries.

3. An assessment by Xu et al. (2012) where NUE was found to operate differently at high levels of nitrogen and that current cultivars which have been bred in soils with high N conditions offer great potential. The authors conclude that "increasing the productivity of crop-acquired N requires the coordination of carbohydrate and N metabolism. Increasing both the grain and N harvest index to drive N acquisition and utilization is important for future breeding programs."

4. McAllister et al. (2012) concludes that although several genes including NR, GS and GOGAT have generated early promise, unlike the over expressed *Alat* gene from Arcadia, they have not delivered improved NUE phenotypes in greenhouse and field experiments which result in significant increased biomass and yield.

# Global Overview

## Global Challenges

### Feeding the World of 2050

Feeding the world of tomorrow is a daunting and formidable task, as several critical factors coincide to precipitate a challenge that the world has not faced before:

- Global population, which was only just over 1.5 billion at the turn of the century in 1900, is now 7 billion, expected to climb to 9 billion by 2050, and will be over 10 billion at the end of this century in 2100.
- Coincidentally, a change is occurring in favour 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 will probably consume more grain than it produced in 2013 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 increase 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 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**

In May 2011, the UN Population Division published its projections of global population for the end of this century in 2100, when the global population could reach 10.1 billion, almost 50% more than today's 7 billion (United Nations, 2011). The most remarkable change is not the increase of 3 billion globally, but the demographic shift that will take place due to the enormous growth in high-fertility developing countries, particularly in Africa. The population of sub Saharan Africa could increase from 1 billion today (15% of global) to 3.6 billion in 2100 which is 35% of global population – that is a startling statement given that Africa cannot even feed its 1 billion people today which is only one-third of its population of 3.6 billion in 2100.

This high population growth in Africa is driven by a group of high-fertility countries, such as Nigeria whose population could increase more than five-fold from 135 million today to 730 million; similarly Kenya whose population could quadruple from 40 million today to 160 million by 2100. There are also some high-fertility countries in Asia such as the Philippines, expected to double from 85 million today to 179 million in 2100. In a landmark event, well before 2100, India will have replaced China as the most populous country in the world with 1.5 billion. India will be followed by China at 940 million, and Nigeria will move up from #9 today to #3 in 2100 with 730 million. Of the top 20 most populous countries today, only 3 are from Africa but this will triple to 9 in 2100 – they include Tanzania at 316 million, Democratic Republic of Congo at 212 million, Uganda at 171 million, Ethiopia at 150 million, Zambia 140 million, Niger 139 million, Malawi 130 million, and Sudan at 128 million.

**Whilst the population of most countries will decline between now and 2100, the high-fertility countries will more than compensate for the decline in population in most industrial countries.** The USA is an exception, expected to grow by about 50% from **300 million today to 478 million in 2100.** The 50% increase in global population between now and 2100, plus a change in life style (creation of an enormous new middle class) and consumption of more meat presents a formidable challenge to increase crop production (the main source of food and animal feed) to achieve food, feed and fiber security in 2100.

The 2012 FAO Report on Food Insecurity in the World and the resulting impact on poverty and malnutrition (FAO, 2012) concluded that 870 million people suffer from hunger and malnutrition today. Whereas this is an improvement on earlier reports, most of the progress was made before the food price hikes of 2008 after which, progress has stagnated. This means that the goal of halving poverty and malnutrition is within reach, only if appropriate action is taken to reverse the slow down in progress since 2008.

Importantly, the report concludes that, ***"Agricultural growth is particularly effective in reducing hunger and malnutrition. Most of the extreme poor depend on agriculture and related activities for a significant part of their livelihoods. Agricultural growth involving smallholders, especially women, will be most effective in reducing extreme poverty and hunger when it increases returns to labor and generates employment for the poor."***

The three regions that suffer most from malnutrition and hunger are:

- Southern Asia (304 million representing ~35% of the world's poor);
- Sub Saharan Africa (224 million equivalent to ~25% of the world's poor); and
- Eastern Asia (167 million or ~20% of the world's poor).

Collectively these three regions total 705 million poor, hungry and malnourished people, equivalent to just over 80% of the world's 870 million hungry and malnourished poor people – these people cannot "live" because they can barely survive and cannot afford adequate food for their sustenance – equally devastating, they have also suffered the loss of their dignity as human beings.

The 2011 edition of FAO's published report on "The State of Food Insecurity in the World" (FAO, 2011), focused on the impact of food price volatility and high food prices. The Report predicts that both price and volatility are likely to continue to increase in the future. The G20 Finance Ministers and Central Bank Governors have become engaged in finding cost-effective ways to reduce price volatility and mitigate its effects when they do occur. The food and economic crises of 2006 to 2008 are challenging efforts to achieve the Millennium Development Goal of reducing, by half, the proportion of people who suffer from hunger.

**In the next fifty years, the world will consume twice as much food as the world has consumed since the beginning of agriculture 10,000 years ago – a profound and consequential statement that deserves a reasoned and urgent response from society. However, regrettably, the vast majority of global society is disinterested and completely unaware of the formidable challenge of feeding the world of tomorrow. Similarly, society is unaware of the potential contribution of technology, particularly the role of the new innovative bio-technologies, such as biotech crops, that already successfully occupy 175 million hectares equivalent to more than 10% of global arable land.**

Given this lack of awareness about the challenge and the role of the new innovative crop biotechnologies, ISAAA initiated a program more than 10 years ago to freely share science-based knowledge about biotech crops with global society, whilst respecting the right of society to make independent informed decisions about the role of the new technologies. ISAAA's most effective initiative has been its Annual Brief on the global status of biotech crops and their impact; remarkably the major messages from the Brief reach up to 3 billion people in over 50 countries speaking more than 50 languages.

- **Hunger and Nutrition**

Despite the fact that we produce enough food today to feed the world (based on 2.720 kcal /capita/day), not surprisingly, an estimated 925 million people, are malnourished equivalent to 13% of the current global population of 7 billion (Heap, 2013). This shortfall is due to a range of factors, including lack of infrastructure to distribute food, inability of the poor to purchase adequate food, food wastage which is as high as one-third of food produced and a myriad of other factors that impact in particular on the poor in the developing countries. Encouragingly, the Global Hunger index has decreased from 19.7 in 1990 to 14.7 in 2012 but there are many countries, in Africa in particular, where hunger stalks and impacts the lives of millions of people, mainly in the rural areas. (Global Hunger Index is: less than 4.9 low hunger; 5-9.9 moderate; 10 -19.9 serious; 20 - 29.9 alarming; and more than 30 is considered extremely alarming.)

- **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 live 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 five countries with the largest number (in millions) of small farms (<2 hectares) in each of the four global regions are listed in Table 52. China with **189 million small farms** (39% of global) in the top five countries 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, is 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 7.5 million small farmers in China (an average of 0.5 ha of Bt cotton) and the 7.3 million small farmers in India (average of 1.5 ha of cotton) who are currently benefiting from Bt cotton, and the 0.398 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 2013, 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) 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 crop Bt brinjal expected to be 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

- **The Chicago Council on Global Affairs**

A new 2013 report from The Chicago Council on Global Affairs calls on the U.S. government "to focus its global food security strategy on prioritizing science, increasing trade flows for agriculture and food, and incentivizing greater business activity in low-income countries" (Chicago Council,

**Table 52. Top Five Countries with the Largest Number (In Millions) of Small Farms (<2 Hectares), By Region**

| Countries/Regions | Number of Small Farms |
|---|---|
| **Asia** | |
| China | 189.4 |
| India | 92.8 |
| Indonesia | 17.3 |
| Bangladesh | 17.0 |
| Vietnam | 9.7 |
| **Total of 5 countries** | **326.2** |
| **Africa** | |
| Ethiopia | 9.4 |
| Nigeria | 6.3 |
| DR Congo | 4.4 |
| Tanzania | 2.9 |
| Egypt | 2.6 |
| **Total of 5 countries** | **25.6** |
| **Americas** | |
| Mexico | 2.2 |
| Peru | 1.0 |
| Brazil | 1.0 |
| Ecuador | 0.4 |
| Venezuela | 0.1 |
| **Total of 5 countries** | **4.7** |
| Europe | |
| Russia | 16.0 |
| Ukraine | 6.2 |
| Romania | 2.3 |
| Bulgaria | 1.7 |
| Poland | 1.5 |
| **Total of 5 countries** | **27.7** |
| | |
| Total of Above countries | **384.2 (73%)** |
| Other countries | **140.8 (27%)** |
| Global | **525.0 (100%)** |

Source: Modified from Nagayets, 2005

2013). The report, *Advancing Global Food Security: The Power of Science, Trade, and Business,* has several key policy recommendations that include:

- Double U.S. investments in agricultural and food research between now and 2023; equipping agriculture in low-income countries to be resilient to water shortages, climate change and weather variability;
- Increase funding for global agricultural development to build research and extension capacity in low-income countries;
- Reform food aid by moving to a cash-based system and ending monetization;
- Leverage the Trans-Pacific Partnership and U.S.-EU Free Trade Agreement to remove barriers to agriculture and food trade; and
- Create more incentives for business investment in low-income countries by reducing regulatory barriers and increasing lending for agricultural development.

Catherine Bertini, the group's co-chair 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 60 percent by 2050."***

The recommended action plan has four thrusts:

- Make global food security a high priority of US economic and foreign development policy;
- Forge a new science of agriculture based on sustainable intensification;
- Reinvigorate trade as a food security and development tool; and
- Make market access and partnership with business a pillar of food security.

It is evident that the biosciences and more specifically crop biotechnology applications can contribute in a significant way to the goals and objectives of the new Chicago Council on Global Affairs program.

- **A View on Food Security from the Private Sector**

Today, the face of poverty and hunger means that more than 1 billion people go to bed hungry, 2 billion people suffer from malnutrition (lack of iron, Vitamin A, Iodine and Zinc – lack of Vitamin A alone results in between 1.9 and 2.5 million per year dying from VAD, plus another half a million become permanently blind. At the same time 1 billion people are obese and we waste one-third of the food that is produced.

In his role as chairman of Nestle, the world's largest nutrition, health and wellness company Peter Brabeck-Letmathe, proposed five pillars for food security (Lethmathe, 2013):

1. **Quantity** of food with sufficient calories and protein remains important acknowledging that a growing global population (currently 7 billion and projected to reach 9 billion in 2050) and a growing middle class in a more prosperous society is demanding more protein, mainly in the form of meat.
2. **Adequate income for farmers and people in rural communities** where poverty and hunger is worst leading to migration to the urban areas distal from the source of food which makes it more expensive.
3. **Affordability of food.** Since 2007 the price of food has escalated, partly due to growing use of biofuels in both developing and developed countries.
4. **Quality of food.** Provision of safe and nutritious food with adequate level of micronutrients, acknowledging that drought, exacerbated by climate change can lead to lower nutrient levels.
5. **Access to food.** A growing and more urbanized global population poses more logistical challenges and will increase the distance between where food is produced and consumed. Between now and 2050 the number of new cities with 1 million will increase by 400, almost doubling the number of cities globally with 1 million or more.

**To address the above five pillars,** Nestle's chair advocates three "overarching" essential initiatives: firstly, investment in infrastructure and institutional initiatives; for example, address **land tenure and gender issues** in developing countries; secondly, **public support and political will** to address macro initiatives such as Golden Rice to remedy VAD; and lastly, political will in support of **free trade** acknowledging that IPCC 2007 projects that up to a three degree increase in average temperature will result in increased food production that will need more redistribution. Effective free trade will be required to facilitate global movement of the food staples and agricultural commodities.

## Overcoming the Challenges

A number of acceptable and feasible technologies have been developed through the years that would allow sensitized people to take action and overcome the enormous challenges enumerated above. First, it is quite apparent that all crop production strategies should be confined to the 1.5 billion hectares of global arable land to protect against deforestation – **this is the concept of sustainable intensification** recommended by many academies of science worldwide. This will conserve biodiversity in the forests and other sanctuaries. Second, the risk of not urgently addressing the above food security issues with a science-based strategy in a timely manner will make matters get worse quickly, exacerbated by climate change, and condemning millions more people to a life of hunger, malnutrition, political instability and conflict. Norman Borlaug, the 1970 Nobel Peace Laureate, who saved up to 1 billion people from hunger used to warn that ***"you cannot build peace on empty stomachs".***

Now, not later, is the time for the G8 to take the lead and devote the necessary resources to support an **innovative, resilient and science-based Global Food Security Strategy** to feed the global population of 9 billion people in 2050 and to alleviate hunger and poverty – failure to do so could result in a global catastrophe.

A review of global crop literature clearly establishes that irrespective of crop or global region, generally the crop losses due to abiotic constraints (water, salinity and nutrients) are much greater than constraints associated with biotic stresses related to weeds, insect pests and disease, so the following paragraphs address abiotic stresses which are being addressed by the second generation of biotech crops.

**Abiotic Traits**

Abiotic stresses related to efficiency of water uptake, drought, salinity and nitrogen use efficiency are under development and the first commercial drought tolerant crop, maize was planted in the US in 2013. The following are useful facts about water and crop production.

- **Water Efficiency, Salinity and Crop Production**

Crops are the major source of food, feed and fiber. In the last 50 years the global cultivated arable land area has increased by only 12% whereas crop production has grown 2.5 to 3.0-fold (FAO SOLAW, 2011). This impressive increase in crop production could not have been achieved without adequate supplies of fresh water. Drought, water efficient crops and salinity are three areas that impact on the use of water for agriculture. Water quality is deteriorating as a result of more recycling of irrigation water and salinity which now affects approximately 100 million hectares of crop land globally.

The following facts on global water supplies (UN Water Statistics-Food, 2013) and their importance for agriculture, provides an appropriate introduction/context for a brief discussion on the extent and impact of drought and salinity on global crop production.

Facts about water and crop production

- Water for irrigation and food production constitutes one of the greatest pressures on freshwater resources. Agriculture accounts for around 70 percent of global freshwater withdrawals, even up to 90 percent in some fast-growing economies.
- Irrigation increases yields of most crops by 100 to 400 percent, and irrigated agriculture currently contributes to 40 percent of the world's food production on 20 percent of the cultivated land.
- The daily drinking water requirement per person is 2-5 litres, but it takes 2,000 to 5,000 litres of water to produce one person's daily food – **a thousand-fold difference.**
- Future global agricultural water consumption (including both rainfed and irrigated agriculture) is expected to increase by 19 percent (to 8,515 km3 per year) by 2050.
- Producing 1 kg of grain requires approximately 1,500 litres of water while 1 kg of beef requires 15,000 litres – **a ten-fold difference.**
- Diets are shifting from predominantly starch-based food to meat and dairy, which requires more water.
- Meat consumption in particular is expected to rise from 37 kg per person per year in 1999/2001 to 52 kg in 2050 (from 27 to 44 kg in developing countries), implying that much of the additional crop production will be used as feed for livestock production.
- This **dietary shift is the greatest to impact on water consumption over the past 30 years,** and is likely to continue well into the middle of the twenty-first century.
- Due to climate change, Himalayan snow and ice, which provide vast amounts of water for agriculture in Asia, are expected to decline by 20 percent by 2030.

- **Progress with Biotech Drought Tolerant Maize**

Biotech based drought tolerance is most advanced in the maize crop. The status of drought tolerant biotech maize was reviewed by Dr. Greg Edmeades last year and published in ISAAA Brief 44: 2012. For the convenience of the reader the abstract is reproduced here (Edmeades, ISAAA Brief 44, 2012).

**Progress in Achieving and Delivering Drought Tolerance in Maize - - An Update**

Drought in 2012 through much of US Midwest has led to reductions of 15% and 21% in national maize production and maize yields, respectively, and cast a sharp focus on progress towards drought tolerance in this important crop. Drought also continues to destabilize maize yield in major regions of sub Saharan Africa where irrigation is not feasible, with a direct human cost. Maize yield under drought mainly reflects tolerance to water stress of the kernel setting mechanism at flowering.

Genetic improvement can probably close 20-25% of the yield gaps between drought-affected and optimal conditions. Conventional selection by CIMMYT specifically for drought tolerance focused on yield and associated secondary traits has resulted in gains of around 100 kg/ha/yr, in tropical maize populations. Selection by the private sector in temperate germplasm, based on multi-location trials for general performance has given gains under drought of ~65 kg/ha/yr. Heat tolerance is becoming more important as climate changes, and the genetic controls of heat and drought tolerance are largely independent of each other. Representative managed stress environments have been endorsed as an important component of efficient selection for drought or heat tolerance.

Marker-assisted selection (MAS) is now having a significant impact, and when well executed could double gains from conventional drought tolerance selection. Current seed company claims, based on 2012 US data, appear to show Syngenta's Agrisure Artesian™ and Pioneer's AQUAmax™ hybrid products, selected using native genes and MAS, out yielding competing hybrids by around 500 kg/ha, while Monsanto's DroughtGard™ transgenic hybrids out yielded AQUAmax hybrids by a further 300 kg/ha. The DroughtGard event, MON87460 will be available to farmers royalty-free under the WEMA Project in five countries in sub Saharan Africa, hopefully from 2015 onwards. Product delivery of drought tolerant hybrids remains a challenge in sub Saharan Africa, but private seed sector capacity is increasing rapidly. Large publicly funded projects are now supplying drought tolerant inbreds and hybrids to national and regional seed companies in sub Saharan Africa and South Asia. Public-private partnerships, though still rare, are using cutting edge doubled haploid, MAS and transgenic technologies to develop drought tolerant hybrids and deliver them successfully to smallholders in sub Saharan Africa. Experience since 2008 has reduced expected gains under drought in a commercial maize breeding context, with the exception of MAS.

Starting with a base yield of 3 t/ha under drought, conventional breeding for regional adaptation should reliably deliver 50 kg/ha/yr (~1.4%/yr). MAS, which has performed well in the recent past, can boost these by a further 25 kg/ha/yr (~0.6%/yr) with potential for significantly larger gains from newer methodologies. The slower than expected development of transgenic drought tolerance suggests gains of 30 kg/ha/yr (0.7%/yr), assuming one new transgene is available every eight year that lifts yield 5% per transgene. **Over the next two decades gains of 1.4, 2.0 and 2.7% per year can be expected from conventional selection, conventional + MAS, and conventional + MAS + transgenes, respectively**. Greater gains are probable if genomic selection attains its potential and drought transgenes can be efficiently stacked. Impacts could be realized much sooner if harmonized biosafety and hybrid release policies was adopted. Germplasm collections are assuming greater importance if gains from native genes are to be sustained. Efficient and accurate field phenotyping remains essential for genetic progress. In sub Saharan Africa trained and well-supported field staffs are urgently needed. Emerging private-public partnerships in crop development and a strong private seed sector will be more than adequate to meet these challenges as long as our resolve does not falter and we use our resources efficiently.

- **The First Commercial Drought Tolerant Biotech Hybrid Maize**

In December 2011, USDA deregulated Monsanto's Genuity©DroughtGard™ hybrid maize and the company proceeded with import approvals in major importing countries. The product is specifically designed to optimize yield of dryland maize and targeted at the Western Great Plains under drought stress with comparable yield to conventional hybrids in the absence of water stress. The product was available commercially for the first time in 2013 for planting by "farmers in the Western Great Plains in a stewarded commercial introduction"; average yield for dry land maize in this region ranges from ~ 70 to 130 bushels per acre, whereas the average yield for maize in the US is about 150 bushels per acre. In 2012, the product (event MON 87460) was planted by about 250 growers in the Western Great Plains in large field experiments. The preliminary analysis of the yield data for the biotech drought maize indicate that the gain (versus conventional maize hybrids) is of the order of 5 bushels or more per acre (300 kg per hectare) (Monsanto, 17 June 2013). In 2013, ~2,000 farmers planted about 50,000 hectares of Drought Guard (MON 87460) in the drought prone area in the Great Plains of the US. Notably, this is the first biotech drought tolerant maize to be approved and commercialized globally. This drought tolerant hybrid has also been given final major import approval from China. China is a major importer of US corn grain and dried distillers grains solubles. ***"With full import approvals in key export markets, US farmers can market their grain more broadly this year and plant with confidence in 2014,"*** said Lisa Safarian U.S. Row Crops Lead for Monsanto (http://www.prnewswire.com/news-releases/monsantos-drought-tolerance-trait-in-genuity-droughtgard-hybrids-receives-final-major-import-approval-from-china-211819151.html)

- **Salinity**

Crop losses due to salinity are difficult to assess but are recognized to be substantial and are expected to increase over time as salinization continues to degrade fertile land, and the process exacerbated by climate change. **Of the ~1.5 billion hectares of global arable land about 80% equivalent 1.2 billion hectares, are rainfed and the balance of 20%, or 300 million hectares are irrigated.** Of this 300 million hectares of irrigated land, which notably produces 40% of total global food production, at least 20% or 60 million hectares are affected by salinity; some estimates indicate that salinity affects as much as 50% or 150 million hectares (Pitman and Lutge, 2002). In addition to the 60 million hectares of saline soils in irrigated areas it is estimated that another ~30 million hectares of the global total of 1.2 million hectares of rainfed land is saline, for a global total of almost 100 million hectares. Salinity of soils is deteriorating with an estimated **additional 1.5 million hectares per year becoming saline annually** and it is an issue that deserves urgent attention.

Whereas salinity is of greatest importance in irrigated soil areas, it is also a problem in non-irrigated areas as a result of seawater intrusions into river estuaries and coastal areas. There are two types of remedial programs; the first involves physical engineering works to remedy inefficient irrigation schemes and drainage to reduce salinity levels in soil and water. The second involves the use of crop breeding improvements. This chapter is limited to a brief overview of the use of biotechnology applications to increase tolerance to salt in crops.

Crop production is heavily dependent on water, using approximately 70 percent of world water withdrawals. The UNESCO World Water Assessment Program forecasts a 40 percent increase in global freshwater demand and a corresponding 35 percent decrease in per capita supply by the year 2025. Thus, the ability to effectively manage crops in saline water is very important. There are several institutions in both public and the private sector working on developing biotech crops tolerant to salinity. One of the private sector companies involved is Arcadia Biosciences (Arcadia Biosciences, 2013a) which is **"developing a technology that will allow plants to produce normal yields and quality under saline conditions. The technology will be applicable to a wide range of crops, including rice, soybeans, wheat, alfalfa, vegetables and turf. Arcadia's salt-tolerant plants will also bind excess salt from soil into the plant and have the ability to rehabilitate salinized land over time. Arcadia's salt-tolerant plants will also bind excess salt from soil into the plant and have the ability to rehabilitate salinized land over time. This technology will improve farming efficiencies and reduce the need to expand agricultural activities into new land areas. In addition, it will reduce the need for fresh water by allowing increased use of salinized irrigation water."**

Development of Arcadia's salt-tolerance technology is underway in canola, rice, cotton and tomatoes. AB has a partnership with AATF to develop rice tolerant to salinity for Africa. The principal rice-growing regions of Africa have saline soils and inadequate freshwater. **"Arcadia is collaborating with AATF (African Agricultural Technology Foundation) to develop salt tolerant rice, royalty-free to smallholder farmers in Africa. Salt tolerant rice technology will increase rice productivity and profitability of African farmers and make more fresh water available for human consumption"** (Arcadia Biosciences, 2013b).

***"The availability of new agricultural technologies to African farmers has historically been slow because of issues around development costs and intellectual property ownership. The partnership between Arcadia and AATF is designed to solve both of these issues,"*** said Eric Rey, president and CEO of Arcadia. ***"Plant yields respond to nitrogen fertilization, but plants are generally inefficient absorbers of nitrogen. Because of this, farmers in highly developed countries often apply more fertilizer than plants are able to absorb. In Africa, the on-farm price of nitrogen fertilizer is very high due to importation and supply chain costs. Hence, the amount of nitrogen fertilizer required to significantly improve yields is cost-prohibitive for***

***many African farmers. Similarly, fresh water is a precious and scarce commodity in Africa, and the ability to irrigate crops with salty water can improve productivity, reduce irrigation costs, and make more fresh water available for human consumption. We believe that NUE and Salt Tolerant African Rice will provide substantial economic benefits to smallholder African farmers by reducing total input costs and increasing yields. This can all happen without increasing the environmental footprint of rice production."***

The technology will be available royalty-free to small holder farmers in Africa as part of Arcadia's commitment to agricultural and environmental improvement in the developing world. Hence, the company will not receive monetary compensation for the research and commercial rights granted in the agreement. Arcadia will complete the early-stage research and development work for the project and will provide improved rice lines to African research collaborators for field-testing. AATF will work with its regional development partners to breed rice varieties that are most effective for local environmental conditions and then distribute to local growers.

Genetically modified rice that contains genes for NUE, salt tolerance and drought has been generated by researchers of Arcadia Biosciences in 2012. According to project coordinator Dr. Jacob Mignouna, efficient *Agrobacterium*-mediated transformation of GM rice was made possible through the 'Pureintro' technology from Japan Tobacco Inc. To gear up on the possible confined field trials, Uganda and Ghana partners prepared and constructed their respective sites. These countries were given approval by their national biosafety committees to conduct the trials (NEWEST (Nitrogen & Water Efficient Salt Tolerant Rice), 2012 Annual Progress Report).

By mid June 2013, test plantings of the NUE rice in Uganda and Ghana were launched. The trial in Ghana is being conducted by the Crop Research Institute and in Uganda by the National Agricultural Research Organizations. The Public Intellectual Property Resource for Agriculture (PIPRA) provided access to enabling technologies, and the international Center for Tropical Agriculture (CIAT) in Cali, Colombia conducted preliminary field evaluations of the most promising varieties. ***"This year's rice trials in Uganda and Ghana are a significant milestone for the project, advancing the prospect of improved rice varieties that will address the constraints of nitrogen deficiency, drought and salinity in rice production for small holder farmers,"*** said Dr. Denis Kyetere, Executive Director of AATF (AgroNews, 13 June 2013).

The two-year field trials of NUE rice was completed in September 2013 at the International Center for Tropical Agriculture in Colombia. Results showed that Arcadia's NUE technology out-yielded the conventional NERICA rice by 22 percent in the first year trial and by 30 percent in the second year trial, with application of 50% lower nitrogen fertilizer application. The NUE rice field trials at CIAT served as initial validation and screening of NUE rice lines before the field trials in Africa, which are now underway (Design, 12 June 2013).

## Specialized Biotech Crop Products

- **Tailored Traits**

The trend for developing and deploying specially tailored GM crops to produce high-value specialized products rather than low-priced commodities is already underway (Top Producer Spring, 2013). This will allow the leading growers to engage in more profitable contractual growing of GM crops to meet pre-defined specifications set by the processor/end-user of the product. One example, "Enogen" maize, is already on the market in the US and is a "high starch" maize for ethanol. Value-added white maize for the snack food industry is another specialized product that commands a premium of about US$1 per bushel. Other products expected on the market in the near term are high oleic oil soybean and enhanced protein levels. This is particularly important since protein percentage has decreased in US soybean over time and are now lower than soybean from Brazil and Argentina, making US soybean less competitive. Another product under development is canola with enhanced levels of omega-3 fatty acids. Some of the specialized products will be multi-purpose. For example, whereas Vista Gold high omega-3 was developed for the food industry it also has potential for industrial use as a hydraulic fluid.

These opportunities with specialized products will not be restricted to industrial country markets but will also be important for developing country markets. For example, "Golden Rice" with enhanced beta carotene to remedy Vitamin A deficiency is at an advanced stage of field trials and hopefully will be approved for commercialization in the Philippines in 2016, and is capable of delivering substantial health benefits. This breakthrough will open up a major opportunity for the rice-eating and vitamin A-deficient people of Asia who produce and consume ~90% of the world's rice. In Africa, programs are also underway to develop bananas, (which is the major staple in certain parts of Africa), sweet potato and bio-fortified sorghum that have higher levels of beta carotene. Severe levels of vitamin A deficiency result in unacceptably high mortality rates of over 50% for pre-school children in the worst affected areas of Africa. Other products under development or consideration include maize with enhanced iron content – this will be important for Africa where anaemia, due to lack of iron in the diet, is a major problem. There are some more ambitious projects underway in Africa that aim to simultaneously confer both quality traits (Vitamin A and iron deficiency) and agronomic traits (resistance to pests or diseases).

There will certainly be challenges associated with the development and utilization of these new specialized products. Product segmentation and identity preservation represents one area which will be a challenge to both farmers and processors; AID administrators will have to deal with a myriad of additional challenges in developing countries. Another critical area is the development and implementation of appropriate science-based regulation that will be suitable for both domestic and international trade. Regulation must be responsible but not onerous, in terms of effort and cost (recently estimated at US$135 million per GM product in industrial countries). A significant shortening of the current long time-frame for product approval is a must for all countries, particularly developing countries, which simply cannot afford very expensive regulation, and as a result are "locked out" from accessing the technology that they urgently need in their quest for food security. Most of the current approval systems are both unnecessarily cumbersome and slow, or virtually impractical, as is the case in the EU. Today, the fast growing numbers of new biotech crops often need to be approved simultaneously for planting and also for export/import to multiple countries – this makes the process very demanding including dealing with critical issues like low level presence (LLP), which must be set at pragmatic not ideological levels. The challenge will get infinitely more complicated as international trade grows and the number of regular and specialty biotech crop products increase over time. Thus, now is the time to address these issues so that appropriate procedures are timely in place to avert enormous potential costs associated with unacceptable delays in international trade which will also impact on food security. These delays can be life–threatening in drought-prone regions like west and east Africa which have experienced many famines in the past, and which maybe exacerbated in the future as a result of climate change.

- **The Merit of Continuing to Analyze Substantial Equivalence**

In an effort to improve regulation of biotech crops by eliminating unnecessary requirements a study in Australia has recommended discontinuation of testing for "Substantial Equivalence". According to a paper in the Journal of Agricultural and Food Chemistry, **it may be time to re-think the use of compositional equivalence studies required of GM crop developers by regulatory regimes globally because unintended compositional effects that could be caused by genetic modification have not materialized. Following a review of 20 years of literature on the subject, the authors argue that compositional equivalence studies uniquely required for GM crops may no longer be justified on the basis of scientific uncertainty** (Agricultural Biotechnology Council of Australia, May 2013).

Since 1993, investigating the compositional equivalence between GM crops and their conventional counterpart has been the cornerstone of the safety evaluation of GM crops and it is designed to investigate any unintended effects of introducing new genetic material into a plant using biotechnology. Since they began regulating the safety of GM crops, the US Food and Drug Administration (FDA) has found all of the 148 GM crops they evaluated to be "substantially equivalent" to their conventional counterparts as have the Japanese regulators for 189 submissions. Over 80 peer-reviewed publications also conclude that all the studies report no differences in composition of GM crops. These studies have covered the full range of GM crops – from soybean, canola and cotton, to tomato, potato and raspberry – and the full range of modifications.

**Our assessment is that there appears to be overwhelming evidence that transgenesis [genetic**

**modification] is less disruptive of crop composition compared with traditional breeding, which itself has a tremendous history of safety** (Herman RA, and WD Price. 2013). **The authors questioned whether the millions of dollars spent each year on compositional studies for GM crops can be justified.** According to the paper, expanding regulatory requirements have increased compositional study costs over 10-fold, from approximately US$100,000 per study, to over US$1 million per study. In conclusion, they state, **The merits of continuing to generally require compositional analysis of GM crops to inform safety seems dubious given the results of 20 years of research, and if agreement can be reached that these studies are no longer warranted, use of this technology will become accessible to a wider array of scientists.**

- **Gossypol-free Cotton – Potential Contribution to Food Security**

Many plants utilize chemical defense mechanisms to reduce or eliminate predation. The cotton plant is no exception. Gossypol, a naturally occurring terpenoid found in visible pigment glands located throughout the cotton plant, is an effective insect deterrent and a cumulative toxin in monogastric animals. The end result is that all the protein produced by the cotton plant is relegated to ruminant feed, primarily dairy and beef cattle. Ruminant species do not utilize protein as efficiently as monogastric or aquaculture species. Elimination of gossypol allows cottonseed protein to be used much more efficiently by using it in food products for direct consumption by humans or as feed for the more efficient monogastric animals. The volume of underutilized cotton protein is not trivial. Each year, about 10-11 million tons of cottonseed protein are produced worldwide. Without gossypol, this is enough protein to satisfy the daily, basic protein needs (50 grams/person) of more than 600 million people for one year.

Modern plant biotechnology utilizing RNAi and a seed specific promoter has produced a cotton plant that has no gossypol in the seed, yet the plant retains normal gossypol levels in all other tissues. This technology has the potential to greatly improve the utilization of this massive protein resource, thus making a substantial contribution to global food and nutrition security. For example, recent research demonstrates 100% replacement of fishmeal in shrimp and black sea bass feed, without a decrease in performance. Several research projects are currently underway, and it is anticipated that Ultra-low Gossypol Cottonseed (ULGCS) can be used in the diets of many economically important aquaculture species. The replacement of fish meal will help allow for the expansion of the aquaculture industry, contributing to improved food and nutrition security, as the standard of living improves around the globe and demand for seafood increases.

For many years, cottonseed meal has been used in catfish, trout, and salmon feeds; however, gossypol has prevented its widespread use in these and other aquaculture species. Preliminary studies with pompano, black sea bass and hybrid striped bass indicate that plant-based, cotton protein has excellent digestibility and can potentially replace significant quantities of fishmeal in many aquaculture diets worldwide. Many locations worldwide have aquaculture operations and cotton production in close proximity. This will facilitate the logistics of using cottonseed protein in aquaculture feeds. Also, food scientists have created a wide range of food products from cottonseed, including humus, plant-based dairy substitutes, chopped nuts, and a peanut butter alternative.

Glandless cotton, a naturally occurring mutant that is devoid of gossypol in all parts of the plant, including the seeds, is being used as a proxy for product utilization research while the biotech version is winding its way through the regulatory process. The regulatory process is facilitated by the fact that the gene targeted to block gossypol production in the ULGCS seeds is the same gene that is inactive in the whole plant in the naturally occurring, glandless mutant. The superiority of the biotechnology-based version comes from the fact that it retains its natural defense mechanism in the non-seed tissues. This technology makes it possible to produce a gossypol-free cottonseed resulting in greatly improved utilization of this valuable, massive protein resource to improve global food and nutrition security.

Now that ULGCS has been developed and field tested, it is time for this technology to enter the commercialization phase. Texas A&M University has begun the process of seeking deregulation from both FDA and USDA. Regulatory field trials were initiated in 2013 and are expected to be completed in 2015. Texas A&M University and Cotton Incorporated are now seeking international partners who are willing to facilitate the development of this technology for humanitarian purposes. Ultra-low Gossypol Cottonseed allows the full value of cotton to remain in the farming community, because seed can be processed locally, providing value-addition, employment, cooking oil, expanded feed, and food. Expanding the value of agricultural products for farmers, while increasing food supply, benefits both rural and urban populations.

This section is contributed by co-inventors of the technology:

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## New Biotech Crop Products Including Non-Transgenics

New applications within the broad field of crop biotechnology, including both transgenic applications (GM) and non – transgenic applications, are continuously evolving at a fast pace. Whereas the first generation of transgenes, featured the agronomic traits: herbicide tolerance, insect resistance and stacks of these two traits, the next generation will feature a broader array of traits including disease and virus resistance and notably quality/nutritional traits. Importantly, the nutritional traits will deliver benefits that will be more evident to consumers (as opposed to largely farmers in the first generation) and this has the potential to significantly enhance consumer acceptance of GM crops. The most prominent nutritional trait that will have impact in developing countries is the long-awaited "Golden Rice" with an enhanced level of beta carotene, the precursor of Vitamin A. Given that an estimated 6,000 people a day die from vitamin A deficiency and its complications, this has the potential of significant health impact on the rice eating people of Asia and elsewhere. It is hoped that Golden Rice will be approved for deployment in the Philippines in 2016. Banana and sweet potato for Africa are also being modified for higher levels of beta carotene. Similarly In the industrial countries, soybean with enhanced levels of omega-3 and maize with high levels of oleic acid are at an advanced stage of development.

Both DuPont and Monsanto have advanced products in which the gene for the enzyme that converts oleic fatty acid into linoleic acid in soybeans is silenced (New York Times, 15 November 2013). This results in products that have three times more oleic acid than regular soybean and is similar to olive in composition. Importantly, these products would benefit consumers, as opposed to past products which have benefited farmers, and thus could impact significantly on acceptance by society of biotech products Although the DuPont product (Plenish) was approved for commercial production three years ago and the Monsanto product two years ago (Vistive Gold) there is no known plan to commercialize because they have no significant competitive advantage over oils currently in use. The pre-commercial hectarage in 2013 was low and not reported, although the United Soybean Board is providing US$60 million for development and marketing of the products in the hope that ~7 million hectares could be planted in the US by 2023. Arctic apple (non-browning) and Innate potato are at an advanced stage in the approval process in the USA; these are just examples, there are others in the pipeline.

- **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 technology** (ZFN) 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 and 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 (Voytas, 2013) 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 genetically modified 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.

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 (Shroeder et al, 2013). 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, (anaemia) and Zinc and Vitamin A deficiencies**. Hence, adequate supplies 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 aluminium toxicity, which in turn could expand available arable land. Acid soils are estimated to occupy 30% of land globally.

**The Contribution of Biotech Crops to Sustainability**

***"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987).***

Biotech crops are already contributing to sustainability and can help mitigate the effects of climate change in the following five ways and have enormous potential for the future:

- **Contributing to food, feed and fiber security and self sufficiency, including more affordable food, by increasing productivity and economic benefits sustainably at the farmer level**

Biotech crops already play an important role by increasing productivity per hectare and coincidentally decreasing cost of production as a result of reduced need for inputs. Economic gains at the farm level of ~US$116.9 billion were generated globally by biotech crops during the sixteen year period 1996 to 2012, of which 58% were due to reduced production costs (less ploughing, fewer pesticide sprays and less labor) and 42% due to substantial yield gains of 377 million tons. The 377 million tons comprised 122.3 million tons of soybean, 230.5 million tons of maize, 17.7 million tons of cotton lint, and 6.5 million tons of canola over the seventeen year period 1996 to 2012. For 2012 alone, economic gains at the farm level were US$18.7 billion, of which approximately 17%, were due to reduced production costs (less ploughing, fewer pesticide sprays and less labor) and approximately 83%, due to substantial yield gains of 48.7 million tons. The 48.7 million tons comprised 12 million tons of soybean, 34.1 million tons of maize, 2.2 million tons of cotton lint, and 0.4 million tons of canola (Brookes and Barfoot, 2014, 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 377 million tons of additional food, feed and fiber produced by biotech crops during the period 1996 to 2012 had not been produced by biotech crops, an additional 123 million hectares of conventional crops would have been required to produce the same tonnage. Some of the additional 377 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 2012 alone, if the 48.7 million tons of additional food, feed and fiber produced by biotech crops during 2012 had not been produced by biotech crops, an additional 14.9 million hectares of conventional crops would have been required to produce the same tonnage for 2012 alone (Brookes and Barfoot, 2014, 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 2013, and this can be enhanced significantly in the remaining 2 years of the second decade of commercialization, 2014 to 2015 principally with biotech cotton and maize.** Of special significance is biotech rice which has the potential to benefit 250 million poor rice-growing households in Asia, (equivalent to one billion beneficiaries based on 4 members per household) growing on average only half a hectare of rice with an income as low as US$1.25 per day – they are some of the poorest people in the world. It is evident that much progress has been made in the first fifteen years of commercialization of biotech crops, but progress to-date is just the "tip of the iceberg" compared with potential progress in the second decade of commercialization, 2006-2015. It is a fortunate coincidence that the last year of the second decade of commercialization of biotech crops, 2015, is also the year of the Millennium Development Goals (MDG). **This offers a unique opportunity for the global crop**

**biotechnology community, from the North and the South, the public and the private sectors, to define in 2014 the contributions that biotech crops can make to the 2015 Millennium Development Goals and also a more sustainable agriculture in the future** – this gives the global biotech crop community five years to work towards implementing a global strategy and action plan for biotech crops that can deliver on the MDG goals of 2015.

- **Reducing agriculture's environmental footprint**

Conventional agriculture has impacted significantly on the environment and biotechnology can be used to reduce the environmental footprint of agriculture. Progress to-date includes: a significant reduction in pesticides; saving on fossil fuels; decreasing $CO_2$ emissions through no/less ploughing; and conserving soil and moisture by optimizing the practice of no till through application of herbicide tolerance. The accumulative reduction in pesticides for the period 1996 to 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, Forthcoming).

**Increasing efficiency of water usage will have a major impact on conservation and availability of water globally**. Seventy percent of fresh water is currently used by agriculture globally, and this is obviously not sustainable in the future as the population increases by almost 30% to over 9 billion by 2050. The first biotech maize hybrids with a degree of drought tolerance 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 20% more than their conventional counterparts. **Drought tolerance is expected to have a major impact on more sustainable cropping systems worldwide, particularly in developing countries, where drought is more prevalent and severe than industrial countries.**

- **Helping mitigate climate change and reducing greenhouse gases**

The important and urgent concerns about the environment have implications for biotech crops, which contribute to a reduction of greenhouse gases and help mitigate climate change in two principal ways. First, permanent savings in carbon dioxide ($CO_2$) emissions through reduced use of fossil-based fuels, associated with fewer insecticide and herbicide sprays; in 2012, this was an estimated saving of 2.1 billion kg of $CO_2$, equivalent to reducing the number of cars on the roads by 0.94 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 2012 to 24.61 billion kg of $CO_2$, or removing 10.9 million cars off the road. Thus in 2012, the combined permanent and additional savings through sequestration was equivalent to a saving of 26.7 billion kg of $CO_2$ or removing 11.8 million cars from the road (Brookes and Barfoot, 2014, Forthcoming).

Droughts, floods, and temperature changes are predicted to become more prevalent and more severe as we face the new challenges associated with climate change, and hence, there will be a **need for faster crop improvement programs to develop varieties and hybrids that are well adapted to more rapid changes in climatic conditions.** Several biotech crop tools, including tissue culture, diagnostics, genomics, molecular marker-assisted selection (MAS) and biotech crops can be used collectively for 'speeding the breeding' and help mitigate the effects of climate change. Biotech crops are already contributing to reducing $CO_2$ emissions by precluding the need for ploughing a significant portion of cropped land, conserving soil, and particularly moisture, and reducing pesticide spraying as well as sequestering $CO_2$.

In summary, collectively the above five thrusts have already demonstrated the capacity of biotech crops to contribute to sustainability in a significant manner and for mitigating the formidable challenges associated with climate change and global warming; and the potential for the future is enormous. Biotech crops can increase productivity and income significantly, and hence, can serve as an engine of rural economic growth that can contribute to the alleviation of poverty for the world's small and resource-poor farmers.

## Selected Developments in Global Regions

### Europe – Strong Political Support

In 213, strong political support for biotech crops have been expressed by top EU and UK government policy makers. **European Union's chief scientific advisor Dr. Anne Glover** fully supported the report published by the European Academies Science Advisory Council (EASAC) which took note of the "grave scientific, economic and social consequences of current European Union policy towards GM crops," Dr. Glover said ***"There is no evidence that <u>GM technologies</u> are any riskier than <u>conventional breeding</u> technologies and this has been confirmed by thousands of research projects. In my view, consumers can believe in the overwhelming amount of evidence***

***demonstrating that GM technology is not any riskier than conventional plant breeding technology. The EASAC Report is a major contribution to this debate as it reflects the view of Europe's most eminent scientists"*** (Crop Biotech Update, 2 October 2013).

UK **Minister of Environment, Food, and Rural affairs Rt. Hon. Owen Paterson**, on many occasions his confidence that biotechnology is one of the tools for meeting the global challenges of increased population in diminishing resources. He has been advocating reforms in British agriculture, especially in relation to biotechnology. In his speech on 29 May 2013, at the British Irish Food Business Innovation Summit, the minister said that the food sector has an important role to play in helping unlock the potential of the UK and Irish economies. He emphasized that the success of the food industry can be attributed to its ability to embrace new technologies such as GM technology. ***"The EU has the strongest and strictest safety-based regime for GMOs in the world - and its right that products should be subject to such controls. But there is more the EU as a whole can do to facilitate fair market access for products which have been through that system. The EU is being left behind when it comes to GM, and I fear we'll regret it if we don't try and catch up,"*** he added (Crop Biotech Update, 5 June 2013).

In a speech at the Rothamstead Research Institute last June 20, Minister Paterson called on the government, industry, media, and the scientific and research community to convert the public and its widespread fear and skepticism towards GM. He said, ***"I want all those here today to play their part. I'll back you all the way. We cannot expect to feed tomorrow's population with yesterday's agriculture."*** He also focused on late blight potato as an example of a GM crop that is very important in the EU, recognizing that late blight potato is a significant problem for growers which require up to 15 fungicide applications per year. This fact creates a heavy toll on burning diesel, soil compaction, and other related negative environmental effects, costing the UK around £60 million to control using insecticides which is not 100 percent effective. Research institutions including Sainsbury Laboratory and BASF have conducted field trials of GM blight-resistant potato in the UK. Once deployed, the Secretary believes that it could deliver both economic and environmental benefits. ***"I'm dismayed by BASF's recent decision to withdraw their Blight Resistant Potato from the EU approvals system. I don't blame BASF. They simply took a commercial decision in response to current market and regulatory conditions. But the fact that those conditions have deteriorated to the point where a potentially economically beneficial and environmentally friendly crop has no prospect of gaining market access should be a wake-up call"*** (Crop Biotech Update, 26 June 2013).

Secretary Paterson's aversion towards the opponents of genetically modified crops who sabotaged the testing of Golden Rice, the vitamin A-enriched GM rice was expressed to a Skynews interview. ***"It's just disgusting that little children are allowed to go blind and die because of a hang-up by a small number of people about this technology. <u>I feel really strongly about it. I think</u>***

***what they do is absolutely wicked"*** (Crop Biotech Update 16 October 2013).

**The UK government Minister for Science, David Willetts** has also called for a relaxation of EU laws for GM/biotech crops food, stating that ***"GM crops can help make agriculture more efficient and also, just as importantly, more sustainable by reducing the use of pesticides and the use of fossil fuels, for example. There are just too many 21st-century technologies that Europe is just being very slow to adopt... one productive way forward is to have this discussion as part of a wider need for Europe to remain innovative rather than a museum of 20th-century technology"*** (Poulter, 2013).

**Africa**

- **Biotech Acceptance and Promise in Africa**

Africa is the most challenging continent for introducing new technologies, such as biotech crops, requiring a critical mass of scientists with state-of-the-art professional expertise and infrastructure/financial resources that can satisfy demanding regulation compliance. Africa uniquely offers a very important advantage that potentially broadens the range of biotech crops and traits, including several important "orphan crops" that reflect the priorities of the poor in developing countries, as opposed to industrial countries.

In 2013, there were three African countries (South Africa, Burkina Faso and Sudan) which commercialized biotech crops. A further seven countries (listed alphabetically, Cameroon, Egypt, Ghana, Kenya, Malawi, Nigeria and Uganda) conducted biotech crop field trials (the penultimate step to approval and commercialization) for a total of ten countries with some activities in biotech crops – that is impressive progress for Africa. Moreover, the current biotech crops and traits in field trials in Africa can significantly expand the potential number of biotech crops and traits adopted and commercialized globally. There are currently nine biotech crops adopted and commercialized globally, listed in Table 53, in descending order of hectarage. There are another 10 "new" biotech crops in field trials in Africa, half of them "orphan" crops listed alphabetically in Table 53: banana, cassava, cowpea, potato, rice, sorghum, sugarcane, sweet potato, tomato and wheat. Thus, Africa has the potential to contribute up to 10 "new" biotech crops, half of them "orphan" crops to the current global number of 9 adopted biotech crops, and thereby more than double the potential global total from 9 to 19. Furthermore, this global list of 19 crops is a much more balanced, inclusive and representative "global list" as a result of including the orphan biotech crops selected as priorities by African countries. Thus, the "new" biotech crops from Africa are very much directly related to food security given that about half of the ten new crops such as banana, cassava, cowpea and sweet potato are "orphan food crops" which are crucially important in the diets of the poor of the world.

Table 53. Biotech Crops Commercialized and in Field Trials in Africa, 2013

| | Current Biotech Crops | Biotech crops in field trials in Africa |
|---|---|---|
| 1 | Soybean | Banana |
| 2 | Maize | Cassava |
| 3 | Cotton | Cowpea |
| 4 | Canola | Potato |
| 5 | Sugar beet | Rice |
| 6 | Alfalfa | Sorghum |
| 7 | Papaya | Sugarcane |
| 8 | Squash | Sweet potato |
| 9 | Poplar | Tomato |
| 10 | -- | Wheat |

Source: Clive James, 2013.

- **Drought Tolerance - WEMA Project Expected to Deliver First Product in 2017**

Encouraging progress is being reported on several fronts in Africa for both drought tolerant conventional and biotech maize, which are complementary. Drought is becoming more important in Africa where 90% of maize is rainfed and rain patterns are becoming increasingly unpredictable as a result of climate change. It is estimated that 25% of maize production in Africa suffers from frequent droughts and an additional 40% is affected by occasional droughts. The DTMA project (Drought Tolerant Maize for Africa) has already released to national programs more than 100 conventional varieties in 13 African countries and over 7,000 tons of drought tolerant maize seeds were produced in 2012. For example, Malawi released three drought tolerant hybrids in 2013 – Malawi 30, 31 and 32 which will contribute to its subsidized maize program, the "Malawi Miracle" (Nemcova, 2013). This program has made Malawi not only self-sufficient in maize but an exporter of maize to neighboring countries.

Simultaneously, field trials under the aegis of the WEMA project (Water Efficient Maize for Africa) project, featuring the genetically modified maize with the MON 87460 event are generating encouraging results. The fourth confined WEMA field trial conducted in Kenya and harvested in May 2013 exhibited superior performance of biotech lines compared to conventional maize lines throughout the growing season (November 2012 to May 2013) and it is expected that yield of the biotech maize will also be superior to the conventional. WEMA lines 18, 36, 41, 50 and 55 are performing particularly well and conventional equivalents of these lines are being entered for the Kenya national performance trials, which is the penultimate step prior to approval and release to national programs and farmers for commercialization. Biosafety workshops for staff from all the WEMA project countries are already underway to train staff in all aspects of regulation compliance for biotech maize in the respective WEMA countries (CIMMYT Informa, 24-31 May, 2013).

- **Nitrogen Use Efficiency (NUE) Maize**

Progress with nitrogen use efficient conventional maize is being reported in CIMMYT's IMAS project (Improved Maize for African Soils). Application of nitrogen fertilizer in sub Saharan Africa is the lowest in the world averaging less than 20 kg per hectare. Because risk averse small farmers grow maize under unpredictable rainfall patterns they are often reluctant to make an additional significant and expensive investment by applying nitrogen in case of a crop failure due to lack of rain. The subsidized price of a 50kg bag of nitrogen in Kenya is US$30 compared with the regular price of US$50. The first selections of IMAS nitrogen efficient maize varieties being tested in southern and eastern Africa are promising and will undergo more rigorous testing. Whereas, nitrogen efficient biotech crops (described in more detail elsewhere in this Brief) is an extremely important goal for Africa for the mid-term, commercialization will take more time than drought tolerant maize, the first products of which are already in advanced WEMA field trials in selected countries including South Africa and Kenya (CIMMYT Informa, 24-31 May 2013).

**Latin America**

- **Supremacy of Brazil in Biotech Crops**

Brazil for the last five consecutive years has shown the largest year-to-year increases in biotech crop hectarage across the globe. The country has emerged to be the second largest grower of biotech crops and this leadership by Brazil is expected to continue in the future with optimal growth in adoption for soybean, maize and cotton and followed by sugarcane. The successful deployment of these biotech crops 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 security. One of the key factors for this success is the presence of EMBRAPA, the Brazilian Agricultural and Livestock Research Company, a dynamic and responsible organization for agricultural research in Brazil. The research institute responds to the agricultural needs of the country by investing resources (US$1 billion annually) in search of new knowledge and technologies, way ahead of other developing countries in Latin America. Dr. Mauricio Lopez, President of EMBRAPA 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."*** Technologies developed in the institute also find their way to partner countries with similar constraints.

In addition, and importantly, political will starting with the administration of former President Lula da Silva including the present administration, as well as the progressive Brazilian farmers believe in the promise and benefits of biotechnology and the contribution it makes to the economic improvement of the country. With climate change and the need to protect the Amazon and other estuaries of the country, 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 with implementation of sustainable intensification ***"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).

- **Approval of the Stacked (HT/IR) Soybean**

The stacked (HT/IR) Intacta soybean was specifically developed for maize grown in the more tropical countries where insect pests are important. The regulatory approval in Brazil was granted as early as August 2010 (CTNBio, 2010) but approval for import by China was protracted . On June 10, 2013, China's Ministry of Agriculture approved the product INTACTA RR2 PRO™, for import along with two other products, BASF's CV127 and Bayer's Liberty Link (Reuters, 10 June 2013). The stacked product has been developed with a Bt gene to combat lepidopteran pests of soybean in South America, including the soybean looper and velvet bean caterpillar. Growers believe that Intacta provides them with three distinct benefits: increased yield potential; protection against major pests that attack soybeans – velvet-bean caterpillar, soybean looper, bean shoot borer, bollworm, corn stalk borer and Helicoverpa; and tolerance to glyphosate herbicide. Intacta occupied a very large 2.5 million hectares in its launch year of 2013 of which 2.2 million hectares was in Brazil with the balance in neighboring countries . The technology probably represents one of the most significant growth drivers in biotech soybean in the tropics and it is estimated that it could deliver benefits to farmers on up to 50 million hectares of soybeans in South America. According to the developers of the technology it is expected to increase yield by up to 10 bushels per hectare or 272 kg per hectare.

In 2013, farmers in Brazil, the number one exporter of soybeans to China, were somewhat anxious by the later than normal approval from China (Agroprofessional, 11 March 2013). However, they also recognized that China has been a loyal and significant importing client of Brazil for many years, with Brazil exporting 5.6 million tons worth US$3 billion in April 2013 alone, accounting for about 78 percent of that month's soybean exports.

- **Home-grown Virus Resistant Bean**

The home-grown biotech resistant bean is an important new biotech crop in Brazil. A severe outbreak of the bean virus disease in early 2013 in the Distrito Federal demonstrated the capacity of the virus to cause catastrophic crop losses. Approximately 70% of bean production was lost due to the golden mosaic virus, valued at approximately US$7 million. Annual losses due to the disease are estimated at 280,000 Metric tons. Insecticide application totaling 12 to 14 per season is an expensive and effective control of the white fly vectors, but does not control the virus disease. It requires only three white flies per plant to effectively transmit the disease.  The golden mosaic virus resistant bean was developed by EMBRAPA for over a decade with an investment of US$3.5 million. RNA interference technology in the biotech bean precludes the synthesis of protein responsible for the viral RNA to replicate in the plant. From 2004 to 2010, green house and field evaluations, and biosafety analysis of the putative transgenic plants were conducted. In 2010, permission was requested for commercial release of this event in Brazil and approved by CTNBio (Brazilian Biosafety Commission) in the same year. 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. For the virus-resistant dry bean, 12 field trials are required for two years in four regions; currently the second year trials are in progress. They are due for completion by January 2014 culminating with initial seed production, prior to commercial seed production by seed companies to supply farmers with commercial seed in early 2015. It is projected that the new biotech virus resistant bean will contribute in three important ways: reduce the need for insecticides from 12 to 14 applications to only 3 applications: increase national bean production by up to 30%; contribute to a more affordable and stable price for beans which recently reached a high of US$5.40 per kilo – equivalent to ~ four times the low price of a year ago. The virus disease is present in other countries in North America, hence providing Brazil an opportunity to share its home-grown technology with neighboring countries.

**North America**

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

Seven selected biotech crops listed in Table 54 are being evaluated using this new process, They include four soybean events with new insect resistant trait, yield, and herbicide tolerance. These new soybean traits address the problem of borer infestation in soybean fields as well as the emergence of glyphosate resistance in some locations. Farmers can now practice rotation of different types of herbicide tolerant soybean to prevent the development of different herbicide resistant weeds. Reduced lignin in alfalfa is a very important trait which increases digestibility in livestock. The other new crops such as apples and potatoes and traits are discussed below.

- **Innate Potato**

The Innate potato dossier for the USA is being considered by APHIS for deregulation (APHIS, 3 May, 2013). **Potatoes are the fourth most important food crop in the world** (after rice, wheat and maize), hence, improved biotech potatoes can play an important role vis-a-vis global food security. Given that potato, is a perishable food product, quality can be negatively impacted by damage to the tubers during harvest, handling and processing (Biology Fortified Inc. 8 May 2013). Innate potatoes are an excellent example of how biotech crops can enhance quality and provide benefits for all stakeholders, growers, processors and consumers. Innate potato was developed using only potato genes, by transferring genes from one potato variety to another. Innate Potato is a safe and

**Table 54. List of Crops and Events at the Enhanced Petition Review Process of APHIS, 2013**

| Applicant | Crop | Phenotype | Event |
|---|---|---|---|
| J.R. Simplot | Potato | Low Acrylamide Potential, Reduced Black Spot Bruise | E12, E24, F10, F37, J3, J55, J78, G11, H37, H50 |
| Monsanto/Forage Genetics | Alfalfa | Reduced Lignin | KK179 |
| Dow | Soybean | Insect Resistant | DAS-81419-2 |
| Syngenta | Soybean | HPPD and Glufosinate Tolerant | SYHT0H2 |
| Monsanto | Soybean | Increased Yield | MON 87712 |
| Okanagan | Apple | Non-Browning | GD743, GS784 |
| BASF | Soybean | Imadazolinone Tolerant | BPS-CV127-9 |

superior product that will confer the following benefits to farmers, processors and consumers:

- Innate potato has lower levels of asparagine, which in turn lowers the potential for production of undesirable acrylamide, when potatoes are boiled.
- They will not discolor and turn brown when cut and exposed to the air, and tubers do not have to be covered with water after peeling.
- There are fewer black spots due to bruising
- Innate potato will store better
- Innate potato will reduce wastage and thus contribute to food security. This is particularly important for a perishable crop like potatoes (especially in developing countries) – it is estimated that up to one-third of all food produced globally is wasted for one reason or another.

Consumer surveys by Simplot indicate that 91% of those surveyed were comfortable with the Innate breeding method. The company expect approval and initial marketing in 2014 and with more seed available in 2015 and 2016 (Capital Press, 14 June 2013).

- **Non-browning Arctic®Apples**

When apples are bruised, cut or sliced, cell walls rupture and this stimulates a chemical reaction between polyphenol oxidase (PPO) and phenolics which results in browning. Arctic apple was developed by a Canadian company, Okanagan Specialty Fruits by limiting the expression of the apple's PPO genes through gene silencing, using low-PPO genes from other apples. Arctic apples produce low levels of PPO and as a result do not brown when cut or sliced. Transformed Arctic apple plantlets are grafted on rootstocks and are cultivated like a regular fruit tree. The product is currently under review by USDA APHIS for de-regulation (Okanagan Specialty Fruits, 22 June 2013). Consumer surveys by Okanagan Speciality Fruits (Capital Press, 14 June 2013) indicate that 78% of those surveyed were comfortable with Arctic apple and only 12% were not likely to buy the product. The company is waiting on approval of the product in the US and Canada.

**Asia**

- **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%. This means that vitamin A availability for all children in undernourished settings could prevent 1.9 to 2.5 million child deaths annually.

After more than a decade, Golden Rice, a biotech rice, genetically-modified to contain enhanced levels of beta carotene, is advancing towards the completion of its regulatory requirements in the Philippines and Bangladesh. In the Philippines, the International Rice Research Institute (IRRI) has successfully bred the Golden Rice traits into IR64 and Asian mega varieties including Philippine and Bangladeshi varieties, PSBRc82 and BRRI dhan 29, respectively. In the wet season of 2010 (September to December), IRRI completed one season of confined field tests of IR64-GR2 and received the certificate of completion from the National Committee on Biosafety of the Philippines. At the Philippine Rice Research Institute (PhilRice), confined field trials of advanced GR2 introgressed lines of PSBRc 82 were conducted from February to June 2011. Selected lines were subjected to multi-location field trials in March 2012 to August 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. Most field and laboratory data have been collected and are now being compiled into a technical dossier for biosafety application. It is 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. Another research effort by the PhilRice scientists is to develop the '3-in-1' rice which incorporates resistance to tungro virus and bacterial blight disease. The researchers have identified promising lines which are being studied further (Antonio A. Alfonso, Personal Communications). In 2012, IRRI scientists have shared advanced breeding lines of Bangladeshi varieties containing the GR traits to the Bangladesh Rice Research Institute (BRRI). These lines have been evaluated under screenhouse conditions and confined field tests are planned (IRRI, 2012).

On August 8, 2013 however, close to 400 activists vandalized one trial site on less than 0.1 hectare field of the Department of Agriculture Regional Field Unit 5's (DA-RFU5) Bicol Experiment Station in Pili, Camarines Sur, by uprooting and trampling on rice plants. Golden Rice project researchers were on the site to meet the farmers who were supposed to conduct a rally and dialogue on biotech rice but instead, they were caught off guard with the swift action of the activists, even the local police who were outnumbered were not able to act. The activists destroyed one of the thirteen multilocational trials started in 2012 in different parts of the Philippines. No adverse environmental effects have been reported on the nine completed trials and the sabotaged GR trial was the third such planting in the same site since March 2012. The scientific data which would have been provided by the trial is the third set of solid observations about the field performance of the Golden Rice.

A media release issued by IRRI on the same day by Dr. Bruce Tolentino, the institute's deputy director expressed the institute's disappointment with the action and stressed the fact that the field trial is a scientific exercise to determine safety and agronomic performance of the selected lines. The different field trials were conducted under the guidance and strict monitoring of the Department of Agriculture–Bureau of Plant Industry, the national regulatory authority in the Philippines for cop biotechnology research and development, after the Department of Science and Technology - National Committee on Biosafety of the Philippines has established that the trials will pose no significant risks to human health and environment. Dr. Tolentino provided assurance that the research on Golden Rice, as well as other nutritionally enhanced rice will continue to improve human nutrition. The Secretary of the Department of Agriculture also affirmed his support to the Golden Rice project while being interviewed on national television the following day (IRRI, 2013).

In 2011, IRRI, PhilRice and BRRI were joined by the Helen Keller International (HKI) institute to assess how the daily consumption of Golden Rice can help reduce vitamin A deficiency. HKI is a leading global health organization that advocates and conducts programs to reduce blindness and prevent malnutrition worldwide over the last 40 years. They have been partnering with governments and other health agencies to reach those most in need through various interventions. Golden Rice has gone through all the safety evaluations that have been appropriate and required at each stage of the project. The researchers are following international and national guidelines for food safety of genetically modified crops, which require an assessment of the nutritional value of Golden Rice and potential toxicity and allergenicity of proteins from the new trans genes. The food safety-related studies that have been completed to date conclude that: 1) Beta carotene in food is a safe source of vitamin A. Beta carotene is found and consumed in may nutritious foods eaten around the world, including fruits and vegetables (Grune et al. 2010); 2) The beta carotene in Golden Rice is the same as the beta carotene that is found in other foods (Paine et al. 2005); and 3) The proteins from the new genes in Golden Rice do not show any toxic or allergenic properties (Goodman et al. 2006).

When Golden Rice is approved by national regulators, the Hellen Keller International will conduct a community-based study in the respective countries to determine if daily consumption of Golden Rice improves vitamin A status among adults. A delivery program will also be developed to ensure that Golden Rice could reach those most in need in vitamin A deficient communities. Golden Rice will be available to farmers and consumers only if it has been determined to be safe for humans, animals, and the environment and authorized for propagation and consumption by the appropriate regulatory authorities (IRRI, 2012).

A notable study to determine the conversion efficiency of beta carotene in Golden Rice was recently conducted in China. Tufts University researchers headed by Guangweng Tang (2012) studied 68 healthy Chinese children, ages 6-8 years old in Hunan province, China. The children were given beta-carotene either in the rice (as GM), in pure form in oil, or in spinach. The beta carotene they received contained isotopes enabling any vitamin A made from it to be distinguished from vitamin A that was already circulating in their blood. Results showed that spinach, GR, and beta carotene in oil capsule can all provide children with vitamin A nutrition. Furthermore, GR is as effective as the pure beta carotene in oil capsule, and both were more effective than spinach at contributing to the vitamin A intake of children. Analyses showed that it took 2.3 grams of beta-carotene derived from rice to make a single gram of vitamin A, slightly less compared to the use of oil which has conversion of 2 grams to 1. The study demonstrated that just 100 to 150 grams of the GM rice – about half the children's daily intake – provided 60% of the recommended daily intake of vitamin A. The paper concluded that, ***The Beta carotene in GR is as effective as pure Beta carotene in oil and better than that in spinach at providing vitamin A to children. A bowl of ~100 to 150g cooked GR (50 g dry weight) can provide ~60% of the Chinese Recommended Nutrient Intake of vitamin A for 6 – 8 old children.***

It is thus apparent that beta carotene enriched rice can overcome deaths due to VAD which numbers 1.9 to 2.5 million annually. This mortality range is higher than mortalities recorded for people with HIV/AIDS (1.8 million), tuberculosis (1.4 million) and malaria (0.7 million), however global expenditures for preventive and curative research to control VAD is much lower at US$15 million, compared to US$8.18 billion for the three diseases (http://www.globalhealthhub.org/2011/03/22/non-cummunicable-disease-and-the-rule-of-rescue/). Therefore, the low expenditure allotted for hunger and malnutrition still does not reflect the high priority given to it by the Copenhagen Consensus of 2012, 2008 and 2004 (http://www.copenhagenconsensus.com/Research/Index/Hunger.aspx). Research on biofortification field remains dramatically underfunded by the global community especially genetically modified biofortified crops. This could be the result of the relative newness of the field, suspicion on genetic engineering, food and environmental safety concerns, and bureaucratic delays. This leads to the reluctance of public, private and philanthropic sectors to support and fully engage in various endeavors for fear of controversy.

Once released, Golden Rice will be able to provide beta carotene fortified carbohydrate staple, providing more than a total of 2,006,869 calories per day to 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) – countries where most VAD occurs (HarvestPlus, Personal Communications). However, the researcher Dr. Guangwen Tang and colleagues were accused by Greenpeace to be using children as guinea pigs for potentially toxic rice. After a thorough investigation by Tufts University's institutional review board, some lapses were indeed committed by Dr. Tang which led to her untimely retirement and closure of her laboratory. But the results of the study was more important as it shows that a single serving of Golden Rice is a very effective source of beta-carotene, the precursor of Vitamin A, as it provides 60% of the recommended intake for children (news.sciencemag.or, September 2013).

Ingo Potrykus (2010), co-inventor of Golden Rice concluded that biotech crops (GM) ***"could save millions from starvation and malnutrition, if they can be freed from excessive regulations."*** He reached this conclusion from his experience over the past 11 years chairing the Golden Rice Humanitarian project (http://www.goldenrice.org), and after a meeting hosted by the Pontifical

Academy of Sciences at the Vatican in 2010 on biotech crops for food security in the context of development (Potrykus and Amman, 2010). **Given that conventional breeding cannot increase Vitamin A, Golden Rice is possible only with biotech crops.** Golden Rice has been stalled for more than ten years because of unnecessary and unjustifiable delays, whilst millions were condemned to suffering. Potrykus concluded that the lag was entirely due to unjustified regulatory processes discriminating against biotech crops versus conventional crops. Hence, Potrykus holds the view that ***"the regulation of genetic engineering is responsible for the death and blindness of thousands of children and young mothers."*** He estimated that it generally takes about ten times more money and ten years longer to bring a biotech crop to market compared to a conventional crop, and de-facto, because of the higher costs, precludes the participation of public research institutions in the development of biotech crops. Biotech crops have enormous potential to alleviate poverty and hunger and contribute to food security in the developing countries of the world.

With all these potential benefits in Golden Rice, still a number of sceptics such as Greenpeace, are conducting an anti-Golden Rice campaign which could further delay the approval and commercialization process. Journalist Margaret Wente (The Globe and Mail, 13 September 2012) expressed her sentiments in her article on "Greenpeace's Golden Rice stand should appall us all". She exposed how Greenpeace and Chinese bloggers negatively played up the Golden Rice trials in China. She said, ***"Are Greenpeace and its allies effectively allowing millions of children to go blind or die when there's a safe solution? The rest of us should be appalled."*** Recently, Ingo Potrykus expressed his hope to live to see how Golden Rice saves lives. He said, ***"I am very much frustrated, offering a technology for free that can save so many children and pregnant mothers. Since the invention of Golden Rice, 2.5 million children are estimated to have died each year from VAD. Around 500,000 go blind each year, of whom 70% die. They wouldn't all have been saved by Golden Rice, but every delay means many unnecessary dead or blind children.....I hope to live long enough to see it through. I was in my mid-50's when I started. It's my 80th birthday in two months' time"*** (New Scientist, 14 October 2013).

Dr. Patrick Moore, co-founder of Greenpeace in his keynote address at the Manitoba Special Crops Symposium in Winnipeg in February 2012 expressed his regrets regarding the slow release of the Golden Rice (Portage Online, 10 February 2012). ***"Other GM rice varieties are able to eliminate micronutrient deficiency in the rice eating countries, which afflicts hundreds of million people, and actually causes between a quarter and half a million children to go blind and die young each year because of vitamin A deficiency because there is no beta carotene in rice,"*** says Moore. ***"We can put beta carotene in rice through genetic modification, but Greenpeace has blocked this."*** He added that this action **"is a crime against humanity"** because they are preventing the curing of people who are dying by the hundreds of thousands a year due to vitamin A deficiency. He also mentioned the positive effect of GM soybeans that produce omega-3 fatty acids not only for humans but also for the aquaculture industry whose fatty acid source is the limited and costly fishmeal.

In 10 September 2012, Dr. Patrick Moore once again criticized Greenpeace in an article published online in climatedepot.com (Climate Depot, 10 September 2012). ***"It is clear by the facts that Greenpeace is guilty of crimes against humanity as defined by the International Criminal Court. They claim that 'Golden Rice is a failure' while they are the ones responsible for preventing the cure that is so desperately needed by millions of civilians. The fact that Greenpeace perpetuate lies about Golden Rice while at the same time doing nothing to solve the problem themselves constitutes gross negligence on top of the crime against humanity."*** The uprooting of the Golden Rice trial stirred numerous sentiments and outpouring of support from the global scientific community. Statements of support by the Department of Agriculture and the PhilRice, as well as the petition of 11 noted scientists on *Global Scientific Community Condemns the Recent Destruction of Field Trials of Golden Rice*. The petition expressed the authors' condemnation of the field trial destruction as well as ***"the use of rumors and misinformation to raise unwarranted fears in vulnerable sectors of the population and to incite anyone to acts of destruction."*** Distributed worldwide, the petition gathered more than 6100 supporters (change. org).

Alexander Stein has written a series of articles on GM rice and some of these have focused on Golden Rice. In one of these, he discussed the Impact and cost-effectiveness of Golden Rice in a representative sample of 120,000 households in India. He said, ***"in a high impact scenario the widespread consumption of Golden Rice in the target groups could reduce the disease burden of VAD in India by almost 60 percent. But even under pessimistic assumptions the burden could still be reduced by almost 10 percent – i.e. over 200,000 "healthy life years" or disability-adjusted life years (DALYs) could be saved. Setting off these gains (in terms of saved lives and improved health) against all the costs needed to make Golden Rice a success (i.e. expenditures for research, breeding, dissemination, public awareness, and others) showed that Golden Rice could prevent the loss of one DALY for less than US$20, even under pessimistic assumptions. In contrast, other vitamin A interventions cost between US$80-US$600 per DALY saved."*** The group used all available information in three years and concluded that, ***"pursuing the development of Golden Rice further is justified"*** (New York Times, 25 August 2013).

Michael Purugganan, Dean of Science, New York University clarified the three myths that make Golden Rice controversial: GR is natural since the genes inserted can be found in other plants; GR and other GMOs are safe based on numerous scientific studies conducted; and there is no big business in GR since its development at IRRI and the NARS were provided with no royalties by Syngenta – the developer of GR2 (acsh.org. 26 August 2013). A number of international media celebrities such as Mark Lynas (Slate), Amy Harmon, (New York Times), David Kroll (Forbes) and contributors from SciDev.net have likewise written exhaustive discourse on Golden Rice and how it will be an additional, more effective and economical measure in combating VAD.

Patrick Moore, a Greenpeace co-founder and advocate for 15 years, led the "Allow Golden Rice Now" group in a grassroots demonstration against Greenpeace on October 11, 2013 near the Greenpeace's ship "Rainbow Warrior" in North Vancouver, Canada. Chanting "Greenpeace be nice, allow Golden Rice" and "Eight million children dead", the group made its way close to the ship carrying a banner that says "Greenpeace's Crime Against Humanity: 8 Million Children Dead." Leaflets and brochures were then handed out to interested onlookers. Patrick Moore said that, ***"the zero tolerance policy towards genetic modification by Greenpeace and its allied has blocked this cure, resulting in 8 million deaths, mostly among poor children. We Believe this is a crime against humanity as defined by the International Criminal Court"*** (acsh.org. 11 October 2013).

Patrick Moore believes that the organization is using its US$300 million plus income to stifle one of the most important advances in human nutrition and disease prevention. Greenpeace-backed the uprooting of Golden Rice field trial in the Philippines and the accused the Chinese scientists in using Chinese children as guinea pigs in the feeding. He said, ***"They claim that there are better ways to cure vitamin A deficiency but they have no program to deliver these supposedly better cures. Greenpeace refuses to listen to the scientists and humanitarians working in the field of nutrient deficiency who to knows that Golden Rice is the best way to deal with this affliction….In my opinion Greenpeace has lost its moral compass"*** (allowgoldenricenow.org, retrieved 26 October 2013).

More than two months after the uprooting of the Golden Rice field trial, Director General of the International Rice Research Institute Dr. Robert Zeigler said that the arguments against Golden Rice are based on ***"abject lies, distortions, and groundless fear."*** Dr. Zeigler believes in the technology because it is safe and has tremendous impact on nutrition of vitamin-A deficient poor countries around the world. He warned that companies with such GM products should not succumb to the extortionists tactics of opponents (IRRI, 2013c). http://oryza.com/news/rice-news/golden-rice-opponents-are-liars-irri-chief-says#sthash.pgQ3uMrM.dpuf

- **Bt Eggplant in Asia**

**Bt Brinjal Approval for Planting in Bangladesh**

Eggplant (*Solanum melongena* L.) is one of the most important indigenous vegetables in India, Philippines and Bangladesh. It is the most popular staple vegetable in these countries and grown commercially in at most 2 hectare farms as well as in backyards. Eggplant 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 implications for producers, consumers and the environment. On 30 October 2013, in a historic decision, Bangladesh approved the official release of four biotech varieties of insect resistant Bt brinjal for seed production and initial commercialization, with planting plans in 2014.

The Bt brinjal project in Bangladesh is an excellent example of a successful public/private sector partnership in technology transfer, underpinned by the full support of Government which has provided the critical "political will" that is absolutely essential for success. The Government and more specifically the Ministers involved should be applauded for their unfailing support which has resulted in a project that is exemplary and can be a model for other developing countries.

### Bt Eggplant Court Ruling in the Philippines

In May 2013, the special 13th division of the court of appeals of the Philippines in judgment on a "Writ of Kalikasan", ordered the permanent stoppage of all field experiments of the biotech crop product, Bt eggplant (called talong in the Philippines). Following the court judgment there have been very strong critical comments, from the Filipino and international scientific community. A very critical response to the Court judgement was published by the former President of the University of the Philippines, and former President of the Philippine National Academy of Science and Technology, Dr. Emil Javier (Business Mirror, 8 June 2013).

In his response to the court judgment to discontinue field trials of Bt eggplant in the Philippines, Dr. Javier noted that it was ***"a pitiful day for Filipino consumers and farmers, a huge setback to the struggling science community, and a serious curtailment of the academic freedom of the University of the Philippines. Dr. Javier concluded that the court judgment 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 (eggplant) research was trying to accomplish. Bt eggplant is resistant to the fruit borer and need not be sprayed, thus reducing the hazard to human health, reducing pollution of the environment, not to mention costs to the small farmers, and ultimately the food price to the consumers."*** Dr. Javier stressed that the Bt gene that conferred insect pest resistance in eggplant was safe, approved for use in organic agriculture and over the last 17 years had been deployed on hundreds of millions of hectares of maize, and cotton, in more than 25 countries worldwide without a single incident on biosafety. In fact, he noted that Filipino farmers have successfully planted and benefited from Bt maize for a decade without incident. He stressed that concern for the environment of the Special Division of the Court of Appeals was misinformed and misplaced.

Unfortunately, this Writ against Bt talong (eggplant) trials may also negatively impact research in the Philippines on other important crops. He noted 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. In other words, varieties developed using genetic engineering technologies are equivalent, or even safer, to those varieties using conventional plant breeding."*** He observed that biotech crops were ***"one advanced technology where Filipino scientists are holding their own in global competition. Sadly, all these Filipino-brand GMOs will be stillborn if this misapplication of the Writ of Kalikasan is not reversed. Between a known health and environment hazard from the overuse of chemical pesticide versus speculation of risk from a gene from a common soil organism being transferred to other unspecified living things, the Court should have not succumbed to the fear of the unknown being sown by GMO opponents".***

Reaction from the international community is equally critical (Ropeik, 2013). Ropeik concluded that the court's decision was an ***"astonishing leap beyond reason".*** Firstly, the court judged that GMO foods were *"an alteration of an otherwise natural state of affairs in our ecology".* Ropeik opines that the assumption that a natural state of affairs exists is utopian and naïve and poses the question ***"imagine what society would have to forego if this standard was consistently applied across all of what modern human life involves."***

Secondly, Ropeik questions the Courts' judgment that Bt eggplant field trials ***"could not be declared safe to human health and to our ecology with full scientific certainty."*** Ropeik concludes that this statement by the court ***"adopts a preposterously severe version of the Precautionary Principle."*** Again, Ropeik poses the pragmatic critical question ***"imagine what that appealing but ludicrous standard – absolute scientific proof of safety – would do if applied against most of how we live our modern lives."***

Ropeik warns that there are profound risks associated with policy makers and courts making decisions which ignore scientific evidence on GM crops which could impact on other court rulings involving GMOs that are ***"more idealistic than realistic, more naive than achievable and enshrine in law a deep ecology utopianism about nature that denies society all the solutions that modern science and technology have to offer."***

## CLOSING COMMENTS

### The Impact of the 2013 World Food Prize's Recognition of Biotechnology's Contribution to Food, Feed and Fiber Security

The World Food Prize (WFP) is the foremost international foundation that recognizes accomplishments of individuals who have advanced human development by improving the quality, quantity, or availability of food in the world. The 2013 Laureates are three biotechnologists who have independently discovered molecular techniques for genetically engineering improved crops.

As the founder of the World Food Prize and a strong advocate of biotech/GM crops, Norman Borlaug, Nobel Peace Prize Laureate in 1970 had expressed his views to the WFP Foundation that biotechnologists should not be excluded from consideration as World Food Prize Laureates because of the controversy surrounding GM crops. He contended that they should be considered on their own merit and judged by their contribution to global food security and the alleviation of poverty.

Borlaug would have been pleased with the decision to award the 2013 World Food Prize to three internationally recognized biotechnologists, whom he knew personally and respected: Marc Van Montagu, Mary-Dell Chilton and Robert Fraley, who have all made important contributions in their respective areas of crop biotechnology. *"The three Laureates have in their own unique ways established the science behind the transfer of genes from other species to the target crops through Agrobacterium tumefaciens in the late 1970's. Marc Van Montagu and colleague Jeff Schell were the first to discover in 1974 that the bacteria carries a Ti-plasmid (plant tumor-inducing plasmid). They did a thorough study on its structure and function which led to the stable transfer of foreign genes into plants. Mary-Dell Chilton and her research team discovered that there is a segment in this plasmid, the Transfer-DNA (T-DNA) that is processed and transferred into the genome of the infected plant cell. Her work provided evidence that plant genomes could be manipulated more precisely than in conventional plant breeding. Robert Fraley and his team's research works were built on the advances made by Van Montagu and Chilton. The team was able to isolate a bacterial marker gene, which was expressed in plant cells. This became the scientific basis of the development of Roundup Ready soybeans"* (WFP website, 2013).

*"The work of the three Laureates became the foundation of plant cell transformation technologies that enabled the development of a host of genetically-enhanced crops with improved yields; resistance to insects and disease; and tolerance against extreme variations in climate. Their combined achievements have contributed significantly to increasing the quantity and availability of food, and can play a critical role as we face the global challenges of the 21st century of producing more food in a sustainable way, while confronting an increasingly volatile climate."*

It is noteworthy that the 2013 World Food Prize served as a unique global forum to stimulate and encourage professional debate, and to increase the awareness of both the scientific community and the public about the formidable challenge of food security and the current and future contributions that biotechnology can make to help feed the world of tomorrow with a population of 9 billion in 2050.

The three 2013 Laureates were of the unanimous view **that sharing knowledge and communicating with the Public on biotech crops was the top priority.** ISAAA is of the same view and initiated its extensive global knowledge-sharing activities with the public more than ten years ago (2000). ISAAA's flagship publication, the Annual Brief on the **"Global Status of Commercialized Biotech/GM Crops", authored for the last 17 years by Dr. Clive James,** is the most quoted publication on biotech crops globally. The major messages from the Brief typically reach up to an unprecedented 3 billion people in ~50 countries and languages. Knowledge-sharing is achieved through multi-media channels, thereby reaching a remarkably large number and broad range of stakeholders from global society at large. Other ISAAA complementary activities, organized by the **Global Knowledge Center (KC)** in knowledge-sharing include its active user-friendly website with various educational/learning materials, including, videos, and infographics, as well as its weekly newsletter **"Crop Biotech Update"** distributed to subscribers in 140 countries. In addition, ISAAA organizes a continuing series of workshops in developing countries to meet the multiple and changing needs of policy makers, regulators and other stakeholders in crop biotechnology. ISAAA, like the three Laureates, believes that knowledge-sharing is key to increasing biotech crop understanding, acceptance and adoption globally.

The three Laureates were also in agreement on several other topics, including the following:

- Biotech crops generate food, feed and fiber products that are as safe, or safer, than conventional crops
- Biotech crops generate significant and multiple agronomic, environmental, economic and humanitarian benefits
- Biotech crops contribute to food security
- Biotech crops can help mitigate the new challenges, associated with climate change, such as more frequent and more severe droughts
- In contrast to the first generation products which concentrated on protection from insect pests and weeds, the second generation of biotech crops will feature quality and nutritional traits such as Golden rice, which can deliver humanitarian benefits

All three Laureates were of the general view that labelling was not required because the products are safe and hence mandatory labelling was not necessary. Individual views varied from no support, to voluntary labelling.

The 2013 World Food Prize and the Borlaug dialogue have contributed in a unique and significant way towards an increased measure of consensus by the scientific community and the public about major issues that have been debated for over a decade or more. For example, there has been some indication of a shift in public sentiment and an increased trust in science-based assessments that confirm that foods from biotech products are safe and that significant productivity and environmental benefits have accrued to both producers and consumers. Similarly, a shift in public support of not denying Golden Rice to millions of malnourished children, who otherwise are condemned to suffer permanent blindness and death, is evident, as Patrick Moore's new and successful moral campaign **"Allow Golden Rice"** in support of Golden Rice has progressed.

The views of the UK Secretary of State for Environment, Food and Rural Affairs, the Hon. Owen Patterson, has gained momentum and support in Europe and worldwide. The science-based and transparent counsel of the Scientific Advisor to the EU, Dr. Anne Glover, has gained the confidence of the scientific community in Europe and society world-wide; this is welcome in an EU environment viewed by non–Europeans as largely influenced by ideology, rather than science. In the view of some Africans this is often to the detriment of African countries, blocked from accessing the technology because of a threat to the loss of food export markets to the EU.

Coincidentally, in some developing countries more "political will" in support of biotech crops is evident. This is so, even in very poor developing countries like Bangladesh, where the Government and its Ministers are to be applauded for approving Bt eggplant on 30th October 2013 (MOEF, 2013), recognizing the massive benefits to small farmers, consumers and the environment resulting from quantum decreases in the use of pesticides on a food crop. On average, the fruit and shoot borer insect pest alone, reduces yield by two-thirds (Rahman, et al. 2002; 2009). Thus, farmers are left no choice except to attempt control with a cocktail of insecticides, which are ineffective. Farmers are often forced to apply insecticides every other day, in some cases totalling up to ~80 sprays per season, at an unacceptable environmental cost and an unaffordable price of up to ~US$180/hectare (Kabir et al. 1996 and Meherunnahar and Paul, 2009). These are totally unacceptable consequences for small poor farmers, their families, the environment and consumers, who unknowingly purchase and consume eggplants that have often been totally immersed in insecticides prior to sale in local markets.

Islam and Norton (2007) estimated that Bt brinjal increases yield by at least 30% and reduces insecticide applications and cost by 70-90%, with a net economic benefit of US$1,868 per hectare, which is a princely sum for the small extremely poor farmers of Bangladesh. 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 Bangladesh. Similar benefits can accrue in India and the Philippines where eggplant, known as the "queen of the vegetables", is very important. Unfortunately ideological, political and legal obstructions preclude a common-sense decision in both countries to adopt Bt eggplant which can deliver an improved, safer and more affordable food product in a win–win situation that can benefit the environment, producers and consumers alike.

There are indications in the developing countries that the debate on biotech crops maybe getting closer to a "tipping point" in favour of the technology, as more developing countries adopt biotech crops and are already planting more hectares than industrial countries. A critical mass of "political will" will be required in developing countries to facilitate and accelerate approval and adoption of biotech crops in Asia, Africa and to a lesser extent in Latin America, where most countries have already adopted biotech crops and are benefiting from their attributes. Brazil is the remarkable engine of growth globally, in terms of development and adoption. It also has credibility because it has the proven capacity to generate its own home-grown biotech crops. Furthermore, it is setting an excellent example by indicating its willingness to freely share its rich experience with other countries in the South, particularly African countries, in the spirit of south-south cooperation and partnership.

**Future Prospects**

In 2013, as expected, growth continued to plateau for the principal biotech crops in industrial countries and in mature biotech crop markets in developing countries where adoption rates are sustained at an optimal rate of ~90%, leaving little or no room for expansion. Growth in adoption in less mature biotech crop markets in developing countries, such as Burkina Faso (>50% growth in 2013) and Sudan (>300% growth in 2013) was very strong in 2013, and for the fifth consecutive year, Brazil posted an impressive 3.7 million hectare increase, equivalent to a 10% growth between 2012 and 2013.

In the scientific community associated with biotechnology, there is cautious optimism that biotech crops, including both staple and orphan crops, will be increasingly adopted by society, particularly by the developing countries. This is where the task of feeding its own people is formidable, given that the global population, most of whom will be in the South, will exceed 10 billion by the turn of the century in 2100. **We cannot feed the world of tomorrow with yesterday's technology.**

Whereas rice is the most important food crop in China, maize is the most important feed crop. Over 35 million hectares of maize is grown in China by an estimated 100 million maize-growing households (~400 million potential beneficiaries based on 4 per family). Phytase maize, which confers increased phosphate uptake in animals is reported to increase the efficiency of meat production – an important new and growing need, as China becomes more prosperous and consumes more meat which requires more expensive imports of maize. China has ~500 million pigs (~50% of the global swine herd) and ~13 billion chickens, ducks and other poultry which need feeds. Given the significant increased demand for maize and rising imports, biotech maize, as a feed crop, may be the first to be commercialized by China and is consistent with the flavored chronology of fiber, feed and food. A group of over 60 senior scientists in China recently reiterated the strategic importance of commercializing biotech crops to the country and its commitment to ensure safe testing of the products before deployment. Biotech phytase maize was approved for biosafety in China on 27 November 2009. Other maize producing countries in Asia, including Indonesia and Vietnam, have field tested HT/Bt maize and are likely to commercialize in the near-term possibly by 2015.

Subject to regulation, another very important product for Asia is Golden Rice which should be ready for release to farmers by 2016 in the Philippines. Bangladesh has also assigned high priority to the product. Golden Rice is being developed to address Vitamin A Deficiency which results in ~2.5 million children a year dying with an additional 500,000 becoming permanently blind. Patrick Moore has opined that denying Golden Rice to malnourished dying children is **"a crime against humanity'** – the moral imperative for Golden Rice is beyond question.

In the Americas the increased adoption of biotech drought tolerant maize and transfer of this technology to selected countries in Africa will be important, as well as the adoption of the virus resistant bean developed by EMBRAPA in Brazil and scheduled for deployment in 2015. The stacked soybean launched in 2013 is expected to reach high adoption rates in Brazil and some neighboring countries in the near-term.

In Africa there are three countries, South Africa, Burkina Faso and Sudan already successfully commercializing biotech crops and the hope is that several of the seven additional countries currently field testing biotech crops will graduate to commercialization. The early predominant products that will likely feature are the well-tested biotech cotton and maize, and subject to regulatory approval, the very important WEMA drought tolerant maize scheduled for 2017. Hopefully, one of several orphan crops such as the insect resistant cowpea will also be made available in the near--term so that farmers can benefit from them as early as possible.

Whereas biotech crops are considered essential as one element (including non-transgenic biotech genome editing tools [such as ZFN-Zinc Finger Nucleases and TALENS - Transcription Activator-Like Effector Nucleases], to increase precision and speed) in a crop improvement program, they 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. Finally, it is important to note that more modest annual gains, and continued plateauing, are predicted for the next few years. This is due to the already optimal (>90%) adoption rates for the principal biotech crops in both industrial and developing countries, leaving little or no room for expansion.

Several countries are gearing up for commercializing biotech crops in 2014 and beyond, these are: Bangladesh's Bt eggplant and Panama's Bt maize, both approved for cultivation in 2013;

Indonesia's drought tolerant sugarcane approved for cultivation for food in 2013; and Russia and Ukraine indicating an intent in setting up new regulation structures to deal with GM crops commercialization.

As more countries approve biotech crops, the potential hectares will grow for medium hectarage crops (such as sugarcane at 25 million hectares) and particularly for larger hectarage crops (such as rice at 163 million hectares, and wheat at 217 million hectares). Increased growth in hectares will also be facilitated by a growing portfolio of products from both the public and private sectors and the events will increasingly feature quality traits for improved health and well-being.

### Norman Borlaug's Legacy and Advocacy of Biotech Crops

It is fitting to close this chapter on "Future Prospects" of biotech crops with a reminder of the counsel of the late 1970 Nobel Peace Laureate, Norman Borlaug, on biotech/GM crops whose birth centenary will be 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.

***"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).

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# Appendices

## Appendix 1. Global Crop Protection Market, 2012

| US$M | Herbicides | Insecticides | Fungicides | Others | Biotech | Total |
|---|---|---|---|---|---|---|
| North America | 7,503 | 1,987 | 1,473 | 613 | 10,441 | 21,568 |
| West Europe | 3,586 | 1,367 | 3,484 | 676 | 32 | 9,146 |
| East Europe | 1,079 | 577 | 586 | 126 | 6 | 2,374 |
| Japan | 1,330 | 1,290 | 1,049 | 120 | 0 | 3,789 |
| Australia | 1,303 | 490 | 278 | 80 | 36 | 2,187 |
| **Industrial Countries** | **14,351** | **5,711** | **6,870** | **1,616** | **10,515** | **39,064** |
| Latin America | 5,366 | 3,394 | 3,529 | 578 | 3,011 | 15,878 |
| Rest of Far East | 1,962 | 2,145 | 2,049 | 205 | 398 | 6,759 |
| Rest of World | 930 | 1,728 | 875 | 111 | 664 | 4,307 |
| **Developing Countries** | **8,258** | **7,267** | **6,453** | **894** | **4,073** | **26,944** |
| **Total** | **22,609** | **12,978** | **13,323** | **2,510** | **14,588** | **66,008** |

Source: Cropnosis Agrochemical Service, 2013

## Appendix 2a. Seed Exports (FOB) of Selected Countries, 2011 (with over 100 Million US$ Market)*

| Country | Field Crops | Vegetable Crops | Total |
|---|---|---|---|
| France | 1,232 | 366 | 1,616 |
| Netherlands | 256 | 1,146 | 1,476 |
| USA | 813 | 507 | 1,394 |
| Germany | 638 | 73 | 745 |
| Hungary | 374 | 18 | 392 |
| Chile | 218 | 131 | 380 |
| Italy | 198 | 118 | 319 |
| Denmark | 232 | 46 | 280 |
| Canada | 256 | 3 | 259 |
| Romania | 214 | 0 | 214 |
| Belgium | 203 | 4 | 209 |
| China | 75 | 105 | 195 |
| Mexico | 175 | 19 | 194 |
| Argentina | 170 | 17 | 187 |
| Brazil | 161 | 11 | 172 |
| Spain | 99 | 64 | 163 |
| Others | 1,065 | 681 | 1,792 |
| **Total** | **6,379** | **3,909** | **9,987** |

## Appendix 2b. Seed Imports (FOB) of Selected Countries, 2011 (with over 100 Million US$ Market)**

| Country | Field Crops | Vegetable Crops | Total |
|---|---|---|---|
| USA | 523 | 318 | 908 |
| Germany | 595 | 97 | 714 |
| France | 522 | 150 | 683 |
| Netherlands | 250 | 330 | 628 |
| Italy | 231 | 177 | 417 |
| Russian Federation | 312 | 70 | 387 |
| Spain | 185 | 195 | 384 |
| Mexico | 123 | 215 | 338 |
| Ukraine | 298 | 30 | 328 |
| United Kingdom | 209 | 83 | 308 |
| China | 113 | 114 | 237 |
| Canada | 128 | 78 | 221 |
| Japan | 93 | 94 | 206 |
| Belgium | 155 | 29 | 187 |
| Poland | 119 | 45 | 166 |
| Turkey | 60 | 104 | 166 |
| Romania | 128 | 17 | 147 |
| Hungary | 116 | 20 | 137 |
| Brazil | 46 | 64 | 113 |
| Others | 1,475 | 922 | 3,423 |
| **Total** | **5,681** | **3,152** | **9,098** |

Source: International Seed Federation, 2011
*http://www.worldseed.org/cms/medias/file/ResourceCenter/SeedStatistics/SeedExports/Seed_Exports_2011.pdf
**http://www.worldseed.org/cms/medias/file/ResourceCenter/SeedStatistics/SeedImports/Seed_Imports_2011.pdf

**Appendix 3. 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 | 4.0 | 15.2 | 0.26 |
| Thailand | 15.3 | 68.1 | 0.22 |
| Laos | 1.4 | 6.7 | 0.20 |
| India | 174.5 | 1,214.5 | 0.14 |
| Pakistan | 21.3 | 184.8 | 0.11 |
| Indonesia | 24.8 | 232.5 | 0.10 |
| North Korea | 2.3 | 24.7 | 0.09 |
| China | 112.8 | 1,354.1 | 0.08 |
| Vietnam | 6.7 | 89.0 | 0.08 |
| Timor-Leste | 0.1 | 1.2 | 0.08 |
| Malaysia | 1.8 | 27.9 | 0.07 |
| Nepal | 2.3 | 30.4 | 0.07 |
| Philippines | 5.4 | 93.6 | 0.06 |
| Bangladesh | 8.4 | 164.4 | 0.05 |
| Sri Lanka | 1.2 | 21.7 | 0.05 |
| Myanmar | 1.0 | 55.2 | 0.02 |
| **Reference Countries** | | | |
| Australia | 46.9 | 21.5 | 2.2 |
| South Korea | 1.6 | 48.5 | 0.03 |
| Japan | 4.5 | 127.0 | 0.03 |
| Argentina | 31.3 | 40.7 | 0.7 |
| South Africa | 14.5 | 50.5 | 0.29 |
| Brazil | 61.3 | 195.4 | 0.3 |
| USA | 166.8 | 317.0 | 0.5 |

## Appendix 5. Estimated Population of the 27 Biotech Countries in 2050, 2100

| | Country | Population in 2013* | Estimated Population in 2050** | Estimated Population in 2100** |
|---|---|---|---|---|
| 1 | USA | 317.6 | 403.1 | 446.4 |
| 2 | Brazil | 195.4 | 222.8 | 177.3 |
| 3 | Argentina | 40.7 | 50.6 | 49.2 |
| 4 | India | 1,214.5 | 1,692.0 | 1,551.0 |
| 5 | Canada | 33.9 | 43.6 | 48.3 |
| 6 | China | 1,354.1 | 1,295.6 | 941.0 |
| 7 | Paraguay | 6.7 | 10.3 | 11.4 |
| 8 | South Africa | 50.5 | 56.8 | 54.5 |
| 9 | Pakistan | 184.8 | 274.8 | 261.3 |
| 10 | Uruguay | 3.4 | 3.7 | 3.6 |
| 11 | Bolivia | 10.5 | 16.8 | 20.0 |
| 12 | Philippines | 93.6 | 155.0 | 177.8 |
| 13 | Australia | 21.5 | 31.3 | 35.9 |
| 14 | Burkina Faso | 16.5 | 46.7 | 96.4 |
| 15 | Myanmar | 52.8 | 55.3 | 46.9 |
| 16 | Spain | 45.3 | 51.3 | 45.0 |
| 17 | Mexico | 110.6 | 144.0 | 127.1 |
| 18 | Colombia | 46.3 | 61.8 | 58.1 |
| 19 | Sudan | 33.0 | 91.0 | 127.6 |
| 20 | Chile | 17.1 | 20.1 | 17.2 |
| 21 | Honduras | 8.6 | 13.0 | 13.8 |
| 22 | Portugal | 10.7 | 9.4 | 6.8 |
| 23 | Cuba | 11.2 | 10.0 | 7.0 |
| 24 | Czech Republic | 10.4 | 10.6 | 10.3 |
| 25 | Costa Rica | 4.7 | 6.0 | 5.0 |
| 26 | Romania | 21.2 | 18.5 | 14.8 |
| 27 | Slovakia | 5.4 | 5.2 | 4.5 |
| | World | 6,908.7 | 9,306.1 | 10,124.9 |

Source:
* Pocket World in Figures 2013, The Economist
** United Nations, Department of Economic and Social Affairs - Population Division, Population Estimates and Projections Section - World Population Prospects, the 2010 Revision

## Appendix 6. 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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