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INTERNATIONAL SERVICE FOR THE ACQUISITION OF AGRI-BIOTECH APPLICATIONS

ISAAA Briefs

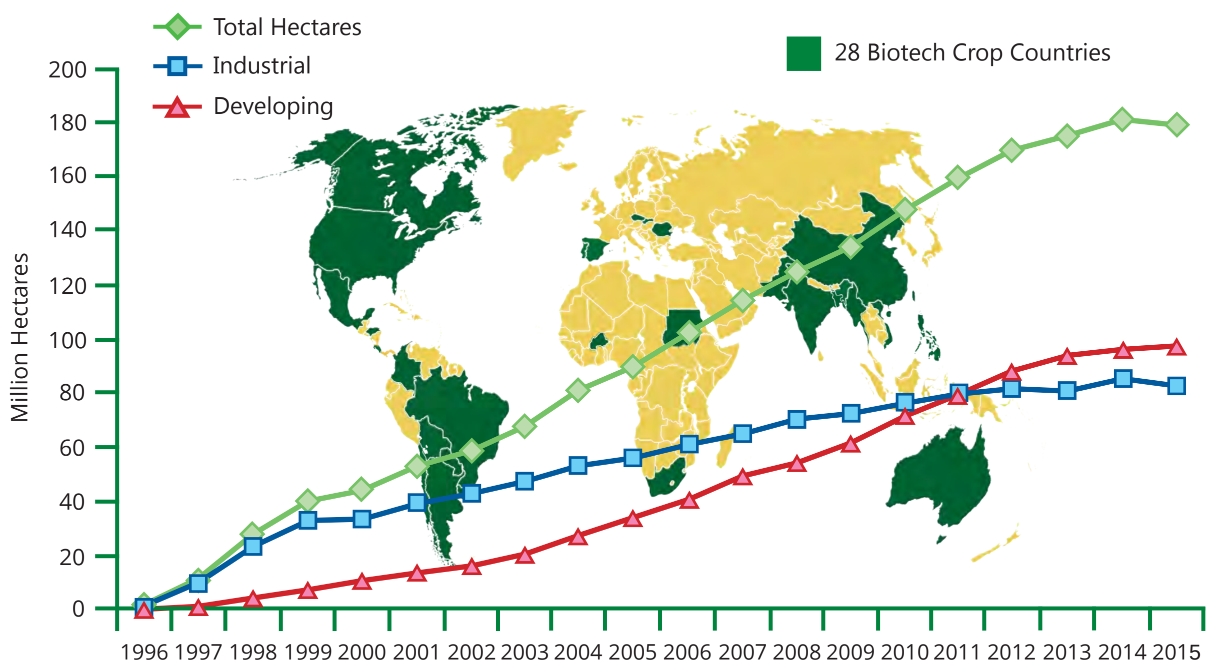
BRIEF 51
20th Anniversary (1996 to 2015) of the Global Commercialization of Biotech Crops and Biotech Crop Highlights in 2015

By

Clive James
Founder and Emeritus Chair of ISAAA

The author has dedicated Brief 51, 2015, to his mentor and colleague, the late Nobel Peace Laureate Norman Borlaug, who was also the founding patron of ISAAA

GLOBAL AREA OF BIOTECH CROPS
Million Hectares (1996-2015)



Up to ~18 million farmers, in 28 countries planted 179.7 million hectares (444 million acres) in 2015, a marginal decrease of 1% or 1.8 million hectares (4.4 million acres) from 2014.

Source: Clive James, 2015.

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AUTHOR'S NOTE:

Global totals and subtotals of millions of hectares planted with biotech crops have been rounded off 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 2015 information for Argentina, Brazil, Australia, South Africa, and Uruguay is hectares usually planted in the last quarter of 2015 and harvested early in 2016 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 2015 and more intensively through January and February 2016 is classified as a 2015 crop in this Brief consistent with a policy which uses the first date of planting to determine the crop year. In the interest of uniformity, continuity, and comparability, wherever possible ISAAA utilizes the same published data source annually; for example, for Brazil the August biotech reports of Celeres are used; similarly, for the US, the USDA/NASS crop acreage reports published on 30 June annually are used. ISAAA is a not-for-profit organization, sponsored by public and private sector organizations. All biotech crops hectare estimates reported in all ISAAA publications are only counted once, irrespective of how many traits are incorporated in the crops. Importantly, all reported biotech crop hectares are for officially approved and planted products, and do not include unofficial plantings of any biotech crops. At the time when this Brief went to press, the estimates of economic benefits, productivity, land-saving, carbon data and pesticide data were for 1996-2014 (Brookes and Barfoot, 2016), and thus, are under estimates for the 20 year period 1996-2015. Details of the references listed in the Executive Summary are found in the full Brief 51.

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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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ISAAA *SEAsia*Center
c/o IRRI
DAPO Box 7777
Metro Manila, Philippines

Info on ISAAA: For information about ISAAA, please contact the Center nearest you:

ISAAA *Ameri*Center
105 Leland Lab
Cornell University
Ithaca NY 14853, U.S.A.

ISAAA *Afri*Center
PO Box 70, ILRI Campus
Old Naivasha Road
Uthiru, Nairobi 00605
Kenya

ISAAA *SEAsia*Center
c/o IRRI
DAPO Box 7777
Metro Manila
Philippines

Electronically: or email to info@isaaa.org

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20th Anniversary of the Global Commercialization of Biotech/GM Crops: 1996 to 2015

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 their First 20 Years, 1996 to 2015

FACT # 1. 2015 marked the 20th year of the successful commercialization of biotech crops. An unprecedented cumulative hectarage of 2 billion hectares of biotech crops, equivalent to twice the total land mass of the US (937 million hectares), were successfully cultivated globally in up to 28 countries annually, in the 20 year period 1996 to 2015; farmer benefits for 1996 to 2015 were conservatively estimated at over US$150 billion. Up to ~18 million risk-averse farmers benefitted annually, of whom, remarkably, 90% were small resource-poor farmers in developing countries.

FACT # 2. Progress with adoption in the first 20 years. Following a remarkable run of 19 years of consecutive yearly growth from 1996 to 2014, the annual global hectarage of biotech crops peaked at 181.5 million in 2014, compared with 179.7 million hectares in 2015, equivalent to a net marginal year-to-year decrease of 1.0% between 2014 and 2015. Some countries increased their total plantings, whilst others reduced their hectarage principally due to the current low prices of commodity crops; these hectarage decreases are likely to revert to higher hectarage levels when crop prices improve. The global hectarage of biotech crops increased 100-fold from 1.7 million hectares in 1996 to 179.7 million hectares making biotech crops the fastest adopted crop technology in recent times.

FACT # 3. For the 4th consecutive year, developing countries planted more biotech crops. In 2015, Latin American, Asian and African farmers collectively grew 97.1 million hectares or 54% of the global 179.7 million biotech hectares (versus 53% in 2014) compared with industrial countries at 82.6 million hectares or 46% (versus 47% in 2014); this trend is likely to continue. Of the 28 countries planting biotech crops in 2015, the majority, 20, were developing and 8 industrial.

FACT # 4. Stacked traits occupied ~33% of the global 179.7 million hectares. Stacked traits are favored by farmers for all 3 major biotech crops. Stacked traits increased from 51.4 million hectares in 2014 to 58.5 million hectares in 2015 – an increase of 7.1 million hectares equivalent to a 14% increase. 14 countries planted stacked biotech crops with two or more traits in 2015, of which 11 were developing countries. Vietnam planted a stacked biotech Bt/HT maize as its first biotech crop in 2015.

FACT # 5. Selected highlights in developing countries in 2015. Latin America had the largest hectarage, led by Brazil, followed by Argentina. In Asia, Vietnam planted for the first time, and Bangladesh's **political will**, advanced planting of Bt eggplant and identified, Golden Rice, biotech potato and cotton as future biotech targets. The Philippines, has grown biotech maize successfully for 13 years, and is appealing a recent Supreme Court decision on biotech crops, whilst Indonesia is close to approving a home-grown drought-tolerant sugarcane. China continues to benefit significantly from Bt cotton (US$18 billion for 1997 to 2014), and notably ChemChina recently bid US$43 billion for Syngenta. In 2015, India became the #1 cotton producer in the world, to which Bt cotton made a significant contribution – benefits for the period 2002 to 2014 are estimated at US$18 billion. Africa progressed despite a devastating drought in South Africa resulting in a decrease in intended plantings of ~700,000 hectares in 2015 – a massive 23% decrease. This underscores yet again the life-threatening importance of drought in Africa, where fortunately, the WEMA biotech drought-tolerant maize is on track for release in 2017. Sudan increased Bt cotton hectarage by 30% to 120,000 hectares in 2015, whilst various factors precluded a higher hectarage in Burkina Faso. In 2015, importantly, 8 African countries field-trialled, pro-poor, priority African crops, the penultimate step prior to approval.

FACT # 6. Major developments in the US in 2015. Progress on many fronts including: several "firsts" in approvals and commercializations of "new" GM crops, such as Innate™ potatoes and Arctic® Apples; commercialization of the first non-transgenic genome-edited crop, SU Canola™; first time approval of a GM animal food product, GM salmon, for human consumption; and increasing R&D use of the powerful genome editing technology, named CRISPR (Clustered Regularly Interspersed Short Palindromic Repeats); high adoption of first biotech drought tolerant maize (see below). Dow and DuPont merged to form DowDuPont.

FACT # 7. High adoption of the first biotech drought-tolerant maize planted in the US. Biotech DroughtGard™ maize, first planted in the US in 2013, increased 15-fold from 50,000 hectares in 2013 to 810,000 hectares in 2015 reflecting high farmer acceptance. The same event has been donated to the public private partnership WEMA (Water Efficient Maize for Africa), aimed at the timely delivery of a biotech drought tolerant maize to selected countries in Africa by 2017.

FACT # 8. Status of biotech crops in the EU. The same five EU countries continued to plant 116,870 hectares of Bt maize, down 18% from 2014. Hectares decreased in all countries due to several factors including, less maize planted, disincentives for farmers with onerous reporting.

FACT # 9. Benefits offered by biotech crops. A global meta-analysis of 147 studies for the last 20 years reported that ***"on average GM technology adoption has reduced chemical pesticide use by 37%, increased crop yields by 22%, and increased farmer profits by 68%"*** (Qaim et al, 2014). These findings corroborate results from other annual global studies (Brookes et al, 2015). From 1996 to 2014, biotech crops contributed to Food Security, Sustainability and the Environment/Climate Change by: increasing crop production valued at US$150 billion; providing a better environment, by saving 584 million kg a.i. of pesticides; in 2014 alone reducing CO_2 emissions by 27 billion kg, equivalent to taking 12 million cars off the road for one year; conserving biodiversity by saving 152 million hectares of land from 1996-2014; and helped alleviate poverty for ~16.5 million small farmers and their families totaling ~65 million people, who are some of the poorest people in the world. Biotech crops are essential but are not a panacea – adherence to good farming practices such as rotations and resistance management, are a must for biotech crops as they are for conventional crops.

FACT # 10. Future Prospects. Three domains merit consideration. **Firstly**, high rates of adoption (90% to 100%) in current major biotech markets **leave little room for expansion**; however, there is a significant potential in other "new" countries for selected products, such as biotech maize, which has **a potential of at least ~100 million hectares globally**, 60 million ha in Asia (35 million ha in China alone), and 35 million ha in Africa. **Secondly**, there **are more than 85 potential new products in the pipeline** now being field-tested, the penultimate step to approval. They include the WEMA-derived biotech drought tolerant maize expected to be released in Africa in 2017, Golden Rice in Asia, and fortified bananas and pest resistant cowpea look promising in Africa. Institutionally, public-private partnerships (PPP) have been successful in developing and delivering approved products to farmers. **Thirdly**, the advent of genome-edited crops may be the most important development identified by today's scientific community. **A recent and promising application is the powerful technology, named CRISPR.** Many well-informed observers are of the view that genome editing offers a timely and powerful unique set of significant comparative advantages over conventional and GM crops in four domains: **precision, speed, cost and regulation**. Unlike the onerous regulation that currently applies to transgenics, genome-edited products logically lend themselves for science-based, fit-for-purpose, proportionate, and non-onerous regulation. A **forward-looking strategy has been proposed** (Flavell, 2015) **featuring the troika of transgenes, genome editing and microbes** (the use of plant microbiomes as a new source of additional genes to modify plant traits) **to increase crop productivity, in a "sustainable intensification" mode, which in turn can viably contribute to the noble and paramount goals of food security and the alleviation of hunger and poverty.**

20th Anniversary of the Global Commercialization of Biotech Crops (1996 to 2015) and Biotech Crop Highlights in 2015.

By

Clive James
Founder and Emeritus Chair, ISAAA

Introduction

This Brief focuses on the 20th Anniversary of the global commercialization of biotech crops (1996 to 2015) and biotech crop highlights in 2015. The author of this Brief, Dr. Clive James, has dedicated this Brief to his mentor and colleague, the late Nobel Peace Laureate Norman Borlaug, who was the founding patron of ISAAA. Borlaug was also the greatest advocate for biotech/GM crops, credited with saving 1 billion poor people from hunger during the 1960s green revolution that he created and pioneered.

2015 marked the 20th anniversary (1996-2015) of the commercialization of biotech crops, also known as genetically modified (GM) or transgenic crops, now more often called "biotech crops" as referred to in this Brief. An unprecedented cumulative hectarage of 2 billion hectares of biotech crops, equivalent to twice the total land mass of China (956 million hectares) or the United States (937 million hectares), were successfully cultivated globally in the 20 year period 1996 to 2015; farmer benefits for the period 1996 to 2015 were estimated at over US$150 billion. The 2 billion accumulated hectares comprise 1.0 billion hectares of biotech soybean, 0.6 billion hectares of biotech maize, 0.3 billion hectares of biotech cotton and 0.1 billion hectares of biotech canola.

The experience of the first 20 years of commercialization, 1996 to 2015, has 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 20 years of commercialization, 1996 to 2015, reflects the substantial multiple benefits realized by both large and small farmers in industrial and developing countries, which have grown biotech crops commercially.

Following a remarkable run of 19 years of consecutive yearly growth from 1996 to 2014, the annual global hectarage of biotech crops peaked at 181.5 million in 2014, compared with 179.7 million hectares in 2015; this change is equivalent to a net marginal year-to-year change of minus 1% between 2014 and 2015. Annual fluctuations in biotech crop hectarage of this order (both increases and decreases) are influenced by several factors. In 2015, a principal factor leading to decreased biotech hectarage in some countries was decreased total crop plantings; for example, for maize it was minus 4% and for cotton minus 5%, driven by low prices, with some farmers switching from maize, cotton and canola to a more easily managed crop such as biotech soybean, and also to other less demanding crops like pulses, sunflower, and sorghum. These marginal year-to-year biotech crop hectarage decreases, driven by low prices in 2015, are likely to reverse when crop prices revert to higher levels in the future.

In the first 20 years, (1996 to 2015) biotech crops were planted by up to 18 million farmers (up to 90% were small/poor farmers) in 28 countries annually. With an increase of 100-fold from 1.7 million hectares in 1996 to 179.7 million hectares in 2015, this makes biotech crops the fastest adopted crop technology in recent times – the reason – biotech crops have the trust of millions of farmers because they deliver significant and multiple benefits. Accordingly, the number of biotech countries has more than quadrupled from 6 in 1996, to 16 in 2002 and 28 in 2015. Cuba, which has planted a small hectarage of biotech maize during the last two years, will resume planting in two years and in the interim will optimize maize hybrid development for the expeditious deployment of biotech hybrid Bt maize. Notably, Vietnam cultivating about 1 million hectares of maize, planted biotech maize for the first time in 2015, with plans to rapidly increase adoption in the near term. Indonesia and India have also completed advance field trials of biotech maize and, subject to approval, are candidates for commercialization in the near term, which would bring the total number of biotech crop countries in Asia/Pacific to eight, compared with 14 in the Americas.

Importantly, adoption rates for biotech crops during the period 1996 to 2015 were unprecedented (see country chapters for details) – the majority is over 90% for major products in principal markets in both developing and industrial countries. By recent agricultural industry standards, the adoption rates represent some of the highest adoption rates for improved crops – for example, as high as the adoption of hybrid maize in its heyday in the mid-west of the USA. High adoption rates reflect farmer satisfaction with the products that offer substantial benefits ranging from more convenient and flexible crop management, lower cost of production, higher productivity and/or net returns per hectare, health and social benefits, and a cleaner environment through decreased use of conventional pesticides, which collectively contribute to a more sustainable agriculture. There is a growing body of consistent evidence across years, countries, crops and traits generated by public sector institutions that clearly demonstrate the benefits from biotech crops. These benefits include improved weed and insect pest control with biotech herbicide tolerant and insect resistant Bt crops, that also benefit from lower input and production costs; biotech crops also offer substantial economic advantages and conveniences to farmers compared with corresponding conventional crops. The severity of weeds, insect pests and diseases varies from year-to-year and country to country, and hence location will directly impact pest control costs and the economic advantages of biotech crops in any given time or place.

Despite the continuing debate on biotech crops, particularly in countries of the European Union (EU), millions of large and small farmers in both industrial and developing countries have continued to increase their plantings of biotech crops by double-digit adoption growth rates in 12 years since 1996, because of the significant multiple benefits and advantages that biotech crops offer. This high rate of adoption is a strong vote of confidence in biotech crops, reflecting farmer satisfaction in both industrial and developing countries. There were up to 18 million farmers annually in up to 28 countries who benefited from significant agronomic, environmental, health, social and economic advantages during the 20 year period 1996 to 2015. Global population was approximately 7.3 billion in 2015 and is expected to reach up to ~9.7 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 DESA, 2015) is that the population will continue to increase until the end of this century to reach 10.8 billion, or more. In 2015, close to 1 billion (795 million) people in the developing countries suffered from hunger, malnutrition and poverty (FAO, 2015). 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 have also made a critically important contribution to the alleviation of poverty under the aegis of the Millennium Development Goals (MDG). Globally, MDG goals have been met in most countries through a cut in poverty, hunger and malnutrition by half in 72 out of 129 countries. Importantly, 2015 was also the year that marked 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.**

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 (well-adapted germplasm) and the best of biotechnology applications (important biotech-derived beneficial traits), 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 20 global reviews of biotech crops annually since 1996 as ISAAA Briefs: James, 2015; James, 2014; James, 2013; James, 2012; James 2011; James, 2010a; James, 2009; James, 2008; James, 2007; James, 2006; James, 2005; James, 2004; James, 2003; James, 2002; James, 2001; James, 2000; James, 1999; James, 1998; James, 1997; James and Krattiger, 1996). The principal aim of this publication is to celebrate the 20th anniversary of the commercialization of biotech crops (1996 to 2015) by providing the latest information on the global status of commercialized biotech crops in the period 1996 to 2015. The global adoption trends during the last 20 years from 1996 to 2015 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. A detailed global data set is also presented on the adoption of commercialized biotech crops for the year 2015 and the changes that have occurred between 2014 and 2015 are highlighted.

This ISAAA Annual Global Review of biotech crops, Brief 51 for 2015, is the twentieth in an annual series. It documents the global database on the adoption and distribution of biotech crops in 2015, and supported by eight sections in the Appendix: 1) a table with global status of crop protection market in 2015, courtesy of Cropnosis; 2) tables on 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) population of 28 planting countries in 2100; 6) biotech crops developed through RNAi 7) list of selected biotech crops at various stages of field testing in different countries; and 8) miscellaneous data and conversions.

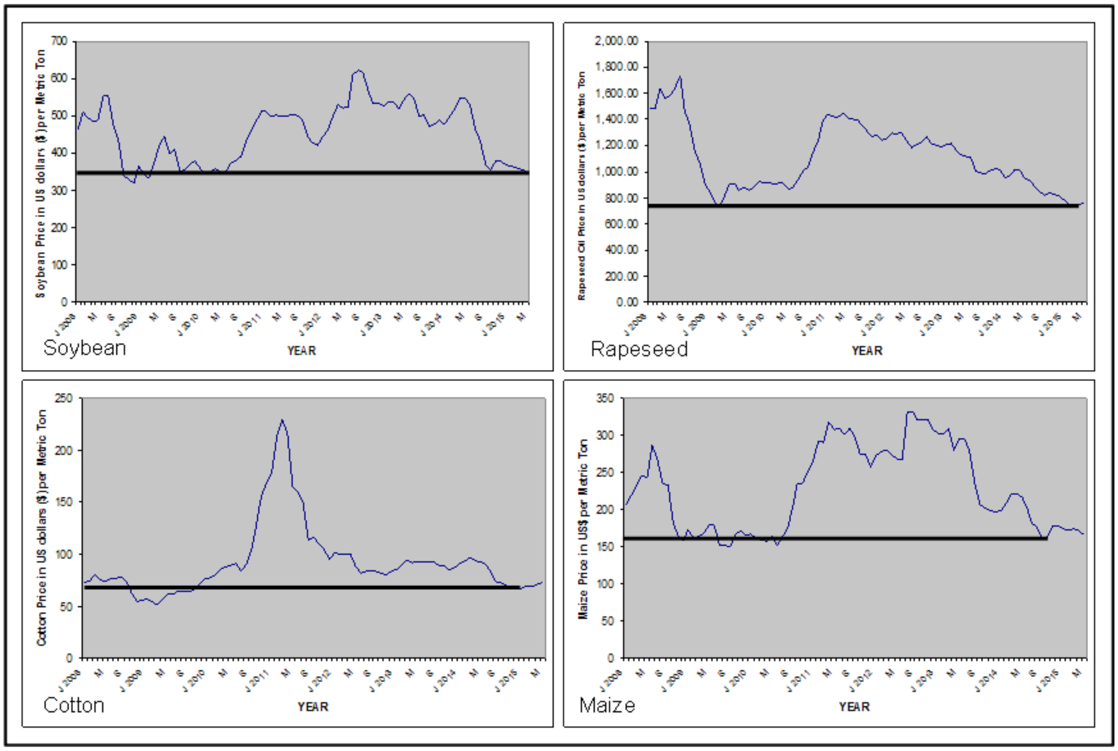
Note that the words rapeseed, canola, and Argentine canola are used synonymously, as well as transgenic, genetically modified crops, GM crops, and biotech crops, reflecting the usage of these words in different regions of the world, with biotech crops being used exclusively in this text because of its growing usage worldwide. Similarly, the words corn, used in North America, and maize, used more commonly elsewhere in the world, are synonymous, with maize being used consistently in this Brief, except for common names like corn rootworm where global usage dictates the use of the word corn. All dollar ($) values in this Brief are US dollars unless otherwise noted. Some of the listed references may not be cited in the text – for convenience they have been included because they are considered useful reading material and were used as preparatory documents for this Brief. Global totals of millions of hectares planted with biotech crops have in some cases 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% due to 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 2015 information for Argentina, Brazil, Australia, South Africa, and Uruguay is hectares usually planted in the last quarter of 2015 and harvested in the first quarter of 2016, 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 2015 and more intensively through January and February 2016, is classified as a 2015 crop in this Brief, consistent with a policy which uses the first date of planting to determine the crop year. All biotech crop hectare estimates in this Brief, and all ISAAA publications, are only counted once, irrespective of how many traits are incorporated in the crops. Country figures were sourced from The Economist, supplemented by data from World Bank, FAO and UNCTAD, when necessary.

Over the last 20 years, ISAAA has devoted considerable effort to consolidate all the available data on officially approved biotech crop adoption globally; it is important to note that the database does not include plantings of biotech crops that are not officially approved. The database draws on a large number of sources of approved biotech crops from both the public and private sectors in many countries throughout the world. The range of crops is those defined as food, feed and fiber crops in the FAO database, 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. In the interest of uniformity, continuity, and comparability, wherever possible, ISAAA utilizes the same published data source annually; for example, for Brazil the August biotech reports of Celeres are used; similarly, for the US, the USDA/NASS crop acreage reports published on 30 June annually are used. 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 20 years and hence provides continuity from the genesis of the commercialization of biotech crops in 1996, to the present. The database has gained acceptance internationally as a reliable benchmark of the global status of biotech food, feed and fiber crops and is widely cited in the scientific literature and the international press. Whereas individual data points make-up the data base, the most valuable information is the trends of adoption over time, for example the increasing dominance of developing countries which is clearly evident.

Global Area of Biotech Crops in 2015

International prices of maize, soybean, cotton and canola (IMF data in Figure 1) have not retraced the high prices of 2008 and 2011/12. The prices of all four biotech crops have been at historical lows and this has created economic uncertainty for farmers. Given this situation, farmers in several countries have favored soybean over maize because soybean has lower production costs and is an easier crop to grow, or have switched to other crops like pulses, sunflower, or sorghum. Generally speaking, the prices

Figure 1. Commodity Prices of Biotech Crops, Soybean, Rapeseed/Canola, Cotton and Maize from June 2008 to May 2015



Source: International Monetary Fund, 2015.

of all four commodities were close to, or at their lowest in 2015 with the US projecting yet another bumper harvest in 2015, particularly, for soybean. However, many years of past positive experience with biotech crops have continued to provide incentives for farmers worldwide, who continue to invest more in improved crop technologies, including biotech crops.

Following an unprecedented experience of 19 years of consecutive yearly growth from 1996 to 2014, the annual global hectarage of biotech crops peaked at 181.5 million in 2014, compared with 179.7 million hectares in 2015 and planted by up to 17 to 18 million farmers – this change in hectarage between 2014 and 2015 is equivalent to a net marginal year-to-year change of minus 1%. Annual fluctuations in biotech crop hectarage of this order (both increases and decreases) are influenced by several factors. In 2015, a principal factor leading to decreased biotech hectarage in some countries was decreased total crop plantings; for example, for maize it was minus 4% and for cotton minus 5%, driven by low prices, with some farmers switching from maize, cotton and canola to a more easily managed crop such as biotech soybean, and also to other less demanding crops like pulses, sunflower, and sorghum. These marginal year-to-year crop hectarage decreases, driven by low prices in 2015, are likely to reverse when crop prices revert to higher levels in the future.

In 2015, the accumulated hectarage (planted since 1996) surged to a record ~2 billion hectares or ~5 billion acres (Table 1). Of the total number of 28 countries planting biotech crops in 2015, 20 were developing countries and 8 industrial countries (Figure 4). Developing countries continued to out-perform industrial countries by 0.9 million hectares and in 2015, for the fourth consecutive year, with developing countries growing more than half (54%) of the global biotech crop hectarage of over 179.7 million hectares (Table 2). This trend of higher adoption by developing countries is expected to continue through 2016 and beyond, and become even stronger when potential large-hectarage crops such as the 35 million hectares of maize in China come on stream in the near term featuring home-grown technology.

To put the 2015 global area of biotech crops into context, 179.7 million hectares of biotech crops is equivalent to almost 20% of the total land area of China (956 million hectares) or the USA (937 million hectares) and more than 7 times the land area of the United Kingdom (24.4 million hectares). The marginal decrease in area between 2014 and 2015, of minus 1%, is equivalent to 1.8 million hectares or 4.44 million acres (Table 1).

Table 1. Global Area of Biotech Crops, the First 20 Years, 1996 to 2015

Year	Hectares (million)	Acres (million)
1996	1.7	4.2
1997	11.0	27.2
1998	27.8	68.7
1999	39.9	98.6
2000	44.2	109.2
2001	52.6	130.0
2002	58.7	145.1
2003	67.7	167.3
2004	81.0	200.2
2005	90.0	222.4
2006	102.0	252.0
2007	114.3	282.4
2008	125.0	308.9
2009	134.0	331.1
2010	148.0	365.7
2011	160.0	395.4
2012	170.3	420.8
2013	175.2	432.9
2014	181.5	448.5
2015	179.7	444.0
Total	**1,964.6**	**4,854.6**

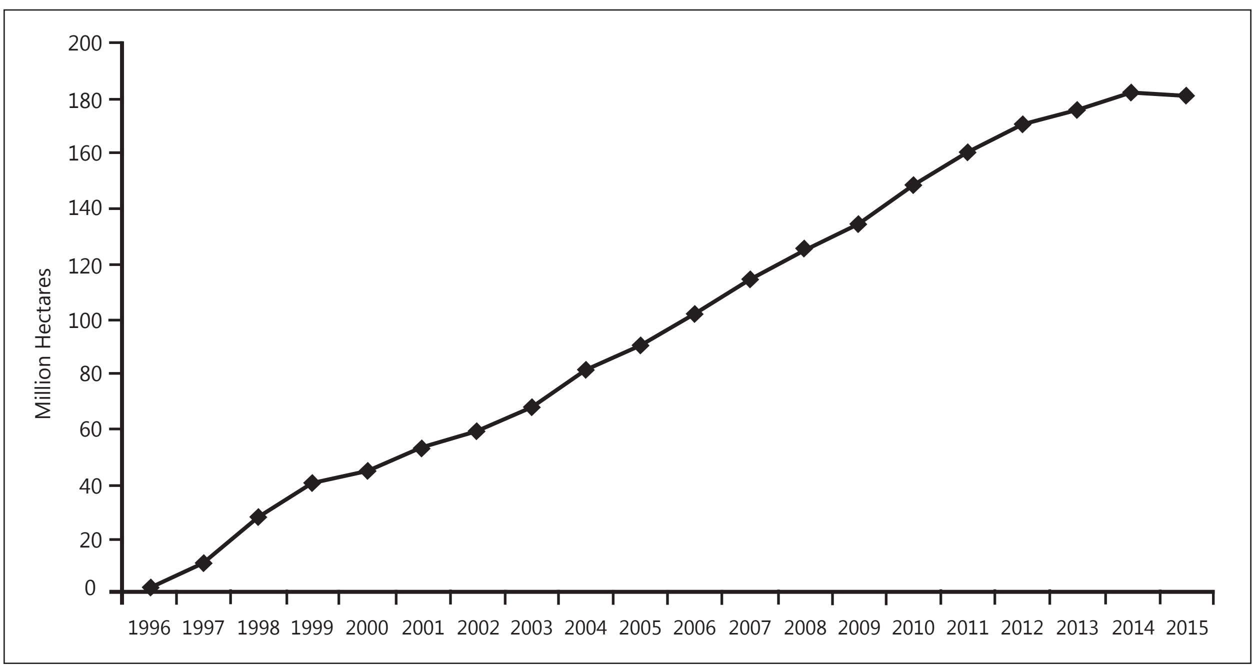
Global hectarage of biotech crops peaked in 2014 at 181.5 million hectares compared with 179.7 million hectares in 2015 — this is equivalent to a marginal decrease of 1% or 1.8 million hectares between 2014 and 2015.
Source: Clive James, 2015.

During the 20 years of commercialization 1996 to 2015, the global area of biotech crops increased 100-fold, from 1.7 million hectares in 1996 to 179.7 million hectares in 2015 (Figure 2). There is continuing acceptance of biotech crops by farmers – both large and small, resource-poor farmers in both industrial and developing countries during the period 1996 to 2015. In the same period, the number of countries growing biotech crops more than quadrupled, increasing from 6 in 1996 to 12 countries in 1999, 17 in 2004, 21 countries in 2005, 25 in 2009, 28 in 2012, 27 in 2013 and 28 in 2014 and 2015, with the addition of Vietnam which commercialized biotech maize in 2015 and the temporary absence of Cuba which plans to resume planting of biotech maize in a couple of years when their improved maize hybrids are ready for deployment. This impressive adoption speaks for itself, in terms of its sustainability, resilience and the significant benefits it delivers to both small and large farmers as well as consumers.

The USA continued to be the lead country in 2015 with 70.9 million hectares (39% of global) with over 90% adoption for the principal crops of maize (92% adoption versus 93% in 2014), soybean (94%, same as last year) and cotton (94% versus 96% in 2014). Biotech sugar beet was 100% biotech for the first time in 2015. Overall, significant progress was made on many fronts in the US in 2015 ranging from: new approvals; new commercialized biotech crops: first time approval of a GM animal food product for human consumption; widespread use of breakthrough new and powerful genome editing technology, named CRISPR; and some success on labeling.

For GM crop products, Innate™ generation 1, an improved multi-trait potato, developed by Simplot, was first commercialized on 160 hectares in 2015; an improved version, Innate™ 2 was approved in 2015, and has added resistance to the fungal disease, potato late blight, the cause of the Irish famine of 1845, when 1 million people died of hunger. Remarkably, it is still the most important disease of potatoes

Figure 2. Global Area of Biotech Crops, 1996 to 2015 (Million Hectares)



Source: Compiled by Clive James, 2015.

150 years after the famine, with annual global losses of US$7.5 billion. Another global first was the commercialization of the first non-transgenic genome-edited crop, SU Canola™, developed by Cibus and grown on 4,000 hectares. Two varieties of Arctic® apples, with less bruising and less browning when sliced were approved for planting in the USA and Canada, with 6 hectares planted in the USA alone in 2015. The first delivery to consumers is planned for next year. The company that developed Arctic® apple, Okanagan Specialty Fruits, from Canada, is applying the same technology to other perishable fruits including peaches, pears and cherries. Okanagan Specialty Fruits was acquired by Intrexon, a US-based synthetic biology company, in 2015. A low lignin alfalfa event, KK179 (HarvXtra™) with higher digestibility and yield (alfalfa is #1 forage crop in the world) was already approved in November 2014 and is a candidate for commercialization in the US in 2016. Hectarage of biotech DroughtGard™ tolerant maize, first planted in the US in 2013, soared more than 15-fold from 50,000 hectares in 2013 to 275,000 hectares in 2014 and 810,000 hectares in 2015 reflecting high farmer acceptance. In December 2015, Dow and DuPont agreed to merge to form DowDuPont, with a view to splitting the new company into three companies focusing on Agriculture, Materials and Specialty Products.

For GM animals, after 20 years of review, in a landmark decision in November 2015, the FDA approved the first GM animal for commercial food production and human consumption – a faster growing GM salmon, which is expected to enter the food chain in the US before 2018. Atlantic salmon normally takes three years to harvest in fish farms, compared with only 18 months, or half the time, for GM salmon. The GM AquAdvantage salmon was developed by AquaBounty Technologies, which was acquired by the US company Intrexon in 2015. FDA approved a new GM chicken whose eggs will be used to treat a rare but fatal human disease called lysosomal acid lipase deficiency.

The award-winning CRISPR genome editing technology was selected by *Science* magazine as the breakthrough technology of 2015. It is being used in many laboratories to develop improved crops and animals. For example, improved soybeans and maize are already being evaluated in greenhouses and, subject to regulation, approval could be commercialized as early as five years from now. Pigs are being developed that are resistant to a deadly viral disease which costs the US pork industry US$600 million a year.

On labeling, whereas a herculean costly effort has been made by both proponents and opponents of GM crops, with mixed results, significant success was achieved by proponents in 2015. Ballots that would require state level labeling in Oregon and Colorado failed in 2014 and similarly ballots in 2015 in California and Washington failed. Perhaps, more importantly, a bill was passed in the House of Representatives in July 2015 that would pre-empt state and local non-GM laws; a similar bill is slated for an imminent hearing in the Senate. In November 2015, FDA rejected a "citizen petition" to require mandatory labeling of GM products. Finally, the food company Chipotle, after announcing that it would eliminate GM products from its menu, and focus solely on non-GM vegetable products sourced locally, is now re-centralizing its vegetable supply after up to 300 people in the US claim they have suffered sickness after consuming Chipotle non-GM locally sourced vegetables.

Brazil, the second largest grower globally with 44.2 million hectares, reached 25% of global (for the first time in 2015) and resumed its important role as the engine of biotech crop growth globally with 2 million hectares more in 2015 than 2014. This compares to minus 2.2 million hectares for the US, which is due to a temporary reduction of total plantings of maize, cotton and canola which are expected to recover when prices of these crops strengthen and total hectarage increases. Notably, Brazil planted the stacked HT/IR soybean on a record 11.9 million hectares up substantially from 5.2 in 2014 in its third year after the launch. In Brazil, approval was gained by FuturaGene/Suzano for cultivation of a 20% higher-yielding home-grown eucalyptus, plus commercialization of two home-grown crop products in 2016 – a virus-resistant bean and a new herbicide tolerant soybean. Argentina with 24.5 million hectares retained third place, and was up modestly from 24.3 million hectares in 2014. India ranked fourth, had 11.6 million hectares of Bt cotton (same as 2014), and a resilient 95% adoption rate. Canada was fifth at 11.0 million hectares, with 0.4 million hectares less total canola grown in 2015, but with a continued high rate of biotech adoption at 93%. In 2015, each of the top 5 countries planted more than 10 million hectares providing a broad, solid foundation for future sustained growth. Notably, biotech cotton adoption remains at ~100% of all cotton grown in Australia and ~99% of it featured the stacked traits (insect resistance and herbicide tolerance). Australia is providing global leadership in deployment of biotech cotton and insect resistance management with Bollgard lll® already field-tested in 2015 on ~30,000 hectares.

Despite lower international crop prices in 2015, Brazil continued to be the global engine of growth in 2015 and reported the largest annual gain (2.0 million hectares) equivalent to 5% growth in national biotech crop hectarage. This significant increase of 2 million hectares in Brazil was followed by more modest increases (+0.1 more) in three countries: Argentina, Australia, and Bolivia (Table 3). Off-setting these increases was a significant decrease of 2.2 million hectares in the US, and by more modest decreases (-0.1 to -0.6) in seven countries including Canada, South Africa, China, Paraguay, Uruguay, Philippines and Burkina Faso with the balance of 16 countries reporting little or no change.

Highlights of biotech crop commercialization in 2015 in Latin America include, two home-grown products approved in Argentina – a drought tolerant soybean and a virus-resistant potato. In Brazil, approval was gained for cultivation of a higher yielding home-grown eucalyptus and commercialization of two home-grown crop products in 2016 – a virus resistant bean and a new herbicide tolerant soybean. In Canada, there was approval of a higher quality non-browning apple. In the USA, there were several "new" products approved for planting or commercialized in 2015; the same non-browning apple approved in Canada was approved in the US; initial commercialization of Generation 1 Innate™ potato on 400 acres (160 hectares); USDA approval of Generation 2 Innate™ potato with late blight resistance (the cause of the Irish famine in 1845 which killed 1 million people).

Cibus, developed and gained approval in the US for SU Canola™, using non-transgenic breeding through precision gene editing; SU Canola™ is the first non-transgenic, genome-edited crop approved in the US and commercialized on 10,000 acres (4,000 hectares) in the US in 2015. Note the important shift in new biotech crop products towards more food crops – current biotech food crops include white maize in South Africa; sugar beet and sweet corn in the US and Canada; papaya and squash in the US; papaya in China; and Bt eggplant in Bangladesh. Finally, a reduced lignin alfalfa event, KK179 (HarvXtra™) with higher digestibility and yield (alfalfa is #1 forage crop in the world) has been approved and is being considered for commercialization in the US in 2016.

Bangladesh, a small, poor country with 150 million people, doubled the commercial hectarage of the prized vegetable Bt brinjal/eggplant; it was grown by 250 small farmers on 25 hectares in 2015 compared with 120 farmers on 12 hectares in 2014. Importantly, seed is now being multiplied to meet the growing needs of substantially more farmers in 2016. Success with Bt brinjal has led Bangladesh to prioritize the field testing of a new late blight resistant potato (an important crop, occupying ~0.5 million hectares in Bangladesh) which could be approved as early as 2017; potato is the fourth most important food staple globally and can contribute to food security in countries like China (6 million hectares of potato), India (2 million) and the EU (~2 million). Given the importance of the large cotton/ textile industry in Bangladesh, Bt cotton is being evaluated in field trials as well as Golden Rice, which could address the prevalent Vitamin A deficiency in the country. This feat of promoting home-grown biotech crops through public/private partnerships, PPP, is very effective but could not have been achieved without strong Government support and **political will**, particularly from the Minister of Agriculture, the Honorable Matia Chowdhury – the experience is exemplary for small poor countries.

It is noteworthy that with the leadership of Spain, planting of Bt maize in the EU in 2015 continues although at an 18% reduction from 143,016 in 2014 to 116,870 hectares in 2015. The five countries which planted Bt maize in 2015 were the same as last year – in descending order of hectares they were Spain, Portugal, Czech Republic, Slovakia and Romania. Spain plants over 92% of the EU hectarage of Bt maize. The decrease in biotech maize planting in Spain is partially attributed to an 8% decrease in total maize planted. There is an enormous disincentive in planting biotech maize in the EU where onerous systems of reporting are a crippling burden for farmers and for developers of biotech crops. Several companies have understandably chosen to exit the EU market since 2013 because of the hostile environment for biotech crops in the EU and a lack of political will and support for the technology. In October 2015, 19 out of the 28 EU countries voted to opt out of growing biotech crops, but importantly, all five countries currently growing Bt maize voted to continue planting so that they can benefit from the significant advantages that biotech crops offer.

The unprecedented global growth in hectarage of biotech crops in the first 20 years of commercialization has been remarkable. Modest growth in biotech crops is expected to resume after global crop prices increase to former levels which will be fueled by several factors including: growth in the 28 countries (developing and industrial) already planting biotech crops in 2015; a strong indication that several new countries will join in the near term including Indonesia in 2016; notable and significant continuing progress in Africa with three countries (South Africa, Burkina Faso, and Sudan), collectively planting over 2.8 million hectares in 2015, and an additional eight countries conducting field trials with biotech crops, Swaziland was a new country in Africa trialing biotech crops in 2015. Africa is the continent with the greatest challenge but there are significant increases in field trials with "new" biotech crops for the poor such as cassava and banana. Brazil opens up significant additional potential hectarage for new biotech crops such as the IR/HT soybean launched in 2013 and which quickly occupied 12.9 million hectares in 2015 in four countries in Latin America led by Brazil.

A landmark development was the planting of the first biotech drought tolerant maize in the US in 2013 – notably the same drought tolerant technology that has been donated to five countries in Africa, through a public-private partnership (PPP) project named "<u>W</u>ater <u>E</u>fficient <u>M</u>aize for <u>A</u>frica" (WEMA). The estimated hectares of DroughtGard™ maize with event MON 87460, planted in the US in 2013 was 50,000 hectares, 275,000 hectares in 2014, and 810,000 hectares in 2015. This is equivalent to a large 3-fold year-to-year increase in planted hectares between 2014 and 2015 and reflects strong US farmer acceptance of the first biotech derived drought-tolerant maize technology to be deployed globally. It is noteworthy that Event MON 87460 was donated by Monsanto to the Water Efficient Maize for Africa

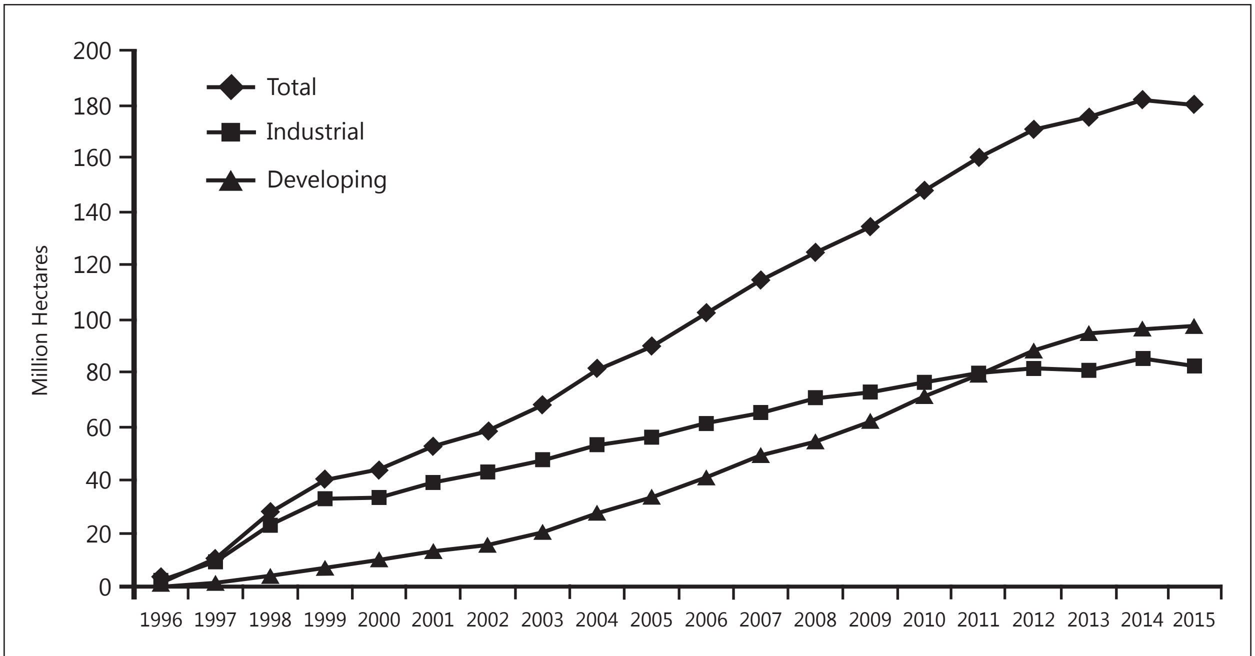
(WEMA) a public-private partnership (PPP) designed to deliver the first biotech drought tolerant maize to selected African countries starting 2017. Notably, the conventional drought tolerant maize has been distributed in South Africa in 2014 which is hoped to facilitate acceptance of the biotech drought tolerant maize Droughtgard™ (MON 87460) which was approved for commercialization in June 2015, and expected to be available to farmers in 2017, as planned.

In summary, in the first 20 year period of commercializing biotech crops, 1996 to 2015, an accumulated global total of ~2 billion hectares were successfully planted and delivered farmer benefits of over ~US$150 billion. In general, significant progress was achieved in the UN Millennium Development Goal of cutting by half the poor and hungry people. Results indicate that 72 developing countries out of 129, or 55% of the countries monitored, reached the MDG hunger target. A new target was recently set by the United Nations in a framework called "Transforming our World: The 2030 Agenda for Sustainable Development" and one of the 17 goals aimed to end hunger, achieve food security and improve nutrition, and promote sustainable agriculture, to which biotech crops can make a significant contribution.

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 2015. It illustrates that, starting in 2012, developing countries planted more biotech crops than industrial countries, and 2015 was the fourth year for developing countries to plant more than half of the global biotech crops estimated at 179.7 million hectares. In 2015, developing countries, planted 54% (compared with 53% in 2014) equivalent to 97.1 million hectares. Industrial countries planted only 46% (compared with 47% in 2014), equivalent to 82.6 million hectares, Table 2). Figure 3 illustrates that prior to 2015, 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, 54% in 2013, 53% in 2014 and 54% in 2015. In 2015, year-to-year growth was higher in developing countries at 0.9 million hectares (1%) than in industrial countries which were reduced by 3% at 2.7 million hectares. This was principally due to higher growth in Brazil and Argentina for soybean, and cotton plantings in Pakistan, Myanmar, and Sudan. Thus, year- to-year growth was significantly faster in developing countries in 2015 and maintained a larger share of global biotech crops at 54% compared with only 46% for industrial countries. The trend for a higher share of global biotech crops in developing countries is likely to continue in the near, mid and long-term, firstly, due to more countries from the South adopting biotech crops and secondly, adoption of crops like rice, 90% of which is grown in developing countries, are deployed as "new" biotech crops.

Figure 3. Global Area of Biotech Crops, 1996 to 2015: Industrial and Developing Countries (Million Hectares)



Source: Clive James, 2015.

Table 2. Global Area of Biotech Crops, 2014 and 2015: Industrial and Developing Countries (Million Hectares)

	2014	%	2015	%	+/-	%
Industrial countries	85.3	47	82.6	46	–2.7	–3
Developing countries	96.2	53	97.1	54	+0.9	+1
Total	**181.5**	**100**	**179.7**	**100**	**–1.8**	**–1**

Source: Clive James, 2015.

Distribution of Biotech Crops, by Country

A total of 28 countries, 20 developing and 8 industrial countries, planted biotech crops in 2015. The top ten countries, each of which grew over 1 million hectares in 2015, are listed by hectarage in Table 3 and Figure 4, led by the USA which grew 70.9 million hectares (39% of global total, compared with 40% in 2014), Brazil with 44.2 million hectares (reached 25% for the first time), Argentina with 24.5 million hectares (14%), India with 11.6 million hectares (6%), Canada with 11 million hectares (6%), China with 3.7 million hectares (2%), Paraguay with 3.6 million hectares (2%), Pakistan 2.9 million hectares (2%), South Africa with 2.3 million hectares (1%), and Uruguay with 1.4 million hectares (1%). An additional 18 countries grew a total of approximately 3.6 million hectares in 2015 (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, with Brazil, Argentina, India, China, Paraguay, Pakistan, South Africa, and Uruguay compared with only two industrial countries, USA and Canada.

The number of biotech mega-countries (countries which grew 50,000 hectares, or more, of biotech crops) was 19, the same as 2014. 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 third 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 2015, 19 out of 28, equivalent to 69% reflects the significant broadening, deepening and stabilizing in biotech crop adoption that has occurred within the group of more progressive mega-countries adopting more than 50,000 hectares of biotech crops, on all six continents in the last 20 years.

It is noteworthy, that in absolute hectares, the largest year-over-year growth, by far, was Brazil with 2 million hectares, Argentina with 200,000 hectares, and Australia (200,000 hectares). The top three biotech countries in terms of global share of the million hectares planted globally were USA at 39%, Brazil at 25% and Argentina at 14% for a total of 78%.

Of the 28 countries that planted biotech crops in 2015, 12 (43%) of the countries were in the Americas, 8 (29%) in Asia, 5 (18%) were in Europe and 3 (10%) in Africa. On a hectarage basis, of the 28 countries that planted biotech crops in 2015, 87% of the hectarage was in the Americas, 11% in Asia, 2% in Africa and <1% in Europe.

It is noteworthy, that there are now 10 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, Honduras, Chile, and Costa Rica, with Cuba opting not to plant this year pending development of their home grown maize hybrids. Cuba has planted biotech maize for the last two years will resume planting biotech maize in two years' time. It is also noteworthy, that Japan grew, for the sixth year, a commercial biotech flower, the "blue rose" in 2015. 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.

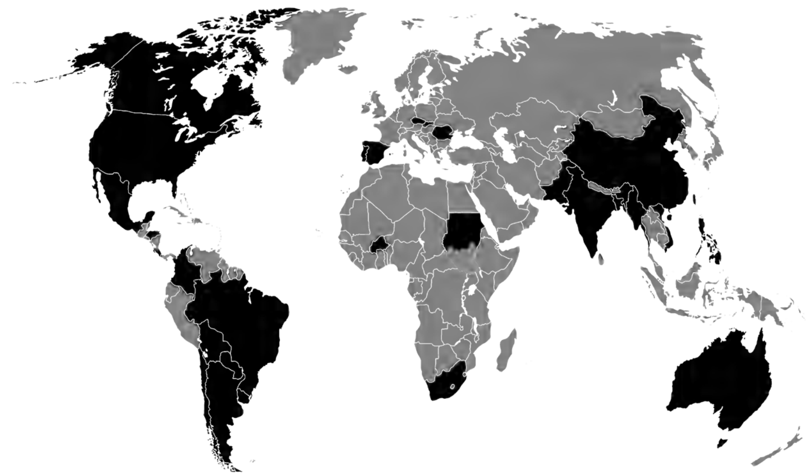
Table 3. Global Area of Biotech Crops in 2014 and 2015: by Country (Million Hectares)**

	Country	2014	%	2015	%	+/-	%
1	USA*	73.1	40	70.9	39	–2.2	–3
2	Brazil*	42.2	23	44.2	25	+2.0	+5
3	Argentina*	24.3	13	24.5	14	+0.2	+1
4	India*	11.6	6	11.6	6	0	0
5	Canada*	11.6	6	11.0	6	–0.6	–5
6	China*	3.9	2	3.7	2	–0.2	–5
7	Paraguay*	3.9	2	3.6	2	–0.3	-8
8	Pakistan*	2.9	2	2.9	2	0	0
9	South Africa*	2.7	2	2.3	1	–0.4	–15
10	Uruguay*	1.6	1	1.4	1	–0.2	–12
11	Bolivia*	1.0	1	1.1	1	+0.1	+10
12	Philippines*	0.8	<1	0.7	<1	–0.1	–12
13	Australia*	0.5	<1	0.7	<1	+0.2	+40
14	Burkina Faso*	0.5	<1	0.4	<1	–0.1	–20
15	Myanmar*	0.3	<1	0.3	<1	0	0
16	Mexico*	0.2	0.1	0.1	<1	–0.1	–50
17	Spain*	0.1	<1	0.1	<1	0	0
18	Colombia*	0.1	<1	0.1	<1	<0.1	<0.1
19	Sudan*	0.1	<1	0.1	<1	<0.1	<0.1
20	Honduras	<0.1	<1	<0.1	<1	<0.1	<0.1
21	Chile	<0.1	<1	<0.1	<1	<0.1	<0.1
22	Portugal	<0.1	<1	<0.1	<1	<0.1	<0.1
23	Vietnam	– –	– –	<0.1	<1	– –	– –
24	Czech Republic	<0.1	<1	<0.1	<1	<0.1	<0.1
25	Slovakia	<0.1	<1	<0.1	<1	<0.1	<0.1
26	Costa Rica	<0.1	<1	<0.1	<1	<0.1	<0.1
27	Bangladesh	<0.1	<1	<0.1	<1	<0.1	<0.1
28	Romania	<0.1	<1	<0.1	<1	<0.1	<0.1
	Total	**181.5**	**100**	**179.7**	**100**	**–1.8**	**–1.0**

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

Source: Clive James, 2015.

Figure 4. Global Area (Million Hectares) of Biotech Crops, 1996 to 2015, by Country, Mega-Countries, and for the Top Ten Countries



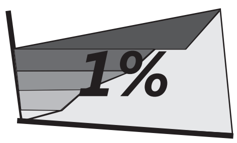
Biotech Mega-Countries	
50,000 hectares, or more	
1. USA	70.9 million
*2. Brazil**	44.2 million
*3. Argentina**	24.5 million
*4. India**	11.6 million
5. Canada	11.0 million
*6. China**	3.7 million
*7. Paraguay**	3.6 million
*8. Pakistan**	2.9 million
*9. South Africa**	2.3 million
*10. Uruguay**	1.4 million
*11. Bolivia**	1.1 million
*12. Philippines**	0.7 million
13. Australia	0.7 million
*14. Burkina Faso**	0.4 million
*15. Myanmar**	0.3 million
*16. Mexico**	0.1 million
17. Spain	0.1 million
*18. Colombia**	0.1 million
*19. Sudan**	0.1 million

Less than 50,000 hectares

*Honduras**, *Chile**, Portugal, *Vietnam**, Czech Republic, Slovakia, *Costa Rica**, *Bangladesh**, Romania

** Developing countries*

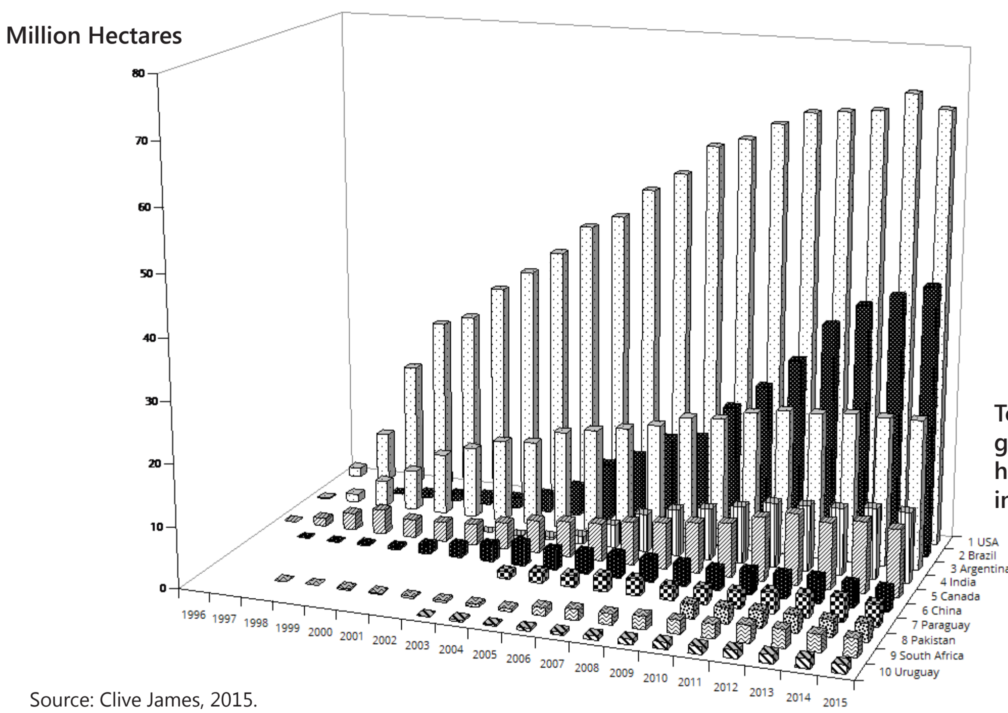
Marginal Decrease from 2014



■ 28 countries which have adopted biotech crops

In 2015, global area of biotech crops was 179.7 million hectares, representing a marginal decrease of 1% from 2014, equivalent to 1.8 million hectares.

Source: Clive James, 2015.



Top 10 countries growing 1 million hectares, or more in 2015

Source: Clive James, 2015.

Status of Bt maize in the EU

The same five EU countries (Spain, Portugal, Czechia, Slovakia and Romania) continued to plant 116,870 hectares of Bt maize, down 18% from the 143,016 hectares planted in 2014. Spain, which grew 92% of all biotech maize led the EU with 107,749 hectares of Bt maize, down 18% from the 131,538 in 2014, with a 28% adoption rate compared with a 31% adoption in 2014. Bt maize hectarage declined in all five EU countries. The decreases in Bt maize were associated with several factors, including not only less total hectares of maize planted in 2015, but also due to significant disincentives for farmers confronted with bureaucratic and onerous reporting of intended plantings of Bt maize. In October 2015, 19 of the 28 EU countries voted to opt out of growing biotech crops but importantly all five countries currently growing Bt maize voted to continue planting in order to continue to benefit from the advantages that biotech crops offer.

Economic benefits of biotech crops

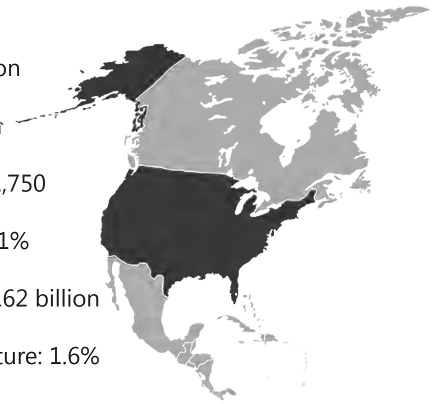
In the latest data, the six principal countries that have gained the most economically from biotech crops, during the first 19 years of commercialization of biotech crops, 1996 to 2014 are, in descending order of magnitude, the USA (US$66.1 billion), Argentina (US$19.3 billion), India (US$18.3 billion), China (US$17.5 billion), Brazil (US$13.6 billion), Canada (US$6.5 billion), and others (US$9 billion), for a total of US$150.4 billion (Brookes and Barfoot, 2016 Forthcoming).

In 2014 alone, economic benefits globally were US$17.8 billion of which US$8.3 billion was for developing and US$9.5 billion was for industrial countries. The six countries that gained the most economically from biotech crops in 2014 were, in descending order of magnitude, the USA (US$8.5 billion), Brazil (US$2.5 billion), Argentina (US$1.7 billion), India (US$1.6 billion), China (US$1.3 billion), and Canada (US$0.9 billion), and others (US$1.2 billion) for a total of US$17.8 billion (Brookes and Barfoot, 2016 Forthcoming).

Country Chapters

USA

USA



Population: 321.7 million

GDP: US$16,245 billion

GDP per Capita: US$51,750

Agriculture as % GDP: 1%

Agricultural GDP: US$162 billion

% employed in agriculture: 1.6%

Arable Land (AL): 164 million hectares

Ratio of AL/Population*: 2.3

Major crops:

- Maize
- Soybean
- Cotton
- Sugarcane
- Sugar beet
- Alfalfa
- Wheat
- Canola
- Potato

Commercialized Biotech Crops:

- HT/Bt/HT-Bt Maize
- HT Soybean
- HT Canola
- Bt/HT/Bt-HT Cotton
- VR Squash
- VR Papaya
- Bt/HT LB Potato
- HT Sugar beet
- HT Alfalfa

Total area under biotech crops and (%) increase in 2015:
70.9 Million Hectares (-3%)

Farm income gain from biotech, 1996-2014: $66.1 billion

*Ratio: % global arable land / % global population

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

In 2015, the USA continued to be the largest producer of biotech crops in the world, with a global market share of ~39%. The USA planted 70.9 million hectares featuring eight biotech crops (maize, soybean, cotton, canola, sugar beet, alfalfa, papaya and squash) in 2015, compared with ~73.1 million hectares in 2014. The modest estimated decrease of up to ~2.2 million hectares (~3%), remarkably the first in 20 years, is mainly attributed to low commodity prices resulting in farmers planting less hectares of maize and cotton, and to a lesser extent marginal decreases (1 to 2%) in adoption of maize and cotton. On the other hand biotech sugar beet reached 100% adoption for the first time in 2015. Growth in hectarage of biotech crops in the US, which remarkably has been consistent for each of the last 19 years, is expected to resume after global prices increase to former levels, more profitable to famers than other competing crops. The USA leads the world in the deployment of stacked traits; 83% of total maize biotech plantings in the US were stacked, and in biotech cotton it was 84% – the stacked traits offer farmers multiple and significant benefits. In 2015, drought tolerant maize was planted in the US on 810,000 hectares compared with 275,000 hectares in 2014, a substantial ~3 fold increase from the 275,000 hectares planted in 2014, indicating strong US farmer acceptance of the technology. Biotech crop adoption rates of the three principal biotech crops in the USA in 2015 remained very high in 2015 with an average of 93%: soybean 94% (same as 2014), maize 92% compared with 93% (2014) and cotton 94% (compared with 96% in 2014). Given the very high rates of adoption, further progress in the US will be achieved through: increases in crop plantings; stacking of multiple traits in the same crop; the introduction of new biotech crops and/or traits. In 2015, a small introductory

hectarage of 160 hectares (400 acres) of Innate™ Generation 1 were planted commercially for the first time as well as 4,000 hectares of SU Canola™. Two "new" biotech crops were approved in 2015 for possible planting in 2016; the first was Innate™ potato Generation 2 with resistance to the most important disease of potatoes globally (late blight), lower levels of sugars after storage, lower levels of acrylamide, a potential carcinogen and less wastage due to bruising; the second product was a non-browning biotech apple. In a landmark decision in November 2015, the FDA in the US approved the first GM animal for commercial production, a faster growing salmon, which is expected to enter the food chain in the US before 2018. Atlantic salmon normally takes three years to harvest in fish farms, compared with only 18 months, or half the time, for GM salmon. In December 2015, Dow and DuPont agreed to merge to form DowDuPont, with a view to splitting the new company into three companies focusing on Agriculture, Materials and Specialty Products. It is estimated that the USA has enhanced farm income from biotech crops by US$66.1 billion in the first nineteen years of commercialization of biotech crops, 1996 to 2014. This represents 44% of global benefits for the same period; the benefits for 2014 alone were estimated at US$8.5 billion (representing 47% of global benefits in 2014). These are the largest economic gains for any biotech crop country.

The USA is the leader of the six "founder biotech crop countries", having spearheaded the commercialization of biotech crops in 1996, the first year of global commercialization of biotech crops. The USA continued to be the lead biotech country in 2015 with 70.9 hectares of biotech crops compared with 73.1 in 2014 at 3% decrease, remarkably the first in 20 years. USDA estimates indicate that the percentage adoption of the three principal biotech crops were at, or close to, optimal adoption: soybean 94% (same as 2014), maize 92% (compared with 93% in 2014) and cotton 94% (similar in 2014) with a very high average of 93%; biotech sugar beets were at 100% adoption for the first time. Total hectares of upland cotton plantings decreased by a substantial 20% in 2015 (USDA NASS, 2015). The total hectarage planted to biotech maize, soybean, cotton, canola, sugar beets, alfalfa, papaya and squash was 70.9 million hectares compared with 73.1 million hectares in 2015, a ~3% difference.

After 20 years of waiting, US Food and Drug Administration finally approved genetically engineered salmon as fit for human consumption (NYTimes, 19 November 2015). The GM AquaAdvantage salmon contains growth hormone gene from a relative Chinook salmon with a genetic switch from another fish ocean pout that renders the introduced gene continuously active even in cold conditions – this is in contrast to the wild type with the gene activity in only parts of the year. The GM fish can grow to market weight in half the time of 18 to 20 months compared with 28 to 36 months for conventional salmon. The fish is expected to be available in markets in two years providing safe and sustainable alternative fish protein source from the oceans which are already overfished. In December 2015, Dow and DuPont agreed to merge to form DowDuPont, with a view to splitting the new company into three companies focusing on Agriculture, Materials and Specialty Products.

Since 1996, USA has approved 188 events of various traits in 20 crop species: alfalfa (3 events), apple (2), Argentine canola (20), chicory (3), cotton (28), creeping bent grass (1), flax(1), maize (39), melon (2), papaya (3), plum (1), potato (40), rice (3), rose (2), soybean (24), squash (2), sugar beet (3), tobacco (1), tomato (8), and wheat (1). In 2015 alone, there were a total of 15 food, feed and cultivation approvals including GM apple events Arctic® Granny Smith and Golden Delicious, two herbicide tolerant cotton events (MON88701 and MON 81910), herbicide tolerant soybean (MON87708), maize event (MON 87411), Innate™ generation 2 potato event with late blight resistance, and maize event MON87403 with new trait for increased ear biomass (ISAAA GMO Approval Database, 2015).

Biotech crops with drought tolerance are now in the pipeline in both public and private sector. The US Drought Monitor (March 2015) reported that over 97% of California's US$45 billion agricultural sector experience severe, extreme, or exceptional drought. Both agriculture and livestock sector suffered exceptional losses (USDA, 20 October 2015). At the State level, the prevailing drought conditions cost staggering economic losses estimated at US$2.2 billion in 2014 alone. Agriculture suffered the highest loss of US$1.5 billion and a reduction of approximately 17,000 jobs in farm sector. The 2015 drought losses are estimated at US$3 billion due to impacts on the agricultural industry, including loss of an estimated 20,000 jobs. The State reported a steep decline in irrigated land by half a million acres due to water shortages in 2014. Many farmers avoided planting in drought hit Central Valley, Central Coast and Southern California. The Central Valley in comparison to Central Cost and Southern California was hardest hit, particularly the Tulare Basin, with mounting losses in crop and livestock sector (Howitt et al. 2014). Biotech crops which can withstand severe and prolonged drought are essential at these times.

Biotech Maize

Total plantings of maize in the USA in 2015 was down for the second year running by 4% at 35.7 million hectares (USDA NASS, 2015) which is the lowest planted hectarage in the US since 2010. The US hybrid maize seed market is valued at US$12 billion annually and biotech maize continued to be attractive in the USA in 2015 because of increasing global demand for feed, ethanol and strong export sales. The US exports more than 40% of world exports of maize.

At 92% adoption rate in 2015, the total biotech maize in the US is 33.1 million hectares, down by 4% from 34.5 million hectares in 2014. The 92% adoption rate is composed of 4% insect resistant (IR), 13% herbicide tolerant (HT), and 83% stacked traits of IR and HT. As of November 2015, the USA has already approved 40 maize events for food, feed, and cultivation since 1996 with insect resistance, herbicide tolerance, drought tolerance and stacks thereof (ISAAA GMO Approval Database, 2015).

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). Aside from the ability to survive in drought, the biotech drought tolerant maize also exhibits improved hydro-efficiency to ensure conservation of soil moisture and reduces yield loss under drought conditions. In 2014, 275,000 hectares DroughtGard™ maize was planted – equivalent to a large 5.5-fold year-to-year increase in planted hectares between 2013 (at 50,000 hectares) and 2014. This increased further to 810,000 hectares in 2015, equivalent to a three-fold increase between 2014 and 2015. This reflects strong US farmer acceptance of the first biotech-derived drought tolerant maize technology to be deployed globally.

It is noteworthy that Event MON 87460 was donated by Monsanto to the Water Efficient Maize for Africa (WEMA), a public-private partnership (PPP) designed to deliver the first biotech drought tolerant maize to selected African countries starting 2017.

Biotech Soybean

USDA for US Oilseed Report (2015) estimated that the total plantings of soybean in the US in 2015 were 34.5 million, up 0.2 million hectares from 2014. Hence at a consistent 94% adoption rate in 2015, the total biotech soybean in the US is 32.4 million hectares. Roundup Ready® soybean was the first and most successful herbicide tolerant soybean to be commercialized in the USA in 1996. Since then, 24 GM soybean events have been approved for food, feed and cultivation of GM soybean. In 2009, a high-yielding second generation GM HT soybeans became available to commercial soybean growers in the USA. This technology increased US soybean production by 3.7 million tons since 2009.

Biotech Cotton

Total planting of upland cotton at 3.69 million hectares in 2015 was down by a substantial 20%. At 94% adoption rate in 2015, the total biotech cotton in the US is 3.4 million hectares, compared to 4.3 million hectares in 2014 – a 20% reduction. The 94% adoption is composed of 5% IR, 11% HT and 84% stacked IR/HT. Biotech cotton has been planted since 1996 and 28 biotech events with insect resistance, herbicide tolerance and stacked IR/HT have been approved in the USA. IR cotton has been planted in an estimated area of 179 thousand hectares in 2015, and US farmers have been benefiting from the technology. Herbicide tolerant cotton was first grown in the US in 1977 and the stacked IR/HT cotton was planted on 2.8 million hectares in 2015.

Biotech Canola including SU Canola™

Canola hectarage in the USA in 2015 was 636,000 hectares, down ~10%, with herbicide canola planted on 93% of total canola (591,000 hectares). This includes biotech canola with resistance to sulfunyl urea (SU Canola™), planted on 10,000 acres (4,000 hectares) in 2015. The SU Canola™ was developed by Cibus using non-transgenic breeding through precision gene editing; the product was not required by USDA to pass through the usual GM regulation in the USA. There are 20 canola events approved for food, feed and cultivation in the USA (as of October 2015). Yield of canola increased by 6% since the introduction of GM canola.

Biotech Sugar beet

Total hectarage of sugar beet in 2015 was similar to 2014 at ~471,000 hectares, with 100% adoption, compared to 98.5% in 2014 and 2013. Since its introduction in 2006, farmers in the USA welcomed the commercialization of biotech sugar beet which provided superior weed control, more cost effective and much easier to cultivate than conventional sugar beet. Thus, from small farmer trials in 2006-2008, adequate seed supplies became available in 2009, where an estimated 95% or ~485,000 hectares were planted in the USA. Critics have tried to pursue legal avenues to stop or restrict planting of RR®sugar beet, but the scientific and farming logic of biotech sugar beet has resisted all these attempts in the courts. Thus, in a landmark decision RR®sugar beet was deregulated by the USDA in July 2012 (USDA, 19 July 2012). From 2010 to 2015, the total hectarage of sugar beet was the same at approximately 500,000 hectares, of which biotech percentage increased from 95% in 2011 to 98.5% in 2014 and finally, 100% in 2015.

Since 2009, three herbicide tolerant sugar beet events have been approved for food, feed, and commercialization in the USA.

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. R&D on biotech sugarcane is progressing in Indonesia, Australia, Brazil, Colombia, Mauritius, South Africa, as well as the United States. Traits under study in cane include, sugar content and quality, herbicide tolerance, pest resistance, disease resistance, and drought, cold and salt tolerance.

Luther Markwart, executive vice president of the American Sugar beet Association, opined that ***"Biotech sugar beet seeds arrived just in time to save a struggling industry that is essential to our nation's food security. Sugar from sugar beet currently provides about half of the nation's sugar consumption. Our industry leaders have spent over 10 years to develop, approve, adopt and transition our US 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 and Low Lignin Alfalfa

Alfalfa is the fourth largest crop in the US occupying 7.4 million hectares. In 2015, it is estimated that 1.3 million hectares was seeded and the accumulated herbicide tolerant canola hectarage was estimated to be of the order of ~1 million hectares. This estimate of HT canola includes alfalfa harvested as hay and alfalfa haylage and green chop.

The USA is a major producer of alfalfa hay 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. Alfalfa is planted as a forage crop and grazed or harvested and fed to animals, and seeded in 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.

Herbicide tolerant RR®alfalfa was first approved for commercialization in the USA in June 2005 with 20,000 hectares planted in the fall of 2005 that increased to 100,000 hectares in 2006/2007. A court order (not based on safety reasons) filed by critics, stopped planting in 2007, pending completion of an environmental impact statement (EIS) by USDA. Farmers who had planted the 100,000 hectares of RR®alfalfa were not required to uproot the RR®alfalfa already planted which has remained in the ground for up to 6 years, due to the perennial nature of alfalfa which is normally ploughed at up to six years. On 21 June 2010, the Supreme Court overturned the ban, and on 16 December, USDA announced that the EIS was completed. By 27 January, it declared that planting of RR®alfalfa could be resumed on 2 February 2011 – the first planting since 2007. Farmer demand has been significant and it is estimated that the total accumulated hectarage of this herbicide tolerant perennial crop planted from 2011 to 2015 was up to ~1 million hectares.

Benefits of RR®alfalfa include improved and more convenient weed control resulting in significant increases in quantity and quality of forage alfalfa as well as the crop and feed safety advantages that the product offers. Import approvals have already been secured for RR®alfalfa in major US export markets for alfalfa hay including Mexico, Canada, Japan, the Philippines and Australia – these countries represent greater than 90% of the US alfalfa hay export market. Japan is the major market for alfalfa hay exports, mainly from California and the west coast states. Monsanto developed the biotech RR® alfalfa in partnership with Forage Genetics International.

There has only been two herbicide tolerant alfalfa events approved for food, feed, and cultivation in the USA since 2005. In 2014, a new biotech low-lignin alfalfa event KK179 was approved for cultivation in the US. The product, which has less lignin, has higher digestibility, and it is claimed to also offer a 15 to 20% increase in yield and hence is likely to be in high demand by farmers.

Other Biotech Crops Planted in the US

A portfolio of biotech crops have been given approval for commercialization in the USA since 1996 including creeping bent grass, flax, melon, papaya, plum, potato, rice, squash, and tobacco. Small areas of biotech virus resistant squash (1,000 hectares) and PRSV resistant papaya in Hawaii (1,000 hectares) continued to be grown in the USA in 2015.

Papaya: Resistant to PRSV

Papaya ring spot virus (PRSV) resistant papaya was developed by Cornell University (USA) and University of Hawaii in 1997 and commercialized immediately in the US since 1998, sixteen years ago. In less than four years, papaya production recovered and Hawaii has started exporting its biotech papayas to Canada and in Japan – in a landmark decision, Japan approved the import of biotech papaya from the US in 2011, for consumption as fresh fruit/food. The Japanese approval was granted and officially announced by Japan's Ministry of Agriculture, Forestry and Fisheries responsible for GM processed food quality labeling, Article 7 Clause 1 on GM fresh food quality labeling was amended on 31 August 2011 to include papaya as Japan's 8th GM imported food; the notification was effective 1 December 2011 (www.caa.go.jp/jas/hyoji/pdf/kijun_03.pdf). Japan has been continuously importing eight approved biotech products including: soybean, maize, potato, rape seed, cotton seed, alfalfa, sugar beet and papaya. Although Hawaiian GMO papayas are resistant only to Hawaiian PRSV, the successful development in Hawaii inspired other papaya cultivating countries to develop virus resistant papayas for their local markets. Resistant papaya varieties are now being developed in Brazil, Taiwan, Jamaica, Indonesia, Malaysia, Thailand, Venezuela, Australia and the Philippines. In the US, there are a nominal 1,000 hectares planted to virus-resistant papaya and 1,000 hectares with virus resistant squash, in 2014.

In 2014, a proposal to ban biotech papaya was submitted to the Maui County Council in Hawaii. The US Environmental Protection Agency relayed to the Council that there is no health problem linked with consumption of biotech papaya rainbow. Chris Wozniak of EPA emphasized that there is no difference between eating rainbow papaya and a papaya with the virus, which is prevalent (Crop Biotech Update, 9 July 2014). Moreover in 2015, US District Court Chief Judge Susan Oki Mollway has ruled that the Maui County's ordinance to ban the cultivation of genetically engineered crops in Hawaii pre empts the federal and state laws and therefore invalid. A county official was quoted as saying that the court ruling decided the issue and made the ordinance null and void (AgProfessional, 6 July 2015).

In summary, the USA continued to grow more biotech crops in 2015 than any other country in the world, at 70.9 million hectares equivalent to ~39% of global biotech crop hectarage. The modest decrease in biotech crop adoption of 3%, remarkably the first in 20 years, is mainly attributed to low commodity prices resulting in decreased hectares of maize and cotton, and to a lesser extent marginal decreases in adoption of maize and cotton. On the other hand, biotech sugar beet reached 100% adoption for the first time. Growth in hectarage of biotech crops in the US, which remarkably has been consistent for each of the last 20 years, is expected to resume after global prices increase. Despite lower international crop prices in 2015, Brazil was again second to the US in biotech crop hectarage (44.2 million hectares). Brazil continued to be the global engine of growth in 2015 and reported the largest annual gain of 2.0 million hectares is equivalent to 5% growth in national biotech crop hectarage.

Stacked (Bt/HT) biotech maize and cotton continued to be the dominant trait in maize and cotton. The two-trait stacked products include biotech maize and biotech 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 2015, in descending order of hectarage were: Brazil, Argentina, South Africa, Canada, the Philippines, Paraguay, Uruguay, Australia, Mexico, Colombia, Chile, and Honduras.

"New" Biotech Crop/Trait Approvals in the US

Biotech crops that are intended for direct human consumption can be regarded as the second generation crops. Compared to the first generation crops which are generally agricultural input traits, the second generation biotech crops target nutritional and food quality, as well as consumer product acceptance. Hence, the newly approved non-browning apples and Innate™ potatoes generation 2 with improved storage and low acrylamide plus late blight resistance were approved by USDA in 2015.

Non-browning apples Arctic®

The US Department of Agriculture's (USDA) Animal and Plant Healthy Inspection Service (APHIS) approved the first two apple varieties genetically engineered to resist browning. The non-browning apple varieties, Arctic® Golden Delicious and Arctic® Granny Smitth apples, were developed by Okanagan Specialty Fruits Inc. (OSF), a small, grower-led company based in Canada (Crop Biotech Update, 18 February 2015). The non-browning Arctic® apples went through rigorous review and were in field trials for more than a decade – the most tested apples on the planet. The US Food and Drug Administration's (USFDA) publicly available risk assessment documents concluded that Arctic® apples are just as safe and healthful as any other apple, and they are unlikely to pose a plant pest risk, and deregulation is not likely to have a significant impact on the human environment. The first two GM Arctic® apple varieties: Arctic® Golden Delicious and Arctic® Granny Smith were approved by USA and Canada consecutively in February and March 2015. The non-browning apple varieties were planted on an initial 15 acres (6 hectares) in Washington State in 2015. In 2016, approximately 60-70 acres (24 to 28 hectares) are expected to be planted primarily in the USA, with some acreage potentially in Canada as well. Significantly more acreage is anticipated in the USA and Canada in 2017 and beyond. Small test-market quantities of Arctic® apples are expected to be available in US stores in late 2016, with more meaningful quantitites becoming available each year.

Innate™ Potato Generation 2

Innate™ potato with lower levels of acrylamide, a potential carcinogen, and less wastage due to bruising was developed by J.R. Simplot. The company licensed the biotech late blight resistant potato from the John Innes Institute in the UK and developed the late blight resistant potato with low acrylamide potential, reduced black spot bruising and lowered reducing sugars. The company has submitted an application for non regulated status to APHIS, and through an enhanced petition review process, APHIS invited public comments on the application. In March 2015, USFDA completed the evaluation of Innate™ potatoes, which concluded that it is as safe and nutritious as conventional varieties (Crop Biotech Update, 18 March 2015). In addition, the USDA Animal and Plant Health Inspection Service (APHIS) released the draft environmental assessments (EA) and preliminary plant pest risk assessment (PRRA) of the biotech potato for a 30-day public review (Crop Biotech Update, 6 May 2015). And in August 2015, the Simplot potato with late blight resistance, low acrylamide potential, reduced black spot bruising, and lowered reducing sugar was given approval by the USDA-APHIS a nonregulated status on 28 August 2015 (Crop Biotech Update, 2 September 2015). The Innate™ potato is now ready for US farmers; this will preclude the frequent spraying to prevent late blight.

To determine how the biotech potato will be accepted by American consumers, researchers at Iowa State University found that consumers are willing to buy products of the biotech potato so as to reduce the potential risk of cancer. The US Food and Drug Administration had urged Americans to cut back on foods that contain acrylamides. Thus, they are willing to pay as much as US$1.78 more for a five-pound bag of potatoes after receiving scientific information on hazards associated with acrylamide exposure and a potato industry perspective on dramatically reducing acrylamide in potato products using biotechnology (Crop Biotech Update, 18 March 2015).

Developments in other Biotech Crops

Biotech Wheat

The US wheat hectarage has declined sharply as compared with biotech maize and soybean. In 1996, 28 million hectares of wheat were planted in the US which declined by 18% or 22 million hectares in 2012, and has remained at the low level in 2015. Maize and soybean hectarages have increased through the years and in 2015 there were 36 million total maize hectares and 34.4 million total soybean hectares. Wheat farmers reported that the decline in wheat is due to its non-competitiveness compared with biotech maize and soybean. USDA estimates that 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. Five years later in 2009 the same wheat industry stakeholders became worried about wheat losing market share to biotech maize and soybean and reached out to Monsanto and other biotech companies to resume work on biotech wheat stating that ***"it is in all our best interests to introduce biotech wheat varieties in a coordinated fashion to minimize market disruptions and shorten the period of adjustment."***

An International Wheat Yield Partnership (IWYP), a group that aims to increase wheat yields by 50 percent in 2034, was launched at the "Borlaug Summit on Wheat for Food Security" in Ciudad Obregón, Mexico in March 2014. The program brought together research funders, international aid agencies, foundations, companies, and major wheat research organizations, to serve as unique vehicle for new discoveries and their speedy incorporation into wheat crops grown in different parts of the world. It also aims to stimulate new research and make scientific discoveries available to farmers in developing and industrial countries. The partnership's initiators include the UK's Biotechnology and Biological Sciences Research Council (BBSRC), the International Maize and Wheat Improvement Center (CIMMYT), the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food of Mexico (SAGARPA) and the United States Agency for International Development (USAID) (Crop Biotech Update, 26 March 2014). Sixteen organizations from Australia, Canada, and the US released a statement of support for the future commercialization of biotech wheat in 2014. The new organizations include American Farm Bureau Federation and the National Farmers Union (Crop Biotech Update, 11 June 2014).

Traits being developed in biotech wheat include herbicide tolerance, disease (*Fusarium*, which produces a mycotoxin) and insect resistance, heat and drought tolerance, nitrogen use efficiency, quality traits such as anti-sprouting and productivity. It is estimated that the first biotech wheat will be ready for commercialization in about ten years from now. Wheat biotech projects are underway in many countries in the public and private sector including Australia, China and USA. To expedite improvement of wheat through biotechnology, the genetic blue print of bread wheat genome was released in 2014 by the International Wheat Genome Sequencing Consortium (IWGSC). The consortium has established the first reference sequence for the largest chromosome, 3B, which could serve as a template for sequencing the remaining chromosomes. With a chromosome-based full sequence in hand, plant breeders now have high quality tools at their disposal to speed up breeding programs and identify how genes control complex traits such as yield, grain quality, disease, pest resistance, or abiotic stress tolerance. They will be able to produce a new generation of wheat varieties with higher yields and improved sustainability to meet the demands of a growing world population in a changing environment (Crop Biotech Update, 23 July 2014, and 14 January 2015).

Biotech/GM American Chestnut Trees

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

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

Citrus Greening Resistant Citrus
A citrus disease has been wreaking havoc in citrus-growing states of Florida and neighboring states. The disease caused by the bacteria *Candidatus liberibacter asiaticus* and spread by psyllids was recorded in the early 70's. The disease turns oranges into green, misshapen, and bitter-tasting fruits, thus the name citrus greening or Huanglongbing (HLB) disease. Millions of acres of citrus crops have already been lost in the US and overseas, and 80% of Florida's citrus trees are infected and declining. The bacterial disease incubates in the tree's roots, moves back up the trunk in full force, causing nutrient flows to seize up. Florida's US$5.1 billion citrus industry could be a complete loss unless it soon finds a way to fight the disease. Cocktails of chemical sprays to kill the vector psyllids are no longer effective. A Texas A&M scientist, with funds from Southern Gardens – a large citrus growing company – inserted a spinach gene to fight the bacteria. A five-year successive small field trials of the transgenic trees have shown high degree of resistance. A successful two-year larger trial of second- and third-generation trees was completed in 2013. Southern Gardens is now seeking to deregulate these oranges for free use, anticipating first commercial planting in three to four years (Food Safety News, 13 December 2013). In 2015, US EPA approved wider testing of the biotech citrus by providing an Experimental Use Permit under the Federal Insecticide, Fungicide and Rodenticide Act. The permit allows Southern Gardens to move forward in its development of the possible use of a spinach protein to help control the devastating citrus greening disease, or Huanglongbing (HLB) (Crop Biotech Update, 20 May 2015).

Benefits from Biotech Crops in the USA

In the most recent global study on the benefits from biotech crops, Brookes and Barfoot (2016, Forthcoming) estimates that USA has enhanced farm income from biotech crops by US$66.1 billion in the first nineteen years of commercialization of biotech crops 1996 to 2014. This represents 44% of global benefits for the same period, and the benefits for 2014 alone are estimated at US$8.5 billion (representing 48% of global benefits in 2014). These are the largest gains for any biotech crop country.

Earlier studies in the US on biotech European corn borer resistant maize indicated the area wide suppression of ECB estimated at US$1 billion annually (Hutchinson et al. 2010). The biotech maize also indirectly affected conventional maize since the insect cannot discern Bt and non-Bt maize. This incidence corroborates with studies reported by 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. ECB has 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.

In this 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). Hence, this is the first study in the USA that included the value of area-wide pest suppression and the subsequent indirect benefits to farmers planting conventional non-Bt maize. 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."***

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

GM Food Labeling Regulations

The US regulatory framework conceived in 1986 was updated in 1992 when GM crops are not yet marketed. Current GMO regulations in the US needs revision since both the GM critics and the GM proponents are not satisfied with the current regulatory framework, described by many as convoluted and confusing regulations. The regulatory guideline for genetically modified crops was divided among three government agencies: the Agriculture Department, the Environmental Protection Agency and the Food and Drug Administration.

Critics of biotech crops have long said that the current system is too lax, and they will be pushing for tougher regulations. Proponents on the other hand observed that public sector GM products have not been commercialized because they are not able to go over the expensive regulatory process and no private company taker wants to do the same either. Thus, some people believe that genetic engineering is woefully over-regulated, and others believe just as ardently that it is under-regulated. With this revamp in mind, the US government should be able to take into consideration new breeding technologies covering genomic editing technologies. This new technology can alter DNA precisely, down to a single link in the DNA chain to improve crop trait. It does not move genetic material from one organism to another hence, products may not be subjected to current regulations. New technologies also allow scientists to see up to the DNA level transgene integration in GM crops which were impossible before (New York Times, 2 July 2015).

In August 2015, the US congress created a mandatory nationwide food labeling bill, officially known as the Safe and Accurate Food Labeling Act of 2015 HR 1599. The bill authored by Rep. Mike Pompeo will pre-empt states from crafting their own laws mandating GMO labeling. Hence, some states which passed labeling laws such as Maine and Vermont will have to follow this upcoming Law. The bill would not require food companies to disclose their use of genetically modified ingredients, but companies may also indicate that a product is GMO-free. It is essential that consumers be provided proper food label that is based on science and not on labels tinged with political, superstitious, myths, and traditions. The bill has been forwarded to the Senate for approval.

It is noteworthy to mention some studies on labeling conducted in the past which revealed that labeling could result to confusing implementation and costly products for the consumers:

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

b. An analysis of GMO labeling costs by two Cornell University scientists estimated the increased costs at US$500 per family of 4 each year. If labeling is accepted, anti-GMO organizations will make life miserable for firms selling GMO-containing foods. Firms will reformulate their products, but will have a hard time sourcing substitutes at reasonable prices. Hence, the main purposes of GMO labeling are just to satisfy "consumer curiosity" and to increase sales of the organic food industry, which funded the initiative. The costs will be huge, the benefits to consumers small, and the effort needed will be immense. Studies by the National Academy of Sciences and the American Medical Association reveal that there is no science-based reason to subject GM foods for mandatory labeling since they have already been deemed safe (Daily Camera Opinion, 19 Sept 2014).

Political Will and Support for Biotech Crops

<u>Recent talks between US President Barrack Obama and the Chinese President Xi Jinping</u> during the launch of the US-China Strategic Agricultural Innovation Dialogue (SAID) held in September 2015, was highlighted with China's agreement to improve agricultural biotechnology approval process. In a fact sheet issued by the White House, details on how China would do it were not indicated. Despite so, the fact sheet said that the two countries committed to improve the approval process. ***"Both sides reaffirmed the importance of implementing timely, transparent, predictable, and science-based approval processes for products of agricultural biotechnology, which are based on international standards,"*** the fact sheet said. The SAID meeting, which was not open to the press, included presentations by Chinese and US industry officials on issues including biotechnology, Big Data and finance. US industry officials are looking for China to accelerate final import approvals for seven biotech traits and to speed up consideration of

other genetically engineered crops in the pipeline. Preceding the meeting was a letter from farm groups, biotech companies, 42 senators and more than 100 House members, urging Pres. Obama to raise the issue with Pres. Xi (Agri-Pulse, 25 September 2015).

US Department of Agriculture Tom Vilsack mentioned that GM crop regulations between the US and European Union will make transatlantic trade deal difficult. During an interview at the G20 agriculture ministers regarding the European Commission proposal to give member governments to have control over GM crops. He suggested ***"You ought to give people the choice, and then let the market decide."*** He also emphasized that GM crops enable more production under difficult circumstances, expanding the food supply and lowering food prices. Thus, Americans are spending around 10 percent of pay for food (Crop Biotech Update, 13 May, 2015).

President Obama joined in celebrating Dr. Norman Borlaug's centennial celebration in the US Capitol, and his passion for feeding the hungry through biotechnology with a letter read by Julie Borlaug. He said, ***"I share his belief that investment in enhanced biotechnology is an essential component of the solution to some of our planet's most pressing agricultural problems...I will continue to work with the Department of Agriculture and others to explore innovative solutions to address food security challenges and mitigate the effects of climate change."*** Julie Borlaug, Assistant Director for External Relations at the Norman Borlaug Institute for International Agriculture said ***"This is a huge endorsement of the importance of agriculture research and biotechnology. My grandfather would have been grateful and appreciative of the president's focus on agriculture and climate change in an effort to feed the 9 billion people expected to live on this planet by 2050"*** (Crop Biotech Update, 16 April 2014).

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

The Coalition for Safe and Affordable Food (including the American Farm Bureau Federation and most major commodity groups) released the following statement in response to the briefing on Mandatory GMO labeling conducted in Washington on 8 July 2015: ***"The scientific evidence regarding the safety of GMOs is overwhelming and undeniable. Thousands of studies, as well as nearly every leading health and safety organization in the world – from the World Health Organizations to the American Medical Association – have all affirmed the safety of the foods produced through genetic engineering. Additionally, the Environmental Protection Agency has reviewed these products and deemed them safe for the environment."***

Scott Faber, executive director of the Just Label It campaign, testified during a hearing before the House Energy and Commerce Subcommittee on Health in December 2014 that he believes GMO foods are as safe as their conventional counterparts. ***"Opponents of GMOs are misleading the public into believing America's food supply is unsafe and farmers are to blame. They seem to overlook or ignore the***

inconvenient truth that pesticides and herbicides are used in the production of conventional crops as well, which means that their demand for mandatory labeling of GMOs would provide consumers with no actionable information whatsoever regarding when, where or if a farmer used these agricultural tools during the growing season. It is also important to remember that, should evidence arise that draws into question the safety of a product, the USDA, FDA and EPA already have the statutory authority to regulate that product as appropriate. "The Just Label It campaign is flailing around with a series of attacks and claims that show their GMO-labeling agenda simply has no scientific footing on which to stand," (Agripulse, 8 July 2015).

Farmer Experience

Jason Mewes, grower of biotech maize and soybean near Colgate, ND and president of the North Dakota Soybean Growers association commented that there is an obvious reason for growing GMOs. ***"The primary reason we grow the GMO crops is we get a better product in the end.... Whether it is better drought resistance, easier herbicide treatments or higher product yield, GMOs offer a competitive advantage over non-GMO crops,"*** he said (Grandfolks Herald, 1 March 2015).

Maryland farmer Jennie Schmidt is a registered dietician who also works on her family farm, growing many types of crops – including GMO corn and soybean – alongside non-GMO crops. Her farm is progressive, continuously trying out new forms of technology in order to strengthen and protect the family business. Schmidt explains that her GMO crops have a higher yield than the non-GMO crops, but the real benefit comes from savings in time, labor, fuel and wear and tear on her machinery. ***"All those things combined are very meaningful to a family farm,"*** she notes.

Ken Kamiya, a farmer in Hawaii and president of the Kamiya Gold Inc. recounted that GMO technology has saved family businesses. Papaya farming is a prime example. He notes that "***without GMO technology, there would be no papaya business, and I would be out of farming."*** Kamiya's family has been growing papayas for the past 40 years, with the past 16 years using GMO papaya. His confidence in the safety of his product is rock solid, and he points out that the papaya industry has marketed roughly 400 million pounds of papaya since the introduction of GMO technology, without a single negative incident (US News and Health, 25 April 2015).

For Katie Pratt, Illinois farmer, her family uses GMO crops because of the clear value they bring to their family business. They have greatly reduced the amount of insecticide that needs to be sprayed, and they only need to treat the weeds at one point, not several times over a growing season. Her soil has now improved, because she and her family don't have to tromp through the fields as often. The family also uses less fuel, because they spend less time in the tractor. ***"No one is more aware than the farmer of the impact we have on the environment, in addition to the urgency to feed and fuel a growing population, while reducing our footprint on the planet,"*** she maintains (US News and Health, 25 April 2015).

According to Kevin Rogers, an Arizona farmer, if it were not for GMO technology, the cotton industry in Arizona would not be thriving or sustainable. The pest that was destroying Arizona cotton crops was winning, and it was costing farmers more money to fight that pest than the crop was worth. GMO cotton has produced plants that resist the pest, and according to Rogers, it ***"has allowed farms in Arizona***

to be sustainable over the long haul. This technology allows us to produce more products on the same footprint, with less expense," (US News and Health, 25 April 2015).

Mary Mertz, Mother of two grown children raised on a farm that has chosen to use biotech seeds for almost twenty years now. She said in response to the comments posted to *Moms Across America* blog, ***"We did this because of the benefits to the land and to all of us. We use less chemicals and till/ plow the ground less frequently. I don't know where you are getting your information, but it is not from those of us that have grown grain for four generations and know how much GMOs have helped to improve soil conditions and safety/nutrition issues. GMOs do not cause detrimental health problems. Twenty years and a trillion meals served and not one substantiated incident of illness…not even a tummy ache, has been associated with genetically engineered crops. I know you want to blame something for the health problems you might be encountering. But blaming a process of crop production that has nothing to do with the end product of the fruit or vegetable produced is misguided. If GMOs were a health risk – then everyone I know in my farming community would be sick on some way. We live next to…work in…walk through GMOS every year. We are not sick. I actually was healthy enough to donate a kidney to my urban niece when none of our urban friends or relatives could. I live on a farm in Kansas. I love being part of agriculture. You can either believe what I say or continue to trust those that not farm but have an agenda. Just wanted to know that so many farm moms across America are saddened by your lack of trust in what we do"*** (Illumination. April 6, 2015).

BRAZIL

In the 2015 crop season, Brazil's total biotech crop hectares of soybean, maize and cotton was estimated at ~44.2 million hectares, an increase of 5%, from 2014, or 2.0 million hectares. Thus, Brazil continues to be the engine of growth in biotech crops worldwide – this 2.0 million hectare increase was by far the highest increase in any country worldwide in 2015. Brazil's 44.2 million hectares of biotech crops in 2015 represents 25% of the global hectarage. In 2015, the total biotech crop hectares in Brazil of 44.2 million hectares comprised: 30.3 million hectares of biotech soybean; 13.1 million hectares of biotech maize (summer and winter maize); and 0.7 million hectares of biotech cotton. The total planted area of these three crops in Brazil was estimated at ~48.7 million hectares of which ~44.2 million hectares or ~91% was biotech. Brazil retained its #2, world ranking after the US (which is the largest country hectarage in the world with 70.9 million hectares), representing 39% of the global hectarage of 179.7 million hectares. In Brazil, biotech soybean is still the highest hectarage with 30.3 million hectares, with a year-to-year increase of 1.3 million hectares or 4.5% and a 94.2% adoption rate of the 32.2 million hectares national soybean crop grown in 2015/16. The second most important biotech crop in Brazil was GM maize for a total of 13.1 million hectares (summer 4.5 million hectares and winter 8.6 million hectares), an increase of 0.6 million hectares or ~5.0% from 2014, due to an increase in the total maize planted area to 15.5 from 15.2 in 2015 and an increase in adoption rate from 82.4% to 84.6%. Biotech cotton was

the third biotech crop in Brazil, estimated to occupy 0.7 million hectares in 2015/16, a 73.3% adoption rate of the total of 1.0 million hectares planted with cotton. In 2015/16, biotech cotton increased by ~27% over 2014. All three categories of events IR, HT, and the stacked IR/HT were deployed in all three crops. "Intacta™", the relatively new IR/HT soybean was first planted on 2.2 million hectares in 2013/14; in its second season, 2014/15, it reached an estimated area of 5.2 million hectares, and further increased to 11.9 million hectares in 2015/2016 – an increase of over five-fold compared with the 2.2 million hectares in 2013. An important development is that Brazil has approved and will commercialize two home grown products in 2016. The home-grown virus-resistant bean, approved for planting in 2011, has completed variety registration trials and will be commercialized in early 2016, with two varieties of the "carioquinha" type. The herbicide (imidazolinone) tolerant soybean "Cultivance™" jointly developed by EMBRAPA and BASF is expected to be commercialized in 2016, on approximately 150,000 hectares. The economic benefits to Brazil from biotech crops, estimated by Celeres for the 17-year period (1996/97 to 2012/13) was US$24.8 billion and US$6.3 billion for 2013 alone. A different annual global study of benefits from biotech crops covering the 10-year period 2003 to 2014 concluded that Brazil gained US$13.9 billion during the nine-year period 2003 to 2014 and US$2.5 for 2014 alone (Brookes and Barfoot 2016, Forthcoming).

BRAZIL

Population: 207.8 million

GDP: US$2,253 billion

GDP per Capita: US$11,340

Agriculture as % GDP: 5%

Agricultural GDP: US$112.6 billion

% employed in agriculture: 15.3%

Arable Land (AL): 72.3 million hectares

Ratio of AL/Population*: 1.6

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

Commercialized Biotech Crops:
- HT & IR/HT Soybean
- HT; IR & IR/TH Cotton
- HT; IR & IR/HT Maize

Total area under biotech crops and (%) increase in 2015:
44.2 Million Hectares (+5%)

Farm income gain from biotech, 1997-2014: US$13.9 billion

*Ratio: % global arable land / % global population

In 2015, Brazil retained its #2 world ranking after the US (which is the largest country hectarage in the world with 70.9 million hectares), representing 39% of the global hectarage of 179.7 million hectares. Brazil's total biotech crop hectarage of soybean, maize and cotton was estimated at ~44.2 million hectares, an increase of 5%, from 2014, or 2.0 million hectares. Thus, Brazil continues to be the engine of growth in biotech crops worldwide – this 2.0 million hectare increase was by far the highest increase in any country worldwide in 2015. Brazil's 44.2 million hectares of biotech crops in 2015 represents 25% of the global hectarage and comprised: 30.3 million hectares of biotech soybean; 13.1 million hectares of biotech maize (summer and winter maize); and 0.7 million hectares of biotech cotton. The total planted area of these three crops in Brazil was estimated at ~48.7 million hectares of which ~44.2 million hectares or ~91% was biotech.

From 2003 to 2015, Brazil has approved 50 events for import for food, feed processing and cultivation including 29 maize events, 12 cotton events, 7 soybean events, one bean event and one eucalyptus. In 2015, Brazil approved nine events for planting: two soybean events (DAS86416-4 and FG72), six maize events (DAS-40278-9, NK603 x T25, TC1507 x MON810 x MIR162 x NK603, DAS1507-1 x MON810 x MIR162, DAS-40278-9 x NK603, Event 5307, and Bt11 x MIR162 x MIR604 x TC1507 x 5307 x GA2), and 1 eucalyptus event (H421).

Biotech Soybean

In Brazil, biotech soybean has the highest hectarage with 30.3 million hectares, with a year-to-year increase of 1.3 million hectares or 4.5% and a 94.2% adoption rate of the 32.2 million hectares national soybean crop grown in 2015/16 (Table 4). The 30.3 million hectares of biotech soybean is comprised of 18.5 million hectares herbicide tolerant (57.4%) and 11.9 million hectares stacked IR/HT (36.8%), with a total of 94.2% adoption. "Intacta™", the relatively new IR/HT soybean was first planted on 2.2 million hectares in 2013/14; in its second season, 2014/15, it reached an estimated area of 5.2 million hectares, and further increased to 11.9 million hectares in 2015/2016 – an increase of over five-fold compared with the 2.2 million hectares in 2013. In 2015, biotech soybean yields as much as 3.02 tons per hectare with a total production in 2015 of 97.1 million tons.

Biotech Maize

The second most important biotech crop in Brazil was GM maize, planted on a total of 13.1 million hectares (summer 4.5 million hectares and winter 8.6 million hectares), an increase of 0.6 million hectares or ~5.0% from 2014 (Table 4). This year-on-year increase is due to an increase in the total maize planted area to 15.5 from 15.2 in 2014 and an increase in adoption rate from 82.4% to 84.6%. The 13.1 million hectares of biotech maize is comprised of 3.3 million hectares IR (21.5%), 0.94 million hectares HT (6%) and 8.9 million hectares IR/HT (57.1%), with a total of 84.6% adoption. Biotech maize adoption in summer is 77% or 4.5 million hectares and 8.6 million hectares at 89% in winter. Biotech maize contributed the 2015 yield of 5.7 tons per hectare and a production of 87.9 million tons.

Biotech Cotton

Biotech cotton was the third biotech crop in Brazil, estimated to occupy 0.7 million hectares in 2015/16, a 73% adoption rate of the total of 1.0 million hectares planted with cotton (Table 4). In 2015/16 biotech cotton increased by ~27% over 2014. The biotech cotton hectarage of 0.7 million hectares is comprised of 0.2 million hectares IR (17%), 0.2 million hectares HT (23%) and stacked IR/HT (33%), with a total of 73% adoption. Biotech cotton contributed to the cotton annual yield of 1.6 tons per hectare and production volume of 1.6 million ton.

In summary, the collective hectares for all three biotech crops in Brazil in 2015/2016 was 44.20 million hectares, equivalent to 90.7% adoption; more specifically GM soybean adoption was 94.2%; GM summer maize adoption was 76.7%; GM winter maize was 89.4% and GM cotton adoption was 73.3% (Table 4 and Figure 5).

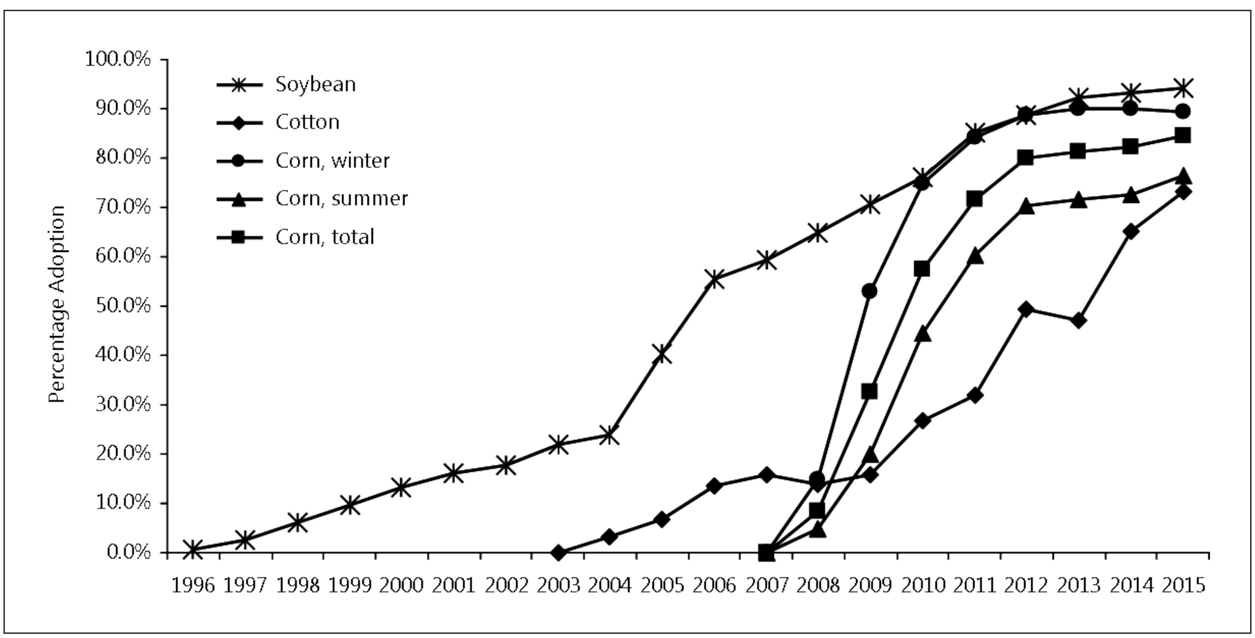
Details of adoption of the three biotech crops in the five regions of Brazil (North, Northeast, Southeast, South, Midwest, North/Northeast and Central South) for 2015 are presented in Tables 5 to 10.

Brazil is one of the leading exporters of biotech soybeans, maize and cotton. China is the main importer of Brazilian biotech soybeans and biotech cotton, followed by the European Union. Brazil is also the largest exporter of conventional soybean.

Table 4. Biotech Crop Hectarage in Brazil, by Crop, 2015

	Planted area (million ha)	Adoption rate | (% of total)				Planted area with biotech | (,000 ha)			
		IR	HT	IR/HT	Total	IR	HT	IR/HT	Total
Soybean	32.19	– –	57.4%	36.8%	94.2%	– –	18.48	11.85	30.33
Corn, summer	5.89	15.5%	7.9%	53.2%	76.7%	0.92	0.47	3.13	4.52
Corn, winter	9.64	25.1%	4.9%	59.5%	89.4%	2.42	0.47	5.73	8.62
Corn, total	15.53	21.5%	6.0%	57.1%	84.6%	3.33	0.94	8.86	13.14
Cotton	1.01	17.0%	23.5%	32.8%	73.3%	0.17	0.24	0.33	0.74
Brazil	48.73	7.2%	40.3%	43.2%	90.7%	3.51	19.66	21.04	44.20

Figure 5. Adoption of Biotech Crops in Brazil, by Crop, 2003 to 2015



Source:

Table 5. Adoption of Biotech Crops by State in Brazil, 2015

	Planted Area (million hectares)	Adoption rate (% of total area)				Biotech Area (million hectares)			
		IR	HT	IR/HT	Total	IR	HT	IR/HT	Total
NORTH	**1.80**	**2.8%**	**34.8%**	**24.9%**	**62.5%**	**0.05**	**0.63**	**0.45**	**1.13**
NORTHEAST	**6.04**	**7.7%**	**28.3%**	**37.5%**	**73.6%**	**0.47**	**1.71**	**2.26**	**4.45**
Maranhão	1.49	10.7%	28.5%	44.4%	83.7%	0.16	0.42	0.66	1.24
Piauí	1.13	7.9%	32.0%	42.0%	81.9%	0.09	0.36	0.47	0.92
Bahia	2.42	6.8%	37.7%	44.5%	89.0%	0.16	0.91	1.08	2.16
SOUTHEAST	**4.30**	**10.2%**	**35.3%**	**45.1%**	**90.6%**	**0.44**	**1.52**	**1.94**	**3.89**
Minas Gerais	2.65	9.5%	36.6%	44.3%	90.5%	0.25	0.97	1.17	2.40
São Paulo	1.63	11.1%	33.6%	46.2%	90.9%	0.18	0.55	0.75	1.48
SOUTH	**14.78**	**5.8%**	**48.2%**	**38.5%**	**92.4%**	**0.85**	**7.12**	**5.69**	**13.66**
Paraná	7.73	8.5%	41.3%	43.8%	93.6%	0.66	3.20	3.38	7.23
Santa Catarina	0.99	5.9%	42.9%	42.0%	90.8%	0.06	0.43	0.42	0.90
Rio Grande do Sul	6.07	2.3%	57.7%	31.2%	91.2%	0.14	3.50	1.89	5.53
MIDWEST	**21.81**	**7.8%**	**39.8%**	**49.1%**	**96.7%**	**1.70**	**8.68**	**10.70**	**21.08**
Mato Grosso	13.07	7.4%	40.3%	49.4%	97.0%	0.96	5.26	6.46	12.68
Mato Grosso do Sul	3.92	10.1%	37.4%	47.2%	94.8%	0.40	1.47	1.85	3.71
Goiás	4.68	7.0%	40.8%	49.5%	97.3%	0.33	1.91	2.32	4.56
Distrito Federal	0.13	10.3%	32.1%	53.4%	95.8%	0.01	0.04	0.07	0.13
N/NE	**7.85**	**6.6%**	**29.8%**	**34.6%**	**71.0%**	**0.52**	**2.34**	**2.71**	**5.57**
C-SOUTH	**40.89**	**7.3%**	**42.4%**	**44.8%**	**94.5%**	**2.99**	**17.32**	**18.33**	**38.63**
BRAZIL	**48.73**	**7.2%**	**40.3%**	**43.2%**	**90.7%**	**3.51**	**19.66**	**21.04**	**44.20**

Source: Céleres®. *Updated in 3 August 2015

Table 6. Biotech Soybean Adoption by State in Brazil, 2015

	Planted Area (million hectares)	Yield (t/ha)	Production (million t)	Adoption rate (% of total area)			Biotech Area (million hectares)		
				HT	IR/HT	Total	HT	IR/HT	Total
NORTH	**1.30**	**3.17**	**4.12**	**46.9%**	**26.8%**	**73.7%**	**0.61**	**0.35**	**0.96**
NORTHEAST	**2.98**	**3.01**	**8.97**	**50.1%**	**37.8%**	**88.0%**	**1.49**	**1.13**	**2.62**
Maranhão	0.86	3.09	2.65	44.6%	37.0%	81.7%	0.38	0.32	0.70
Piauí	0.69	2.85	1.97	46.4%	31.0%	77.4%	0.32	0.21	0.54
Bahia	1.43	3.05	4.35	55.3%	41.6%	96.9%	0.79	0.59	1.38
SOUTHEAST	**2.17**	**3.05**	**6.64**	**61.8%**	**28.4%**	**90.2%**	**1.34**	**0.62**	**1.96**
Minas Gerais	1.42	3.09	4.40	60.9%	29.1%	90.0%	0.87	0.41	1.28
São Paulo	0.75	2.98	2.24	63.6%	27.1%	90.8%	0.48	0.20	0.68
SOUTH	**10.88**	**2.93**	**31.83**	**62.7%**	**30.4%**	**93.1%**	**6.82**	**3.31**	**10.13**
Paraná	5.18	3.16	16.38	58.5%	35.7%	94.2%	3.03	1.85	4.88
Santa Catarina	0.58	3.05	1.78	66.0%	27.5%	93.5%	0.38	0.16	0.54
Rio Grande do Sul	5.12	2.67	13.67	66.6%	25.4%	92.0%	3.41	1.30	4.71
MIDWEST	**14.86**	**3.06**	**45.52**	**55.3%**	**43.4%**	**98.6%**	**8.22**	**6.44**	**14.66**
Mato Grosso	9.13	3.15	28.72	54.4%	45.0%	99.3%	4.96	4.10	9.07
Mato Grosso do Sul	2.34	2.85	6.69	59.0%	36.4%	95.4%	1.38	0.85	2.24
Goiás	3.32	2.97	9.87	55.2%	43.8%	99.0%	1.83	1.45	3.28
Distrito Federal	0.07	3.38	0.24	55.4%	43.8%	99.2%	0.04	0.03	0.07
N/NE	**4.28**	**3.06**	**13.10**	**49.2%**	**34.5%**	**83.6%**	**2.10**	**1.48**	**3.58**
C-SOUTH	**27.91**	**3.01**	**83.98**	**58.7%**	**37.2%**	**95.8%**	**16.38**	**10.37**	**26.75**
BRAZIL	**32.19**	**3.02**	**97.08**	**57.4%**	**36.8%**	**94.2%**	**18.48**	**11.85**	**30.33**

Source: Céleres®. *Updated in 3 August 2015

Table 7. Biotech Corn Adoption by State in Brazil. Summer + Winter Seasons, 2015

	Planted Area (million hectares)	Yield (t/ha)	Production (million t)	Adoption rate (% of total area)				Biotech Area (million hectares)			
				IR	HT	IR/HT	Total	IR	HT	IR/HT	Total
NORTH	**0.49**	**3.87**	**1.91**	**9.9%**	**3.0%**	**19.9%**	**32.8%**	**0.05**	**0.01**	**0.10**	**0.16**
NORTHEAST	**2.74**	**2.58**	**7.06**	**15.5%**	**4.9%**	**38.1%**	**58.4%**	**0.42**	**0.13**	**1.04**	**1.60**
Maranhão	0.61	3.03	1.83	25.6%	5.8%	55.6%	87.0%	0.15	0.04	0.34	0.53
Piauí	0.42	2.68	1.12	20.5%	8.3%	60.9%	89.7%	0.09	0.03	0.25	0.37
Bahia	0.71	4.05	2.88	18.1%	6.9%	56.1%	81.2%	0.13	0.05	0.40	0.58
SOUTHEAST	**2.10**	**5.99**	**12.58**	**20.5%**	**8.1%**	**62.4%**	**91.1%**	**0.43**	**0.17**	**1.31**	**1.91**
Minas Gerais	1.21	6.03	7.28	20.5%	8.3%	62.4%	91.2%	0.25	0.10	0.75	1.10
São Paulo	0.88	5.99	5.26	20.6%	7.8%	62.6%	91.0%	0.18	0.07	0.55	0.80
SOUTH	**3.91**	**6.63**	**25.91**	**21.8%**	**7.7%**	**60.9%**	**90.4%**	**0.85**	**0.30**	**2.38**	**3.54**
Paraná	2.55	6.84	17.43	25.7%	6.6%	60.1%	92.4%	0.66	0.17	1.53	2.35
Santa Catarina	0.41	7.58	3.10	14.4%	9.9%	62.6%	86.8%	0.06	0.04	0.26	0.36
Rio Grande do Sul	0.95	5.66	5.37	14.4%	9.9%	62.6%	86.8%	0.14	0.09	0.59	0.82
MIDWEST	**6.29**	**6.43**	**40.44**	**25.1%**	**5.1%**	**64.1%**	**94.2%**	**1.58**	**0.32**	**4.03**	**5.93**
Mato Grosso	3.36	6.71	22.55	25.4%	5.0%	64.0%	94.4%	0.85	0.17	2.15	3.17
Mato Grosso do Sul	1.54	5.35	8.24	25.4%	5.0%	64.0%	94.4%	0.39	0.08	0.99	1.45
Goiás	1.33	6.81	9.06	24.1%	5.4%	64.3%	93.7%	0.32	0.07	0.85	1.25
Distrito Federal	0.06	9.45	0.59	21.9%	6.0%	64.8%	92.6%	0.01	0.00	0.04	0.06
N/NE	**3.23**	**2.78**	**8.96**	**14.6%**	**4.6%**	**35.3%**	**54.5%**	**0.47**	**0.15**	**1.14**	**1.76**
C-SOUTH	**12.30**	**6.42**	**78.92**	**23.3%**	**6.4%**	**62.8%**	**92.5%**	**2.86**	**0.79**	**7.73**	**11.38**
BRAZIL	**15.53**	**5.66**	**87.88**	**21.5%**	**6.0%**	**57.1%**	**84.6%**	**3.33**	**0.94**	**8.86**	**13.14**

Source: Céleres®. *Updated in 3 August 2015

Table 8. Biotech Maize Adoption by State in Brazil, Summer Season, 2015

	Planted Area (million hectares)	Yield (t/ha)	Production (million t)	Adoption rate (% of total area)				Biotech Area (million hectares)			
				IR	HT	IR/HT	Total	IR	HT	IR/HT	Total
NORTH	**0.22**	**3.07**	**0.67**	**9.4%**	**4.7%**	**13.5%**	**27.6%**	**0.02**	**0.01**	**0.03**	**0.06**
NORTHEAST	**2.01**	**2.42**	**4.85**	**14.3%**	**6.1%**	**39.9%**	**60.3%**	**0.29**	**0.12**	**0.80**	**1.21**
Maranhão	0.40	2.23	0.88	19.2%	8.9%	62.2%	90.3%	0.08	0.04	0.25	0.36
Piauí	0.39	2.51	0.98	19.2%	8.9%	62.2%	90.3%	0.07	0.03	0.24	0.35
Bahia	0.47	4.68	2.21	18.1%	8.9%	62.2%	89.1%	0.09	0.04	0.29	0.42
SOUTHEAST	**1.42**	**6.21**	**8.83**	**19.6%**	**8.8%**	**62.1%**	**90.5%**	**0.28**	**0.13**	**0.88**	**1.29**
Minas Gerais	0.92	5.94	5.48	19.9%	8.9%	62.2%	90.9%	0.18	0.08	0.57	0.84
São Paulo	0.48	6.85	3.30	19.0%	8.9%	62.2%	90.0%	0.09	0.04	0.30	0.43
SOUTH	**1.91**	**7.18**	**13.70**	**14.4%**	**9.9%**	**62.6%**	**86.8%**	**0.27**	**0.19**	**1.19**	**1.66**
Paraná	0.55	9.51	5.22	14.4%	9.9%	62.6%	86.8%	0.08	0.05	0.34	0.48
Santa Catarina	0.41	7.58	3.10	14.4%	9.9%	62.6%	86.8%	0.06	0.04	0.26	0.36
Rio Grande do Sul	0.95	5.66	5.37	14.4%	9.9%	62.6%	86.8%	0.14	0.09	0.59	0.82
MIDWEST	**0.34**	**8.34**	**2.81**	**16.8%**	**6.4%**	**67.0%**	**90.3%**	**0.06**	**0.02**	**0.23**	**0.30**
Mato Grosso	0.06	7.29	0.44	16.0%	3.7%	70.5%	90.2%	0.01	0.00	0.04	0.05
Mato Grosso do Sul	0.02	8.43	0.17	16.0%	3.7%	70.5%	90.2%	0.00	0.00	0.01	0.02
Goiás	0.23	8.46	1.95	17.1%	7.2%	66.0%	90.3%	0.04	0.02	0.15	0.21
Distrito Federal	0.03	9.60	0.26	17.1%	7.2%	66.0%	90.3%	0.00	0.00	0.02	0.02
N/NE	**2.22**	**2.48**	**5.52**	**13.8%**	**6.0%**	**37.3%**	**57.1%**	**0.31**	**0.13**	**0.83**	**1.27**
C-SOUTH	**3.67**	**6.91**	**25.34**	**16.6%**	**9.1%**	**62.8%**	**88.6%**	**0.61**	**0.34**	**2.30**	**3.25**
BRAZIL	**5.89**	**5.24**	**30.86**	**15.5%**	**7.9%**	**53.2%**	**76.7%**	**0.92**	**0.47**	**3.13**	**4.52**

Source: Céleres®. *Updated in 3 August 2015

Table 9. Biotech Maize Adoption by State in Brazil, Winter Season, 2015

	Planted Area (million hectares)	Yield (t/ha)	Production (million t)	Adoption rate (% of total area)				Biotech Area (million hectares)			
				IR	HT	IR/HT	Total	IR	HT	IR/HT	Total
NORTH	**0.28**	**4.51**	**1.24**	**10.3%**	**1.7%**	**24.9%**	**37.0%**	**0.03**	**0.00**	**0.07**	**0.10**
NORTHEAST	**0.73**	**3.02**	**2.20**	**18.8%**	**1.5%**	**33.0%**	**53.3%**	**0.14**	**0.01**	**0.24**	**0.39**
Maranhão	0.21	4.54	0.95	37.5%	0.0%	43.3%	80.8%	0.08	0.00	0.09	0.17
Piauí	0.03	5.04	0.14	37.5%	0.0%	43.3%	80.8%	0.01	0.00	0.01	0.02
Bahia	0.24	2.81	0.67	18.3%	3.1%	44.2%	65.6%	0.04	0.01	0.11	0.16
SOUTHEAST	**0.68**	**5.52**	**3.75**	**22.6%**	**6.6%**	**63.1%**	**92.2%**	**0.15**	**0.04**	**0.43**	**0.63**
Minas Gerais	0.29	6.31	1.80	22.6%	6.6%	63.1%	92.2%	0.06	0.02	0.18	0.26
São Paulo	0.40	4.95	1.96	22.6%	6.6%	63.1%	92.2%	0.09	0.03	0.25	0.36
SOUTH	**2.00**	**6.10**	**12.21**	**28.8%**	**5.7%**	**59.4%**	**93.9%**	**0.58**	**0.11**	**1.19**	**1.88**
Paraná	2.00	6.10	12.21	28.8%	5.7%	59.4%	93.9%	0.58	0.11	1.19	1.88
Santa Catarina	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	0.00	0.00	0.00	0.00
Rio Grande do Sul	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	0.00	0.00	0.00	0.00
MIDWEST	**5.96**	**6.32**	**37.62**	**25.6%**	**5.0%**	**63.9%**	**94.4%**	**1.52**	**0.30**	**3.81**	**5.62**
Mato Grosso	3.30	6.70	22.11	25.6%	5.0%	63.9%	94.4%	0.84	0.16	2.11	3.12
Mato Grosso do Sul	1.52	5.31	8.07	25.6%	5.0%	63.9%	94.4%	0.39	0.08	0.97	1.44
Goiás	1.10	6.47	7.12	25.6%	5.0%	63.9%	94.4%	0.28	0.05	0.70	1.04
Distrito Federal	0.04	9.33	0.33	25.6%	5.0%	63.9%	94.4%	0.01	0.00	0.02	0.03
N/NE	**1.01**	**3.43**	**3.44**	**16.5%**	**1.6%**	**30.8%**	**48.8%**	**0.17**	**0.02**	**0.31**	**0.49**
C-SOUTH	**8.64**	**6.20**	**53.58**	**26.1%**	**5.3%**	**62.8%**	**94.1%**	**2.25**	**0.45**	**5.42**	**8.13**
BRAZIL	**9.64**	**5.92**	**57.02**	**25.1%**	**4.9%**	**59.5%**	**89.4%**	**2.42**	**0.47**	**5.73**	**8.62**

Source: Céleres®. *Updated in 3 August 2015

Table 10. Biotech Cotton Adoption by State in Brazil, 2015

	Planted Area (million hectares)	Yield (t/ha)	Production (million t)	Adoption rate (% of total area)				Biotech Area (million hectares)			
				IR	HT	IR/HT	Total	IR	HT	IR/HT	Total
NORTH	**0.01**	**1.55**	**0.01**	**19.8%**	**23.5%**	**25.7%**	**69.0%**	**0.00**	**0.00**	**0.00**	**0.01**
NORTHEAST	**0.33**	**1.70**	**0.56**	**13.6%**	**26.3%**	**29.2%**	**69.2%**	**0.04**	**0.09**	**0.10**	**0.23**
Maranhão	0.02	1.65	0.04	19.8%	25.5%	25.7%	71.0%	0.00	0.01	0.01	0.02
Piauí	0.02	1.58	0.03	19.8%	25.5%	25.7%	71.0%	0.00	0.00	0.00	0.01
Bahia	0.29	1.73	0.49	12.6%	26.5%	29.9%	69.0%	0.04	0.08	0.09	0.20
SOUTHEAST	**0.02**	**1.63**	**0.04**	**25.3%**	**15.8%**	**37.2%**	**78.3%**	**0.01**	**0.00**	**0.01**	**0.02**
Minas Gerais	0.02	1.64	0.03	25.3%	15.8%	37.2%	78.3%	0.00	0.00	0.01	0.02
São Paulo	0.00	1.54	0.01	25.3%	15.8%	37.2%	78.3%	0.00	0.00	0.00	0.00
SOUTH	**0.00**	**0.86**	**0.00**	**8.6%**	**18.4%**	**37.2%**	**64.2%**	**0.00**	**0.00**	**0.00**	**0.00**
Paraná	0.00	0.86	0.00	8.6%	18.4%	37.2%	64.2%	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	**0.65**	**1.58**	**1.03**	**18.4%**	**22.3%**	**34.5%**	**75.2%**	**0.12**	**0.15**	**0.22**	**0.49**
Mato Grosso	0.58	1.57	0.91	18.6%	22.5%	34.4%	75.5%	0.11	0.13	0.20	0.44
Mato Grosso do Sul	0.03	1.74	0.06	17.4%	21.5%	36.8%	75.7%	0.01	0.01	0.01	0.02
Goiás	0.04	1.74	0.06	17.2%	20.6%	33.4%	71.2%	0.01	0.01	0.01	0.03
Distrito Federal	0.00	1.50	0.00	17.2%	20.6%	33.4%	71.2%	0.00	0.00	0.00	0.00
N/NE	**0.34**	**1.70**	**0.57**	**13.8%**	**26.2%**	**29.1%**	**69.2%**	**0.05**	**0.09**	**0.10**	**0.23**
C-SOUTH	**0.67**	**1.59**	**1.07**	**18.7%**	**22.1%**	**34.6%**	**75.3%**	**0.13**	**0.15**	**0.23**	**0.51**
BRAZIL	**1.01**	**1.62**	**1.64**	**17.0%**	**23.5%**	**32.8%**	**73.3%**	**0.17**	**0.24**	**0.33**	**0.74**

Source: Céleres®. *Updated in 3 August 2015

Biotech Crops in the Pipeline

Brazilian and multinational seed companies and public sector research institutions are working on the development of various GE plants. Currently, there are a number of biotech crops in the pipeline waiting for commercial approval, of which the most important are sugar cane, potatoes, papaya, rice and citrus. Except for sugarcane, most of these crops are in the early stages of development and approvals are not expected within the next five years.

Herbicide Tolerant Soybean

In particular, EMBRAPA is developing a range of new GM products, including soybean and sugarcane drought-resistant, folate-fortified lettuce, soybean as a biofactory of HIV antibody and a virus-resistant bean expected to be commercially launched in 2016. The herbicide (imidazolinone) tolerant soybean "Cultivance™" jointly developed by EMBRAPA and BASF is expected to be commercialized in 2016, on approximately 150,000 hectares. Cultivance™ will be launched initially in the states of Bahia, Goiás, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Paraná, Rondônia, São Paulo and Distrito Federal. The distribution takes into account the characteristics of the cultivars that will be placed on the market in the 2015/2016 season. The technology is also approved for import in 17 countries, including China, the largest global importer, and the European Union, which is a huge buyer of soy meal.

Biotech Bean

An important development is that Brazil has approved and will commercialize two home grown products in 2016. The home-grown virus-resistant bean, approved for planting in 2011, has completed variety registration trials and will be commercialized in early 2016, with two varieties of the "carioquinha" type. The golden mosaic virus disease is considered as one of the most important diseases that limits bean production in Latin America. In 2011, the transgenic bean event Embrapa 5.1, with resistance to bean golden mosaic virus was approved for commercial release in Brazil. The team of scientists led by Francisco Aragão, from Embrapa Recursos Genéticos e Biotecnologia in Brazil, evaluated the nutritional components of the beans in the primary transgenic line as well as lines derived from crosses and backcrosses of the transgenic with two commercial cultivars. Results revealed that the transgenic bean event was nutritionally equivalent to the non-transgenic bean plants. Moreover, the amounts of the nutritional components are within the range of values observed for several bean commercial varieties grown.

GE Eucalyptus

FuturaGene Brasil Technology Ltd, developed a fast growing GM eucalyptus with 20 percent higher productivity (between 30 and 40 percent more) for use in other applications such as bioenergy. Despite environmentalist opposition and vandalism attacks on their experimental greenhouses in Sao Paulo, this GM Eucalyptus was approved for commercial release by the CTNBio in April. According to the company's CEO Stanley Hirsch (Personal communication), "the approval represents the most significant productivity milestone for the renewable plantation forest industry since the adoption of clonal technology in the early 1990's. It represents the beginning of a new era for sustainable forest management, and Brazil is the first country to complete the cycle of development of such a technology, which will enhance production using less resources. The yield increase provided by the GM eucalyptus will provide economic, environmental and social benefits. The economic benefits include increased competitiveness for the Brazilian forestry sector. The main environmental benefits derived from using less land to produce more fiber will include lowered carbon emission through the reduction of distance between the forests and the mills, reduced use of chemical inputs and greater availability of land for other purposes, such as conservation and food production. Partners of Suzano Pulp and Paper's out growers program, including small landholders, who have already benefited from the company´s best seedlings for years, will have access to the technology under terms of current contracts, which do not involve the payment of royalties." Specific plans for commercialization have not been outlined at this time.

Other institutes in Brazil include the Centro de Tecnologia Canavieira (CTC) working on genetically engineered varieties of sugar cane, a major crop in the country; the Federal University of Rio de Janeiro is developing insect-resistant GM rice, the Federal University of Viçosa is developing drought-resistant GM bean, and Fundecitrus is developing a GM citrus resistant to citrus canker and citrus black spot.

Benefits from Biotech Crops in Brazil

Rural producers of cotton, maize and soybean crops first adopted agricultural biotechnology in Brazil 20 years ago. For the seventh consecutive year Céleres® has studied and analyzed the economic benefits resulting from the use of this technology, collected from rural producers and the industries that control the technology. Based on field studies, it is estimated that since the introduction of agricultural biotechnology in Brazil in the 1996/97 crop period, the economic benefits to users of this technology ~ in this case rural producers and the controlling industry – have reached US$24.8 billion, which is the result of 17 years of genetically modified crops.

Another annual global study of benefits from biotech crops covering a different period (2003 to 2014) concluded that Brazil gained US$13.9 billion during the ten year period 2003 to 2014 and US$2.5 billion for 2014 alone (Brookes and Barfoot, 2016 Forthcoming). The successful development of the home-grown biotech bean and herbicide tolerant soybean 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.

ARGENTINA

Total biotech crop hectares in Argentina in 2015 were estimated at 24.5 million hectares, 0.2 million hectares more than the 24.3 million hectares in 2014. Argentina maintained its ranking as the third largest producer of biotech crops in the world in 2015, after the US and Brazil, occupying 14% of global hectarage. In 2015, the 24.5 million hectares comprised an all-time high of 21.1 million hectares of biotech soybean, of which 20.4 million hectares were HT and 700,000 hectares were the stacked Bt/HT soybean; 2.9 million hectares of biotech maize (~3% lower than 2014 at 3.0 million hectares); and 0.5 million hectares of biotech cotton at 100% adoption (similar to 2014). Consistent with

many other countries worldwide, farmers substituted maize with soybean (and also crops such as sunflower) because of the higher returns from soybean, ease, less expensive crop management, and less inputs. Farmers have made these planting decisions in a general climate of political uncertainty and where choice of crop is also influenced by affordability of inputs. Positive trade discussion between Argentina and China to export Argentinean biotech maize to China continues to provide a significant incentive and boost for biotech maize, for the longer term in Argentina. Over the last several years, Argentina has achieved a marked improvement in its promotion of biotech crops and has pursued their timely regulation aggressively. In 2015, in an important development, Argentina approved two home-grown biotech crops: a drought tolerant soybean and a virus Y resistant potato –this reflects Argentina's increasing national capability of developing its own biotech crops which is also the case in neighboring Brazil which has approved and will commercialize two new home-grown biotech crops in 2016, a virus resistant bean and a herbicide tolerant soybean. Brookes and Barfoot estimated benefits from biotech crops in Argentina from 1996-2014 that amounted to US$19.3 billion while US$1.7 billion for 2014 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.

ARGENTINA

Population: 43.4 million

GDP: US$476 billion

GDP per Capita: US$11,570

Agriculture as % GDP: 9%

Agricultural GDP: US$42.84 billion

% employed in agriculture: 1%

Arable Land (AL): 38 million hectares

Ratio of AL/Population*: 4

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

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

Total area under biotech crops and (%) increase in 2015:
24.5 Million Hectares (+1%)

Farm income gain from biotech, 1996-2014: US$19.3 billion

*Ratio: % global arable land / % global population

Total biotech crop hectares in Argentina in 2015 were estimated at 24.5 million hectares, 0.2 million hectares more than the 24.3 million hectares in 2014. Argentina maintained its ranking as the third largest producer of biotech crops in the world in 2015, after the US and Brazil, occupying 14% of global hectarage. In 2015, the 24.5 million hectares comprised an all-time high of 21.1 million hectares of biotech soybean, 2.9 million hectares of biotech maize and 0.5 million hectares of biotech cotton (similar to 2014). 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.

Argentina has achieved a marked improvement in its promotion of biotech crops and has pursued their timely regulation aggressively. The 41 biotech crop products approved for commercial planting in Argentina and for import as food and feed products from 1996 to 2015 include: 3 cotton events, 29 maize events, 1 potato event and 8 soybean events (Table 11). In 2015, three soybean events were approved including the herbicide tolerant soybean DAS 44406-6, drought tolerant IND 00410-5, and modified fatty acid profile x HT DP 305423-1 x MON 04032-6, and more importantly the potato virus Y resistant potato TIC-AR233-5 (ArgenBio, 2015). The approval by Argentina of two home-grown biotech crops reflects Argentina's increasing national capability of developing its own biotech crops which is also the case in neighboring Brazil which has approved and will commercialize two new home-grown biotech crops in 2016, a virus resistant bean and a herbicide tolerant soybean.

Biotech Soybean

In 2015, Argentina planted 21.1 million hectares of biotech soybean, 86% of the 24.5 million hectares of biotech crops planted in the country. There is a 1.4% (300,000 hectares) increase of biotech soybean from 20.8 million hectares in 2014. It comprised an all-time high of 20.4 million hectares HT and 700,000 hectares stacked Bt/HT soybean. Consistent with many other countries worldwide, farmers substituted maize with soybean (and also crops such as sunflower) because of the higher returns from soybean, ease, less expensive crop management, and less inputs, plus a general political climate of uncertainty in a country where choice of crop is also influenced by affordability. In addition, there is high liquidity, relatively stable international demand for soybean and can be stored in silos as an alternate store of value.

In 6 October 2015, the Secretary of Agriculture, Livestock and Fisheries Gabriel Delgado approved the conditional marketing in all of Argentina, the drought tolerant soybeans and salinity (IND-ØØ41Ø-5 event) developed by the Institute of Agricultural Biotechnology of Rosario (Indear). Drought tolerant soybean was developed by Universidad Nacional del Litoral (UNL) led by Dr. Rachel Chan who identified and used sunflower gene *hahba-4* which has related natural plant response to abiotic stresses such as drought and salinity (Valorsoja, 6 October 2015). The drought tolerant soybean has the potential to increase soybean yields by up to 14% especially in marginal areas including drought and low-water conditions, typical in soybean production areas. This new biotech soybean was developed by a company owned by farmers and Insud group in Argentina in collaboration with Arcadia Biosciences Inc and Verdeca. It is important to note that this approval is momentous news for farmers trying to meet the growing global demand for soybeans under challenging environmental conditions. HB4 soybeans will create significant value for soybean growers and end markets by increasing the productivity and sustainability of the world's most important protein crop (Verdeca, 6 October 2015).

Majority of Argentina's soybean oil and soybean meal are exported, but for 2015/16, food use consumption of soybean oil at the retail level is slowly increasing. About two thirds of soybean oil is used to make biodiesel and the rest is used domestically to meet the national biodiesel blend mandate of ten percent. In 2015, Argentina has become eligible to export biodiesel to the US and be qualified for its export count against the US domestic renewable fuel standards obligations. Some analysts forecast that Argentine biodiesel exports to the United States can grow to as high as 400,000 mt.

Table 11. Commercial Biotech Event Approvals for Planting, Food and Feed in Argentina, 1996 to 2015

Crop	Event	Argentina
Soybean	40-3-2	1996
Soybean	A2704-12	2011
Soybean	A5547-127	2011
Soybean	MON89788 X MON87701	2012
Soybean	BPS-CV127-9	2013
Soybean	DAS-44406-6	2015
Soybean	IND-ØØ41Ø-5	2015
Soybean	DP-305423-1 x MON-04032-6	2015
Maize	176	1998
Maize	T25	1998
Maize	MON810	1998
Maize	Bt11	2001
Maize	NK603	2004
Maize	TC1507	2005
Maize	GA21	2005
Maize	NK603 x MON810	2007
Maize	1507 x NK603	2008
Maize	GA21 x Bt11	2009
Maize	MON 89034	2010
Maize	MON 88017	2010
Maize	MON 89034 x MON 88017	2010
Maize	MIR162	2011
Maize	Bt11 x GA21 x MIR162	2011
Maize	DP-098140-6	2011
Maize	MIR604	2012
Maize	Bt11 x MIR162 x MIR604 x GA21	2012
Maize	MON89034 x TC1507 x NK603	2012
Maize	MON89034 x NK603	2012
Maize	TC1507 x MON810	2013
Maize	TC1507 x MON810 x NK603	2013
Maize	Bt11 x MIR162 x TC1507 x GA21	2014
Maize	MIR162 x GA21	2014
Maize	MIR162 x TC1507	2014
Maize	MIR162 x TC1507 x GA21	2014
Maize	Bt11 x GA21	2014
Maize	Bt11 x MIR162 x TC1507	2014
Maize	Bt11 x TC1507	2014
Cotton	MON531	1998
Cotton	MON1445	2001
Cotton	MON 1445 x MON531	2009
Potato	TIC-AR233-5	2015

Source: Clive James, 2015.

Approximately three-quarters of Argentina's soybeans are crushed in the country. Nearly all of the remaining whole soybeans are exported to China, which in 2014/15 nearly 80 percent of all whole soybeans were shipped to China, equivalent to 6.1 mmt. Other important markets for whole beans include Egypt, Bangladesh and Iran. Argentina dominates the world market as the largest exporter of soybean oil. In 2014/15, the largest export markets for Argentine soybean oil were China, Malaysia, South Korea and Morocco. The largest soybean meal markets for Argentina in 2014/15 were the European Union (approximately a third of all meal exports), Vietnam, Indonesia, and Iran. Soybean exports for 2015/16 are forecast to reach 10 mmt, based on a higher production forecast and high carry over stocks from 2014/15.

Biotech Corn

Of the total maize hectarage in 2015 of 2.9 million hectares, 2 million hectares were planted to stacked trait (insect resistant and herbicide tolerant) maize, 595,000 hectares were Bt and 238,000 hectares were HT). Thus, the stacked gene Bt/HT maize product occupied ~69% of the biotech maize and is expected to retain this premier position in the future. Positive trade discussion between Argentina and China to export Argentinean biotech maize to China continues to provide a significant incentive and boost for biotech maize, for the longer term in Argentina.

USDA FAS-GAIN (2015) project corn production for crop season 2015/2016 at 20.0 million tons, lower than the previous season as a result of a slightly lower planted area and normal yields. Farmers are quite discouraged with corn production as it is the crop which demands the highest investment (current direct costs are US$600 per hectare) and has significantly lower projected returns than soybeans. Corn will still be produced by farmers owning the land (roughly 70 percent of the total area is leased land), have operations close to ports (no more than 200-300 kilometers) since high freight costs have a severe negative impact on returns, by producers which are contractually obliged to plant corn, and in the northern part of the country which due to environmental and productive issues need to rotate corn with soybeans almost every year. In Argentina, the current ratio of planted area between soybeans and corn is roughly 6 to 1.

Insect resistant biotech maize was introduced in Argentina in 1998 and herbicide tolerant maize in 2004. Stacked trait (Bt/HT) varieties became available in 2007, and by 2015, 69% of biotech maize hectarage is planted to stacked varieties.

Biotech Cotton

Biotech insect resistant cotton has been planted in Argentina since 1998 and herbicide tolerant cotton since 2002. A total of 530,000 hectares was planted to biotech cotton in 2015, similar to 2014, and at ~100% adoption. It is composed of 488,000 hectares Bt/HT stacked products and 42,000 hectares herbicide tolerant (HT) cotton. In 2015, there is no recorded Bt cotton planted in the country. 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.

Biotech 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 was 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) with Alejandro Mentaberry. 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).

Secretary of Agriculture, Livestock and Fisheries Gabriel Delgado authorized the marketing of a potato event (TIC-AR233-5) resistant to PVY (Potato Virus Y) throughout the national territory on 6 October 2015. The authorization does not cover Valles and some places of the Oasis Irrigation; the provinces of Salta and Jujuy to preserve commercially producing areas of Andean tubers (Valorsoja. 6 October 2015). Although the potato event TIC-AR233-5 will not eliminate the need to repurchase PVY free seed, it will allow producers to replant their own seed and eventually reduce production costs for two to three seasons.

Biotech Crops in the Pipeline

Wheat is being developed in the country to be drought resistant by researchers at INTA in collaboration with lead scientist Eduardo Blumwald of University of California Department of Plant Sciences at UC Davis. The team used a cytokinin synthesis gene under a water stress inducible promoter to confer drought resistance in wheat. Regenerated plants remain green and do not enter into senescence during drought stress (Valorsoja, 6 October 2015). Also in the pipeline is a glyphosate tolerant sugarcane being developed at the Obispo Colombres Agricultural Station.

Benefits from Biotech Crops in Argentina

Recent data on the benefits from biotech crops, Brookes and Barfoot (2016, Forthcoming) estimates that Argentina has enhanced farm income from biotech crops by US$19.3 billion in the first 19 years of commercialization of biotech crops 1996 to 2014, and the benefits for 2014 alone were estimated at ~US$1.7 billion.

A comprehensive study on the benefits of biotech crops in Argentina for the fifteen years of its commercialization (1996-2010) was conducted by Trigo (2011). The study indicated that gross benefit generated by this adoption process for the period 1996-2010 reached US$72,363 million. Economic benefits of biotech crops that accrue to various stakeholders are presented in Table 12.

The author concluded that 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 (2011). He further 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 Trigo (2011).

ArgenBio Executive Director Gabriela Levitus explained the key to success of biotech crop adoption in Argentina. ***"The biotechnology adoption process in Argentine agriculture has been undoubtedly very successful 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 (Trigo (2011).

Political Support in Argentina

Former Argentinian ambassador to the European Union Gustavo Idigoras told delegates at the International Federation of Agriculture Journalists Congress in Argentina that ***"Biotechnology in Argentina is not questioned, it is lived as it benefits all of society…Adoption of technology is a reality here. We are for it and we will continue to be for it"*** (Food and Farming Canada, 4 October 2013)."

Table 12. 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.

In the same fora, Argentinian no-till expert Victor Trucco stated that, ***"The biggest threat to the environment and soil health comes not from pesticide use or biotechnology but rather from the humble plow."*** This message has been part of the driving force behind the widespread adoption of no-till techniques in a country where more than 60 percent of the total seeded area is devoted to soybean production. Trucco added that, ***"No till vastly reduces the amount of time and resources farmers have to invest into land and is one of the main reasons, next to biotech, that average yields for Argentina's main crops – soybeans, corn and wheat – have doubled in the last two decades"*** (Food and Farming Canada, 4 October 2013).

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.

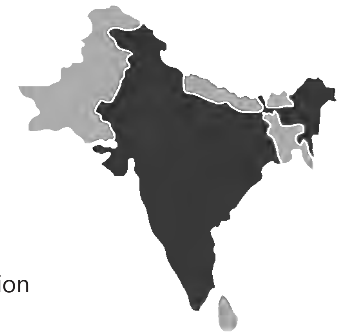
He first incorporated biotechnology into his farm more than 10 years ago when he started planting glyphosate-resistant soybean. ***"We have seen many advantages over the years with the new products. Before, it was a lot of mechanical work to get rid of weeds. Now, the producer is more free, there is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

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

INDIA

INDIA



Population: 1,311.0 million

GDP: US$1,859 billion

GDP per Capita: US$1,500

Agriculture as % GDP: 18%

Agricultural GDP: US$334.6 billion

% employed in agriculture: 47%

Arable Land (AL): 174 million hectares

Ratio of AL/Population*: 0.6

Major crops:

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

Commercialized Biotech Crop: Bt Cotton

Total area under biotech crops and (%) increase in 2015:
11.6 Million Hectares (0%)

Farm income gain from biotech, 2002-2014: US$18.3 billion

*Ratio: % global arable land / % global population

In 2015, India displaced China to become the number one cotton producing country in the world. Notably, USDA and ICAC estimate that India produces marginally more cotton than China in 2015 for the first time in history (USDA, 2015; ICAC, 2015). In the last fourteen years, India achieved a remarkable feat in cotton production and climbed up the global cotton ladder from third position to second in 2006 and to number one position in 2015. China and USA are the second and third largest cotton producers after India. Not only did India produce more cotton in 2015 but it also narrowed the yield gap with China and USA. In 2015, India produced 6.51 million tones of cotton fiber compared to 6.48 million tons produced by China in the cotton year 2014-15. At the macro level, India has emerged as a significant exporter in a few agricultural crops including cotton.

India maintained a record 11.6 million hectares of Bt cotton in 2015, equivalent to a high adoption rate of 95% of 12.2 million hectares total cotton area. In 2015, cotton planting has marginally reduced whereas the adoption remains strong and robust. Estimated number of Bt cotton farmers remains at 7.7 million. Thus, in 2015, India achieved a near– optimal adoption rate of 95% at the national level, and this was distributed evenly among the ten major cotton growing States. Notably, the rapid adoption of Bt cotton hybrids spurred the growth of cotton production by a factor of three to 39 million bales in 2014-15 from 13 million bales in the base year 2002. However, in 2015, cotton production in India has slightly contracted due to heavy infestation of the cotton leaf curl virus (CLCV) particularly in the Northern cotton growing zones including Haryana and Punjab. However, at the global level, India increased its cotton market share to 27% of the total global cotton production in 2015.

India continues to debate the relevance and need of biotech crops since it imposed the moratorium on Bt brinjal on 9th Feb 2010. The following three important biotech

crops, which are ready to be commercialized, would trigger a new phase of growth and momentum in the crop biotech sector in the country;

- **first, the approval of country's first biotech mustard (*Brassica juncea*) with enhanced heterosis (hybridization) in mustard, the most important edible oil crop in India**
- **second, the approval of the country's first stacked trait – the insect resistant and herbicide tolerant cotton, Bollgard II Roundup Ready Flex® cotton (BG-II RRF®) and,**
- **third, the approval of country's first vegetable crop Bt brinjal (eggplant) by revisiting its 5-year old moratorium in the context of the large scale commercial planting of Bt brinjal in the neighboring country of Bangladesh; it is noteworthy that a noticeable increase in pesticide residues is occurring in important vegetables and fruits; biotech crops could help reduce the use of pesticides on food crops.**

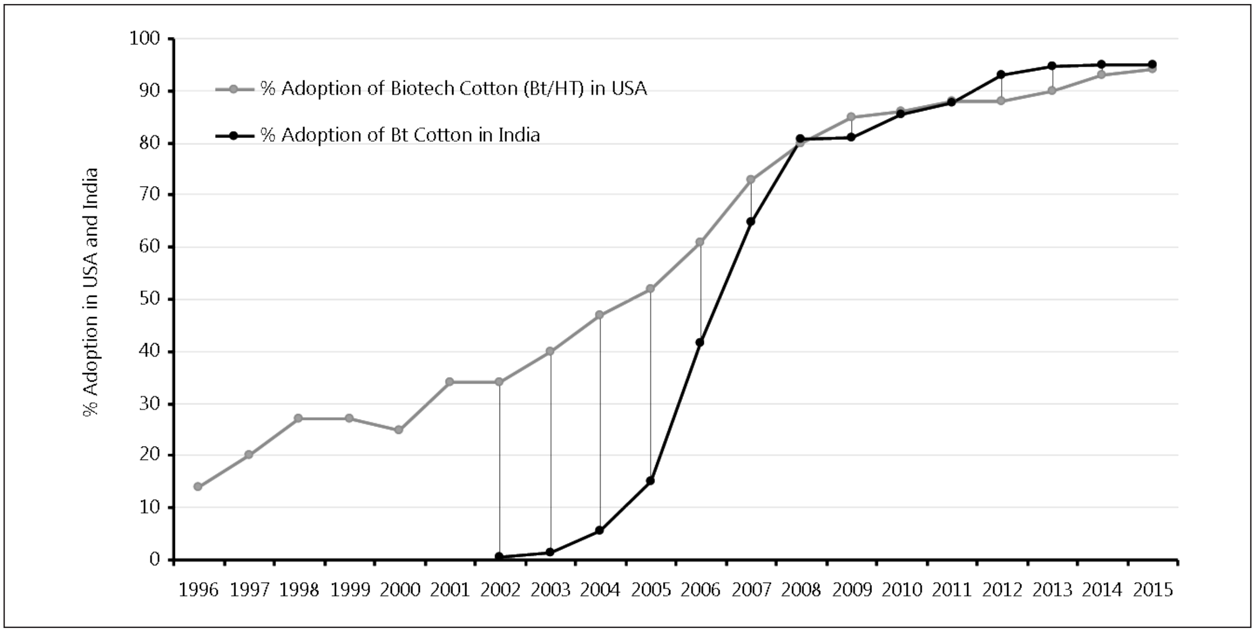
Remarkably, Bt cotton has made an enormous contribution to India's farm economy. Brookes and Barfoot provisionally estimated that India had enhanced farm income from Bt cotton by US$18.3 billion in the thirteen-year period 2002 to 2014 and US$1.6 billion in 2014 alone.

India Becomes the Number One Cotton Producing Country in the world

Biotech crops are the fastest adopted crop technology by smallholder farmers in the history of agriculture. It can be best judged by comparing the adoption of biotech cotton by large farmers of USA and smallholder farmers in India. Figure 6 compares the farm level adoption of biotech cotton by farmers in India and USA from 1996 to 2015. USA introduced Bt cotton in 1996 followed by commercial approval of Bt cotton in India in 2002. The process of adoption of Bt cotton by large farmers was slow in the USA for initial six years followed by a rapid diffusion of the technology. On the contrary, smallholder farmers in India took less than 2 years to achieve a rapid expansion of Bt cotton in the country. Figure 7 indicates the adoption and diffusion of biotech cotton by smallholder farmers compared to large farmers provided that right technology is made available to them in a timely manner. India achieved an adoption of 95% of double gene Bt cotton whereas, farmers in USA were at advantage in the adoption process due to availability of multiple trait cotton technology including stacking of insect resistant and herbicide tolerant traits.

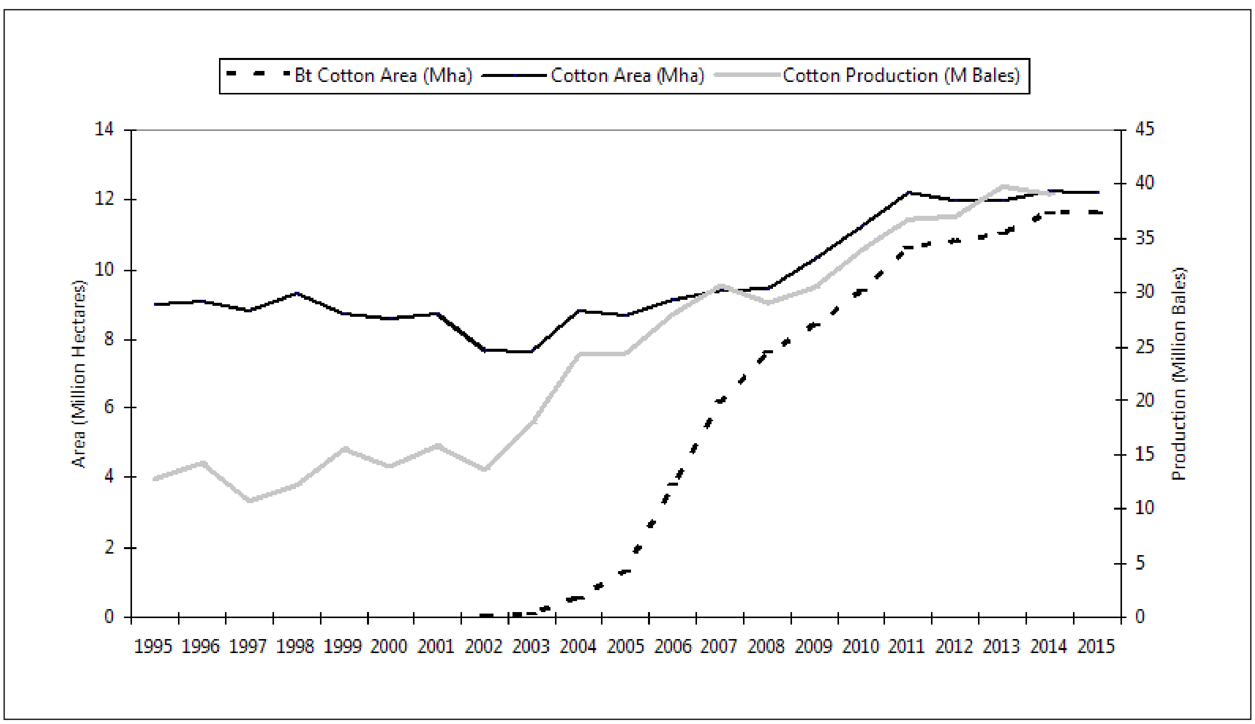
India approved the commercial cultivation of Bt cotton in 2002 – six years after the approval of Bt cotton in the USA. It was a breakthrough step to revive the ailing cotton sector in the country. The cotton industry at that time was characterized by stagnation in cotton production, decelerating trend 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 2015, the average yield of cotton in India, which used to have one of the lowest yields in the world, increased from 308 kg per hectare in 2001-02, to 567 kg per hectare in 2007-08 and continued to hover close to 500 kg per hectare in 2011-12 before reaching the highest national cotton yield of 570 kg per hectare in 2013-14. Cotton production increased from 13.6 million bales in 2002-03 to 39.8 million bales in 2013-14 and 39 million bales in 2014-15, which was a record cotton crop for India. Notably, the States of Punjab, Haryana and Gujarat

Figure 6. Adoption of Biotech Cotton by Farmers in India and the USA, 1996 to 2015



Source: Analyzed and Compiled by ISAAA, 2015.

Figure 7. Adoption and Impact of Bt Cotton on the Cotton Production in India, 1995 to 2015



Source: CAB, 2015; Blaise et al., 2014; Analyzed by ISAAA, 2015.

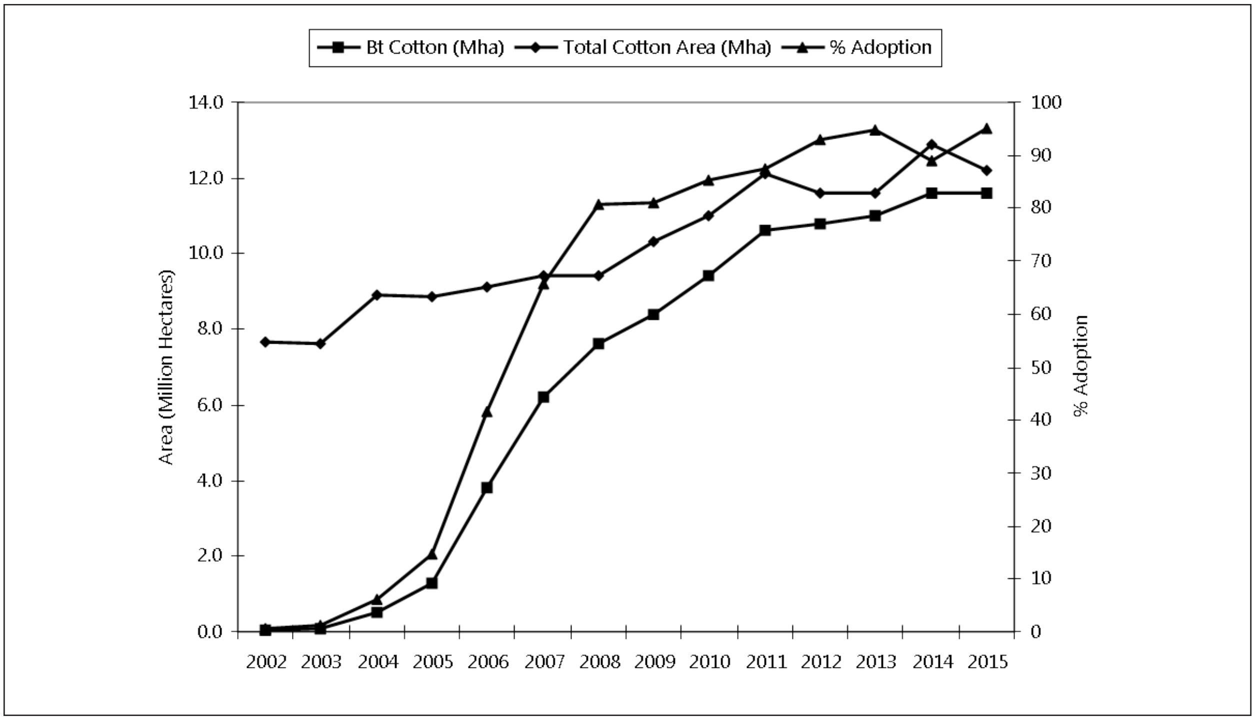
have crossed the average yield of 750 kg lint per hectare at the State level, which is higher than the average world cotton yield. However, in 2015, the infestation of the cotton leaf curl virus has caused a substantial damage to cotton crop which will impact the total production in 2015-16 seasons. Other major cotton producing States that predominantly grow cotton in rainfed conditions have shown remarkable hike in cotton yield in 2014 up to 360 kg lint per hectare in 2013 in Maharashtra and 570 kg lint per hectare in Andhra Pradesh, and are expected to show upward trend in 2015-2016 season (CAB, 2015).

The phenomenal rise in cotton production is attributed to the wide scale adoption of Bt cotton: single gene Bt cotton from 2002 to 2006 and dual gene Bt cotton from 2006 onwards, by smallholder cotton farmers across the ten cotton growing States. In 2015, 7.7 million cotton farmers adopted Bt cotton representing 95% of estimated 12.2 million hectares in India. In recent years, farmers increased the density of cotton planting particularly in irrigated and semi-irrigated conditions that led to substantial increase in cotton productivity per hectare across the States. Figure 8 shows the adoption of Bt cotton from 2002 to 2015 in Maharashtra, Gujarat, Andhra Pradesh and Telangana, Madhya Pradesh, Punjab, Haryana, Rajasthan, Karnataka, Tamil Nadu and Odisha. The high percentage adoption of Bt cotton by farmers across the different States reflects the priority of controlling the menace of the American bollworm complex, a group of deadly borer insects that caused heavy damage to cotton crop in the past. Evidently, the country achieved a near phasing out of single gene Bollgard-1® cotton hybrids, which has been almost replaced with dual gene Bollgard-II® (BG-II®) cotton hybrids introduced in 2006. The double gene Bt cotton hybrids provide additional protection to *Spodoptera* (a leaf eating tobacco caterpillar) while protecting cotton crop from American bollworm, pink bollworm and spotted bollworm. It is reported that double gene Bt cotton farmers earn higher profit through cost savings associated with fewer sprays for *Spodoptera* control as well as increasing yield by 8-10% over single gene Bt cotton hybrids.

Bt technology accelerated the adoption of cotton hybrids in India, which increased from 45% in 2002 to 95% of total cotton in 2015. The approval of a large number of Bt cotton hybrids (primarily *G. hirsutum* x *G. hirsutum*) suitable for different agro climatic cotton zones spurred the adoption of Bt cotton hybrid technology in India. As of 2015, a total of around 1,167 Bt cotton hybrids have been released for cultivation across 10 cotton growing States. Bt cotton hybrids displaced other species of cotton which are now grown only in a very limited cotton area in India. However, in the recent years, new Bt cotton hybrids consisting of *G. hirsutum* x *G. barbadense* have been approved for cultivation. Notably, CICR has developed improved desi cotton varieties *G. arboreum* and *G. herbaceum*, which are being field tested under the high density planting system in India.

Over the last fourteen years, India has greatly diversified deployment of approved events into different cotton genotypes, which are well-adapted to India's agro-ecological zones to ensure equitable distribution to small and resource-poor cotton farmers. The significant increase in area under hybrid cotton cultivation is credited to the introduction of Bt technology which spurred the hybridization of cotton from three Bt cotton hybrids in 2002-03 to 1167 Bt cotton hybrids in 2015. ISAAA Brief 43, 44, 46 and 49 (James, 2011, 2012, 2013 and 2014) provide the details of the approval of different Bt cotton events and hybrids, the developer of these events and hybrids, adoption and spread of single and double gene Bt cotton hybrid, reduction of pesticide usages, export and import of cotton and growth of seed sector from 2002 onwards.

Figure 8. Fourteen Years of Bt Cotton Adoption in India, 2002 to 2015



Source: CAB, 2015; Blaise et al., 2014; Analyzed by ISAAA, 2015.

Three New Biotech Crops Awaiting Commercial Approval

Since the moratorium imposed on Bt brinjal on 9th February 2010, the regulatory approval for field trials and commercial cultivation of different biotech crops developed by both public and private sector institution in India remained restrained and sluggish. The regulatory system was constrained due to policy dilemma and political impasse. In the interim, the applications for field trials and commercial approval of different biotech crops piled up. A very limited approval of field trials was granted subject to the no objection certificate (NOC) from the respective States. In the absence of NOC, the applicants could not carry out field trials necessary for the evaluation of different characteristics under field conditions, and thus caused delays in the approval of new crops. However, in mid 2014, the new Government led by Prime Minister Mr. Narendra Modi has revisited the functioning of the regulatory committees, including GEAC. Subsequently, GEAC resumed meeting regularly and approved the field trials of GM mustard, chickpea, rice, cotton, maize, sugarcane and brinjal in meetings held in August and September 2014 and in February and September 2015.

Notably, the biosafety dossiers of BGII-RRF® cotton developed by Mahyco and biotech mustard developed by Delhi University have been submitted to GEAC for commercial approval. GEAC has circulated the biosafety dossiers for comments from the experts and is expected to discuss the commercial approval of BGII-RRF® cotton and biotech mustard in the near future. Meanwhile, there has been an indication to revisit the moratorium on Bt brinjal in India due to increasing demand for

Bt brinjal by farmers from West Bengal and other major brinjal growing States. The rapid expansion of area under Bt brinjal in neighboring country Bangladesh is another reason for India to revisit the moratorium on Bt brinjal.

Ironically, the demand for pesticide-free food and vegetables is growing amidst a recent report indicating a substantial increase in the level of pesticide residue above the Maximum Residue Limit (MRL) and the presence of unapproved pesticides in food items. At the national level, over 20,618 samples of different food items were collected and analyzed during the year 2014-15 under the central scheme 'Monitoring of Pesticide Residues' administered by India's Ministry of Agriculture and Farmers' Welfare. Pesticide residues were detected in 18.7% of the collected samples, 2.6% had residues above the MRL and 12.5% of the samples revealed residues of non-approved pesticides. Notably, the situation seemed to be grim when it came to vegetables and fruits. A total of 10,593 vegetable samples were collected from various markets, farm gate and organic outlets mainly for brinjal, okra, tomato, cabbage, cauliflower, green chili, capsicum, cucumber, green pea, bitter gourd and coriander leaves. Astoundingly, a total of 2,253 vegetable samples (21.3%) contained measurable pesticide residues whereas 306 or 2.9% of the vegetable samples were found to exceed the MRL specified by the Food Safety and Standards Authority of India (FSSAI). These vegetable samples were detected with chlorpyrifos, ethion, acetamiprid, dichlorvos, imidacloprid and cypermethrin. The residues of non-approved pesticides were detected in 1,180 vegetable samples; mainly of acephate, bifenthrin, acetamiprid, triazofos, metalaxyl, malathion, and others. Vegetable samples of brinjal, okra, cauliflower, cabbage and chili were detected with maximum amount of pesticide residue (AINPPR, 2015).

In this context, it is important to note the development in these three important biotech crops, which are under the final stages of regulatory review to be commercialized in the near future. These commercial approvals would trigger a new phase of growth and momentum in crop biotech sector in the country:

- **first, the approval of the country's first biotech mustard (*Brassica juncea*) with enhanced heterosis (hybridization) in mustard, the most important edible oil crop in India**
- **second, the approval of the country's first stacked trait cotton – the insect resistant and herbicide tolerant cotton, Bollgard II Roundup Ready Flex® cotton (BG-II RRF®) and,**
- **third, the approval of the country's first vegetable crop Bt brinjal (eggplant) by revisiting its 5 years old moratorium in the context of the large scale commercial planting of Bt brinjal in neighboring country Bangladesh and a noticeable increase in the pesticide residues in important vegetables and fruits including brinjal**

Biotech Crop 1: Biotech Mustard with Enhanced Heterosis

India's first biotech mustard (*Brassica juncea*) hybrid DMH-11 was developed by University of Delhi South Campus from 1996 to 2015. Biotech mustard project is the first public sector edible oil biotech crop developed indigenously with the funding of the Department of Biotechnology of the Ministry of Science and Technology (MOST) and the National Dairy Development Board (NDDB) – the largest producer and supplier of milk and milk-based products in India. The biotech mustard event Bn 3.6 x mdbs 2.99 expressing bar, barnase and barstar genes was developed between 1996 to 2002 and was ready for deployment into mustard breeding lines of Delhi University in 2002. The Centre for Genetic Manipulation of Crop Plants (CGMCP) of University of Delhi South Campus under the scientific leadership of Dr. Deepak Pental developed the high yielding biotech mustard hybrid DMH-11.

Biotech mustard hybrid DMH-11 is a combination of the event Bn 3.6 (Varuna Barnase line) and event modbs 2.99 (EH-2 Barstar line) which were selected in RLM 198 and Varuna variety of *B. juncea* respectively, by University of Delhi South Campus. The event Bn 3.6 and modbs 2.99 were backcrossed into variety Varuna and east-European type mustard line EH-2, respectively, which were further crossed to form hybrid DMH-11 expressing events Bn 3.6 x modbs 2.99. Biotech mustard hybrid DMH-11 has been tested for biosafety, efficacy, hybridization, cross ability and field performance under the Indian regulatory framework over the period of ten years. Multiple field trials were conducted to assess the field level performance of biotech mustard hybrid DMH-11 by public sector institutions. Biosafety studies including the cross ability study of the transgenic *Brassica juncea* hybrid DMH-11 with related Brassica species such as *B. rapa* (toria, yellow sarson, brown sarson), *B. nigra*, *B. oleracea* (early types), *B. napus*, *B. carinata*, *B. touneforti*. *Eruca sativa* and *Raphanus sativus,* were carried out to assess the gene flow and its consequences on the environment. Multiple field trials were conducted in the mustard growing States of Rajasthan, Haryana, Uttar Pradesh, Punjab and Delhi.

It is important to note that another species of Brassica, *Brassica napus* popularly known as canola expressing the bar, barnase and barstar genes has been approved for commercial cultivation in many countries. Biotech canola is grown on a very large scale in many countries including Canada, USA and Australia. Studies conducted in India, along with numerous earlier studies from USA, Canada, Australia, Japan and EU have shown that proteins encoded by the *bar, barstar* and *barnase* genes are neither allergenic nor toxic. Edible oil and meal extracted from biotech canola is a major source of edible oil for food and animal feed in the world. Notably, biotech hybrid DMH-11 seed does not contain any Barnase or Barstar protein, except that the Bar protein is present at very low levels. Edible oil extracted from biotech mustard does not contain any of the three proteins, and therefore it is completely safe for human consumption.

India faces a huge deficit in edible oil production and annually imports approximately 11-12 million tons of edible oil, including oil extracted from biotech soybean and canola. Annually, India spends approximately US$10 billion (Indian Rupee 65,000 crore) on imported edible oil to meet domestic requirements. The edible oil deficit will continue to widen with the increase in the population and per capita income. To address this insurmountable challenge, India needs to critically look into ways and means to increase productivity of oilseed crops including mustard, soybean and cotton. Biotech mustard hybrid DMH-11 is one of the promising technologies to improve the yield gap in mustard. Multiple field trials of DMH-11 over different locations in growing season demonstrate that biotech mustard hybrid DMH-11 yields significantly higher than the popular mustard varieties in India. On average, biotech DMH-11 hybrid has shown yield increase of 28 percent over the mega variety Varuna and 38 percent over the control varieties. Given the high seed replacement rates (SRR) in mustard, around 71% at the national level and almost 100% in some of the States like Gujarat, the deployment of the barnase-barstar system will open a new opportunity in improving mustard yield and production necessary to narrow down the edible oil deficit.

In the past, the conventional mustard hybrid production system using Cytoplasmic Male Sterility (CMS) system, a non-biotech method for pollination control has been used to produce mustard hybrids in India. The conventional hybrid system suffers from some limitations including low purity of hybrid seed, limitation in different combination and temperature sensitivity. The biotech barnase-barstar system of mustard hybridization is very versatile, which will accelerate the mustard breeding program in India.

Currently, the biosafety dossier is under consideration for commercial release in 2015.

Biotech Crop 2: Stacked Trait Biotech Cotton

BGII-RRF® (event MON 15985 × MON 88913) is India's first stacked trait, insect resistant and herbicide tolerant (IR/HT) cotton developed by Mahyco. It was developed by crossing MON 15985 (BGII®) with MON 88913 (Roundup Ready Flex®) using traditional breeding methods. BGII-RRF® cotton expresses the lepidopteran insect (bollworms and *Spodoptera*) resistance trait inherited from event MON 15985 and imparts tolerance to herbicide glyphosate inherited from event MON 88913. Biotech event MON 15985 (BGII®) was released for commercial cultivation in 2006, and is now being planted over 95% of total cotton in India. BGII-RRF® is a combination of events MON 15985 (IR) and MON 88913 (HT), and therefore requires a regulatory approval for commercial cultivation in India.

BGII-RRF® cotton has been rigorously tested for biosafety, efficacy and field performance during 2005 to 2014. It has completed all the regulatory requirements including different stages of field trials in India and a dossier was prepared and submitted for the commercial release in 2014. BGII-RRF®event is the first stacked IR/HT trait cotton to be commercialized in India. Globally, BGII-RRF® cotton has been approved for commercial cultivation in major cotton growing countries including USA, Brazil, Mexico, South Africa, Columbia and Australia. It is being cultivated over a large scale in these cotton growing countries since 2005. The approval of BGII-RRF® cotton will be a milestone achievement as it is India's first herbicide tolerant trait and is likely to be approved for commercial release in the near future.

In the fourteen year period, 2002 to 2015, Bt cotton has delivered substantial benefits to cotton value chain at both macro and micro levels. India achieved a remarkable increase in cotton yield and production. Cotton yield increased from 300 kg lint per hectare to more than 500 kg lint per hectare. India now produces more cotton than any other country contributing 27% of the global cotton production. However, India's cotton yield is still lower than the world average of 785 kg lint per hectare. The stacked trait (IR/HT) cotton technology, which is under regulatory review can further increase cotton yield and profitability of cotton farming in the context of yield losses due to poor weed management and increased cost of cultivation resulting from weed control.

It is estimated that the stacked Bt/HT cotton can help the farmers in reducing cost of weed management by Rs. 8015 per hectare over traditional manual weed control practices. The introduction of stacked trait Bt/HT cotton is paramount given that farmers across India already use pre- or post-emergent herbicides to manage weeds in the backdrop of increasing non-availability of labour during the cropping season and higher labour wages. The non-selective nature of herbicide is not an effective method to control cotton weeds. The field experiments indicate that Bt/Ht cotton will optimize yield gain and bring ease in weed control. At national level, Bt/HT cotton is estimated to contribute to total benefits of Rs. 3,218 crore per annum of which 62% benefits will accrue to smallholder farmers.

Estimated direct benefits of BG II® RRF® weed management system is Rs 8015 per hectare based on the difference of cost of weed management for manually weeded plots (Rs. 13,573 per hectare) and herbicide sprayed plots (Rs. 5558 per hectare). Indirect benefits include efficient utilization of nutrients and fertilizers, conserve moisture and reduce cost of production.

Biotech Crop 3: Insect Resistant Bt Brinjal in India

Bt brinjal is India's first vegetable biotech crop developed by Indian seed and biotech company, Mahyco. Bt brinjal incorporates the event EE-1 expressing insecticidal protein to confer resistance against the Fruit and Shoot Borer (FSB) – the most destructive pest of brinjal that causes losses up to 70% in commercial crop. The *cry1Ac* gene is sourced from the soil bacterium *Bacillus thuringiensis* (Bt). When ingested by the FSB larvae, the Bt protein is activated in the insect's alkaline gut and binds to the gut wall, which breaks down, allowing the Bt spores to invade the insect's body cavity. The FSB larvae die a few days later. Bt brinjal has been rigorously tested for biosafety by Indian regulatory authorities between 2000 to 2009. GEAC declared Bt brinjal event EE-1 safe for environmental release in India on 14th October 2009 (GEAC, 2009). Later, MOEF imposed a moratorium on its commercial release on 9th February 2010 after conducting public consultations on Bt brinjal (MOEF, 2010).

Bt brinjal event EE-1 has been introduced and backcrossed into popular 8 brinjal hybrids in Mahyco's breeding program. Mahyco also generously donated Bt brinjal technology to the Tamil Nadu Agricultural University (TNAU), Coimbatore; University of Agricultural Sciences (UAS), Dharwad and Indian Institute of Vegetable Research (IIVR), Varanasi. The event EE-1 was backcrossed into 16 popular open-pollinated brinjal varieties developed by three public sector institutions (Table 13). Mahyco also donated the technology to public research institutions in the Philippines and Bangladesh. Bangladesh was the first country to approve the commercial cultivation of 4 varieties of Bt brinjal on 30 October 2014. First set of Bt brinjal varieties were planted by approximately 120 farmers in Summer and Winter season of 2014 (Choudhary, Nasiruddin and Gaur, 2014).

Table 13. Distribution of Bt Brinjal Hybrids and Open Pollinated Varieties in Selected Institutions

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

Source: Choudhary and Gaur, 2008.

In the interim, India's GEAC has approved the field trials of another Bt brinjal event developed by NRCPB (ICAR), which is to be commercialized by a set of Indian private companies including Bejo Sheetal, Ankur Seeds and Rasi Seeds. GEAC's approval of field trials of Bt brinjal event opens up an opportunity for the Government of India to revisit the moratorium on Bt brinjal event EE-1 which was declared safe for environmental release by GEAC on 14 October 2009. The moratorium on Bt brinjal has blocked the approval and field trials of other biotech crops in the last five years. India has not made any significant progress on new farm technology in this period. Therefore, it is paramount for the Government of India to prioritize the commercial approval of public-bred 16 open pollinated varieties of Bt brinjal with event EE-1 developed by TNAU, Coimbatore; UAS Dharward and IIVR, Varanasi pending commercialization for five years now. Notably, the public sector investment in developing these varieties set to go to waste because seeds tend to lose their vitality with time (Sud, 2014).

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

- Six top science academies of India reviewed and ultimately endorsed the safety of Bt brinjal and recommended limited release of Bt brinjal in the "Inter-Academy Report on GM Crops" released in September 2010 and further updated in December 2010. Vindicating the doubt raised by opponents of the technology, the Academy Report states that "the overwhelming view is that the available evidence has shown, adequately and beyond reasonable doubt, that Bt brinjal is safe for human consumption and that its environmental effects are negligible. It is appropriate now to release Bt brinjal for cultivation in specific farmers' fields in identified states" (INSA, 2010a; INSA, 2010b; INSA, 2010c).
- As a follow up to the moratorium on Bt brinjal, MOEF constituted a committee comprising experts, scientists and members of GEAC and called on a meeting "Consultation with experts and scientists on regulatory process for Genetically Modified Crops as part of Bt brinjal post moratorium follow-up" on 27 April 2011. The committee recommended the "limited release of Bt brinjal seeds to identified farmers under strict expert supervision to evaluate its performance in public space."
- The meeting of scientific advisory council of PM (SAC-PM) on biotechnology and agriculture chaired by Bharat Ratna Prof. CNR Rao held on 9 October 2012 deliberated on the important issue of application of biotechnology for social and economic advancement of the country, particularly in the area of agriculture. The committee noted that a science-informed, evidence-based approach is lacking in the current debate on biotechnologies for agriculture (PIB, 2012).
- Neighboring Bangladesh approved Bt brinjal event EE-1 for commercial cultivation on 30 October 2013 followed by distribution of Bt Brinjal seedlings to farmers on 22 January 2014. Bangladesh became the first pioneering country in the world to successfully cultivate Bt brinjal where 120 farmers reaped a bountiful harvest of Bt brinjal in 2014. Notably, India continues to deny their farmers' access to Bt brinjal while farmers in Bangladesh harvest benefits of the technology to control the menace of pest, the fruit and shoot borer (Choudhary, Nasiruddin and Gaur, 2014).

Benefits of Bt brinjal translate to an average increase of 116% in marketable fruits over conventional hybrids, and 166% increase over popular open-pollinated varieties (OPVs). Furthermore, the significant decrease in insecticide usage reduced farmers' exposure to insecticides and results in a substantial decline in pesticide residues in brinjal fruits. Estimated net economic benefit ranging from Rs.16,299 (US$330) to Rs.19,744 (US$397) per acre with national benefits to India exceeding US$400 million per year.

Socio-Economic Benefits and Impact of Bt cotton in India

In 2015, 7.7 million small holder cotton farmers having an average land holding of less than 1.5 hectares benefited from planting Bt cotton over 11.6 million hectares equivalent to 95% of 12.2 million cotton area. Remarkably, a cumulative ~61 million small-holder cotton farmers planted Bt cotton in the fourteen-year period showing a plausibly high repeat decision of planting of Bt cotton in 2002-03 to 2015-16. Notably, the increase from 50,000 hectares of Bt cotton in 2002, (when Bt cotton was first commercialized), to 11.6 million hectares in 2015, represents an unprecedented 230-fold increase in thirteen years. Estimates by Brookes and Barfoot (2016, Forthcoming) indicate that India enhanced farm income from Bt cotton by US$18.3 billion in the thirteen-year period 2002 to 2014 and US$1.6 billion in 2014 alone.

The field performance and socio-economic assessment of Bt cotton have been the integral part of the regulatory process of commercialization of Bt cotton in India. Until now, fourteen peer-reviewed research studies have been conducted over the years, three studies were conducted prior to the commercialization of Bt cotton from 1998 to 2001, whereas eleven studies were carried out to assess ex-ante impact of Bt cotton, which were reported during the post commercialization of Bt cotton from 2002 to 2013. The results of these studies on Bt cotton were consistent with the study undertaken by Gandhi and Namboodiri in 2006 showing yield gains of approximately 31%, a significant 39% reduction in the number of insecticide sprays, leading to an 88% increase in profitability, equivalent to a substantial increase of approximately US$250 per hectare (Gandhi and Namboodiri, 2006). The summary and key findings of these fourteen studies conducted by public institutes on cost-benefits of Bt cotton were included in previous briefs, ISAAA Brief 26 to 49 released from 2002 to 2014. Readers are encouraged to refer to previous ISAAA briefs for more details about the socio-economic benefits of Bt cotton in India from 2002 to 2014.

India's Cotton Vision 2050

The Prime Minister of India Mr. Narendra Modi released the ICAR Vision 2050 along with Vision 2050 documents for each crop including cotton during the 87th Foundation Day of the Indian Council of Agricultural Research (ICAR) in Patna, Bihar on July 25, 2015. ICAR Vision 2050 provides the strategic framework for innovation-led inclusive and sustainable agricultural growth in the country whereas Vision 2050 for cotton presents a path towards sustainable cotton farming to circumvent the enormous challenge of ever-increasing chemical dependence.

In the same occasion, Mr. Modi also launched three new initiatives to stress on the 'lab to land' concept of the Centre. He called on agricultural scientists from all over the country to speed up the 'lab to land' approach, intended to provide new technologies to farmers, which will lead to a quantum jump in agriculture productivity. Mr. Modi reiterated the need for a second green revolution and urged agricultural scientists to blend their knowledge with potential of farmers to enhance farm productivity per hectare.

The Vision 2050 envisages the technology led cotton revolution allowing Indian cotton farmer to produce the best ever quality cotton at the lowest ever production cost to get the highest ever yields in the world. The following paragraphs highlight the salient features of the ICAR CICR Vision 2050 (CICR, 2015).

First, to attain productivity levels – equivalent to the best in the world: India doubled its cotton yield in the last fourteen years and significantly decreased yield gap with global average cotton yield. CICR Vision 2050 aims at increasing cotton yield to at least 2000 kg per hectare by 2050, if possible more.

Second, to produce premium quality cotton: India has significantly increased the production of medium to long staple cotton in the last fourteen years. More than 90% of total cotton produced in India is medium and long staple cotton. However, India continues to import the extra-long staple (ELS) cotton to meet the fine quality clothing requirements. In recent years, the ELS Bt cotton hybrids such as Mahyco's 'Bahubali' have been commercialized. CICR has developed world's best Extra Long Staple variety 'Suvin'. Efforts are on to breed for premium quality such as Extra Long Staple varieties and hybrids with premium fibre traits, high harvest index, high ginning out-turn and early maturing traits.

Third, to reduce cost of cultivation by reducing the dependence on chemical fertilizers, pesticides and labour: CICR Vision 2050 focuses on R&D efforts to develop cropping systems comprising of cotton with nitrogen fixing legumes fodders, pulses and oilseeds in order to reduce dependence on chemical agriculture. The vision document also aims at deploying multiple abiotic/biotic resistant varieties and Integrated Pest Management (IPM) to reduce pesticide use immensely thus resulting in increased food and environmental safety and export.

Fourth, to produce cotton for employment generation and earn foreign exchange: Cotton is an engine of employment in rural India. Hybrid cotton seed production employs millions of farmers and laborers while around 8 million farm families are involved in cotton production. In addition, it is estimated that about 30 million people are employed in cotton value addition. CICR estimates that by enhancing cotton production even by 10% (4 million bales raw cotton), it will generate employment for additional 10 million persons if raw cotton is converted to fabric.

Fifth, to reduce the area under cotton in favour of food crops: Over the past fourteen years, area under cotton cultivation has increased from 8 million hectares to around 13 million hectares in 2015. CICR estimates to reduce area under cotton cultivation to 8 million hectares and double the cotton productivity so as to ensure that the 5 million hectares are cultivated for India's food security.

Finally, to develop technologies that can reduce labour drudgery and create comfortable machine based farming systems: CICR Vision 2050 lays a greater emphasis on the use of information and communication technologies that can contribute to rapid dissemination of technology at least cost. Notably, India has experimented with BGII-RRF® cotton for last several years. BGII-RRF® cotton features stacking of two traits including insect resistance and herbicide tolerance. The application for BGII-RRF® cotton is pending for the commercial release in the near future. Similarly, India is experimenting with the high density cotton system to introduce mechanical picking in cotton.

Political Will and Support to GM Crops in India

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

<u>India's Prime Minister calls for technology-driven agriculture including GM crops.</u> India's Prime Minister, Mr. Narendera Modi is convinced that a second green revolution will be triggered by biotech crops just as the first was triggered by high-yielding wheat and rice crops. Launching the Doordarshan Kisan channel for farmers on 26 May 2015, Mr. Modi came out strongly for biotech crops declaring that this would give a major boost to farmers' incomes. While calling for better research and higher productivity to boost farm earnings, he said, ***"Today, the country has to import pulses. Let's resolve that by 2022 we will no longer have to import pulses. I have been telling our universities, especially our agricultural universities that, each of them, should take up a specific variety of pulse, how to do research in it, how to do genetic engineering in it, how to increase productivity, how to increase protein content so that farmers get good prices."*** The PM raised his concern for increasing production in edible oil and pulses given that India has emerged as a major importer of both the commodities. At present, India's import bill on edible oil alone stands at US$10 billion per annum. In fact, edible oil is its biggest import item after (crude) oil and gold. The PM also called for increasing food grain productivity from 2 tonnes a hectare to 3 tonnes, saying this was necessary to ensure food security for the country's rising population (Modi, 2015).

<u>India's Prime Minister Mr. Narendra Modi urges for technology adoption for second green revolution.</u> India's Prime Minister Mr. Narendra Modi called for a second Green Revolution, saying it should start immediately as ***"Indian agriculture has been lagging in several areas including inputs, irrigation, value addition and market linkages and my government is committed to modernizing the sector and making it more productive."*** The Prime Minister also emphasized the need for use of scientific methods for farming to increase productivity, while unveiling, the foundation stone of Indian Agriculture Research Institute at Jharkhand on 28 June 2015. Mr. Modi said, ***"Unless we prepare a balanced and a***

comprehensive integrated plan, we will not be able to change the lives of farmers." The scientists and experts feel that technology intervention and improvement in infrastructure are key to higher agricultural production (ICAR, 2015).

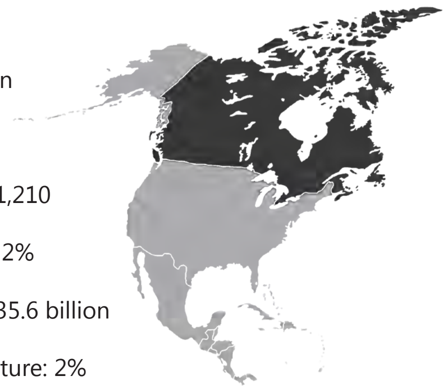
<u>India's Agriculture Minister pitches for GM crops for food security.</u> India's Union Agriculture Minister Mr. Radha Mohan Singh supported genetically modified (GM) crops stating that technologically enhanced seeds could help India realize its food security ambition and believed it held great promise in minimizing productivity losses particularly on account of abiotic stress factors like floods and drought. Speaking at the inauguration of India Seed Congress-2015 held at Agra, Mr. Singh said, ***"While agriculture feeds the nation, seeds feed agriculture. Bt Cotton in Gujarat, Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu has clearly demonstrated what these new technologies can do to boost farmer incomes."*** The Minister pointed out that agri-income could rise further when technologies like herbicide tolerance, drought tolerance, nitrogen use efficiency, nutrition enhancement was introduced commercially in India. ***"Losses that occur due to droughts, floods, salinity, biotic and other abiotic stresses also need to be eliminated decisively through the adoption of appropriate technologies. In this context, genetic engineering holds great promise, would increase farmers' incomes and quality food supply to consumers at affordable prices; substantially increase productivity leading to greater farmer incomes and farmer well-being,"*** he said. While addressing at the Seed Congress, the Minister emphasised that the superior genetics encapsulated in seed combined with improved agronomies shall be the key strategy to break the yield barriers. He said that in this direction the privately-organized seed industry has significantly contributed and successfully complemented with the public sector. Government shall therefore support PPP initiatives for overall development of the sector, he said. He also stressed that appropriate policy support for seed improvements through conventional and biotech methods, in combination with improved agronomic practices, would greatly help in ensuring food and nutritional security of the country (PIB, 2015).

India's Renowned Scientist and Father of Green Revolution, Prof. M.S. Swaminathan emphasized that GM technology is essential for Climate Smart Agriculture. Prof. MS Swaminathan, in an exclusive interview, shared his views on stalled field trials of GM crops and the current scenario of agriculture in India. Talking about the need of GM crops in the country, Prof. Swaminathan said that ***"GM technology helps us to produce varieties which are climate-smart. Green Revolution involves the use of new plant architecture."*** Discussing the challenges of food security in India, he stated that the average yields in most crops are low in relation to what other countries including China are achieving. India has a large untapped yield reservoir which can be maximized by utilizing the potential of technology, services and public policies. On the issue of stalling of GM field trials in the country, Prof. Swaminathan quoted, ***"It is right time that we get large number of GM varieties in the breeders' assembly line tested at the field level. Without field testing we will not know the merits and demerits. Farmer can benefit from GM crops if government enlarges its support for public good research. The ICAR and other government organisations should concentrate on producing GM varieties rather than GM hybrids"*** (FNB, 2015).

CANADA

In 2015, Canada retained its fifth place in world ranking of biotech crops with biotech crop hectarage at 11.0 million hectares compared with 11.6 million hectares in 2014 – a ~5% decrease. Of the 11.0 million hectares of biotech crops, canola was by far the most important at 7.4 million hectares compared with 8.0 million hectares in 2014. A principal reason underlying the decrease in hectarage of biotech canola was the significant decrease in total hectares of canola from 8.4 million hectares in 2014 to 8.0 million hectares in 2015. Farmers planted less canola because of several reasons including; low canola prices and more use of alternate crops to canola, such as pulses, to improve rotation. The decrease in total canola hectares in 2015 is expected to reverse when prices of canola increase, and become more competitive versus other alternate crops. The four biotech crops grown in Canada in 2015 were biotech canola (7.4 million hectares with a 93% adoption rate in 2015 versus 95% in 2014), maize (1.4 million hectares), soybean (2.1 million hectare) and sugar beet (0.015 million hectares with virtually optimal adoption). Canada is estimated to have enhanced farm income from biotech canola, maize and soybean by US$6.5 billion in the period 1996 to 2014 and the benefits for 2014 alone is estimated at US$874 million.

CANADA



Population: 35.9 million

GDP: US$1,780 billion

GDP per Capita: US$51,210

Agriculture as % GDP: 2%

Agricultural GDP: US$35.6 billion

% employed in agriculture: 2%

Arable Land (AL): 46.8 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 2015:
11.0 Million Hectares (-5%)

Farm income gain from biotech, 1996-2014: US$6.5 billion

*Ratio: % global arable land / % global population

Canada is a member of the group of six "founder biotech crop countries", having commercialized herbicide tolerant canola in 1996, the first year of commercialization of biotech crops. In 2015, Canada is fifth place in world ranking of biotech crops with an area of 11.0 million hectares, a ~5% decrease in 2014, largely due to a decrease in hectarage of total canola. The four biotech crops grown in Canada in 2015 were canola (7.4 million), maize (1.4 million hectares), soybean (2.1 million hectare) and sugar beet (0.015 million hectares with 100% adoption).

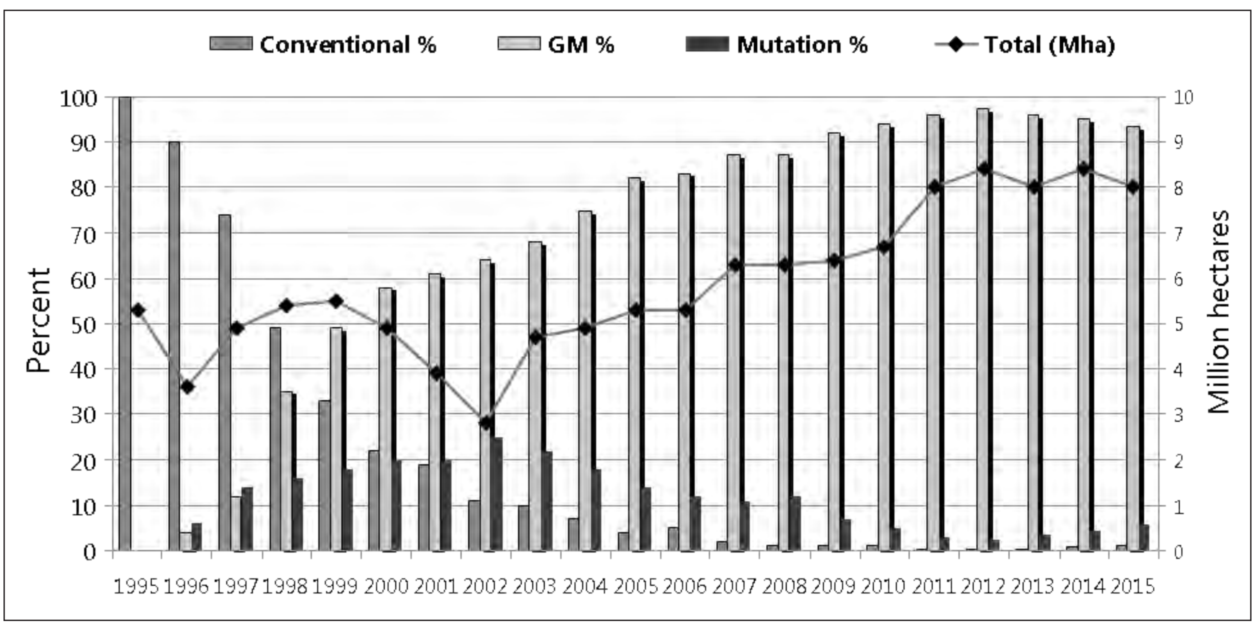
Since 1996, Canada has approved 161 biotech events for food and feed use and cultivation in various crops: alfalfa (2), apple (2), Argentine canola (18), cotton (25), flax (1), maize (59), papaya (1), Polish canola (4), potato (20), rice (1), soybean (20), squash (1), sugar beet (2), and tomato (4). In 2015, Canada approved the new Arctic® apple events GD743 and GD784 for food, feed, and cultivation, as well as cotton event DAS 81910 for food and feed use.

Biotech Canola

Canada was the first country to commercialize biotech herbicide tolerant canola in 1996. HT canola occupied the largest biotech crop area in the country in 2015 at 7.4 million hectares of the total area planted of 8 million hectares, compared with 8.4 million hectares in 2014. In 2015, the national adoption rate for biotech canola was 93% down from 95% in 2014, this compares with 96% in 2011, 94% in 2010, 93% in 2009, 86% in both 2008 and 2007, 84% in 2006 and 82% in 2005 (Figure 9). In 2015, biotech herbicide tolerant canola was grown on 7.4 million hectares, compared with 8.0 million in 2014, 7.8 million hectares in 2013, 8.4 million hectares in 2012, 7.7 in 2011, 6.3 million hectares in 2010, 6.0 million hectares in 2009, 5.5 million hectares in 2008, 5.1 million hectares in 2007 and 4.5 million hectares in 2006.

The principal underlying reason for the decrease in total hectares of canola (8.4 million hectares in 2014 versus 8.0 million hectares in 2015) is low canola prices and to favor other alternate crops such as grain legumes (pulses), lentils, chickpeas, peas, edible beans, as well as flax with a view to improving rotation with canola. The decrease in total canola hectares in 2015 is expected to reverse when prices of canola increase and are more competitive with other crops. In 2015, biotech canola

Figure 9. Percentage of Conventional, Biotech and Mutation-based Herbicide Tolerant (HT) Canola Planted in Canada, 1995 to 2015 (Million Hectares)



Source: Canola Council of Canada, 2015.

was estimated at an adoption rate of 93.4%; mutation based canola at 5.6% and conventional at 1% (Personal Communication Canola Council of Canada, 2015).

The Canola Council of Canada, the first industry association in the country, continues to promote its 2025 Strategic Plan that set industry targets; increased canola production to 26 MMT by 2025. This target is planned to be achieved through yield improvement of up to 52 bushels per acre, up from 40 bushels per acre in 2013/2014. Likewise, the Council sets export seed targets of 12 MMT by 2025, up 40% from 2013/2014 levels as well as to double domestic processing from 7.5 MMT to 14 MMT.

It is also noteworthy that the Canada-South Korea Free Trade Agreement came into force on January 2015. This allows entry of Canada seed, oil and meal to enter Korea market tariff-free, hence increasing export sales to South Korea (Foreign Affairs, Trade and Development, Canada, 1 January, 2015). Trading of Canadian canola with EU will be undertaken by the Canada-Europe Comprehensive Economic and Trade Agreement which is planned to commence in 2016. This features the elimination of oil tariffs and provision to reduce biotechnology related non-tariff barriers. Thus, tariffs on canola oil will be eliminated immediately upon implementation which is estimated to provide exporters the opportunity to increase sales by up to US$90 million.

The industry has been working on value adding canola by using canola meal as partial substitute for soybean meal. Research on canola meal studies revealed an increase in milk production in dairy cows. With an increasing export to the US of canola meal, strong domestic supplies and a depreciated Canadian dollar, Canadian meal exports are expected to reach 3.69 MMT in 2015/2016, an increase over 3.59 MMT in 2014/2015.

Benefits of planting biotech HT canola have been due to lower cost of production and cost of the technology. Thus, savings were due to reduced expenditure on herbicides and some savings in fuel and labor.

Biotech Soybean

Biotech herbicide tolerant soybean has been cultivated in Canada since 1997. In 2015, total soybean planting in Ontario and Quebec is 2.2 million hectares, with biotech herbicide tolerant soybean at 2.1 million hectares, 100,000 hectares lower at 94% adoption. Soybean planting in Canada increased through the years, particularly in Quebec and Ontario because of new varieties developed for the Western Canadian climates. Increased farmer interest was mainly due to the resilience of the crop, its profitability, as well as high oilseed prices. In addition, soybean has a different disease profile than canola and wheat so it fits well in a crop rotation system.

Soybean produced in Canada is exported, and for 2015/2016, exports are forecast to increase to 4.1 million metric tons, representing a 5% increase over previous year. China is a large importer of Canadian soybean with 2015/2016 export volume expected to be similar to last year (Oilseeds and Products Annual – CA15032 2015). In 2015/2016, demand for soybean oil will maintain a relatively stable export levels similar to 2014/2015 at 110 TMT. In 2014/2015, Canada soybeans were exported to China (22%), the United States (18%), the Netherlands (12%), Japan (11%), and Belgium (6%).

Biotech Maize

Biotech insect resistant (IR) maize has been grown commercially in Canada since 1996 and the herbicide tolerant (HT) maize in 1999. Throughout the 20-year period, biotech adoption has increased significantly and by 2015, the area of biotech maize was 1.4 million hectares of the total 1.6 million hectares planted in Ontario and Quebec. Biotech maize hectarage of 1.44 million is marginally higher than last year's 1.39 million hectares and at 92% adoption (marginally lower than last year's 93%). Canada is one of only 11 countries (others are the USA, Brazil, Argentina, South Africa, the Philippines, Paraguay, Uruguay, Colombia, Chile and Honduras) 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 2015, only 3% contained a Bt gene, 13% are herbicide tolerant and Bt/HT products are 84%. Percentage of stacked products has been increasing: from 54% in 2009, 70% (2010), 76% (2011), 79% (2012), and 80% in 2013 and 2014, and 84% in 2015. 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.

USDA FAS GAIN Report for Grains and Feeds in Canada (2015) estimated that maize planting in 2015/16 was anticipated to increase over 2014/15 due to farmers in Eastern Canada who were not able to get the winter wheat in the ground in fall. However, this increase is still below the 5-year average at 1.5%. Production is forecast to reach 12,245 trillion metric tons, a 7% increase over 2014/2015 levels and in line with the 5-year average. This increase will not, however, offset the low carry in stocks and will result in above average imports. Exports are forecast at average levels due to adequate supplies; however, they will draw down stocks to historical lows. Feed and industrial uses are expected to remain on trend. There is no expansion of the domestic ethanol fuel industry expected for 2015/2016 as there is a steady demand from the ethanol industry resulting from a mix of federal and provincial mandates, as well as provincial targets for greenhouse gas reductions.

Biotech Sugar beet

Biotech RR®sugar beet was launched in 2008 and planting in 2015 is estimated at 15,000 hectares at virtually optimal adoption. This was the eighth year of planting in Ontario in Eastern Canada, (with the beets transported and processed in the USA), and the fifth year of production in Western Canada where they were also processed.

Biotech Alfalfa

On 26 April 2013, the Canadian Food Inspection Agency 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 (USDA FAS-GAIN Agri-biotech Annual, Canada, 2015). At the time when this Brief went to press, to ISAAA's knowledge, no further details were available regarding commercialization which has not yet been initiated in Canada, despite approval of the product in the country.

Benefits from Biotech Crops in Canada

Canada is estimated to have enhanced farm income from biotech canola, maize and soybean by US$6.5 billion in the period 1996 to 2014 and the benefits for 2014 alone is estimated at US$874 million (Brookes and Barfoot, 2016, Forthcoming).

Smyth (2010) reported that herbicide tolerant canola in Western Canada had generated 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 (Table 14). 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 ***"refutes the claims and accusations made by critics of agricultural biotechnology that genetically modified crops do not benefit farmers and are harmful to the environment"*** – on the contrary it reports that the economic and environmental benefits are numerous and substantial.

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

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

The report commissioned to a leading agri-business research firm LMC International by CCC and the Agriculture and Agri-Food Canada of the Agriculture and Agricultural Flexibility Fund, is a part of the Canola Market Access Plan. The Report is based on the best practices to estimate the total benefits derived from Canadian-grown canola from farm to market, in three crop years 2009 to 2012. The

Table 14. 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.

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

Developments in New Biotech Crops

The Canadian government revised its proposed Policy on the Management of Low-Level Presence of Genetically Modified Crops in Imported Grain, Food and Feed and its Associated Implementation Framework for Grain. The policy was developed to provide transparency and predictability, and minimize disruptions to trade while protecting the health and safety of people, animals and the environment. It also aims to facilitate an efficient risk-based approach to manage an expected increase in occurrences of low-level presence (LLP) in international trade, while promoting compliance with Canadian regulatory requirements.

Public comments on the policy were solicited in 2012-2013, which served as basis for the revisions in the drafted policy. The revisions include the addition of important technical details to help clarify different parts of the Policy and Implementation Framework and to ensure consistency with Canada's legislative framework with respect to compliance promotion and enforcement actions (Crop Biotech Update, 6 May 2015).

Genetically modified (GM) Roundup Ready® alfalfa was not sold commercially in Canada in 2015. In response to farmers' request for seeds and a sustainable technology, the US-based company Forest Genetics International, is developing a "hay-to-hay" coexistence plan for West Canada. Similar stewardship plan has allowed organic, conventional and genetically modified (GM) alfalfa farmers to coexist regardless of the production method they choose. Farmers who participated in 2014 on-farm field trial program confirms that Genuity Roundup Ready® alfalfa delivers outstanding weed control, superior crop safety, quick stand establishment and vigorous growth. Small-scale research trials in East Canada will include FGI's newest GM alfalfa, HarvXtra™, which is the Roundup Ready® trait, stacked with a reduced lignin trait for better nutritional and digestability benefits for cattle. The GM alfalfa was approved in Canada in December 2014 (AGCanada, 11 April 2015).

Table 15. 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

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

Genetically modified (GM) purple tomatoes developed by John Innes Centre (JIC) scientists in the UK were harvested in Ontario, Canada, for future research and to attract private investors. The harvest from the 5,000 square-foot glass house yielded GM tomatoes to produce 2,000 liters of purple tomato juice. It will be used to generate new research and industry collaborations and to start the process of seeking the regulatory authorization needed to bring a commercial juice to market. The tomatoes derive their color from high levels of anthocyanins and have been shown to have anti-inflammatory effects compared to regular ones and slow down the progression of soft-tissue carcinoma in cancer-prone mice. They have also doubled the shelf life of regular tomatoes (Crop Biotech Update, 29 January 2014).

Farmer Support

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

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

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

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

Jay Schultz, Canadian farmer. Farmers use many different tools to manage a healthy, sustainable farm. Farming involves weed management, insect control and the wise use of resources in order for a farm to thrive as a business. Schultz notes that farmers take the issues of health and environmental safety very seriously when choosing farm management tools. ***"As a farmer, I would not produce anything that I am not willing to serve to my own family,"*** he says. ***"Farmers work very closely with the environment, and I want to leave the land in better condition than when I found it. I want to create more with using less, with less impact on the environment. GMOs are an invaluable technology to help achieve this end goal"*** (US News Health, 25 April 2014).

CHINA

In 2015, China successfully planted ~3.7 million hectares of biotech cotton at an adoption rate of 96% (up from 93% in 2014) of its 3.8 million total cotton hectarage. In addition, ~7,000 hectares of virus resistant papaya were planted in Guangdong, Hunan Island and Guangxi; plus ~543 hectares of Bt poplar, the same as last year. Despite China's decreased total cotton hectarage from 4.2 million hectares in 2014 to 3.8 million hectares in 2015 mainly due to lower prices and high stockpiles of cotton in China, biotech cotton adoption has increased from 93% in 2014 to 96% in 2015, and planted by an estimated ~6.6 million or more farmers. Virus resistant papaya plantings decreased from 8,475 hectares in 2014 to 7,000 hectares in 2015 due to over supply of papaya in 2014, but the adoption rate remained high at ~90%. In addition to the 6.6 million small farmers benefiting directly from biotech Bt cotton there may be an additional 10 million secondary beneficiary farmers cultivating 22 million hectares of crops which are alternate hosts for cotton bollworm and benefit from decreased pest infestation due to the planting of Bt cotton. Thus, the actual total number of beneficiary farmers of biotech Bt cotton in China alone may well exceed 17 million. Economic gains at the farmer level from Bt cotton for the period 1997 to 2014 was US$17.5 billion and US$1.3 billion for 2014 alone.

Bt maize, and Bt rice, offer significant potential benefits and have enormous implications for China, Asia and the rest of the world in the near, mid and long term, because rice is the most important food crop and maize the most important feed crop in the world. China's research and commercialization of Bt maize, herbicide tolerant maize and phytase maize as well as Bt rice, will be very important potential contributions to China and the global food and feed needs. Whereas, President Xi Jinping has endorsed the technology that is used in biotech soybean and maize imported by China in very large quantities (77 million tons of soybean and 3.3 million tons of maize in 2015), domestic production of these biotech crops has not been implemented to-date. It is noteworthy that at the same time that the US approved biotech potato in 2015, China, the largest producer of potatoes in the world (6 million hectares), announced its intention to double its potato hectarage and designated potato as its fourth food staple following rice, maize, and wheat.

The Chinese government has disbursed at least US$3 billion to research institutes and

domestic companies to develop home grown biotech seeds and discussions are underway to expedite approvals of pending biotech crops for cultivation. Domestic production of biotech maize would increase productivity and reduce China's dependency on imports of increasing quantities of maize, most of which (more than 90%) are biotech. China consumes one-third of global soybean production and imports 65% of global soybean imports, over 90% of which is biotech. Some observers speculate that home-grown biotech maize (Bt or phytase maize) will be commercialized in the next three years opening up an enormous potential market of 35 million hectares of maize. Thus, biotech crops could help China become less dependent on increasing imports of soybean and maize, over 90% of which are biotech. Bloomberg (November 2015) reported that President Xi Jinping has been urging China to support "strong research and innovation" on GM crops. His urging is consistent with the unsuccessful US$43 billion bid from ChemChina for Syngenta, which could have high potential impact on the timely adoption of biotech maize on up to 35 million hectares in China in the near-term. A successful bid would provide ChemChina with immediate access to a large portfolio of ready-made, safety-tested commercial GM crop products that have been grown globally for many years.

<u>CHINA</u>

Population: 1,376 million

GDP: US$8,227 billion

GDP per Capita: US$6,900

Agriculture as % GDP: 10%

Agricultural GDP: US$822.7 billion

% employed in agriculture: 35%

Arable Land (AL): 114.7 million hectares

Ratio of AL/Population*: 0.4

Major crops:

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

Commercialized Biotech Crops:

- Bt Cotton
- Bt Poplar
- PRSV Papaya

Total area under biotech crops and (%) increase in 2015:
3.7 Million Hectares (-5%)

Increased farm income for 1997-2014: US$17.5 billion

*Ratio: % global arable land / % global population

China has been planting large hectarages of Bt cotton since 1997, as well as small hectarages of GM papaya, poplar and other vegetables. In 2009, biosafety certificates were issued for Bt rice and phytase maize and were later renewed in late 2014. In 2015, Bt cotton was planted on 3.7 million hectares in 2015 compared to 3.9 million hectares in 2014. However, adoption rates increased to 96% in 2015, compared to 93% in 2014. Less total hectarage of cotton at 3.8 million hectares was planted in 2015 compared with 4.2 million hectares in 2014 due to high reserve stocks and global low cotton prices in 2015. In addition to cotton, China also grew virus resistant papaya on ~7,000 hectares compared with 8,475 hectares in 2014 – some observers attributed the decrease to over supply of papaya in 2014. Papaya growing regions Guangdong province and Hunan Island were joined by a new province, Guangxi in 2014. A small Bt poplar hectarage has been cultivated in China since 2003, an estimated total of ~500 hectares has been planted in China.

China has approved 60 biotech crop events for food and feed use and cultivation since 1994 including Argentine canola (12 events), cotton (10), maize (17), papaya (1), petunia (1), poplar (2), rice (2), soybean (10), sugar beet (1), sweet pepper (1) and tomato (3).

Progress on Bt Cotton Adoption in China

Similar to the USA, Argentina and Canada, China is a member of the group of six "founder biotech crop countries", having first commercialized biotech crops in 1996, the first year of global commercialization. The national area planted to cotton in China in 2015 was 3.8 million hectares compared to 4.2 million hectares in 2014. Consistent with several other cotton growing countries including the US, the decrease in national cotton hectares in China is attributed to low cotton prices leading farmers to decrease total hectares of cotton planted. Despite so, the adoption rate of biotech cotton planting increased to 96% in 2015 from 93% in 2014, thus, offsetting the decrease in total area of cotton in 2015.

The average size of farm in China, 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. Bt cotton in China is planted by 6.6 million farmers on 3.7 million hectares.

After Bt cotton was introduced in the market in 1996, the area of Bt cotton has increased more than 12 times, from 0.26 million ha in 1998 to 3.8 million hectares in 2015. Bt cotton adoption in China was further recorded from 68% in 2008 and 2009, 69% (2010), 71.5% (2011), 80% (2012), 90% (2013), 93% (2014) and 95% (2015).

The increased adoption in the last 20 years reflects farmer's confidence in the Bt cotton technology. This was confirmed in a study by the Center for Chinese Agricultural Policy (CCAP) where 240 cotton growing households in 12 villages, in three provinces (Hebei, Henan and Shandong) in 2006 and 2007 where every single family that reported growing Bt cotton in 2006 also elected to grow Bt cotton in 2007, a 100% repeat index. A few farmers planted non Bt cotton side by side with the biotech for comparison – an intrinsic farmer trait to compare the old with the new technology.

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

Benefits of Bt cotton in China

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 or more. A paper by Hutchinson (2010) based on studies in the USA draws similar conclusions to Wu et al. (2008) 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 are alternate host of cotton bollworm – these include maize, peanut, sesame, legumes, wheat, sorghum, vegetables and melons. Whereas cotton occupies only about 3 million hectares and farmed by an estimated 5 million farmers in the six northern provinces in China, host crops of cotton bollworm occupy 7 times the area at 22 million hectares and are farmed by more than 10 million farmers receiving indirect benefits from Bt cotton – i.e. the number of farmers that benefit indirectly from Bt cotton may be twice the number of Bt cotton farmers (6 million) that directly benefit from Bt cotton. His study concludes that Bt cotton not only control the damaging cotton bollworm on cotton, but also suppress cotton bollworm on several other important host crops that occupy more than seven times the area of Bt cotton. 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 other crops that host cotton bollworm were not known and have not been considered or included in impact studies of Bt cotton.

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

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

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

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

Adoption of Virus Resistant Papaya

In September 2006, China's National Biosafety Committee recommended the commercialization of a locally-developed biotech papaya resistant to papaya ring spot virus (PRSV). 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. In 2015, PRSV resistant papaya was planted in 7,000 hectares in China, compared to 8,475 hectares in 2014. The decrease in 2015 was due to oversupply in 2014 leading farmers to plant fewer hectares in 2015. Guangdong is the main province for papaya production in China which was joined by Hainan Island in 2012 which planted 4,000 hectares and by Guangxi province in 2014 at 2,000 hectares (Personal Communication, Prof Li, South China Agricultural University).

Biotech Insect Resistant Poplar

Bt poplar has been cultivated since 2003, according to the latest information available. From 2013 to 2014, a total of 543 hectares were planted in China. This will help supply the estimated 330-340 million cubic meters of timber that China needs in 2015. In order to further meet this challenging goal, the development of improved tree plantations in China was accelerated. Some fast-growing trees, such as poplar, eucalyptus, larch, and Chinese fir, were carefully selected and widely planted in China. During the past 20 years, a total of 7.04 million hectares of selected poplar clones were planted in China for commercial production; this represents a significant 19% of total tree plantations in China. However, it was observed that these monoclonal plantations were susceptible to insect pests which caused severe infestations resulting in significant damage, estimated at millions of US dollars annually.

GM/biotech poplars were developed by the Research Institute of Forestry in Beijing, which is part of the Chinese Academy of Forestry. The first Bt poplars were developed and commercialized in 2003. More specifically, *Populus nigra* clones 12, 172 and 153, were developed with *cry1Aa* and a hybrid white poplar, clone 741, was transformed with a fusion product of *cry1Aa* and API coding for a proteinase inhibitor from *Sagittaria sagittifolia*. Under rigorous performance testing, the Bt poplar clones have exhibited high level of resistance to leaf pests, resulting in a substantial 90% reduction in leaf damage. By 2008, 400 hectares were planted, and this increased to 447 in 2009, 453 in 2010 (although the 30 hectare plantation in Huairou, Beijing was felled in 2011). Six hectares of 490 transgenic poplars were harvested in Manasi Plain Forest Station, Xinjiang Uygur Autonomous Region in 2011. Nearly 7 hectares of seedlings of the commercialized transgenic *P. nigra* transformed with cry1Aa were grown in 2011. About 91% of the 490 hectares in 2011 were Bt *P. nigra* clones, and the balance of 9% was clone 741 featuring *cry1Aa* and API. With the harvesting of 6 hectares of the 490 hectares and the planting of an additional 7 hectares, a net gain of 1 hectare for a total of 491 hectares of mature Bt poplars were planted in China in 2012. In 2013, the hectarage of Bt poplars increased slightly from 491 to 543 hectares due to additional plantings of 50 hectares of Bt black poplar (*P. nigra*) in Xingtai Handan, Hebei province and 2 hectares of transgenic white hybrid poplar in Ninghe and Tianjin. The same hectarage was planted in 2014 and 2015.

The transgenic poplar plantations have effectively inhibited the fast-spread of target insect pests and have significantly reduced the number of insecticide applications required. The performance of the Bt black poplar plantations is significantly better than the clones deployed locally. The availability of commercial Bt poplar plantations has made it possible to empirically assess gene flow via pollen and seeds, and also for assessing the impact of Bt poplar on the insect community when intercropping with Bt cotton.

Comparisons between Bt poplar and non-Bt checks, confirm that Bt poplars require no insect pest control in the first 6 years, compared with the checks, which required 2 to 3 insecticide sprays (Lu M-Z, 2010, Personal Communication). This is consistent with experimental data (Table 16) confirming that Bt clones performed better and grew faster than their conventional counterparts. For example, at 10 years old, the tree trunk diameter was 28.2 cms for the Bt clone at the Beijing location versus 25.4 cms for the non-Bt clone “Zhonglin 46”. Similarly, the Bt clone at the Hebei location had 20.9 cm diameter after 8 years, versus 18.6 cms compared to the non-Bt clone “*P. deltoides* cv Chuangxin”.

The transgenic *Populus nigra* has also been used for hybridizing with non-transgenic *P. deltoides* to generate an insect resistant source in a breeding program designed to generate new hybrid clones.

Table 16. 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.

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.

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.

Genomics

Genomics research in China and the use of new breeding technologies in developing improved crops are in progress. The genome of vanilla and upland cotton have been decoded and will be used for the further development of varieties resilient to climate change. In addition to cotton which is already deployed, China has an impressive portfolio of a dozen other biotech crops being field-tested, including maize, wheat, potato, tomato, soybean, cabbage, peanut, melon, papaya, sweet pepper, chili, rapeseed, and tobacco.

Genome editing technologies

China is also active in genome editing technologies and has reported success with developing wheat resistant to the globally important fungal disease powdery mildew. First-hand experience by Wang et al (2014) and an early involvement in this very promising genome-edited technologies, featuring applications such as CRISPR, could be strategically very important for China as it seeks to accelerate progress and delivery of biotechnology-derived crops to feed a growing population and to mitigate the new challenges posed by climate change.

Chinese Private Sector Seed Companies and Public-Private Sector Partnerships

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

On 22 September 2010, Origin announced that it had reached an agreement with the Institute of Plant Protection of the Chinese Academy of Agricultural Sciences (CAAS) for the worldwide exclusive rights of the Bt gene developed by the Academy. Origin already had the rights to use the Bt gene in

China. Under the new agreement, Origin has the right to sublicense the Bt gene and/or to improve its performance (Business Wire, 22 September 2010). Bt rice offers the potential to generate benefits of US$4 billion annually from an average yield increase of up to 8%, and an 80% decrease in insecticides, equivalent to 17 kg per hectare on China's major staple food crop, rice, which occupies 30 million hectares (Huang et al. 2005). It is estimated that 75% of all rice in China is infested with the rice stem borer pest, which Bt rice controls. China is the biggest producer of rice in the world (178 million tons of paddy) with 110 million rice-growing households (a total of 440 million people based on 4 per family) who could benefit directly as farmers from this technology, as well as China's 1.3 billion rice consumers. Bt rice will increase productivity of more affordable rice at the very time when China needs new technology to maintain self-sufficiency and increase food production to overcome drought, salinity, pests and other yield constraints associated with climate change and dropping water tables. Crops that use water efficiently and the development of drought tolerant crops is top priority for China. China also needs to increase its rice yield to 7.85 tonnes per hectare by 2030 when its population will be 1.6 billion (Chen et al. 2010). Thus, in 2030, China will need approximately 235 million tonnes of paddy annually, equivalent to one third of global production of approximately 750 million tonnes.

Earlier, Origin had also acquired the rights to phytase maize from CAAS and this product was approved for biosafety by China on 27 November 2009 (Origin Agritech, 2009). The potential phytase maize market worldwide is estimated at US$500 million per year, of which US$200 million is in China alone. To put this into context, the current conventional maize seed market in China is estimated to be worth over US$1 billion per year – this compares with US$12 billion for the hybrid maize seed market annually in the US. Phytase maize was expected to be the first biotech maize to be commercialized in China by Origin followed by glyphosate tolerant maize, which is currently in Phase 3 of environmental field tests, and then Bt maize. Origin has already submitted Bt maize for phase 3 field trials and stacking all three genes coding for phytase, glyphosate tolerance and Bt, is a future option. Many maize growing countries have already successfully implemented the option of stacking genes with herbicide tolerance and Bt insect resistance but China could be the first to deploy phytase maize. This is a very important product for China given the importance of pork as a meat, in the country which has over 500 million swine, equivalent to about half of the global swine herd. Phytase maize will also be beneficial to the Chinese US$13 billion poultry industry, the largest in the world, and will coincidentally result in less ecological pollution by phosphates of ecological zones and waterways (Science Insider, 20 August 2014).

China, the most populous country in the world is also the largest consumer of edible soybean. China spent US$29 billion importing US soybean in 2007 which accounted for 38% of all US soybean exports. Collaborations for import of RR2Yield® soybean to China started in 2008 – the product had already been approved as safe for food, feed in Canada, Mexico, Taiwan, Japan, the Philippines, Australia and New Zealand which collectively import 30% of all US soy exports. The approval from China means that over two thirds (68%) of the US soybean export markets have already been cleared with China representing more than half (38% out of 68%). In 2014, China has imported more than 444 million bushels of the 2014/2015 crop.

In June 10, 2013, China's Ministry of Agriculture eventually approved three GM soybean products for importation as food that included Monsanto's Intacta™ RR2®, BASF's CV127™ and Bayer's Liberty Link®.

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

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

Benefits from Biotech Crops in China

Benefits from Bt cotton resulted in higher yields and significant cost savings on insecticide use, as well as on labour use in spray application. It is estimated that China has enhanced its farm income from biotech cotton by US$17.5 billion in the period 1997 to 2014 and by US$1.3 billion in 2014 alone (Brookes and Barfoot, 2016, Forthcoming).

Based on studies conducted by the Center for Chinese Agricultural Policy (CCAP), it was concluded that, on average at the farm level, Bt cotton increases yield by 10%, reduces insecticide use by 60%, with positive implications for both the environment and the farmers' health, and generates a substantial US$220 per hectare increase in income which makes a significant contribution to their livelihood as the income of many cotton farmers can be as low as around US$1 per day (Jikun Huang, 2008, Personal Communication). At the national level, it is estimated that increased income from Bt cotton was approximately US$1 billion per year in 2011.

Support for Biotech Crops in China

Some observers speculate that home-grown biotech maize (Bt or phytase maize) will be commercialized in the next three years opening up an enormous potential market of 35 million hectares of maize. Biotech crops could help China become less dependent on increasing imports of soybean and maize, over 90% of which are biotech. Bloomberg (17 November 2015) reported that President Xi Jinping has been urging China to support "strong research and innovation" on GM crops. His urging is consistent with the US$43 billion bid from ChemChina for Syngenta, which could have high potential impact on the timely adoption of home-grown biotech maize on up to 35 million hectares in China in the near-term. A successful bid would provide ChemChina with immediate access to a large portfolio of ready-made, safety-tested commercial GM crop products that have been grown globally for many years.

Whereas President Xi Jinping has endorsed the technology that is used to import biotech soybean and maize imported by China in very large quantities (77 million tons of soybean and 3.3 million tons of maize in 2015, according to USDA, 2015), domestic production of these biotech food crops has not been implemented to- date. **President Xi stated at the Communist Party Conference in December 2013** that, because the technology is new ***"it's reasonable that society should hold controversial views and doubts"*** (Bloomberg News, 9 October 2014). Importantly, China, through the Ministry of Agriculture, has launched a large national public information media campaign to increase the awareness of the public regarding the multiple and significant benefits that biotech crops offer China. Continuing high priority to R and D support for biotech crops in China reflect the country's long term commitment to biotech crops. China imports increasing quantities of maize, most of that is biotech, and consumes one-third of global soybean production. China imports 65% of global soybean imports, over 90% of which is biotech.

With the full government support on biotechnology shown by China's top officials in the past and the realization that more than 60% of global soybean production goes to China, recent government enactment imposed a more lengthy and stringent approval process for foreign biotech crops. It was opined that Chinese government decision was made to build a domestic biotech/GMO industry, acknowledging its potential in decreasing crop imports. The government has disbursed at least US$3 billion to research institutes and local companies to develop biotech seeds as what President Xi Jinping said, ***"We cannot let foreign companies dominate the GMO market"*** (Bloomberg, 22 May 2015).

The increasing farmers' interest in biotech crops has been manifested in the illegal planting of biotech soybeans found in the northeastern provinces of China, specifically the Heilongjiang Province (Global Times, Sept. 7, 2015). Authorities are still investigating the case, but the reality is clear as it has been in some countries, farmers are the prime movers of the technology because they experience first hand the benefits of the technology.

The recent 2015 visit of Chinese President Xi Jinping to the US may pave the way for approval of biotech crops in China. There were reports of possible approvals of four soybean, two maize and one cotton varieties that have been languishing in China's approval process for up to four years represent some of the biotech industry's recent blockbusters. On the list include Dow's Enlist™ corn, which is resistant to the herbicides 2,4-D and glyphosate, and Monsanto's Vistive® Gold high oleic soybeans and Roundup Xtend® soybeans, which have resistance to glyphosate as well as dicamba (Politico, 9 September 2015). Farm groups however want most of all is a pledge from China that it will make structural changes to its process and speed up approvals.

To address these concerns, it is noteworthy that **Yu Zhengsheng, chairman of the National Committee of the Chinese People's Political Consultative Conference (CPPCC)** presided over a bi-weekly consultation session to discuss the opportunity and risk of genetically modified agricultural products in Beijing (Xinhua, 8 October, 2015). According to a statement issued after the session, members of the CPPCC suggested that the Chinese government should research, promote and supervise GM crops from the perspective of overall national interest and long-term development. In addition, there should be emphasis on basic research while encouraging enterprises to play a more active role in applied research.

The Ministry of Agriculture of China through its website has issued a statement saying that all certified genetically modified foods that are sold on the Chinese market are safe. China has established a safety supervision system that covers the complete chain of GM products, including research, production and trading, according to the ministry. The ministry will work with other departments to improve legislation of GM products and their testing technologies to ensure their safety, the ministry said in a reply to a March proposal by 10 members of China's top political advisory body on the improved safety management of GM foods. The reply, posted on the ministry's website, said that China and other countries have done much research on the safety of GM foods that proved certified GM foods are as safe as traditional foods.

"Internationally, there is a conclusion on the safety of GM foods, that is, that all GM foods that have passed safety evaluation and been certified are safe," the ministry said. The reply added, ***"The conclusion by the World Health Organization is that no health damage has been seen in any people worldwide who have consumed GM foods that have been approved by authorities"*** (Crop Biotech Update 2 September 2015).

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

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

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

Farmer Testimonies

The following are excerpts from the monograph *Farmers First: Feedback from the Farm* (ISAAA, 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 11 years since 2004. In 2015, Paraguay grew 3.6 million hectares of biotech soybean, maize and cotton compared with 3.9 million in 2014, a decrease of ~300,000 hectares or 8%. Of the total biotech crop hectarage of 3.6 million hectares, 3.3 million hectares were soybean (including up to 98,000 of the stacked

Bt/HT product) 305,000 hectares of biotech maize and 12,000 hectares of biotech cotton. Gains over the period 2004 to 2014 are estimated at US$1.1 billion and the benefits for 2014 alone at US$131 million.

PARAGUAY

Population: 6.6 million

GDP: US$25.5 billion

GDP per Capita: US$6,040

Agriculture as % GDP: 22%

Agricultural GDP: US$5.6 billion

% employed in agriculture: 23.5%

Arable Land (AL): 4.4 million hectares

Ratio of AL/Population*: 3.0

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

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

Total area under biotech crops and (%) increase in 2015:
3.6 Million Hectares (-8%)

Farm income gain from biotech, 2004-2014: US$1.1 billion

*Ratio: % global arable land / % global population

Paraguay lies in the heart of South America, bordered by biotech crop growing countries: Bolivia, Argentina and Brazil. It is a small country with relatively lower population compared to its neighbors, with few mineral resources, and economy revolves around agriculture. In 2015, Paraguay planted a total of 3.6 million hectares biotech crops: 3.3 million hectares soybean, 305,000 hectares maize and 12,000 hectares cotton. Consistent with several other countries in 2015, low prices led farmers to reduce total plantings, particularly maize, which requires more inputs and more management. Constraints may also have slowed recent and fast expansion of the second soybean crop.

Since 2004, Paraguay, has improved its regulatory framework, which is now (more) science-based and predictable and has granted several approvals. In 2015, the country approved 20 biotech events with insect resistance, herbicide tolerance and stacked traits of soybean (3), maize (14), and cotton (3). Six biotech maize events were officially approved in 2015 (Table 17).

Cotton was once a principal crop but was replaced by soybean in 1980. Within 20 years, soybean was cultivated on more land and generated export revenues over US$150 million. In 2012, total soybean export of Paraguay was valued at US$1.6 billion, contributing close to 30% of the country's GDP.

Soybean farming in Paraguay has changed the country's agriculture. The area dedicated to soybean has tripled and has grown steadily at an average rate of 6% per year. Land conversion in the Eastern/Southern Paraguay from cattle grazing areas occurred during this time. However, with the increase in beef prices and the decrease in soybean prices, incentive for further land conversion is no longer there. Increase in production will rely on the second cropping system of the farmers. USDA FAS forecasts that the 2015/16 area to be planted with second crop soybeans (zafriña) will be at a record 1 million ha. Second soybean planting started in Paraguay in 2011/2012 and by 2015/16, this area has increased

Table 17. Commercial Approvals for Planting in Paraguay, 2004 to 2015

Crop	Trait	Event	Year
Soybean	Herbicide tolerance (HT)	40-3-2	2004
	HT x IR	MON 87701 x MON89788	2013
	HT	CV127	2014
Cotton	Insect tolerance (IR)	MON 531	2011
	IR x HT	MON 531 x MON 1445	2012
	HT	MON 1445	2012
Maize	IR	MON 810	2012
	IR	BT11	2012
	IR, HT	TC1507	2012
	HT	MON 89034	2012
	IR x HT	MON 89034 x MON 88017	2012
	HT	NK603	2014
	IR	MIR 162	2014
	IR x HT	MON 89034 x TC1507 x NK603	2014
	HT	GA21	2015
	IR x HT	GA 21 x Bt11	2015
	IR X HT	Bt 11 x GA21 x MIR 162	2015
	IR x HT	TC 1507 x MON 810	2015
	IR x HT	TC 1507 x MON 810 x NK 603	2015
	IR x HT	MIR 162 x GA21	2015

Source: G. Levitus (Personal Communication), 2015.

four-fold. Good weather and less disease pressure allowed two croppings in the country. Hence, farmers continue to use soybean varieties with short life cycle (90-110 days maturity).

Paraguay is the world's fifth exporter of soybeans, after the USA, Brazil, Argentina and Canada (FAOSTAT, 2012). It grew biotech soybean unofficially for several years before it approved four herbicide tolerant soybean varieties in 2004. In 2015, Paraguay was expected to grow a total of 3.4 million hectares of soybean, of which a record 3.2 million hectares (approximately 94% adoption) was herbicide tolerant soybean and 98,000 hectares were the IR/HT stacked. This increase in 2015 was mainly due to more total plantings of soybean, with the addition of expanded area for second soybean crop. 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, Brazil, Argentina, Paraguay, Canada, Uruguay, Bolivia, South Africa, Mexico, Chile and Costa Rica.

In 2013, a second generation GM soybean with stacked HT and IR traits (Intacta™) was planted to 46,000 hectares in 2013. In 2015, Intacta™ soybean was planted to 98,000 hectares compared to ~170,000 hectares in 2014.

Biotech Cotton and Maize

In October 2011, Paraguay approved Bt cotton for commercial production. Paraguay was expected to grow 12,000 hectares of cotton in 2015, of which 100% were biotech Bt/HT resistant; this is compared with 36,000 hectares of biotech cotton in 45,000 hectares at 80% adoption in 2014. Paraguay will benefit from biotech cotton also successfully grown in the neighboring countries of Argentina and Brazil.

Biotech insect resistant maize was first commercialized in 2013 in Paraguay at 550,000 ha. Total Plantings in 2015 of biotech maize were 305,000 hectares, comprised of 53,000 hectares Bt, 8,000 HT and 244,000 hectares Bt/HT maize. There are economic, environmental and social benefits in utilizing biotech maize and its neighbors Argentina and Brazil are already benefiting from Bt and herbicide tolerant maize, as well as the stacked product for many years.

Reduction in biotech cotton and maize planting in Paraguay is due to reduced total hectarage and the low global market price, especially cotton.

Benefits from Biotech Crops in Paraguay

Paraguay is estimated to have enhanced farm income from biotech soybean by US$1.1 billion in the period 2004 to 2014 and the benefits for 2014 alone is estimated at US$131 million (Brookes and Barfoot, 2016, 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 in the region.
- Instruct CAS to continue its coordination, harmonization and promotional efforts on activities related to GMOs.

PAKISTAN

Pakistan achieved a near-optimal adoption of insect resistant Bt cotton varieties in the sixth year of commercial cultivation, beginning 2010. In 2015, Pakistan increased adoption slightly from 2.85 million hectares in 2014 to 2.9 million hectares, equivalent to 93% adoption of a total of 3.12 million hectares of cotton. Approximately 750,000 smallholder cotton farmers continued to successfully grow Bt cotton varieties in the absence of approvals of new Bt cotton varieties either by Punjab Seed Council (PSC) or by the National Biosafety Committee (NBC). Notwithstanding this issue, Bt cotton has proliferated in Baluchistan and Khyber Pakhtunkhwa and occupied almost the entire cotton crop hectarage in the Punjab and Sindh provinces. Farmers in the four cotton growing provinces continued to plant 30 open pollinated Bt cotton varieties and 2 hybrids of Bt cotton approved during the period 2010 to 2014. The Pakistan Central Cotton Committee (PCCC) of the Ministry of Textile Industry has estimated cotton production at 15.48 million bales from 3.12 million hectares for the 2015-16 planting season.

PAKISTAN

Population: 188.9 million

GDP: US$225 billion

GDP per Capita: US$1,260

Agriculture as % GDP: 24%

Agricultural GDP: US$54.0 billion

% employed in agriculture: 44%

Arable Land (AL): 21.6 million hectares

Ratio of AL/Population*: 0.4

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

Commercialized Biotech Crop: Bt Cotton

Total area under biotech crops and (%) increase in 2015:
2.9 Million Hectares (0)

Farm income gain from biotech, 2010-2014: US$1.9 billion

*Ratio: % global arable land / % global population

In 2015, Pakistan has strengthened the legislation of the seed sector by enacting the Seed (Amendment) Act 2015 on 23 July 2015. It amends the provisions of the Seed Act, 1976 aimed at strengthening the regulation of the supply of quality seeds by public and private sector in Pakistan. The Seed (Amendment) Act 2015 sets a new framework to establish the Federal Seed Committee (FSC), enhance participation of the private sector, improve regulation of seeds, establish seed testing laboratories, and to register genetically modified plant varieties under the Federal Seed Certification and Registration Department of the Ministry of National Food Security and Research (MONFS&R). Similarly, the Ministry of Textile Industry (MOTI) has released the Textile Policy 2014-19 to overcome cotton production constraints and enhance value addition in textile sector in Pakistan in February 2015. The Textile Policy 2014-2019 envisages Pakistan as a leading country in the field of export of value-added textile products. It aims at

doubling value-addition from US$1 billion per million bales to US$2 billion per million bales, and also doubling textiles exports from US$13 billion per annum to US$26 billion per annum in next five years.

In 2015, the Technical Advisory Committee (TAC) recommended the release of 21 Bt cotton varieties to the National Biosafety Committee (NBC) of the Ministry of Climate Change, the administrative agency of the biosafety regulation in Pakistan. However, the statutory authority of NBC was challenged in the Lahore High Court in the wake of the 18th Amendment of the Constitution, which devolved many federal subjects including environment to the Provinces. The NBC has not convened since July 2014, and remained dysfunctional in the absence of clarity on its statutory status. However, in the future, the R&D and commercial approval of biotech crops in Pakistan depends on the enactment of two important legislations; the Pakistan Biosafety Act and the Plant Breeders Rights Act. The Pakistan Biosafety Act, which is being drafted, will determine whether the federal or provincial governments should regulate biotechnology in Pakistan. Similarly, the Plant Breeders Rights Act, which is pending for submission in the Pakistan National Assembly in 2015, will accelerate the growth of R&D, production and commercialization of the seed and biotech sector in Pakistan.

On the socio-economic benefits of Bt cotton, two new research studies on the socio economic benefits of Bt cotton indicated significant benefits to smallholder Bt cotton farmers as compared to medium and large farmers, and higher profitability of growing Bt cotton as compared to conventional cotton. Nasir et al. (2015) reported the analysis of Benefit Cost Ratio (BCR) which was highest for small farmers followed by large farmers in the study area whereas Noonari et al. (2015), published the study that clearly indicates that Bt cotton farmers were increasing farm yield and farm profit as compared to conventional cotton. At the national level, it is estimated that economic gains from existing Bt cotton varieties for Pakistan for the period 2010 to 2014 was US$1.9 billion and US$299 million for 2014 alone.

Status Quo on the Biosafety Regulatory System

In the absence of the statutory clarity, the National Biosafety Committee (NBC) of the Ministry of Climate Change (MOCC) has maintained the status quo on the approval of field trials and commercial release of GM crops in Pakistan in 2015. Ironically, the Technical Advisory Committee (TAC) has recommended the commercial approval of 21 new Bt cotton varieties to be approved to provide access to Bt cotton genotypes exhibiting tolerance to sucking pests and cotton leaf curl virus (CLCV), a major problem in Punjab province of Pakistan. However, NBC has not yet convened and remained dysfunctional in the absence of clarity on its statutory status since July 2014. Neither field trials of pending GM crops nor the commercial approval of recommended Bt cotton varieties have been considered by the NBC. The NBC merely exists as a developmental project of the EPA of MOCC without having statutory authority to approve GM crops post the enactment of the 18th Amendment pursuant to the Constitution (18th Amendment) Act, 2010 which devolved many federal subjects including environment to the Provinces in April 2010. The environment became the subject matter of regulation at Province level, therefore the statuary authority of NBC became the subject of judicial interpretation hence challenged in the

Lahore High Court in 2014 (Dawn, 2014). The 18th Constitutional Amendment effected a major change in the administration of various ministries at Federal and Provincial levels.

In this situation, the future of R&D and commercial approval of biotech crops in Pakistan depends on the enactment of two important legislations; the Pakistan Biosafety Act and the Plant Breeders Rights Act. The Pakistan Biosafety Act, which is being drafted, will determine whether the federal or provincial governments should regulate biotechnology in Pakistan. In principle, the biosafety regulation has to be the subject of regulation at Federal level given Pakistan's international obligation with respect to the Cartagena Protocol on Biosafety (CPB) of which Pakistan is a party since 31 May 2009. Pakistan has to show expediency in drafting and the enactment of the Pakistan Biosafety Law necessary for the establishment and functioning of the biotech regulatory system in the country. Notably, there are around 100 applications of different biotech crops expressing various traits, which are pending for field trials and commercial approval with NBC of MOCC. As an interim arrangement, the Government of Pakistan needs to reinstate the biosafety regulatory system of NBC at federal level by issuing a new Ordinance by the President or expedite enactment of the Pakistan Biosafety Act to be passed by the Parliament of Pakistan (Khursid, 2014). Similarly, the Plant Breeders Rights Act, which is pending for submission in the Pakistan National Assembly in 2015, will accelerate the growth of R&D, production and commercialization of the seed and biotech sector in Pakistan. Notably, the key steps for further development of the seed and biotech sector in Pakistan mainly depend on the approval and implementation of the National Biosafety Act and the Plant Breeders' Rights Act (USDA, 2015a).

Enactment of the Seed (Amendment) Act 2015

In a significant boost to R&D and commercialization of seeds, Pakistan's President approved the amendments to the Seed Act 1976. The new seed act referred to as "The Seed (Amendment) Act 2015" came into force on 23 July 2015. In 2014, the Minister for National Food Security and Research (MONFS&R) Mr. Sikandar Hayyat Khan Bosan moved the Seed (Amendment) Bill 2014 to amend the Seed Act, 1976 which was initially drafted in 2007. The Bill was reviewed by the National Assembly for the first time during the fall of 2014. The National Assembly approved the amendments on March 16, 2015 followed by the Senate on July 7, 2015. The Ministry of National Food Security and Research (MONFS&R) will now be in-charged of developing procedures for implementing the new provisions of the Act (USDA, 2015).

The Seed Act, 1976 provides the overall framework for seed provision in Pakistan, which was implemented through the Federal Seed Certification and Registration Department (FSC&RD) of the MONFS&R. The FSC&RD viewed it inadequate for the implementation of effective regulation whereas, the seed industry found it overly restrictive and outdated. The Seed (Amendment) Act 2015 include following key features;

a) Establishment of Federal Seed Committee (FSC)
b) Enhanced participation of the private sector
    - Accreditation of private laboratories for seed testing
    - Basic seed can also be produced by the private sector
c) Enhanced regulation of GM and non-GM seeds
    - Misbranded seed has been defined
    - Variety registration procedure specified

- Selling of banned or unapproved varieties/hybrids prohibited
- Registration with FSC&RD compulsory either for doing seed business or setting up a seed processing plant or being a seed dealer
- Registration to lapse if not renewed periodically
- Prohibition of seed sale except by a registered dealer and,

d) Enhanced penalties for noncompliance with the stipulations of the Act
e) Establishment of seed testing laboratories
f) Registration of genetically modified plant varieties

In case of the genetically modified seeds, the Seed (Amendment) Act 2015 clearly defines the scope of regulation of genetically modified plant varieties under the Act. The FSC&RD is authorized to register a GM crop variety under the Act 2015 provided that the applicant declares the absence of terminator gene technology, a clearance certificate from NBC set up by “Federal Government” accompanied with the performance trials data for two years (Ali, 2015; The Gazette of Pakistan, 2015).

Announcement of the Textile Policy 2014-2019

Agriculture and textile sectors are the backbone of the economy of Pakistan. The importance of agriculture precedes all other sectors as it produces food, generates employment, provides raw material for industry and is the base for foreign trade. Agriculture in Pakistan employs about 42% of country’s labor force, contributes 21% of the GDP and caters for 45% of exports. Textile sector plays a similar role in the economy of Pakistan. The textile sector largely depends on the domestic cotton production. Pakistan is the 4th largest producer and 3rd largest consumer of cotton globally. In recent years, the textile sector in Pakistan faces multiple constraints that diminish its comparative advantage in cotton and textile sector globally. In order to overcome cotton production constraints and enhance value addition in textile sector, Pakistan released the Textile Policy 2014-2019 in February 2015. The Textile Policy 2014-19 envisages Pakistan as a leading country in the field of export of value-added textile products. It is based on actionable plans to make the textile sector competitive and sustainable. The Policy sets the following key goals which will be achieved by working out a strategic framework and providing necessary budgetary support, policy interventions and sectoral focus.

- To double value-addition from US$1 billion per million bales to US$2 billion per million bales in five years.
- To double textiles exports from US$13 billion per annum to US$26 billion per annum in next five years.
- To facilitate additional investment of US$5 billion in machinery and technology.
- To improve fibers mix in favour of non-cotton i.e. 14% to 30%.
- To improve product mix especially in the garment sector from 28% to 45%.
- To strengthen existing textile firms and establish new ones.
- To facilitate the creation of 3 million new jobs.
- To adopt measures to increase ease of doing business and reducing cost of doing business (MOTI, 2015a).

The cotton sector received special attention to harness huge potential to further increase crop yield. The Textile Policy 2014-15 emphasizes on setting up the model cotton trading houses in collaboration with the PCCC to facilitate farmers, ginners and other stakeholders. In order to strengthen cotton regulatory regime, the Ministry of Textile Industry will pursue for enactment of Plant Breeders Right Act as well as amendment in Seed Act and Quarantine to facilitate research, attract new technologies and increase the availability of certified quality seed. The government will also facilitate the implementation of Cotton Control Act to improve standardization of cotton, reduced contamination levels and ginning sector. The Government would take measures to introduce extra-long staple (ELS) cotton and a comprehensive training and capacity building programme will be developed to establish a system in the private sector for grading and classifying cotton ensuring that proper premiums are paid based on grading and classification. The Textile Policy 2014-19 laid a greater emphasis on restructuring and strengthening of research activities of the Pakistan Central Cotton Committee (PCCC). Apparently, the Textile Policy sets targets to increase per hectare cotton yields, reduce the risk of cotton leave curl virus (CLCV) and introduce longer staple length varieties (MOTI, 2015a). To achieve the goals of the Textile Policy 2014-19, the Ministry of National Food Security and Research (MNFS&R) has targets to expand the area under cotton in Pakistan to meet the cotton requirement of the domestic textile industry.

The Federal government is implementing a project through the provincial governments to promote the cultivation of cotton as relay crop in standing wheat for enhancing productivity of cotton and wheat crop (MOTI, 2015c). Expansion of cotton area and cotton yield is essential to meet the demand for cotton consumption by textile industry, which is increasing due to expanded textile exports to the European Union under the Generalized System of Preferences "Plus" program. The imports of cotton are expected to surge to 2.5 million lb bales to meet higher demand and offset the decline in domestic cotton production. Therefore, it is paramount for Pakistan to introduce new technologies like hybridization of cotton, double genes IR trait and stacked Bt/HT cotton to increase cotton yield and production to meet the growing cotton demand. The goals of the Textile Policy 2014-2019 particularly the export policy and its intention to double the value of textile exports over the next five years, principally by shifting more value addition to Pakistan can only be achieved by increasing domestic cotton production.

Ironically, the area under cotton has not increased substantially over the last two decades from 2.7 million hectares in 1990-91 to 3.12 million hectares in 2015-16. During the same period, cotton yields remained almost stagnant at 550 kg to 750 kg of lint per hectare. However, in 2014-15, Pakistan achieved a record yield of 775 kg lint per hectare. It is estimated that the country will produce slightly lower cotton estimated at 13.38 million bales in 2015-16 as yields are forecast lower than the near record level achieved in 2014-15 (CCAC, 2015). Over the last few years, the annual cotton production has stalled between 12 to 14 million bales whereas demand for cotton doubled from 6.6 million bales in 1990-91 to 15-16 million bales in 2015-16. It is estimated that Pakistan will import around 2-3 million bales to meet the increasing cotton consumption by the domestic textile industry in 2015-16.

Adoption of Bt Cotton in Pakistan, 2010 to 2015

In the sixth year of commercialization, Pakistan achieved a near optimal adoption of insect resistant Bt cotton varieties. In 2015, Pakistan increased the adoption to 2.9 million hectares equivalent to 93% of a total of 3.12 million hectares of cotton (Table 18). Approximately ~725,000 smallholder cotton farmers continued to grow Bt cotton varieties in the absence of approval of new Bt cotton varieties either by Punjab Seed Council (PSC) or by the National Biosafety Committee (NBC). Notwithstanding,

Table 18. Adoption of Bt Cotton in Pakistan, 2010 to 2015

Year	Adoption of Bt Cotton (Mha)	Total Cotton (Mha)	% Adoption
2010 - 11	2.4	3.1	75%
2011 - 12	2.6	3.2	81%
2012 - 13	2.8	3.4	82%
2013 - 14	2.8	3.2	86%
2014 - 15	2.85	3.2	88%
2015 - 16	2.90	3.12	93%

Source: Analyzed and compiled by ISAAA, 2015.

Bt cotton has proliferated in Baluchistan and Khyber Pakhtunkhwa and occupied almost the entire cotton crop hectarage in the Punjab and Sindh provinces of Pakistan.

Pakistan officially allowed the commercial cultivation of Bt cotton in 2010. It is noteworthy to mention that Pakistan is the 4th among the 14 countries growing Bt cotton, in descending order includes India, China, USA, Brazil, Argentina, Burkina Faso, Myanmar, Australia, Mexico, Sudan, Colombia, South Africa, and Paraguay. These countries contribute a very large proportion of global cotton production and trade. This official approval was spurred by the demand for genuine good quality Bt cotton in the country with the following specifications: resistant to cotton leaf curl virus (CLCV), 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).

Farmers planted 30 open pollinated Bt cotton varieties and 2 hybrids of Bt cotton, which were approved from 2010 to 2014. In 2015, the Technical Advisory Committee (TAC) recommended the release of 21 Bt cotton varieties to the National Biosafety Committee (NBC) of the Ministry of Climate Change, the administrative agency of the biosafety regulation in Pakistan. However, the statutory authority of NBC was challenged in the Lahore High Court in the wake of the 18th Amendment of the Constitution and therefore has not approved new Bt cotton varieties in 2015. These 21 new Bt cotton varieties are likely to be approved in the near future to provide farmers with a choice of high yielding Bt cotton varieties which impart tolerance to CLCV and other sucking pests necessary for farmers to overcome production constraints. The details of the approval of different Bt cotton varieties by the Provincial Punjab Seed Council (PSC) and the National Biosafety Committee (NBC) between 2010 and 2014 can be obtained from ISAAA Brief 49.

Socio-Economic Benefits of Bt Cotton in Pakistan

Bt cotton occupies 93% of cotton farmed in Pakistan in 2015, the sixth year of official release of Bt cotton varieties developed by public and private sector institutions. Many observers reported that Pakistan probably began growing Bt cotton varieties unofficially as early as 2002 when India officially allowed commercial cultivation of Bt cotton hybrids. However, in Pakistan, unofficial Bt cotton varieties couldn't flourish due to poor seed and fiber quality and were susceptible to cotton leaf curl virus

(CLCuV) requiring high inputs (Ahsan, 2009). The situation changed in 2010 when Punjab Seed Corporation (PSC) officially approved 8 Bt cotton varieties and one hybrid containing event MON531 and GFM event. In 2015, around 30 Bt cotton varieties and 2 Bt cotton hybrids were available for planting across the major cotton growing area. The rapid adoption of Bt cotton varieties in the last six years demonstrate the additional value creation to farmers and to the cotton economy. In this period, four socio-economic groups in Pakistan have carried out survey of Bt cotton fields and published their study that underscore the socio-economic benefits of Bt cotton to the farmers, laborer, farm families and to the cotton economy. The summary of socio-economic impact of the four research studies on Bt cotton varieties are highlighted as follow;

- Nasir et al. (2015) published a research study on "Estimation of Cost Benefit Ratio of Bt Cotton Growers in District Khanewl-Pakistan in 2015", which demonstrates the profitability of small, medium and larger farmers in terms of gross margin, net revenue and economic profit in district Khanewal, Punjab, Pakistan. This study reveals that large farmers of Khanewal district earned more net revenue and gross margin compared with medium and small farmers of Khanewal district because of more inputs induced profitability. Economic profit and gross margin depict the farmer's economic conditions. Benefit Cost Ratio (BCR) takes into account the amount of monetary gain realized by performing an economic activity versus the amount it costs to execute the economic activity. The higher the BCR, the better the investment is, i.e., if the benefit is higher than the cost, the activity is a good investment. The study concludes that **The analysis of Benefit Cost Ratio (BCR) reflects that BCR is highest for small farmers followed by large farmers in the study area.** The study concludes that cost of production of large farmers is quite high as compared with small and medium farmers. It is high because of more use of inputs by large farmers in Khanewal district. **In the study area, small farmers of Khanewal district have less revenue, with more business profit (due to less average variable cost) as compared with medium farmers. BCR is highest for small farmers followed by large farmers,** the study reported (Nasir et al., 2015).

- Noonari et al. (2015) published a research study on "Comparative Economics Analysis of the Bt Cotton V/S Conventional Cotton Production in Khairpur District, Sindh, Pakistan" in 2015. The study demonstrates that **Higher profit was observed in cultivating Bt cotton as compared to low profit obtained in growing conventional cotton.** The study examined the financial gain from Bt cotton in comparison with conventional cotton in district Khairpur where both Bt cotton and conventional cotton varieties were grown. Higher income (Pakistani Rupee 155,401 per acre), higher costs (Rupee 98,677 per acre) and higher profits (Rupee 56,724 per acre) were gained in sowing Bt cotton compared to conventional cotton that gave poor results, lower income (Rupee 75,372), lower costs (Rupee 57,939) and very low profits (Rupee 17,433) were recorded. Overall, the cost of cultivation and seed cost of Bt cotton was high as compared to conventional cotton due to high seed rate. The pesticides cost was more in conventional cotton as compared to Bt cotton due to more application of pesticides. Total cost of production on Bt cotton of Rupee 98,677 per acre was higher than conventional cotton at Rupee 69,539 per acre; however, overall high yield of 40.2 mounds per acre from Bt cotton was obtained compared to 28.5 mounds per acre by conventional cotton. **The study clearly indicates that Bt cotton farmers were increasing farm yield and farm profit compared to conventional cotton. Farmers were reducing cotton area that severely affected the cotton production.**

Farmers were focusing to increase Bt cotton area, study concluded (Noonari et al., 2015).

- 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)** (Nazli et al. 2012).

- In 2012, Kouser & Qaim presented a research study on "Valuing a financial, health and environmental benefits of Bt cotton in Pakistan", which concluded that Bt cotton adoption results in significantly lower chemical pesticide use, higher yields, and higher gross margins, 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.** 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 (Kouser & Qaim, 2012).

It is estimated that the economic gains from biotech crops for Pakistan for the period 2010 to 2014 was US$1.9 billion and US$299 million for 2014 alone (Brookes and Barfoot, 2016, Forthcoming).

SOUTH AFRICA

In recent years, South African spring rains came late but picked up in midsummer resulting in a record maize crop of over 14 million tonnes in 2013, but in 2014, it was less, decreasing maize crop production by 30%. The projected El Niño for 2015-2016 was even more severe and of longer intensity and duration than expected with dire consequences for the agricultural industry and food prices. The devastating drought in 2015 was much worse than expected decreasing the intended GM hectarage of all biotech crops in South Africa in 2015 by ~700,000 hectares or 25% to 2.3 million hectares of GM crops in 2015. Thus, the overall effect of the devastating 2015 drought was to decrease GM hectarage from an intended record of 3.0 million hectares in 2015 to 2.3 million hectares.

Total biotech crop area for maize soybean and cotton in 2015 is projected to be planted on 2.3 million hectares down from the 2,700 million hectares in 2014, a decrease of 15%,

but down by a massive 25% from the intended 2015 hectarage of 3.0 million hectares of biotech crops. In 2015, biotech maize is expected to be planted on 1.8 (1.774) million hectares at an adoption level of 90% of the 2 million total maize hectares. Herbicide tolerant soybean is projected at 508,000 hectares to be adopted at 95% of 535,000 hectares in 2015 – down from 552,000 hectares in 2014 and down significantly (162,000 hectares) from an intended 670,000 GM hectares in 2015. The modest area of cotton is expected to increase from 8,000 hectares in 2014 with 100% adoption of the stacked Bt/HT. Hence, a total of 2.3 million of GM hectarage was planted in 2015, with 1.8 million hectares biotech maize, 0.580 million hectares of biotech soybean and 0.012 million has of biotech cotton. Thus, the total GM crops of 2.3 million hectares for 2015 was down significantly from 2.7 million hectares in 2014 for total GM crops of 2.3 million hectares down from 2.7 million hectares in 2014 by 700,000 hectares, or ~25% from the intended GM hectarage of a record 3.0 million hectares in 2015. Economic gains for biotech crops in South Africa for the period 1998 to 2014 was US$1.8 billion and US$245 million for 2014 alone.

SOUTH AFRICA

Population: 54.5 million

GDP: US$384 billion

GDP per Capita: US$7,350

Agriculture as % GDP: 3%

Agricultural GDP: US$11.5 billion

% employed in agriculture: 5%

Arable Land (AL): 12.1 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 2015:
2.3 Million Hectares (-15%)

Farm income gain from biotech, 1998-2014: US$1.8 billion

*Ratio: % global arable land / % global population

South Africa planted its first biotech crops in 1998 with insect resistant cotton, in 2000 with insect resistant maize, herbicide tolerant soybean in 2001 and herbicide tolerant maize in 2003. In 2015, 67 biotech events have been approved for food, feed and cultivation, including four Argentine canola events, 10 for cotton, 40 for maize, and 12 soybean events. Biotech maize, soybean and cotton are projected to be planted on 2.3 million hectares, down from 2.7 million hectares in 2014, and down 700,000 hectares from the intended 3.0 million hectares equivalent to a substantial 25%.

Biotech Maize is expected to be planted on 1.8 million hectares at an adoption level of ~90%. This hectarage is broken down into 550,000 hectares insect tolerant, 284,000 hectares herbicide tolerant and 940,000 hectares of stacked Bt/HT. USDA GAIN estimates that 86% of 1.03 million hectares of total white maize planted is biotech, and 92% of 0.96 million hectares yellow maize planted is biotech. This makes a total of ~2.0 million hectares of maize. Human consumption of maize is expected to drop in 2015 by 4% to 4.7 million tons as consumers are expected to substitute white corn products for wheat and rice products due to cheaper price. Animal consumption of corn is expected to remain at 4.9 million tons and will consist of mainly yellow corn.

Small farmers in South Africa (who account for about 5% of total maize production) obtained yield gains of between +3% and +8% using herbicide tolerant maize compared to the conventional, where hand weeding was the primary form of weed control practice (Gouse et al. 2012).

Biotech Soybean has been planted in South Africa since 2001. Herbicide tolerant soybean is projected at 508,000 hectares to be adopted at 95% of 535,000 hectares in 2015 – down 8% from 552,000 hectares biotech in 2014, and down by ~160,000 hectares (24% decrease) from an intended 670,000 hectares in 2015. The increase in soybean planting was intended to replace soybean meal imports. An additional 1.2 million tons of oilseed processing capacity has been created, bringing the country's total oilseed capacity to an estimated 2.2 million tons per annum.

Biotech Cotton with insect resistance has been planted in South Africa since 1998. In 2015, 12,000 hectares were planted which compares with 8,000 hectares in 2014 – adoption in 2015 was 100% of the stacked Bt/HT. Cotton is cultivated in Northern Cape, Limpopo, Mpumalanga, KwaZulu-Natal and North West. Cotton produced in South Africa is less than the country's demand, but it is of high quality, 70-80% of which is exported.

Multifaceted Support Systems for Biotech R & D and Adoption of Biotech/GM Crops

Much of the present status of adoption of biotech/GM crops can be ascribed to a diverse environment of supportive systems: a functional biosafety regulatory framework – compliant with the Cartagena Protocol – that ensured that no verified adverse impacts on humans, animals or the environment occurred; a strong science foundation; farmer access to a wide range of genetically improved varieties; farmer and ag-industry support for biotech crops, enabling disadvantaged smallholders to enter main stream agricultural production; government support for biotech research; and access by breeders to international biotech germplasm.

Biosafety Regulatory System in South Africa

The comprehensive GMO regulatory framework is based on a permit system of which there are some 12 types, apart from compulsory registration of facilities where GMOs are handled. There were 262 GMO permits granted from 1 January to 30 September 2015 of which maize accounted for 87.0%, soybeans for 6.9%, cotton 5.0%, and TB vaccines for 1.1%.

Commodity clearance permits (for LMO imports) were three for maize grain events: GA21xT25, MON87460 x MON89034 x MON8817, and Bt11 x Mir162. Commodity import permits numbered 61 involving 1.2 million MT maize grain necessitated by drought damage to 2015 crop, temporary shortfall and anticipated crop losses to 2016 harvest from current severe drought damage, as yet unquantified; and 11 permits for commodity soybean imports of 479,000 MT, caused by expected drought damage and excess capacity at oil pressers. LMO commodity exports for maize amounted to only 45,800 MT and 24 permits, and only one export permit for 880 MT soybeans. Seed for commercial planting amounted to GM maize seed imports of 560 MT and export permits covered 10 permits for 3,633 MT, again showing the positive trade balance in GM maize seed trade, permits numbered four and ten, respectively. Imported soybean seed for planting came to 9 permits for 443,000MT, a major negative trade balance for South Africa. Permits were granted for contained field trials (trial release) that included 14 maize events (Table 19).

Other permits covered small import / export samples for contained use (labs, green houses), contained field trials, seed multiplication, variety testing, and others.

Local Biotechnology Initiatives

Modern biotechnology research started many decades ago and a small group of scientists set up the South African Committee on Genetic Experimentation in 1978 to advise both industry and government. They developed the first biosafety guidelines and assisted in the first approvals for field testing. The GMO Act was drafted in 1995-96 and approved in 1997, and entered into force in 1999 when GMO regulations were approved. Applications for permits are assessed by the national scientific Advisory Committee and their subcommittees, with recommendations forwarded to the national government's GMO Executive Council.

Today, South Africa scientists interact and collaborate internationally with biotech counterparts, and conduct research on genomics and all other 'omics. The first sequencing of an organism in Africa was done by local scientists on the livestock heart water parasite, as was the first animal cloning of a goat. State-of –the- art diagnostics and robotics are found at many public and industry facilities. Many foreign students are studying at local universities while others are employed at local public and private institutions.

Table 19. Biotech Maize Events Granted Contained Field Trials in 2015

	Maize Events Approved
1	Bt11x1507xGA21
2	Bt11xMir162x1507xGA21
3	Bt11xMir162xGA21
4	Bt11xMir162
5	Bt11xGA21
6	GA21
7	Bt11
8	MON87460xMON89034
9	MON87461xNK603
10	MON87460xMON810
11	DAS40278-9
12	NK603xDAS40278-9
13	MON89034x1507xNK603
14	MON89034x1507xDAS40278-9

Some new local innovations in biotech are: a patent on RNA hairpin duplexes for resistance to plant viruses, exploring valuable proteins in cassava leaves and modifying cassava to resist viruses, developing tobacco plants as biopharma factories for antibodies, a new anti-malaria drug, and marker genes for improved detection of new gene mutations that cause cystic fibrosis.

However, no home-grown biotech/GM crop innovations have as yet entered the commercial market, partly due to cost of obtaining regulatory approval. These include novel promoters, drought tolerance genes, maize streak virus resistance, and a range of experimental GM sugarcane events.

Government Support for Biotech

The national biotechnology strategy of 2001 has since been replaced by a Bio-Economy strategy and implementation is in process. The strategy includes agri-biotech research, much of it to be funded by the National Research Foundation. The publication on agricultural research priorities released at the October 10th Plenary Session of the National Agricultural Research Forum (NARF) of the Department of Agriculture, Forestry and Fisheries (DAFF) contains the following statement on one priority:

"Biotechnology as an aid to improve productivity of all crops of importance – present, historic and imported – for climate change, pest and disease tolerance, including interventions and innovations such as breeding, cultivar development; utilizing genomics, proteomics, to unravel genomes with technology-based platforms to support crop research and address post-harvest constraints."

The Agricultural Research Council already has a biotech platform in place to coordinate biotech research at their 11 national institutes. The DAFF Executive Council on GMOs which comprises officials from six government departments, though not intended to boost biotech research but to assess for safety of all GMOs, approved for general commercial release the Monsanto drought tolerant maize in June 2015 (the conventional drought tolerant maize, not needing a permit, was released in 2014). This development was most relevant considering periodic droughts in Southern Africa that reduced the South African maize harvest by 32% and soybeans by 26% in the 2015 crop, and present plantings and yields by as yet unquantified magnitude.

Access to Improved Varieties/Hybrids and Quality Seed

Farmers can choose different varieties based on their needs and capabilities. Table 20 lists the type of seed technologies in the four major crops: 312 varieties for white maize, 298 for yellow maize, 149 for soybean, and 15 cotton varieties. It is noteworthy that 33% to 100% of the varieties are biotech, which indicates a continuous supply of new seed technologies that will provide additional benefit for the farmers in terms of reduced cost of production and increased yield.

Getting Smallholders into Mainstream Crop Production

Government has a basic policy to get previously disadvantaged smallholder farmers into main stream production by purchasing commercial farms. At the same time, a range of stakeholders is engaged in mentorship, capacity building and support to uplift and assist new emerging farmers into food production. Collaborators include present commercial farmers, producer associations, and seed companies.

For example, a mid-2015 survey showed that seed companies sold GM maize seed to smallholders

Table 20. List of Crops and Varieties for Farmers in South Africa

	Other Varieties	GM Hybrids (% of Total)	Total Varieties
White Maize	132 Conventional 24 OPVs 9 High Lysine OPV 4 Hybrids	103 (33%)	312
Yellow Maize	131 Conventional 153 Hybrids 7 High Lysine OPV 7 High Protein Hybrids	153 (51%)	298
Soybean	33 Conventional	115 (77%)	148
Cotton		15 (100%)	15

who moved their GM areas planted in 2014 from a total of 12,500 hectares in 2013 to 26,000 hectares in 2014. The seed pocket size ranged from 2kg, 10kg, and 25kg. GM maize seed sold to provincial authorities on a tender bid system also reaches smallholders but these data are not available.

In addition, Grain South Africa, a national grain producers association representing maize, wheat, and sorghum producers has been driving smallholder development for several years. Their results up to early 2015 indicate that apart from existing 5,795 large-scale commercial farmer members, they now have 5,959 subsistence farmer members producing maize on 10 hectares and harvesting at least 250 MT each of grain, as well as 838 smallholder farmers planting maize under 10 hectares. Their share of GM maize planted has been estimated at 70 – 80%, almost the same as large-scale commercial farmers. These farmers plant an estimated 80,000 hectares. The schools' ag-awareness project has reached 122,500 students and their dedicated magazine has a circulation of 240,000, while their training courses had 1,295 participants.

Economic Benefits

It is estimated that the economic gains from biotech crops for South Africa for the period 1998 to 2014 was US$1.8 billion and US$245 million for 2014 alone (Brookes and Barfoot, 2016, Forthcoming).

Farmer Testimonies

Frans Mallela, one of the large-scale farmers in Limpopo Province. ***"We were fed up with weeding and spraying pesticides to control bollworms and weeds. When the technology was introduced, we rapidly picked it up."*** According to Mr. Mallela, since he started growing GM cotton, he recorded an increase in yields, from 4 hectares to 150 hectares. He has moved from GM cotton with a single trait to stacked traits (insect resistance and herbicide tolerance). "Cotton with the two traits does not require a big land for refugia. This helps me to maximize on yields," said Mallela. "When I first went into farming, as a part time job, I used to plant conventional maize and the harvest never went beyond one tonne per hectare. Now with biotechnology, I get up to 7 tonnes per hectare if the rain is good," Mr. Mallela added (Crop Biotech Update, 2 May 2015).

Ms. Maria Swele from Ephraim Mong'ale Municipality, Limpopo Province. ***"I was inspired into Bt cotton farming by my former farmer employer Mr. Frans Mallela 4 years ago. He discouraged me from taking up a clerical office job but instead try out 5 Ha of the crop and that has made all the difference. In 4 years, I have increased area of production to 50 Ha. of Bt cotton."*** This is the message from 35-year old Maria Swele, a Bt cotton woman farmer from Ephraim Mong'ale Municipality, Limpopo province. ***"Bt cotton enterprise has been rewarding, enabling me to purchase 2 tractors, a car and a house. I have also managed to pay for my younger sister's education."*** Further, she has won the local award for youth and technology adoption twice in a row, becoming a role model for many young people in her region. ***"Attending to our crops is so much easier and has drastically reduced labor. We no longer need to carry crude tools to weed and spray as most of this is now done mechanically."*** She rotates her crop with sun flowers and hopes to advance to stacked trait Bt/HT cotton so that she can reduce the area required for refugia crop.

Mr. Gift Mafuleka from Bronkhorstspruit, Gauteng Province. For 28-year old agricultural engineer-turned-farmer, Mafuleka from Bronkhorstspruit, Gauteng Province quit employment to start his maize farming enterprise called Beyon Mzanzi Agriculture. ***"I sought a loan from the Government of South Africa's Rural Development and Land Reform department to start maize production on 500 Ha, which I established 2 years ago (2013). The farm is efficiently run by 9 employees since there is no need for agronomic services such as weeding or pesticide spraying against stalk borer with the stacked HT/Bt Maize that I grow. I am satisfied with biotech maize because I can effectively practice zero tillage.*** He rotates the maize crop with herbicide tolerant soy bean, which he wants to incorporate as his second enterprise in the farm. Mafuleka says he has managed to clear his loan from the proceeds of biotech maize and is looking forward to breaking even in a year's time.

URUGUAY

Uruguay had reduced planting of biotech soybean and maize at 1.4 million hectares compared to 1.64 million hectares in 2014, a decrease of 200,000 hectares or 12%. Consistent with several other countries a decrease in total plantings of the two crops due to low prices was probably a principal cause along with other management factors detailed in the text. Biotech soybean occupies 100% of the national soybean hectarage of ~1.33 million hectares. Biotech maize occupied 88,000 hectares in 2015, compared with 90,000 hectares in 2014. Of the 88,000 hectares of biotech maize, 97% was the stacked Bt/HT product. 2015 was the 12th year for Uruguay to plant biotech maize. Uruguay has enhanced farm income from biotech soybean and maize of US$179 million in the period 2000 to 2014 and for 2014 alone at US$30 million.

Uruguay, which introduced biotech soybean in 1996, followed by Bt maize in 2003 had a decreased biotech crops hectarage in 2015 at 1.4 million hectares compared to 1.6 million hectares in 2014, a decrease of 200,000 hectares or 12%; consistent with several other countries a decrease in total plantings of the two crops, due to low prices, was probably the principal cause, along with other issues described below. Biotech soybean occupies 100% of the national soybean hectarage of ~1.33 million hectares. Biotech maize occupied 88,000 hectares in 2015, compared with 90,000 hectares in 2014 a 2% decrease equivalent to 2,000 hectares.

Uruguay approved 17 biotech events composed of 10 maize events and 7 soybean events from 2003 to 2014. Uruguay approved five maize events on the same day in early 2011. In September 2012, the stacked biotech soybean with insect resistance and herbicide tolerance, Bt/RR2Y®, was approved for commercialization. Thus, in the short span of only two years (2011-2012), the efficient, science–based regulation system in Uruguay has approved a total of 11 products, emulating its neighbor Brazil which approved 14 products in two years, 2010 and 2011. In 2014, herbicide tolerant soybean CV127, insect tolerant corn MIR 162 and stacked Bt/HT MON 89034 × TC1507 × NK603 were approved for planting, for a total of 17 event approvals from 1996 to 2014 (ArgenBio, 2015). In 2014, the regulatory system authorized a few trials. The lack of decision on GMOs was due to "internal affairs" in the Government and biosafety committees were restructured delaying approvals.

URUGUAY

Population: 3.4 million

GDP: US$49.9 billion

GDP per Capita: US$15,780

Agriculture as % GDP: 10%

Agricultural GDP: ~US$5 billion

% employed in agriculture: 10%

Arable Land (AL): 1.8 million hectares

Ratio of AL/Population*: 2.2

Major crops:

• Rice	• Maize	• Soybean
• Wheat	• Barley	• Sugarcane

Commercialized Biotech Crops:
- HT Soybean
- Bt Maize

Total area under biotech crops and (%) increase in 2015:
1.4 Million Hectares (-12%)

Farm income gain from biotech, 2000 to 2014: US$179 million

*Ratio: % global arable land / % global population

Biotech Soybean

Uruguay planted a total of 1.3 million hectares soybean which is 100% biotech, comprised of 227,000 hectares Bt/HT and 1.1 million hectares HT. Biotech soybean planting was reduced by 217,000 hectares or 14%. The projected exit of some Argentine pool investor farm group and the national government's natural resource management plan were the two factors behind the decrease in soybean production area. Argentine investors who farmed in Uruguay when the soybean price was high have opted to leave the country due to high production costs in Uruguay farming and the low soybean price.

The required mandatory natural resources management and soil use plan by the Ministry of Agriculture is a 30 year old national conservation policy that mandates all farming plans should involve information on soil use, irrigation, crop rotation, maps on field drainage, fertility, drought risk, and erosion risk. Compliance is strict for farm owners with more than 100 hectares, and non-compliance is sanctioned. As such, soybean area dropped in 2015/16 and more winter crops, including oats, were planted in order to comply with rotation management under the plan. Despite this, it is estimated that production is at 3.65 million metric tons, a marginal increase from 2014/2015 due to higher yields resulting from farmer experience with soybean production.

Uruguay farmers are responsive to precision agriculture technologies, said Minister of Agriculture Tabere Aguerrein, in a video interview (ScienceDaily, 24 December. 2014). They are also open to production methods and enjoy low level of indebtedness compared to neighboring countries. The video highlighted that GM crops in Uruguay is accepted and planted by farmers who aim to feed 50 million people. Using smart agriculture, diversification and sustainable intensification, as well as improved institutional capabilities and private-public partnerships, this will certainly be attained

Since 2014, soybean planted in Uruguay is already 100% biotech, a result of the country's patent protection and royalty collection regimes which are robust and functioning well. With the development of biotech seeds which are able to adapt to the country's farming conditions as well as increased farmer expertise in cultivating soybean, the yield of the crop is higher. There is less pest pressure in the country, hence Bt varieties did not take off as much in the market.

Nearly 95 percent of Uruguayan soybeans are exported as whole beans. China dominates the market share with three-quarters (77%) of all exports being shipped annually. Around 7% goes to Egypt, 5% to the EU, 3% to Mexico, 2% to Bangladesh and 6% to other countries that import from Uruguay in smaller quantities. USDA estimated an export volume of 3.85 million metric tons in 2015/2016, marginally higher than in previous years.

Biotech Maize

Uruguay has planted biotech maize for 12 years starting in 2003. Stacked trait (insect resistant and herbicide tolerant maize) maize was introduced in 2011. In 2015, maize farmers in Uruguay planted 100,000 hectares of maize, of which 88% (88,000 hectares) is biotech, comprised of 86,000 Bt/HT and 2,000 hectares HT. Biotech maize planting was reduced by 2,000 hectares from 90,000 in 2014.

The country has completed its biosafety regulatory framework since 2000 and got updated in 2008. The promotion of coexistence policy of GM and non-GM crops will provide more flexibility in farming and trading. GM crops are evaluated on a case by case basis, following the biosafety guidelines under the National Biosafety Board (GNBio) composed of the Ministers of Agriculture, Environment, Health, Economy and Finance, Foreign Affairs, and Industry. The guidance set by the government allows farmers to enjoy the benefits of the technology with: increases in productivity, less use of agrochemicals (with less toxicity and residuality), less exposure of operators and rural population to chemicals, better care of natural resources (soil, water), better conservation of biodiversity, and better quality products.

Setting Uruguay's capability to handle large shipments of grain for export was realized in 2015 after the new grain terminal in Montevideo doubles port capacity to 2 million metric tons. Prior to this, grain shippers had to use the public port terminal which was not set up for continuous grain exports (USDA FAS GAIN, Grains Annual for Uruguay, 2015).

Benefits from Biotech Crops in Uruguay

Uruguay is estimated to have enhanced farm income from biotech soybean and maize of US$179 million in the period 2000 to 2014 and the benefits for 2014 alone is estimated at US$30 million (Brookes and Barfoot, 2016, Forthcoming).

BOLIVIA

RR®soybean was grown on an estimated ~1.1 million hectares in 2015 in Bolivia, a slight increase from the 2014 hectarage of ~1.0 million hectares. The adoption rate of RR®soybean in 2015 was estimated at ~80% of the total 1.308 million hectares. In 2008, Bolivia became the tenth country to officially grow RR®soybean, at 600,000 hectares. Thus, the almost doubling of RR®soybean hectarage from 2008 to 2015 has been significant. It estimated that economic gains from biotech crops for Bolivia for the period 2008 to 2014 was US$636 million and US$107 million for 2014 alone.

BOLIVIA

Population: 11 million

GDP: US$59.2 billion

GDP per Capita: US$5,364

Agriculture as % GDP: 10%

Agricultural GDP: US$2.4 billion

% employed in agriculture: 32%

Arable Land (AL): 4.3 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 2015:
1.1 Million Hectares (+10%)

Farm income gain from biotech, 2008 to 2014: US$636 million

*Ratio: % global arable land / % global population

Bolivia is a small country in the Andean region of Latin America with a population of 11 million and a GDP of more than US$59.2 billion in 2015. 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 occupying 1.28 million hectares.

Soybean production started to expand in Bolivia in the early 1980s. Soybeans contribute to 3% of GDP and 10% of total exports, employ 45,000 workers and generate 65,000 indirect jobs (USDA-FAS GAIN Bolivian Soybean Update, 2015). The only genetically modified (GM) crop that has been approved for production or human consumption in Bolivia is Roundup Ready®(RR®) soybean event GTS-40-3-2, which is resistant to the herbicide Roundup®. The first approved crop was planted in 2005, but farmers had already introduced RR® soybeans from Brazil through family networks. By 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.

According to the most recent estimates of global hectarage of soybean (FAO, 2015), Bolivia ranks eighth in the world with 1.2 million hectares, after the USA (31 million hectares), Brazil (28), Argentina (19), India (12), China (6.6), Paraguay (3), and Canada (1.8). Of the top eight soybean countries, six (USA, Argentina, Brazil, Paraguay, Bolivia and Canada) grow RR®soybean.

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. IFPRI reports that 97% of the soybeans in the country are grown in Santa Cruz where most of the producers are relatively small farmers (classified as less than 50 hectares), although the majority of the production is by larger farms. In 2008, the percentage of certified soybeans in Bolivia reached a high of 75% despite the fact that in Bolivia there is a tradition, which is constantly changing, for smaller farmers to save their own soybean seed. However, smaller farmers are becoming increasingly aware of the benefits associated with certified seed and are adopting it within their traditional farming systems, resulting in a high level of adoption of 75% in 2008. At the national level and at the Santa Cruz State level, Bolivia has well organized extension programs that provide technical assistance to seed producers regarding the value of high quality certified seed with a focus on the significant benefits it offers smaller low-income farmers. The presence of an effective and efficient certified seed industry in Bolivia greatly facilitates access and adoption of certified RR®soybean seed which is used not only by the larger farmers but increasingly by smaller subsistence farmers. Local, private input dealers and producer organizations are currently the source of approximately 21 herbicide tolerant (HT) soybean varieties.

Adoption of Biotech Soybean

In 2008, Bolivia became the tenth soybean country to officially grow RR®soybean with 600,000 hectares planted, equivalent to 63% of the total national hectarage of 960,000 hectares. RR®soybean has been adopted on extensive hectarages in Bolivia's two neighboring countries of Brazil (currently at 23.9 million hectares of RR®soybean) and Paraguay (currently at 3.2 million hectares) for many years. The Law of the Productive Revolution introduced on 26 June 2011 prohibits the introduction of modified organisms into Bolivia, if the country is the centre of origin and diversity. This opened 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.

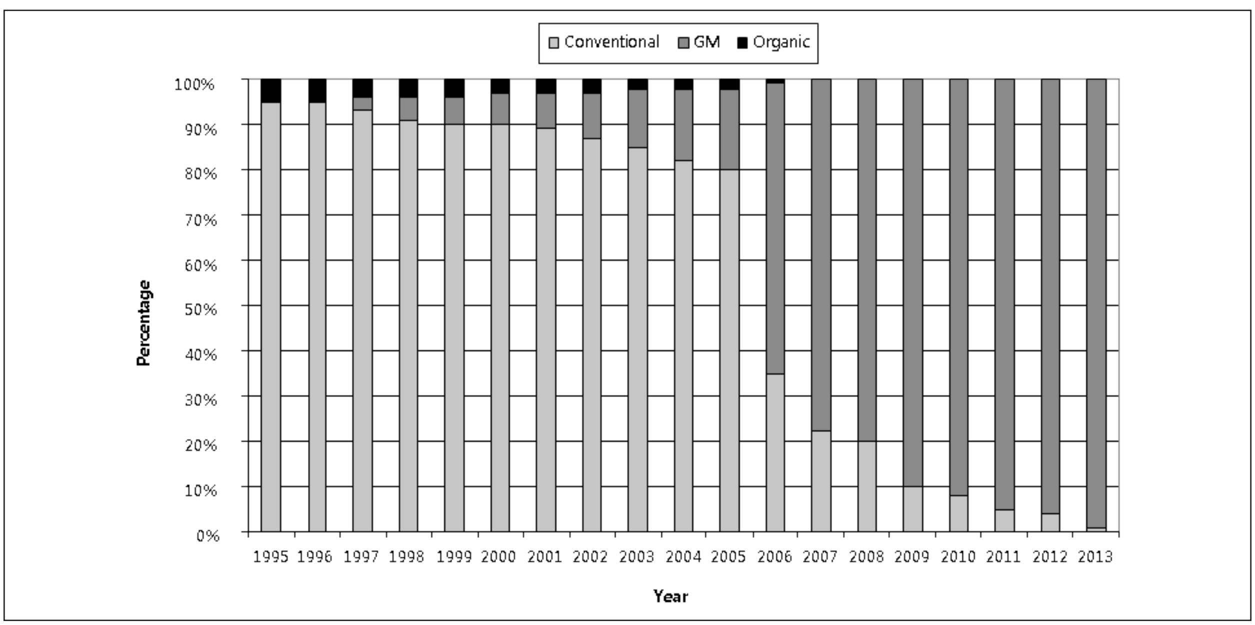
RR®soybean was grown on an estimated 1.1 million hectares in 2015 in Bolivia, slightly more (0.1 million hectares) than last year 2014. The adoption rate of RR®soybean n 2015 was estimated at ~80% of the total 1.3 million hectares, similar to 2014. The growth rate between 2008 and 2015 has been significant with almost a doubling of RR®soybean hectares from 600,000 in 2008 to 1.1 million hectares in 2015.

Adoption of soybean in Bolivia is depicted in Figure 10 (Smale et al 2012, and Hoiby and Hopp, 2015). Soybean hectarage has increased impressively from 1991 to 2005 and production has stabilized at around 1.6 million metric tons. A decreased hectarage occurred in 2008 because of poor weather conditions – El Niño, followed by La Niña. Adoption of biotech soybean consistently increased since its informal introduction by farmers and official approval in 2005 (Figure 10). According to ANAPO, the estimated share of HT soybeans was 21% in 2005, 78% in 2007 and 92% in 2010 (Zeballos-Hurtado, 2011).

In the beginning of CY 2015, 12% of the one million hectares planted in summer was affected by drought, losing around 120,000 soybean hectares. Soybean yields vary considerably from 1.8 to 2.3 MT per hectare, depending on efficiency and technical know how of producers. The average yields in 2014 winter crop were 2.3 MT per hectare, with a cost of production per hectare of about US$280 of which US$110 is used for pesticide use (USDA-FAS GAIN Bolivia Soybean Update, 2015).

USDA FAS (Bolivian Soybean Update, 2015) revealed that biotechnology divided the country into biotech soy growers (Sta. Cruz) and non-biotech soy growers (La Paz). According to Bolivian producers, Paraguay is more efficient in producing soybeans due to the extensive use of biotechnology. Bolivian

Figure 10. Percentage Distribution of Different Types of Soy Planted in Bolivia, 1995-2013



Source: Hoiby and Hopp, 2015.

farmers are inspired by Paraguayan producers whereby both countries produce soybean levels about the same 10 years ago, and now Paraguay produces three times as much soybean as Bolivia.

Soybean products from Bolivia are exported to Andean countries: Chile, Colombia, Ecuador, Peru and Venezuela. Total soy export in 2014 was 1.5 MMT at US$1.1 billion and an estimated 1.7 MMT in CY2015.

Nowadays, even though some soy is marketed and sold under the label of conventional soy, the leaders of ANAPO (Oilseed and Wheat Producers Association) state that GM soy has virtually replaced the remainder of conventional soy production due to the unchecked incursion of GM soy seeds into conventional soy fields.

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

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

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 21) indicates that the net benefits favor RR®soybean over conventional, which is approximately US$200 (US$196) per hectare. The principal benefits, include a 30% increase in yield, a 22% savings on herbicides and more modest savings in labor and other variable costs; in some cases, cost of RR®seed was lower than conventional seed. Based on a net return of US$196 per hectare with 910,000 hectares of RR®soybeans, the 2012 benefits at the national level could be of the order of approximately US$200 million, which is a significant benefit for a small poor country such as Bolivia.

It is estimated that the economic gains from biotech crops for Bolivia for the period 2008 to 2014 was US$636 million and US$107 million for 2014 alone (Brookes and Barfoot, 2016, Forthcoming).

Table 21. 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.

Political Support of Biotechnology

In a Biotechnology Debate, prominent government officials and farmer leaders expressed their support to biotechnology (TelerSurtv, 23 April 2015):

Bolivian Vice-President Alvaro Garcia suggested biotechnology could be profitable to Bolivian farmers, calling the use of GMOs ***"a modern way to increase food production in the country"*** **during the conclusion of an event that gathered 100 farming organizations from across the country.** In his opinion "the modern way" to do it consisted of "improving seeds, irrigation, and introducing biotechnology" (TelerSurtv, 23 April 2015).

President of the Farming Eastern Chamber (CAO) Julio Alberto advocated for a "technical" debate rather than an "ideological" one over the subject. ***"There were more ideological arguments than technical ones… We will achieve a technical work and demonstrate the [benefits of] the use of biotechnology,"*** he asserted.

PHILIPPINES

In 2015, the area planted to biotech maize in the Philippines decreased to 702,000 hectares (63% adoption) from 831,000 hectares in 2014 due to drought conditions in the maize-growing areas of the country. Notably, the area occupied in 2015 by the stacked traits Bt/HT maize is 646,600 hectares or 92% of the total area planted for biotech maize and with only 8% for herbicide tolerance at 55,000 hectares. This reflects the preference of farmers for stacked traits and the superior benefits they offer over a single trait. The number of small resource-poor farmers, growing on average 2 hectares of biotech maize in the Philippines in 2015 was estimated at 350,000. In December 2015, the Supreme Court of the Philippines ruled that Bt brinjal, already successfully grown in Bangladesh, was not approved for the Philippines. Farm level economic gains from biotech maize in the Philippines in the period 2003 to 2014 is estimated at US$560 million and for 2014 alone at US$89 million.

PHILIPPINES

Population: 100.7 million

GDP: US$250 billion

GDP per Capita: US$2,590

Agriculture as % GDP: 12%

Agricultural GDP: US$30 billion

% employed in agriculture: 32%

Arable Land (AL): 5.4 million hectares

Ratio of AL/Population*: 0.2

Major crops:

- Sugarcane
- Coconut
- Rice
- Maize
- Banana
- Cassava
- Pineapple
- Mango

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

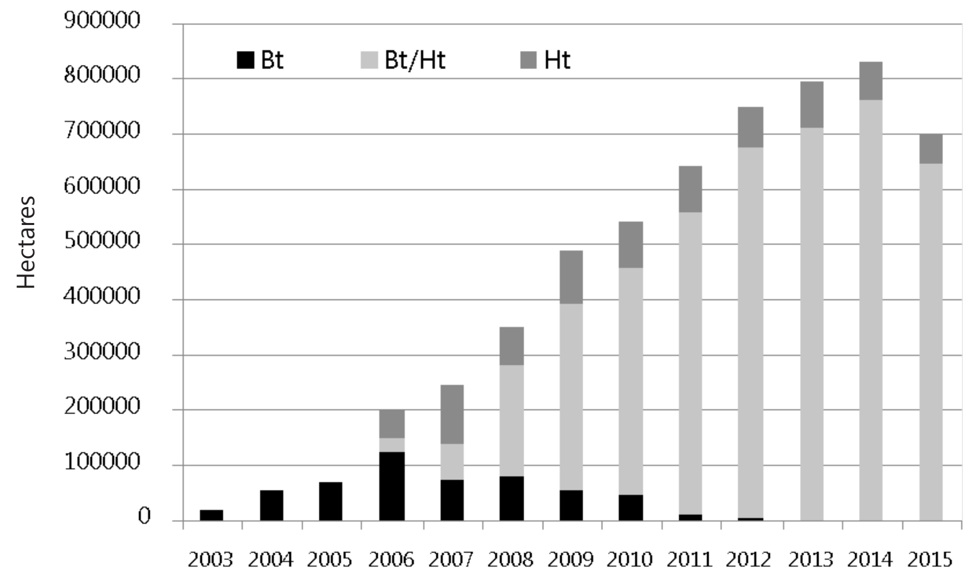
Total area under biotech crops and (%) increase in 2015:
0.702 Million Hectares (-12%)

Increased farm income for 2003-2015: US$560 million

*Ratio: % global arable land / % global population

In 2015, the area planted to biotech maize in the Philippines decreased to 702,000 hectares, (equivalent to ~15% decrease) due to drought conditions in the maize-growing areas of the country. Notably, the area occupied in 2015 by the stacked traits Bt/HT maize is 92% of the total biotech maize planted with 646,660 hectares compared with only 8% for herbicide tolerance at 55,000 hectares. This reflects the preference of farmers for stacked traits and the superior benefits they offer over a single trait. The number of small resource-poor farmers, growing on average two hectares of biotech maize in the Philippines in 2015 was estimated at 350,000. The hectarage planted to the single trait Bt maize decreased to 32% (2008 to 2009), to 76% in 2012, with a total of only 3,000 hectares, and a single trait Bt maize has not been planted since 2013. Single trait herbicide tolerant (HT) maize was planted on 70,000 hectares in 2014, which is only 8.4%, of the total biotech maize planted in the country, and this was further reduced to 8% or 55,000 hectares in 2015. Adoption rate of biotech maize in 2015 is similar to 2014 at 63%. In the period 2003 to 2015 there were 13 years of consecutive growth in hectarage of biotech maize with the exception of 2015 due to drought (Figure 11). This is consistent with the

Figure 11. Increase in Hectarage of Biotech Maize in the Philippines and Proportion of Commercialized Traits, 2003-2015



Source: Compiled by ISAAA, 2015.

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.

Since biotech maize was planted in 2003, yield of maize has increased from 1.85 metric tons per hectare to the current 2.93 metric tons per hectare (Figure 12). Thus, farmers have benefited immensely due to this increased yield. During the 12-year period, biotech maize hectarage peaked in 2014 at close to 830,000 hectares and decreased slightly in 2015 at 702,000 hectares due to drought. At a constant land area of 2.6 million hectares, maize production has provided sufficient local supply that reduced maize imports and set the country's road to maize self sufficiency since 2011 (Figure 13). In 2014, local yellow maize supply was 5.5 million metric tons providing local maize demand for feeds of 5 million metric tons, with only 575,000 metric tons of maize imports for special purpose. Hence, due to particularly clean and healthy crops, maize silage was exported to South Korea from 2013 at 64 metric tons which was increased to 14,000 metric tons in 2014, and 1,056 metric tons in 2015 (National Corn Competitiveness Board, Personal Communications).

The number of small resource-poor farmers, growing on average 2 hectares of biotech maize in the Philippines in 2015, was estimated at 350,000, down from 415,000 in 2014. Maize planting and production in the Philippines was affected by continuous drought in the country since the first half of 2015.

Figure 12. Production and Yield Increase of Maize (White and Yellow) in the Philippines, 2000 to 2015

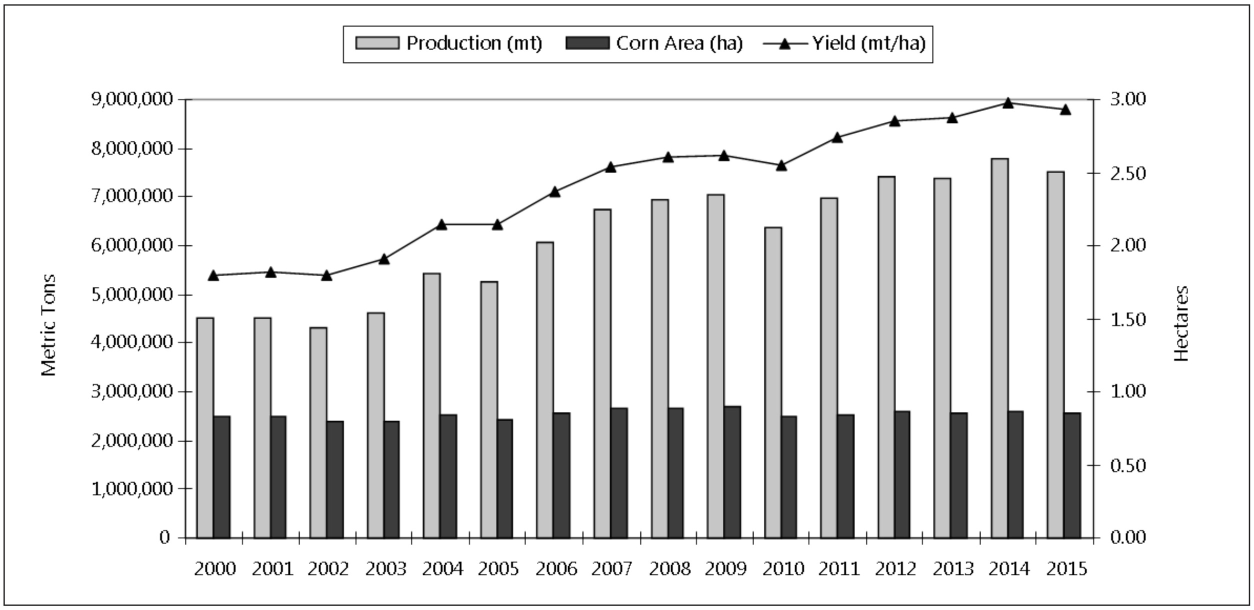
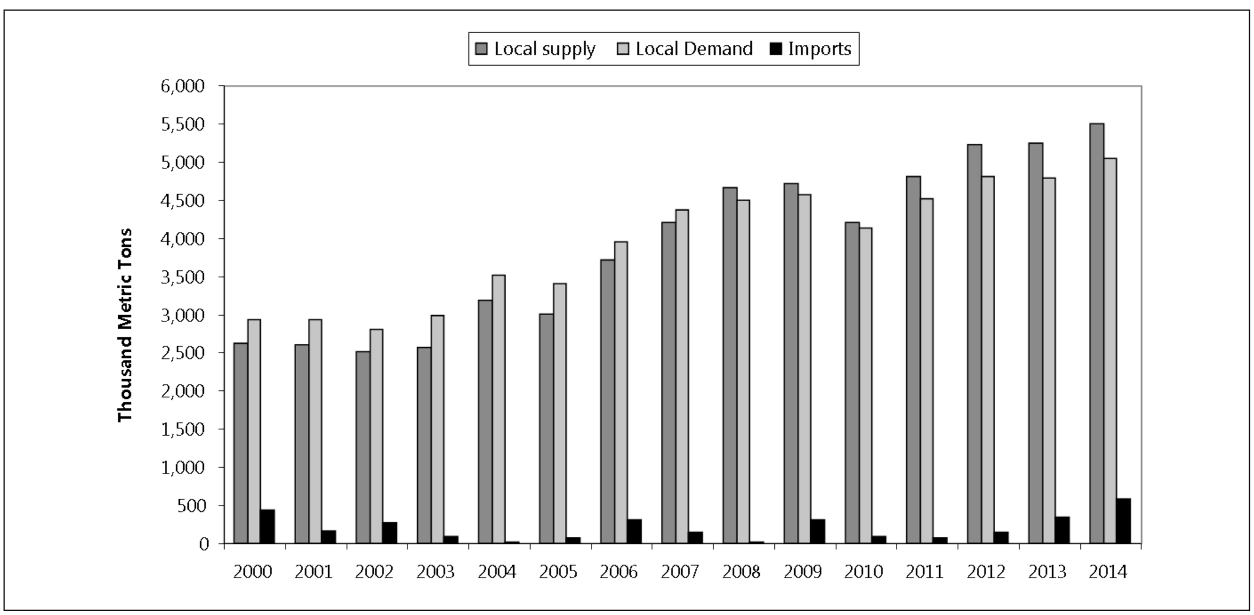


Figure 13. Supply, Demand, and Yellow Maize Imports in the Philippines, 2000 to 2014



Since 2002, there have been 88 biotech crop event approvals for food, feed, processing and cultivation in the Philippines: alfalfa (2 events), rapeseed (2), cotton (8), maize (52), potato (8), rice (1), soybean (14), and sugar beet (1). Biotech maize is the only biotech crop commercialized in the Philippines. Table 22 lists the 13 events approved for cultivation in the Philippines since 2002.

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

Golden Rice (GR) is a biotech rice biofortified with provitamin A beta carotene that is being developed by the Philippine Rice Research Institute (PhilRice) and the International Rice Research Institute (IRRI). Golden Rice can be a potential sustainable complement to alleviate vitamin A deficiency (VAD), complementing other existing VAD interventions. IRRI reports that research, analysis and testing of beta carotene-enriched Golden Rice continues, in partnership with collaborating national research agencies in the Philippines, Indonesia, and Bangladesh. At the end of the multi-locational trials using event R (GR2-R) in March 2014, the target level of beta-carotene in the grain was attained, yield was on an average lower than yields from comparable local varieties preferred by farmers. Research is still ongoing with Golden Rice introgression lines in Asian rice mega-varieties, to ensure that it will have comparable yield and quality as the local high-yielding varieties and be assessed safe for human

Table 22. Approval of Biotech Maize Events in the Philippines, 2002 to 2015

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

IR: Insect resistance, HT: Herbicide Tolerance
Source: Compiled by ISAAA, 2015.

consumption. At IRRI, the Golden Rice trait in GR2-E was bred into mega varieties to get suitable advance lines and the series of confined field trials resumed. In compliance to national regulatory requirements, confined field tests on Event GR2-E are currently being conducted in the Philippines; similar tests will be conducted in Bangladesh and other partner countries. Only after getting approvals from respective regulatory agencies will Golden Rice be released. IRRI and its many research partners remain committed to developing a high-performing Golden Rice variety that benefits farmers and consumers. The important mission of the Golden Rice project – to contribute to improving the health of millions of people suffering from micronutrient deficiency – demands that every step and aspect of the scientific study of Golden Rice produces good results. IRRI and all participating organizations will continue to rigorously follow all biosafety and other regulatory protocols in continuing the research to develop and disseminate Golden Rice.

The anticipated global impact of the Golden Rice project in alleviating malnutrition was acknowledged in March 2015 when it was granted by the United States Patent and Trademark Office (USPTO) the prestigious 2015 Patents for Humanity Award on nutrition (IRRI, 20 April 2015). The award recognized the vision of Golden Rice (GR) co-inventors Ingo Potrykus and Peter Beyer, and the GR Humanitarian Board Secretary Adrian Dubock for their royalty free access patent application for the Project, enabling small holder farmers to benefit from Golden Rice. This royalty free access has enabled IRRI and partner public institutions to continue research and development of Golden Rice on a not-for-profit basis. Thus, by breeding Golden Rice into already popular inbred varieties, resource-poor farmers can afford and reuse the seeds when they become available.

In attempts to raise awareness of the global community towards Golden Rice, Dr. Patrick Moore (co-founder and former president of Greenpeace) established the "Allow Golden Rice Now" campaign in 2013 (Allow Golden Rice website). The group composed of scientists and environmentalists have been staging protests and holding seminars to various stakeholders in major cities around the world. In 2014, the team held these activities twice in Europe including cities of Hamburg, Amsterdam, Brussels, Rome and London. In March 2015, the campaign reached the Philippines, Bangladesh and India – the three countries which have high rates of vitamin A deficiency and where Golden Rice have the most impact.

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

In May 2012, Greenpeace and other anti-biotech environmentalists and politicians lodged a petition to the Supreme Court calling for the imposition of *Writ of Kalikasan* and issuance of a Temporary

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

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

The Department of Agriculture Undersecretary Segfredo Serrano received petition letters in support of the approval and propagation of Bt eggplant, signed by 700 farmers. The petition was handed by the chairman of the Philippine Farmers Advisory Board (FAB) Edwin Y. Paraluman during the Forum on the Global Alliance for Agri-biotech (GAABT) Model on Low-level Presence and GM and Organic Farming Co-existence held on September 30, 2015 at the Iloilo Convention Center. Serrano recognized the farmers and stakeholders' sentiments and said ***"I would also hope that there will come a day when we don't need exhaustive resources to get a petition for government to appreciate and to remind us to push a particular issue that is a legitimate right of our farmers and our stakeholders"*** (Crop Biotech Update, 7 October 2015). However, in December 2015, the Supreme Court of the Philippines ruled that Bt brinjal, already successfully grown in Bangladesh, was not approved for the Philippines.

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 soon to be conducted in a larger area pending release of regulatory approvals and research funds.

Bt cotton is being developed by the Philippine Fiber Development Administration (PFIDA, formerly the Cotton Development Authority). The technology, provided by Nath Biogene Ltd. and the Global Transgene Ltd. from India was tested for the first time in a confined field trial in 2010, started multi location field trials in 2012, and in 2013, data to complete regulatory dossiers are being collected in 2015 for commercialization purposes.

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 supportive of research and development activities on biotech crops and eager to support products that will emerge from the public sector R&D pipeline for commercialization in the near term.

It is important to note that the Philippines is the first country in the ASEAN region to implement a regulatory system for transgenic crops; the system has also served as a model for other countries in the region and other developing countries outside Asia. The Philippine biotechnology regulatory system was formalized with the issuance of Executive Order No. 430 in 1990 establishing the National Committee on Biosafety of the Philippines (NCBP). In 2002, the Department of Agriculture (DA) issued Administrative Order No. 8, which provided the basis for commercial release of biotech crops. Subsequently, in 2006, Executive Order 514 was issued, further strengthening the NCBP and establishing the National Biosafety Framework. In 2008, the country launched 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 2.6 million hectares of maize is joined by Vietnam in 2015 to be the only two Southeast Asian countries who plant biotech maize. The Philippines achieved a biotech mega-country status with biotech maize in 2004, i.e. 50,000 hectares or more. Asia grows 59.4 million (32.3%) of the global 184 million hectares of maize with China itself growing 35 million hectares, plus significant production in India (9.5 million hectares), Indonesia (3.8), Philippines (2.6), Vietnam (1.2), Pakistan (1.2) and Thailand (1.1) (FAO, 2015).

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 2014 is estimated to have reached US$560 million. For 2014 alone, the net national impact of biotech maize on farm income was estimated at US$89 million (Brookes and Barfoot, 2016, 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$560 million, from biotech maize in a short span of 12 years, 2003 to 2014 (Brookes and Barfoot, 2016, Forthcoming), and is advancing the adoption of the maize stacked traits, IR/HT. In 2015, stacked traits in maize represented around 92% of the total biotech maize area in the Philippines. Future prospects look encouraging, with "home grown" biotech products likely to be commercialized in the very near future.

Adoption and Uptake Pathways of Biotechnology Crops in the Philippines

In an ISAAA-commissioned study on "Adoption and Uptake Pathways of GM/Biotech Crops by Small-Scale, Resource-poor Filipino Farmers" (Torres et al. 2013), farmers revealed the factors for their continuous adoption of biotech maize. These include 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 by their co-farmers (30.3%). In addition, while seed suppliers/traders were considered primary information sources, it was their co-farmers who influenced them to adopt 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. 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 primarily due to both material and non-material benefits they derive from it.

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.

Statements of Support on Biotech Crops

Dr. Emil Javier, Academician, National Academy of Science and Technology (NAST)

> "The ban in growing GMOs is not supported by science. The mass of evidence belie the contention that GMO crops are harmful to human health and the environment. Since GM crops were commercialized in 1996, close to two billion hectares of GM maize, soybean, canola, cotton and other crops have been harvested and utilized world-wide. To date, no single instance of human allergy and poisoning caused by GM crops has been reported. This bans deprive our farmers of an effective technology that can raise their productivity, increase their incomes, and enhance competitiveness of our agricultural products vis-a-vis our neighbors. Thus, these proscriptions are misdirected, unlawfully restricts free choice in business, anti-farmer and consequently anti-poor" (Manila Bulletin, 26 September 2015).
>
> "The broad acceptance of GMO technology by our corn farmers who planted 830,000 hectares of GMO corn hybrids in 2014 is eloquent proof of the productivity and income-raising potential of modern biotechnology. Instead of attaining an average national yield of only 1.75 tons per hectare with non-GMO white corn, our yellow corn GMO farmers average 4.17 tons per hectare, a productivity advantage of 138%" (Manila Bulletin, 10 October, 2015).
>
> "Although there are still plenty of sceptics particularly in Europe who refuse to recognize the potential value to mankind of GMO technology in crops to enhance farmers income, raise yields, improve adaptation to drought and other environment stresses as well as to increase their nutritive value, the weight of scientific consensus in favor of GMO technology is abundantly clear from published statements of the world's leading academies of science and responsible development agencies" (Manila Bulletin, 10 October, 2015).

Department of Agriculture Undersecretary Segfredo Serrano, during the Forum on the Global Alliance for Agri-biotech (GAABT) Model on Low-level Presence and GM and Organic Farming Co-existence, Iloilo City (30 September 2015)

> "We, in the Department of Agriculture can pretty much establish this science-based and objective system. We continue to try – lean, and mean, and small as it is; we have fewer people, we lack equipment – but over the past 12 years, we've not had any single anecdote (on the negative effects of biotech crops). We are very proud of the record of our regulatory system and the way our stakeholders have complied.
>
> All endeavors in civilizations and in the economy are fueled by investments – individual investments of farmers, and their decisions are based on things that they perceive. If you look at climate change, obliterating a lot of the risks and converting them into uncertainties, our farmers are faced with an investment problem. And you can only give clarity by converting those uncertainties into calculable risks through science and technology. I would commend our scientists for being able to carry on."

<u>Dr. Desiree Hautea, Project Leader, Bt eggplant, UP Los Baños</u>

> "We developed Bt eggplant because breeders, for the past 40 years – this is both public and private sector breeders of eggplant – have been trying to develop a variety that is commercially acceptable to the farmers to address the issue of this major pest. We all know the health effects of excessive and improper use of chemical insecticides and these have impacts on the health of the people who are handling them as well as those around the farm. Eggplant farming in the Philippines is usually like a garden or backyard type – your house is in the middle of the eggplant farm, so if you spray, then everything goes to the household."

<u>Dr. Gil C. Saguiguit, Jr., SEARCA Director</u>, during the Media Conference on the Global Status of the Commercialized Biotech/GM Crops in 2014, Makati City (27 February 2015)

> "With the continuing opposition to biotechnology by some quarters, it is all the more important that we effectively communicate it in the context of scientific and empirical evidence and of course with the ultimate objective of feeding a world population growing by leaps and bounds under conditions of deteriorating and limited natural resources."

<u>Dr. Ernelea Cao, Professor University of the Philippines, Diliman,</u> during the Public Dialogue on Bt Eggplant, Ilagan, Isabela, 22 July 2015)

> "When we talk about biotech crops mainly from various claims on the internet and social media, there is usually a lot of what we call fallacies or misinformation being spread, especially among consumers. Are we going to be afraid of this technology, are we going to adopt this, are we going to use this? This evidence-based principle applies not only for biotech crops but also for any technology that would be introduced."

<u>Mr. Mario Navasero, University Researcher, University of the Philippines Los Baños,</u> during the Public Dialogue on Bt Eggplant, Ilagan, Isabela, 22 July 2015)

> "For now, we can say that we can have an effective IPM (Integrated Pest Management) program for eggplant fruit and shoot borer if we will have a resistant variety. This is what Bt eggplant can provide. If we have Bt eggplant, then we are sure that this IPM program will work."

Mr. Manuel Espiritu a farmer from Echague, Isabela

"I stand to declare my support for Bt eggplant because I am a long time farmer. We from Echague wholeheartedly declare our support (for Bt eggplant) which we hope is shared by fellow farmers in the whole region. I have no qualms in supporting Bt eggplant because I know that aside from the studies conducted, the product is safe."

Mr. Lorenzo Caranguian, Regional Technical Director for Operations of DA Regional Field Unit-2, Echague, Isabela

"Whatever we have, that's what we should value and develop. That's why if Bt eggplant is the solution, then so be it."

AUSTRALIA

AUSTRALIA

Population: 23.9 million

GDP: US$1,532 billion

GDP per Capita: US$67,440

Agriculture as % GDP: 2%

Agricultural GDP: US$30.64 billion

% employed in agriculture: 5%

Arable Land (AL): 47.6 million hectares

Ratio of AL/Population*: 10.0

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

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

Total area under biotech crops and (%) increase in 2015:
0.658 Million Hectares (+40%)

Farm income gain from biotech, 1996-2014: US$952 million

*Ratio: % global arable land / % global population

Australia grew 658,000 hectares of biotech crops in 2015, compared with 542,000 hectares in 2014 – a significant increase of 116,000 hectares, equivalent to over a 20% increase. The 658,000 hectares comprises 214,000 hectares cotton, a 7% increase from 200,000 hectares in 2014; and 444,000 hectares biotech canola, a 30% increase from 342,000 hectares in 2014. Notably, biotech cotton adoption remains at 100% of all cotton grown in Australia and ~99% of it featured the stacked traits (insect resistance and herbicide tolerance) and the small remainder of 1% herbicide tolerant. The total biotech crop hectarage in 2015 represents a ~14-fold increase over the 48,000 hectares of biotech crops in 2007, during which Australia suffered a very severe multi year drought. The severe drought (attributed to climate change) continues in Australia in 2015 and has affected crops and livestock in the country, including biotech crops. Australia is a world leader in managing resistance and Bollgard III® is already being field-tested in 2015 on ~30,000

hectares in Australia. Estimates indicate that enhanced farm income from biotech crops is at US$952 million for the period 1996 to 2014 and the benefits for 2014 alone at US$68 million.

In 2015, Australia grew 658,000 hectares of biotech crops, up by 21% from 542,000 hectares planted in 2014. The biotech area is comprised of 444,000 hectares herbicide tolerant canola and 214,000 stacked (insect tolerant and herbicide tolerant) trait cotton. The herbicide tolerant canola is 11-fold more than the 41,200 biotech canola hectares in 2009. A remarkable 100% of all cotton grown in Australia in 2015 was biotech and 99% of it featured the stacked genes for insect resistance and herbicide tolerance.

Australia approved 105 biotech events for food/feed use and cultivation since it started commercialization in 2008. There were 3 events approved for alfalfa, 14 events for Argentine canola, 12 for ornamental carnation, 23 for cotton, 22 for maize, 10 for potato, 1 rice event, 1 rose event, 16 soybean events, 2 sugar beet events and 1 wheat event. In 2015, Australia approved maize event MON 87411 (IR/HT stacked) for food and cultivation, and 3 carnation events for import.

Biotech Canola

For the eighth year in 2015, Australia grew herbicide tolerant RR®canola which this year includes two new varieties containing RR® and Triazine tolerant traits (although Triazine is not a biotech product). Herbicide tolerant RT (glyphosate and triazine) is the first dual trait herbicide tolerant product marketed by Pacific Seeds which will provide another alternative for chemical rotation to prevent glyphosate tolerance.

Herbicide canola is grown in three states: New South Wales (NSW), Victoria and Western Australia. According to the Australian Oilseeds Federation (2015), an estimated total of 2 million hectares of canola were grown in Australia (Table 23), a decline of 8% from 2014 (2,175,000 hectares). Despite a decrease in the total canola hectarage, the biotech canola adoption increased in 2015 to 22% (443,069 hectares) compared to 14% (342,000) in 2014 (a 57% increase). Farmers in Western Australia grew 341,097 hectares (30% of total canola) biotech canola, 50,148 hectares (14%) in Victoria, and 50,148 hectares (11%) in NSW. There is a potential 1.6 million hectares in Australia that can be planted to biotech canola for the benefit of the farmers and consumers in the country (Table 23).

GM canola farmers are benefiting from high performing varieties driving higher yields, up to 9.5% higher than non-GM herbicide tolerant varieties, as revealed in the latest National Variety Trials in WA. Prior to the introduction of GM canola, farmers were largely reliant on alternative herbicide tolerant varieties that had a yield 'drag'.

GM canola lowers the environmental footprint of farmers by reducing their carbon emissions and their use of higher risk herbicides as well as improving soil conservation. The largest survey of Australian canola growers found that GM canola offers significant environmental benefits. The research commissioned by the Birchip Cropping Group and Grains Research and Development Corporation revealed that Roundup Ready® canola growers reduced the cultivation of their soil and their use of diesel and high-risk herbicides. Former Prime Minister Abbott announced in July 2015 that one quarter of northern Australia's land area would eventually be opened for agricultural development under a 20-

Table 23. Hectares of Canola, Conventional and RR®* Biotech Planted in Australia, by State, 2014-2015

State	Total Canola (Ha)		Biotech Canola (Ha)		Biotech Canola (%)		Non-Biotech
	2014*	2015**	2014*	2015**	2014	2015	2015
NSW	550,000	490,000	50,000	52,364	9%	11%	437,636
Victoria	400,000	370,000	36,400	50,148	9%	14%	319,852
Western Australia	1,180,000	1,140,000	255,600	341,097	21%	30%	798,903
Total	**2,175,000**	**2,000,000**	**342,000**	**443,069**	**14%**	**22%**	**1,556,319**

* Sourced from industry data, compiled by Australian Oilseeds Federation (2015)
** Area estimate based on seed sold using a 2.3 kg/Ha seeding rate

year program. The area will be opened for farming rice, soybeans, cotton and other crops including sugar which is already being farmed in northern Queensland (USDA-FAS GAIN, Agriculture in Northern Australia, 1 July 2015). This opens opportunities for the country to widen planting of biotech crops including new crops and traits. In addition, various water and drought management initiatives will be put in place to maximize agriculture potential in the area.

Biotech Cotton

A total of 214,000 hectares of cotton was planted in Australia in 2015. Stacked (insect resistant and herbicide tolerant) traits cotton comprise 99% of the total hectarage or 190,000 hectares. Bollgard III®, is still regulated by an approval for 20,000 hectares for trials and seed crops is in progress for 2015/16.

Australia ranks as the world's third largest cotton exporter after the USA and India. The country exports 95% of the raw cotton to China, its leading market. Biotech cotton has been grown for 20 years at close to 100% adoption. The use of biotech cotton varieties with insect resistance and herbicide tolerance reduced pesticide use on the crop by 85% compared to conventional varieties. New varieties of cotton suitable to local conditions are continuously developed with a series of GM cotton trial plantings in NSW. The cotton R&D program is supported by the compulsory levy per bale of cotton growers, matched by the Australian government. Cotton breeding is led by the Commonwealth Scientific and Industrial Organization, including Cotton Australia and the Cotton Research and Development Corporation (USDA-FAS GAIN Cotton and Products Annual for Australia, 4 August 2015).

Cotton production in Australia as in the past is extremely influenced by limitations of rainfall during the planting season of September to November. In early 2015, low rainfall reduced the average storage level of public irrigation dams in cotton growing regions to less than 40% of normal compared to 43% in 2014 and 66% in 2013. Overall current dam levels are 5 percentage points below the 10-year average of 2010. In the Macquarie cotton region, only 7,000-8,000 hectares were planted in early 2015 compared to its capacity of around 50,000 hectares. Cotton regions Riverina, Lachlan and Murrumbidgee regions have planted a higher proportion of cotton due to better water availability (USDA-FAS GAIN Cotton and Products Annual for Australia, 4 August 2015).

Figure 14 shows the long term average area in Australia where the severe drought in 2007 catastrophically reduced the area of cultivated to crops to 60,000 hectares. Ample rainfall and even floods, as well as good prices spiked the crop area cultivated in 2011 to more than 700,000 hectares.

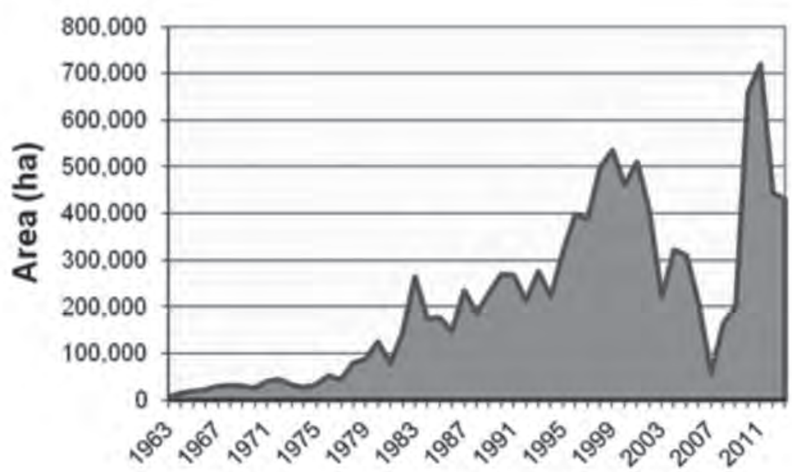
Bollgard III®, the biotech cotton which contains three different insect resistant genes is planned for deployment in large areas for the 2016-17 cotton season. Australian cotton growers will be the first in the world to benefit from Bollgard III® provided the government grants approval for its commercialization. In 2015, Bollgard III® is already being grown in more than a dozen trial sites across all cotton valleys in NSW and Queensland. The three gene Bollgard III® will make it much more difficult for Helicoverpa moths to develop resistance, according to the technology developers (The Land, 24 February 2015).

Other Biotech Crops in the Pipeline

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. Biotech wheat research can be grouped into two main categories based on the target clientele. For growers, wheat is being improved for agronomic performance such as the development of plants with greater ability to survive and thrive in heat/drought conditions and cope with climate change. For consumers, research is on altering grain composition such as developing foods that have the potential to address diabetes, heart disease and other illnesses.

Figure 14. Cultivated Area of Cotton in Australia as Affected by Rainfall Patterns



Source: CSIRO, Personal Communication

Some 14 biotech wheat research project field trial licenses were approved in Australia from 2007 to 2015 which include: improved tolerance to drought and other abiotic stresses, improved ability to utilize nutrients, increased dietary fiber and different grain compositions – including characteristics for improved bread making and increased nutritional value. Currently, biotech wheat is at least seven to ten years away from the marketplace. Prior to commercialization, biotech wheat varieties will have to undergo a thorough assessment from Australia's regulatory authorities including the OGTR and Food Standards Australia New Zealand (FSANZ). It will be comprehensively assessed for human health and environmental safety. Alongside this timeframe, the Australian grains industry will work to address market and trade considerations, just as it does with all new crops (Agrifood Awareness Australia, 2010).

Field trial applications and approvals as well as map of trial sites are available to the public through the OGTR website. Public trust in the Australian system of GMO approval has been high due to its transparency and science-based regulatory system, and can serve as exemplary model for other countries.

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

Biotech Sugarcane

Biotech sugarcane is not yet grown commercially in Australia; however, the OGTR (2015) has issued seven licenses for field trials for sugarcane. Biotech sugarcane is being studied for traits such as herbicide tolerance, altered plant growth, enhanced drought tolerance, enhanced nitrogen use efficiency, altered sucrose accumulation and improved cellulosic ethanol production from sugarcane biomass. Trials are currently being conducted by the University of Queensland and BSES Ltd., a sugarcane research and development institution in Australia.

Biotech Banana

Cavendish and Lady Finger bananas have been genetically modified to resist Fusarium wilt or Panama disease. The field trial is being conducted by the Queensland University of Technology led by Dr. James Dale in Litchfield Municipality, Northern Territory on a maximum area of 1.5 ha from November 2010 to 2014 (OGTR, 2012). Panama disease race 1 wiped out the 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 field trial of these two biotech bananas will hopefully provide a remedy for this devastating Panama disease.

However in March 2015, the field trial near Darwin was put on hold by the government to focus research on eradicating a different, less threatening fungus called "banana freckle". This decision delays significantly the research on Panama disease Tropical Race (TR4), which Panama disease-stricken farmers in Far Northern Australia and Africa are waiting for (The Cairnspost, 21 March 2015).

Commenting on the progress of the TR4 trial, Prof. Dale opined that ***"We're very pleased with the results so far and we're going to do a final assessment at the end of April. We'll probably have at least 12 months out of the ground and then hopefully, if freckle is eradicated, we'll be able to go back and recommence field trials in the Northern Territory."***

In another project, Dr. Dale has also received a grant for a provitamin A-enriched banana project from the Bill and Melinda Gates Foundation. A field test 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 was conducted from May 2011 to May 2013. Philanthropist Bill Gates 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 a four-fold increase. The technology has been transferred to Ugandan research partners at the national Agricultural Research Organization of Uganda where the bananas are also under field trial (Fresh Plaza, 2012).

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

Dr. Dale confirmed that the feeding trial was expcted to be completed by midyear 2015. In an email sent to The Des Moines Register in January 2015, he wrote, ***"Importantly, the nutrition study will go forward, but not until all of us are satisfied that the banana material meets quality standards... As you might imagine, given how you see bananas ripen in your own home, it has been a challenge shipping bananas from Australia to the US and having them arrive in good condition"*** USA Today: The Des Moines Register, 13 January 2015).

Stress Tolerant Legumes

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

Researchers from University of Adelaide and Chinese Academy of Agricultural Sciences have carefully identified and analyzed a salt tolerant gene *GmSALT3* in chromosome 3 from a selection of soybean varieties. The gene will be studied in detail and used in salt-tolerant breeding of soybean (Crop Biotech Update, 14 January 2015).

The above portfolio of collaborative projects involving Australian scientists is impressive by any standard. Equally impressive is the contribution of Australia to philanthropic projects in developing countries. Given its dry climate and arid lands, Australia is in a key position to take the lead with drought tolerance and to mitigate the new challenges associated with climate change which are probably already affecting some regions of Australia in 2015. The public sector investment in crop biotechnology in Australia is one of the most effective worldwide. By sharing the technology with developing countries, Australia is making an important contribution to increased crop productivity and global food security.

Benefits from Biotech Crops in Australia

Australia is estimated to have enhanced farm income from biotech cotton by US$952 million in the period 1996 to 2014 and the benefits for 2014 alone is estimated at US$68 million (Brookes and Barfoot 2016, Forthcoming).

The results of a federal study released in September 2005 by the Australian Bureau of Agricultural and Resource Economics (ABARE), Apted et al. (2005) is consistent with the views of some farmers, and estimates that a ban on biotech canola in Australia over 10 years could have cost Australian farmers US$3 billion.

Stakeholder Support to Biotech Crops in Australia

Federal senators David Leyonhjelm, Bob Day and Dio Wang raised a motion that supports genetically modified crop (GM) crops during the Crawford Fund annual conference. The motion urged the Senate to recognize GM crops for being an environment friendly farming technology; provide higher yields per hectare than conventional crops; require fewer pesticide applications and therefore reduce farming costs and the environmental impact of farming practices. Gerda Verburg, chair of the UN Committee on World Food Security and of the World Economic Forum Council on Food Security and Nutrition, told the conference, ***"Not shying away from addressing contentious issues in a multi stakeholder dialogue, like the role of genetic engineering, how to optimise land use, or how we can combine traditional knowledge with innovation and technology, is the only way to build consensus and truly create food systems where sustainability and profitability are inextricably linked"*** (Farm Weekly, 12 August 2015).

Federal Agriculture Minister Barnaby Joyce has urged South Australia to lift its moratorium on biotech crops. Speaking during a dinner for agri-business leaders in Adelaide, Joyce stressed that it was about time for South Australia to make that decision. If not, Darwin will overtake Adelaide as the major city in central Australia. ***"Unless we get the same vitality in Adelaide, Darwin will overtake them as the main city of central Australia, with a choice between Darwin and Adelaide... the business will go north and the prosperity will be closely in tow with it...We don't want that, we want them both to prosper, but this area has to be the area that says 'yes'"*** (Crop Biotech Update, 22 April, 2015).

In a study by the Commonwealth Scientific and Industrial Research Organization (CSIRO) released by author Craig Cormick showed that there is generally a high level of interest and trust in science in Australia (Crop Biotech Update, 10 September 2014). They also found minimal impact of negative media coverage on science and research organizations. It was also noted in the report that pro-science and technology values are strong predictors of support for even controversial topics such as GM foods. The other key findings of the study include the following points:

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

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

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

Farmer Testimonies

A group of Western Australian grain growers have formed a 'pro GM' group, claiming farmers in the Great Southern Shire of Williams have embraced genetically modified (GM) technology and rely on its future to remain internationally competitive. Grain producer Lewis Johnston doesn't believe that farmers in his area project anti-GM sentiments. He says he is frustrated by the perception that his community is wholly anti-biotechnology. ***"For four or five years, we've had no representation from this area of people that have enjoyed the progress that obviously GM canola has made. At the same time, as respecting other people's viewpoints, we thought it was time to get another voice out here. The uptake of it is not as broad as the acceptance of it. It's the acceptance of it that encourages me. If research can't be done in any sort of biotechnology, the effect it could have is limitless. We'll just fall further behind the rest of the world"*** (ABC Rural, 3 December. 2014).

According to Jason Size, a stonefruit grower from the Riverland of South Australia, *"Fruit and vegetable growers in South Australia have abided by a moratorium, and from an industry perspective there's been 'no comment'…I have been a reasonable advocate of GMO's, and that's my personal belief. I do get harangued quite often from a negative perspective, but I think a lot of people don't truly understand GMO cropping and the potential benefits,"* he said. ***"I certainly support organic growing principles, but have not yet seen production data to say that organic methods will be able to feed the growing population"*** (Freshplaza, 13 August. 2015).

Western Australia grain growers Raylene and Brad Burns and Aimee and Kyle Carson have taken to social media to launch a pro-genetically modified crops (GM) campaign to inform the public on why it is necessary for agriculture. ***"At the moment we are using a GM crop that allows us to fight weed resistance and in the future we hope to have access to GM technology that allows us to further improve the quality of our food and fight the very real possibility of drought,"*** Ms. Carson said. ***"From a farmer's perspective we are excited by the prospects of future possibilities.... Because of this we want to share what we have learnt with as many people as we can and social media is a great way to reach people,"*** she said (Farm Weekly, 11 September 2015).

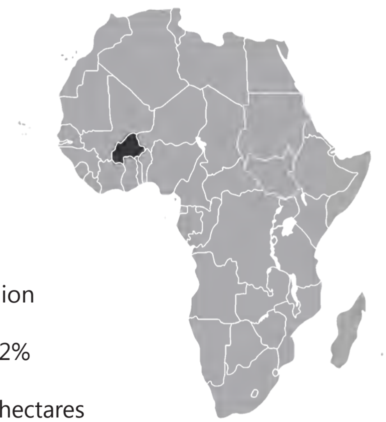
South Australian grain growers will petition the State Government for the right to grow genetically-modified crops to put an extra US$140 million a year in farmers' pockets. Grain Producer SA chief executive Darren Arney told *InDaily* today the state's 2,500 farmers would be asked to sign a petition to be delivered to the Minister for Agriculture, Leon Bignell, to lift a moratorium on GM crops. SA's moratorium on GM crop production is slated to remain in place until at least September 2019 (Indaily, 29 September 2015).

BURKINA FASO

2015 was the eighth year for farmers in Burkina Faso to benefit significantly from Bt cotton. A total of 350,000 ha out of a total cotton planting area of 700,000 hectares or 50% were planted to Bt cotton (BGII®) in the country in 2015. This represents a 23.8% drop in adoption from the 73.8% in 2014. Based on an average cotton holding of 3.16 hectares, the number of farmers growing Bt cotton in 2015 was approximately 110,760. The anxiety created by two coups in a span of one year and subsequent government transitions may have contributed to a downside on the agricultural sector in general. Furthermore, a concern raised among seed producers, ginners and Burkinabe farmers over the staple length of the cotton fiber has caused some uncertainties. Specifically, some ginners have reported a slightly shorter fiber length from Bt cotton compared to some historical conventional cotton varieties. This is not a Bollgard® issue and doesn't impact the technology's high level of performance observed by farmers. These concerns notwithstanding, the Government, cotton companies and the research institute (INERA) continue to support Bt cotton and in collaboration with the technology developer are working together to establish the cause of fiber length variation. Some options are potentially promising and, if confirmed, might be available commercially by 2014. Health benefits have been estimated at US$1 million annually. 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. Economic benefits of farmers is estimated to be at US$178 million from 2008 to 2014 and US$41 million for 2014 alone.

BURKINA FASO



Population: 18.2 million

GDP: US$10.7 billion

GDP per Capita: US$1,480

Agriculture as % GDP: 34%

Agricultural GDP: US$3.6 billion

% employed in agriculture: 92%

Arable Land (AL): 6.0 million hectares

Ratio of AL/Population*: 2.0

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

Commercialized Biotech Crops: Bt Cotton

Total area under biotech crops and (%) increase in 2015:
0.350 Million Hectares (-20%)

Farm income gain from biotech, 2008-2014: US$178 million

*Ratio: % global arable land / % global population

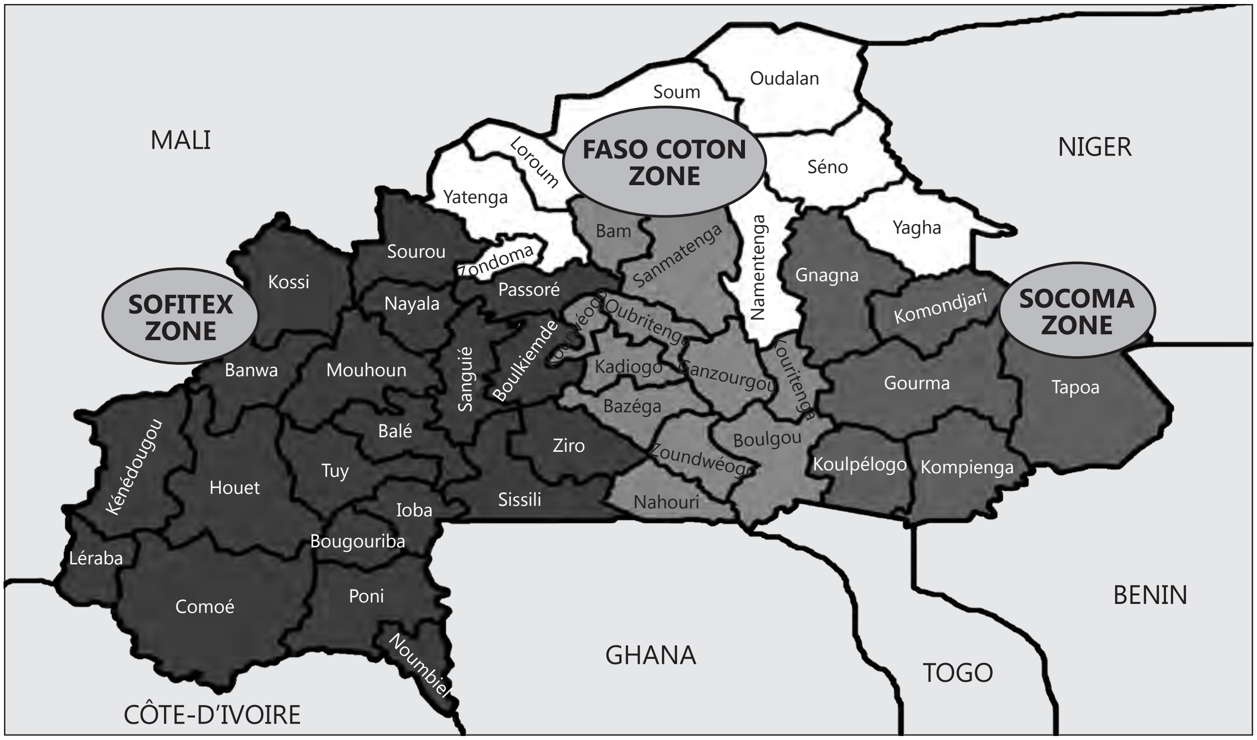
Cotton remains Burkina Faso's principal cash crop generating over US$300 million in annual revenues. This represents over 60% of the country's export earnings and 20% of GDP (ICAC, 2013). The country has maintained a leadership role on biotechnology and biosafety matters in the Western African region. Aside from sustained Bt cotton adoption, the country provides a model of how effective partnerships with diverse stakeholders – public, private sector and the farming community can deliver the benefit of biotechnology sustainably.

The country's cotton sector is organized through a concentrated regional concession system with strong state involvement. Sofitex remains the largest of the three cotton companies in Burkina Faso, accounting for 80% of cotton production. The remaining 20% is channelled via Faso Coton and Socoma companies (Figure 15).

Yields of seed cotton in the field have improved, rising from an average of 700 kg/ha in the early 1990s to around a tonne at present (1,073 kg/ha in 2014/2015, as opposed to 1,007 kg/ha in 2013/2014 and 1,006 kg/ha in 2012/2013). Despite a 20% drop in world cotton prices over the past year, the Interprofessional Cotton Association of Burkina Faso (AICB) raised the farmer price from 225 CFA francs (US$0.3850) per kg last season to 235 CFA francs/kg for 2015/16. The AICB, which is responsible for the price-setting mechanism for seed cotton and the selling price of inputs, also reduced the price of inputs for producers in a bid to boost production. Given that cotton fiber exports are the second largest source of foreign exchange earnings, after gold exports, the Burkinabè government plans to offset the cost of higher farm gate prices elsewhere in the chain, rather than risk a collapse in output (EcoBank 2015). The subsidy has been made possible due to improved management of the sector, under a World Bank-led reform program. The country is aiming to increase the land used to plant cotton to nearly 740,000 hectares in the near future. Burkina Faso's cotton sector is entirely rain-fed.

2015 was the eighth year for farmers in Burkina Faso to benefit significantly from Bt cotton. Out of a

Figure 15. Three Zones of Burkina Faso's Cotton-growing Basin

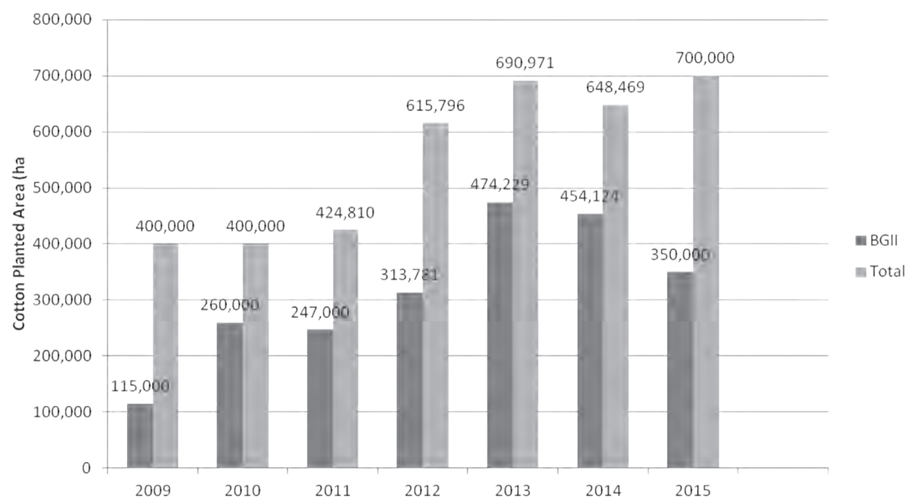


total of 700,000 hectares (FAOSTAT 2015) planted to cotton in the country in 2015, 350,000 hectares or 50% were planted to Bt cotton (BGII®) (Figure 16). Based on average cotton holding of 3.16 hectares, the number of farmers growing Bt cotton in 2015 was approximately 110,760. This represented a 23.8% reduction of Bt cotton planting, which was a voluntary move by the cotton companies together with partners, to address a concern that has been observed with the staple length. This has nothing to do with the performance of Bollgard®, which continues to offer excellent control of the targeted insects, increased yield through reduced workload, allowing farmers to spend more time and energy on food crops, reducing significantly exposure to insecticides, improving wildlife in cotton fields and general welfare. Moreover, a general decline of cotton market prices globally has affected most countries and with the rapid adoption of Bollgard® by Burkinabé growers, the cotton companies were not able to supply their historical fiber markets.

It has been estimated that adoption of Bt cotton generates an economic benefit of more than US$70 million per year for Burkina Faso, based on yield increases of 20.5% (Figure 17), 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 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.

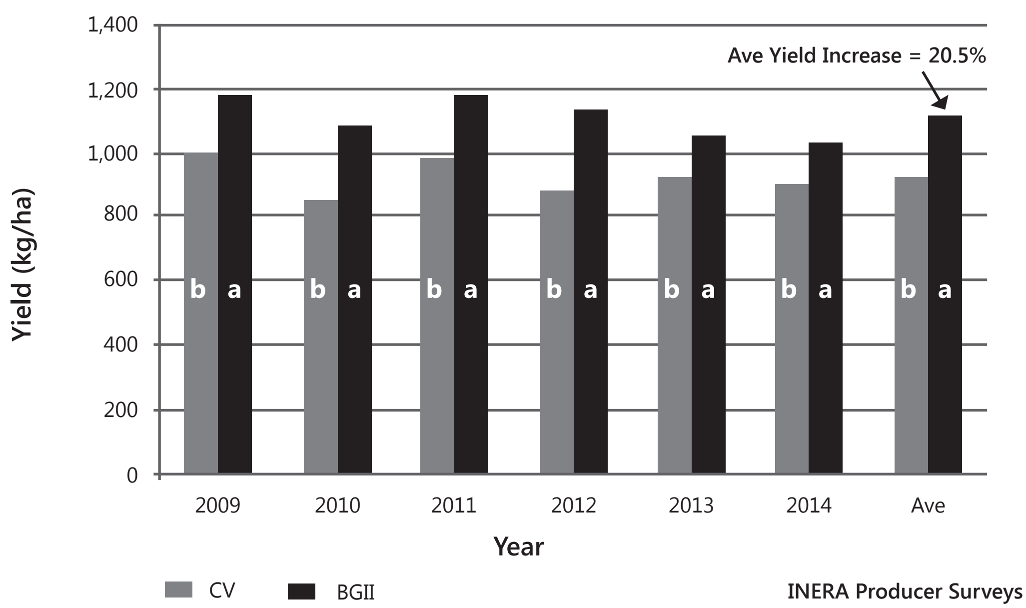
An emerging issue in recent years has been whether farm structure affects how these benefits accruing from Bt cotton in Burkina Faso are distributed. This is in compliance with Burkina Faso's biosafety legal

Figure 16. Bt Cotton Adoption Profile in Burkina Faso



Source: Compiled by ISAAA, 2015; adopted from Vognan et al 2015.

Figure 17. Yield of Bt Cotton as Compared to Conventional Cotton, 2009-2014



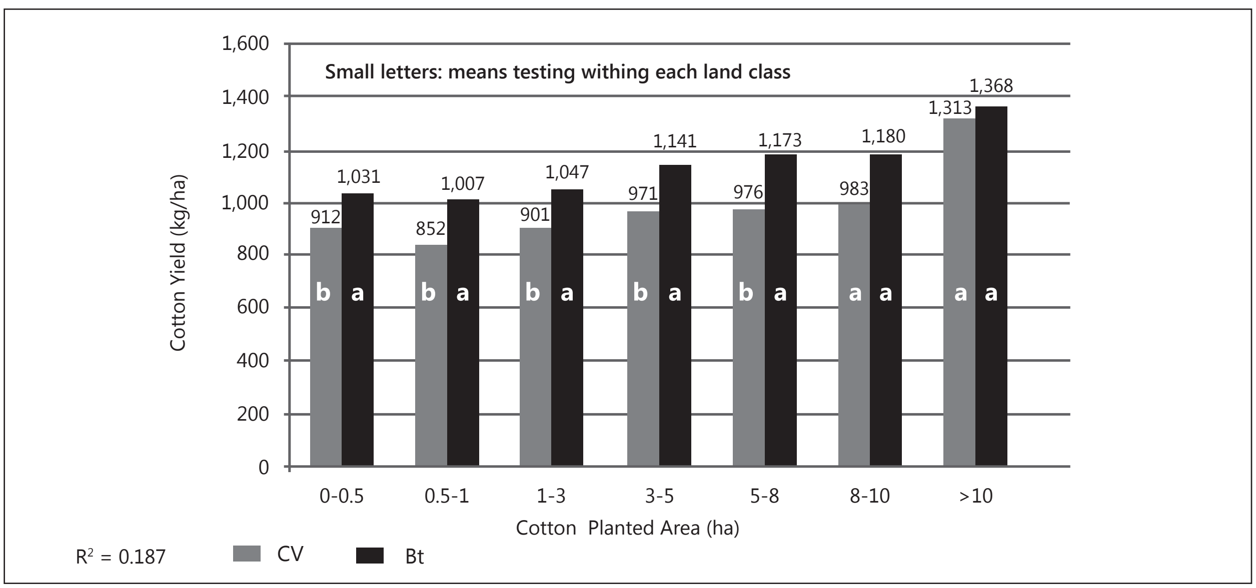
Source: Vitale J. and Vognan G., 2015

framework, which explicitly advocates key consideration to the welfare of the "smallholder farmer" in the biosafety decision-making process. Findings from a collaborative study between INERA researchers and Vitale et al (2015), indicate modest regional difference, but importantly, producers in all zones obtained significantly higher yields in growing Bt cotton compared to conventional cotton. In relation to farm size, "larger" farms were found to have higher yields but again, farms of all sizes, including smallholder farms, obtained significantly higher yields growing Bt cotton compared to conventional cotton (Figure 18). This study re-affirms earlier conclusions that Bt cotton provides significantly higher yields and economic returns for all types of farmers, including smallholder farmers.

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 Burkinabé cotton partners and Monsanto — the technology owner — have intensified efforts and are working together to identify potential solutions to the staple length concern. Some options are potentially promising and, if confirmed, might be available commercially by 2018. INERA multiyear trials are showing that Burkinabé growers can increase their cotton yield and quality by germplasm diversification improving other agronomic practices and finding alternative markets, which are important lessons for aspiring Bt cotton adopting countries.

The scientific work to evaluate performance and selection of approved varieties was conducted by local scientists under authority of Burkina Faso's National BioSecurity 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.

Figure 18. Farm Size: Yields by Planted Area



Source: Vitale J. and Vognan G., 2015

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 is considered as gross income which will be divided into three parts. Two-thirds will remain at the farm gate, thus, most of the gain goes to the farmers with the remaining one-third to be shared between Monsanto and the seed companies that provide the seeds for planting. The company (Monsanto) has been issued a new authorization from the National Biosafety Authority (NBA) to continue commercialization of Bt cotton for another ten years (2013-2023). Meanwhile, the NBA will continue with post-release monitoring and documentation of environmental and socio-economic studies on Bt cotton.

Burkina Faso continues to take the lead within the Economic Community of West African States (ECOWAS) for its development capabilities in biotechnology with Bt cotton in a legal context. The Bt cotton program, initiated and expedited by the Government of Burkina Faso is serving as a model for many other developing countries having similar challenges. As the pioneer in the sub-region, the country continues to provide useful lessons through sharing its experience on Bt cotton with its neighboring countries, so that if they so wish, can expedite the commercialization of Bt cotton, taking into consideration these important lessons to refine their own adoption pathways. The Ghanaian government for example initiated multi-location trials for Bt cotton (Bollgard II®) in 2014 in the Northern part of the country bordering Burkina Faso. The trials in the three northern regions of the country have yielded positive results. There has also been heightened awareness and demand from farmers in neighboring countries such as Benin, Cote de Ivoire, Ghana, Nigeria and Togo for Bt cotton and are urging their governments to facilitate the process. This is an indication that the Burkina Faso experience is inspiring more and more countries into putting governance mechanisms for safe use of modern biotechnology. With the Nigerian President's assent to the Biosafety Law and review advances made by other West African countries to make their biosafety laws functional, it is expected that more farmers in the sub-region will soon benefit from Bt cotton.

Benefits of Biotech Crops in Burkina Faso

Consistent with yield increase, higher economic returns have been reported in all years of commercial production of Bt cotton in Burkina Faso. Economic benefits of Burkinabé farmers was at US$178 million from 2008-2014 and US$41 million for 2014 alone (Brookes and Barfoot, 2016, Forthcoming). 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. Health benefits have been estimated in the range of US$1 million annually (Vitale, 2015). Other benefits include reduced insecticide exposure during chemical storage, preparations of spray solutions and chemical waste handling, reduced environmental impact from reduced insecticide usage, labor savings and the related time spent. Saved time and labor translates to other welfare gains.

Despite facing significant political, institutional and recent varietal/fiber quality challenges, Burkina Faso, sub-Saharan Africa's leading cotton producer, is looking to sustain cotton outputs. Burkinabé cotton growers will continue to benefit from Bollgard® cotton. Bollgard® has been widely planted and harvested again in 2015 at 350,000 hectares — 50% of total cotton planted hectarage in 2015/16 season. Undeterred by erratic weather and political instability in the middle of last season, Burkina Faso's seed cotton production rose to 707,145 MT, up 10% from 650,000 MT in 2013/14, the second successive season of record outturn. Production of cotton fiber also rose to 300,000 MT, representing 31% of Francophone West Africa's total output and cementing the country's position as the region's leading producer. 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.

Farmer Testimonials

<u>Sibiri Antoine Nikiéma, Burkinabé cotton farmer.</u>

"I am very satisfied with Bt cotton due to its many advantages, especially in terms of monetary returns. For example, I made 600,000 FCFA on a 2.75 hectare plot last year. Problems arise when we don't get enough rains. This year, rains were poor but I expect to get more money with the 3 hectares I have planted now."
This is the message from 38 year-old Sibiri Antoine Nikiéma, a cotton farmer from Lado (Saponé) in Burkina Faso. He has been cultivating cotton since 2003 but started planting Bt cotton in 2013. He has three wives and 10 children, 5 of which are in school. Before starting cotton farming, Mr. Nikiéma used to rear cattle but later switched entirely to cotton because he found the latter more advantageous. ***"Bt cotton has improved the quality of our lives and the labor is not as tedious as before since we don't spray that much now. My colleagues and I are relieved from harmful chemicals sprayed to Bollworm"*** he says. Like others in his Lado village, he farms other crops such as sorghum, sesame, maize and millet. His wives and brothers provide help for farm labor. He recommends that Burkina Faso increases Bt cotton production because farmers earn more money with it but wishes price of Bt cotton seeds was lowered. With proceeds from Bt cotton, he has acquired a bicycle, a motorbike and built a family house. He also pays school fees for his children, comfortably, he concludes.

<u>Rasmané Bélem, a Burkinabé cotton farmer.</u>

"I am proud of my Bt cotton plantation which fetches me more than one million CFA Francs every year." This is the message from 57 year-old Rasmané Bélem, from Maneg Konma village in Burkina Faso and chairman of Sougr-noma cotton farmer group. He has three wives and 19 children. He has been cultivating cotton since 2001 and also grows millet, maize, cowpea and groundnuts in his farm.
"I have been growing Bt cotton but recently they sensitized us to also plant conventional cotton to prevent insect resistance. I now have 5 hectares of Bt cotton and 2 hectares of conventional cotton. With 5 children in high school and 10 others in primary school, revenues from Bt cotton come in handy to pay for their school fees "I don't get any assistance to pay for my children's school fees. Revenues from Bt cotton suffice to provide for my family needs. Sincerely, I wouldn't manage to provide for my family needs without Bt cotton," he says. With Bt cotton, Bélem has also acquired a Satelite antenna, built rental houses in neighboring town – Parpaing, and is able to feed his family. ***"My first experience with cotton fetched me 300,000 CFA francs. At the time, I had never handled that kind of money before in my life. I had to carry a bag to withdraw that much cash! Since then, I have always hit that amount or even more. Last year, I made 1.3 million CFA francs. It is only when we get poor rainfall that I find myself below one million CFA francs."***

MYANMAR

In 2015, Myanmar reported a marginal increase in the planting of *Ngwe chi-6* to approximately 325,000 hectares equivalent (up from 318,000 hectares) with an adoption rate of 93% (up from 88% in 2014) on the 350,000 hectares of cotton grown. Approximately 460,000 small holder farmers (average of 0.7 hectare of cotton farm per farmer) planted the long staple Bt cotton variety in the tenth consecutive year of cultivation, 2006 to 2015. It is noteworthy that the ratio of the short versus the superior long staple cotton has dramatically changed with the introduction of the favoured long staple Bt cotton variety *Ngwe chi-6*. Notably Myanmar for the first time in 2015, planted its new home-grown Bt cotton variety *Ngwe chi-9* on 60 hectares. Myanmar's National Seed Committee (NSC) officially registered and approved the commercial cultivation of the second insect resistant cotton variety known as "*Ngwe chi-9*" developed by the Department of Industrial Crops Development (DICD) of the Ministry of Agriculture and Irrigation (MOAI). Bt cotton variety "*Ngwe chi-9*" was developed by crossing the popular Bt cotton variety "*Ngwe chi-6*" with conventional cotton variety *Shwetaung-8*. The new Bt cotton variety "*Ngwe chi-9*" expresses the *cry1Ac* gene –an improved version of Bt cotton variety "*Ngwe chi-6*" or "silver sixth", which was approved for commercial cultivation in Myanmar in 2010.

MYANMAR

Population: 59.3 million

GDP: US$55.8 billion

GDP per Capita: US$1,160

Agriculture as % GDP: 38.8%

Agricultural GDP: US$22.3 billion

% employed in agriculture: 66%

Arable Land (AL): 10.8 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 2015:
0.325 Million Hectares (0)

Increased farm income for 2006-2014: US$185 million

*Ratio: % global arable land / % global population

In 2015, the World Bank announced the launching of US$100 million "Myanmar Agricultural Development Support (MADS)" project in a major initiative to strengthen agriculture production system in the country. The MADS project will be implemented by the Ministry of Agriculture and Irrigation of the Government of Myanmar. The MADS project aims at increasing crop yields and cropping intensity in the selected existing irrigation sites in the regions of Bago East, Nay Pyi Taw, Mandalay, and

Sagaing of Myanmar. Notably, on 25 March 2015, Myanmar launched the first-ever Myanmar National Export Strategy (NES) in collaboration with the International Trade Centre (ITC) designed to fuel the country's sustainable development through export promotion. The National Export Strategy identifies sectors with great export potential including beans, pulses, oilseeds, rice, textiles and garments, rubber, fisheries and forestry products.

Despite the rapid progress in 2015, the overall production of agricultural crops suffered a major setback due to heavy storms, floods and landslides across nearly all of Myanmar in late July and early August 2015. It enundated and destroyed rice fields and severely affected rice production, reducing it by an estimated half a million tons and also moderately affected cotton production in the country. However, it is estimated that the farm income has enhanced due to the large scale adoption of Bt cotton *Ngwe chi-6*, estimated at US$185 million for the period 2006 to 2014 and the benefits for 2014 alone at US$37 million.

Adoption of Bt Cotton in Myanmar

In the last ten years 2006 to 2015, smallholder cotton farmers in Myanmar rapidly adopted Bt cotton variety *Ngwe chi-6* which replaced almost all conventional cotton varieties. The large scale adoption of *Ngwe chi-6*, a long staple cotton variety has significantly increased the total area under long staple cotton in the country (Table 24). In 2015, Myanmar reported a marginal increase in the planting of *Ngwe chi-6* to approximately 325,000 hectares equivalent to an adoption rate of 93% on the 350,000 hectares of cotton grown. Approximately 460,000 small holder farmers (average of 0.7 hectare of cotton farm per farmer) planted the long staple Bt cotton variety in the tenth consecutive year of cultivation, 2006 to 2015. Simultaneously, Myanmar for the first time planted Bt cotton variety *Ngwe chi-9* on 150 acres (60 hectares) in 2015. Bt cotton variety *Ngwe chi-9* was developed and tested

Table 24. Adoption of Bt Cotton in Myanmar, 2006 to 2015

Year	Adoption of Bt Cotton (ha)	Total Cotton (ha)	% Adoption
2006-07	<500	300,000	<1%
2007-08	8,300	368,000	2%
2008-09	140,000	360,000	39%
2009-10	270,000	360,000	75%
2010-11	270,000	360,000	75%
2011-12	283,000	358,000	79%
2012-13	300,000	359,000	84%
2013-14	305,000	360,000	85%
2014-15	318,000	360,000	88%
2015-16	325,000	350,000	93%

Source: James, 2015; Analyzed and compiled by ISAAA, 2015 extensively between 2011 and 2015. *Ngwe chi-9* outperformed the popular Bt cotton *Ngwe chi-6* on all agronomic parameters and reported higher yield than the counterpart Bt cotton variety. It will be produced and distributed by the State-owned Myanmar Industrial Crops Development Enterprise (MICDE).

The composition of short and long staple cotton has dramatically changed with the introduction of long staple Bt cotton variety *Ngwe chi-6*. 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. With the introduction of new Bt cotton variety *Ngwe chi-9*, it is expected that Bt cotton variety *Ngwe chi-9* will gradually replace the existing Bt cotton variety *Ngwe chi-6*, which was grown over 93% of total cotton area on 2015.

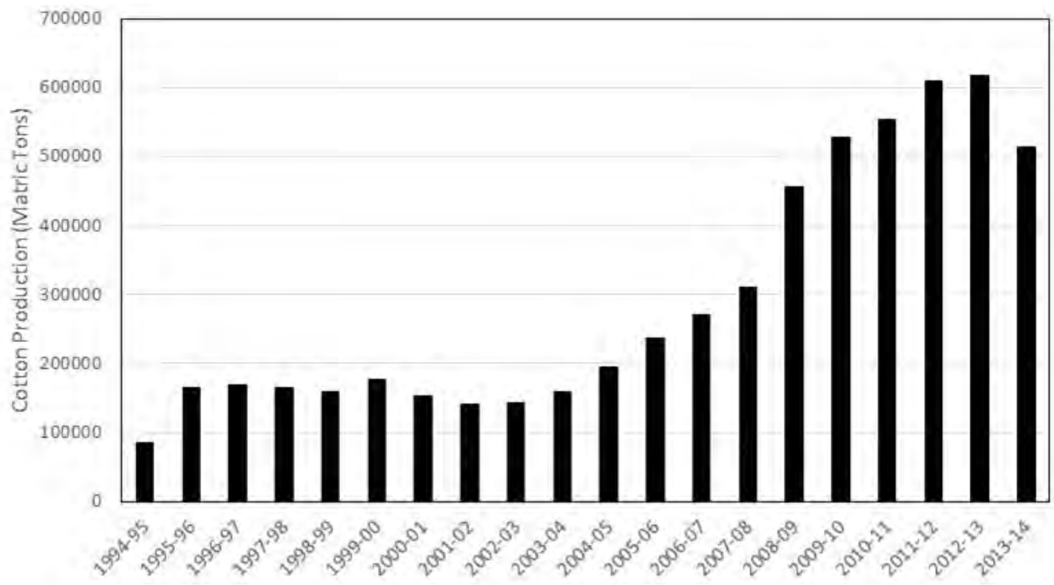
There has been a remarkable increase in cotton yield and production in Myanmar from 2009 to 2015. The cotton yield has increased substantially from 770 kg per hectare in 2006-07 to 1,472 kg per hectare in 2009-10 and 1,719 kg per hectare in 2013-14, 125% increase in cotton yield (MICDE, 2012 and MICDE, 2014). Yield losses from bollworms such as American bollworm and pink bollworms were significant, ranging from 30 to 70 percent (Nu, 2011). Therefore, the commercial release of Bt cotton variety *Ngwe chi-6* has imparted a significant control to insect pests resulting to a significant reduction in yield losses and a major contribution to steep yield increases in the last few years in Myanmar. Similarly, cotton production more than doubled from 271,069 MT in 2006-07 to 535,057 MT in 2013-14 (Figure 19). The country, after a remarkable success with the deployment of insect resistant Bt cotton variety *Ngwe chi-6,* new Bt cotton variety *Ngwe chi-9* released in 2015, and the introduction of cotton hybrids in collaboration with national and international institutions will further improve cotton yield and competitiveness.

Approval of Second Bt Cotton Variety *"Ngwe chi-9"*

New Bt cotton variety *Ngwe chi-9* is a promising variety in Myanmar which boasts for high yield, early maturing, compact and erected plant type suitable for high density planting and good seasonal and regional adaptation. *Ngwe chi-9* is a long staple length variety that favorably meets the demand of quality cotton by growing textiles and garments industry in Myanmar. It offers good fiber quality, high ginning percent and outturn. Bt cotton variety *Ngwe chi-9* is resistant to major insect pests bollworm and moreover, is tolerant to sucking pests resulting in reduced insecticide and spraying cost for farmers (Nu, 2015).

In 2015, Myanmar's National Seed Committee (NSC) officially registered and approved the commercial cultivation of the second insect resistant cotton variety *Ngwe chi-9* developed by the Department of Industrial Crops Development (DICD) of the Ministry of Agriculture and Irrigation (MOAI). Bt cotton variety *Ngwe chi-9* was developed by crossing the popular Bt cotton variety *Ngwe chi-6* with conventional cotton variety *Shwetaung-8*. New Bt cotton variety *Ngwe chi-9* express *cry1Ac* gene –an

Figure 19. Cotton Production in Myanmar, 1994 to 2014



Source: Analyzed and compiled by ISAAA, 2015.

improved version of Bt cotton variety *Ngwe chi-6* or "silver sixth", which was approved for commercial cultivation in Myanmar in 2010.

Myanmar Agricultural Development Support Project (MADS Project)

Agriculture is an important sector for Myanmar, which contributes more than 36% to GDP, employs around 53% of the work force and is a major source of export earnings in the country. Agriculture remains the main source of livelihood for people in rural areas. Agriculture has two distinct agro-eco-climates – the temperate North and tropical South. Approximately 4.5 million farm families cultivate various crops on an estimated arable land of 12 million hectares, with an average 2.35 hectare per farm family. It is estimated that around 3 million farms (two-thirds of all farms) cultivate less than an average 2 hectares. Major crops, commodities and exportable products include rice, beans and pulses, oilseeds, cotton textiles and garments, rubber, fisheries and forestry products. Agriculture sector is viewed as a center piece to achieve the twin goals of ending extreme poverty and promoting shared prosperity in the country.

Given the significance of agriculture in Myanmar, the World Bank launched the US$100 million "Myanmar Agricultural Development Support Project (MADS)" in 2015. The Agricultural Development Support Project will be implemented by the Ministry of Agriculture and Irrigation of the Government of Myanmar. The MADS project aims at increasing crop yields and cropping intensity in the selected existing irrigation sites in the regions of Bago East, Nay Pyi Taw, Mandalay, and Sagaing of Myanmar. The project will target 120,000 farm households dependent on irrigation systems in these regions.

The MADS project will strengthen many existing irrigation schemes which are in disrepair limiting farmers from having access to irrigation water and promote the access to modern technology and farming services (World Bank, 2015a).

The Agricultural Development Support Project has four components including Irrigation and Drainage Management earmarked with US$78.4 million; Farm Advisory and Technical Services with allocation of US$17.2 million; Project Coordination and Management with US$4.4 million and Contingent Emergency Response with the allocation of US$10 million. Under the Irrigation and Drainage Management component, the MADS project will initiate the improvement and rehabilitation of irrigation and drainage infrastructure covering about 35,000 hectares within up to 8 selected schemes in the project regions. It will pilot 2-3 small land improvement sites in these schemes. The Farm Advisory and Technical Services component seeks to enhance MOAI technology development and farm advisory services at target townships to improve farmer crop choices and increase farm productivity. Importantly, this component will support quality seed production, soil nutrition management, integrated pest management, agricultural extension services, and farm mechanization. Finally, the Contingent Emergency Response component will allow a rapid reallocation of credit proceeds to provide emergency recovery and reconstruction support following an eligible crisis or emergency situation similar to the 2015 flood catastrophe (World Bank, 2015a).

The World Bank noted that MADS project will help in increasing productivity and create jobs by making farming system more resilient to drought and climate change in some of the country's poorest areas. While launching the project in 2015, the World Bank Country Director for Myanmar Mr. Ulrich Zachau stated that ***"improving irrigation will increase farm productivity, allow planting during the dry season, and increase incomes of farming families."*** The Union Minister of the Ministry of Agriculture and Irrigation H.E. U Myint Hlaing, referred the project as a significant milestone in improving agriculture in Myanmar. ***"The Agricultural Development Support Project will assist Myanmar's Government to increase the productivity and profitability of farming, while helping farmers improve water and land management and employ climate-smart farming practices,"*** alluded the Minister U Myint Hlaing (World Bank, 2015b).

Myanmar National Export Strategy

Myanmar launched the first-ever Myanmar National Export Strategy (NES) in collaboration with the International Trade Centre (ITC) designed to fuel the country's sustainable development through export promotion. The National Export Strategy was launched by Myanmar's Vice President U Nyan Tun, Minister of Commerce U Win Myint and Executive Director of the International Trade Centre (ITC) Arancha Gonzalez on 25th March 2015 at Nay Pyi Taw. The strategy will be implemented by the Ministry of Commerce in collaboration with other public and private sector partners.

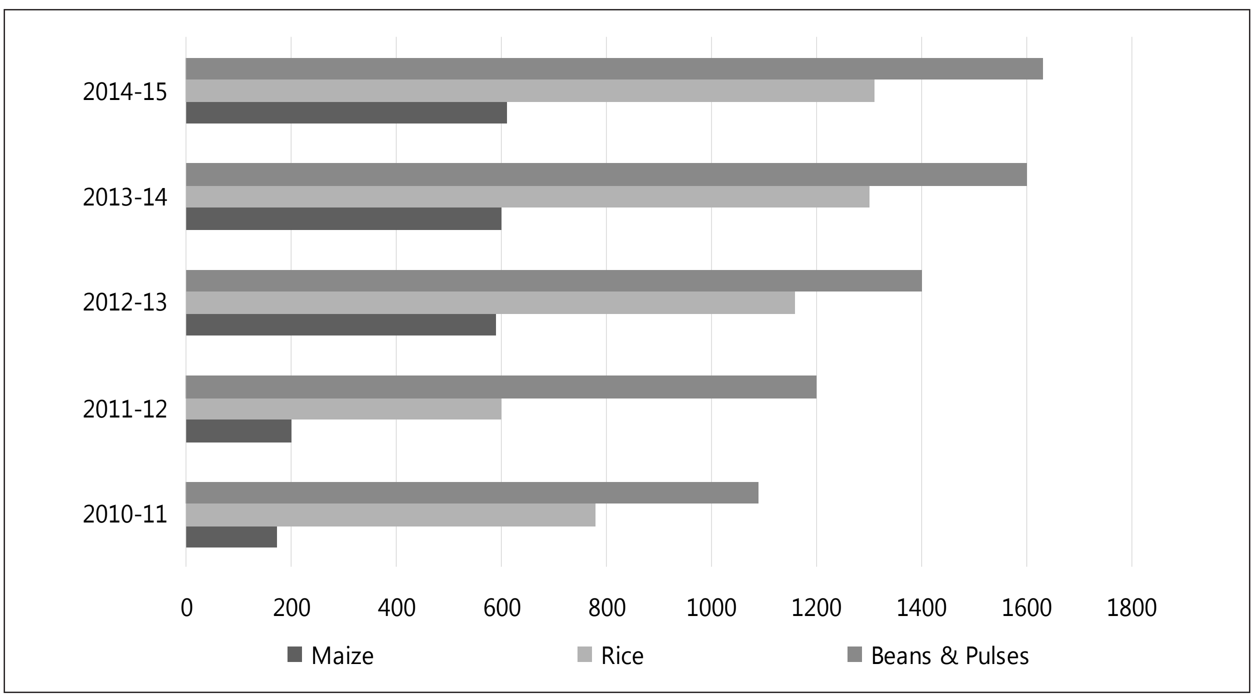
The National Export Strategy identifies sectors with great export potential including beans, pulses, oilseeds, rice, textiles and garments, rubber, fisheries and forestry products (ITC, 2015). It is important to note that Myanmar annually exports approximately US$9 billion worth of agricultural products which accounts for more than 16% of total national export earnings. The Vice President of Myanmar U Nyan Tun lauded the launching of the National Export Strategy in collaboration with the International Trade Centre (ITC). **"The priority sectors identified in the strategy have been selected as the most**

effective export sectors to deliver socioeconomic development to the people of Myanmar. The effective implementation of NES will lead to poverty alleviation, rural development and broad based income growth," said the Vice President.

The National Export Strategy outlines a five-year roadmap to meet the country's priorities and ambitions by facilitating trade as a drive of growth and sustainable development (ITC, 2015). Figure 20 shows the trend in export of key agriculture commodities in Myanmar from 2010 to 2015. Notably, rice occupies the largest cultivated areas of approximately 7 million hectares followed by beans and pulses at 4.3 million hectares, maize occupies 450,000 hectares and cotton occupies about 350,000 hectares of cultivated area (MCSE, 2001; UNEP GEF, 2006; GAIN, 2014).

Emphasizing the focus on the textiles and garments industry of Myanmar National Export Strategy, the Myanmar Garment Manufacturers Association (MGMF) released a new report "Myanmar's Garment Sector: Opportunities and Challenges in 2015". The MGMF highlighted the significant jump in retailers sourcing 'Made in Myanmar' textiles and garments in the recent past. It estimated that Myanmar registered a substantial increase in the export of garments likely to cross US$1.5 billion by the end of 2015. Myanmar garments sector increased export by 25% year-on-year in 2015. Notably, the MGMA have registered more than one new garment factory opening each week throughout 2014, a consistent indicator of high growth in the industry (MGMA, 2015). The textiles and garments sector accounts for 90% of the total foreign investment that has created 100,000 job opportunities in 2014-15. It is expected that the National Export Strategy will propel the growth of textiles and garment industry that enjoys the uninterrupted supply of cotton in the country (IANS, 2015 and YFNX, 2015).

Figure 20. Trend in Export of Key Agriculture Commodities in Myanmar, 2010 to 2015 ('000 tons)



Source: Analyzed and Compiled by ISAAA, 2015

Enabling Legislative Environment

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

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

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

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, there is emphasis to enhance collaboration with private seed companies to increase the availability of quality seeds by involving private companies such as CP Seeds Company for hybrid corn, Known You Seeds Company for melon and cucumber, Malar Myaing and other small seed companies for vegetable seeds: Myat Min Seeds for rice and Bayer CropScience for hybrid rice and others. More recently, Dupont Pioneer has opened an office in Myanmar to use new technologies to modify seeds and set up a marketing network to provide high value and high yielding hybrid seeds of maize and rice to farmers in Myanmar (Myanmar Times, 2015).

The biggest challenge faced by private sector is the absence of intellectual property protection and regulatory system of genetically enhanced crops. As of 2013, Myanmar was 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 25 shows the enactment of different legislative system to regulate

Table 25. Legislative System to Regulate & Promote Agriculture Inputs by the MOAI in Myanmar, 2015

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

Source: Shein, 2013; Shein & Myint, 2013; Aung and Thet, 2009; Compiled by ISAAA, 2015.

and promote agriculture inputs including seeds, pesticides and fertilizer in Myanmar. To facilitate the introduction of improved seeds and biotechnology, Myanmar has to enact both the Biosafety law and the Plant Varieties law in the country. Notably, Myanmar has the potential to become the hybrid seed production center in the near future not only to cater to Asian Economic Community (AEC) but also to neighboring countries of the South Asian Association for Regional Cooperation (SAARC).

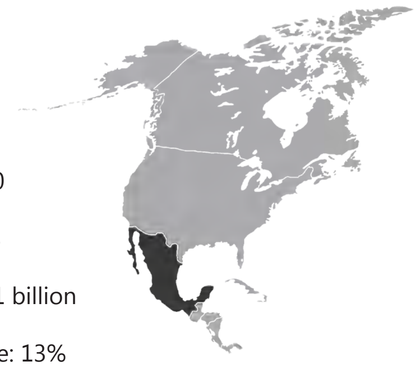
Benefits of Bt Cotton in Myanmar

Despite the rapid progress in 2015, the overall production of agriculture crops suffered a major setback due to heavy storms, floods and landslides across nearly all of Myanmar in late July and early August 2015 (FAO, 2015). It enundated and destroyed rice fields and severely affected rice production estimated to have reduced by half a million tons and also moderately affected cotton production in the country. However, it is estimated that the farm income has enhanced due to the large scale adoption of Bt cotton *Ngwe chi-6*, provisionally estimated at US$185 million for the period 2006 to 2014 and the benefits for 2014 alone at US$37 million (Brookes and Barfoot, 2016, Forthcoming).

MEXICO

In 2015, Mexico planted 141,000 hectares of biotech crops, down from 170,000 hectares in 2014. The 141,000 hectares comprised 123,000 hectares of biotech cotton (with an adoption rate of 96%) and 18,000 hectares of biotech soybean (10% adoption rate) compared to 10,000 hectares in 2014 based on a 10% adoption rate. Of the 123,000 hectares of cotton, 118,000 hectares are stacked and 5,000 hectares are HT. The decrease in total hectares of cotton in Mexico, consistent with some other cotton-growing countries around the world, is due to the historically low prices for cotton, which leads famers to reduce total cotton plantings. Soybean adoption in Mexico in 2015 at 18,000 hectares is almost double the modest 2014 hectarage of 10,000 hectares with an adoption rate of 10% for both years. The principal issue in relation to biotech crops in Mexico is the proposed cultivation of biotech maize in the country, which is part of the center of origin and diversity (CO&D) of maize. The 2013 legal ban on planting biotech maize in Mexico was overturned in 2015 by a court decision which in turn was appealed. Mexico is increasingly dependent on large and costly imports of maize from the US and there is merit in exploring options that would reduce increasing dependency on imported maize. The hope of proponents of biotech maize in Mexico is that the federal government will adopt a national, science-based public policy that will allow the CO&D of maize, in the south, center and north of the country to be protected, with commercial production of biotech maize restricted to certain regions of the northern states of the country. This strategy would ensure that Mexico and its people would benefit from biotech maize which can contribute to national food/feed security and also mitigate the new challenges, such as more frequent and severe droughts, associated with climate change. Mexico cultivates about 8 million hectares of maize and is heavily dependent on ~10 million tons of mainly GM maize imports annually valued at about US$2.75 billion. Mexico is estimated to have enhanced farm income from biotech cotton and soybean by US$384 million in the period 1996 to 2014 and the benefits for 2014 alone is US$91 million.

MEXICO



Population: 127.0 million

GDP: US$1,178.1 billion

GDP per Capita: US$9,750

Agriculture as % GDP: 4%

Agricultural GDP: US$47.1 billion

% employed in agriculture: 13%

Arable Land (AL): 25.8 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 2015:
0.141 Million Hectares (-50%)

Farm income gain from biotech, 1996-2014: US$384 million

*Ratio: % global arable land / % global population

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 2015, Mexico planted 141,000 hectares of biotech crops, down from 170,000 hectares in 2014, and comprised 123,000 hectares of biotech cotton (compared to 160,000 hectares in 2014) and 18,000 hectares of biotech soybean (compared to 10,000 hectares in 2014).

Since 1996, Mexico approved 158 biotech events for food/feed use and cultivation. There were 5 alfalfa events, 13 for Argentine canola, 30 for cotton events, 68 for maize, 13 potato, 1 rice, 22 soybean, 1 sugar beet, and 5 tomato events.

Biotech Cotton

Mexico planted insect resistant cotton commercially in 1996 and herbicide cotton in 2005. In 2015, Mexico planted 123,000 hectares of biotech cotton, at an adoption rate of 96% of a total 128,000 total cotton hectarage, a decrease of 61% biotech cotton planting from 2014's 160,000 hectares. It is comprised of 5,000 hectares herbicide tolerant and 118,000 hectares stacked IR/HT cotton. Table 26 shows that 92% of the total biotech cotton was planted to the stacked gene HT/IR compared to 90.5% in 2014; 3.8% as HT and the balance of 4.1% as conventional. The decrease in total hectares of cotton in Mexico, consistent with many other cotton-growing countries around the world, is due to the historically low prices for cotton which leads farmers to reduce cotton plantings. In addition, there was an increase in planting of alternative crops such as sorghum and corn as an offshoot of less attractive prices for cotton compared to livestock feed crops (USDA-FAS GAIN Oilseeds and Products Annual for Mexico, 1 April, 2015).

Mexico has planned to be self sufficient in cotton, following productive discussions between the private, social and public sectors to develop a "best practices regulatory system" that would facilitate predictable access to biotech cotton for farmers in Mexico. In this plan, approval was sought and 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 has not materialized. Mexico is positioned on a clear path to achieve in the midterm, cotton self-sufficiency and has the ability to become a key global exporter of this important crop. This success story is a good example of the benefits that can result from building alliances between Government authorities, farmer representatives and the private sector to support the ambitious expectations of Mexico to move forward to solidify its agricultural goals.

Table 26. Adoption of Biotech Cotton in Mexico, 2014 and 2015

Trait	2014	2015	Adoption Rate
Bt/HT	154,000	118,080	92%
HT	6,000	4,920	4%
Conventional	10,000	5,320	4%
TOTAL	**170,000**	**128,320**	**100%**

Source: Compiled by Clive James, 2015.

Average cotton yields for MY 2015/16 are estimated at almost 7 bales/ha. The highest yielding area is expected to be in the region of Ojinaga, Chihuahua with 7.7 bales/ha, while the lowest yielding areas are located in Tamaulipas and Sinaloa with 4.5 bales/ha. Adoption of biotech cotton in these areas is recorded at a high of 96%, but due to weather and water, yield levels vary. With the use of biotech cotton since 1996, the Confederation of Mexican Cotton Association (CMCA) reported that pesticide application has dropped by over 50% since the use of biotech seeds while at the same time, yields have increased dramatically. The binational program for the Eradication of Pink Bollworm and Boll Weevil include the use of biotech seeds. GE seed use covers about 96% of the planted area for cotton in the country. As a result, according to the National Service for Health, Food Safety and Food Quality (SENASICA), 85% of the cotton producing area of the country is free of the pink bollworm and 70% is absent of boll weevil (USDA-FAS GAIN Agricultural Biotechnology Annual Mexico, 15 July 2015).

It is noteworthy that in January 2015, Chihuahua state was recognized by the Secretariat of Agriculture, Livestock, Rural Development and Fishery (SAGARPA) through the National Health Service, Food Safety and Quality Service (SENASICA) the status of "free zone of pink bollworm in cotton". USDA was also recognized for their help in the conduct of the "Binational Program for the Eradication of Pink Bollworm and Boll Weevil." The status was made possible through the use of integrated pest management, genetic engineered seeds, and applying the sterile insect and pheromone mating disruption techniques. Hence, Chihuahua farmers saved 30% on production costs from 1996, with number of insecticide spraying reduced from 18 to one, yields increased from 3.7 to 7.7 bales of cotton per hectare, according to SENASICA officials (USDA-FAS GAIN Oilseeds and Products Annual, 1 April 2015).

Biotech Soybean

Mexico planted herbicide tolerant soybean on a trial basis in 1997. The first commercial permit was granted for herbicide tolerant soybean planting on 6 June 2012. In 2013, there were 12,000 hectares biotech soybean planted, 11,961 hectares for 2014 and 18,000 hectares in 2015. Soybean is produced in the country for food and feed use. Soybean meal production is forecast to increase 3.7% to 3.48 MMT for market year 2015/2016, due to the expected strong demand from the livestock and poultry sectors. Leading crushers and vegetable oil refiners in the country have expanded their facility capacities and will continue till 2015.

Biotech Maize and Lifting of Field Trial Ban

Mexico cultivates about 8 million hectares of maize and is heavily dependent on more than 11 million tons of maize imports (Table 27) valued at more than US$3 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. With 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

Table 27. Total Imports of GM Crops by Mexico (Thousand Metric Tons), 2011 to 2015

Crops	2011/2012	2012/2013	2013/2014	2014/2015
Corn	10,881	7,700	7,800	11,200
Cotton	992	1,100	1,036	1,100
Soybean	3,606	3,300	3,450	3,740
Rapeseed	1,520	1,450	1,480	1,490

Source: USDA FAS GAIN: Agriculture Biotechnology Annual, 2015.

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 tolerant maize. These field trials demonstrated that biotech maize is as safe as conventional maize, and effective; this is consistent with international experience in commercializing biotech maize by 20 countries around the world for 20 years. The field 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.

A legal ban on planting biotech maize in Mexico was introduced in 2013, since then, no biotech maize has been planted. However, the 2013 ban was overturned in August 2015 by a court decision which in turn was appealed. Mexico is increasingly dependent on large and costly imports of maize from the US and there is merit in exploring options that would reduce increasing dependency on imported maize. The hope of proponents of biotech maize in Mexico is that the federal government will adopt a national, science-based public policy that will allow the centers of origin and diversity of maize, in the south, center and north of the country to be protected, with commercial production of biotech maize restricted to certain regions of the northern states of the country. This strategy would ensure that Mexico and its people would benefit from biotech maize which can contribute to national food/feed security and also mitigate the new challenges, like more frequent and severe droughts, associated with climate change.

Researcher Center and Advanced Studies (CINVESTAV), Mexico City developed a biotech maize drought tolerant "CIEA-9" through antisense RNA technology. The team headed by Dr. Beatriz Xoconostle modified the plant's metabolism by inhibiting an enzyme that destroys trehalose, a sugar involved in stress response; hence, the biotech plant requires only two-thirds of the water needed by a normal plant. The transgenic lines have already passed drought and cold trial in the greenhouse and by August 23, 2012, the Government of Mexico granted a 4 ha experimental trial in Sinaloa, Mexico. In addition, the team of Dr. Xoconostle is developing biotech lemon tree resistant to citrus greening disease more commonly known as Huanglongbing (HLB). Three experimental release permits were granted in 2014 to test different events in Tecoman, Colima (USDA- FAS GAIN Agricultural Biotechnology Annual Mexico, 15 July 2015).

Biotech Crops in the Pipeline

The National Institute of Forestry, Agriculture and Livestock Research (INIFAP) has developed biotech beans (*Phaseolus vulgaris*) with resistance to fungus *Colletorichum lindemuthianum*, *Fusarium lateritium* and *Rhizoctonia solani*. Biotech bean events FMA-pdf1.2-INIFAP were tested in Celaya, Guanajuato after a permit for experimental release was granted in 2014. The non-profit International Maize and Wheat Improvement Center (CYMMYT) have tested experimental releases of GE wheat over the last seven years with various traits including drought tolerance. Various institutes in Mexico including the National Laboratory of Genomics for Biodiversity (LANGEBIO) at the Research Center and Advanced Studies (CINVESTAV) and a private company are developing biotech crops that will absorb and optimize the use of phosphorus. Less fertilizer and phosphorus applied to soil is a disadvantage to weeds, hence less herbicide use (USDA_FAS GAIN Agricultural Biotechnology Annual Mexico, 15 July 2015).

Benefits from Biotech Crops in Mexico

Mexico is estimated to have enhanced farm income from biotech cotton and soybean by US$384 million in the period 1996 to 2014 and the benefits for 2014 alone is estimated at US$91 million (Brookes and Barfoot, 2016, Forthcoming).

SPAIN

Spain is the lead biotech crop country of five in Europe, and grew 107,749 hectares of Bt maize in 2015; this compares with 131,538 in 2014, which is a decrease of 23,789 hectares equivalent to 18%. The decrease of 18% is firstly, due to less total maize plantings of approximately 382,000 hectares in 2015, compared with 416,690 hectares in 2014; secondly it is due to the lower adoption rate of 28% in 2015 versus 31% in 2014. In general, the major factor responsible for the decline in Bt maize hectares in Spain is the general EU hostile reaction to GM crops, resulting in major disincentives to farmers seeking to grow Bt maize. Despite the counterproductive efforts of the EU, Spain has steadfastly successfully grown Bt maize for eighteen years, and grew 92% of all the Bt maize in the EU in 2015, the same as last year. Spain elected not to ban the growing of biotech crops in Spain. Enhanced farm income from biotech Bt maize is estimated at US$232 million for the period 1998 to 2014 and for 2014 alone at US$26 million.

SPAIN

Population: 46.1 million

GDP: US$1,323 billion

GDP per Capita: US$28,290

Agriculture as % GDP: 2.0%

Agricultural GDP: US$26.46 billion

% employed in agriculture: 4%

Arable Land (AL): 12.7 million hectares

Ratio of AL/Population*: 1.3

Major crops:

- Grape
- Maize
- Wheat
- Sugar beet
- Potato

Commercialized Biotech Crops: Bt maize

Total area under biotech crops and (%) increase in 2015:
0.108 Million Hectares (0)

Farm income gain from biotech, 1998-2014: US$232 million

*Ratio: % global arable land / % global population

Spain is the only country and the largest grower of biotech maize in the European Union to grow a substantial area of biotech crop insect resistant maize MON 810. In 2015, Spain grew 92% of the 116,870 hectares of biotech maize in the EU in 2015. Note that the 2015 estimates by the Government of Spain include, Bt maize hybrids approved in other EU countries. Spain has successfully grown Bt maize for eighteen 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 2015, the Bt maize area in Spain reached 107,749 hectares compared with 131,538 hectares in 2014, a decrease of 18%. The decrease of 18% is firstly due to less total maize plantings of approximately 382,000 hectares in 2015, compared with 416,690 hectares in 2014 and secondly, the lower adoption rate of 28% in 2015 versus 31% in 2014. In general, the major factor responsible for the decline in Bt maize hectares in Spain is the general EU hostile reaction to GM crops, resulting in major disincentives to farmers seeking to grow Bt maize. Despite the counterproductive efforts of the EU, Spain has steadfastly successfully grown Bt maize for eighteen years, and grew 92% of all the Bt maize in the EU in 2015, the same as last year. It is noteworthy that in the recent EU vote, Spain elected not to ban the growing of biotech crops in Spain.

Currently, more than 200 hybrids from about ten seed companies, all with the dominant event MON810 have been approved for commercial planting. Total area planted to maize varies annually due to water availability, irrigation costs, prices paid to farmers and competition from alternative crops. Up until 2002, only the variety COMPA CB was grown with Bt-176 for insect resistance, and this variety was grown until the 2005 season. MON810 varieties for insect resistance were approved in 2003. There are about 200 registered hybrids of which 30 to 40 were estimated to have been planted in 2013. In November 2004, herbicide tolerant NK603 maize was approved for import, but the approval for planting in the European Union is still pending. When approved, biotech maize hybrids with NK603 are likely to be deployed throughout Spain.

Spain 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.

In 2015, the area planted to maize declined for the third consecutive year and consequently the biotech maize planting. Low market prices, high irrigation costs and to a lesser extent, crop diversification established by greening measures contributed to the decline in planting. The passing of the country's greening measures with crop diversification entails that farms between 10 and 30 ha must grow at least two different crops, and farms with over 30 ha must grow at least three different crops on their arable land. Hence, farmers are switching to alternative irrigated crops, namely high quality wheat, sugar beet, tomatoes for processing, cotton or rice depending on the region.

Spain is a net importer of grains and oilseeds because domestic production is not sufficient to meet the demand of the country's export-oriented livestock sector. Biotech crops and products imported to Spain consists mainly of soybean and soybean products from Brazil, the USA, and Argentina. Grain imports to Spain range from 9 to 12 million MT, and soybean and soybean meal imports combined amount to nearly 6 million MT. It is thus imperative that with the country's dependency on imported feedstuffs, and the science-based approach to biotech crops, acceptance of the technology resulted to an expansion of crop cultivation and imports over the years.

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. Although maize is the only biotech crop planted as yet in the country, the demand for soybean and soybean products may open possibilities for its planting. Field trial for biotech soybean is therefore desirable as well as new traits of maize for cultivation such as herbicide tolerance.

Biotech acceptance in the country has been well documented. In 2013, the Food and Resource Economics Department from the University of Florida found that respondents in Spain showed optimistic attitudes towards the benefits of agricultural biotechnology. The respondents valued the reduction of pesticide use that the technology allowed (Kim and House, 2013).

A survey of 200 farmers in Catalunia and Aragon in October and November 2011 showed that around 95% of farmers would plant biotech corn again in 2012. The survey by the Foundation for Antama Markin entitled *Seeds of Bt Maize in Spain* indicated that the preference of farmers were for biotech maize seeds with stacked traits of insect resistance and herbicide tolerance for planting in 2012, rather than the single Bt trait which is the only trait approved for the EU (Crop Biotech Update, 20 January 2012).

A study on "How market demand for non-GM maize affect profitability of Bt and conventional maize in the Ebro Valley" concluded that the use of Bt maize in Spain increases farmer's partial gross margin by 95 Euros per hectare on average (Riesgo et al. 2012). A study funded by the Antama Foundations entitled *The 15 years of Bt maize cultivation in Spain: Economic, social and environmental* *benefits* highlighted the reduction in total maize imports by more than 853,000 metric tons (Riesgo, 2013). Franciso J. Areal of the University of Reading (UK), in his study on *Genetically Modified Soy: an irreplaceable raw material in the EU. Assessment of Alternatives and Economic impact on the Spanish Feed and livestock farming sector* highlighted the importance of soybean for feed production in the country. Biotech soybean and product imports to Spain from 2000-2014 provided 55,000 Euros in savings compared to importing the alternative conventional soybean and products at the same period. Hence, the replacement of biotech soybean and products during the same period by conventional soybean would command a price increase of 291% for soybeans and 301% for soybean meal (Areal, 2015).

Benefits from Biotech Crops in Spain

Spain is estimated to have enhanced farm income from biotech Bt maize by US$232 million in the period 1998 to 2014 and the benefits for 2014 alone is estimated at US$26 million (Brookes and Barfoot, 2016, Forthcoming).

Farmers' Views on Biotech Crops

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

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

COLOMBIA

In 2015, Colombia grew 16,000 hectares of biotech cotton and 73,000 hectares of biotech maize (91% adoption) for a total of 89,000 hectares, compared with 99,000 hectares in 2014; a 10% decrease probably due to low crop prices driving farmers to decrease total plantings of both maize and cotton. Around 94% of biotech maize is the stacked trait and 6% HT. Colombia is estimated to have enhanced farm income from biotech crops of US$124 million in the period 2002 to 2014 and the benefits for 2014 alone is estimated at US$22 million.

In 2015, Colombia grew 16,000 hectares of biotech cotton and 73,000 hectares of biotech maize for a total of 89,000 hectares, compared with 99,000 hectares in 2014; a 10% decrease was due to low crop prices driving farmers to decrease total plantings of both maize and cotton. Around 94% of biotech maize is the stacked trait and 6% HT.

COLOMBIA

Population: 48.2 million

GDP: US$370 billion

GDP per Capita: US$7,750

Agriculture as % GDP: 7%

Agricultural GDP: US$25.9 billion

% employed in agriculture: 17%

Arable Land (AL): 2.2 million hectares

Ratio of AL/Population*: 0.1

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

Commercialized Biotech Crops:
- Bt Maize
- Bt Cotton

Total area under biotech crops and (%) increase in 2015:
0.089 Million Hectares (-10%)

Farm income gain from biotech, 2002-2014: US$124 million

*Ratio: % global arable land / % global population

Since biotech crops were first commercialized in 2006, Colombia has approved biotech maize and cotton for food/feed use and commercialization. Since 2009, Colombia has approved 73 events for food/feed use and cultivation; these comprised 9 cotton events, 1 flax, 39 maize, 2 rice, 10 soybean, 1 wheat, 2 rose, and 8 carnation events.

Biotech Maize

In Colombia, biotech maize was previously grown under a pre-commercial project in 2007 under the "controlled planting program" in two regions: on the Coast and Llanos region and in the interior of the country. In 2009, Colombia planted the first biotech herbicide tolerant maize in the form of stacked traited seed with the insect resistant trait. Colombia grew 73,000 hectares of biotech maize in 2015.

Colombia is a net importer of maize (white and yellow) with 95% for animal feed supply and 5% for human consumption. Local maize production goes to animal feed (10%) and for food processing (90%)

which can only satisfy 30% of the total domestic consumption. The poultry industry use up 67% of the animal feed available in Colombia, 23% goes to the livestock and swine and the remaining 10% for aquaculture and household pets. With the increasing sustained economic growth and the increase in the household income of the populace, feed demand will continue to grow primarily in the poultry sector, the preferred meat in the country. This will require planting or imports of more biotech maize in the future.

Biotech Cotton

Biotech insect resistant cotton was commercialized in Colombia in 2002 and the biotech herbicide tolerant cotton in 2006. By 2015, adoption of biotech is virtually complete and composed of 94% stacked product, and 6% HT. The main impact of the biotech insect resistant cotton is significant improvement in yield and decrease in number of insecticide sprays with important environmental and health implications.

Biotech Potato in the Pipeline

A potato resistant to the Guatemalan moth is being developed at the Medellin's Corporation for Biological Research (CIB). The biotech moth resistant potato is expected to be available to producers within three years. This technology could bring benefits in terms of protection against pests, herbicide resistance, saving in production costs and increased productivity. Other research institutes working on crop improvement through biotechnology include the International Center for Tropical Agriculture (CIAT) on cassava, rice and sugarcane; Cenicaña for sugarcane improvement; and the National University on maize, potato and rice improvement (Freshplaza, 5 March 2015).

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 crops by US$124 million in the period 2002 to 2014 and the benefits for 2014 alone is estimated at US$22 million (Brookes and Barfoot, 2016, Forthcoming).

Farmer Testimonies

Sergio Valencia of Llanos Orientales (Eastern Plains), Colombia has farmed corn, soybeans, coffee, citrus, tomatoes, passion fruit, banana, and African palm, for 20 years. He heard about the benefits of planting biotech maize in 2009 and has since then planted a 60 hectare field of biotech maize. Valencia believes that although the biotech maize seeds are slightly more expensive than conventional seeds, the extra expense translates into overall savings because planting biotech maize reduces the application of inputs. He explains that, ***"In conventional maize crops, he would spend about 500 thousand pesos (approximately US$250) per hectare during a farming season. However, by planting biotech seeds, he has been able to reduce that amount to just 70 thousand pesos (approximately, US$35) per hectare. The use of biotech seeds has enabled him to save 86 percent in costs per hectare."*** He added that, ***"which means I get to enjoy more free time! I can focus in other activities in my farm or… just rest!"***

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

SUDAN

2015, was the fourth year of commercial planting of Bt cotton in Sudan. A total of 120,000 hectares of Bt cotton were planted in both rainfed and irrigated areas, up from 90,000 hectares and a 33% increase from 2014. Close to 45,000 farmers planted Bt cotton compared with the initial 10,000 beneficiaries who have an average of about 1 to 2.5 hectares of land. In just four years, the country has recorded a 95% adoption rate. A key development in 2015 was the approval of three additional GM varieties (Hybrid JKCH1974; Hybrid JKCH1050 and O.P SCRC37) for commercial planting by the National Biosafety Council (NBC) and the National Variety Release Committee. This will expand the choice for farmers and complement the first and only Bt cotton variety "Seeni 1"

SUDAN

Population: 40.2 million

GDP: US$58.8 billion

GDP per Capita: US$2,160

Agriculture as % GDP: 33%

Agricultural GDP: US$19.4 billion

% employed in agriculture: 48%

Arable Land (AL): 21.05 million hectares

Ratio of AL/Population*: 3.0

Major crops:
- Cotton
- Wheat
- Sugarcane
- Cassava
- Sorghum
- Millet

Commercialized Biotech Crop: Bt Cotton

Total area under biotech crops and (%) increase in 2015:
0.120 Million Hectares (+33%)

*Ratio: % global arable land / % global population

released for commercial production in 2012. The new varieties yield about 2-3 times higher than local non-Bt varieties Abdin and Hamid. The yields are also significantly higher than "Seeni 1" without the need for chemical control across 7-8 irrigated areas and 6 rainfed environments and consistently over two seasons 2012/13 and 2013/14. Beside reduction in cost of production (due to reduced insecticide application) and maximization of farmer returns, the approved varieties also demonstrated environmental safety benefits. In the first year of commercialization, Bt cotton saved 37% of the direct cost of cotton production: the cost of producing non-Bt cotton was much higher at US$372 for one feddan (0.42 hectares) compared with US$246 for Bt cotton. The net profit for a farmer planting Bt cotton was US$170 per feddan (equivalent to US$410 per hectare). The Ministry of Agriculture has embarked on an extensive tracking of the socio-economic impacts as more farmers engage in planting Bt cotton.

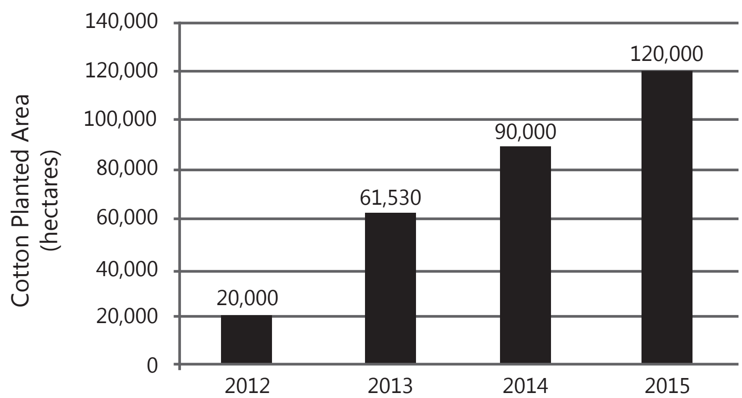
The Republic of Sudan is situated in north eastern Africa with international boundaries on the seven countries of Egypt, Eritrea, Ethiopia, South Sudan, the Central African Republic, Chad, and Libya. Once the largest country in Africa, in July 2011, South Sudan was granted independence and Sudan became the third largest country in Africa after Algeria and the Democratic Republic of Congo with a land mass of 1,882,000 square kilometers and a population of 33 million, at a population growth rate of 2.5%. The Blue and the White Niles run from South to North, and to the east, Sudan borders the Red Sea. The irrigated areas around the Nile are fertile and today, cotton is cultivated on about 150,000 hectares largely in the famous Gezira region. Almost half (46%) of the population in Sudan are poor and the goal is to reduce this to 23% by the MDG goal year of 2015. Agriculture employs about 80% of the population and contributes a third of the GDP. Cotton and gum Arabic are the major agricultural exports while sorghum is the main staple food crop. Other important staple crops are wheat and millet. Cash crops for domestic consumption and export includes peanuts and sesame.

Sudan has a long history of cultivating extra-long staple cottons, but the variety spectrum has broadened to include long, medium and short staple varieties. Over the past decade, the share of cotton in Sudan's foreign export earnings has declined relative to other crops like sesame as well as meat and animal products, even so, cotton still plays a major role in the economy. Cotton is an important source of income for a large number (>200,000) of growers and their families. Cotton crop residues are also an important source of animal feed for a large number of livestock. The cotton industry also employs a considerable amount of hired seasonal labor during picking and ginning operations.

2015 was the fourth year of commercial planting of Bt cotton in Sudan. A total of 120,000 hectares up from 61,530 hectares in 2014 were planted in both rainfed and irrigated areas by close to 45,000 farmers, up from 30,000 in 2014 (Figure 21). The total hectarage of Bt cotton of 120,000 was distributed in six of the major irrigated areas: Gezira, Rahad, New Halfa, Suki, Sennar and White Nile; and in the rainfed areas of Blue Nile State, North Kurdufan and, Arab Company Sudan and Egyptian Company under large scale mechanized production system. The adoption rate was 95% with very small quantities of conventional cotton grown.

The evaluation process which started in 2009 using Chinese Bt cotton varieties, demonstrated efficient control of the major pest, cotton bollworm. The first 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.

Figure 21. Bt Cotton Adoption Profile in Sudan, 2012 to 2015



Source: Compiled by ISAAA, 2015.

Notably in 2015, the National Biosafety Council (NBC) and the National Variety Release Committee (NVRC) approved three additional GM cotton varieties for commercial planting in Sudan. These include another variety of Chinese origin carrying the same gene as "Seeni1", the first one to be approved in 2012, and two hybrids carrying a similar Bt gene source from India. The three Bt cotton varieties had already been approved by the national authorities in the countries of origin (China and India) and cultivated for more than 10 years, respectively. According to Prof. Abdelbagi M. Ali, cotton breeder & biotechnologist, and the Principal Investigator of the Biosafety/agronomic evaluation work in Sudan, biosafety evaluation under Sudanes environment revealed no concerns with the 3 new varieties. Moreover, studies conducted on non-target organisms and beneficial insects during the multi-location and large scale field trials of JK- Bt cotton event in Sudan re-affirmed that Bt cotton hybrids do not have any toxic effects on non-target species such as sap-sucking pests (aphids, jassids, white fly and mites). The population of secondary lepidopteran pests (Spodopteralitura) remained negligible during the study period in both Bt and non-Bt hybrids. Movements of beneficial insect populations (Chrysopa, Coccinellids, Syrphids and Spider) were equal and remained active over both Bt and non Bt cotton plots. The extensive evaluations for biosafety and agronomic evaluation of the genotypes (SCRC37, Hindi1 and Hindi2) carrying the Bt genes at various levels and review stages were conducted by more than 40 experts from the research institutes and Universities in Sudan.

By approving the three additional varieties, farmers will have more choices and enhance stewardship measures aimed at resistance management. The genes were expressed adequately and have sufficiently protected the crop from damage caused by the African and Egyptian bollworms. This has led to a significantly higher cotton yield of about 2-3 times more than the local non-Bt varieties Abdin and Hamid. The yields are also significantly higher than Bt variety "Seeni 1" without the need for chemicals to control bollworm across 7-8 irrigated and 6 rainfed environments, consistently over two seasons 2012/13 and 2013/14. Besides reduction in crop protection cost and maximization of farmers return, the evaluated Bt varieties were also proven safe to the environment.

Cotton is one of the most important crops produced in Sudan. More than 300,000 families in Sudan depend on cotton for their livelihood. Several other thousands are engaged in cotton-related activities. Cotton farming is mainly conducted by male farmers and involves planting, irrigation and picking. Women's contribution is mainly in hand weeding, fertilizer application and hand picking. However except for cotton picking, the other practices are now almost mechanized.

The introduction and sustained expansion of Bt cotton planting in Sudan is expected to boost cotton productivity and restore cotton as a main cash crop and a major contributor to the country's economy. Experiences from four years of planting reinforce the importance of good farm management, timely availability of seeds and inputs, as well as sustained communication with stakeholders to address misinformation. Expanding the area under Bt cotton will thus require an agronomic package supported by an efficient extension service and coordinated awareness and outreach strategies. This was confirmed by members of the Sudanese Biosafety Authority after a recent (August 2015) study tour to India Bt cotton hybrid fields. Experiences and lessons learnt include the need to intensify farmer extension services, adherence to correct agronomic practices and enforcement of a farmer-friendly refugia strategy for insect resistance management. Indian seed producers have evaluated different seed-mixing regimes and are convinced that 5% of non-Bt seeds would adequately provide the refugia needed. An application has been submitted to the Indian Biosafety Committee and Sudanese regulators are keen to test the same once approved.

Most of Sudan's cotton is exported as lint. Major importers of Sudan's cotton are Egypt in Africa; Germany and Italy in Europe; and Thailand and Bangladesh in Asia. However, in absolute terms, domestic lint consumption consistently declined from an average of 86,000 bales during the 1980s to only 16,000 bales in 2001 due to problems of the local textile industry. Earnest efforts are now being made to revive both cotton production and the domestic textile industry. The Bt cotton program is one such effort that responds to a real need and is poised to position Sudan back on the global map as a major player in the world cotton trade.

The major outcomes from the four seasons of planting Bt cotton in Sudan were: Bt cotton adoption should continue due to its endogenous control of bollworms. 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.

Benefits of Biotech Cotton in Sudan

The rapid adoption of Bt cotton in Sudan was triggered by the realization of farmer benefits and an assurance of safety of Bt cotton to the environment, human beings and animal health. There has been no single report related to safety incident during the last three years of production of "Seeni1" in the country. To ensure sustainable production of Bt cotton, testing and evaluation of other cropping options will continue. Bt cotton saved 37% of the direct cost of cotton production while the cost of producing non Bt cotton was much higher at US$372 for one feddan compared with US$246 for Bt cotton. The net profit for a farmer planting Bt cotton was US$170 per feddan (equivalent to US$410 per hectare). Welfare benefits to farmers accrue as a result of increased yield and drastic reduction in production cost, due to elimination of chemical sprays for bollworm control. To sustain these gains, a strict monitoring process, sustainable seed production and distribution system will need to be strengthened to ensure durability of insect resistance.

Farmer Voices

"When you plant Bt cotton, you are assured of high quality and quantity. There is no guarantee with the old varieties." That is the message to other farmers from 45 year-old Elameen Alseddeg Alzain from Eltekana village. A father of five (5) children, Elameen is a small scale farmer with 2 feddan (less than one hectare) of Bt cotton farm. In his village, there are about 220 farmers growing cotton. What attracted him to Bt cotton was a visit to a demonstration field by the research cooperation. ***"I saw an opportunity to improve my lifestyle. The yields were very high and with no bollworm damage, I realized I could make big savings,"*** he proudly says. He expects to harvest at least 1860kg/fadden (770kg/ha), which is three times what he was getting with the old varieties.

"Plant Bt cotton because it changes your life to the best – you get high quality and quantity," This is the message from Mrs. Alazza Eshag Seiam Ibrahim, another Sudanese Bt cotton farmer from Eltekana (Alshoply) village. She is 70 years old and married with eight children. She decided to plant Bt cotton after seeing demonstration field by the agriculture extension from his village. Labor was a big problem with the old varieties. ***"The advantages I have seen with this new cotton (Bt cotton) are many – high yields, low production cost; resistant to bollworms and healthier bolls. I expect to harvest 2945kg/fadden (1,227kg/ha). I have never come close to this kind of yield in my many years of growing cotton. This season is very good and I will never go back to the old varieties."***

"Thank you for bringing us better seeds, which will solve our financial problems. Bring more of these seeds for other crops." This is the message from 40 year-old Neema Hassan Abdalla who started growing Bt cotton immediately after seeing its performance from the pioneer farmers who took the risk of starting the planting first. That was in 2014. What attracted her most was the high yield and less spraying, hence sufficient income. She expects to harvest 3875kg/fadden (1614kg/ha) this season because the crop is very good. ***"Bt cotton has improved my life style,"*** she says.

"I realized an income of 28,000 Sudanese pounds from the sale of Bt cotton as opposed to the 10,000 I would get on the same piece of land growing conventional cotton. The yield has more than doubled from 1,300 Kg/ ha to 2,700 Kg/ha after switching to Bt cotton. I used the proceeds from Bt cotton to pay for my children's education and build a better house for my family." Mr. Abdurahim Rahim from Shiekh proudly narrates, in his 3rd year of growing Bt cotton. Abdurahim grows the crop on the scheme's allocation of 5 feddans per farmer. He now sprays only 2 times on Bt cotton for mealy bugs and Jassids as opposed to the 6-8 times he would spray on conventional cotton for bollworms. He uses the time saved in spraying to maximize on the crop's other agronomic requirements and tending to his livestock. He plants sorghum, groundnuts and wheat as rotation crops for cotton and as food for his family.

For Mr. Ibrahim Ahmed, 2015 was his 3rd year of planting Bt cotton. He has planted the crop on 9 feddans(~4 hectares) of Bt cotton and says this has made a complete transformation in his life. ***"I realized 4 times the yield I used to get with conventional cotton, 4 quintal/ feddan (952Kg/ Ha) to 15-18 quintal/feddan (3571-4285kg/ha). I have bought a car, 25 cows and sheep from the***

additional income I am now earning from growing Bt cotton.” In addition to growing Bt cotton, Ibrahim grows groundnuts and sorghum to feed his family. He sells the extra produce but says the proceeds are too little compared to what he gets from Bt cotton. The farmer says he now sprays only 2 times for mealy bugs, aphids and jassids on Bt cotton compared to 8 or more times that he would spray for the insects and African bollworm on conventional cotton. He uses the time saved from spraying to optimize on agronomic management of Bt cotton such as irrigation and weeding, as well as tending to his livestock ***“I thank the government for bringing us this technology and all those working to make our farming conditions better,”*** he concludes.

HONDURAS

Honduras grew 27,000 hectares of biotech maize in 2015 compared with 29,000 hectares in 2014; a marginal decrease. The biotech maize in Honduras successfully commercialized for several years, comprises ~25,000 hectares stacked Bt/HT products and 2,000 hectares of HT maize. Honduras is estimated to have enhanced farm income from biotech maize by US$10 million in the period 2002 to 2014 and the benefits for 2014 alone is US$1 million.

Honduras is a relatively poor country in Central America with a GDP per capita of US$2,290 – one of the poorest in the region. Both large and small farmers cultivate maize which is the major staple in the country. The average yield is 1.6 tons per hectare which is one of the lowest in the region; this low yield is due to several factors, including weeds and lepidopteran pests which can cause significant losses, particularly on smallholdings.

Honduras was the first country to adopt biotech maize in Central America and introduced herbicide tolerant maize in 2002 with a pre-commercial introductory area of approximately 500 hectares. In the interim, the biotech maize area increased to 15,000 hectares in 2009 and a record 27,000 hectares in 2012. In 2013, the 20,000 hectares of biotech maize planted was surpassed in 2014 by planting 29,000 hectares and decreased marginally to 27,000 hectares in 2015. This is comprised of 25,000 hectares of Bt/HT maize and 2,000 hectares of HT maize.

The country allows the commercial cultivation of biotech crops including those for seed production with no expiration date. Farmers in seven areas in Honduras plant biotech maize: Intibucá, Lempira, Gracias a Dios, and in the municipality of Pespire, and Choluteca. Production of biotech maize has been restricted to some areas away from native corn stocks, which were characterized to have high levels of poverty and hunger. Since biotech maize was commercialized in 2002, there were 8 corn events and 1 rice event approved for food/feed use and cultivation (ISAAA GMO Approval Database). Lines with stacked trait MON 89034 x NK603 x TC1507 will be semi commercialized in 2015 in 15 hectares in 2015 (USDA-FAS GAIN Agribiotechnology Annual Honduras July 8, 2015).

Preliminary data from producers indicate that the per hectare maximum traditional maize yield is 4 metric tons, hybrid yield is 9 metric tons, and biotech maize yield is 10.3 metric tons. Honduras’ maize seed is sold within the domestic market for the agro-industry and is exported to Colombia and the

United States. Honduras imports maize and soybeans from the United States to supply its poultry, livestock, shrimp, and tilapia industries. Around US$97.3 million of yellow maize and US$98.5 million were imported from the US in 2014. There were also recorded biotech yellow maize imports from Argentina.

Benefits from Biotech Maize in Honduras

Zepeda (2014) presented their results on the "Adoption, Impacts and Access to Innovation in Small Resource Poor Countries: Results from a Second Round Survey and Institutional Assessment in Honduras" during the Templeton Foundation reporting meeting in Cambridge, UK on April 2014. The study concluded that "Bt-RR® maize reduced damage due to target lepidopteran insects, and has decreased slightly pesticide use by adopters. Net benefits are substantially higher for Bt-RR® maize adopters than for the non-adopters in our sample. Yet, Bt-RR® maize adoption remains at around 8-10% of total area planted to maize in Honduras in 2013. Our qualitative and quantitative analysis seems to indicate that there are other organizational and institutional constraints which are limiting such adoption. The current Bt-RR® maize technology as it stands now is not intending for subsistence farmers much less the poorest of the poor producers in Honduras. This opens questions of whether there may be potential interventions to improve these producers' productivity through conditional transfer programs that include cash and/or productive inputs such as seed, fertilizer and in some cases pesticides and herbicides." During the presentation, the team also highlighted that yields across the study area indicated an increase of 29-35% compared to conventional hybrid, despite higher production cost of the biotech crop. This has been compensated by a significantly lower pesticide and fossil fuel use.

The experience of Honduras, 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$10 million in the period 2002 to 2014 and the benefits for 2014 alone is US$1 million (Brookes and Barfoot, 2016, Forthcoming).

CHILE

In 2015, Chile grew a total of 10,000 hectares of biotech crops comprised of biotech maize at 5,000 hectares, canola (4,000 hectares) and soybean (1,000 hectares), exclusively for seed exports, similar to 2014. This compares with 24,000 in 2013 and 62,300 hectares

in 2012. Hectarage changes annually based on demand for seed and on relative net demand for Chile compared to other seed producing countries.

Chile has a population of 17.4 million and a GDP of US$270 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 10% of the population is involved in agriculture and the export market requires that the products are of top quality to compete in the global market

Chile 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 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. In 2015, Chile was projected to plant 5,000 hectares of biotech maize, 4,000 hectares of biotech canola and 1,000 hectares of biotech soybean for a total of 10,000 hectares for seed export. Chile has approved planting for seed export with one event each for soybean, maize and Argentine canola since 1996.

Producers report that the plateauing of seed hectarage at 10,000 hectares is due to the over stock of seeds in the north hemisphere. Other transgenic seeds reproduced in the country were cotton seed, tomato, and grape seeds, which in total accounted for less than 0.012 percent of the total area of transgenic seed (SAG, 2015).

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 32,300 hectares in 2012, and a total of 10,000 hectares in each of 2014 and 2015 (Table 28).

Multiplication of biotech seed for export is a significant business activity that was valued at approximately US$400 million in 2009, of which the value of biotech seed alone was at least US$200 million. Maize has always been the most important biotech seed crop grown in Chile and was at 20,000 hectares in 2013/14, but was reduced to 7,000 hectares in 2014 and 5,000 hectares in 2015. The hectarage for biotech canola was 4,000 hectares and 1,000 for biotech soybean for seed export. The number of biotech seed crops multiplied in Chile is now more than 10 crop/trait combinations. The country has broad and diversified experience in successfully managing all aspects related to the growing of biotech crops for over 10 years.

From a biotech crop standpoint, it is important to recognize that Chile is the fifth largest producer of export seed in the world in 2012, with a value of US$388 million (Appendix 2). 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. Biotech seeds produced in Chile are exported primarily to the USA and Canada. In the season of 2013/2014, the total genetically engineered seeds that Chile exported to the world accounted to US$190 million (USDA FAS-GAIN, Chile's Agricultural Biotechnology Annual, 2015).

Commercialization of biotech crops produced in Chile is under consideration. This is a logical development given that Chile already imports significant quantities of biotech crops, such as biotech

Table 28. Hectares of Major Biotech Seed Crops Grown for Export in Chile, 2002/03 to 2015/16*

Crop	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
Maize	10,400	8,450	7,614	12,120	17,981	25,000	30,000	28,000	9,378	25,000	45,000	20,000	7,0000	5,000
Canola	110	140	746	628	444	2,500	4,200	1,200	3,500	15,000	15,000	3,000	2,0000	4,000
Soybean	215	128	273	166	250	500	1,800	3,000	3,800	2,300	2,300	1,000	1,0000	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**	**10,0000**	**10,000**

Source: Government of Chile statistics, SAG, 2015. *industry estimates maize for consumption, from its neighboring country, Argentina, the third largest producer of biotech crops in the world. Chile also imports biotech maize and soy animal feed from Brazil, Argentina and the USA, and does not require labeling as genetically engineered products. When used in food products, the Ministry of Health requires that all events be registered. The product must be labeled only if substantially different from the conventional counterpart.

Chile has 143,000 (FAOSTAT, 2015) hectares of maize which could benefit significantly from biotechnology and substitute for some of the imports of biotech maize from Argentina. Chile also has 50,000 hectares (FAOSTAT, 2015) 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. Chile could also be a viable producer of biotech sugar beets, maize and alfalfa.

Biotech Research in Chile

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.

Biotech grape resistant to gray mold and powdery mildew disease were developed by scientists of Universidad de Santiago, Chile and partners (Rubio et al. 2014). Two endochitinase genes and one N-acetyl-b-Dhexosaminidase gene from biocontrol agents related to Trichoderma spp were introduced into Thompson Seedless lines. Some 568 transgenic lines were initially tested in open field for resistance to the two diseases and with consecutive field evaluation for four years (2007-2009), 19 lines were selected. Plants from these lines were grafted onto rootstock Harmony and further characterized in the field. Molecular analysis (Southern blot, realtime PCR, ELISA and immunostrip) indicate the transgenic status of the selected line. Gray mold assays in Petri dishes were supplemented with juices of the transgenic lines revealed suppression of fungi growth.

Biofrutales, a consortium of research institutions (Fundacion Chile, INIA, Fedefruta, Univiveros and several universities) bought the rights to the technology and will be conducting further evaluation for commercial release. The consortium also plans to develop biotech varieties of stone fruits (peaches and nectarines). The company has allocated US$3 billion between 2006-2011 to conduct various breeding programs for vines (61% of the budget), nectarine and cherry trees. Grape is an economically important crop in Chile because of its wine industry. The consortium has also been awarded three 10-year projects in InnovaChile and Fondef with US$5 billion in project support (Freshplaza, 20 May, 2015).

PORTUGAL

In 2015, Portugal planted a total of 126,413 hectares of all-purpose maize, which was a decrease of 10,251 hectares or a ~8% decline in total hectares, compared with 136,664 hectares in 2014. In 2015, the Bt maize hectarage was 8,017 hectares compared with 8,542 in 2014, which is a decline of 525 hectares or 6%. The Bt maize adoption rate in 2015 was 6%, the same as in 2014. In general, a major issue confronting Portugal and the other four EU countries growing Bt maize in the EU is the very hostile environment in the EU towards GM crops that results in disincentives to farmers growing Bt maize. The principal reason for the decline in hectares in 2015 was the decrease in total maize area and not due to farmers choosing to adopt less Bt maize. In 2015, the 8,017 hectares of Bt maize were grown in 5 regions by 219 Portuguese farmers. Portugal first grew Bt maize in 1999, resumed successful planting in 2005, and since then, they have elected to continue to plant for ten years due to the benefits that it offers, despite the bureaucracy and inconvenience associated with reporting the growing of Bt maize in Portugal. It is noteworthy that in the recent EU vote, Portugal elected not to ban the growing of biotech crops in Portugal.

Portugal resumed 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 2015, Portugal planted 8,017 hectares of Bt maize compared with 8,542 hectares in 2014, a 6% decrease. In 2015, Portugal planted a total of 126,413 hectares of all-purpose maize, which was a decrease of 10,251 hectares or a ~8% decline in total hectares, compared with 136,664 hectares in 2014. The Bt maize adoption rate in 2015 was 6%, the same as in 2014. Thus, the principal reason for the decline in hectares in 2015 was the decrease in total maize area and not, due to farmers choosing to adopt less Bt maize which was the same at 6% in both 2014 and 2015. In general, a major issue confronting Portugal and the other four EU countries growing Bt maize in the EU is the very hostile environment in the EU towards GM crops that results in disincentives to farmers growing Bt maize. It is noteworthy that in the recent EU vote, Portugal elected not to ban the growing of biotech crops in Portugal.

The major five regions for planting Bt maize in Portugal are listed in Table 29 in descending order of percent adoption and contribution to the total Bt maize national hectarage of 8,017 hectares in 2015.

The total hectarage of maize plantings in Portugal in 2015 was 126,413 total hectares. The region of Alentejo had the largest hectarage of Bt maize at 4,942 hectares or 61% of the national hectarage. Alentejo was followed by the Lisbon and Tejo Valley regions with 2,002 hectares of Bt maize or 25% of the national hectarage. The central region was third with 1,013 hectares of Bt maize or 13% of

Table 29. Major Regions Planting Bt Maize in Portugal, 2015

Region	Hectares	Percentage of National Bt Maize Hectares
Alentejo	4,942	61
Lisbon/de Tejo	2,002	25
Central	1,013	13
North	60	1
National	**8,017**	**100**

Source: Ministry of Agriculture, Rural Development, and Fisheries, Lisbon, Portugal, www.dgadr.pt, September, 2015.

the national hectarage. Norte area was the fourth with 60 hectares of Bt maize, 1% of the national hectarage of biotech maize. All the Bt maize in Portugal is MON 810, resistant to European corn borer. As a member country of the EU, Portugal's continued cultivation of Bt maize is an important development, acknowledging that the national maize area is modest.

The Government of Portugal passed a Decree in September 2005 (Decree no. 160/2005 of September 21st), which requires a minimum distance of 200 meters between biotech and conventional maize and 300 meters between biotech maize and organic maize. Portugal is one of the few European Union countries that practice "coexistence" within a legal framework. Since 2005, Bt maize crops have been grown in different regions—either in small or large farms—in compliance with a law that envisages coexistence procedures. This covers either individual farmers or groups of farmers that agree to establish the so called "production zones" or "buffer zones" that can substitute for the required distance. Implementation of coexistence laws results in biotech maize being grown in the central and southern regions of Portugal where the farms are bigger, where coexistence distances can be accommodated and also, where producers are more responsive to the introduction of new and more cost effective technologies. The Ministry of Agriculture also passed legislation to establish biotech free areas where all the farmers in one town, or 3,000 hectare area, can elect not to grow biotech varieties. All biotech varieties approved in the EC catalogue can be grown in Portugal.

Benefits from Biotech Crop in Portugal

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

Farmer Experience

João Grilo, a Portuguese farmer based in Vale do Mondego, Coimbra commented, ***"I have planted GM maize in 2006, and I adopted it because I saw results – healthier plants due to less insect damage, a better harvest and better grain quality. For me, it is very important for more crops to be made available to European farmers. I have been in contact with farmers in other countries who produce other GM crops, and they have higher yields. We import some of their GM crops to Europe, yet we are not allowed to grow them in our own fields. We are all competing for the same market but with different rules. Having access to more GM crops would improve the long-term sustainability of Portuguese and European agriculture. But once again, Europe and Portugal are trailing far behind the rest of the world."*** (EuropaBio (10 June 2011)

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."***

VIETNAM

In 2015, Vietnam became the 29th country globally and the 7th biotech country in Asia to commercialize biotech crops. The country launched its first planting of stacked insect resistant and herbicide tolerant maize on 3,500 hectares in 2015.

Vietnam, with its total land area of 33 million hectares is located in southeastern Asia, bordering the Gulf of Thailand, Gulf of Tonkin and South China Sea, and with China, Laos and Cambodia. The country is characterized by a low, flat delta in the south and north; central highlands; and hilly, mountainous terrain in the far north and northwest. Up to 48% of the 89.7 million people are employed in agriculture, which contributes 20% to a GDP of US$156 billion. The country's agricultural crops include paddy rice,

VIETNAM

Population: 89.7 million

GDP: US$156 billion

GDP per Capita: US$3,790

Agriculture as % GDP: 20%

Agricultural GDP: US$31.2 billion

% employed in agriculture: 47%

Arable Land (AL): 6.9 million hectares

Ratio of AL/Population*: 0.3

Major crops:
- Rice
- Coffee
- Soybeans
- Sugarcane
- Peanuts
- Bananas

Commercialized Biotech Crop: Bt/HT Maize

Total area under biotech crops in 2015: 3,500 Hectares

*Ratio: % global arable land / % global population

coffee, rubber, cotton, tea, maize, pepper, soybeans, cashews, sugar cane, peanuts, and bananas. Prime agricultural lands abound along the Mekong River which is affected by extensive flooding during the occasional typhoons. Logging and slash-and-burn agricultural practices contribute to deforestation and soil degradation, water pollution, and overfishing threaten marine life populations.

Since Vietnam's renovation policy in 1986, Vietnamese authorities have committed to increased economic liberalization and enacted structural reforms needed to modernize the economy and to produce more competitive, export-driven industries. Vietnam's economy has been dominated by state-owned enterprises which contribute about 40% of the GDP. Vietnam joined the WTO in January 2007 and hence became an official negotiating partner in developing Trans-Pacific Partnership trade agreement in 2010.

Biotech Regulation in Vietnam

Vietnam has identified biotechnology as an essential prerequisite not only for increasing domestic needs, but also for conserving natural resources in the development of improved and more sustainable agricultural systems. The government decree No. 18/CP in 1994 placed scientific research in biotechnology development as the country's first priority for the period 1995-2010. The Ministry of Science, Technology and Environment (MOSTE) was tasked to facilitate and enhance biotechnology development by establishing and implementing projects in the "Capacity Development Program on Biotechnology". In coordination with the Ministry of Agriculture and Rural Development, Ministry of Health, Ministry of Fisheries, Ministry of Forestry, and Ministry of Industry, MOSTE established the biotechnology development programs in their respective areas. In 1997, the National Commission on Biotechnology was established and consists of an interdisciplinary team with the Minister of MOSTE as chairman. It is composed of representatives from the Ministries of Agriculture Research and Development, Health, Industry, Fisheries, Education and Training, and the National Center for Natural Science and Technology. Its mandate is to assist the Prime Minister in the implementation of the national program on biotechnology.

In August 2005, the government of Vietnam ratified a landmark decision for the development of biotechnology in the country. The Directive on Biosafety Regulation promulgates the regulation and management of biological safety of genetically modified organisms, products and goods. The following year, January 2006, the Prime Minister approved the agricultural biotechnology program that will be operational until 2020, covering all aspects of biotechnology research, training and application for agricultural industrialization and modernization of the country. Included in the program are the development of new crop varieties, livestock breeds, strains of microorganisms, and biological agro-products for higher productivity, and to increase the quality of agricultural products.

In the biotech program, the first five years (2006-2010) were devoted to research activities that focused on developing pest resistance, drought tolerance and nutritionally enhanced cotton, soybean, maize, rice, sugarcane, forest trees, and ornamental plants. In 2011-2015, genetically modified lines of cotton, soybean, maize, forest trees and ornamental plants are in the trial stage and ready for commercialization. Finally, by 2020, the goal is to expand GM crop planting area with more types of crops and traits for commercialization.

Vietnam's Prime Minister approved the Biosafety Decree 69/2010/ND-CP, replacing Vietnam's Biosafety

Regulation approved in 2005. This Decree entered into force on August 10, 2010 provides the legal framework for biosafety management of genetically modified organisms (GMO), genetic specimens and products derived from GMOs. Prime Minister Dung signed Decree 108 that revised Decree 69, hence changing the responsible Ministry for certification for food use derived from agricultural biotechnology from the Ministry of Health (MOH) to Ministry of Agriculture and Rural Development.

By May 16, 2013, the Ministry of Natural Resources and Environment (MONRE) published Circular 8/2013/TT-BTNMT, providing the procedure for granting and revoking Certificates of Biosafety. Circular 8 entered into force on July 1, 2013 and laid out the regulatory structure to evaluate the biosafety of agricultural traits derived from biotechnology through the issuance of a biosafety certificate.

On January 24, 2014, MARD issued circular 2/2014/TT-BNNPTNT that promulgated the Approval Process of Issuing and Withdrawing Certification for Genetically modified Plants for use as food and feed. The circular entered into force on March 10, 2014. At this point, companies submitted dossiers for different trait of food and feed approvals. Hence, MARD formed a committee consisting of 11 experts and scientists representing different Ministries including MONRE, MARD, MOH, MOIT, the Vietnam Academy of Sciences, the Vietnam Academy of Agricultural Sciences and Ho Chi Minh City's Biotechnology Center, to review and evaluate the dossiers.

Field Testing of Biotech Maize

Small scale field trials have been completed and the positive results obtained allowed the conduct of large scale trials for the following biotech maize hybrids from May to December 2011:

1. Bt 11, GA 21, Bt11 x GA21 of Syngenta by the Institute of Plant Protection, Centre for Testing Seed in the regions of Hung Yen, Son La and Dak Lak province and Ba Ria-Vung Tao;
2. MON 89034, NK603, and MON 89034 x NK603 of DEKALB, Vietnam by the Agricultural Genetics Institute in Vinh Phuc, Son La and Dak Lak Province and Ba Ria-Vung Tau;
3. TC 1507 of Pioneer Hi-bred Vietnam by the Institute of Plant Protection; Centre for Testing Seed in Vinh Phuc, Nghe An, Dak Lak and Ba Ria-Vung Tau from May to Dec 2011.

Results of these multi-location field trials were validated by MARD in the summer of 2013, completing a pre-requisite of the MONRE Bio-Safety Certification process.

Opening of Market for Biotech Crops

With the establishment of the country's regulatory framework, the Ministry of Agriculture granted licenses to four biotech maize hybrids in September 2014. They were:

- Mon 89034, pyramided insect resistant (Dekalb Vietnam Co., Ltd.)
- NK603, herbicide tolerant (Dekalb Vietnam Co., Ltd.)
- Bt11, insect resistant (Syngenta)
- MIR 162, insect resistant (Syngenta)

These import approvals were granted following careful evaluation of dossiers submitted to the Council of Food Safety for GM Food and Animal Feed for consideration, which confirmed that the products had no harmful effects on health. Three GM events were henceforth granted biosafety certificates in 2014

by the Ministry of Natural Resources and Environment (MONRE):
- Mon 89034, pyramided insect resistant (Dekalb Vietnam Co., Ltd.)
- GA21, herbicide tolerant (Syngenta)
- NK603, herbicide tolerant (Dekalb Vietnam Co., Ltd.)

On March 17, 2015, MONRE approved Bt11 x GA21 double stack Bt/HT maize for commercial cultivation in the country (Crop Biotech Update, 18 March 2015). Farmers in the southern province of Dong Nai have been provided the first integrated knowledge transfer training by seed companies to inform fellow farmers about the benefits of the technology. In 2015, a total of 6 maize events have been approved for cultivation including Bt11, Bt11 x GA 21, GA21, MIR162, MON89034 and NK603. From these 6 events Bt11 x GA21 and MON89034 events in local Vietnamese varieties are being commercialized. The first year of commercialized farming in Vietnam features a modest 3,500 hectares of biotech maize with stacked traits, planted in maize-growing areas of the country.

Grain and Feed Imports/Exports

Vietnam is a big importer of grains and feed raw materials. Vietnam's wheat import volume in 2014/2015 was 2.10 million tons, a slight increase compared to 2013/2014 imported volume, with expectations of an increase in the use of feed wheat. Imported volume for 2015/2016 is forecast at 2.2 million tons, with the same expectation of increased feed wheat use. For maize, imported volume in 2014/2015 was at 2.0 million tons, down from the 2.4 million tons of 2013/2014 due to the expected increase of local production from biotech maize. The import volume of maize in 2015/2016 is forecast at 1.8 million tons, a 200,000-ton decrease compared with 2014/2015, due to expected higher local maize production and carry-over stocks from 2013/2014. Total rice production for 2014/2015 reached 44.88 million tons of paddy rice, about 320,000 tons of paddy less than USDA's official number due mainly to the adjustment of seasonal rice planted/harvested area. Vietnam's 2014/2015 rice exported volume is revised to 6.7 million tons due to expected strong competition from Thailand, India, Pakistan and other new exporters such as Cambodia and Myanmar (USDA GAIN Feed Report for Vietnam, 2015).

Stakeholder Support to Biotech Crops

Dr. Le Huy Ham, director of the Agricultural Genetics Institute (AGI) under the Ministry of Agriculture and Rural Development, said at a conference on food biotechnology held in October 2015 at the Centre for Viet Nam Science and Technology Internationalization Promotion under the Ministry of Science and Technology that ***"GM products would partly reduce the dependence on imported animal feed materials such as soybean and maize. GMOs would improve plant productivity and insect resilience."*** Statistics from the Ministry of Agriculture and Rural Development (MARD) showed that Vietnam had 1.2 million ha of maize and produced 5.6 million tonnes of maize last year. However, the country had to import 4.79 million tonnes in 2015 (Vietnam News, 22 October 2015). Under Dr. Ham's direction agricultural biotechnology research in AGI is focused on tropical crops including cotton, cassava, and soybean.

Farmer Nguyen Hong Lam who owns three hectares of arable land in Dong Nai said that GM allowed him to obtain 1.5 times more profit. ***"So I will buy more seeds and plant them in half my land,"*** he added. Farmers who have conducted trials in northern province of Son La and the southern provinces of Ba Ria-Vung Tau and Dong Nai near Ho Chi Minh City witnessed yield increases of up to 30% resulting to profits of up to VND10 million (US$448) per hectare. There were farmers along the Mekong River who have obtained 6% more harvest. Seed companies are providing technical support for farmers who are aiming to increase planting by 12 to 15% in 2015 and up to 50% in the next five years. There will also be savings of US$90 to US$134 from reduced pesticide use per hectare per year and better quality of produce that can command twice more than the current price of VND80,000 (US$3.58) to VND190,000 (US$8.50) (Thanh Nien News, 5 November 2015).

Le Ba Lich, chairman of the Vietnam Animal Feed Association, told VnExpress that Vietnam has already imported 4 M tons of maize in 2015, 80% of them are GM, and so growing GMO crops in the country would save money spent on imports. Current outputs of maize in the country can only provide feed for half of animal feed businesses' demands of 8 to 10 million tons per year. Thus, there is a need to expand GMO maize fields with high yields and pest resistance. Since seeds are obtained from foreign companies, government should support research to produce competitive varieties in Vietnam to reduce the dependence on foreign supplies. Vietnam imported US$939 million worth of maize in the first eight months, up 24.9% from the same period last year, according to official statistics. Most imports came from Brazil and Argentina, where GMO crops are allowed (Thanh Nien News, 5 November 2015).

CZECH REPUBLIC

> **In 2015, the Czech Republic grew 997 hectares compared to 1,754 hectares in 2014, a 757 hectares decrease. The principal reason for the decrease is the inconvenience of stringent reporting requirements for farmers growing Bt maize resulting in less incentive for farmers and all stakeholders seeking to capture the benefits offered by Bt maize.**

The Czech Republic, more familiarly known as Czechia, is one of the few EU member states with rational and pragmatic approach towards agricultural biotechnology. The country approved the commercial production of a biotech crop for the first time in 2005 when it grew 150 hectares of Bt maize. In 2015, the Czech Republic grew 997 hectares of biotech maize, compared with 1,754 hectares in 2014, a decrease of 757 hectares. The decrease is attributed to the inconvenience to farmers of stringent reporting requirements regarding cultivation of GM crops in a hostile EU context. It is noteworthy that in the recent EU vote, Czechia elected not to ban the growing of biotech crops in Czechia.

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 published information shows that Czechia grew up to 400,000 hectares of maize, of which the majority was for silage; there is less incentive for farmers to grow biotech maize for silage because losses due to borer are lower compared to maize for grain. It is estimated that up to 30,000 to 50,000 hectares of maize are affected by the corn borer to a degree that would warrant the deployment of Bt maize planting, thus the potential for biotech maize expansion is significant.

Czech scientists and farm groups have been vocal in their support for more crop biotechnology. With its rational and scientific approach to agricultural biotechnology, scientists and academia do not hesitate to publicly dispel myths spread by some non-governmental entities. There were several field trials of biotech crops which were given permission in the country. In 2014, there were a total of 3.1 hectares planted to biotech crops including buffer zones: They were:

- Maize NK603 with tolerance to glyphosate by the University of Life Sciences Prague;
- Flax with various modifications, by the Czech company Agritec (a small trial for research purposes);
- Plum trees with a modification conferring virus-resistance (resistance to plum pox), by the Crop Research Institute (a small trial for research purposes);
- Barley producing enzyme phytase, notified by the Institute of Experimental Botany, Czech Academy of Science (a small trial for research purposes).

In 2015, a small trial for research purposes of genetically engineered barley producing additional cytokinin dehydrogenase in roots was notified by the Palacky University in Olomouc. The field trial of herbicide tolerant maize NK603 was already concluded in 2015 and only small trials for research purposes continue.

A consortium of the Czech Republic forged with USDA's Agricultural Research Service and the French's INRA has developed a biotech plum pox virus resistant plum tree called HoneySweet. Field trials indicated the resistance of the tree to the virus. The team are now seeking EU deregulation for commercial release.

Biotech maize has been used in biogas production and in on-farm cattle feed, eliminating the need for commercial marketing of the product. Czech farmers prefer to use the locally produced biotech maize on farm, to avoid any marketing issues. It is fed to animals or used as a feedstock for biogas stations. Czech Republic imports bioengineered soybean meal, a main protein source for feed mixes. In 2014, the soybean meal imports totalled 367 thousand MT.

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.

Zdeňka Svobodová et al. (2015) conducted a study on the Risk Assessment of Genetically Engineered Maize Resistant to *Diabrotica spp.*: Influence on Above-Ground Arthropods in the Czech Republic. The following is the unedited abstract reproduced in its entirety.

> "GM crops have significant potential for effective pest management while conserving beneficial natural enemies, including the diversity of generalist parasitoids and predators. However, implementation of any GM event in most European countries has been hindered by fears of unpredictable environmental damage. The mistrust might be overcome by research such as this study but educational programs for growers and policy makers are also required. The deployment of GM maize MON88017, expressing the Cry3Bb1 toxin is a promising strategy for controlling a new and dangerous pest that continues to spread in Europe inspite of insecticide treatments. The tolerance of current GM maize to the herbicide glyphosate provides an additional advantage for growers. Our analyses showed mostly similarity of abundance and diversity of above-ground arthropods in maize with the same genetic background, for both Bt (MON88017) and non-Bt (DK315) untreated or insecticide treated. Hybrids KIPOUS and PR38N86 showed some differences in species abundance relative to the Bt maize and its near-isogenic hybrid; this was probably due to the distinct hybrids' characteristics. Since we did not detect any detrimental environmental effect of MON88017, this GM crop should be acceptable in the EU as the best alternative for curbing the spread of *D. v. virgifera*."

SLOVAKIA

In 2015, the hectarage of Bt maize in Slovakia was 104 hectares compared with 411 hectares in 2014. Data on total plantings of maize in 2015 was not available when this Brief went to press. The decline of Bt maize hectarage in Slovakia in 2015 is attributed to the enforced requirement of laborious and onerous reporting for Bt maize farmers. Onerous reporting is an administrative chore and a compelling disincentive for farmers seeking to plant Bt maize. 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, hence Bt maize offers significant benefits. 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. It is noteworthy that in the recent EU vote, Slovakia elected not to ban the growing of biotech crops in Slovakia.

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 2015, the hectarage of biotech maize was 104 hectares compared with 411 hectares in 2014; data on total plantings of maize in 2015 was not available when this Brief went to press. The hectarage in 2015 would be much higher if it were not for the government requirement for laborious reporting which is a significant disincentive for farmers seeking to plant Bt maize for the benefits it offers.

As an EU member state, Slovakia can only grow MON810 maize event which has been approved by the EU for all of its 28 member countries. Slovakia is estimated to have grown 236,000 hectares of maize in 2008 comprising 157,000 for grain and 79,000 for silage.

Slovakia maintains a scientific approach towards biotechnology and considers the use of biotech crops to increase agricultural productivity and sustainability. The Slovak Ministry of Agriculture strictly regulates the use of biotechnology; nonetheless its scientific approach has supported the use of Bt corn for biogas production and animal feed. Slovakia has been one of a few EU member states to allow and to conduct field trials of various bioengineered events. It is noteworthy that in the recent EU vote, Slovakia elected not to ban the growing of biotech crops in the country.

Benefits from Biotech Crops in Slovakia

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

COSTA RICA

> **Costa Rica planted a small hectarage of biotech cotton and soybean for seed export only for the first time in 2009, and has continued to grow them in the interim period including 2015. Biotech crops planted in the country in 2015 were 101 hectares comprising 100 hectares of biotech cotton, which could reach up to 200 hectares by year-end 2015 and less than one hectare of herbicide tolerant soybean. This compares with 36.3 hectares of biotech cotton and 1.7 hectares of biotech soybean in 2014. Costa Rica plants commercial biotech crops exclusively for the seed export trade.**

Costa Rica is a Spanish speaking country with a population of approximately 4.7 million situated in Central America. Costa Rica is bounded by Nicaragua to the north, Panama to the east and south, the Pacific Ocean to the south and east, and the Caribbean to the East. The major cash crops for domestic consumption and exports are coffee, bananas and pineapples. About a quarter of Costa Rica is designated as national parks and the country was one of the first in the world to develop ecotourism. Whereas Costa Rica has only about 0.1% of the world's landmass, it contains 5% of the world's biodiversity. Expressed as a percentage of its land area, Costa Rica has the largest area of land devoted to national parks and protected areas than any other country in the world.

Costa Rica was included for the first time in 2009 in the global list of countries officially planting biotech crops, because like Chile, it plants commercial biotech crops exclusively for the export seed trade. The 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.

Since 2009, there have been 15 biotech events approved for feed use and cultivation for seed export: 13 for cotton and 2 for soybean. The country imports biotech maize and soybeans from the US for animal feed production and a small volume of cotton for processing. In 2015, approximately 100 hectares of biotech cotton were planted commercially, which could reach up to 200 hectares by year end 2015, as well as about 0.1 hectares of biotech soybean for a total of 101 hectares. Cotton and soybean are planted in October and harvested in April/May of the following year. In 2015, an estimated 101 ha were re planted with biotech cotton and soybean for export to the country of origin. The hectarages of biotech crops peaked in 2009 at 1,679 hectares. Consumption of biotech crop products is still not approved in the country (Department of Agriculture Costa Rica, Personal Communication).

Biotech researches conducted by Costa Rican scientists include the development of bananas with resistance to black Sigatoka, pineapples with high content of antioxidants, and herbicide tolerant rice. Some of the products are already in the field trial stage, approved under biosafety regulations which conform to international standards, but commercialization may still be a long way off.

Agricultural biotechnology continues to face challenges in Costa Rica. Two political parties are supporting a bill in the Legislative Assembly intended to declare a 15 year moratorium on the "liberation and cultivation of modified living organisms for any purpose." Also, groups opposed to agricultural biotechnology have been vocal in their opposition to biotechnology and sued the Government in 2013 over the procedure followed to approve biotech events. However, a decision from the Constitutional Court at the end of 2014 generally supported the way biotech products are reviewed and approved (USDA-FAS GAIN Agbiotechnology Annual, Costa Rica, 2015).

Support for Biotech Crops

Representatives from the Central American Federation of Agricultural and Agroindustrial Chambers, known by its acronym as FECAGRO said, "The use of agricultural biotechnology allows for improved technology that enables high productivity seeds, reduces agrochemical use, creates more drought-resistant crops that can also be irrigated with salt water and are completely safe for human consumption (Central America Data, 11 February, 2015).

BANGLADESH

2015 was the second year of successful cultivation of insect resistant Bt brinjal in Bangladesh. In the last two years, 2014 and 2015, when farmers planted four varieties of Bt brinjal in three successive seasons –summer spring 2014, winter 2014 and winter 2015. The planting was executed under the strict supervision of the Government of Bangladesh Agricultural Research Institute (BARI). In 2015 winter season, the hectarage of Bt brinjal was doubled to 25 hectares; this compares with 12 hectares of Bt brinjal in 2014, comprising (2 hectares in spring and 10 hectares in 2014 winter season). In 2015, approximately 250 farmers planted Bt brinjal on 25 hectares in 2015, equivalent to more than double the number of farmers planting Bt brinjal in 2014. Moreover, BARI in collaboration with Bangladesh Agricultural Development Corporation (BADC) has produced and bulked a large quantity of seeds of four varieties of Bt brinjal to meet the growing needs of large number of farmers in Bangladesh in 2016.

In 2015, farmers could choose from up to four Bt brinjal varieties (Uttara, Kazla, Nayantara and ISD-006) approved for commercial cultivation in four brinjal growing regions. Bangladesh is expected to approve five additional Bt brinjal varieties (Dohazari, Shingnath, Khatkati, Chaga and Islampuri) for commercial release and cultivation in the near future. Completed biosafety dossiers of the first three varieties have been submitted to the National Committee on Biosafety (NCB), to be followed by the latter two, for possible approval and release in early 2016.

The first socio-economic report on Bt brinjal in Bangladesh was released by ABSP-II. Results indicated that no brinjal growers among the ~100 brinjal farmers in 14 districts of Bangladesh reported infestation of the fruit and shoot borer in the 2014-2015 growing season. This indicates a 100% success rate in the use of the technology, reduced insecticide application to 7 times per season, and reduced cost of production. In addition, BARI released agronomic performance data of 19 Bt brinjal demonstration plots established in 108 farmers' field in 19 districts in the country. BARI did not observe any infestation of the fruit and shoot borer (FSB) in any of the Bt brinjal demonstration plots. On average, Bt brinjal farmers harvested 25-39 tons per hectare, which is – more than double the national yield of conventional brinjal. Detailed field data confirmed close to nil infestation in the shoots and fruits of Bt brinjal recorded at up to 0.05% and 0.88%, respectively, compared to the non-Bt brinjal with up to 40% in shoots and 48% in fruits. All four Bt brinjal varieties out yielded their non-Bt brinjal counterpart varieties. BARI Bt Begun-1 (Uttara) yielded 66% higher than its counterpart non-Bt brinjal; BARI Bt Begun-2 (Kajla) by 68%; BARI Bt Begun-3 (Nayantara) by 40% and BARI Bt Begun-4 (ISD 006) yielded 100% higher than the counterpart non-Bt brinjal variety. Farmers benefited from Bt brinjal as a result of reduced cost of production, a bountiful harvest of brinjal fruits while consumers bought unblemished brinjal fruits with almost no pesticide residue.

With the continuing political support of the Minister of Agriculture, Hon Matia Chowdhury in 2015, Bangladesh conducted confined field trials of a Bt cotton variety under controlled conditions at the experimental facility of BARI. The Bt cotton variety, expressing cry1Ac

gene, was developed by Bangladesh's Supreme Seed in collaboration with the Chinese Hubei Provincial Seed Group Company. Bangladeshi cotton farmers suffer significant losses of 20% or more and spend around 40% of total production cost on insecticides sprays to control insect pest *Helicoverpa armigera*. Effective deployment of Bt cotton in Bangladesh is required to increase cotton production, reduce dependence on imported cotton and spur expansion of cotton area, which is recommended in the country's Vision 2021. Bangladesh has also made significant progress in field evaluation of the late blight resistant (LBR) potato in the last few years. USAID has awarded a ~US$6 million project to the Michigan State University (MSU) under the "Feed the Future" Biotechnology Partnership Project –the US Government's global hunger and food security initiative. Golden Rice field trials has been conducted in collaboration with the International Rice Research Institute (IRRI).

The World Food Prize Foundation awarded its 2015 World Food Prize to Sir Fazle Hasan Abed of the Bangladesh Rural Advancement Committee (BRAC) for his unparalleled achievement in building a unique, integrated development organization which, many have hailed as the most effective anti-poverty organization in the world. In the past, Dr. Muhammad Yunus of Gramin Bank received the World Food Prize 1994 for his original approach to promoting the economic and social empowerment of the poorest citizens of Bangladesh, specifically women and children.

Progress on Bt Brinjal in Bangladesh

2015 was the second year of successful cultivation of insect resistant Bt brinjal in Bangladesh. In the last two years, farmers planted four varieties of Bt brinjal in three successive seasons: summer 2014, winter 2014 and winter 2015. The planting was executed under the strict supervision of the Bangladesh Agricultural Research Institute (BARI), Government of Bangladesh. In 2015 winter season, the hectarage of Bt brinjal was doubled to 25 hectares (Table 30); this compares with 12 hectares of Bt brinjal in 2014, comprising (2 hectares in spring and 10 hectares in 2014 winter season). In 2015, approximately 250 farmers planted Bt brinjal on 25 hectares in 2015, equivalent to more than double the number of farmers planting Bt brinjal in 2014.

Bangladesh Agricultural Research Institute (BARI) has completed the biosafety dossier of additional three Bt brinjal varieties including Dohazari, Shingnath and submitted to the National Committee on Biosafety (NCB) for possible commercial release in early 2016. BARI was in the process to complete

Table 30. Bt eggplant Hectarage and Number of Farmers in 2014 and 2015

Planting Season	Planting/Harvest Duration	Number of Farmers Planting Bt Eggplant	Number of Hectares of Bt Eggplant
2014 Spring Season	Jan-Feb to June-July	20	2
2014 Winter Season	Oct-Nov to March-April	100	10
2015 Winter Season	Oct-Nov to March-April	250	25

Source: Rashid and Singh, 2000; Chowdhury and Hassan, 2013; MOEF, 2013; Compiled by ISAAA, 2015.

biosafety dossiers of two additional varieties of Bt brinjal namely Chaga and Islampuri in 2015. Therefore, it is expected that Bangladesh will consider approval of five additional Bt brinjal varieties with EE1 event (cry1Ac) to be released for commercial cultivation in the near future. As of 2015, farmers in Bangladesh can choose from four Bt brinjal varieties namely Uttara, Kazla, Nayantara and ISD-006, which were officially approved for commercial cultivation in four brinjal growing regions on 30th October 2013 (Table 31).

Development and Approval of Bt Brinjal

Brinjal (*Solanum melongena*), popularly known as Begun, is a very important vegetable in Bangladesh where it is grown by about 150,000 very small resource poor farmers on about 50,000 hectares, in both the winter and summer seasons. Majority of farmers grow BARI-bred open pollinated brinjal varieties. However, no brinjal variety imparts field level resistance against the major insect-pest of brinjal – the fruit and shoot borer (*Leucinodes orbonalis*). It is one of the major insect-pests of brinjal, which causes losses of up to 70% in commercial plantings. It not only damages shoots but also infests fruits, rendering them unfit for sale in the market. It is estimated that the fruit and shoot borer alone reduces marketable produce by about two-thirds (ABSP-II, 2007; Rahman, et al. 2002 and 2009). As a result, farmers are left with little choice except controlling it with insecticides, which invariably prove ineffective. Notably, farmers are often forced to apply insecticides every other day, amounting in some cases of up to 80 sprays per season, at an unacceptable environmental cost and an unaffordable price of up to around US$180 per hectare (Kabir et al. 1996; Meherunnahar and Paul, 2009). A socio-economic study on the impact of fruit and shoot borer conducted by the AVRDC (the World Vegetable Centre) in Jessore district of Bangladesh indicated that 98% of farmers relied exclusively on the use of pesticides and more than 60% sprayed their crop 140 times or more in the 6-7 months cropping season (Alam et al. 2003). AVRDC estimated that the pesticides alone contribute to one third of the total cost of production of brinjal, thus, constituting a major cost component of brinjal cultivation in Bangladesh. Significantly, farmers indiscriminately spray insecticides disregarding the recommendation, based on the economic threshold level (ETL), of spraying at an interval of 7-14 days or whenever necessary (Rashid and Singh, 2000). It is reported that the decision of farmers to spray is influenced more by subjective assessment of visual presence of FSB rather than by the more objective science-based methodology of economic threshold levels. This leads to gross over-application of insecticides, higher pesticide residues and needless increase in the farmers' exposure to chemical based insecticides

Table 31. Five Bt Brinjal Varieties for Possible Commercialization in 2016

Variety/Popular Name	Fruit Shape	Fruit Color	Status
Bt Brinjal-7/ (Singhnath)	Long Cylindrical	Deep purple	Application Submitted
BL117/Khatkhatia	Cylindrical	Greenish purple	Application Submitted
BL072/Dohazari	Oblong	Green with white stripe	Application Submitted
Islampuri	Round	Uniform Deep Purple	Dossier under Preparation
Chaga	Oblong	Uniform Light Green	Dossier under Preparation

Source: Mondal, 2015; Compiled by ISAAA, 2015.

(Choudhary and Gaur, 2009). This is wholly untenable for resource-poor small farmers, their families, environment and unwary consumers who unknowingly purchase and consume brinjal that have often been immersed in insecticides prior to sale in local markets.

In order to overcome the production constraints, BARI developed 9 popular brinjal varieties expressing Elite Event-1 (EE-1) that can effectively control the infestation of target insect-pest, the fruit and shoot borer (FSB). BARI chose to develop the open pollinated varieties of Bt brinjal in order to provide affordable seeds to farmers in Bangladesh. These Bt brinjal varieties were developed under the public-private partnership project between Bangladesh, India and the USA. Indian private seed company Mahyco donated Bt brinjal event EE-1 to BARI under a tripartite arrangement funded by the USAID's Agricultural Biotechnology Support Project II (ABSP-II) managed by the Cornell University (ABSP-II, 2014). BARI successfully implemented Bt brinjal project in Bangladesh. These 9 open pollinated brinjal varieties were subjected to rigorous testing under the biosafety and regulatory system of Bangladesh from 2005 to 2013.

In a landmark historic decision, the Government of Bangladesh approved the official release of four varieties of insect resistant Bt brinjal for commercial cultivation in the country on 30 October 2013 (MOEF, 2013). The Ministry of Environment and Forests (MOEF) issued an official notification, following the approval, for limited cultivation in the fields of four Bt brinjal varieties developed by the Bangladesh Agricultural Research Institute (BARI) of the Ministry of Agriculture, Bangladesh. These four Bt brinjal varieties, named BARI Bt Brinjal-1, BARI Bt Brinjal-2, BARI Bt Brinjal-3 and BARI Bt Brinjal-4, were approved based on the proposal and recommendation of the Bangladesh Agricultural Research Council (BARC), the Ministry of Agriculture (MOA) and the National Committee on Biosafety (NCB) of the Ministry of Environment and Forests. The commercial release notification issued by MOEF directed BARI to comply with the conditions stipulated in the order before release of Bt brinjal varieties in the field (MOEF, 2013). BARI Bt brinjal-1 variety popularly known as Uttara was approved for planting in Rajshahi region whereas BARI Bt brinjal-2 known as Kajla in Barisal region, BARI Bt brinjal-3 known as Nayantara in Rangpur and Dhaka regions and BARI Bt brinjal-4 variety Iswardi/ISD006 in Pabna and Chittagong regions. Readers are referred to ISAAA Brief 47 "The Status of Commercialized Bt Brinjal in Bangladesh" that carries a detailed overview about the agriculture in Bangladesh in general, and the importance of brinjal as a vegetable crop particularly from the point of view of the application of biotechnology in developing FSB resistant Bt brinjal varieties that are effective in reducing cost of cultivation and improving productivity and production of brinjal in the country (Choudhary, Nasiruddin and Gaur, 2014).

Commercial Plantings of Bt Brinjal in Bangladesh

The planting of Bt brinjal started in summer season of 2014 when Honorable Minister of Agriculture, Ms. Matia Chowdhury distributed the seedlings of four Bt brinjal varieties to 20 small brinjal farmers on 22 January 2014. Of 20 farmers, five farmers each belonged to the four important brinjal growing regions including Gazipur, Pabna/Ishurdi, Jamalpur and Rangpur. Each farmer was given Bt brinjal seedlings for planting one bigha (about 0.13 hectare) representing 5 bigha for each region. These seedlings were sufficient to plant a total of 2 hectares of Bt brinjal in the summer season of 2014. Subsequently, in the winter season of 2014, additional seedlings of Bt brinjal were distributed to 100 more farmers for planting. Winter is the major brinjal growing season contributing 60% of the total

50,000 hectares planted by 150,000 small brinjal farmers in Bangladesh. Therefore, in the first year of the limited commercial planting in 2014, Bangladesh planted a limited area of approximately 12 hectares of Bt brinjal by 120 farmers in two seasons – 2 hectares by 20 farmers in spring season and 10 hectares by 100 farmers in the winter season of 2014. Bt brinjal fruits were successfully harvested from the first plantings in June and July 2014, and April-May 2015 from second planting in winter season of 2014 and sold in local markets and labeled "BARI Bt Begun #, No Pesticide Used" for human consumption.

2015 was the second year of successful cultivation of insect resistant Bt brinjal in Bangladesh. The area under Bt brinjal has been cautiously expanded to 25 hectares in 2015 winter season. This is an increase of 108% as compared to 12 hectares of Bt brinjal planted in 2014 including 2 hectares in summer and 10 hectares in winter seasons. Approximately 250 farmers planted Bt brinjal over 25 hectares in 2015, which is more than double the number of farmers planting Bt brinjal in 2014 (Table 32). Moreover, BARI in collaboration with Bangladesh Agricultural Development Corporation (BADC) has produced and bulked large quantities of seeds of four varieties of Bt brinjal to be distributed to more farmers in Bangladesh in 2016. It is expected that the area under Bt brinjal will increase by multiple factors when BARI in collaboration with BADC will undertake a large scale distribution of Bt brinjal seeds and seedlings to Bangladeshi farmers. Notably, it is estimated that Bangladesh grows brinjal over 50,000 hectares planted by about 150,000 farmers.

In the last two years, farmers planted four varieties of Bt brinjal in three successive seasons including summer 2014, winter 2014 and winter 2015 under the strict supervision of the Bangladesh Agricultural Research Institute (BARI), Government of Bangladesh. The experience of initial limited planting of Bt brinjal in 2014 and 2015 shows that Bt technology is set to mitigate economic losses to the farmers and substantially increase the marketable yield. Notably, the cumulative commercial cultivation of Bt brinjal by total 370 farmers in three seasons in 2014 and 2015 demonstrated the true value of Bt brinjal technology in farmers' field.

Biotech Crops in the Pipeline in Bangladesh

Field Testing of Bt Cotton

In 2015, Bangladesh for the first time conducted the confined field trials of the insect resistant Bt cotton variety under controlled conditions in the experimental facility of BARI. Bt cotton variety expressing cry1Ac gene were developed by Bangladesh's Supreme Seed under a joint collaboration with Chinese Hubei Provincial Seed Group Company (Daily Star, 2015). Annually, cotton farmers in Bangladesh suffer huge crop losses often more than 20% and spend around 40% of total production cost on insecticides

Table 32. Adoption of Bt Brinjal in Bangladesh, 2014 and 2015

Year	Adoption of Bt Brinjal (ha)	Total Brinjal Area (ha)	Number of Bt Brinjal Farmers	% Adoption
2014	12	50,000	120	<1
2015	25	50,000	250	<1

Source: Compiled by ISAAA, 2015.

sprays to control insect pest *Helicoverpa armigera*. The deployment of Bt cotton in Bangladesh is paramount to increase cotton production, reduce dependence on imported cotton and spur the expansion of cotton area, which is a part of the country's Vision 2021.

Bangladesh with a total cultivable land of ~9 million hectares grows cotton on 42,000 hectares by roughly 70,000 smallholder cotton farmers in the country. Predominantly, Bangladesh grows open pollinated varieties of *G. hirsutum* and *G. arboreum*. Popular cotton varieties include (CB-1 to CB-14 (*G. hirsutum*) and HC-1 and HC-2 (*G. arboreum*). Annually, Bangladesh produces approximately 27,000 metric tons of raw cotton. However, the demand for raw cotton is estimated at approx. 800,000 tons per annum (~4.7 million bales) by the textiles and apparels industry in Bangladesh. Ironically, the domestic production of cotton contributes a meager 2-3% of the total cotton demand in the country in 2014-15. Bangladesh is the second largest importer of cotton in the world after China. The major suppliers of cotton to Bangladesh include India, Uzbekistan, Africa, USA, CIS and others. By 2020, Bangladesh is expected to consume 2.5 million tons of raw cotton as projected by the Cotton Development Board (CDB) of the Ministry of Agriculture of Government of Bangladesh (Farid Uddin, 2014).

Bangladesh is the second largest importer and the fifth largest consumer of raw cotton. Bangladesh consumes approximately 4 to 4.5 million bales of cotton to spin the textile sector. In 2014, Bangladesh procured 4.5 million bales of cotton costing US$5.3 billion to its foreign exchequer. This is equivalent to almost 10% of total import of cotton in the world. According to Bangladesh Textile Mills Association (BTMA), Bangladesh cotton imports will double in next six years.

To spur the growth in cotton production, the Cotton Development Board (CDB) has initiated contained field trials for Bt cotton variety at BARI's greenhouses on 15 July 2015. The confined field trials were initiated when a kg of Bt cotton seeds was provided by Bangladesh's Supreme Seed Company Ltd in collaboration with the Hubei Provincial Seed Group Company, China. The cotton board expects that Bt cotton variety will be made available to cotton farmers once the trials are done in three years' time. In parallel, the board has been making efforts to procure and field test high yielding Bt cotton hybrids in Bangladesh. It is expected that Bt cotton can revolutionize the cotton sector in Bangladesh and follow the feat achieved by the neighbouring countries including India, China, Myanmar and Pakistan who have been growing Bt cotton for many years now. In a hope to replicate the experience of the neighbouring countries in Bangladesh, Dr. Md Farid Uddin of the Cotton Development Board was optimistic about the growth possibility of cotton sector in Bangladesh. **"Bt cotton has the potential to increase the yields up to 20 percent and enhance fibre quality of cottons as those are not attacked by the bollworms,"** believes Dr. Farid Uddin (Daily Star, 2014). The Cotton Development Board (CDB) has been implementing an intensive project to expand cotton cultivation and increase cotton production as a part of its vision 2021 (Farid Uddin, 2014).

In June 2014, Bangladesh Minister of Agriculture Ms. Matia Chowdhury while inaugurating the 6th Meeting of the Asian Cotton Research & Development Network of ICAC in Dhaka, called on neighboring countries including India and China to assist Bangladesh in accessing and introducing Bt cotton. She reiterated the Government's commitment to genetically modified crops and stated that ***"Genetically Modified (GM) for cotton is another important issue for Bangladesh. Bangladesh Government has approved biosafety rule for the introduction of GMO crop. Within this time, Government of Bangladesh has approved the Bt Brinjal for growing at the farmer's level. Very***

urgently we are trying to introduce Bt cotton in the country. China, India and other many cotton growing countries are more advanced in Bt cotton cultivation and they have increased their national cotton production through the introduction of Bt cotton. They can provide assistance for introduction of Bt cotton in Bangladesh. ICAC can also extend their cooperation for introducing Bt cotton in Bangladesh" (ICAC, 2014). In the past, Hon. Prime Minister, Begum Sheikh Hasina made an appeal to the textile mill owners to discover means to produce cotton domestically. She emphasized on the need to expand area under cotton in the country to increase cotton production (PMO, 2010 and Daily Star, 2010).

Other Biotech Crops

Bangladesh has also made significant progress on the laboratory testing and field evaluation of the late blight resistant (LBR) potato in the last few years. The field evaluation of Golden Rice, a biofortified rice, is being carried out by the Bangladesh Rice Research Institute (BARI) in collaboration with the International Rice Research Institute (IRRI) in the last few years (Table 33).

ABSP-II facilitated the transfer of the Rb gene technology from the University of Wisconsin to BARI to develop late-blight resistant potato varieties, suitable for the major potato growing areas in Bangladesh. Rb gene is sourced from *Solanum bulbocastanum*, a wild relative of potato and introgressed into two popular potato varieties using gene transfer technology (GAIN, 2014). The biotech potato varieties confer resistance to the lethal fungal disease caused by *Phytophthora infestans* that causes devastating losses world-wide estimated at US$7.5 billion annually in potato. It is estimated that late blight disease can cause yield losses ranging from 19% to as much as 75% in Bangladesh. Farmers apply numerous sprays to save their potato crop planted annually on over a quarter of a million hectares in Bangladesh. Potato alone consumes approximately 80-85% of total fungicides applied in agriculture in Bangladesh (USAID, 2013; ABSP-II, 2014; Islam and Norton, 2007). The field trials of late blight resistant potato varieties conducted by BARI in Bangladesh indicate a substantial reduction in fungicide cost of US$77 per hectare, minimum yield increase of 15% resulting in a net benefit of US$821 per hectare. Islam and Norton estimated that LBR potato can contribute sizable social benefits to potato growers and can generate farm benefits estimated at US$261 million, over a ten year period. In 2015, USAID has awarded ~US$6 million project to the Michigan State University (MSU) to intensify the development of LBR potato in Bangladesh under the Feed the Future Biotechnology Partnership Project –the US Government's global hunger and food security initiative (MSU, 2015).

Table 33. Status of Field Trials of GM Crops in Bangladesh, 2015

Crop	Gene/Trait	Organization	Status
Brinjal	Insect Resistance	BARI (5 additional varieties)	Final Stage
Cotton	Insect Resistance	Supreme-Hubei Seeds	Import approval & field testing
Potato	Late Blight Resistance	Bangladesh Agricultural Research Institute / ABSP-II	Confined Field Trials
Golden Rice	Nutritional Enhancement	Bangladesh Rice Research Institute/IRRI	Confined Field Trials

Source: Compiled by ISAAA, 2015.

Bangladesh's Sir Fazle Hasan Abed Awarded the World Food Prize 2015

In 2105, the World Food Prize Foundation awarded the 2015 World Food Prize Laureate to Sir Fazle Hasan Abed of the Bangladesh Rural Advancement Committee (BRAC) for his unparalleled achievement in building a unique, integrated development organization that many have hailed as the most effective anti-poverty organization in the world (World Food Prize Foundation, 2015). He is the second person from Bangladesh to be honored with the World Food Prize. In 1994, Dr Muhammad Yunus was the first Bangladeshi to be awarded the World Food Prize for his original approach to promoting the economic and social empowerment of the poorest citizens of Bangladesh, specifically women and children (World Food Prize Foundation, 1998). Both Bangladeshi Dr. Muhammad Yunus and Sir Fazle Hasan Abed received the World Food Prize for setting up the institutional infrastructures such as Gramin Bank and BRAC, respectively.

2015 World Food Prize Laureate Dr. Sir Fazle Hasan Abed achieved the unparalleled milestone in building the unique, integrated development organization BRAC, which is headquartered in Bangladesh and operates programs in 10 other countries around the globe. BRAC has provided the opportunity for nearly 150 million people worldwide to improve their lives, have enhanced food security and follow a pathway out of poverty through its dynamic and effective development programs (World Food Prize Foundation, 2015). In the past, Sir Fazle was knighted by the British Crown in 2009 for his achievements in setting up and expanding BRAC as the world's largest non-governmental organization.

In recognizing Sir Fazle's achievement, the World Food Prize Foundation notes that Sir Fazle pioneered a new approach to development that has effectively and sustainably addressed the interconnectedness between hunger and poverty. Sir Fazle has broken new ground by melding scalable development models, scientific innovation, and local participation to confront the complex causes of poverty, hunger, and powerlessness among the poor. Upon receiving the World Food Prize award, Sir Fazle stated that ***"the real heroes in our story are the poor themselves and, in particular, women struggling with poverty who overcome enormous challenges each day of their lives. Through our work across the world we have learnt that countries and cultures vary, but the realities, struggles, aspirations and dreams of poor and marginalized people are remarkably similar"*** (World Food Prize Foundation, 2015).

Notably, under the food security program, BRAC runs a sophisticated plant biotechnology lab that focuses on traditional plant breeding techniques to produce hybrids of rice, maize and vegetables. BRAC is the largest producer of hybrid maize in Bangladesh and are recognized by the national seed board. BRAC also undertakes research on plant tissue culture to produce disease free planting materials of potato, banana, medicinal plants, fruits and some other ornamental plants like flowers and cactus. BRAC also runs Bangladesh's largest private university, BRAC University that offers bachelor and master level teaching and training courses in plant biotechnology (BRAC, 2015).

Socio-Economic Benefits of Bt Brinjal

In 2015, ABSP-II released the first comprehensive report on socio-economic benefits of Bt brinjal in Bangladesh. The study on *Bt eggplant production in Bangladesh: Survey Results from the 2014-2015* seasons was conducted by Dr. Md. Abdul Rashid and Dr. Md. Kamrul Hasan of the Bangladesh

Agricultural Research Institute with the collaboration of Cornell University and Sathguru Management Consultants under the ABSP 11 Project.

The study revealed that no eggplant growers among the 104 eggplant farmers in 14 districts of Bangladesh reported infestation of the fruit and shoot borer in the 2014-2015 growing season. This indicates a 100% success rate in the use of the technology to control this serious pest.

Bt eggplant farmers have reduced insecticide application down to 7 times per season compared to 39 times for non-Bt eggplant farmers. Bt cotton farmers have limited insecticide exposure, thus improved health. Non-Bt farmers reported to suffer health problems resulting from pesticide applications such as: breathing problems (25% and 55%), skin irritation (10% and 45%), nausea (12% and 47%), eye irritation (14% and 43%) and vomiting tendency (10% and 65%).

Bt eggplant farmers have higher profit due to better yield and reduced cost of production. Although the yield difference between Bt eggplant (22.7 tons per hectare) and non-Bt eggplant farmers (21.33 tons per hectare) is marginal, the difference in cost in growing the two crop types is significant (Table 34). Bt eggplant farmers require a meagre production cost of Tk. 9,046 compared to Tk. 34,298 for non-Bt farmers. The higher production cost incurred by non-Bt eggplant farmers is due to higher fertilizer, pesticide and labor inputs to control the insect pest. Bt eggplant farmers experienced a net economic benefit of US$1,700 per hectare – a princely sum for the some of the world's poorest farmers in a country where the annual per capita income is about US$ 1,314. Finally, the survey study indicated that overall, a higher net income was obtained by Bt eggplant farmers of Tk. 166,980/ha as compared to Tk. 33,089/ha for non-Bt farmers.

Results of another study was released by BARI in 2015 on agronomic performance data of 19 Bt brinjal demonstration plots established in 108 farmers' field across 19 districts in the country in 2014-15. On average, BARI reported that Bt brinjal farmers harvested a bountiful brinjal fruits of 25-39 tons per hectare –more than double the national brinjal yield. The field level data reported almost nil infestation

Table 34. Yield of Bt and Non-Bt BARI Brinjal Varieties in Five Regions in Bangladesh in 2014-2015 Planting Seasons

Region	Yield (t/ha)									
	BARI Bt Begun-1	BARI Begun- 1 (Uttara)	BARI Bt Begun-2	BARI Begun-4 (Kazla)	BARI Bt Begun-3	BARI Begun-5 (Navantara)	BARI Bt Begun-4	BARI Begun- 6 (ISD006)	*All*	
									Bt varieties	*Non-Bt varieties*
Chittagong	14.46	13.38	29.66	27.48	21.03	-	24.48	23.49	22.41	21.45
Dhaka	-	-	29.06	24.82	18.99	19.48	-	-	24.03	22.15
Khulna	-	-	30.73	27.48	19.49	18.31	23.49	21.98	24.57	22.59
Rajshahi	15.47	14.39	27.95	26.46	19.35	18.31	22.74	20.79	21.38	19.99
Rangpur	19.47	18.46	30.37	-	23.40	22.48	-	-	24.41	20.47
All	**17.47**	**15.81**	**29.51**	**26.86**	**20.48**	**19.85**	**23.37**	**22.79**	**22.71**	**21.33**

Source: BARI, 2014; Compiled by ISAAA, 2015.

in the shoots and fruits in Bt brinjal recorded at 0.00-0.05% and 0.04-0.88%, respectively, compared to non-Bt brinjal varieties which suffered high infestations of 30-40% in shoots and 48-50% in fruits. All four Bt brinjal varieties outperformed their counterpart non-Bt brinjal varieties including BARI Bt Begun-1 (Uttara) which yielded 66% higher than its counterpart non-Bt brinjal; BARI Bt Begun-2 (Kajla) by 68%; BARI Bt Begun-3 (Nayantara) by 40% and BARI Bt Begun-4 (ISD 006) which yielded 100% higher than the counterpart non-Bt brinjal variety. Farmers benefited from reduced cost of production and a bountiful harvest of brinjal fruits while the consumers had access to buy unblemished brinjal fruits with almost no pesticide residue.

Previous experiments showed that Bt brinjal increases yield by at least 30% and reduces the number of insecticide applications by a massive 70-90% resulting in a net economic benefit of US$1,868 per hectare over non-Bt brinjal (Islam and Norton, 2007). Indirectly, farmers and their families enjoyed invaluable benefits due to a substantial reduction in direct insecticide exposure. Higher net benefit, estimated at around US$1,868 per hectare is a princely sum for smallholder farmers which should trigger large scale adoption of Bt brinjal among growers across the country in subsequent seasons. BARI estimated that Bt brinjal will occupy approximately 20,000 hectares or 40% of total 50,000 hectares across 20 districts under nine Bt brinjal varieties in the next five years in Bangladesh. It is estimated that at the national level, Bt brinjal has the capacity to generate a net additional economic benefit of US$200 million per year for around 150,000 brinjal growers in Bangladesh.

However, the large scale adoption of Bt brinjal will also come with an enormous responsibility to educate and increase awareness of Bt brinjal farmers and consumers. Farmers have to be educated about the importance of implementing insect resistant management schemes and stewardship programs that will play a significant role in the large scale durable adoption and acceptance of Bt brinjal. Farmers need to acquire new skills, techniques and farm practices to comply with the conditions necessary to sustainably reap bountiful harvests of Bt brinjal. Notably, the anti-biotech groups have escalated protest against Bt brinjal and have been spreading lies and fear among farmers and consumers. In response to the protest of Bt brinjal by anti-biotech NGOs, Minister of Agriculture Begum Matia Chowdhury has said that those protesting against Bt brinjal cultivation in Bangladesh are either "devious" or "ignorant" (BDNews24, 2015). Therefore, it is essential to enhance public understanding of Bt brinjal and effectively engage a trio scientists-consumers-farmers in the debate on the usefulness of Bt brinjal in Bangladesh, which is becoming paramount in the acceptance of technology at the consumer level.

ROMANIA

Romania planted 3 hectares of Bt maize in 2015, compared to 771 hectares in 2014. Romania grew its first 350 hectares of Bt maize in 2007 which increased to a significant 7,146 hectares in 2008. Following the severe economic recession (which severely restricted farmer access to credit), the biotech maize area in 2009 declined to 3,243 hectares, 822 hectares in 2010, 588 hectares in 2011, 217 hectares in 2012, 220 hectares in 2013, a modest increase of 771 hectares in 2014, and finally to a low of 3 hectares in 2015. The hectarage in Romania is unlikely to grow and benefit poor Romanian farmers. There

are several factors that led to a disincentive for farmers to plant Bt maize; of particular concern is the onerous and bureaucratic reporting requirements for farmers regarding intended planting details of Bt maize. In some years, this is exacerbated by a limited supply of biotech Bt maize seed, as seed suppliers understandably assign lower priorities in a social environment that is hostile to biotech crops and provides no incentives to farmers who are keen to benefit from the technology.

Romania grew its first 350 hectares of Bt maize in 2007, and this increased more than 20-fold in 2008 to 7,146 hectares. This was the highest percent increase for any country in 2008, acknowledging that the base hectarage of 350 hectares in 2007 was very low. Following the severe economic recession particularly restricted access to credit, the biotech maize area in 2009 declined to 3,243 hectares, 822 hectares in 2010, 588 hectares in 2011, 217 hectares in 2012, a marginal 220 hectares in 2013, an increase to 771 hectares in 2014, and 3 hectares in 2015. There are several factors that contribute to a disincentive for farmers growing Bt maize that include: an EU stimulated hostile social environment to acceptance of biotech crops; onerous reporting requirements for farmers regarding intended planting details; a limited and decreasing supply of biotech Bt maize seed in a country where understandably seed suppliers assign low priority to the country in the absence of incentives. It is noteworthy that there are 4.5 million small farms in Romania, which remarkably represent almost a third of all farms in the EU who could benefit substantially from the use of biotech crops (The Economist, 2007).

The total maize planting is forecast to increase in Romania from 2.5 million ha to 2.6 million ha in 2015. The widespread use of unapproved insecticides, including neonicotinoides in some regions to control insect attacks, represents an unnecessary risk, and where Bt maize offers a significant safety advantages.

Romania remains, by far, the leader among EU-28 countries in terms of maize planted area and ranks second in terms of maize production. Despite tremendous progress recorded at the level of commercial farms, average maize yield remains at the lowest level among the EU maize producing countries. One of the factors which keep productivity low is the utilization in large extent of non-certified seeds. Total output is predicted to fall in MY 2015/16 by 4 percent due to expected lower yields.

Maize has been exported in 2014/2015 from Romania mainly to European countries including Spain which imported 616,000 MT, Netherlands (409,000 MT), Italy (283,000 MT) and Portugal (147,000 MT). Non European importers include Turkey (270,000 MT), Egypt (200,000 MT), South Korea (190,000 MT), Libya (69,000 MT) and Lebanon (68,000 MT) (AgroChart, 2 June, 2015).

EU Ruling against Biotech Soybean Affected Romania

Until 2006, Romania successfully grew over 100,000 hectares of RR®soybean, but on entry to the EU in January 2007, was forced to discontinue the use of an extremely cost-effective technology because RR®soybean is not approved for commercialized planting in the EU. This has been a great loss to both producers and consumers alike. It is noteworthy that because conventional soybeans yield substantially less (approximately up to 30% less) than RR®soybean, the hectarage of soybeans has dropped precipitously in Romania from 177,000 hectares in 2006 to 48,000 hectares in 2009. Romania is estimated to have enhanced farm income from RR®soybean of US$45 million in the period 1999-

2006 after which it had to discontinue planting when Romania became an EU member state. Despite the EU legal requirement for Romania to discontinue the cultivation of RR®soybean, it has been able to take advantage of the fact that Bt maize is registered for commercialized planting in the EU.

Romania ranked equally with France as the third largest producers of soybean in Europe, after Italy and Serbia Montenegro, with approximately 150,000 hectares of soybean planted in 2007. Romania first grew herbicide tolerant soybean in 1999 when it planted 15,500 hectares of RR®soybean of its national soybean hectarage of approximately 100,000 hectares – a 15.5% adoption rate. In 2006, of its national soybean hectarage of 145,000 hectares, 115,000 hectares were planted with RR®soybean, equivalent to a 79% adoption rate. The very high adoption rate of 79% reflects the confidence of farmers in RR®soybean, which has delivered unprecedented benefits compared with RR®soybean in other countries, particularly in terms of yield gains. Brookes (2005) found that as farmers were able to clean up the weeds from fields in early years of adoption, yield gains were graduated from 31% in 2003, 25% in 2004, 19% in 2005 and 13% in 2006. To be able to deliver a yield gain of 13% in 2006 is still a credit to the effectiveness of the technology to control weeds (Brookes, 2005).

Given that RR®soybean technology is usually yield-neutral in other countries such as the USA and Argentina which have embraced the technology at high adoption rates, the yield increases in Romania are quite unprecedented. The high yield increases that ranged reflect past low usage of herbicides and ineffective weed management, particularly of Johnson grass, which is very difficult to control.

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

In summary benefits from biotech soybean in Romania are the highest recorded worldwide (increase in yield of up to ~30%) and thus it is a shame that millions of poor Romanian farmers,who have demonstrated their ability to grow biotech soybeans very profitably, are denied the opportunity for all the wrong reasons. The consequence is that Romania has to use scarce foreign exchange to pay for imports of biotech soybean which could have been produced much more economically in Romania. It is noteworthy that in the recent EU vote, Romania elected not to ban the growing of biotech crops in Romania.

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 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 increase of 31% in Romania in 2003 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.

New EU legislation now allows countries to opt in or out of growing biotech crops. As of 3 October, 19 countries equivalent to approximately two thirds of all 28 EU countries have opted to ban growing of biotech crops. But importantly Romania has decided against a ban for biotech crops. Agriculture Minister Daniel Constantin has declared that Romania will not opt out of growing biotech crops. Laurentiu Baciu, head of the Agricultural Producers' League, LAPAR, said ***"We want to be allowed to cultivate GM crops... if the seed are scientifically proved to be safe and not to harm the health of people"*** (Balkan Insight, 6 October, 2015).

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."

Progress with Biotech Crops in Africa

In 2015, Africa's biotechnology and biosafety landscape realized significant developments from all the four sub-regions. In West Africa, the Nigerian President's assent to the long-awaited Biosafety Bill and establishment of a National Biosafety Management Agency sent a strong message of political commitment to biotechnology development in Africa's most populous country. In East Africa, and for the very first time, the Kenya National Biosafety Authority received two applications for Environmental release (open cultivation) of genetically modified maize and cotton. The insect resistance Bt-WEMA maize application under the WEMA-Water Efficient Maize for Africa project was jointly made by Kenya's national research organization – the Kenya Agricultural and Livestock Research Organisation (KALRO) and the African Agricultural Technology Foundation (AATF).

Towards the north, Egypt completed drafting a biosafety bill which is waiting at the Parliament while the National Biosafety Council and the National Variety Release Committee of Sudan approved the release of three additional GM cotton varieties for commercial planting. The three varieties will complement the currently grown Bt cotton variety "Seeni 1". Further south, the Republic of South Africa's Executive Council of the GMO Act approved the drought tolerant maize (DroughtGard®) under the WEMA project for general release. The DroughtGard® trait is designed to help maize plant use less water when drought stress occurs, creating the opportunity to conserve soil moisture and help minimize yield loss under drought conditions. Maize is the most widely grown staple crop in Africa with more than 300 million Africans depending on the cereal as the main (and sometimes only) source of food. Drought, whose occurrence has become more severe with climate change, can lead to unpredictable and low yields, and at worst, complete crop failure.

The Kingdom of Swaziland was a new entry in 2015 of countries conducting CFTs in Africa. The Swaziland Cotton Board (SCB) successfully planted trials on six demonstration sites: Siphofaneni (2 ha); Tabankhulu (5 ha); Lavumisa (4 ha); Buseleni (5 ha); Mafutseni (5 ha); and, Big Bend Research Station (5 ha) making a total of 27 hectares. The trials were planted in December 2014 after approval by the National Biosafety Advisory Committee. According to the Cotton Board CEO Daniel Khumalo, the performance was exemplary and he is convinced they should now be given a permit to provide Bt cotton seeds to farmers. The Board has submitted an application for a permit to allow commercialization of Bt cotton in the country.

Other countries that reported substantial progress include Tanzania, with amendment of stringent clauses in the country's liability and redress regulations to allow conduct of research on GM crops, Mozambique's revision of Biosafety law to allow WEMA trials, and, Ethiopian Government's initiative to review the non-functional biosafety law to give room for research and commercialization of GM crops. Togo, Benin and Cote D'Ivoire in West Africa are also working towards reviewing their biosafety laws to make them functional as more farmers in the sub-region aspire to manage the bollworm menace through adoption of Bt cotton.

Momentum was maintained in the three countries – South Africa, Burkina Faso and Sudan that have taken the lead in commercialization of biotech crops: cotton, maize and soybean. This was despite severe drought that hit the southern African region affecting maize plantings and a concern with Burkina Faso's cotton staple length that led partners (mainly cotton companies) to opt for modest reduction in Bt cotton acreage as the issue is addressed. Additionally, expansion of multi-location trials for important cash and food crops continued with extension of approved confined field trials and approval of new ones.

The map of Africa (Figure 22) provides a self-explanatory summary of the three countries that continued to grow biotech crops and eight additional countries that sustained conduct of field trials of biotech crops in 2015. These are: Cameroon, Egypt, Ghana, Kenya, Malawi, Nigeria, Swaziland and Uganda. The key crops at various stages of experimentation in both confined and open trials include banana, cassava, cotton, cowpea, maize, potato, rice, sorghum, sweet potato and wheat. In Mozambique, an application to start CFTs on WEMA has been completed following the Council of Ministers approval of a revised biosafety decree and biosafety implementing regulations. Submission of the application will be made once the Biosafety Committee is re-constituted following restructuring of the Ministry of Agriculture to include food security thus the new name - Ministry of Agriculture and Food Security.

The on-going trials focus on traits of high relevance to challenges facing Africa, key among them drought, nitrogen use efficiency, salt tolerance and nutritional enhancement, as well as resistance to tropical pests and diseases. In Ghana and Uganda, field trials of Nitrogen Use Efficient rice have demonstrated an average yield increase of 19% over conventional rice. The NUE trait was developed to help farmers increase crop yields per unit of applied nitrogen fertilizer, while reducing agriculture's environmental footprint. 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 experiments are being conducted under the aegis of existing legislation.

A range of policy pronouncements in support of biotechnology and regulatory capacity development efforts intensified in 2015. Farmers and scientists have also expressed their support of biotechnology and are highlighted below.

Government Support to Biotechnology

Benin

In May 2015, Mr. Gbeve Ahoudji Daniel of the Ministry of Industry emphasized the need to fast track the legislation and commercialization of biotech crops in the country since the moratorium on GMOs had expired in 2013.

Burkina Faso

The new Minister for Science and Technology, Dr. Jean-Noel Poda reiterated the government's commitment to use biotechnology, which had already given considerable benefits to farmers and the country. He quoted a report from the Institut de l'Environnement et de Recherches Agricoles (INERA), the country's agricultural research institute, which showed that Bt cotton farmers gained about 31% yield increase, making the country number one in cotton production in West Africa with 700,000 tonnes produced per year.

Cote d'Ivoire

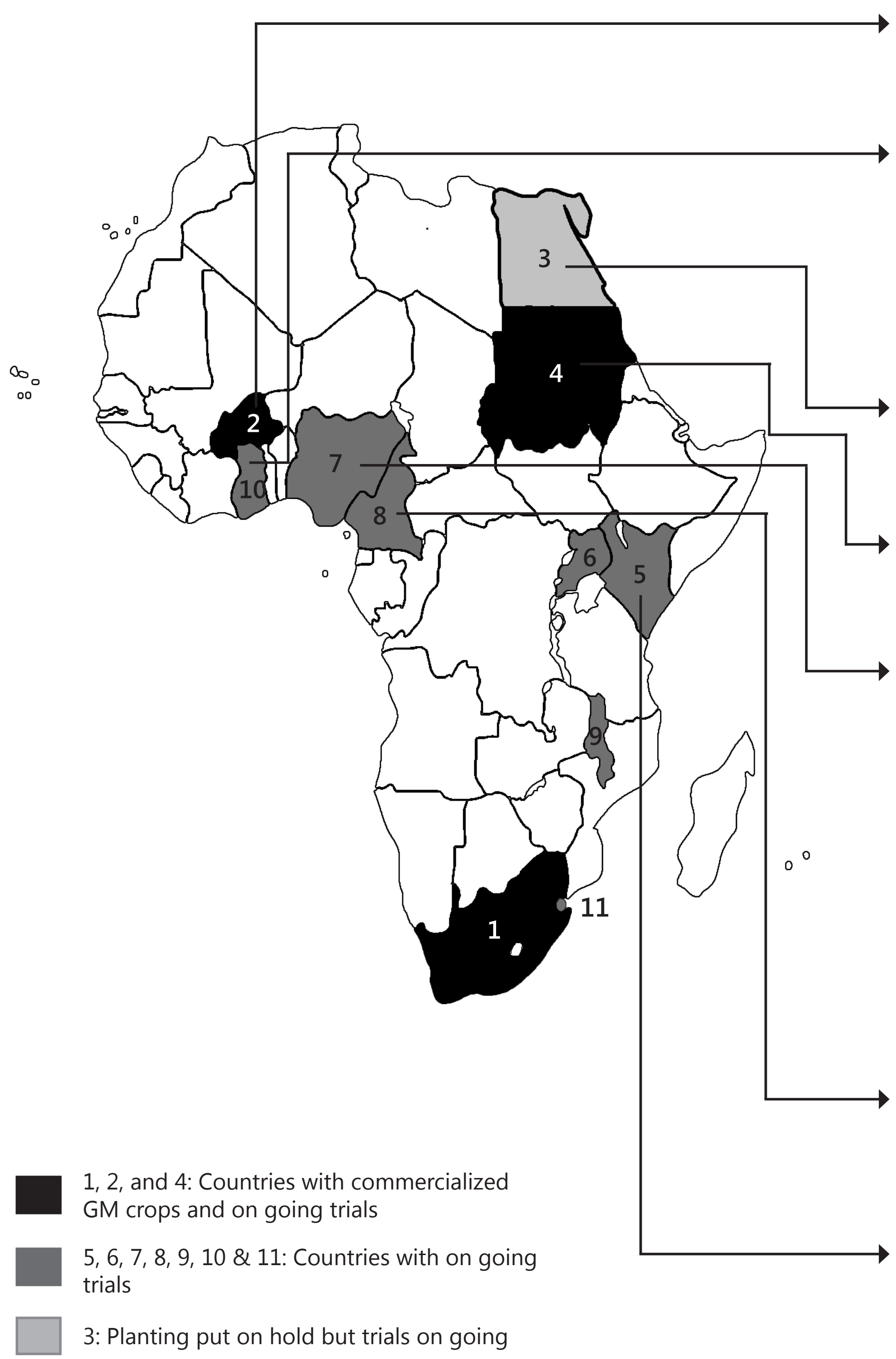
The country signed and adopted the Cartagena Protocol on Biosafety in June 2015. They have also reviewed the draft biosafety bill, to be resubmitted to the Government, after which the Bill will be sent to Parliament for approval.

Kenya

While presiding over the opening of the 4th Annual Biosafety Conference of the National Biosafety Authority in August 2015, Kenyan Deputy President, H.E William Ruto announced plans by the Government to lift a 2012 ban on importation of GMOs. He confirmed the ban would be lifted in two months and allayed fears of stakeholders who were concerned that achievements in biotech research would be rolled back. He also assured the country's scientific community of government's full support in facilitating their work. Ruto further reiterated the importance of intensifying public education and awareness creation efforts by providing the evidence on how biotech tools contribute to resolving agricultural problems. He pointed out the dwindling cotton sector, climate change, pests and diseases attack on staple crops like maize, as key areas where biotechnology can offer solutions in the country.

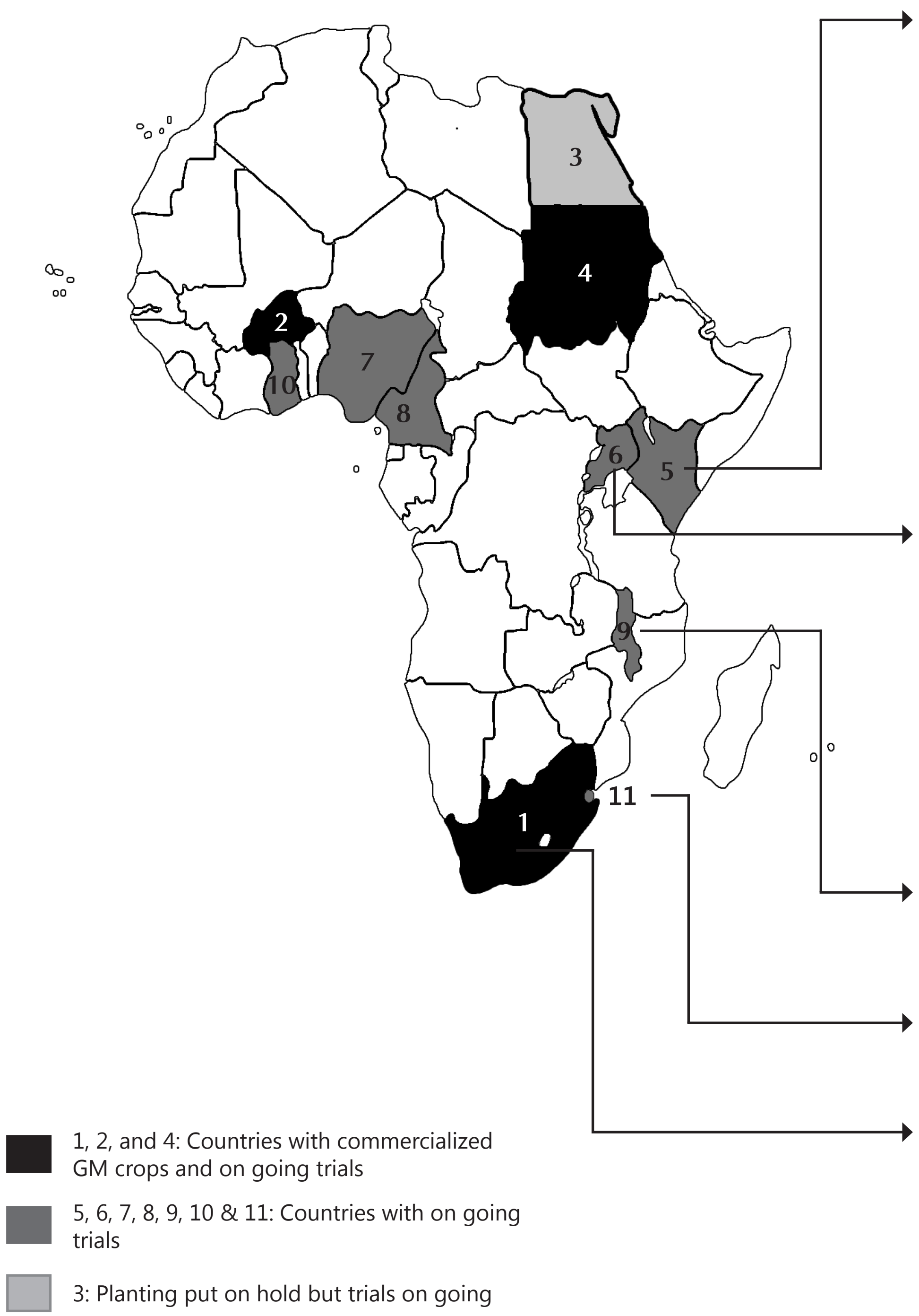
Several Parliamentarians provided political anchor to the Deputy President's pledge to get the ban lifted. They included: Kareke Mbiuki (Vice-chair, Agriculture Committee), Florence Mutua (Member, Agriculture Committee), Robert Pukose (Vice–chair, Health Committee) and James Wandayi (Agriculture Committee) who said the lifting of the ban was long overdue since it was based on unsubstantiated safety claims. Citing experiences from a fact-finding study tour to Europe, they confirmed that EU has approved at least 58 GM events for food and feed including GMO maize, soya, oilseed, sugar beet and cotton. According to European farmers, biosafety authorities, policy makers and scientists they interacted with, there has not been any harm due to GM crops over the years.

Figure 22. On-going Biotech/GM Crops Research Activities in Africa as of October 2015



Country	Crop	Trait	Institutions Involved	Stage as of October 2015
Burkina Faso	Cowpea, *Vigna unguiculata*	Insect resistance	INERA, AATF, NGICA, CSIRO	Multi-location trials in 3 sites
	Cotton	Insect resistance and Herbicide tolerant	INERA	CFT - 2nd season
Ghana	Bt/HT Cotton (Bollgard II®)	Insect resistance/Herbicide tolerant	Savannah Agricultural Research Institute	Multi-location trials in 2 sites
	NUWEST rice	Nitrogen Use Efficiency/Water Use Efficiency and Salt Tolerance	Crops Research Institute	2nd CFT ending, Nov 2015 application for extension and relocation of sites to a more drier area (uplands)
	Bt Cowpea	Insect resistance	AATF, Savannah Agricultural Research Institute	2nd CFT in Northern region ending in Nov 2015; application for multilocation submitted, assessing two places - Upper East and Northern regions
Egypt	Wheat, *Triticum durum* L.	Drought tolerant	AGERI	CFT approved by NBC in 2010; extended in 2015, ongoing
		Fungal resistance	AGERI	3rd season CFT approved by NBC in 2010; extended in 2015 - ongoing
Sudan 4th year Bt cotton commercialized	Cotton, *Gossypium hirsutum* L.	Insect resistance: 2 Indian Bt hybrids 1 Chinese Bt cotton variety SCRC37	Biotechnology and Biosafety Research Center; China-aid Agricultural Technology Demonstration Center, Elfaw	Multi-location trials completed for 3 additional Bt varieties; Approved for commercial planting
Nigeria	Cassava	Biofortified with increased level of beta-carotene, provitamin A	National Root Crops Research Institute	CFT 2nd season completed
	Cassava	Bio-fortified cassava enhanced with Iron (concluded)	National Root Crops Research Institute	Trials completed
	Cowpea	Insect resistant against Maruca pest	AATF, Institute of Agricultural Research	Back crossed, 2nd season Multi-locational trials in 3 sites, still on going
	Sorghum (ABS)	Biofortification	Africa Harvest, Pioneer Hi-Bred, a company of DuPont business, IAR and NABDA	4th CFT and back crossing with preferred Nigerian varieties, still on going
	Rice	Nitrogen use, Water efficient and salt tolerant (NUWEST) Rice	AATF, National Cereals Research Institute, Badeggi	Permit granted to commence trial in 2014 but yet to commence trial
	Cassava	Cassava resistant to African cassava mosaic virus (ACMV) and Cassava brown streak virus (CBSV)	National Root Crops Research Institute, Umudike	Permit granted, commenced trial in 2014 and still on going
	Corn	Bt + Glyphosate ht corn	Monsanto, National Biotechnology Development Agency, Abuja	Application being processed
Cameroon	Cotton	Insect resistance and Herbicide tolerant	Bayer	CFTs completed; Application for Environmental release
Kenya	Maize, *Zea mays* L.	Drought Tolerance (WEMA)	AATF, CIMMYT, KALRO	CFT - 6th season completed
		WEMA Insect resistance (Bt maize-MON 810)	AATF, CIMMYT, KALRO	Review for Environmental release
		Stack maize event for Bt (MON 810) and Drought (MON 87460)	AATF, CIMMYT, KALRO	1st CFT approval granted
	Cotton, *Gossypium hirsutum* L.	Insect resistance	KALRO, Monsanto	Review for Environmental release

Figure 22. On-going Biotech/GM Crops Research Activities in Africa as of October 2015



Country	Crop	Trait	Institutions Involved	Stage as of October 2015
Kenya	Cassava, *Manihot esculenta Crantz*	Cassava mosaic disease	KALRO, Danforth Plant Science Center (DDPSC), IITA	CFT - 2nd season completed
		Cassava Brown Streak Disease Introgression into CMD tolerant background materials	KALRO, Danforth Plant Science Center (DDPSC), IITA	1st CFT completed
		Cassava Brown streak virus (CBSV) and African Cassava Mosaic Virus (ACMV)	Masinde Muliro University of Science and Technology (MMUST)	CFT - 1st season ongoing
	Sweetpotato, *Ipomoea batatas*	siRNA resistance to Sweet potato virus disease	KALRO-Kakamega, Danforth Plant Science Center (DDPSC)	1st CFT on-going
	Sorghum (ABS) *Sorghum bicolor Moench*	Enhanced pro-Vit. A levels, Bio-available Zinc and Iron	Africa Harvest, Pioneer Hi-Bred, a DuPont business and KALRO	CFT - 7th Season ongoing
Uganda	Maize, *Zea mays L.*	Drought tolerance	NARO, AATF, Monsanto, CIMMYT	CFT - 6th trial terminated in May
		Insect resistance	NARO, AATF, Monsanto, CIMMYT	CFT- 4th trial planted in August
	Banana, *Musa spp.*	Bacterial wilt resistance	NARO, AATF, IITA	CFT – 2nd trial of 10 lines selected lines will be harvested in November
		Nutrition enhancement (Fe and Pro-vitamin A)	NARO, QUT (Queensland University of Technology)	
		Banana parasitic nematode resistance	NARO, University of Leeds	CFT- 1st trial harvested in June
	Cassava, *Manihot esculenta Crantz*	Cassava brown streak virus (CBSV) resistance	NARO, DDPSC, IITA	CFT – 3rd trial terminated in July
		Cassava brown streak virus (CBSV) resistance	NARO, DDPSC, IITA	CFTs – 1st trial in 2nd site planted
	NEWEST Rice	Nitrogen Use Efficiency/Water Use Efficiency	NARO, AATF, Arcadia Biosciences	CFT - 2nd trial harvested in July, constructing a rain-out shelter is on going
	Potato	Disease resistance	NARO, CIP	CFT - 2nd trial planted in October
Malawi	Cotton - *Gossypium hirsutum L.*	Insect resistance (Bt)	LUANAR, DARS, Monsanto	CFT – 3rd trial completed in September 2015 Application for general release under review
	Cowpea - *(Vigna unguiculata)*	Insect resistance	LUANAR, DARS, AATF	CFT- Approval granted in June 2015 CFT- 1st trial expected to be planted in December 2015
Swaziland	Cotton	Insect resistance	Swaziland Cotton Board	Multi-location trials – 6 sites
South Africa	Maize, *Zea mays* L.	Drought tolerance Stacked traits (2-3 events) Drought tolerance/Herbicide tolerance/Insect resistance	Monsanto	DroughtGard® approved for conditional general release; Extensive testing under commercial circumstances to commence Approved for Multi-location trials 3 events in 3rd year, 1 event in 1st year (Total – 4 events)
		Stacked traits – (5 events) Insect resistance and Herbicide Tolerance	Syngenta	Approved for multi-location CFTs 3 events in 3rd year; 2 events in 1st year
		Stacked traits - (4 events) Insect resistance/herbicide tolerance	Dow AgroScience	Approved for Multi-location CFTs 3 events in 1st year; 1 event in 4th year

Moreover, ten Parliamentarians from various house committees assured scientists of their support to biotech research. They said this after touring various agri-biotechnology research facilities, which included Kenyatta University, Biosciences east and central Africa (BecA-ILRI) Hub, and the Kenya Agricultural and Livestock Research Organization biotechnology center. They re-affirmed the country's requisite capacity for handling GMO crops. Led by Hon. Wilbur Otichillo, the legislators hailed the scientists for the commendable work in the research institutes, noting that once commercialized, the research would go a long way in addressing farmers' perennial challenges with insect infestation. ***"We are convinced beyond doubt that the country has the necessary capacity,"*** he said. On her part, the chair of the education and research committee in parliament, Hon. Sabina Chege said, ***"I have never had a chance like this to interact with so many scientists and get the right information on GMOs. She called on the scientists to organize more of such events to equip the legislatures with vital pieces of information on the subject to enable them to make informed decisions. This would also help in disseminating the right information to their electorate and fellow parliamentarians,"*** she said.

Hon. Dr. Robert Pukose, deputy chair of the Parliamentary Committee on Health called for the lifting of the ban on GM food imports in Kenya, saying that fears related to their safety are unfounded. In his opinion as a medical doctor, foods derived from GM crops were healthier than conventional foods because scientists and regulators test GM foods extensively for any adverse effects to human's well-being before placing them on the market.

Senegal

Senegalese Parliamentarians (MPs) and their advisors (CESE) reached a consensus that the benefits of biotechnology outweigh the risks. In a meeting in September, they called on the Government of Senegal to educate various stakeholders and the general public on the facts about the technology. They also recommended that relevant documents are translated into different local languages spoken across the country to ensure wider understanding. Most of the Parliamentarians lamented the fact that Senegal is lagging behind Burkina Faso, in adopting the technology.

Swaziland

In May, Hon. Jabulani Mapuza, Minister of Tourism and Environment confirmed that over the last 19 years of GM crops commercial production, no ill effects have been reported over their use on either human, animal health or the environment. Swaziland imports yellow GM maize from South Africa for feed and in 2014/15 started conducting multi-location trials on Bt cotton.

Tanzania

In June, Hon. Godfrey Zambi, Deputy Minister in the Ministry of Agriculture, Food Security and Cooperatives acknowledged the potential of biotechnology for Tanzania's food security. Hon. Zambi stated that the country could not afford to ignore benefits of biotechnology in developing various sectors of the economy, especially agriculture. He also informed participants that the government's responsibility is to partner with other stakeholders to ensure that the country has capacity for safe and progressive use of agri-biotech.

The Minister of Science and Technology, Prof. Makame Mbarawa confirmed that the Government of Tanzania had finalized the revision of clauses in liability and redress regulations to facilitate biotechnology research in the country. The Minister assured scientists that the country is going to focus on research and will work with both public and private sector players.

Togo

In June, the technical advisor to the Minister of Agriculture, Livestock and Water Dr. Gbetogbe Koffi underscored the importance of continued agricultural research that would promote innovations to address farmers' needs, especially those related to mitigating effects of climate change and environment conservation. He said that transgenic crops reduce the use of pesticides in favor of the environment and also increase yields and income for farmers.

Uganda

Speaking at the 2015 World Food Day celebrations in October, Ugandan President Yoweri Kaguta Museveni urged Members of Parliament to support the passage of Biotechnology and Biosafety Bill 2012. He said this would allow agricultural scientists to release improved crop varieties that can withstand certain pests, diseases and drought to farmers. The President believes the technology will improve quality of crops in the country. Earlier in the year - May 2015, the ruling political organization in Uganda – the National Resistance Movement (NRM), held a Caucus session in which they had resolved to support the Bill when tabled on the floor of Parliament. Scientists were highly expectant of the passage of this piece of legislation before the end of current Parliament and will count on the President's backing.

Uganda's State Minister for Industry and Technology Hon. James Mutende (late) supported the adoption of biotech crops in Uganda noting that they have the potential to enhance productivity, address food security issues, increase production, and increase the country's export base. He appealed to scientists who have openly criticized the technology to embrace dialogue with researchers working on biotech/GM crops so that they can have a harmonized voice. Hon. Mutende cautioned that divided viewpoints about the technology by scientists had been partly responsible for Parliamentarians' delay in passing the 2012 Biosafety Bill into Law. Citing his experiences in a study tour to Brazil, a lead biotech crops producer, Hon. Mutende called on Uganda farmers to consider adopting biotech crops if they are to compete in commercial farming. ***Ironically, Hon Mutende passed away in August 2015. The highest honour fellow Parliamentarians would give Dr. Mutende is to pass the Biosafety Bill once presented in Parliament.***

West Africa

Several countries - Cote d'Ivoire, Senegal, Togo and Mali have expressed interest and willingness to adopt Bt cotton among other crops. However, their current biosafety laws contain clauses that make it difficult to conduct research leading to eventual commercialization. The NEPAD's African Biosafety Network of Expertise has been working with the national regulatory authorities in these countries to assist in revising the current national biosafety laws to make them functional.

Voices of the African farmers

Egypt

Egyptian farmers pledged their support for GM wheat resistant to wheat rust when it gets ready for commercialization. They said this after visiting field trials where fungal rust and powdery mildew resistant wheat are being evaluated at Gemiza station. They noted the clear difference between conventional wheat fields, which had been highly infected compared to transgenic lines that showed different degrees of tolerance to fungal infection. Farmers were impressed with the high degree of tolerance to the infection and pledged their support for GM wheat.

Ghana

The President of the Ghana National Association of Farmers and Fishermen said that farmers, especially small holder farmers, have recognized the important role that improved seeds and fertilizers play in increasing yield and income. He noted that Ghana needs a vigorous education campaign on GMOs, plant breeding and biosafety issues to clear misconceptions in the minds of Ghanaians and also enable the general public to understand the biosafety issues.

Presidents of four key farmer organizations in Ghana signed a communiqué calling on the government to facilitate adoption of GM crops since they had been adequately educated about the biosafety framework in the country. The communiqué also appealed to scientists to work towards strengthening their relationship with farmers. The farmer leaders implored government to give science and technology "space to improve the quality, accessibility, affordability and sustainability of food production."

Nigeria

Speaking on behalf of a coalition of Nigerian farmers, the President of Cotton Ginners Association (CGA), Alhaji Salmanu Abudullahi in April 2015 said that the Biosafety Law in Nigeria would boost the Federal Government's on-going agricultural transformation Agenda and empower agricultural research institutes to continue with their work on biotech crops. This would ultimately lead to commercialization of the positive outcome of their research findings for the farmer's benefit.

A member of Cotton Farmers Association, Samuel Ishaku, said a biotechnology law in the country would make their members rich like farmers in Burkinabes and developed countries that have taken to the cultivation of Bt cotton.

Kenya

Cotton farmers submitted petitions to the Government to lift a 2-year GM products import ban. The farmers signed Communiqués to the Kenyan President. They demanded for Bt cotton seeds asking the government to allow them to enjoy the benefits of GM crops similar to other farmers around the world who have been planting Bt cotton. In the petition, farmers cited systematic failures in the cotton value chain, including pests and diseases as factors that have contributed to the collapse of the once vibrant cotton sector in the country. The Communiqué also noted that farmers should reap from research efforts realized through the Bt cotton project of the Kenya Agricultural and Livestock Research Organization (KALRO), whose results indicated viability of Bt cotton in the country.

Farmers from the Cereal Growers Association, mainly maize and soybean growers from the Rift Valley and Western counties of Kenya expressed their support for the introduction and commercialization of GM maize in the country. After hearing testimonies from their colleagues' experiences on visiting Brazil GM crop farms, they realized a lot of what they had heard before about GMOs was not based on evidence. Discussions held at the meeting revealed that the introduction of biotech crops into Brazil's farming systems had enabled the country to be a net exporter of maize and soya beans to other countries like Canada and United States. According to one of the presenters, a local farm manager, Mr. Robert Mburu, Brazil had achieved higher crop yield, lowered production costs, realized better quality produce and reduced pesticide applications.

Biotech Support by Scientists and Professionals

Doctors in Kenya voiced their views on the safety of GM crops. Through the chairman of the Kenya Medical Association, Dr. Elly Nyaim, they re-affirmed the safety record of GM crops that have already gone through the regulatory process. Dr. Nyaim said the technology has been used to produce medicines and improve agricultural crops, and there was no harm if it will be used to attain food security. He said that inadequate information and misconceptions have hampered uptake of otherwise safe technology for food production, health and environmental protection.

Tanzanian researchers welcomed the news of revision of stringent clauses in the 2009 Biosafety Regulations saying they had hindered the conduct of confined trials in a number of important crops in the country.

A senior biotechnology advisor of the Alliance for Commodity Trade in Eastern and Southern Africa (ACTESA/ COMESA) Dr. Getachew Belay, called on African countries to reinforce linkages between national biosafety regulatory authorities in order to improve the continent's ability to manage GM products. He argued that Biosafety issues are regional in nature and environmental impacts don't respect borders, thus, the need for regional mechanisms for sharing regional expertise and infrastructure. He said that sharing of information and proper coordination of transboundary movement of GM products would help to develop a robust continental biosafety system.

Mr. Alik Manda, Director of Planning at National Commission for Science and Technology (NCST) said Malawian stakeholders recognize agricultural biotechnology as a key driver of socio economic development in the country. A Biotechnology Rapid Response Committee was formed in 2015 to foster agri-biotech acceptance in the country.

Prof. Alhassan, the Director of Biotechnology and Stewardship for Sustainable Agriculture in West Africa (BSSA) has urged farmers to ignore claims against GMOs, saying that there was no tangible evidence to prove its threat to humans. He added that the usage of GM seeds in the country was a matter of choice and advised that biotechnology should be given a chance to revolutionize agriculture and move with modern trends.

Mozambique

The Director General of IIAM Mozambique, Dr. Inacio Mapossé, underscored the country's focus on GMO projects such as WEMA, to develop drought tolerant maize, the main staple crop for majority of Mozambicans. After the Council of Ministers' approval of a revised biosafety decree and biosafety implementing regulations, applications to start CFTs on drought-tolerant maize under the (WEMA) and Bt cowpea will be developed. This will enable the beginning of confined field trials on drought tolerant maize at the Instituto de Investigação Agrária de Moçambique (IIAM or Agricultural Research Institute of Mozambique) research station at Chokwe.

Angola

In October 2015, the Board of Directors of the African Development Bank (AfDB) approved a loan of US$90 million for the Republic of Angola to finance a Science and Technology Development project to contribute to the diversification of the economy through research and development in agro-industry, biotechnology and health, energy, information and communication technologies, nanotechnology and mechatronics. In addition to building and equipping a world-class science and technology park in Mabubas, the project will also: provide 155 scholarships to train researchers, of which 55% will be given to women scholars; fund 40 research projects to support Angolan researchers with innovative project ideas; support the participation of women in science; develop skills in science and technology within secondary schools to both students and teachers; as well as build the capacity of intellectual property system in Angola. "Mabubas Science and Technology Park, strategically located near the future Bara do Dande Harbour and the Special Economic Zone between Luanda and Bengo, will greatly contribute to industrial development, competitiveness, innovation, and job creation," said Sunita Pitamber, AfDB's Acting Director for Human Development.

The park is expected to serve the needs of young Angolan entrepreneurs and businesses alike through training and research and development within industrial incubators. The project is part of the implementation of Angola's National Policy for Science, Technology and Innovation and is aligned with the National Development Plan. It is also fully aligned with the AfDB's Strategy 2013-2022, on skills human capital and gender.

The director of the Cotton Development Trust (CDT) of Zambia, Mr. Lwisya Silwimba is positive that insect resistant cotton will help decrease the concerns of farmers and will effectively contribute to cotton development in Zambia. According to Mr. Silwimba, small-scale farmers face low productivity and high cost of production, which negatively affects the cotton industry in the country. Thus, there is a need for solutions to help the small-scale farmers. He added that low seed cotton yields are the biggest production cost since they hamper income growth in the smallholder cotton sector and reduce its competitiveness. One solution would be to adopt Bt cotton which will help achieve increased earnings for the farmers both in terms of revenue, and improved profit margins, he said. It would also provide an attractive environment for other potential farmers to enter the country's cotton industry. CDT submitted an application letter in 2013 to the National Biosafety Authority to conduct research on biotech cotton in Zambia, which awaits approval.

Progress was also reported on regional initiatives towards harmonization of policies and regulatory frameworks to allow for cost-efficiency in the sharing of knowledge, expertise and resources.

COMESA

The COMESA regional biotechnology and biosafety policy implementation plan was validated in a regional workshop held in Addis Ababa, Ethiopia from March 11-13, 2015. COMESA Member States through country delegations validated the implementation plan - COMBIP. This came a year after the approval and adoption of the COMESA policy on commercial planting, trade and access to emergency food assistance involving GMOs, by the 32nd Meeting of the COMESA Council of Ministers in February 2014. COMBIP is designed to translate the COMESA Policy on Biotechnology and Biosafety into an effective, region-wide implementation program. The overall goal of the plan is to support the Member States to realize their aspirations of becoming active participants in the global biotechnology enterprise through commercial planting of GM crops, trade in products of GM technology and improve procedures in accessing emergency food aid with GM content. The plan will involve the enhancing of awareness and outreach activities in a continuous and progressive manner. A regional biosafety risk assessment mechanism is also envisaged in the plan.

In West Africa, WEAMU Ministers adopted the need for a regional biosafety law. Ministries recommended that the three organizations WAEMU1 , ECOWAS2, and CILSS3 continue their collaboration to finalize the regional biosafety law, which they believe benefit all members states.

Ministries from WEAMU countries in charge of environment, agriculture, animal resources and fisheries, and scientific research met in Ouagadougou in February 2015 and adopted the regional biosafety law with an amendment on Article 25 to read "Any who wishes to do confined testing, develop, import, disseminate or introduce to the market LMOs and / derived product should submit a written request to the competent national authority of the concerned WAEMU country member" instead of written request to the WAEMU Commission.

The aforementioned progress notwithstanding, a number of challenges were experienced in 2015 with a bearing on the development pace and political goodwill for biotech crops in the continent. Gross misinformation was cited as the first key challenge posing great danger to acceptance of crop biotechnology. There has also been a proliferation of court cases against Biosafety authorities in Ghana and Kenya.

Prof. Jennifer Thomson, Professor of Molecular Biology from the University of Cape Town in South Africa further provided some of the reasons why there is slow adoption of GM crops in Africa. In an article published on *The Conservation*, Dr. Thomson said that except South Africa, Burkina Faso and Sudan no other country in the continent has commercialized GM crops. She explained that the main reasons for such conditions are political and economic. In particular, she said negative attitude towards GM in Europe have influenced African politicians and many African countries are afraid that adopting GM crops would affect trade with other countries, especially in Europe where a number of countries have banned the importation of GM products.

The second challenge is the political interference with the biosafety process. A case in point is the prolonged (2012) import suspension of GM produce in Kenya and Egypt, slowing down the stipulated timelines of getting Bt cotton commercialized by 2014 (Kenya) and expansion of Bt corn growing in Egypt. The third challenge is the increased activism against the technology, which continues to put unnecessary burden to the regulatory process. It is imperative that the issues are urgently addressed to avert further delay of safe and beneficial crop technologies to African farmers who need them most. Over-regulation of GM products limits transition of agri-biotech research to commercialization.

THE EUROPEAN UNION (EU 28)

The same five EU countries as in 2014 continued to plant 116,870 hectares of biotech maize in 2015 – this is equivalent to a significant 18% decrease or 23,789 hectares, from 143,016 hectares in 2014; the decrease by and large was due to farmers planting less maize. For example, Spain planted 416,960 hectares in 2014 but only 382,342 or 34,348 hectares less, equivalent to an 8% decline in 2015; low international prices for maize has driven farmers to reduce hectarage of maize

as well as other crops such as cotton. The five countries growing biotech maize in the EU, the same as last year, in decreasing order of hectarage were Spain, Portugal, Czechia, Slovakia and Romania. Spain was by far the largest Bt maize grower with 92% (the same as last year) or 107,749 hectares of the total 116,870 hectares maize in the EU. Bt maize adoption in Spain was down marginally at 28%, compared with 31% in 2014. Bt maize hectarage was down in all five countries. The decreases in Bt maize were associated with several factors, principally due to less total hectares of maize planted in 2015, but also due to disincentives for farmers related to bureaucratic and general onerous reporting of intended plantings of Bt maize. In some cases, there was limited seed supply as well as the general hostile environment towards GM crops in the EU leading to less incentive to market biotech maize in the EU. If the EU does not deregulate a biotech winter sugar beet being developed by KWS, EU farmers will be denied a significant 20 to 30% increase in productivity and make them uncompetitive in the international market. In October 2015, 19 of the 28 EU countries voted to opt out of growing biotech crops but importantly all five EU countries currently growing Bt maize voted to continue planting in order to continue to benefit from the significant advantages that biotech crops offer. The EU (including Spain) is estimated to have enhanced farm income from biotech maize by US$254 million in the period 2006 to 2014 and the benefits for 2014 alone is US$28 million.

The European Union comprises 28 states (as of July 2015, with the ascension of Croatia), a population of almost 507 million (7% of global) with a GDP in 2015 of more than US$14 trillion, equivalent to over 18% of global GDP. Around 2% of the EU's workforce is employed in agriculture and the principal major crops occupy just over 90 million hectares (versus 1.5 billion hectares globally) of which maize is 13 million hectares, about 10% of global hectarage. There are approximately 15 million farms in the EU; Romania has the largest number of farms (almost a third of the EU total, followed by Poland, Italy and Spain). Table 35 summarizes the planting of Bt maize in the countries of the European Union from 2006 to 2015.

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All five EU countries which grew Bt maize commercially in 2015 provided benefits to farmers, to the environment and a more affordable feed source for animals, which in turn benefited consumers who eat meat. As of October 2015, 86 biotech crop events have been approved for food, feed and processing: oilseed rape (12 events), cotton (11), maize (41), potato (1), soybean (13), sugar beet (1) and the ornamental carnation (7 events). In 2015 alone, 22 events were approved by the EU including 1 canola, 5 soybean, 4 cotton, and 1 maize (ISAAA GMO Approval Database, 2015).

Table 35. Hectares of Bt Maize Planted in EU Countries in 2006 to 2015*

	Country	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	Spain	53,667	75,148	79,269	76,057	76,575	97,326	116,307	136,962	131,538	107,749
2	Portugal	1,250	4,263	4,851	5,094	4,868	7,724	9,278	8,171	8,542	8,017
3	Czechia	1,290	5,000	8,380	6,480	4,680	5,091	3,080	2,560	1,754	997
4	Romania*	– –	350	7,146	3,244	822	588	217	220	771	3
5	Slovakia	30	900	1,900	875	1,248	761	189	100	411	104
6	Germany*	950	2,685	3,173	– –	– –	– –	– –	– –	– –	– –
7	Poland	100	327	3,000	3,000	3,000	3,000	N/A	– –	– –	– –
	Total	**57,287**	**88,673**	**107,719**	**94,750**	**91,193**	**114,490**	**129,071**	**148,013**	**143,016**	**116,870**

* 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 ISAAA.

GMOs in the European Union

On 2nd April 2015, the European Commission made a significant change in the process of the EU authorization for cultivation of genetically modified organisms (GMOs) (EC, 2015a). The decision bifurcates the current authorization into a two-tier regulatory system for GMOs. The current authorization has evolved over a period of three decades. The bifurcation decision would allow Member State(s) to restrict, or prohibit the use of EU-authorized GMOs for cultivation on their territory. This "opt-out" provision legalizes the individual Member State to accept or reject the EU's authorization on the placing of GMOs in the common EU market. The EU authorization follows a case-by-case risk assessment of GMOs by the European Food Safety Authority (EFSA). Notably, the Member State(s) can now decide on whether to accept or reject the cultivation of EU authorized GMOs on their territory based on reasons other than risk on health and environment.

Subsequently, on 22 April 2015, the European Commission (EC) initiated a similar proposal to amend the EU authorization of GMOs for food and feed imports into their territory (EC, 2015b). If it had been adopted by the EU Parliament and the Council, the "Opt-Out" provision would allow Member State(s) to decide to re-import and use in the EU-authorized GMOs in food and feed on their territory. The "Opt-Out" provision on imports of biotech crops could disrupt the internal trade of grain, food and feed products, and could jeopardize the unified common EU market. As of 15 October 2015, EU members rejected the opt-out imports of GM grain.

The EU regulation for authorization of GMOs applies to both the cultivation of GMOs and use of GMOs for food and feed purpose. The GMOs for food and feed include the products;

– containing or consisting of genetically modified organisms (GMOs), and

– produced from, but not containing, genetically modified organisms (GMOs)

For this purpose, the EU legislation defines GMOs as "organisms in which the genetic material (DNA) has been altered in a way that does not occur naturally by mating and/or natural recombination" (Plan and Eede, 2010). The EU authorization follows a science based risk assessment and creates a unified community system for assessment of GMOs from the point of view of public health and environment before they are placed on the market within the community. The EU authorization covers both GMOs for cultivation and GMOs for food and feed. The GMOs for cultivation refers to the deliberate release into the environment of genetically modified organisms (GMOs) for planting purpose. With the new EU directive 2015/412, the Member State(s) are allowed to accept or reject the EU authorized GMOs for planting in their territory. As a consequence, Scotland became the first country to consider the rejection of the EU authorized GMOs to be planted in their territory, and by 3 October 2014, the deadline of application, 19 countries have indicated their decision to opt-out of planting GM crops (Forbes, 5 October 2015). Bt maize Mon810 event, is the only biotech crop authorized by the EU regulatory system for cultivation in the EU in 1998. In 2015, five countries planted approximately 116,870 hectares of Bt maize (Mon810 event) in the European Union.

In addition to "Opt Out" provision on cultivation of GMOs to Member State(s), the EU deliberated on a proposal to extend the "Opt Out" provision on GMOs that are imported for food and feed use. Imported GMOs for food and feed refer to the food & feed items and processed products either containing or derived from GMOs imported for the purpose of food and feed use within the community. The new proposal from the EC would create a two-tier system where the Member State(s) can either accept or reject the EU authorized GMOs imported for food and feed use. At present, the EU imports approximately 30 million tons of grains and/or meal either containing or derived from GMOs for food and feed consumption by the Member State(s) (EuropaBio, 2015). The EU authorizes the import of GMOs grains and meals and such authorization is binding on all member States. Additionally, the EU regulation for authorization mandates the labeling requirements for the presence of genetically modified organisms in the food and food products sold in the European market except the bulk consignments. All food and food products must carry a label for the presence of traces of the approved GMOs at a percent threshold of 0.9. Such products containing the traces of GMOs not approved in the EU for consumption, irrespective of their threshold cannot be put on the market, regardless of whether or not they are labeled. The EU Environment Committee rejected the bill in 13 October (Reuters, 13 October 2015) and finally rejected by the Parliament on 28 October, 2015 with 577 votes (against) to 75 votes (for) (ICSTD, 4 November, 2015).

Status of GMO Approval in the EU

In the last three decades, the European Commission (EC) approved only one GM crop, Bt maize expressing Mon810 event for commercial cultivation and food and feed use in the EU in 1998. Subsequently, many EU member countries planted Bt maize over thousands of hectares. In 2015, five EU countries planted Bt maize of 116,870 hectares. The Bt maize growing countries include Spain, Portugal, Czechia, Slovakia and Romania. In the past, Germany and Poland planted Bt maize over a limited area and discontinued in 2009 and 2012, respectively. In addition to Bt maize, the EC authorized a strain of GM potato known as Amflora potato event EH92-527-1 that produces pure amylopectin starch, developed by BASF Plant Science in 2010. In the following year, Amflora potatoes were grown on two hectares in Germany. In

2011, BASF discontinued the cultivation of Amflora potatoes due to widespread popular and political resistance and subsequently decided to halt the commercialization of GM crops in the EU in 2012. As of 2015, Bt maize remains the only GM crop to be cultivated by five EU member countries.

In the interim, the EU has authorized 79 events (including those which have expired) of biotech cotton, maize, soybean, oilseed rape and sugar beet for importation of grains for food and feed use from 1998 to 2015. The 79 GMOs consists of 12 events of oilseed rape, 11 events of cotton, 41 events of maize, 13 events of GM soybean, one sugar beet event, and 1 potato event (ISAAA GMO Approval Database, 2015). Crops developed with these events express either single Bt and HT trait or stacked with Bt and HT traits (JOCAM, 2015). The grains, meals and food products of the GM crops are imported from North and Latin America and consumed for food and feed purpose. In addition, the EC has authorized the production of one event of GM bacterial biomass and one event of GM yeast biomass for the production of feed additives for animals. Therefore, as of 2015, the EU is importing and consuming a large quantity of GMO grain, meal, edible oil and food products either containing or derived from GMOs.

Generally, approval of GM crops has been relatively slow in the EU compared to other countries. As of May 2015, there were 41 biotech events of oilseed rape, cotton, maize, and soybean single and stacked traits for insect resistance, herbicide tolerance, and product quality that are waiting approvals in the EU.

KWS and Syngenta are developing winter sugar beet for future cultivation in the EU. Sugar beet growers in the EU would be facing a yield efficiency challenge in planting sugar beet if they do not adopt biotech sugar beet in the very near future. Existing GM seed that are being adopted in the USA had fostered an average annual increase of 0.55 tonnes per hectare of sugar beet, 69% more than the conventional ones. The upcoming biotech winter beet being developed has shown increased yield of 20-30%. It is now up to the EU regulators how fast they can approve commercialization of biotech sugar beet which produce sugar similar to the conventional seed at molecular level, and environmentally safe with fewer herbicide application and reduced use of machinery and fuel.

A study by EMBO (Fagerström, et al. 2012) reported that EU farmers denied of the privilege of using biotech sugar beet, potato and canola, are costing them and the EU annually of 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 endeavors, 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."

EU member state farmers who opt to plant biotech and/or non-biotech crops are required by Law to apply coexistence measures to preserve their identity in accordance with relevant labeling rules. This includes minimum distances between fields with and without GM, that allow GM and non-GM crops to be grown in the same area and transported and sold side by side. A study conducted by the Technische Universitat Munchen led by Prof. Justus Wesseler has studied the implementation and cost of coexistence strategies for farmers, agri-food supply chain operators and supply chain in a project called PRICE. Some 1,473 farmers in Germany, Spain, Portugal and the UK were surveyed. The study revealed that the current measures implemented to ensure coexistence in the EU are practically feasible, both at farm level and along the supply chain. However, these measures come with additional costs, which are partly paid by consumers and other supply chain stakeholders. In addition, lower thresholds or other stricter measures would cause difficulties for the supply chain on non-GM feedstock (Food Science Technology Journal News, 1 June 2015).

Import of GMOs in the EU

The EU imports a large quantity of GMOs for food and feed purpose. A substantial portion of imported GMOs is meant for animal feed to meet the growing demand from poultry, pig, beef and other livestock sectors. The EU imports approximately 40 million tons of GMOs every year from GMO-producing countries in North and Latin America. The EU imported GMOs come in varied forms ranging from GMO grains, meal, cake, distiller dried grains (DDGs) and corn gluten feed (CGF) primarily used for livestock feeds. In addition, the EU imports various processed food products either containing or derived from GMO crops like soybean, maize, canola and sugar beet. Of the 40 million tons of imported GMOs, approximately 35 million tons consist of soymeal and soy grains, roughly 22 million tons of soymeal and 13 million tons of soy grains. Remaining 5 million tons of imported grains comprises 2.5 million tons of maize (grain, corn gluten feed and Distiller dried grain), 2 million tons of oilseed rape (both meal and edible oil) and 0.1 million tons of cotton (cake and fibre) (Table 36). Majority of European farmers rely on imported grain and meal for feeding their livestock (Europabio, 2015; EC, 2015c).

It is estimated that the EU imports approximately US$12.5 billion worth of GMO soybean products alone every year (Dalton, 2015). The imported GMO soybean products meet 90% feed requirement for animal feed of the EU member countries. Four countries including Brazil, the US, Argentina and Paraguay supply majority of soybean products to the EU. However, differences in GM crop regulations between the US and European Union will make transatlantic trade deal difficult, according to the US Department of Agriculture Secretary Tom Vilsack. He opined at the G20 agriculture ministers meeting held in Istanbul that "You can't use and create a system of open or free trade if you are creating ways in which countries can develop barriers to products for political or cultural reasons," Vilsack pointed out the recent European Commission proposal to give member governments control over GM crops. "You ought to give people the choice, then let the market decide," he suggested. He also emphasized that GM crops enable more production under difficult circumstances, expanding the food supply and

Table 36. Import of GMOs by the EU

Year	Value (Millions of US$)
Soybean	13.0
Soymeal	22.0
Maize	2.5
Oilseed Rape	2.0
Cotton	0.1
Total	**~40.0**

Source: EuropaBio, 2015.

lowering food prices. Thus, Americans are spending around 10 percent of pay for food (Crop Biotech Update, 13 May 2015).

Stakeholder Support for GM Crop Policy in EU

Scientists of Thirty Research Organizations Unite to Support GM Crops in Scotland
In August 2015, Scotland's Environment Minister said that the country is set to ban genetically modified crops to protect the country's "clean and green status" as well as its £14 billion food and drink sector. Thirty research organizations including Edinburgh University, Roslin Institute, the Eden Project and the National Farmers Union and the Science Council) signed an open letter accusing the Scottish environment secretary of taking political decisions not based on scientific evidence (The Guardian, 18 August 2015). The letter's signatories said: ***"By banning their use in Scotland, this country would be prevented from benefiting from future innovations in agriculture, fisheries and healthcare, and consigned to continued use of the old. We are thus extremely concerned about the potential negative effect on science in Scotland."*** Noted ministers and scientists also expressed their concerns towards the move to ban GM crops:

Professor Huw Jones, a leading scientist and professor of molecular genetics at Rothamstead Research Institute in Scotland described the planned ban as ***"a sad day for science and a sad day for Scotland."*** He also countered that ***"GM crops approved by the EU are safe for humans, animals and the environment and it's a shame the Scottish parliament think cultivation would harm their food and drink sector"*** (Arstechnica.com, 10 August 2015).

Dame Anne Glover, of the University of Aberdeen, UK, and former chief scientist to the European commission, agreed, with Huw Jones' remarks that the safety of GM crops has been "supported by a global scientific consensus." She added that GM crops could also be capable of fulfilling the Scottish government's stated desire to enhance the country's clean, green status. ***"With appropriate choices, GM technology can offer one approach to sustainable farming by reducing the need for chemical inputs which benefits the consumer, the farmer and the environment"*** she said (RSC.org, 12 August, 2015). More recently, Dame Glover opined that the ban in Scotland, designed to provide "green and clean products" will in fact result in quite the opposite and condemn Scotland to "old and dirty" technologies for food and feed production. **Conservative MSP Murdo Fraser** also condemned the ban, saying, ***"All the SNPs stance will do is drive research out of Scotland into other parts of the UK and Europe and send the message that this Government prefers superstition to science"*** (The Guardian, 9 August, 2015).

National Farmers Union, Scotland described the decision as naive and taken without an adequate debate. Scott Walker, chief executive of NFU Scotland, said: ***"Other countries are embracing biotechnology where appropriate and we should be open to doing the same here in Scotland... Decisions should be taken on the individual merits of each variety, based on science and determined by whether the variety will deliver overall benefit. These crops could have a role in shaping sustainable agriculture at some point and at the same time protecting the environment which we all cherish in Scotland,"*** (Arstechnica.com, 10 August 2015).

At the closing date of Opt-Out application to the new EU rule of 3 October, 2015, 19 countries (Austria, Belgium (Wallonia), Bulgaria, Croatia, Cyprus, Denmark, France, Germany (except research), Greece, Hungary, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Slovenia, UK (NI, Wales and Scotland) opted to prohibit planting of biotech crops, and 11 countries (Belgium (Flanders), Czech Rep, Estonia, Finland, Ireland, Portugal, Romania, Slovakia, Spain, Sweden, UK (England) opted to continue to field test and commercialize biotech crops. The new EU rule (Directive 2015/412) permits the cultivation of GM crops by EU countries if they are deemed "healthy and safe". The law, adopted in March 2015 and came into force in April, cleared the way for new GM crops to be approved after years of deadlock. However the new rule also gave individual countries the right to ban or grow biotech crops. It is notable that all five countries (Spain, Portugal, Czechia, Slovakia and Romania) currently growing Bt maize (MON 810) have all elected to continue to grow biotech crops. They know from first hand experience that GM crops generate value, they are also anxious not to miss-out on benefits from superior future technologies, such as genome-edited crops.

Biotech Endorsement by EU's Scientific Bodies and Stakeholders

The agriculture committee of the European Parliament rejected the Commission's draft law that would give member states the power to restrict or prohibit the use of EU-approved GM food or feed on their territory. It fears that arbitrary national bans could distort competition on the EU's single market and jeopardize the Union's food production sectors which are heavily dependent on imports of GM feed. The agriculture committee's opinion, adopted by 28 votes in favor to eight against, with six abstentions, was closely looked at by the environment committee, which has the lead on this file. Albert Dess, draftsman of the opinion, said, ***"Today's vote in the agriculture committee sends a clear message: the Commission's proposal to allow member states to decide whether or not to restrict or ban the use (import) of GM food and feed on their territory must be rejected. We have not been building the EU's single market to let arbitrary political decisions distort it completely."*** Dess added that the Commission's approach is completely unrealistic, as many sectors in the EU greatly rely on GM feed imports, and would not be able to survive if it is banned (Crop Biotech Update, 8 September 2015). As of 14 October, the EU Environment Committee rejected the bill (Institute of Food Technologists, 14 October, 2015) and the whole parliament rejected the draft law on 28 October, 2015 (ICSTD, 4 November 2015).

Farmer Testimonies and Stakeholder Views

Stephen Tindale, former Greenpeace UK member accused green groups (including Greenpeace) of ***"putting ideology before the need for humanitarian action by repeatedly targeting the development of GM crops in the UK."*** On the issue of biosafety, he said, ***"The overwhelming majority of scientists think that it is safe. It is in my view unacceptable, morally unacceptable to stand out against these new technologies."*** Mr. Tindale decided to speak out on GMO because ***"I think it is necessary for people like me who've opposed it to say things have changed. I think it should be a case by case basis, what is being done for and is worth taking the risk"*** (Telegraph UK, 8 June, 2015).

U.K. farmer Paul Temple farms 340 hectares of wheat, barley, oilseed rape, peas, maize and potatoes and once lobbied to keep GMO crops out of Europe. However, after he saw how they could boost farm productivity and sustainability first hand, he changed his mind. Today, he is one of the strongest proponents for the technology. He said ***"Seeing the benefits first hand opened my mind to the new breeding technique. We could leave weeds within the crop over winter to benefit wildlife, the herbicide was easier to use and less harsh on the crop and our yields increased. We could tolerate weeds knowing we would be able to control them properly and precisely post-emergence.***

After three years I felt properly informed and offered to share my practical experience about the benefits of the technology....We need education to show that the technology is sustainable both environmentally and economically. For example if people and politicians realized that something like 90% of their packets of meat were from animals fed on GM, they would see how important the technology is for affordable food. Farmers need to be educated too. Rather than being shown PowerPoints with graphs going up and down they need to see the success of the crop in the field and the choice it offers, like I did" (CropLife, 4 March 2015).

CUBA

In 2015, Cuba continued to work on biotech crops, whilst reassigning top priority to the production of maize hybrids that will form a foundation for the biotech maize initiative. The plan is to reinitiate the program for producing improved Bt maize hybrids in two years' time. In order to optimize the progress with hybrid maize, the provision of small amounts of Bt maize to farmers has been temporarily discontinued and is planned for resumption in 2 years time. In 2012, 2013 and 2014 Cuban farmers were provided annually with a small amount of Bt maize to plant commercially on about 3,000 hectares. In 2012, 2013 and 2104, biotech Bt maize was planted in a "regulated commercialization" initiative, in which selected farmers sought permission to grow biotech maize commercially. The initiative is part of an "ecologically sustainable pesticide-free program" featuring biotech maize hybrids and mycorrhizal additives. Reinitiation of the biotech maize initiative in Cuba is anticipated in two years' time, subsequent to the establishment of an effective hybrid maize program to meet the demands of Cuban farmers. Progress with Bt maize in Cuba over the last three years has been encouraging. The Cuban Bt maize is resistant to the major pest, fall armyworm, and was developed by the Havana-based Institute for Genetic Engineering and Biotechnology (CIGB). Extensive field tests in Cuba have demonstrated that the significant and multiple benefits associated with Bt maize are similar to those reported by other countries, which have already commercialized Bt maize on over 6 million hectares in 2015 alone. These benefits include, reduction in insecticides for the control of fall armyworm, less exposure of farmers and the environment to pesticides, protection of the enhanced diversity of more prevalent beneficial insects, and sustainable increases in productivity of up to 30%, or more. This depends on the severity of the armyworm infestation, which varies significantly with climatic and ecological conditions.

Cuba, a country of 11 million people, imports around 60% of its food and feed including large tonnages of maize, soy and wheat. Cuba has assigned high priority for increased agricultural output to contribute to "national security" following the unprecedented global food price crisis in 2008. Food and feed imports were valued at US$1.5 billion of foreign exchange in Cuba in 2009. During the food crisis of 2008, the situation was exacerbated by 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.

Cuban food production continues to increase, with an increase in rice production by 44.6% from 2008 to 2009, from 207,500 to 300,000 tones. With President Raul Castro in 2008, the state decentralized agricultural decision-making and distribution; leased 50% of vacant state lands to 100,000 individuals as well as private and state-owned cooperative farms. There was a continuous development and use of biopesticides which saved the Cuban economy US$15 million annually. Cuba has been importing 80% of its food and has received US agricultural exports on a limited basis since 2001, under a complicated payment system that requires prepaid cash or letters of credit handled by banks in third countries. Minnesota exported to Cuba maize, soybeans and soybean meals worth about US$26 million in 2012, and some US$20 million in 2013. With the introduction of the Freedom to Export to Cuba act by Sen. Amy Klobuchar, D-Minn in early 2015, more trade exchanges is expected in the future (Star Tribune, 27 February, 2015).

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.

An initiative for "regulated commercialization" was underway in Cuba in which selected farmers sought permission to grow about 3,000 hectares biotech maize "commercially" annually in 2012, 2013 and 2014. The regulated commercialization program in Cuba was similar to the situation in several EU countries where farmers seek permission to grow Bt maize. In 2012, 2013 and 2014, the regulated commercialization program featured hybrid Bt maize covered up to 3,000 hectares. In 2015, Cuba continued to work on maize hybrids as the top priority with a view to producing improved Bt maize hybrids in about two years time. In order to optimize the progress with hybrid maize, the provision of small amount of Bt maize to farmers has been temporarily discontinued and is expected to resume in about 2 years time. The aim of increasing this Bt maize hybrid hectarage substantially over time is to increase domestic maize production in Cuba with less reliance on imported maize. In a landmark development, Cuba was included since 2012 in the group of countries that were cultivating biotech crops.

The Bt maize being developed by Cuba is similar to that grown on over 50 million hectares in 16 countries. Thus, Cuba has the advantage of benefiting from 20 years of commercialization by a large number of countries in all continents of the world, including several EU countries, which have been successfully growing and benefiting from Bt maize for more than a decade, and which also import large tonnages of biotech crops. The potential benefits of commercializing Bt maize in Cuba are significant. The latest published import information indicated that Cuba imported significant tonnages of maize ranging from 599,917 tons in 2006 valued at approximately US$86 million to approximately 700,000 tons in 2007 to 2009 valued at up to US$200 million (Table 37). Some of these imports could be substituted by domestic production, if the yield losses due to armyworm alone, which are up to 30%, are controlled, thus making the country substantially more self-sufficient in maize production. This is a very important benefit to Cuba because the alternative is to keep relying on maize imports, which are likely to become more expensive as prices of staples trend upwards in the future. Work is also underway in Cuba to develop biotech soybean, potatoes and tomato, but unlike Bt maize, these biotech crops are at the R&D stage.

Scientists in Cuba began to explore the genetic modification technology in 1980. A team of researchers at the Center for Genetic Engineering and Biotechnology (CIGB), one of the most prestigious Cuban institutions devoted to research on plant and animal transgenesis are now studying biotech soybean and maize with insect resistance and herbicide tolerance as well as rice, tomato, and sweet potato for resistance to various pathogens and herbicide tolerance. Field trials are already being planned for a few thousand hectares in the country. Although there are questions on biosafety of the technology, the Center scientists believe that there has been no important or categorical conclusion saying that transgenics provoke health problem on plants and animals. The controversy over GM foods shows the importance of accessing to information to promote social control over this technology. A recent study by the Cuban researcher Manuel Álvarez Gil reveals that 73% of people in Cuba do not know about genetically modified food, partly because it is a matter of relative novelty.

To follow through the safety process, various Cuban regulatory agencies closely monitor the development of transgenics for food, feed and environmental safety. Among them are: the National Biosafety Centre, the Institute of Nutrition and Food Hygiene and the Institute of Hygiene, Epidemiology and Microbiology. The technology is being looked in the country as a service of society without economic and social conflicts in its use. It has also been realized that the importance of access to information on biotechnology by the citizens will allow them to participate in decision-making on the use of the technology and conscious consumption of biotech foods and products (On Cuba Magazine, 27 March 2015).

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

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

Source: Annuario Estadistico de Cuba, 2009 * metric tonnes

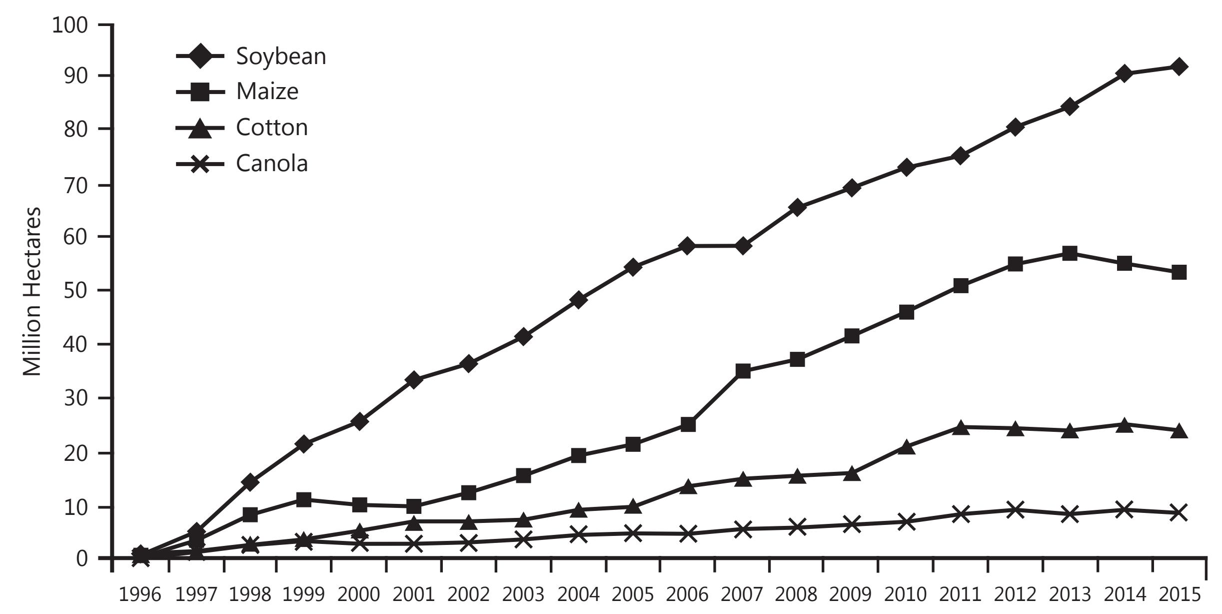
Distribution of Biotech Crops, by Crop

The distribution of the global biotech crop area for the four major crops is illustrated in Figure 23 and Table 38 for the period 1996 to 2015. In 2015, the four biotech crops are planted by up to 17 to 18 million farmers in 179.7 million hectares. Of the four biotech crops, hectarage of biotech soybean is the only one that has increased between 2014 and 2015; the principal reason for the decreases in biotech maize, cotton and canola is due to lower total plantings by farmers because of low prices. The data clearly shows the continuing dominance of biotech soybean occupying 51% (92.1 million hectares) of the global area of biotech crops in 2015. With the exception of about ~12.9 million hectares of the stacked soybean (HT/Bt) in four countries in Latin America (Brazil, Argentina, Paraguay and Uruguay), the entire biotech soybean hectarage is herbicide tolerant at 79.2 million hectares. As predicted in ISAAA Brief 46 for 2013 and Brief 49 in 2014 the stacked soybean product HT/Bt penetrated deeply in 2015 into tropical areas of four countries in South America. Biotech soybean retained its position in 2015 as being by far the biotech crop occupying the largest area globally, at 92.1 million hectares, 2% higher than the 90.7 million hectares in 2014. Biotech maize had the second largest area at 53.6 million hectares, with decrease in hectarage of 1.6 million hectares, due to farmers shifting from maize to soybean and the high reserve stocks. Upland biotech cotton hectarage was reduced to 24.0 million hectares in 2015 (-4%) from the 25 million hectares grown in 2014 due to low global price leading to decreased total cotton planting. Canola reached 8.5 million hectares in 2015, down 6% compared with 9 million hectares in 2014. Sugar beet was first commercialized in the USA and Canada in 2007, and quickly plateaued at a high adoption rate of 96% in 2011, 2012 and 2013, 98.5% in 2014, and 100% in 2015, becoming the biotech crop with the fastest adoption rate. RR®alfalfa, first grown in 2006, had a five-year gap of no planting, pending legal clearance, and then occupied ~200,000 hectares in 2011; this was equivalent to approximately 15% of the 1.3 million hectares seeded in the USA in 2011. In 2012, another estimated 225,000 hectares were planted for a total of 425,000 hectares and again 325,000 hectares in 2013, 862,000 hectares in 2014 and to ~1 million hectares in 2015. This is likely to increase in the near term as the newly-approved reduced lignin alfalfa is commercialized in 2016. Small hectarages (1,000 hectares each) of biotech virus-resistant squash, papaya and sweet corn continued to be grown in the USA. China also grew a total of 6,985 hectares of biotech papaya in 2015 compared to 8,475 hectares in 2014, a decrease of 17%, due to over supply in the market place. Guangxi province planted its first biotech papaya in 2014 at 2,000 hectares, with a 90% adoption rate. A total of 543 hectares of Bt poplar were grown in China.

Biotech soybean

In 2015, biotech soybean accounted for 51% 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 2015 was 92.1 million hectares, up by ~1.4 million hectares, or 2% from 2014 at 90.7 million hectares. The increase resulted from higher adoption in Brazil, Argentina, the USA, Bolivia, and Mexico. Of the 11 countries which reported growing biotech soybean in 2015, the top three countries growing by far the largest hectarage of herbicide tolerant and HT/Bt soybean were the USA (32.4 million hectares), Brazil (30.3 million hectares) and Argentina (21.1 million hectares). The other eight countries growing RR®soybean in decreasing order of hectarage include Paraguay, Canada, Uruguay, Bolivia, South Africa, Mexico, Chile and Costa Rica. Of the global hectarage of 111 million hectares of soybean (latest data of FAO, 2015), an impressive 83% or 92.1 million hectares were RR®soybean and HT/IR soybean. In 2015, drought tolerant soybean was

Figure 23. Global Area of Biotech Crops, 1996 to 2015: by Crop (Million Hectares)



Source: Clive James, 2015.

Table 38. Global Area of Biotech Crops, 2014 and 2015: by Crop (Million Hectares)

Crop	2014	%	2015	%	+/–	%
Soybean	90.7	50	92.1	51	+1.4	+2
Maize	55.2	30	53.6	30	–1.6	–3
Cotton	25.1	14	24.0	13	–1.1	–4
Canola	9.0	5	8.5	5	–0.5	–6
Sugar beet	0.5	<1	0.5	<1	<1	<1
Alfalfa	0.9	<1	1.0	<1	+0.1	+11
Papaya	>0.1	<1	<1	<1	<1	<1
Others	<0.1	<1	<1	<1	<1	<1
Total	**181.5**	**100**	**179.7**	**100**	**–1.8**	**–1**

Source: Clive James, 2015.

approved for commercialization in Argentina which increases the roster of biotech soybean that will cater to the needs of farmers in marginalized and stressed conditions.

The increase in income benefits for farmers growing biotech soybean during the 19-year period 1996 to 2014 was US$47.8 billion and for 2014 alone, US$6 billion (Brookes and Barfoot, 2016, Forthcoming).

Biotech maize

In 2015, 53.6 million hectares of biotech maize were planted compared to 55.2 million hectares in 2014, representing a decrease of 3%, equivalent to ~1.6 million hectares. The reduced planting is mainly due to a 4% decreased planting in the US, with several other countries also decreasing maize hectarage marginally in favor of the less demanding soybean in 2015. It is noteworthy that 17 countries grew biotech maize in 2015 with Vietnam joining the biotech maize-planting countries in 2015. There were five countries which grew more than 1 million hectares of biotech maize in 2015 in decreasing order of hectarage they were: USA (33.1 million hectares), Brazil (13.1 million), Argentina (2.9 million), South Africa (1.8 million) and Canada (1.4 million hectares). Modest decreases were reported by the other countries including five EU countries which planted 116,870 hectares of biotech Bt maize in 2015, equivalent to an 18% decrease over 2014 of 143,016 hectares. The five EU countries, in decreasing order of hectarage were Spain, Portugal, Czechia, Slovakia and Romania. An important feature of biotech maize is stacking, which is discussed in the sections on countries and traits.

Of the global maize hectarage of 185 million hectares (the latest data of FAO, 2015), grown in 17 countries in 2015, 29% or 53.6 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. With the continuing beneficial adoption of drought tolerant maize in the USA and by 2017 in Africa, biotech maize adoption will likely increase with more countries facing drought stress due to climate change. 2015 was the hottest year in recent times indicating that climate change is already generating temperature regime changes. Coincidentally, maize continued to be used for ethanol production in the US, estimated at approximately 40% of total maize hectarage in 2015.

The increase in income benefits for farmers growing biotech maize during the 19 years (1996 to 2014) was US$50.6 billion and US$7 billion for 2014 alone (Brookes and Barfoot, 2016, Forthcoming).

Biotech cotton

The area planted to biotech upland cotton globally in 2015 was 24 million hectares down from 25.1 million hectares in 2014, a decrease of 4%. A total of 15 countries grew biotech cotton in 2015 and four grew more than 1.0 million hectares, in descending order of hectarage, they were: India (11.6 million hectares), China (3.6 million), USA (3.4 million), and Pakistan (2.9 million hectares). Another 11 countries grew biotech cotton in 2015, for a total of 15 countries.

RR®Flex cotton was introduced in the USA and Australia for the first time in 2006 and was widely grown in 2015. In 2015, biotech hybrid cotton in India, the largest cotton growing country in the world, occupied 11.6 million hectares of approved Bt cotton despite almost optimal levels of adoption which reached 95% in 2015. The advantages of Bt cotton hybrid in India are significant and the increased adoption in 2015 at low national and global cotton hectarages 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 on 115,000 hectares in 2009 to 247,000 hectares in 2011, over 300,000 hectares in 2012, 474,229 hectares in 2013, 454,124 hectares in 2014 (with the highest adoption of 73.8%) and 350,000 hectares (0.4 million hectares) in 2015; the decrease was due to several factors discussed in the Burkina Faso chapter. Australia planted only 214,000 hectares biotech cotton in 2015 at over 99% adoption rate after a peak hectarage of almost 600,000 hectares in 2011. Lack of water/drought is the main element that determines the extent of cotton hectares in Australia; nevertheless, over 99% biotech adoption rate was maintained irrespective of the absolute hectarage of cotton. Based on the latest global hectarage in 2013 of 32 million hectares (latest FAO, 2015 data), 75% or 24.0 million hectares, were biotech cotton and grown in 15 of the 28 biotech crop countries worldwide.

The increase in income benefits for farmers growing biotech cotton during the 19-year period 1996 to 2014 was US$46.5 billion and US$4.1 billion for 2014 alone (Brookes and Barfoot, 2016, Forthcoming).

Biotech canola

The global area of biotech canola is estimated to have decreased by a significant 549,000 hectares or 6% from 9.0 million hectares in 2014 to 8.5 million hectares in 2015. Most of the increase came from Australia with a 102,000 hectares increase; decreases were reported in Canada and the USA due to reduced planting of total canola in 2015, compared with 2014. Only four countries currently grow biotech canola: Canada, the USA, Australia and Chile (for GM seed export only). The global hectarage and prevalence of canola could increase significantly in the near term in response to the likely increased use of canola for vegetable oil and biodiesel. Less than 1% of the canola crop in Canada is used for biodiesel; this is expected to remain low at around 2% until new biodiesel plants come on stream.

Of the global hectarage of 36 million hectares of canola (the latest data, FAO 2015), 24%, or 8.5 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 19-year period 1996 to 2014 was US$4.9 billion and US$0.6 billion for 2014 alone (Brookes and Barfoot, 2016, Forthcoming).

Biotech alfalfa

Herbicide tolerant RR®alfalfa was first approved for commercialization in the USA in 2005. The first pre-commercial plantings (20,000 hectares) were sown in the fall of 2005, followed by larger commercial plantings of 60,000 in 2006. The 60,000 hectares of RR®alfalfa represented approximately 5% of the ~1.3 million hectares of alfalfa seeded in 2006. Herbicide tolerance is probably the first of several traits that will be incorporated into this globally important forage crop. A court injunction in 2007 suspended further plantings of RR®alfalfa until a new dossier of information was submitted to the regulators for consideration. Before the injunction came into force, another 22,000 hectares were planted, bringing the total accumulated RR®alfalfa in the ground in the USA in 2007 to 102,000 hectares. There are approximately 8 to 9 million hectares of alfalfa grown for dry hay in the USA, annually worth ~US$7 billion. Unlike the large biotech row crops of soybean and maize, biotech alfalfa is a perennial and may occupy more of a niche market. 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, 862,000 hectares in 2014 (11% of total 7.4 million hectares), and up to 1 million hectares in 2015 (13% of total 7.4 million hectares).

Unlike adoption rates for the principal crops of soybean, maize and cotton, USDA does not publish adoption rates for biotech alfalfa – however observers familiar with the product opine that it could reach up to 50% in the near term when the stacked HT/low lignin that offers higher digestibility will be an added benefit attractive to alfalfa growers. In 2014, biotech low-lignin alfalfa was approved for cultivation in the US and is being considered for commercial planting in the US in 2016. The new low-lignin product, has less lignin, higher digestibility, and is claimed to also offer a 15 to 20% increase in yield and hence, is likely to be in high demand by farmers.

Other biotech crops

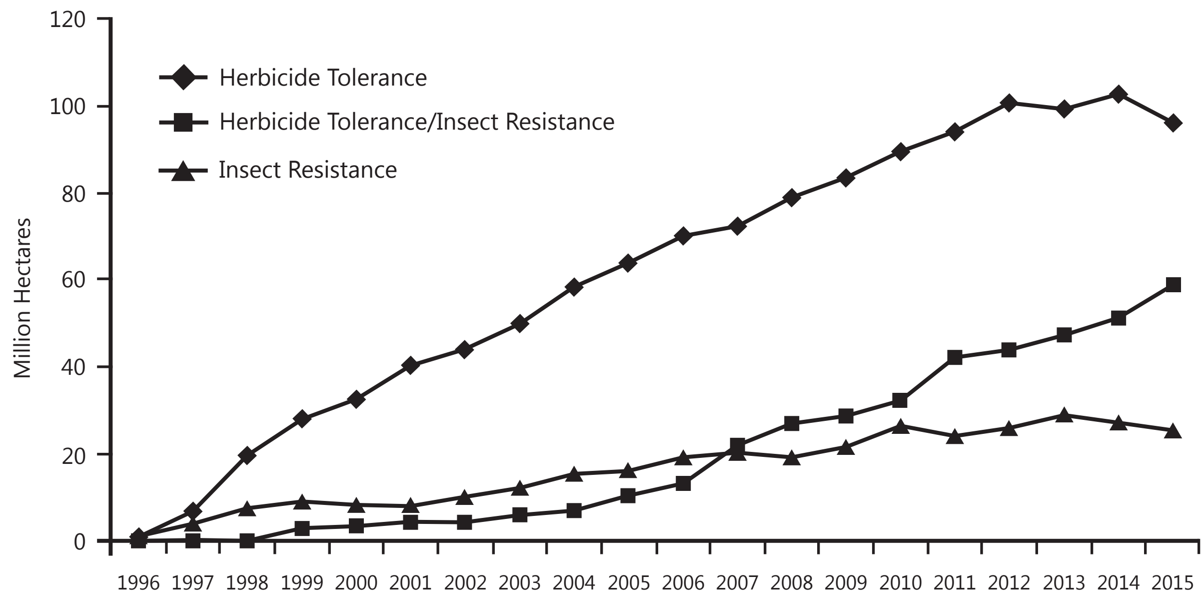
Biotech sweet corn in the US is very conservatively estimated at a minimal nominal hectarage of 1,000 hectares of the sweet corn hectarage of an estimated 300,000 hectares; no adoption data are available but it is certain to be well above the token 1,000 hectare estimate reported in this Brief. Small areas of biotech virus resistant squash (1,000 hectares) and PRSV resistant papaya in Hawaii (1,000 hectares) continued to be grown in the USA in 2015; the papaya industry in Hawaii was destroyed by PRSV and saved by the biotech papaya which is resistant to PRSV. China also grew a total of 6,985 hectares of biotech papaya in 2015 compared to 8,475 hectares in 2014 attributed to over-supply of papaya in the market place. Guangxi province planted its first biotech papaya in 2014 at 2,000 hectares, with a 90% adoption rate. A total of 543 hectares of Bt poplar were planted in China. Modest hectarages (400 acres or 160 hectares) of Innate™ Generation 1 biotech potato were planted for the first time in 2015 in the US. SU Canola™, a product developed by Cibus (using non-transgenic breeding through precision gene editing) was commercialized for the first time on an estimated 10,000 acres or 4,000 hectares in the US in 2015.

Distribution of Biotech Crops, by Trait

During the 20 year period 1996 to 2015, herbicide tolerance has consistently been the dominant trait (Figure 24). In 2015, herbicide tolerance, deployed in soybean, maize, canola, cotton, sugar beet and alfalfa occupied 95.9 million hectares or 53% of the 179.7 million hectares of biotech crops planted by up to 17 to 18 million farmers globally (Table 39); this compares with 102.6 million hectares equivalent to 57% adoption of the total biotech hectarage in 2014. Thus, herbicide tolerance (HT) decreased by a net 6.7 million hectares (7%) from 102.6 million hectares in 2014 to 95.9 million hectares in 2015. The big decrease in herbicide tolerant crops was in Brazil (5.1 million hectares), due to the large switch from HT soybean to Bt/HT soybean) followed by a significant decrease in HT canola in Canada. More modest decreases in HT were recorded in the USA, Argentina, Uruguay, South Africa, Paraguay, and the Philippines, with minimal increases in Australia, Mexico, Colombia, Chile and Honduras.

Stacked traits are favored by farmers in all countries for all crops and soybean is no different. Stacked traits increased from 51.4 million hectares in 2014 to 58.5 million hectares in 2015 – an increase

Figure 24. Global Area of Biotech Crops, 1996 to 2015: by Trait (Million Hectares)



Source: Clive James, 2015.

Table 39. Global Area of Biotech Crops, 2014 and 2015: by Trait (Million Hectares)

Trait	2014	%	2015	%	+/–	%
Herbicide tolerance	102.6	57	95.9	53	–6.7	–7
Stacked traits	51.4	28	58.5	33	+7.1	+14
Insect resistance (Bt)	27.4	15	25.2	14	–2.2	–8
Virus resistance/Other	<1	<1	<1	<1	<1	<1
Total	**181.5**	**100**	**179.7**	**100**	**–1.8**	**–1**

Source: Clive James, 2015.

of 7.1 million hectares equivalent to 14%. The large shift to stacked traits was due to an increase in Bt/Ht soybean principally in Brazil and to a lesser extent by its neighbors. Hectarage featuring insect resistance decreased by 8% from 27.4 million hectares in 2014 to 25.2 million hectares in 2015. The global decrease in cotton prices resulted in reduced total cotton plantings in cotton growing countries, principally in the US but also in China and to a lesser extent in other countries. Decreases in total cotton areas automatically reduced hectares of Bt cotton.

Generally, the changes in trait hectarage were mainly due to changes in the key countries of the USA, Brazil, Canada, China and South Africa. In addition, countries like Pakistan and Australia continued to report changes. 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, canola, and alfalfa. The Bt/Bt/IR stack refers to different Bt or other IR genes that code for different insect resistant traits, for example for maize, above ground pests, 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 notable for stacked traits at 14%, with consequent decreases in single trait herbicide tolerance at 7% and insect tolerance at 8% most of which was the net result of a mix of increases and decreases in many countries. The trend for increased use of stacks is expected to continue as country markets mature and more stacks 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 as well as in Innate™ potato generation 2 which was approved for cultivation in 2015 in the USA.

The deployment of stacked traits of different Bt genes and herbicide tolerance is becoming increasingly important and is most prevalent in the USA which had approximately two thirds (52%) of the 58.5 million hectares “stacked traits” in 2015 at 30.4 million hectares followed by Brazil at 36%. 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 in new countries. Adoption of HT/Bt in Brazil and neighboring countries increased very rapidly, close to 10 million hectares. In 2015, the other nine principal countries, of a total of 14, which deployed stacked traits were: Brazil (21.0 million hectares), Argentina (3.2), Canada (1.2), South Africa (1.0), Philippines (0.65), Paraguay (0.35), Uruguay (0.3), Australia (0.2 million hectares), and Mexico (0.1 million hectares). Colombia, Vietnam, Chile, and Honduras planted less than 0.1 million hectares of stacks 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. Vietnam in its first year of planting biotech crop employed stacked Bt/HT maize.

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, cotton, and important pro-poor vegetables such as eggplant. Both industrial countries like the US or Canada, as well as poor countries like Burkina Faso and Bangladesh have benefited from Bt genes and the potentials for the future is enormous.

Entomologist Dr. Anthony M. Shelton from Cornell University shares his views on insect resistance trait through the Bt gene (AM Shelton, 2013, Personal communication).

"The commercialization of plants expressing insecticidal crystal (Cry) proteins from *Bacillus thuringiensis* (Bt) for insect management has revolutionized agriculture and become a major tool for integrated pest management (IPM) programs (Shelton et al. 2002; Romeis et al. 2008). In 2011, Bt crops were grown on more than 66 million ha in 26 countries (James, 2011). Bt crops have provided economic benefits to growers and reduced the use of other insecticides (Shelton et al. 2002; Qaim et al. 2008; Kathage and Qaim 2012; Lu et al. 2012), suppressed pest populations on a regional basis (Carrière et al. 2003; Wu et al. 2008; Hutchinson et al. 2010), conserved natural enemies (Naranjo, 2009) and promoted biological control services in agricultural landscapes (Lu et al. 2012).

While this revolution in insect management in field crops should be applauded, it is unfortunate that these benefits have largely not been realized for vegetables. Although statistics for insecticide use worldwide are combined for vegetables and fruits (45% of total insecticide value), if vegetables were conservatively estimated to equal half of this total (22.5%), the insecticide use for vegetables would exceed that for corn (7.6%) plus cotton (14.1%) (Shelton, 2012).

Sweet corn has been the most successful Bt vegetable to date. Bt sweet corn was introduced into the North American market in 1998 by Novartis Seeds and was based on event Bt 11, which expresses Cry1Ab and had already been registered for field corn in 1996 (Such piggy-backing on an event registered for field corn substantially reduces registration costs for "minor crops" such as sweet corn). This product provided excellent control of the European corn borer (ECB) but lesser control of the corn earworm (CEW) which required supplemental foliar sprays under high CEW populations. As with Bt cotton and Bt field corn, there is a trend to using multiple Bt toxins in sweet corn to enhance performance across a range of species. Thus, trials conducted in Maryland and Minnesota under high CEW pressure indicated superior control, compared to Bt11, with sweet corn expressing both Cry1Ab endotoxin (Bt11 event) and the vegetative insecticidal protein VIP3A (MIR 162 event) (Burkness et al. 2010).

In 2010 and 2011, trials were conducted in New York, Minnesota, Maryland, Ohio and Georgia to test the efficacy of newly developed Bt sweet corn varieties (Seminis® Performance Series™) expressing Cry1Ab.150 and Cry2Ab2 proteins. Across all locations, Cry1A.105 + Cry2Ab2 plants produced 98% ears free from insect damage. In New York in 2010, this product provided ≥99% clean ears even under very high CEW pressure, without the use of any foliar sprays. This was in stark contrast to the non-Bt isoline that had only 18% clean ears even with 8 sprays of a commonly used pyrethroid insecticide. These new Bt varieties were commercialized in 2011.

The early varieties of Bt sweet corn, based on the Bt 11 event, were embraced by growers, but then got caught up in the anti-biotech fervor of the late 1990s and early 2000s. They have now regained much of their market share and the newer varieties, including the Seminis® Performance Series™, will lead to much larger adoption of Bt sweet corn. While the environmental, health and economic benefits of Bt sweet corn adoption are clear, misinformation can still challenge their adoption. It is noteworthy that in 2012, anti-biotech activists submitted a petition to Walmart, the world's largest food retailer, with 463,000 signatures urging them not to sell Bt sweet corn (Common Dreams, 2012). However, Walmart denied their request saying they had examined the issue and determined that the corn was safe."

Distribution of economic benefits at the farm level by trait, for the first 19 years of commercialization of biotech crops 1996 to 2014 was as follows: all herbicide tolerant crops at US$63.1 billion and all insect resistant crops at US$86.9 billion, with the balance of US$0.4 billion for other minor biotech crops. For 2014 alone, the benefits were: all herbicide tolerant crops US$8 billion, and all insect resistant crops US$9.8 billion plus a balance of US$0.07 billion for the minor biotech crops for a total of ~US$17.84 billion (Brookes and Barfoot, 2016, Forthcoming).

Global Adoption of Biotech Soybean, Maize, Cotton and Canola

Another way to provide a global perspective of the status of biotech crops is to characterize the global adoption rates as a percentage of the latest (FAO, 2015, with latest 2013 data) respective global areas of the four principal crops – soybean, cotton, maize and canola – in which biotechnology is utilized (Table 40 and Figure 25). The data indicate that in 2015, 83% (92.1 million hectares) of the 111 million hectares of soybean planted globally were biotech. Of the 32 million hectares of global cotton, 75% or 24 million hectares were biotech in 2015. Of the 185 million hectares of global maize planted, almost one-third (29%) or 53.6 million hectares were biotech maize. Finally, of the 36 million hectares of canola grown globally in 2015, 24% were herbicide tolerant biotech canola, equivalent to 8.5 million hectares. If the global areas (conventional plus biotech) of these four crops are aggregated, the total area is 364 million hectares, of which half (49%) or 179.7 million hectares were biotech in 2015 planted by up to 17 to 18 million farmers. 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 364 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 Approval of Biotech Crops

As of November 15, 2015, a total of 40 countries (39 + EU - 28) have granted regulatory approvals to genetically modified crops for use as food and/or feed use or for environmental release since 1994. From these countries, 3,418 regulatory approvals have been issued by regulatory authorities across 26 GM crops (not including carnation, rose and petunia) and 363 GM events. Of these approvals, 1,615 are for food use (direct use or for processing), 1,113 are for feed use (direct use or for processing) and 690 are for environmental release or cultivation. Japan has the most number of GM events approved (214), followed by USA (187 not including stacked events), Canada (161), Mexico (158), South Korea (136), Taiwan (104), Australia (102), New Zealand (90), Philippines (86), European Union (86 including approvals that have expired or under renewal), Colombia (73), South Africa (67) and China (60). Maize still has the most number of approved events (142 in 29 countries), followed by cotton (56 events in 22 countries), potato (44 events in 11 countries), canola (32 events in 13 countries), and soybean (31 events in 28 countries).

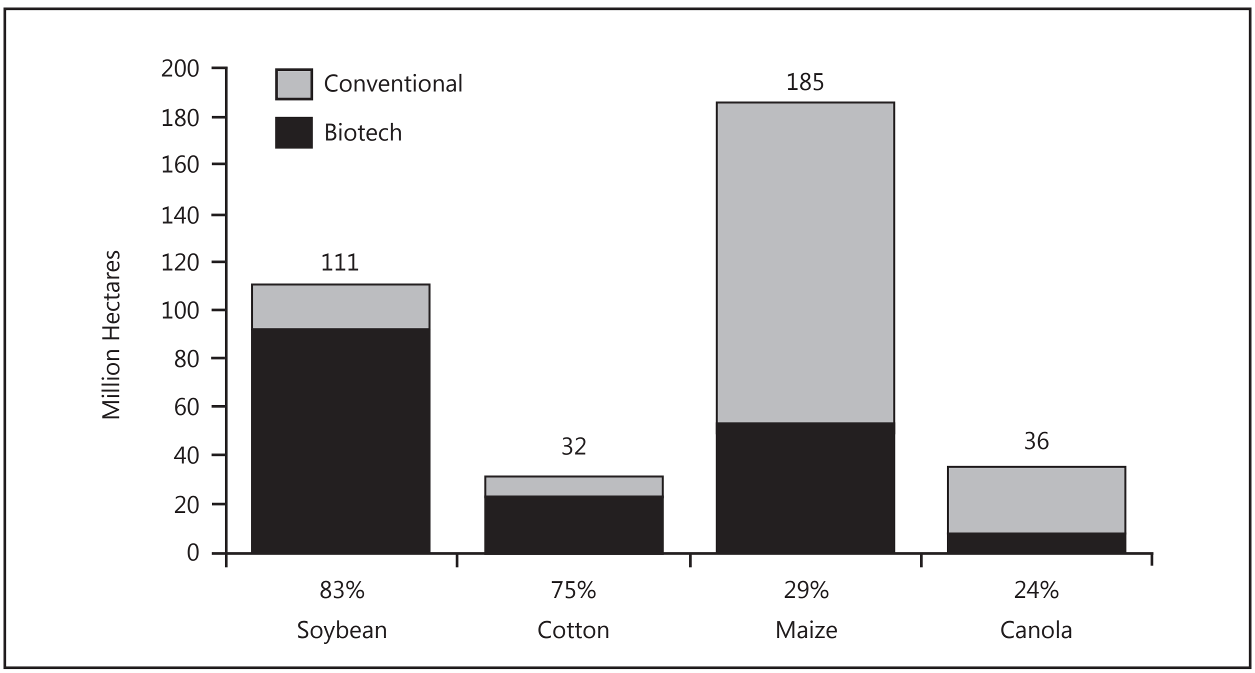
Table 40. Biotech Crop Area as Percent of Global Area of Principal Crops, 2015 (Million Hectares)

Crop	Global Area*	Biotech Crop Area	Biotech Area as % of Global Area
Soybean	111	92.1	83
Cotton	32	24.0	75
Maize	185	53.6	29
Canola	36	8.5	24
Others	—	1.5	—
Total	**364**	**179.7**	**49**

Source: Compiled by ISAAA, 2015.

*Latest FAO, 2015 (Global hectarage data for 2013)

Figure 25. Global Adoption Rates (%) for Principal Biotech Crops, 2015 (Million Hectares)



Global Hectarages Data for 2012 (FAO, 2013)
Source: Compiled by Clive James, 2014.

Among the GM events, the herbicide-tolerant maize event NK603 (54 approvals in 26 countries + EU-28) has the most number of approvals. It is followed by the herbicide-tolerant soybean event GTS 40-3-2 (52 approvals in 26 countries + EU-28), the insect-resistant maize MON810 (50 approvals in 25 countries + EU-28), the insect-resistant maize Bt11 (50 approvals in 24 countries + EU-28), the insect resistant maize TC1507 (48 approvals in 23 countries + EU-28), the herbicide-tolerant maize GA21 (47 approvals in 22 countries + EU-28), the insect-resistant maize MON89034 (46 approvals in 24 countries + EU-28), the insect-resistant cotton MON531 (41 approval in 21 countries + EU-28), the herbicide tolerant soybean A2704-12 (40 approvals in 22 countries + EU-28), the insect-resistant maize MON88017 (39 approvals in 21 countries + EU-28), the herbicide-tolerant maize T25 (38 approvals in 19 countries + EU-28) and the insect-resistant cotton MON1445 (38 approvals in 18 countries + EU-28). Details can be seen at ISAAA GMO Approval Database.

In December 8, 2015, the Supreme Court of the Philippines decided that the conduct of Bt eggplant field testing is permanently enjoined; the Department of Agriculture Administrative Order No. 08 series of 2002 is declared null and void; and consequently, any application of contained use, field testing, propagation and commercialization, and importation of genetically modified organisms is temporarily enjoined until a new administrative order is promulgated in accordance with the law.

The Global Value of the Biotech Crop Market

Global value of the biotech seed market alone was US$15.3 billion in 2015

In 2015, the global market value of biotech crops, estimated by Cropnosis was **US$15.3 billion** (down marginally by 3% from US$15.7 billion in 2014) (Table 38); this represents 20% of the US$76.2 billion global crop protection market in 2014, and 34% of the ~US$45 billion global commercial seed market (Appendix 3). The US$15.3 billion biotech crop market comprised: US$8.1 billion for biotech maize (equivalent to 54.8% of global biotech crop market, and down marginally from 8.6 billion or 6% in 2014); US$5.4 billion for biotech soybean, up 4% from US$5.2 billion in 2014 and 32.6% of the global biotech crop market; US$1.1 billion for biotech cotton (8.7% of global), US$0.39 billion for biotech canola (2.5% of global) and US$0.2 billion (1.4% of global) for sugar beet and others. Of the US$15.3 billion biotech crop market, US$10.9 billion (72%) was in the industrial countries and US$4.4 billion (28%) was in the developing countries. The market value of the global biotech crop market is based on the sale price of biotech seed plus any technology fees that apply. The accumulated global value for the 20 year period, since biotech crops were first commercialized in 1996, is estimated at US$148,808 million (Table 41).

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).

Table 41. The Global Value of the Biotech Crop Market, 1996 to 2015

Year	Value (Millions of US$)
1996	93
1997	591
1998	1,560
1999	2,354
2000	2,429
2001	2,928
2002	3,470
2003	4,046
2004	5,090
2005	5,714
2006	6,670
2007	7,773
2008	9,045
2009	10,607
2010	11,780
2011	13,251
2012	14,840
2013	15,610
2014	15,690
2015	**15,267**
Total	**148,808**

Source: Cropnosis, 2015 (Personal Communication).

In a recent report by the Transparency Market Research titled *Agricultural Biotechnology Market: Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2013-2019*, global agricultural biotechnology which was worth US$15.3 billion in 2012 is expected to be worth US$28.7 billion by 2019. The value is estimated to expand at a rate of 9.5% compounded annual growth rate (CAGR) from 2013 to 2019 due to the rising demand for higher crop yield, combined with diminishing amounts of arable land that will drive the transgenic application segment of the market.

The report concluded that GM crops with higher yield, resistance to pests, longer shelf-life, and high nutritional value were widely accepted in both developed and developing countries, particularly maize and soybean. These are components of animal feeds which will increase in demand due to the rising population and demand for meat, and thus drive the growth of agricultural biotechnology. Soybean is expected to exhibit the fastest growth among other GM crops in the coming years and maize which has food, feed and industrial applications in the production of bioplastics and biofuels will also contribute significantly to the market.

The Report also indicated that the textile industry in Asia Pacific accounts for a major share in demand for cotton. Other GM crops such as sugar beet, sugar cane, and canola accounted for almost 10% of the overall market in 2012. North America has faster adoption of technological advancements due to higher cultivation of GM crops and adoption of these crops by consumers. North America dominates the global agricultural biotechnology market and held 32.5% of the overall market in 2012.

Europe accounts for substantial consumption of imported GM crops for animal feed, sourced from the US and Brazil. But due to strict government regulations and non-acceptance of GM crops by consumers, the region does not feature high among GM crop producers and hence does not contribute directly to the agricultural biotechnology market. The enabling regulatory support in the Americas and Asia Pacific is expected to boost market growth in the next few years. Rising demand for biofuels is further boosting the market (Transparency Market Research, 29 October 2015).

CURRENT AND FUTURE CHALLENGES

Feeding the World of 2050

Feeding 9.7 billion people in 2050, and 11.0 billion in 2100 is one of, if not THE most daunting challenges facing mankind during the remaining years of this century. Global population, which was only 1.7 billion at the turn of the century in 1900, is now 7.3 billion (July 2015) – the world has added approximately 1 billion people in the span of the last 12 years. It is expected to climb to 9.7 billion by 2050, and to 11 billion at the end of 2100. Globally, 870 million people are currently chronically hungry and 2 billion are malnourished. The world may consume more grain than it produced in 2015 whilst grain reserves are at a low level. Rates of growth in crop productivity have declined subsequent to the significant contribution of the green revolutions of the 1960s for wheat and rice. It is now evident that conventional crop technology alone will not allow us to feed over 9 billion in 2050 and neither is biotechnology a panacea. An option being proposed by the global scientific community is a balanced, safe and sustainable approach, using the best of conventional crop technology (well adapted germplasm) and the best of biotechnology (appropriate GM and /non-GM traits) to achieve **sustainable intensification** of crop productivity on the 1.5 billion hectares of cropland globally. The returns on investments in agriculture are high and furthermore they directly impact on poverty alleviation, particularly small resource-poor farmers and the rural landless dependent on agriculture, who represent 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

Millenium Development Goals
The year 2015 marked the end of the monitoring period for the Millennium Development Goal targets.

The 2015 edition of "Food Insecurity in the World" presents the updated estimates of undernourishment and progress towards the Millennium Development Goals and World Food Summit hunger targets. For the developing regions as a whole, **the share of undernourished people in the total population decreased from 23.3% in 1990-1992 to 12.9%.** The Report indicates that global hunger reduction continues with about 795 million people chronically undernourished in 2015, down 167 million over the last decade and 216 million less than in 1990-1992.

A total of 72 developing countries out of 129, or more than half the countries monitored, have reached the MDG hunger target. Most of these countries are politically and economically stable with accompanying social protection policies. For the developing regions as a whole, the prevalence of undernourishment and the proportion of underweight children under 5 years of age have declined. In western Africa, south-eastern Asia and South America, undernourishment declined faster than the rate for underweight children, suggesting that there is room for improving the quality of diets, hygiene conditions and access to clean water, particularly for poorer population groups.

Economic growth was found to be essential and a key factor for reducing undernourishment. It should however be inclusive and provide opportunities for improving the livelihoods of the poor. **Enhancing the productivity and incomes of smallholder family farmers is also key to progress.**

Social protection systems have been critical in fostering progress towards the MDG hunger and poverty targets in a number of developing countries. Social protection directly contributes to the reduction of poverty, hunger and malnutrition by promoting income security and access to better nutrition, health care and education. By improving human capacities and mitigating the impacts of shocks, social protection fosters the ability of the poor to participate in growth through better access to employment.

The 2015 edition of the report "Food Insecurity in the World" concluded that in many countries that have failed to reach the international hunger targets, natural and human-induced disasters or political instability have resulted in protracted crises with increased vulnerability and food insecurity of large parts of the population. In such contexts, measures to protect vulnerable population groups and improve livelihoods have been difficult to implement or ineffective.

In July 2015, the United Nations (UN) released the new population projections till 2100. The data reveals that the world population continues to grow though more slowly than in recent past. World population is growing at 1.18% per year compared to ten years ago (1.24% per year). The world population is projected to increase by more than 1 billion people within the next 15 years, reaching 8.5 billion in 2030, 9.7 billion in 2050 and 11.2 billion by 2100 (UN DESA, 2015). There are currently 4.4 billion people in Asia (60% of global), 1.2 billion in Africa (16%), 738 million in Europe (10%), 634 million in Latin American and Caribbean (9%), 358 million in Northern America (5%) and 39 million in Oceania (<1%).

The increase in population growth will occur in high fertility countries mainly in Africa (such as Nigeria with 182 million in 2015, estimated to increase to 752 million in 2100), five in Asia (Bangladesh, China, India, Indonesia and Pakistan), two in Latin America (Brazil and Mexico), one in Northern America (United States of America), and one in Europe (Russian Federation). Nigeria, currently the 7th largest country in the world has the most rapid population growth. It is projected to surpass that of the US by about 2050, becoming the 3rd largest country in 2050. This is a startling scenario as Africa has not been able to feed its current population of 1.1 billion.

In Asia, China and India are the most populated countries. Within seven years, the population of India is expected to surpass that of China. By 2022, both countries are expected to have approximately 1.4 billion people. Thereafter, India's population is projected to grow to 1.5 billion in 2030 and 1.7 billion in 2050, while the population of China is expected to remain fairly constant until the 2030s, after which it is expected to slightly decrease.

Whilst the population of most European 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 40% from **321 million today to 450 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.

Thus, in the next fifty years, the world will consume up to twice as much food as the world has consumed since the beginning of agriculture 10,000 years ago – a profound and consequential statement that deserves a reasoned and urgent response from society. However, regrettably, the vast majority of global society is disinterested and completely unaware of the formidable challenge of feeding the world of tomorrow. Similarly, society is unaware of the potential contribution of technology, particularly the role of the new innovative biotechnologies, such as biotech crops, that already successfully occupy up to 181.5 million hectares in 2014 and 179.7 million hectares in 2015, equivalent to more than 10% of global arable land.

Alleviating Poverty in 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-poor farmers, who represent the majority of the world's poorest people. Small farms have been defined by various criteria (Hazell et al, 2010; Nagayets, 2005; Lipton, 2005; and World Bank, 2003). The most common features used to define small farms are size of land holding and dependency on family labor. **The definition of small farms used in the ISAAA Briefs is 2 hectares or less of crop land and/or with the majority of labor being provided by family members.** The following commentary on small farms is mainly drawn from the above four key references.

There are approximately 525 million (half a billion) small farms globally which are becoming smaller and more numerous as they are inherited by larger number of family members. Small farmers and their **families comprise about 2.5 billion people globally** and the poorer amongst them represent about 70% of the poorest people in the world (~50% are poor farmers and 20% are the rural landless who are completely dependent on agriculture for their livelihoods). Today, poverty is largely a rural phenomenon closely linked to agriculture but this will change as urbanization progresses – more than 50% of the world population already lives in towns and cities. Based on a 525 million global total of small farms **over three-quarters (87% or ~457 million) of the world's small farms are in Asia,**

8% (~42 million) in Africa, only 4% (2 million) in Europe and the lowest number equivalent to 1% (0.5 million) in the Americas. Thus, the predominance (95%) of small farms are in the two continents of Asia and Africa where they account for >75% of the total crop hectarage. The top two countries with the largest number (in millions) of small farms (<2 hectares) in Asia are China with 189 million small farms (39% of global) and India with 92 million (18% of global) and are by far the biggest; the two countries together account for over half (56%) of the global total of 525 million small farms.

Some of the important features of small farms, compared with large farms, are that they are more economically efficient, they generate more employment, and whilst increasing productivity on their own small farms, they also directly contribute to improvements in their own goals for food security and poverty alleviation. This is the case for the 7.1 million small farmers in China (an average of 0.5 ha of Bt cotton) and the 7.7 million small farmers in India (average of 1.5 ha of cotton) in 2014 who benefited from Bt cotton, and the ~0.4 million farmers who benefited 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 improved new technologies and thus the number of beneficiaries of new technologies can escalate quickly. For example, it is estimated that of the 18 million farmers who adopted biotech crops in 2014, more than 16.5 million equivalent to more than 90% were small resource poor-farmers. This trend for high adoption by small farmers will continue as countries like Bangladesh and Vietnam which started to adopt biotech crops in 2015, plans to expand rapidly. Indonesia, ties with Bangladesh for the third largest number of small farms per country in the world at 17 million each. 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 Golden Rice and, in October 2013 approved for commercialization, for the first time, a GM food staple, Bt, brinjal that was commercialized in 2014 in a record time of less than 100 days from approval.

As was also demonstrated during the green revolution of wheat and rice in the 1960s, increased productivity on small farms can also be the engine of growth for the local rural communities because long distance high-cost transport is not required to deliver locally produced food which is consumed in the same location where it was produced.

Food Security and Climate Change

It is estimated that in the USA, soybean farmers lost a massive US$11 billion in the last 20 years due to changes in weather patterns. According to the study conducted by the University of Wisconsin-Madison, the loss has been hidden by annual growth in soybean yields from other factors – growth could have been 30 percent higher if weather variations resulting from climate change had not occurred. Averaging the data across the US, researchers found that **soybean yields fell by around 2.4 percent for every one-degree rise in temperature.** The states with the biggest yield losses are also the nation's biggest soybean producers, hence the national impact is estimated at 30% yield loss overall (Crop Biotech Update, 1 April 2015).

Numerous studies in the past decade have predicted the effects of climate change on food security such as global yields, commodity prices, and nutritional quality. In a Food Security Report published by the UK Environment, Food and Rural Affairs (DEFRA), it was noted that UK's self sufficiency on food has declined over the years. Thus, the long-term challenge for the food production system is to produce more food despite the negative effects of climate change. The Report supports the concept of **sustainable intensification** which requires production of more food with fewer resources on the current 1.5 billion hectares of crop land globally. The report calls on DEFRA to stem decline in the UK self-sufficiency and deliver more resilience in the UK food system (Crop Biotech Update, 2 July 2014). Researchers David Lobell of Stanford University and Claudia Tebaldi from the National Center for Atmospheric Research found that there is substantial increased risk over the next two decades of a major slowdown in the growth of global crop yield. They opined that whereas the odds of a major production slowdown of wheat and maize are not high, the risk is about 20 times more significant than it would be without global warming (Crop Biotech Update, 30 July 2014).

Similar results were obtained in a study by nine leading global research teams under the Agricultural Model Intercomparison and Improvement Project (AgMIP) and the Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP). Analysis reveals that the average climate change effect on crop yields is a 17 percent decline, but with significant differences by crop, region, and climate models. **The final average yield effect is an 11 percent decline** as farmers respond by altering input use and management practices on increasing agricultural area, expanding production into new areas (an increase in area globally of about 8 percent) and reduced consumption (a decline of about 3 percent) (Crop Biotech Update, 30 July 2014). Food quality will also suffer with rising CO_2 due to climate change, as shown by a study on wheat by University of California, Davis plant scientist Arnold Bloom. **Elevated levels of CO_2 inhibit plant's assimilation of nitrate into proteins indicating that the nutritional quality of food crops is at risk as climate change intensifies.** Other studies have also indicated that protein concentrations in the grain of wheat, rice, barley as well as potato tubers will decline on average by approximately 8 percent under elevated levels of atmospheric dioxide (Crop Biotech Update, 10 April 2014).

Climate change also influences food safety, according to a report by scientists from Wageningen University. **A warmer climate means higher risk of contamination and growth of pathogens.** Fungi are more likely to grow, so more pesticides may be used. When there is heavy rainfall, the irrigation water, or cultivation itself may be contaminated with bacteria. Yet, according to the study, strong ultraviolet (UV) radiation from the sun and the many bacteria that are naturally present in plants can also disable these unwanted germs quickly. **The report concludes that an increased use of pesticides is expected due to climate change,** and the effects will differ strongly for different regions, crops, and pesticide types (Crop Biotech Update, 11 March 2015).

The Food and Agriculture Organization of the United Nations (FAO) Director General José Graziano da Silva, during the International Forum on Agriculture and Climate Change in France called for a new approach in ending food hunger. The new approach termed climate-smart agriculture will promote farming practices that will make crops adaptive and more resilient to environmental pressures, while at the same time decreasing farmer's impacts on the environment. To this end, FAO has formed a coalition of stakeholders called Global Alliance on Climate-Smart Agriculture with an objective of promoting sustainable and equitable increases in agricultural productivity and incomes; building greater resilience of food systems and farming livelihoods; and achieving reductions or removals of greenhouse gas emissions from agriculture (Crop Biotech Update, 25 February, 2015).

Catherine Bertini, the Chicago Council on Global Affairs co-chair has observed that ***"Growth in the agriculture sector is twice as effective at reducing poverty as growth in other sectors. A global food security strategy centered on agricultural development will alleviate poverty, guard the world's natural resource base, make agriculture more resilient to climate change and contribute to economic growth and social stability in low-income countries."***

The study reported that ***"although there has been progress in advancing global food security, investments in science need to be ramped up to increase production sustainably and nutritiously. Innovations especially need to be targeted to small scale farmers in developing countries, whose productivity must be increased if the world is to raise food production by at least 60 percent by 2050."***

Increased population, food insecurity and climate change may indeed impact food availability and accessibility for poor and hungry people. Various initiatives have been put in place in countries to at least reduce this impact, and whereas biotechnology can make an important contribution, it is not a panacea to solve all problems. A number of acceptable and feasible biotechnologies have been developed through the years that can in many ways meet these enormous challenges.

MEETING THE CHALLENGES

Global Efforts to Reduce Hunger and Poverty

2015 is the anniversary of two global efforts by the United Nations aimed at conquering hunger and poverty. It is the 20th celebration of the World Food Summit (WSF, founded in 1996 in Rome), when 182 governments committed "to eradicate hunger in all countries, with an immediate view to reducing the number of undernourished people to half the level in 1996, by no later than 2015." 2015 is also the 15th anniversary of the Millennium Development Goal 1 (MDG1) established in 2000 by the United Nations members to **"cut by half the proportion of people who suffer from hunger by 2015."**

The two UN agencies have recently published the 2015 progress report that detailed achievements as well as shortcomings in fulfilling their respective goals as enumerated below (UN, 2015).

- The commitment to halve the percentage of hungry people has been almost met at the global level. Of the 129 countries monitored for progress, 72 have reached the MDG target and 29 have also reached the more ambitious goal of halving the number of undernourished people in the populations.
  - The prevalence of hunger has been reduced rapidly in Central, Eastern and South-Eastern Asia, as well as in Latin America;
  - In Northern Africa, a low level has been maintained throughout the MDG and WFS monitoring periods;

  - Caribbean, Oceania and Western Asia, saw some overall progress, but at a slower pace;
  - **In Southern Asia and sub-Saharan Africa, progress has been slow overall, despite many success stories at country and sub-regional levels;**
  - However, in many countries that have achieved modest progress, factors such as war, civil unrest and the displacement of refugees have often frustrated efforts to reduce hunger, sometimes even raising the ranks of the hungry.
- Progress towards undernourishment, a second indicator of MDG1 target measures the prevalence of underweight children less than five years of age. Global indicators were similar as a whole, but they diverge significantly at the regional level owing to the different determinants of child underweight.

Hunger remains an everyday challenge for almost 795 million people worldwide, including 780 million in the developing regions. Hence, hunger eradication should remain a key commitment of decision-makers at all levels.

The United Nations- FAO (2015b) has developed a successor framework – the 2015 development agenda – being led by the UN Members States. This will be supported by the UN system and inputs came from multiple stakeholders. Termed as **Sustainable Development Goals (SDGs)** the strategies are "universally applicable to all countries while taking into account different national realities, capacities and levels of development and respecting national policies and priorities." The new goals are expected to be action-oriented, concise, easy to communicate, limited in number, aspirational, and global in nature. An agreement among the Member States on the outcome document was endorsed on July 15, 2015 and adoption of the document was ratified at a Summit of Heads of State and Government level in September 2015.

The 193-member United Nations General Assembly formally adopted the 2030 Agenda for Sustainable Development, together with the new Global Goals, at the UN Sustainable Development Summit on September 25, 2015. UN Secretary-General Ban Ki-moon hails the new Global Goals as universal, integrated, and transformative vision for a better world. The new framework, called **"Transforming our World: The 2030 Agenda for Sustainable Development,"** is composed of 17 goals and 169 specific targets to eliminate poverty, fight inequality, and tackle climate change in the next 15 years. One of the 17 goals aims to end hunger, achieve food security and improve nutrition, and promote sustainable agriculture. The Goals aim to build on the historic Millennium Development Goals. According to Mr. Ban, the new agenda is a promise by leaders to all people everywhere, to end poverty in all its forms – an agenda for the planet, our common home (UN Sustainable Development, 7 October 2015).

Climate Change: Papal Encyclical and COP 21 in Paris

Pope Francis in his 2015 papal encyclical, 'Laudato Si', **underscored the importance for everyone, in a coordinated effort, to implement the necessary strategies to address climate change and environmental destruction which will affect everyone, especially the vulnerable members of global society** – the poor and the hungry. Efforts in the past to address the problem by rich countries were not sufficient, hence there is an urgent global need to double and unify efforts.

The Pope's concern was also appropriately addressed **in a clarion call for action (not promises)** during the 21st Session of the Conference of the Parties (COP21) to the UN Framework Convention on Climate Change (UNFCCC) held in Paris, France in December 2015. Importantly, for the first time ever, a legally binding agreement was signed by 195 countries to limit global warming to below 2^{o}C, above which, global crop production will decline substantially, particularly the developing countries, which can least afford the losses due to abiotic-stresses (higher temperatures and droughts) and biotic-stresses (pests and diseases). It is very important to acknowledge that **GM/biotech crops are already making a contribution to reduce the effects of increased stresses associated with climate change, as detailed in the next paragraph. Moreover, the potential of GM and the new biotech applications, such as CRISPR, is enormous for the future, when global population will reach 11 billion in 2100.** The challenge for society is to adopt harmonized, science-based appropriate/proportionate regulation, which is practical and not overly onerous, that will ensure timely deployment to farmers of improved crops that can increase productivity, and double food production.

Contribution of Biotech Crops to Food Security, Sustainability and Climate Change

Since 1996, biotech crops are already contributing to sustainability and can help mitigate the effects of climate change in the following five ways and have enormous potential for the future:

- **Contributing to food, feed and fiber security and self sufficiency, including more affordable food, by increasing productivity and economic benefits sustainably at the farmer level**

Biotech crops already play an important role by increasing productivity per hectare and coincidentally decreasing cost of production as a result of reduced need for inputs. Economic gains at the farm level of ~US$150.3 billion were generated globally by biotech crops during the nineteen year period 1996 to 2014, of which 35% were due to reduced production costs (less ploughing, fewer pesticide sprays and less labor) and 65% due to substantial yield gains of 514.7 million tons. The 514.7 million tons comprised 158.7 million tons of soybean, 322.4 million tons of maize, 24.7 million tons of cotton lint, and 9.2 million tons of canola over the nineteen year period 1996 to 2014. For 2014 alone, economic gains at the farm level were US$17.8 billion, of which approximately 15%, were due to reduced production costs (less ploughing, fewer pesticide sprays and less labor), and approximately 85% due to substantial yield gains of 75 million tons. The 75 million tons comprised 20.2 million tons of soybean, 50.8 million tons of maize, 2.9 million tons of cotton lint, and 1.2 million tons of canola (Brookes and Barfoot, 2016, 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 514.7 million tons of additional food, feed and fiber produced by biotech crops during the period 1996 to 2014 had not been produced by biotech crops, an additional 152 million hectares of conventional crops would have been required to produce the same tonnage. Some of the additional 152 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 2014 alone, if the 75 million tons of additional food, feed and fiber produced by biotech crops during 2014 had not been produced by biotech crops, an additional 20.8 million hectares of conventional crops would have been required to produce the same tonnage for 2014 alone (Brookes and Barfoot, 2016, 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 2015, and this can be enhanced significantly in the remaining years of this decade 2010 – 2020. Of special significance is biotech rice which has the potential to benefit 250 million poor rice-growing households in Asia, (equivalent to one billion beneficiaries based on 4 members per household) growing on average only half a hectare of rice with an income as low as US$1.25 per day – they are some of the poorest people in the world. It is evident that much progress has been made in the first fifteen years of commercialization of biotech crops, but progress to-date is just the "tip of the iceberg" compared with potential progress in the second decade of commercialization, 2006-2015. It is a fortunate coincidence that the last year of the second decade of commercialization of biotech crops, 2015, is also the year of the Millennium Development Goals (MDG). This offers a unique opportunity for the global crop biotechnology community, from the North and the South, the public and the private sectors, to strategize about the contributions that biotech crops can make beyond the 2015 Millennium Development Goals.

- **Reducing agriculture's environmental footprint**

Conventional agriculture has impacted significantly on the environment and biotechnology can be used to reduce the environmental footprint of agriculture. Progress to-date includes: a significant reduction in pesticides; saving on fossil fuels; decreasing CO_2 emissions through no/less ploughing; and conserving soil and moisture by optimizing the practice of no till through application of herbicide tolerance. The accumulative reduction in pesticides based on the latest information for the period 1996 to 2014 was estimated at 583.5 million kilograms (kgs) of active ingredient (a.i.), a saving of 8.2% 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 2014 alone was a reduction of 40.4 million kgs a.i. (equivalent to a saving of 6.4% in pesticides) and a reduction of 17.6% in EIQ (Brookes and Barfoot, 2016, 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 9.6 billion by 2050. The first biotech maize hybrid with a degree of drought tolerance was commercialized in 2013 in the USA, and the first tropical drought tolerant biotech maize is expected by ~2017 for sub Saharan Africa. The advent of drought tolerance in temperate tropical maize in the industrial countries will be a major milestone but will be of even much greater significance in tropical maize in sub Saharan Africa, Latin America and Asia. Drought tolerance has also been incorporated in several other crops such as sugarcane in Indonesia and wheat in Australia which has performed well in initial field trials, with the best lines yielding up to 20% more than their conventional counterparts. Drought tolerance is expected to have a major impact on more sustainable cropping systems worldwide, particularly in developing countries, where drought is more prevalent and severe than industrial countries.

- **Helping mitigate climate change and reducing greenhouse gases**

The important and urgent concerns about the environment have implications for biotech crops, which contribute to a reduction of greenhouse gases and help mitigate climate change in two principal ways. First, permanent savings in carbon dioxide (CO_2) emissions through reduced use of fossil-based fuels, associated with fewer insecticide and herbicide sprays. In 2014 alone, this was an estimated saving of 2.24 billion kg of CO_2, equivalent to reducing the number of cars on the roads by 0.97 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 2014 to 24.8 billion kg of CO_2, or removing 11 million cars off the road. Thus in 2014 alone, the combined permanent and additional savings through sequestration was equivalent to a saving of 27 billion kg of CO_2 or removing 12 million cars from the road (Brookes and Barfoot, 2016, Forthcoming).

Regulation of biotech crops

Onerous regulation for transgenic biotech crops remains the principal constraint to adoption, which is particularly important for many developing countries, denied the opportunity of using biotech crops to address food, feed and fiber security. Unlike the onerous regulation that currently applies to transgenics, genome-edited products logically lend themselves for science-based, fit-for-purpose, proportionate and appropriate regulation. Opponents of GM crops and the new genome editing technologies such as CRISPR are opposed to science/evidence-based regulation and are demanding onerous regulation that is denying poor farmers in the developing countries, as well as Europe's access to the technologies. By using these technologies, small poor farmers will be able to survive and contribute to the doubling of food production to meet the needs of a growing population which will reach 11 billion in 2100. Moreover, the opponents of GM crops and the biotech applications such as CRISPR are estimated to have a massive global budget which doubled from an estimated US$10 billion in 2011 to US$20 billion in 2014.

The encouraging outlook is that technology, in conjunction with conducive policies can double food production. However, the doubling of food production cannot be realized by society unless it ensures that regulation of GM and genome-edited derived crops is science/evidence-based, fit-for-purpose, and to the extent possible harmonized globally. Failure by global society to ensure timely and appropriate regulation on food production will have dire consequences. On the one hand, the world will suffer because of inadequate food supplies, whilst on the other hand, the power of science and technology to produce a safe, adequate and assured supply of food for all of mankind will be rejected because of the dominant ideological voices of the opponents of the new biotech technologies.

Global meta-analysis confers significant and multiple benefits

A 2014 comprehensive global meta-analysis of benefits from biotech crops of 147 published biotech crop studies over the last 20 years, confirmed the significant and multiple benefits that biotech crops have generated over the past 20 years (1995 to 2014). The meta analysis concluded that ***"On average, GM technology adoption has reduced chemical pesticide use by 37%, increased crop yields by 22%, and increased farmer profits by 68%. Yield gains and pesticide reductions are larger for insect-resistant crops than for herbicide-tolerant crops. Yield and profit gains are higher in developing countries than in developed countries. Yield and farmer profit gains are higher in developing countries than in developed countries"*** (Klumper and Qaim 2014). Qaim (2015) presented a more thorough description of the impacts of current and possible future GM crop applications and their substantial contribution to sustainable agricultural development and food security in his recent book *Genetically Modified Crops and Agricultural Development*. He concluded that continued opposition to technologies that were shown to be beneficial and safe entails unnecessary human suffering and environmental degradation.

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In summary, collectively the above five thrusts have already demonstrated the capacity of biotech crops to contribute to sustainability in a significant manner and for mitigating the formidable challenges associated with climate change – global warming; and the potential for the future is enormous. Biotech crops can increase productivity and income significantly, and hence, can serve as an engine of rural economic growth that can contribute to the alleviation of poverty for the world's small and resource-poor farmers.

Status of Golden Rice

WHO concluded that 190 to 250 million preschool children worldwide are affected by VAD annually. Golden Rice could prevent 1.3 to 2.5 million child deaths annually. At IRRI, the Golden Rice trait event E, has been bred into mega varieties, and confined field tests are in progress in the Philippines and field trial has been approved in Bangladesh. The important mission of the Golden Rice project is to contribute to improving the health of millions of people suffering from micronutrient deficiency. Rice is the staple of 4 billion in the South who collectively consume only 2,006,869 calories per day. This consumption is broken down by region, per day in: South Asia (1,130,648 calories), Southeast Asia (660,979 calories), Africa (125,124), Latin America (75,238), and Central Asia (14,880) for a total of 2,006,869 calories per day (HarvestPlus, Personal Communications). These are the regions where most Vitamin A Deficiency (VAD) and associated illnesses occur – these can be reduced if people are provided with Golden Rice, a biotech rice with beta carotene.

Stewardship and Resistance Management of Biotech Crops

The two major biotech crop traits of insect resistance (IR) and herbicide tolerance (HT) have made an enormous contribution to global food, feed and fiber production since they were first approved for commercial cultivation in 1996, almost 20 years ago. In 2015, insect resistance and herbicide tolerance traits, were deployed singly or stacked in the four principal biotech crops of maize, soybean, cotton and canola, and were planted globally in 2015 on 179.7 million hectares in 28 countries. Moreover, in the 20 year period, 1996 to 2015 the IR/HT biotech crops have gained the trust of millions of farmers world-wide and as a result have achieved a near-optimal adoption of 90% or more in virtually all the principal countries growing biotech crops. The IR/HT biotech crops have provided a successful complementary and alternative system to the conventional pesticide-based crop production systems and they are judged by farmers to be efficient, convenient and environmentally-friendly. Notably, Scientific American included biotech-based insect resistance (IR) and herbicide tolerance (HT) traits in a list of 10 **biotechnology innovations that have revolutionized agriculture** (Scientific American, 2014). These same two trait(s) have also been successfully incorporated in a range of other commercialized biotech crops including alfalfa, brinjal (eggplant), sugar beet and poplar; the two traits have also been successfully incorporated in the other two major staples of rice and wheat for future deployment as new commercial biotech crops.

The insect resistance trait in biotech crops expresses insecticidal proteins that control targeted insect pests, whereas the herbicide tolerant trait confers tolerance to herbicides (mainly glyphosate and glufosinate) and controls weeds without damaging the crop. Irrespective of whether the technology is conventional or biotech, the widespread adoption of insect resistance and herbicide tolerance leads, over time, to insect pest resistance and resistant weeds, thereby diminishing their benefits to farmers. The issues of resistance management of IR/HT traits were anticipated and discussed by the scientific community, regulators and policy makers prior to the introduction of biotech crops in 1996. Accordingly, several scientific and policy approaches were considered to manage the development of resistance in IR/HT crops, prior to and during their deployment in 1996 (McGaughey and Whalon, 1992; Bates et al., 2005 and Dill et al., 2007). The policy approaches ranged from the deployment of refugia, integration of IRM into general insect pest management (IPM) schemes, using insect resistant management (IRM) strategies, and post-release monitoring of biotech crops for early detection of resistance. Coincidentally, new scientific methods evolved around gene pyramiding, and stacking of traits to enable more effective management and stewardship of resistance in the new biotech crops. Thus, resistance management including IRM, stewardship, and good farming practices have played a significant role in the successful large scale adoption and acceptance of IR/HT biotech crops from the very beginning in 1996. These approaches are credited with prolonging the life of biotech crops, and making them more durable than conventional technology thereby extending the benefits to farmers from planting IR/HT biotech crops season-after-season.

As anticipated, studies have confirmed that the first generation IR and HT traits are becoming susceptible to resistant targeted insect pests and weeds, respectively. Single or stacked IR/HT GM crops involving single and multiple gene(s) in maize in the USA have led to field-evolved resistance of insect pests. Hence, approaches for managing Bt resistance must be assigned a high priority, particularly as more crops feature Bt genes (single and stacked), which in 2015 already occupied over 58 million hectares. It is noteworthy that the first stacked IR/HT soybean was launched in 2013 in four countries in Latin America, and in 2015 occupied almost 13 million hectares. Bt brinjal was also first introduced in Bangladesh in 2014. A study by Gassman et al. (2014) documents the field-evolved resistance by western corn rootworm to multiple *Bacillus thuringiensis* toxins in biotech maize crops. It also confirms that IR GM crops producing less than a high dose of toxin against target pests may select for resistance rapidly. Similarly, several studies indicate that a considerable number of weeds have shown resistance to the application of herbicides including the widely used glyphosate, thereby potentially limiting the future use of the product in its current form. Thus, the management of insect resistance and stewardship of IR/HT biotech crops have assumed greater importance, over time and in the future deserves priority and appropriate attention and implementation at the field level.

The current system of policy and scientific approaches to effectively manage IR/HT crops has served its purpose for 20 years. A paradigm shift in technology to new, more resilient and durable technologies and stewardship, along with strict implementation of the current policy and scientific approaches are judged by observers to be of the highest priority in order to sustain future gains from IR/HT biotech crops. The two decades of experience and the trend in technological development suggest that the following 12 elements be considered to achieve effective and strict implementation of resistance management and stewardship:

- Planting of refugia and innovative methods for deploying them in such simple but creative schemes such as refuge in the bag (RIB)
- Integration of Insect resistant management (IRM) in integrated pest management (IPM) systems
- Stricter implementation of package of recommended practices
- Post-release monitoring and timely reporting of detection of resistance
- Ensuring seed purity and adequate expression of traits
- Assurance of supply of high quality IR/HT seeds
- Gene pyramiding and stacking of insect resistance and herbicide tolerance traits
- Integrating multiple modes-of-action for IR/HT traits
- Development of innovative and more resilient new technologies capable of reversing resistance
- Timely replacement of current IR/HT products with improved versions
- Education, training and outreach to the farming community in managing IR/HT biotech crops and,
- Strengthen compliance of regulatory requirements

The US approved Enlist™ Duo for dual mode herbicide tolerance to glyphosate and 2,4-D in soybean and maize for use in six US states in 2014 was extended to nine other US states in 2015. This is in addition to USDA-APHIS' deregulation of Monsanto's Dicamba-tolerant trait technologies – Roundup Ready 2 Xtend™ soybeans and Bollgard II® XtendFlex™ cotton. These approvals are designed to target problems of glyphosate resistant weeds in many US states using biotech crops which contain herbicide resistance genes with varying modes of action.

The approval of second generation of IR/HT crops, such as Bollgard III® and Enlist™ products (USDA, 6 August 2014) with dual and triple modes-of-action for insect and weed tolerant traits is important, and helps overcome the current challenges of managing the insect and weed resistance to IR/HT crops. **The wide scale use of the refuge-in-bag (RIB) strategy and regulatory compliance also needs to be strictly implemented.** In addition, farmers, the scientific community and industry have to work in tandem to devise on-farm and off-farm strategies to prolong durability of resistance. The need for appropriate and strict management of resistance and stewardship is greater in developing countries (than industrial countries) where the infrastructure and other constraints are much greater.

Farmers in developing countries in particular, need to be more aware and educated about the importance of good quality seeds, planting of refugia, and compliance with the recommended agronomy and crop management practices; this includes safe and appropriate use of pesticides based on objective assessments of economic threshold levels (ETLs). Developing countries in particular, also need to consider the timely replacement of existing products with improved products, to enhance the value and durability of IR/HT technology. Farmers must also be made more aware of the importance of scouting for surviving larvae of pests and the need to apply timely pesticides to eradicate resistant larvae. Farmers must exercise diligence in planting of refugia as this will help in prolonging the life of IR/HT technology and extending the benefits to farmers in planting biotech crop season after season. Education and increased awareness of the importance of managing resistance is paramount, as well as strict implementation of recommended practices. Importantly, all stakeholders including the scientific community, farmers, policy makers and the private sector must be made aware of their collective responsibility and the fact that the overall system of managing resistance will **NOT** work if any single stakeholder is delinquent in its implementation.

Carriere et al (2015) proposed a new strategy to slow down resistance in pyramided Bt crops. Technology developers introduced pyramided Bt crops which contain two or more Bt toxins to slow down insect resistance. Biotech crop countries have introduced these pyramids since 2003 with phenomenal adoption rates in the United States, India, and Australia – 19,000 hectares of Bollgard III/ RRFlex® cotton is being field-trialed under permit in Australia in 2015. Analysis of 38 studies at the College of Agriculture and Life Sciences in Arizona University indicate that the crops' actual efficacy against pests did not live up to expectations because some pyramided Bt crops contain Bt genes that bind to the same receptor. They opined that ideally, if each Bt toxin is highly effective on its own and the two toxins act independently, the pyramid should kill at least 99.75% of the Bt susceptible pests. The authors of the study proposed that toxins with different amino acid similarities in domains involved in evolution of resistance be combined to produce more effective and durable pyramids. This could help technology developers to swap domains and engineer each Bt toxin with the desired domain configuration (Carriere et al. 2015).

Progress of New Product Approvals and Commercialization

In Argentina, two home- grown products were approved – a drought tolerant soybean and a virus-resistant potato. In Brazil, approval was gained for cultivation of a higher yielding home-grown eucalyptus and commercialization of two home-grown crop products in 2016 – a virus resistant bean and a new herbicide tolerant soybean. In Canada, there was approval of a higher quality non-browning apple. In the US, approval of the same non-browning apple, the initial commercialization of Generation 1 Innate™ potato, plus the approval of Generation 2 Innate™ potato with late blight resistance (the cause of the Irish famine in 1845 which killed 1 million people), and commercialization of SU Canola™, a non-transgenic, genome-edited crop. Note the shift towards more food crops – current biotech food crops include white maize in South Africa; sugar beet and sweet corn in the US and Canada; papaya and squash in the US; papaya in China; and Bt eggplant in Bangladesh. Finally, a reduced lignin alfalfa event, KK179 (HarvXtra™) with higher digestibility and yield (alfalfa is #1 forage crop in the world) has been approved and is being considered for commercialization in the US in 2016.

The company Cibus has developed SU Canola™ using a non-transgenic breeding through precision gene editing; the product was commercialized for the first time in the US in 2015 on 10,000 acres (4,000 hectares).

- **Non-Browning Biotech Apple**

The US Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS) has announced its approval for the first two apple varieties genetically engineered to resist browning. The non-browning apple varieties, Arctic® Golden and Arctic® Granny apples, were developed by Okanagan Specialty Fruits Inc. (OSF), a small, grower-led company based in Canada. The non-browning Arctic® apples which went through rigorous review, were grown in field trials for more than a decade, and are likely the most tested apples on the planet. The USDA's publicly available risk assessment documents concluded that Arctic® apples are just as safe and healthful as any other apple, and they are unlikely to pose a plant pest risk, and deregulation is not likely to have a significant impact on the human environment. The non-browning apple trait will be appreciated by the food industry and consumers alike (Crop Biotech Update, 18 February 2015). The Arctic® apples have also been approved for commercial sale in Canada, after the evaluation of Canadian Food Inspection Agency (CFIA) and Health Canada (HC). According to a letter sent by CFIA to OSF, the Agency has concluded that the Arctic® apples "are as safe and nutritious as traditional apple varieties." On the other hand, HC stated that Arctic® apple is "safe for consumption, still has all its nutritional value and therefore does not differ from other apples available on the market" (Crop Biotech Update, 25 March 2015).

The first two GM Arctic® apple varieties: Arctic® Golden and Arctic® Granny were approved by the USA and Canada consecutively, in February and March 2015. The non-browning apple varieties were planted on an initial 15 acres (6 hectares) in Washington State in 2015. In 2016, approximately 60-70 acres (24 to 48 hectares) are expected to be planted primarily in the USA, with some acreage potentially in Canada as well. Significantly more acreage is anticipated in the USA and Canada in 2017 and beyond. Small test-market quantities of Arctic® apples are expected to be available in US stores in late 2016, with more meaningful quantities becoming available each year. Aquabounty owner Intrexon, developer of GM salmon has bought the non-browning apple developer Okanagan Specialty fruits in March 2015. It is noteworthy that in a landmark decision in November 2015, the FDA in the US approved the first GM animal for commercial production, a faster growing salmon, which is expected to enter the food chain in the US before 2018. Atlantic salmon normally takes three years to harvest in fish farms, compared with only 18 months, or half the time, for GM salmon (NYTimes, 19 November, 2015).

- **Biotech Potatoes - Innate™ Generation 1 and 2 (Contributed by the Simplot Company)**

The year 2015 was instrumental in the advancement of biotech potato in the US and beyond. Early in 2015, the J.R. Simplot Company, a US-based global agribusiness company, completed the food and feed safety consultation with the Food and Drug Administration (FDA) for its first generation of Innate™ potato varieties. The FDA clearance came after the US Department of Agriculture (USDA) deregulation of Innate™ potatoes in late 2014. These federal clearances involved years of technical review and a thorough public comment period that drew the support of 14 leading potato research universities in the US and Europe.

Three varieties of Innate™ potatoes – Russet Burbank, Ranger Russet and Atlantic – have fewer black spots from bruising, stay white longer when cut or peeled, and have lower levels of naturally-occurring asparagine, resulting in less acrylamide when cooked at high temperatures. Innate™ potatoes are also less prone to pressure bruising during storage, resulting in less potato waste and potentially millions of dollars in savings to growers every year. Simplot used the techniques of modern biotechnology to accelerate the traditional breeding process and introduce new traits by triggering the potato's own RNA interference (RNAi) pathway. RNAi is a natural cellular process commonly used by plants and animals to modulate expression of certain genes, and has been used effectively in multiple commercial crops sold over the last decade. The three Innate™ varieties were available in limited quantities (400 acres or 162 hectares) beginning in 2015 in the fresh whole and fresh-cut markets where the sustainability, higher quality and health benefits have significant value to growers and consumers.

A second generation of Innate™ potatoes approved by the USDA in August, is under current review by the FDA and the US Environmental Protection Agency (EPA). These potatoes offer two additional improvements to the potato, including increased resistance to late blight disease and better storability. These advantages are expected to create significant sustainability advances, such as reduced reliance on fungicides and fewer rejected potatoes. Early research shows that Innate™ second generation potatoes will further contribute to reducing waste associated with bruise, blight and storage losses by reducing waste at multiple stages of the value chain, including in-field, during storage, processing, and in food service. That research suggests that these traits will translate to less land, water and pesticide applications to produce these potatoes. Academics consulted by Simplot, for instance, estimate that the Innate™ late blight resistance trait, regulated by the EPA, can result in a 25-45% reduction in fungicide applications annually to control late blight. Lower asparagine means that accumulation levels of acrylamide can be reduced by up to 90% or more when these potatoes are cooked at very high temperatures. In addition, lowered reducing sugars enable cold storage at 38°F for more than 6 months without the build-up of sugars which improves quality.

Simplot's commercialization success with the Innate™ biotechnology platform has led the US Agency for International Development (USAID) to identify them as a public-private partner with Michigan State University on a US$5.8 million cooperative agreement to improve potato production in Bangladesh and Indonesia. The grant supports USAID's work under Feed the Future, the US Government's global hunger and food security initiative. The grant, awarded in October 2015, is geared towards improving potato varieties available to smallholder farmers. Such varieties can help protect against yield loss and improve livelihoods for those who depend on the crop to survive. Potatoes are the third-largest food crop grown in the world and a major staple crop in both Bangladesh and Indonesia. Late blight, the disease responsible for the historic Irish potato famine, is caused by a fungus-like pathogen and still has the potential to wreak havoc on today's potato and tomato crops. To fight the disease, and subsequently increase Bangladesh's and Indonesia's food security, the researchers will work with in-country partners to assess the validity of genetically engineered varieties, along with other approaches such as conventional fungicides, to develop the most-sustainable approach to maintain this important crop.

Developing genetically engineered crops to adapt to drought, temperature extremes and pests is not new. They have been in use for nearly 20 years and in 2015 were planted in 28 countries on 179.7 million hectares by 18 million farmers, 90% of whom were smallholder farmers in developing countries. Biotechnology can be utilized to overcome challenges for which traditional breeding has been unable to address, and hasten the development of new resilient crop varieties made available to farmers in developing countries. Already, farmers in Bangladesh are growing a pest-resistant genetically engineered eggplant, reducing the number of pesticide sprays needed by nearly 10-fold. Simplot is working on future generations of potatoes with sustainability benefits for the US and developing countries and looking at potential advancements such as water-use efficiency and nitrogen-use efficiency. The speed of US and foreign regulatory approvals and the consumer acceptance and political environments will dictate how fast these promising technologies enter the marketplace and are available to farmers around the world.

- **Biotech Eucalyptus Approved for Commercial Use in Brazil**

The Brazilian National Technical Commission on Biosafety (CTNBio) has approved the commercial use of the yield enhanced biotech eucalyptus developed by FuturaGene, a wholly owned subsidiary of Suzano Pulp and Paper. Field experiments conducted since 2006 at various locations in Brazil have demonstrated an approximate 20% increase in yield compared to its equivalent conventional variety. This is the first GM eucalyptus event to be approved worldwide and represents the most significant productivity milestone for the renewable plantation forest industry. The approval also represents the beginning of a new era for sustainable forest management by enabling the production of more fiber, using less resources. Brazil is the first country to complete the development cycle of such a technology. The biotech tree has been under development since 2001 and has undergone extensive biosafety assessment prior to submission for commercial approval (Crop Biotech Update, 15 April, 2015).

Potential Biotech Crops in the Next 5 to 10 Years

The unending global challenges to feed the spiraling population and declining agricultural resources, motivate scientists and technology developers to create new and improved food products and agricultural technologies. Appendix 7 provides an incomplete listing of 87 selected new biotech crop/trait(s) that have at a minimum, been subjected to contained field tests and therefore could potentially be candidates for approval in the next 5 to 10 years. The information provided in the Appendix includes details of the biotech crops being field tested by crop, traits, technology developer/facilitator, and country/ies. The database of 87 entries highlights the fact that:

a. More than half of the technologies are being field tested in developing countries, an appropriate scenario given that the need for food and fiber is more acute in the developing countries of the South, in Africa, Asia and Latin America where food security is a life-threatening issue for millions of poor people and an urgent priority.

b. About 40% of these are on “new” priority biotech crops including apple, bean, banana, camelina, cassava, citrus, chickpea, cowpea, groundnut, mustard, chickpea, pigeon pea, potato, rice, safflower, sorghum, sugarcane, tomato and wheat. There are by and large pro-poor orphan crops that can make important contributions to food security for poor people.

c. New consumer traits (nutritious, anti-browning/bruising, high phytase, high oleic acid, high sugar content), high yield, pest and disease resistance (against bacteria, virus, nematodes), and abiotic tolerance (drought, salinity, nutrient efficiency) are highlighted, in addition to single and stacked traits of insect resistance and herbicide tolerance.

d. Approximately 40% of the listed entries represent technologies developed by public sector, 45% by private sector organizations and 15% are researches done through public/private sector partnerships.

New Breeding Technologies (NBT): The critical role of utilizing evolving and promising biotechnology applications in crop improvement

Twenty years after the commercialization of biotech/GM crops developed through the use of *Agrobacterium* or particle bombardment, the scientific global community are again enthusiastic about the potential of a new crop biotechnology called **"genome or gene editing".** There are different types of genome editing technologies; the most recent named CRISPR (Clustered Regularly Interspaced Short Palindromic Repeat) is judged to be promising by many stakeholders. These new technologies 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. Readers are referred to two essays on new breeding technologies and genome-edited applications in the collection of invitational essays in the companion document to the Brief on the ISAAA website. Experts in the field believe that potentially the "real power" of these new technologies is their ability to "edit" and modify single or multiple native plant genes (non GM), coding for important traits such as drought and, generating useful improved crops that are not transgenic. Products already under development include all the major food and feed crops: canola (herbicide tolerance), maize (drought tolerance), wheat (disease resistance and hybrid technology), soybean (oil quality), rice (disease resistance), potato (improved storage qualities), tomato (fruit ripening), and peanuts (allergen-free). More complex traits, coded by multiple genes, such as improved photosynthesis, are planned for the future, which may be closer than some people think. CRISPR earned *Science*'s 2015 "Breakthrough of the Year Laurels," a runner-up in 2012 and 2013, the technology now revolutionizing genetic research and gene therapy "broke away from the pack, revealing its true power in a series of spectacular achievements," opined *Science* correspondent John Travis in the December 18 issue.

Acknowledging that no technology, including genome editing, is a panacea or a silver bullet, many well-informed observers in the scientific community (gene therapy in medicine, where the technology was first developed, and crop improvement in agriculture) are of the view that genome editing offers a timely and unique set of significant advantages over conventional and GM crops in four domains: **precision** – due to its ability to precisely control single or multiple genes resulting in products that do not differ from natural mutations; **regulation** – unlike the onerous regulation that currently applies to transgenics, genome-edited products logically lend themselves for science-based, fit-for-purpose, and proportionate regulation; **speed** – some products, for example, genome-edited derived potato, have been developed in only one year, compared with up to 10 years using conventional or GM technology; and **cost** – speed of improving crops and reduced regulation translates into significant overall savings. The average cost for developing a GM crop is US$135 million of which US$35 million is onerous regulation costs. The hope is that regulatory bodies worldwide will not require stringent regulation for genome-edited crops and to the extent possible, facilitate harmonization of regulations internationally. This augers well for the new genome-edited technologies which will allow more affordable, superior, state-of-the-art crops to be offered to producers and consumers.

To ISAAA's knowledge, the first non-GM, genome-edited product, to be approved and commercialized is SU Canola™ developed by Cibus and grown on 10,000 acres (4,000 hectares) in the USA in 2015. Canada has also approved SU Canola™ for planting. Similar non-GM products are under development in many laboratories globally with a view to commercialization by farmers as early as five years from now in 2020. For example, DuPont has indicated that it already has CRISPR-derived maize and wheat plants growing in the greenhouse and is hoping to conduct the first field tests in 2016. Several countries – USA, Canada, Sweden and Argentina, have already considered regulation of simply mutated products through CRISPR and similar technologies, and concluded that they do not require to be deregulated under their respective national GM regulations. Dr. Jansson from Sweden has opined that **"the decision of the Swedish Board of Agriculture is the only logical one"** for their particular genome-edited products. Importantly, the determination of the need to regulate should be focused on the specific product and not the process.

Leading scientists from the global scientific community are of the view that international harmonization of science-based regulation of genome-edited crops is absolutely critical for plant breeding programs. This is because these programs are required to urgently increase global crop productivity, in order to achieve food security for 11 billion people in 2100, as well as mitigating the additional and formidable challenges, such as more frequent and more severe droughts, posed by climate change. **The EU and many other countries are expected to report their findings, positions and decisions on regulation of genome-edited technologies in the near term – these will be critical game-changing decisions with global implications for the role of science in food security, climate change, and the alleviation of hunger and poverty for almost one billion people in the developing countries**.

To summarize, the unusual degree of interest and enthusiasm in genome editing is that relative to other conventional and GM technologies, it is simple, swift, precise and affordable – features that make it a universally attractive development for most stakeholders. Genome editing can help solve the misery of the ~850 million poor people who are suffering from food insecurity in the developing countries, where one thousand people an hour die from hunger and malnutrition – a situation that is unacceptable in a just society. Norman Borlaug opined that you cannot build peace on empty stomachs, and that **technology can contribute to food security** and a better quality of life for millions of poor – he was right – the right to adequate food is imperative, and **biotechnology** can help make it happen.

FUTURE PROSPECTS

There are three domains that merit consideration:

Firstly, the high rates of adoption (90% to 100%) of current major biotech crops **leave little room** for expansion in mature markets in principal biotech crop countries. However, there is a significant potential for selected products such as biotech maize. For example, in Asia, there are about 60 million hectares of potential biotech maize with 35 million hectares in China alone; there is a similar potential in Africa for up to 35 million hectares of biotech maize and for Bt cotton in up to 10 African countries growing 100,000 hectares, or more, of cotton.

Secondly, the pipeline is full of new biotech crop products which could (subject to regulatory approval for planting and import) be available during the next 5 years or so – a portfolio of over 85 potential products are listed in Appendix 7. They include, the WEMA derived biotech drought tolerant maize expected to be released in Africa in 2017, a broad range of new crops and traits including products with multiple modes of resistance to pests/diseases and tolerance to herbicides, as well as resistance to nematodes. Golden Rice is progressing well with field testing in Asia. Crops for the poor, particularly in Africa, such as fortified bananas and pest resistant cowpea, look promising and institutionally, **public-private partnerships (PPP) have been relatively successful in developing and delivering approved products to farmers** – four PPP case studies, featuring a broad range of different crops and traits in all three continents of the South, are presented in the Appendix.

Thirdly, the advent of the genome-edited crops may be, by far, the most important development identified by today's scientific community. A recent and promising application is the powerful technology named **CRISPR**. Many well-informed observers in the global scientific community are of the view that genome editing offers a timely and powerful unique set of significant advantages over conventional and GM crops in four domains: **precision, speed, cost and regulation** – unlike the onerous regulation that currently applies to transgenics, genome-edited products logically lend themselves for science-based, fit-for-purpose, and proportionate regulation. Progress with the latter would be an enormous advantage. For more details the reader is referred to two essays in the companion document to Brief 51 on the ISAAA website (to celebrate the 20th anniversary of the commercialization of biotech crops) which describe the evolution of crop improvement technology, particularly the role of the New Breeding Technologies (NBT). It includes **a proposed forward looking strategy using the troika of transgenes, genome editing and microbes** to increase crop productivity, which in turn can contribute to the noble goal of food security and the alleviation of poverty and hunger.

CLOSING COMMENTS

The Way Forward

The way forward is to work together – collaboration – between the North and the South, East and West, Public and Private Partnerships (PPP), using both conventional (well-adapted germplasm) and biotechnology applications (enhanced traits). In reviewing crop technology transfer projects over the last two decades, the progress and promise of public-private sector partnerships (PPP) is striking. PPP projects offer flexibility and have been successful under a very broad range of circumstances. **Importantly, PPP offer advantages that increase the probability of delivering an approved biotech crop product at the farmer level within a reasonable time frame.** Four PPP case studies/projects, selected and reviewed by ISAAA illustrate the range of diversity in the four model PPP projects: Bt brinjal (eggplant) in Bangladesh, herbicide tolerant soybean in Brazil, drought tolerant sugarcane in Indonesia, and the WEMA project for drought tolerance in maize in selected countries in Africa. For the convenience of readers, short updated descriptions of each of the four case studies, are summarized at the end of this Brief.

Norman Borlaug's Legacy and Advocacy of Crop Biotechnology

It is fitting and timely to close this celebratory 20th Anniversary ISAAA Brief for 2015, by chronicling the counsel of the late 1970 Nobel Peace Laureate, Norman Borlaug, on biotechnology including GM crops. 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 and poverty. Norman Borlaug was also the founding patron of ISAAA, and the greatest advocate for biotechnology and biotech/GM crops worldwide.

Below is a memorable Norman Borlaug quote, in which he calls for **courage** from our leaders, (both scientific and political) to support crop biotechnology which can contribute to global food security and a more peaceful world. It is noteworthy that the quote is from the man who knew more than anyone about feeding the world because he had **"done it"** during the green revolution of the 1960s and understood the essence of the proverb – **reading is learning, seeing is believing, but doing is knowing – knowledge.** This Brief seeks to share knowledge freely about all aspects of biotech crops whilst respecting the rights of readers to make their own informed-decisions about crop biotechnology.

Norman Borlaug Quote:

"What we need is courage by the leaders of those countries where farmers still have no choice but to use older and less effective methods. The Green Revolution and now plant biotechnology are helping meet the growing demand for food production, while preserving our environment for future generations"(ISAAA, 2009).

Case Study 1 – Insect Resistant (Bt) Brinjal/Eggplant in Bangladesh

Brief Description: The Bt brinjal project in Bangladesh may lay claim to be the first crop biotechnology transfer project to deliver a product to farmers. Bt brinjal was developed as an international public private partnership, between an Indian seed company Mahyco generously donating technology to the Bangladesh public sector R&D institute Bangladesh Agricultural Research Institute (BARI), facilitated by Cornell University led project ABSP-II and funded by USAID. Bangladesh approved Bt brinjal for commercial cultivation on 30 Oct 2013 and in record time – less than 100 days – on 22 January 2014, a group of small farmers planted the first commercial product in their own fields. In 2015, a total of 25 hectares of Bt brinjal were planted by 250 farmers and the area is expected to increase substantially in 2016. Five additional Bt brinjal varieties – three of them received NCB approval in 2015, will be available in 2016 and remaining two in the near future. This feat would not have been possible without strong support for the project from the Government of Bangladesh and in particular the political will and support of the Minister of Agriculture, the Honorable Matia Chowdhury. Bt brinjal drastically reduces pesticide application, increases marketable yield and improves fruit quality. Farmers have successfully sold Bt brinjal fruits in the open market labelled as *"BARI Bt Begun #, no pesticide used"*. More specific information is provided below.

Country: Bangladesh
Crop: Brinjal/Eggplant
Area: ~50,000 hectares farmed by approx. 150,000 smallholder farmers – average holding of 0.3 hectare
Importance: The poor man's vegetable crop, known as "the queen of the vegetables"
Gene: *cry1Ac* gene from *Bacillus thuringiensis* (Bt)
Trait(s): Insect resistance (IR); imparts protection against the lethal insect pest fruit and shoot borer (*Leucinodes orbonalis*) which often requires small farmers to apply a polluting insecticide spray every other day and even then adequate control is not possible
Event: Elite Event EE-1
Technology Donor: the private sector company Mahyco, from India
Technology Recipient: Bangladesh Agricultural Research Institute (BARI)
Donor Funding Agency: USAID
Facilitator: Agricultural Biotechnology Support Program-II (ABSP-II) managed by Cornell University
Status of Approval: Approved for food, feed and environmental release on 30 Oct 2013 and commercialized in less than 100 days later on 22 January 2014
Varieties Approved: Brinjal-1 (Uttara), Bt Brinjal-2 (Kajla), Bt Brinjal-3 (Nayantara) and Bt Brinjal-4 (Iswardi/ISD 006) in 2014; possible five additional Bt brinjal varieties (Dohazari, Shingnath, Khatkati, Chaga and Islampuri) for commercial release and cultivation in 2016

Commercialization: 120 farmers planted Bt brinjal on 12 hectares in 2014; 250 hectares planted by 250 farmers in 2015.

Number of Potential Beneficiary Farmers: 150,000 of the poorest and smallest farmers in Bangladesh which has a per capita of less than US$1,000 per annum.

Socio-Economic Impact: Increases marketable yield by at least 30% and reduces the number of insecticide applications by 70-90%, with a net economic benefit of US$1,868 per hectare, equivalent to a gain of up to US$200 million per annum. The first socio-economic report on Bt brinjal in Bangladesh by ABSP II indicated 100% success rate in the use of the technology by ~100 farmers, reduced insecticide application to 7 times per season and reduced cost of production. Agronomic performance data released by BARI from 19 Bt brinjal demonstration plots, established in 108 farmers in 19 districts showed close to zero infestation, increased yield of up to 100% compared to non Bt variety.

Case Study 2 – Herbicide Tolerant (HT) Soybean in Brazil

Brief Description: In 2010, the Brazilian regulator authority CTNBio approved the commercial cultivation of a new herbicide tolerant soybean variety developed through a public private partnership jointly executed by the private sector company BASF Germany and the public sector R&D institute EMBRAPA, the Brazilian Agricultural Research Cooperation. In this collaborative project, BASF provided EMBRAPA with the csr1-2 gene, which confers tolerance to the herbicide imidazolinone, whilst the Brazilian institution also provided an additional gene and was responsible for the insertion of the trait into well adapted soybean germplasm. EMBRAPA and BASF share the patent for the new varieties, which represent the first home-grown biotech crop developed through PPP and approved in Brazil. Commercialization in Brazil is waiting on final import approval from the EU. It is expected that the new HT soybean varieties will be commercialized in Brazil by 2016, increasing the choice of weed management options for Brazilian growers. More specific information is provided below.

Country: Brazil
Crop: Soybean
Area: ~31 million hectares
Importance: Most important export crop of Brazil
Gene: *csr1-2* from *Arabidopsis thaliana* conferring tolerance to imidazolinone herbicides
Trait(s): Herbicide tolerance
Event: BPS-CV127-9
Technology Provider: BASF, Germany/EMBRAPA, Brazil (there are 2 main patents supporting the product development, one gene from BASF and another from EMBRAPA = soy gene transfer
Technology Recipient/ Donor Funding Agency/ Facilitators and Collaborators: BASF, Germany/ EMBRAPA, Brazil

Status of Approval: Approved for commercial cultivation in 2009 (December), but pending EU final import approval
Variety Approved: Varieties to be sold under the brand name Cultivance™
Commercialization: Expected planting as commercial crop in 2016 on approximately 150,000 hectares with two varieties of the "carioquinha" type.
Potenial Beneficiaries: Farmers, seed growers and consumers
Socio-Economic Impact: Cultivance™ expected to reach up to 20% of market share on 31 million hectares of soybean with an export value of US$17 billion

Case Study 3 – Drought Tolerant (DT) Sugarcane in Indonesia

Brief Description: In May 2013, Indonesia – the second largest (2.4 million tonnes, valued at US$1.6 billion) raw sugar importing country in the world, issued food and environmental safety certificates for the country's first home-grown genetically modified drought tolerant sugarcane. The biotech sugarcane variety "Cane PRG Drought Tolerant NX1-4T" was developed under a public private partnership between the Indonesian State-owned sugar company, PT. Perkebunan Nusantara XI (PTPN-11) and Ajinomoto Company, Japan in collaboration with Jember University in East Java, Indonesia. The drought tolerant sugarcane varieties can withstand water stress up to 36 days and under drought stress can yield substantially higher than the control variety BL-19; yield increases from 2 to 75% in the first planting, 14 to 57% in the first ratoon, and from 11 to 44% in the second ratoon. The DT sugarcane is being tested at five PTPN XI experiment stations in Situbondo, Banyuwangi, Bondowoso, Jember and Lumajang. It was expected that the first home-grown drought tolerant sugarcane will be officially planted in Indonesia in 2016 that will reach 50-60 hectares once feed approval is obtained. More specific information is provided below.

Country: Indonesia
Crop: Sugarcane
Area: ~450,000 hectares
Importance: Indonesia is the second largest sugar importing country in the world
Gene: *betA* from *Rhizobium meliloti*
Trait(s): Drought tolerance
Event: NX1-4T
Technology Provider: Ajinomoto, Japan
Technology Recipient: PT. Perkebunan Nusantara XI (PTPN-11), Indonesia
Donor Agency: Government of Indonesia
Facilitator/Collaborator: Jember University, East Java, Indonesia
Status of Approval: Approved for food and environmental release in 2013, pending feed approval

Variety Approved: Cane PRG Drought Tolerant NX1-4T
Commercialization: Expected commercial planting in 2016 or until feed safety approval is obtained

Case Study 4 – Drought Tolerant (DT) Maize for Africa (WEMA Project)

Brief Description: Monsanto donated the biotech drought tolerant (DT) maize technology (MON 87460), DroughtGard™ to the public sector agriculture R&D institutions in five countries in Sub Saharan Africa including South Africa, Kenya, Uganda, Mozambique, and Tanzania through a public-private partnership project entitled **"Water Efficient Maize for Africa (WEMA)".** WEMA is coordinated by the African Agricultural Technology Foundation (AATF) based in Kenya in collaboration with Monsanto and CIMMYT for further technology development. The project is funded jointly by the Gates Foundation, the Howard G. Buffett Foundation and USAID. The first stacked biotech insect resistant/drought tolerant (Bt/DT) maize hybrids are expected to be available to farmers and commercialized (subject to regulatory approval) as early as 2017. South Africa is expected to be the first country to deploy the technology in 2017, followed by Kenya and Uganda which were granted regulatory approval to conduct confined field trials (CFT) of the stack in 2015. The three countries have conducted CFTs with DT maize for at least 5 seasons with very encouraging results. A significant development was the submission of an application for environmental release for Bt maize (Mon 810 also donated by Monsanto) in Kenya and is undergoing review by the National Biosafety Authority. Uganda is continuing with the 3rd season field testing of Bt maize awaiting preparation of a third site for the stack trait as recommended by the NBC. In Mozambique, a revised Biosafety Decree and implementing regulations received approval by the Council of Ministers in October 2014, and the country has initiated preparations for a WEMA CFTs. In 2015, an application for the CFT was submitted to the interim biosafety committee and awaits review once the members are confirmed by the new Minsiterial establishment. Tanzania completed amendment of the 2009 Biosafety regulations and an application for drought tolerant trait is under review.

It is projected that the WEMA stacked DT/BT maize hybrids may yield up to 20 to 35% more grain than other commercial hybrids under moderate drought, resulting in an additional 2 to 5 million MT of maize to feed 14 to 21 million Africans.

Country: South Africa, Kenya, Uganda, Tanzania and Mozambique
Crop: Maize
Area: ~8 million hectares in the five countries
Importance: Africa grows 90% of its maize under rainfed conditions and up to 25% of the area suffers from frequent droughts
Gene: Cold shock protein gene (*CspB*) from *Bacillus subtilis*
Trait(s): Drought tolerance
Event: Event MON87460 to be deployed as a stacked hybrid maize, also featuring a Bt gene (MON 810 in Kenya and Uganda; MON 89 in South Africa) for insect control also donated by Monsanto

subsequent to the initiation of the project; the DT event is the same as that deployed in the 50,000 hectares of biotech drought tolerant maize in the US in 2013, which increased 5.5-fold to 275,000 hectares in the US in 2014, and 810,000 hectares in 2015.

Technology Provider: Monsanto, USA

Technology Recipients: South Africa, Kenya, Uganda, Mozambique and Tanzania

Donor Funding Agencies: The Gates Foundation, the Howard G. Buffet Foundation & USAID

Facilitators: African Agricultural Technology Foundation (AATF), NARIs in 5 WEMA countries, CIMMYT

Status of Approval: First deployment of stacked DT/BT expected in South Africa in 2017, followed by Kenya and Uganda who are expected to conduct confined field trials (CFT) of the stacked product next year, 2015. Revised Biosafety decree and implementing regulations endorsed in Mozambique and in 2015, an application for CFT was submitted and awaits approval once the new Biosafety Committee is appointed – this was occasioned by completion of term for the previous committee and re-organization within government. With the completion of amendment of biosafety regulations in Tanzania, an application for drought tolerant maize is under review as the project team prepares to submit an application for the stack trait by 2016.

Commercialization: To begin (subject to regulatory approval) in South Africa in 2017

Socio-Economic Impact: Could increase maize production by up to 2 to 5 million tons under moderate drought, to feed about 14 to 21 million people.

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Appendices

Appendix 1. Global Crop Protection Market, 2014

US$M	Herbicides	Insecticides	Fungicides	Others	Biotech	Total
North America	7,702	2,109	1,658	588	11,774	23,831
West Europe	3,674	1,443	3,780	723	10	9,631
East Europe	3,417	724	859	158	5	5,162
Japan	1,458	1,446	1,055	113	0	4,072
Australia	1,492	445	250	73	32	2,292
Industrial Countries	**17,744**	**6,166**	**7,603**	**1,655**	**11,821**	**44,988**
Latin America	6,125	4,174	4,134	598	3,357	18,388
Rest of Far East	2,333	2,682	2,673	207	398	8,293
Rest of World	1,041	1,857	828	112	662	4,499
Developing Countries	**9,499**	**8,713**	**7,634**	**917**	**4,417**	**31,180**
Total	**27,242**	**14,879**	**15,237**	**2,572**	**16,238**	**76,168**

Source: Cropnosis Agrochemical Service, 2015

Appendix 2a. Seed Exports (FOB) of Selected Countries, 2012 (with over 100 Million US$ Market)

Country	Field Crops	Vegetable Crops	Total
France	1,437	349	1,804
Netherlands	256	1,225	1,583
USA	930	529	1,531
Germany	638	58	727
Chile	218	150	388
Hungary	374	11	385
Canada	317	6	323
Italy	198	116	315
Denmark	221	42	265
China	79	158	251
Romania	217	1	218
Belgium	203	3	208
Mexico	175	27	203
Brazil	151	14	165
United Kingdom	120	21	151
Argentina	135	15	150
Others	1,123	722	8,667
Total	**6,792**	**3,447**	**10,543**

Appendix 2b. Seed Imports (FOB) of Selected Countries, 2012 (with over 100 Million US$ Market)

Country	Field Crops	Vegetable Crops	Total
United States	837	369	1,312
Germany	590	90	700
France	540	137	687
Netherlands	263	373	685
Italy	242	170	422
Spain	176	197	374
Russian Federation	310	58	373
Mexico	133	221	355
United Kingdom	202	70	287
China	143	111	268
Ukraine	238	30	268
Japan	98	113	231
Belgium	195	31	228
Canada	133	75	223
Turkey	64	122	188
Poland	122	50	175
Romania	129	16	147
Hungary	125	14	139
Brazil	50	67	120
Others	1,633	933	2,567
Total	**6,223**	**3,247**	**9,749**

Source: International Seed Federation, 2012 http://www.worldseed.org/isf/seed_statistics.html

Appendix 3. Estimated Value of the Domestic Seed Market in Selected Countries for the Year 2012 (Updated June 2013).

Country	Value (USD million)	Country	Value (USD million)
USA	12,000	Morocco	140
China	9,950	Switzerland	140
France	2,800	Bulgaria	120
Brazil	2,625	Chile	120
Canada	2,120	Nigeria	120
India	2,000	Serbia	120
Japan	1,350	Slovakia	110
Germany	1,170	New Zealand	100
Argentina	990	Uruguay	96
Italy	767	Ireland	80
Turkey	750	Paraguay	80
Spain	660	Portugal	80
Netherlands	590	Algeria	70
Russian Federation	500	Kenya	60
United Kingdom	450	Iran	55
South Africa	428	Israel	50
Australia	400	Tunisia	45
Republic of Korea	400	Bolivia	40
Mexico	350	Colombia	40
Czech Republic	305	Slovenia	40
Hungary	300	Peru	30
China, Taiwan	300	Zimbabwe	30
Poland	280	Malawi	26
Sweden	250	Libya	25
Romania	220	Saudi Arabia	20
Denmark	218	Zambia	20
Greece	200	Philippines	18
Belgium	185	Ecuador	15
Finland	160	Tanzania	15
Austria	145	Uganda	10
Egypt	140	Dominican Republic	7

Total US$44,925 million

The commercial world seed market is assessed at approximately 45 billion dollars

Source: http://www.worldseed.org/isf/seed_statistics.html

Appendix 4. Arable Land per Capita of Selected Countries in Asia

Country	Arable Land (Million Ha)	Population (Million)	Arable Land/Capita
Cambodia	4.0	15.6	0.26
Thailand	15.8	67.9	0.23
Laos	1.4	6.8	0.21
Myanmar	10.8	53.9	0.20
India	173.8	1,311.0	0.13
Pakistan	21.6	188.9	0.11
Indonesia	24.7	257.6	0.10
North Korea	2.3	24.6	0.09
China	114.7	1,376.0	0.08
Vietnam	6.9	93.4	0.07
Timor-Leste	0.1	1.2	0.08
Malaysia	1.8	30.3	0.06
Nepal	2.2	28.5	0.08
Philippines	5.4	100.7	0.05
Bangladesh	8.4	160.9	0.05
Sri Lanka	1.3	20.7	0.06
Reference Countries			
Australia	47.6	23.9	1.99
South Korea	1.5	48.6	0.03
Japan	4.4	126.6	0.03
Argentina	38.4	43.4	0.88
South Africa	12.1	54.5	0.22
Brazil	72.3	207.8	0.35
USA	164.0	321.7	0.51

Source: PocketWorld in Figures, The Economist, 2015, World Population Prospects (WPP): Key findings and advance tables. 2015 UN Revision, and The World Factbook

Appendix 5. Estimated Population of the 28 Biotech Countries in 2015, 2050, 2100

	Country	Population in 2015*	Estimated Population in 2050*	Estimated Population in 2100*
1	USA	321.7	388.9	450.4
2	Brazil	207.8	238.3	200.3
3	Argentina	43.4	55.4	58.6
4	India	1,311.0	1,705.3	1,659.8
5	Canada	35.9	44.1	49.7
6	China	1,376.0	1,348.0	1,004.4
7	Paraguay	6.6	8.9	8.7
8	South Africa	54.5	65 540	65 696
9	Pakistan	188.9	309.6	364.3
10	Uruguay	3.4	3.7	3.2
11	Bolivia	10.7	16.0	18.1
12	Philippines	100.7	148.3	168.6
13	Australia	23.9	33.5	42.4
14	Burkina Faso	18.2	42.8	81.0
15	Myanmar	53.9	63.6	56.0
16	Mexico	127.0	163.7	148.4
17	Spain	46.1	44.8	38.3
18	Colombia	48.2	54.9	45.3
19	Sudan	40.2	80.2	127.3
20	Honduras	8.0	11.2	10.6
21	Chile	17.9	21.6	19.7
22	Portugal	10.3	9.2	7.4
23	Vietnam	93.4	112.8	105.0
24	Czech Republic	10.5	10.0	8.8
25	Slovakia	5.4	4.9	3.7
26	Costa Rica	4.8	5.7	5.0
27	Bangladesh	160.9	202.2	169.5
28	Romania	19.1	15.2	10.7
	World	**7,349.1**	**9,725.1**	**11,213.3**

Source: World Population Prospects (WPP): Key findings and advance tables. 2015 UN Revision, Department of Economic and Social Affairs. Population Division. esa.un.org/unpd/wpp/publications/files/key_findings_wpp_2015.pdf.

Appendix 6. Crops Modified through RNA/Gene Silencing Mechanisms

Trait	Crop	Event/Developer	Gene/Source	Mechanism	Authorized since
Altered lignin production	Alfalfa	KK179 (Monsanto Co. and Forage Genetics International)	*ccomt* (inverted repeat)	dsRNA that suppresses endogenous S-adenosyl-L-methionine:transcaffeoyl CoA 3-0 methyltransferase RNA transcript levels via the RNAi	2013
Altered polygalactu-ronase enzyme	Tomato	B (ZenecaPlant Science and Petoseed Co.)	*pg* (antisense) *L.esculentum*	Gene silencing (GS) No functional polygalacturonase enzyme produced	1994
Altered polygalactu-ronase enzyme		Da (ZenecaPlant Science and Petoseed Co.)	*pg* (antisense) *L.esculentum*	GS - No functional polygalacturonase enzyme produced	1994
Altered polygalactu-ronase enzyme		F (10401F, h38F, 11013F, 7913F) (ZenecaPlant Science and Petoseed Co.)	*pg* (antisense) *L. esculentum*	GS - No functional polygalacturonase enzyme produced	1994
Altered polygalactu-ronase enzyme		FLAVR SAVR™ (Monsanto Co.)	*pg* (antisense) *L. esculentum*	GS - No functional polygalacturonase enzyme produced	1992
Delayed ripening	Tomato	1345-4 (DNA Plant Tech Corp, USA)	*acc* (truncated) antisense *L. esculentum*	GS-Suppresses normal expression of native ACC synthase gene – reduced ethylene production and delayed ripening	1995
Delayed ripening/ senescence	Carnation	66 (Florigene Pty Ltd, Aus)	*acc* (truncated) antisense *L. esculentum*	GS-Reduced synthesis of endogenous ethylene through gene silencing	1995
Delayed ripening/ senescence	Tomato	Huafan No. 1 (Huazhong Agricultural Univ., China)	*efe* antisense *L. esculentum*	Delayed ripening through cyclopropane-1-carboxylase oxidase silencing	1997
Coleopteran insect resistance	Maize	Mon 87411 (Monsanto Co.)	*dvsnf7* *Diabrotica virgifera virgifera*	RNAi down regulating the function of *Snf7* gene	2014
Modified oil/fatty acid	Soybean	Mon 87705* (Monsanto Co.)	*fatb1-A* antisense *Glycine max*	RNAi suppression of acyl-acyl carrier protein	2011
			fad2-1a antisense *Glycine max*	RNAi suppression of delta 12 desaturase	
Modified oil/fatty acid	Soybean	DP 305423* (Du Pont (Pioneer Hi-Bred International Inc.)	*gm-fad2-1* (partial sequence) *Glycine max*	Gene silencing of omega 6 desaturase enzyme allows accumulation of oleic acid	2009

Appendix 6. Crops Modified through RNA/Gene Silencing Mechanisms

Trait	Crop	Event/Developer	Gene/Source	Mechanism	Authorized since
Modified oil/fatty acid	Soybean	260-05 (G94-1, G94-19, G168) (Du Pont (Pioneer Hi-Bred International Inc.)	*qm-fad2-1* (silencing locus) *Glycine max*	Gene silencing via additional copy of the *qm-fad2-1* gene	1997
Modified Starch/ carbohydrate	Potato	AMO4-1020 (BASF)	*gbss* (antisense fragment) *Solanum tuberosum*	Gene silencing suppressed granule-bound starch synthase	2014
Modified starch/ carbohydrate	Potato	EH 92-527-1 (BASF)	*gbss* (antisense fragment) *Solanum tuberosum*	Gene silencing suppressed granule-bound starch synthase	2010**
Mod starch/carb Reduced acryl potential, black spot bruise tolerance	Potato	E12/E24/F10/F37 (Ranger Russet Burbank) G11/H37/H50 (Innate Potato) J3, J55, J78 (Atlantic Potato) (J.R. Simplot Co.)	*asn1* (9 Ds RNA) *pPhL* (16 DS RNA) *ppo5* (8 DS RNA) *pR1* (15 DS RNA *Solanum tuberosum*	dsRNA triggers degradation of corresponding RNA of ASN1, PhL, PPO5 and R1 to effect phenotype	2014
Nicotine reduction	Tobacco	Vector 21-41 (Vector Tobacco Inc.,USA)	*NtQPT1* (antisense) *Nicotiana tabacum*	Antisense RNA silenced quinolinic acid phosphoribosyl transferase	2002
Non browning phenotype	Apple	GD743 (Okanagan Specialty Fruits Inc.)	PGAA PPO suppression gene *Malus domestica*	dsRNA is processed into small interfering RNAs, direct cleavage of target mRNA through sequence complementarity and suppresses polyphenyl oxidase (PPO)	2015
Non browning phenotype		GD 784 (Okanagan Specialty Fruits Inc.)	PGAA PPO suppression gene *Malus domestica*	dSRNA is processed into small interfering RNAs, direct cleavage of target mRNA through sequence complementarity and suppresses polyphenyl oxidase (PPO)	2015
Viral disease resistance	Bean	Embrapa 5.1 (Embrapa)	Sense/antisense RNA of viral replicase from Bean Golden Mosaic Virus	Inhibits synthesis of viral replicase – confers resistance to the BGMV	2011
	Papaya	55-1, 63-1, (University of Hawaii and Cornell University)	Coat protein of PRSV	Pathogen-derived resistance	1996
		X17-2 (University of Florida)	Coat protein of PRSV	Pathogen-derived resistance	2008
		Huanong No.1 (South China Agricultural University)	Coat protein of PRSV	Pathogen-derived resistance	2006

Appendix 6. Crops Modified through RNA/Gene Silencing Mechanisms

Trait	Crop	Event/Developer	Gene/Source	Mechanism	Authorized since
	Plum	C-5 (USDA-ARS)	Coat protein of plum pox virus (PPV)	Pathogen-derived resistance	2007
	Potato	14 events: HLMT 15-15 HLMT 15-3 HMLT 15-46 RBMT15-101 (Monsanto Co.)	Coat protein of potato virus Y (PVY)	Pathogen-derived resistance	1998
		RBMT 21-129 RBMT 21-152 RBMT 21-350 RBMT 22-082 RBMT 22-186 RBMT 22-238 RBMT 22-262 (Monsanto Co.)	Putative replicase domain of the potato leaf roll virus PLRV orf 1 and 2	Pathogen-derived resistance	1997
		SEMT 15-02 SEMT 15-07 SEMT 15-15 (Monsanto Co.)	Coat protein of potato virus Y (PVY)	Pathogen-derived resistance	1997
	Squash	CZW3 (Zeminis Vegetable Seeds, Canada) and Monsanto)	CP of cucumber mosaic cucumovirus (CNV), zucchini yellow mosaic potyvirus, and watermelon mosaic potyvirus	Pathogen-derived resistance	1994
		ZW20 (Zeminis Vegetable Seeds, Canada) and Monsanto Co.)	CP of zucchini yellow mosaic potyvirus, and watermelon mosaic potyvirus 2	Pathogen-derived resistance	1994
	Sweet Pepper	PK-SP01 (Beijing University)	CP of cucumber mosaic cucumovirus (CNV)	Pathogen-derived resistance	1998
	Tomato	PK-TM8805R (Beijing University)	CP of cucumber mosaic cucumovirus (CNV)	Pathogen-derived resistance	1998

Appendix 7. A List of Selected Biotech Crops at Various Stages of Field Testing in Different Countries

	Crop	Trait(s)	Attributes	Institutions	Country
1	Apple	AP	Anti-Browning and Anti Bruising	Okanagan Speciality	Canada, USA
2	Apple	DR	Blight resistant	ETH Zurich & JKI	Germany & Switzerland
3	Alfalfa	AP	Low Lignin	Monsanto, Forage Genetic International & Pioneer	USA
4	Banana	QT	Enhanced Vitamin-A	QUT, NARO & Gates Foundation	Uganda
5	Banana	DR	Banana Xanthomonas Wilt	AATF, Academia Sinica, NARO, IITA, Gatsby Foundation & USAID	Uganda
6	Banana	IR/NR	Parasitic, weevil & nematode resistant	NARO, UC, UP, Rockefeller Foundation & USAID	Uganda
7	Banana	QT/DR	Vitamin A and fungal and viral disease resistance	BARC, IIHR & DBT	India
8	Bean	VR	Gemini Virus Resistance	Embrapa	Brazil
9	Brinjal/ Eggplant	IR	Fruit and shoot borer	NRCPB/ICAR, Bejo Sheetal, Ankur Seed & Rasi Seed	India
10	Camelina/ False flax	QT	Enhanced Omega-3	Rothamsted Research	UK
11	Canola	HT	Multiple mode herbicide tolerant	Pacific Seeds, Pioneed Hi-Bred	Australia
12	Canola	HT	Multiple-mode herbicide tolerant	Bayer CropScience, Monsanto & DuPont Pioneer	USA, Canada
13	Canola	QT	Enhanced Omega-3	Cargill & BASF	USA
14	Canola	QT	ProPound Advanced Canola Meal	Dow AgroSciences	USA
15	Cassava	VR	Brown streak virus resistant	Danforth Center, Howard Buffet Foundation, Gates Foundation, NARS, Monsanto, ETH Zurich & USAID	Kenya & Uganda
16	Cassava	QT	Enhanced Vitamin-A	AATF, KARI & NARO	Nigeria, Kenya & Uganda
17	Citrus	DR/ HLB/ ACP	Citrus Greening	USDA & HLB-MAC	USA
18	Chickpea	IR	Pod Borer Resistant	AAU, DBT & Sungro Seeds	India
19	Cotton	IR/HT	Stacked insect resistant and herbicide tolerant	KALRO, INERA & Monsanto	Cameroon, Burkina Faso, Ghana, Kenya, Malawi & Togo
20	Cotton	IR/HT	Stacked insect resistant and herbicide tolerant	Monsanto	Pakistan
21	Cotton	IR/HT	Stacked insect resistant and herbicide tolerant	Mahyco & Monsanto	India
22	Cotton	IR/HT	Triple gene insect resistant & herbicide tolerant	Monsanto	India
23	Cotton	NUE	Nitrogen use efficient	Mahyco	India
24	Cotton	IR/HT	Multiple-mode insect and herbicide tolerant	Bayer CropScience, Dow AgroScience & Monsanto	USA

Appendix 7. A List of Selected Biotech Crops at Various Stages of Field Testing in Different Countries

	Crop	Trait(s)	Attributes	Institutions	Country
25	Cotton	IR/HT	Lygus Control	Monsanto	USA
26	Cotton	QT	Ultra low Gossypol	TAMU	USA
27	Cotton	AP, QT	Agronomic performance and product quality	CSIRO	Australia
28	Corn	QT	High Phytase	Origin Agritech & CAAS	China
29	Corn	IR/DT	Double gene insect resistant & drought tolerant	AATF, CIMMYT, Gates Foundation, Buffet Foundation, Monsanto, NARS & WEMA	Kenya, Uganda & South Africa
30	Corn	IR/HT	Stacked insect resistant and herbicide tolerant	Pioneer, Monsanto, Syngenta & Metahelix	India
31	Corn	IR/HT	Stacked insect resistant & herbicide tolerant	Pioneer & Monsanto	Indonesia
32	Corn	IR/HT	Stacked insect resistant & herbicide tolerant	Pioneer, Monsanto & Syngenta	Pakistan
33	Corn	IR/HT	Stacked insect resistant and herbicide tolerant	Pioneer & Monsanto	South Africa
34	Corn	IR/HT	Multiple-mode insect & herbicide resistant	Dow AgroScience, Monsanto, Du Pont Pioneer & Syngenta	USA
35	Corn	NUE	Nitrogen use efficiency	Pioneer & Syngenta	USA
36	Corn	ST	Stress tolerance and yield enhancement	Pioneer, Monsanto & BASF	USA
37	Corn	IR/HT	Stacked insect resistant & herbicide tolerant	Pioneer, Monsanto & Syngenta	Vietnam
38	Corn	AP	High Yield	Monsanto and BASF	USA
39	Corn	AP	High Yield	Rothamstead Research and Syngenta	UK
40	Cowpea	IR	Pod borer resistant	AATF, CSIRO, IITA, Monsanto, NARS, NGICA, PBS, Rockefeller Foundation & USAID	Burkina Faso, Ghana & Nigeria
41	Groundnut	VR/FR	Groundnut rosette virus, *Aspergillus flavus* & aflatoxin	ICRISAT	India
42	Mustard	AP	Heterosis exploitation	University of Delhi South Asia	India
43	Pigeon pea	IR	Pod borer resistant	ICRISAT	India
44	Potato	DR	Late blight resistant	WU, VIB & GU	Netherlands & Belgium
45	Potato	VR	Potato Virus Y (PVY) resistant	INBEBI/CONICET-UBA & Tecnoplant-SIDUS SA	Argentina
46	Potato	DR	Late blight resistant	BARI, PRC, ABSP-II & USAID	Bangladesh
47	Potato	DR	Late blight resistant	IAARD, ICABIOGRAD, IVEGRI, ABSP-II & USAID	Indonesia
48	Potato	DR	Late blight resistant	CPRI, ICAR, ABSP-II & USAID	India
49	Potato	DR/QT	Late Blight Resistant, Anti-Browning, Anti Bruising & Low Acrylamide	J.R. Simplot Company	USA
50	Rice	IR	Insect resistant	HuAU	China
51	Rice	NU-WEST	Nitrogen use efficiency, Water efficient & salt tolerant	AATF, Arcadia biosciences, CIAT, Japan Tobacco, NARS, UC, DFID & USAID	Ghana & Uganda

Appendix 7. A List of Selected Biotech Crops at Various Stages of Field Testing in Different Countries

	Crop	Trait(s)	Attributes	Institutions	Country
52	Rice	IR	Insect resistant	Mahyco, Rasi Seed, Metahelix, Bayer, Pioneer, JK Agrigenetics & Bioseeds	India
53	Rice	NUE	Nitrogen use efficiency	Mahyco	India
54	Rice	QT	High iron	CU & DBT	India
55	Rice	NUE	Nitrogen use efficiency	Mahyco	India
56	Rice	AP	Yield enhancement	BASF	India
57	Rice	QT	Enhanced Vitamin-A	IRRI	Bangladesh, India, Indonesia & Philippines
58	Rice	QT	Enhanced Vitamin-A	IRRI & PhilRice	Philippines
59	Rice	IR/HT	Multiple gene insect resistant & herbicide tolerant	Bayer CropScience, Pioneer, Dow AgroSciences	USA
60	Safflower	QT	High Oleic acid	CSIRO	Australia
61	Sorghum	QT	Enhanced Vit-A, Bio-available Zinc and Iron	Africa Harvest, Pioneer Hi-Bred, a DuPont business and KALRO; IAR and NABDA	Kenya, Nigeria
62	Soybean	HT	Herbicide tolerant	EMBRAPA & BASF	Brazil
63	Soybean	HT/QT	Herbicide tolerant & modified fatty acid	Pioneer	South Africa
64	Soybean	HT	Multiple mode herbicide tolerant	Bayer CropScience, Dow AgroScience, Monsanto, Pioneer & Syngenta	USA
65	Soybean	QT	SDA Omega-3 & Zero trans-fat oil	Monsanto	USA
66	Soybean	AP	Yield enhancement	Monsanto & BASF	USA
67	Soybean	NR	Soybean cyst nematode tolerant	Bayer, BASF, Syngenta & Monsanto	USA
68	Soybean	DR/AP	Asian soybean rust tolerant and increased oil & improved feed efficiency	Pioneer	USA
69	Soybean	DR	Disease resistance	Syngenta	USA
70	Soybean	ST	Multiple environmental stress	Verdeca LLC (Bioceres and Arcadia)	Argentina
71	Sugar beet	AP/DT	High yielding & drought tolerant	KWS & BASF	Germany
72	Sugarcane	IR/HT	Insect resistant & herbicide tolerant	SRA & Monsanto	Australia & USA
73	Sugarcane	AP	High yielding & drought tolerant	CTC & BASF	Brazil
74	Sugarcane	AP	Drought tolerant	SRI & UPCSUR	India
75	Sugarcane	DT,AP	Drought tolerant and Increased biomass	CERES	USA and South America
76	Sugarcane	DT/QT	Drought tolerant & high sugar content	PTPN-XI, JU & Ajinomoto	Indonesia
77	Sugarcane	QT	Enhanced sugar content	University of Queensland	Australia
78	Sunflower	QT	Omega 9	Dow AgroSciences	USA

Appendix 7. A List of Selected Biotech Crops at Various Stages of Field Testing in Different Countries

	Crop	Trait(s)	Attributes	Institutions	Country
79	Tomato	AP	Purple color	Jonn Innes Centre	Canada
80	Wheat	DT	Drought tolerant	CSIRO & VDEPI	Australia
81	Wheat	QT	Improved grain quality	MU	Australia
82	Wheat	DR	Powdery mildew resistance	CAS	China
83	Wheat	DR	Fusarium resistant	CAAS	China
84	Wheat	VR	Yellow mosaic resistant	CAAS	China
85	Wheat	DT/DR	Drought tolerant and disease resistant	AGERI	Egypt
86	Wheat	IR	Aphid Resistant	Rothamsted Research	UK
87	Wheat	HT	Multiple mode herbicide tolerant	Monsanto	USA

Source: Analyzed and compiled by ISAAA, 2015.

Legend (Trait): ACP-Asian Citrus Psyllid; AP-Agronomic Performance; IR-Insect Resistance;DT-Drought Tolerance; DR-Disease Resistance; FR- Fungal Resistance; HLB-Huanglongbing ; HT-Herbicide Tolerance; NE- Nutrition Enhancement; NR-Nematode resistance; NUE- Nitrogen Use efficiency; NUWEST-Nitrogen Use Efficiency, Water Efficient & Salt Tolerant; QT-Quality Trait; ST- Stress tolerance and VR-Virus Resistance.

Acronyms (Developer): AATF-Africa Agricultural Technology Foundation; ABSPII-Agricultural Biotechnology Support Project; AAU- Assam agricultural University, India; ABS- Africa Biofortified Sorghum; AGERI- Agricultural Genetic Engineering Research Institute, Egypt; AU- Adelaide University, Australia; BARC- Bhabha Atomic Research Centre; BARI- Bangladesh Agricultural Research Institute; CAAS- Chinese Academy of Agricultural Sciences; CAS-Chinese Academy of Sciences; CONICET-Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina; CIAT- Centro Internacional de Agricultura Tropica; CPRI-Central Potato Research Institute, India; CSIRO- Commonwealth Scientific and Industrial Research Organization, Australia; CTC- Centro de Tecnologia Canavieira, Brazil; CU-Calcutta University, India; DU- Delhi University, India; DBT-Department of Biotechnology, India; DFID-Department for International Development, UK; EMBRAPA- Empresa Brasileira de Pesquisa Agropecuária, Brazil; GU-Ghent University, Belgium; HuAU- Huazhong Agricultural University, China; ICAR-Indian Council of Agricultural Research, India; IITA- International Institute of Tropical Agriculture; INERA- Institut Nationale d'Economie Rurale, Burkina Faso; ICRISAT- International Crops Research Institute for the Semi-Arid-Tropics; INGEBI-Instituto de Investigaciones en Ingeniería Genética y Biología Molecular, Argentina; IRRI- International Rice Research Institute, IAARD-Indonesian Agency for Agricultural Research and Development; IAR-Institute for Agricultural Research, Nigeria; ICABIOGRAD-Indonesian Center for Agricultural Biotechnology and Genetic Resources Research and Development; IVEGRI-Indonesian Vegetable Research Institute; JKI- Julius Kühn Institute, Germany; JU- Jamber University, Indonesia; KARI- Kenya Agricultural Research Institute; KALRO- Kenya Agricultural and Livestock Research Organization; MU- Murdoch University , Australia; NARS-National Agricultural Research Systems; NARO- National Agricultural Research Organization; NDDB- National Dairy Development Board, India; NGICA- Network for the Genetic Improvement of Cowpea for Africa; PBS-Program for Biosafety Systems; PRC-Potato Research Center, Bangladesh; PhilRice- Philippines Rice Research Institute; PTPN XI- PT. Perkebunan Nusantara XI, Indonesia; QUT- Queensland University of Technology, Australia; SRA- Sugar Research Australia; Sugarcane Research Institute; TAMU- Texas A&M University; UC- University of California, USA; UP- University of Pretoria, South Africa; UPCSUR- UP Council of Sugarcane Research; USAID- United States Agency for International Development; USDA- United States Department of Agriculture; VDEPI- Victorian Department of Environment & Primary Industries, Australia; VIB- Vlaams Instituut voor Biotechnologie, Belgium; WU-Wageningen University, Netherlands and WEMA- Water Efficient Maize for Africa

Appendix 8. Miscellaneous Data and Conversions

Source: Iowa State University (Extension and Outreach)
https://www.extension.iastate.edu/agdm/wholefarm/html/c6-80.html

Weights

1 bushel corn/canola (56 lb) = 25.40 (~25) kilograms
1 bushel wheat/soybeans (60 lb) = 27.22 (~27) kilograms
1 quintal = 3.937 (~4) bushels corn (56 lb bu)
1 quintal = 3.674 (~3.7) bushels wheat/soybeans (60 lb bu)
1 metric ton = 39.37 (~40) bushels corn /canola (56 lb bu)
1 metric ton = 36.74 (~37) bushels wheat/soybeans (60 lb bu)

Grain yields

A corn yield of 200 bushels per acre is first expressed by weight (200 bu @ 56 lb/bu = 11,200 lbs) and then converted to kilograms (11,200 lbs * .4536 kg/lb = 5,080 kg). Because a hectare is equal to 2.471 acres, it means that 200 bu/ac is equal to about 12,553 kg/ha (5,080 kg/ac x 2.471 ac/ha = 12,553 kg/ha). This also translates into 126 quintals per hectare (200 bushels per acre x .63 quintals/hectare) and 12.55 metric tons per hectare (200 bushels per acre x .0628 metric tons/hectare)

Corn/canola (56lb/bu)

1 kilogram/hectare (kg/ha) = .0159 (~.016) bushels/acre
1 bushel/acre = 62.77 (~63) kilograms/hectare
1 quintal/hectare (q/ha) = 1.593 (~1.6) bushels/acre
1 bushel/acre = .6277 (~.63) quintals/hectare
1 metric ton/hectare (MT/ha) = 15.93 (~16) bushels/acre
1 bushel/acre = .0628 (~.06) metric tons/ hectare

Wheat/soybeans (60# bu)

1 kilogram/hectare (kg/ha) = .0149 (~.015) bushels/acre
1 bushel/acre = 67.25 (~67) kilograms/hectare
1 quintal/hectare = 1.487 (~1.5) bushels/acre
1 bushel/acre = .6725 (~.67) quintals/hectare
1 metric ton/hectare = 14.87 (~15) bushels/acre
1 bushel/acre = .0673 (~.07) metric tons/hectare

Rate

Application rates are often given in weight of material per unit of area covered (pounds per acre) or volume of material per unit of area covered (quarts per acre).

1 kilogram/hectare (kg/ha) = .8922 (~.9) pounds/acre
1 pound/acre = 1.121 (~1.1) kilograms/hectare
1 liter/hectare (L/ha) = .4276 (~.4) quarts/acre
1 quart/acre = 2.338 (~2.3) liters/hectare

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