ISAAA
INTERNATIONAL SERVICE FOR THE ACQUISITION OF AGRI-BIOTECH APPLICATIONS

ISAAA Briefs

BRIEF 53

Global Status of Commercialized Biotech/GM Crops in 2017:

Biotech Crop Adoption Surges as Economic Benefits Accumulate in 22 Years

Up to 17 million farmers in 24 countries planted 189.8 million hectares (469 million acres) in 2017, an increase of 3% or 4.7 million hectares (11.6 million acres) from 2016.

No. 53 – 2017

Over the last 21 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.

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 2017 information for Argentina, Brazil, Australia, South Africa, and Uruguay is hectares usually planted in the last quarter of 2017 and harvested in the first quarter of 2018, 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 2017 and more intensively through January and February 2018, is classified as a 2017 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.

ISASA Briefs

BRIEF 53

Global Status of Commercialized Biotech/GM Crops in 2017:

Biotech Crop Adoption Surges as Economic Benefits Accumulate in 22 Years

No. 53 – 2017

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. ISAAA takes full responsibility for the views expressed in this publication and for any errors of omission or misinterpretation.

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This 2017 ISAAA Brief is the second extension of the 20 Volumes of Annual Briefs (1996 to 2015) on global status of biotech/GM crops authored by Clive James, Founder & Emeritus Chairman of ISAAA.

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INTRODUCTION

The first 21 years of commercialization of biotech crops (1996 to 2016) has confirmed that biotech crops have delivered substantial agronomic, environmental, economic, health, and social benefits to farmers, and increasingly to the consumers (ISAAA, 2016). The rapid adoption of biotech crops reflects the substantial multiple benefits realized by both large and small farmers in industrial and developing countries which have commercially grown biotech crops. In 21 years, an accumulated 2.15 billion hectares of biotech crops have been grown commercially, comprised of 1.04 billion hectares of biotech soybean, 0.64 billion hectares of biotech maize, 0.34 billion hectares of biotech cotton, and 0.13 billion hectares of biotech canola. Biotech products derived from 2.15 billion hectares significantly contribute food, feed, fiber and fuel to the current 7.6 billion people. Hence, feeding the world which is continuously increasing and predicted to be 9.8 billion in 2050 and 11.2 billion in 2100 (UN, 2017) is indeed a daunting task.

It is quite unfortunate though that the successes of the UN Millennium Development Goals (UN-MDG) that ended in 2015 were not altogether successful as indicated in current situationer released by the global food insecurity report (FAO, July 23, 2017). The Global Report on Food Crises in 2017 revealed that around 108 million people in 48 food crisis-affected countries are still at risk or in severe acute food insecurity since 2016. Moreover, the number of hungry people has reversed years of progress accomplished by the UN-MDG, with about 60% of the hungry people being located in 19 countries facing conflict and climate change situations. The situation is expected to worsen with the documented decline in productivity and protein content of major staple crops with climate change. It is thus estimated that the world will require some 50% to 70% increase in food production (Pennsylvania State University, 2017) with dwindling resources of land, water, and the environmental and agricultural challenges brought by climate change.

It is noteworthy, however, that productivity gained in the last 21 years through biotech crops proved that conventional crop technology alone cannot allow us to feed the immense increase in population, but neither is biotechnology a panacea. The global scientific community adheres to the option of a balanced, safe, and sustainable approach using the best of conventional crop technology such as the well-adapted and agronomically desirable and high-yielding germplasm, and the best of biotechnology (GM and non-GM traits), to achieve **sustainable intensification** crop productivity on the 1.5 billion hectares of cropland globally.

The more than 18 million farmers (up to 90% were small/poor farmers) in up to 30 countries who have planted biotech crops attest to the multiple benefits they derived in the last 21 years as follows:

- Increased productivity that contributes to global food, feed, and fiber security;
- Self-sufficiency on a nation's arable land;
- Conserving biodiversity, precluding deforestation and protecting biodiversity sanctuaries;
- Mitigating the challenges associated with climate change; and
- Improving economic, health, and social benefits.

These economic benefits, health improvement, and social gains obtained through biotech crop adoption should be made known to the global community so that farmers and consumers can make informed-choice in what crops to grow and consume, respectively; to the policy makers and regulators to craft enabling biosafety guidelines for commercialization and adoption of biotech crops; and to the science communicators and the media to facilitate dissemination of the benefits and potentials of the technology.

In consonance with the above, the International Service for the Acquisition of Agri-biotech Applications (ISAAA) has been publishing the annual series of Global Status of Commercialized Biotech/GM Crops. This publication documents the latest information on the subject, global database on the adoption and distribution of biotech crops since the first year of commercialization in 1996, country situations and future prospects of the technology in the countries and the world. Termed as ISAAA Briefs, the annual reports from 1997 to 2015 were authored by Dr. Clive James, and the 1996 report was co-authored with Dr. Anatole Krattiger.

In 2017, global hectarage of biotech crops increased from 185.1 million hectares to 189.8 million hectares, a 3% increase equivalent to 4.7 million hectares. As predicted by James (2015), the slight decline in biotech crop area in 2015 easily reverted back to the increasing trend of biotech crop area in 2016 and 2017 with changes in global prices of commodities, demand for biofuels, need for livestock and poultry feeds, environmental stresses, disease/pest pressure, country policies, and consumer perception. Thus, adoption of biotech crops in 2017, detailed in each country chapter was a result of an interplay of these various factors, but it is noteworthy that the majority was over 90% of major products in principal markets in both developing and industrial countries. 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.

This 2017 Report also includes a detailed discussion on how biotechnology addresses global food insecurity in the face of high population growth, declining food production as a consequence of the effects of climate change in agriculture, and a call to international bodies for new urgent action to reverse the rise in hunger. The chapter discussed at length current high adoption of biotech crops and the benefits that the global population can derive such as increased productivity, conservation of biodiversity and land savings, reduction of environmental footprint, and in mitigating the harmful effects of climate change to the environment. Also, benefits from specific biotech crops and traits (insect resistance [IR], herbicide tolerance [HT], stacked [IR/HT) based from the analysis of Brookes and Barfoot (2018, Forthcoming) were discussed for a thorough appreciation of this technology from the time they were first commercialized in 1996 to 2016. This is followed by a discussion on the current global value of biotech crops at US$17.2 billion and the future of global GM crops and seeds market revenue obtained from two sources which estimated an increase of 8.3% in 2022 to 10.5% in 2025. A chapter on opportunity cost without global biotech crops provides information on the monetary losses that will be incurred when there is restrictive regulation in biotech commercialization that cause delay or total non-planting of biotech crops. Finally, a chapter on the delayed benefits of public sector biotech crops, including Golden Rice, Bt eggplant in India, virus resistant bean in Brazil, and water efficient maize in Africa were discussed to highlight the benefits that farmers and consumers should have been enjoying if these public sector biotech crops are already in the farm and commercialized.

ISAAA dedicates this Brief to Dr. Clive James, Founder and Emeritus Chair of ISAAA, who has painstakingly authored the 20 Annual Reports making it the most credible source of information on biotech crops in the last two decades. He has been a great advocate of biotechnology and biotech products following the footsteps of his great mentor and colleague the late Nobel Peace Laureate Norman Borlaug, who was also the founding patron of ISAAA.

GLOBAL AREA OF BIOTECH CROPS IN 2017

In 2017, the accumulated biotech crop area (planted since 1996) surged to a record 2.3 billion hectares or 5.8 billion acres (Table 1). Of the total number of 24 countries planting biotech crops in 2017, 19 were developing countries and 5 industrialized countries (Table 2, Figure 1). To put the 2017 global area of biotech crops into context, 189.8 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 3% increase between 2016 and 2017 is equivalent to 4.7 million hectares or 11.6 million acres (Table 1).

Table 1. Global Area of Biotech Crops, 22 Years, 1996 to 2017

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	145.0
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
2016	185.1	457.4
2017*	**189.8**	**469.0**
Total	**2,339.5**	**5,780**

*Global area of biotech crops in 2017 increased to 189.8 million hectares compared with 185.1 million hectares in 2017, equivalent to 3% or 4.7 million hectares (11.6 million acres).

Source: ISAAA, 2017

DISTRIBUTION OF BIOTECH CROPS IN INDUSTRIAL AND DEVELOPING COUNTRIES

Developing countries continued to outperform industrialized countries since 2012. Prior to 2011, industrial countries consistently outperformed developing countries, and by 2011, the global area of biotech crops was evenly distributed between industrialized and developing countries. Starting 2012, developing countries consistently increased in area and by 2017, a difference of 11.4 million hectares between developing and industrialized countries was achieved. Developing countries grew 53% of the global biotech hectares compared to 47% for industrialized countries (Table 2, Figure 1). Moreover, industrialized countries increased by 4.3% in 2017, compared to 2016, while developing countries increased by 1.0%.

Table 2. Global Area of Biotech Crops, 2015 and 2017: Industrialized and Developing Countries (Million Hectares)

	2016	%	2017	%	+/–	%
Industrialized countries	85.5	46	89.2	47	+3.7	+4.3
Developing countries	99.6	54	100.6	53	+1.0	+1.0
Total	**185.1**	**100**	**189.8**	**100**	**4.7**	**+3%**

Source: ISAAA, 2017

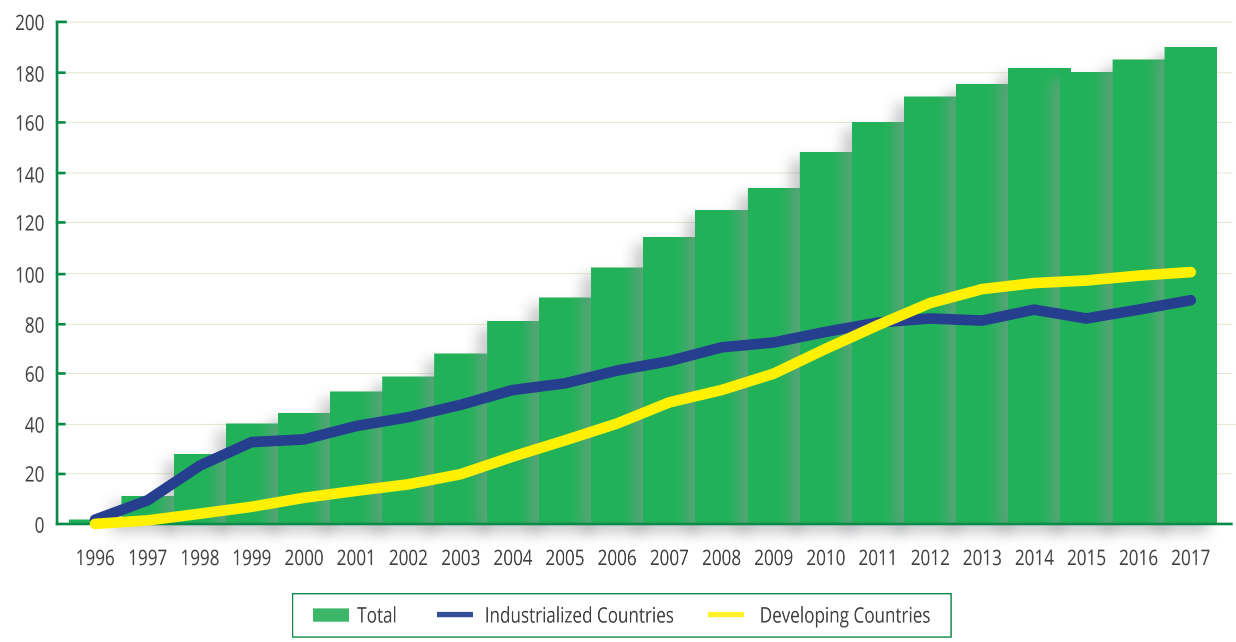


Figure 1. Global Area of Biotech Crops, 1996 to 2017: Industrialized and Developing Countries (Million Hectares)

Source: ISAAA, 2017

The 3.7 million hectares increment in the industrialized countries between 2016 and 2017 is due mainly to increases in the USA at 3% and Canada at 13%, as well as small increases in Australia, Spain and Portugal. Increases in developing countries, led by India at 6%, Brazil and Pakistan at 3%, and increases in the biotech area in Bolivia, Vietnam, Chile and most especially in Bangladesh at 242% (Tables 2 and 3). 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 such as rice and potato, which are grown in developing countries, and will be deployed as "new" biotech crops.

DISTRIBUTION OF BIOTECH CROPS, BY COUNTRY

A total of 24 countries, 19 developing and 5 industrialized countries, planted biotech crops in 2017. The top ten countries, each of which grew over 1 million hectares in 2017, was led by the USA which grew 75 million hectares (40% of global total, higher by 1% in 2016), Brazil with 50.2 million hectares (26%), Argentina with 23.6 million hectares (12%), Canada with 13.1 million hectares (7%), India with 11.4 million hectares (6%), Paraguay with 3.0 million hectares (2%), Pakistan with 3 million hectares (2%), China with 2.8 million hectares (1%), South Africa with 2.7 million hectares (1%) and Bolivia with 1.3 million hectares (1%). An additional 14 countries grew a total of approximately 3.7 million hectares in 2017 (Table 3 and Figure 3).

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, Paraguay, Pakistan, China, South Africa, and Bolivia, compared with only two industrialized countries, USA and Canada. The Czech Republic and Slovakia did not plant biotech crops in 2017 due to internal problems brought by the onerous reporting of biotech crop planting and the preference of manufacturers to non-GM source materials.

A total of 18 biotech mega-countries (countries which grew 50,000 hectares, or more, of biotech crops) was recorded in 2017. **Notably, 14 of the 18 mega-countries were developing countries from Latin America, Asia, and Africa.** The high proportion of biotech mega-countries in 2017, 18 out of 24, equivalent to 75%, 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.

It is noteworthy, that in absolute hectares, the largest year-over-year growth, by far, was the USA with 2.1 million hectares, followed by Canada with 1.5 million hectares, Brazil with 1.1 million hectares, India with 600,000 hectares and Pakistan with 100,000 hectares. The top three biotech countries in terms of global share of the million hectares planted globally were the USA at 40%, Brazil at 26%, and Argentina at 12%, for a total of 78%.

Of the 24 countries that planted biotech crops in 2017, 12 (50%) of the countries were in the Americas, 8 (33.4%) were in Asia, 2 (8.3%) were in Europe, and 2 (8.3%) were in Africa. In terms of biotech crop area, of the 24 countries that planted biotech crops in 2017, 88% of the area was in the Americas, 10% in Asia, 1.5% in Africa and 0.5% in Europe.

There were 10 countries in Latin America, which benefit from the extensive adoption of biotech crops. Listed in descending order of biotech area, they were Brazil, Argentina, Paraguay, Bolivia, Uruguay, Mexico, Colombia, Honduras, Chile, and Costa Rica. There were 8 countries that planted biotech crops in Asia and the Pacific led by India, Pakistan, China, Australia, Philippines, Myanmar, Vietnam, and Bangladesh. For the sixth year since its approval, Japan grew the “blue rose” a commercial biotech flower, in 2017. 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 carnation.

In Africa, Sudan and South Africa grew a total of 2.9 million hectares of biotech crops; South Africa for 2.7 million hectares of biotech soybeans, maize and cotton, and Sudan for 192,000 hectares biotech cotton. Africa currently has 12 biotech crops in 13 countries and 14 traits under different stages of planting, experimentation and research. There is also

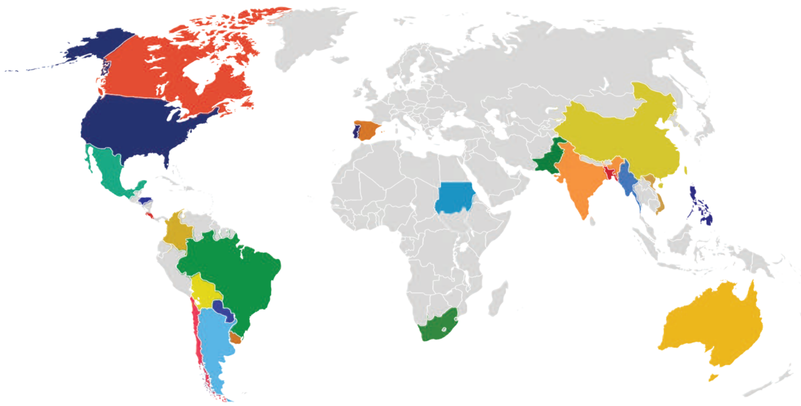
Table 3. Global Area of Biotech Crops in 2016 and 2017: by Country (Million Hectares)**

	Country	2016	%	2017	%	+/–	%
1	USA*	72.9	39	75.0	40%	2.1	3%
2	Brazil*	49.1	27	50.2	26%	1.1	2%
3	Argentina*	23.8	13	23.6	12%	-0.2	-1%
4	Canada*	11.1	6	13.1	7%	1.5	18%
5	India*	10.8	6	11.4	6%	0.6	6%
6	Paraguay*	3.6	2	3.0	2%	-0.6	-18%
7	Pakistan*	2.9	2	3.0	2%	0.1	3%
8	China*	2.8	2	2.8	1%	0.0	0
9	South Africa*	2.7	1	2.7	1%	0.0	0
10	Bolivia*	1.2	1	1.3	1%	0.1	7%
11	Uruguay*	1.3	1	1.1	1%	-0.2	-12%
12	Australia*	0.9	<1	0.9	<1	0.1	0%
13	Philippines*	0.8	<1	0.6	<1	-0.2	-21%
14	Myanmar*	0.3	<1	0.3	<1	0.0	0
15	Sudan*	0.1	<1	0.2	<1	0.1	59%
16	Spain*	0.1	<1	0.1	<1	0.0	0%
17	Mexico*	0.1	<1	0.1	<1	0.1	9%
18	Colombia*	0.1	<1	0.1	<1	<0.1	7%
19	Vietnam	<0.1	<1	<0.1	<1	<0.1	29%
20	Honduras	<0.1	<1	<0.1	<1	<0.1	3%
21	Chile	<0.1	<1	<0.1	<1	<0.1	23%
22	Portugal	<0.1	<1	<0.1	<1	<0.1	0
23	Bangladesh	<0.1	<1	<0.1	<1	<0.1	242%
24	Costa Rica	<0.1	<1	<0.1	<1	<0.1	0
25	Slovakia	<0.1	<1	--	--	--	--
26	Czech Republic	<0.1	<1	--	--	--	--
	Total	**185.1**	**100**	**189.8**	**100%**	**5.4**	**+3%**

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

Source: ISAAA, 2017

Figure 2. Global Area (Million Hectares) of Biotech Crops, 1996 to 2017, by Country, Mega-Countries, and for the Top Ten Countries



24 countries which have adopted biotech crops

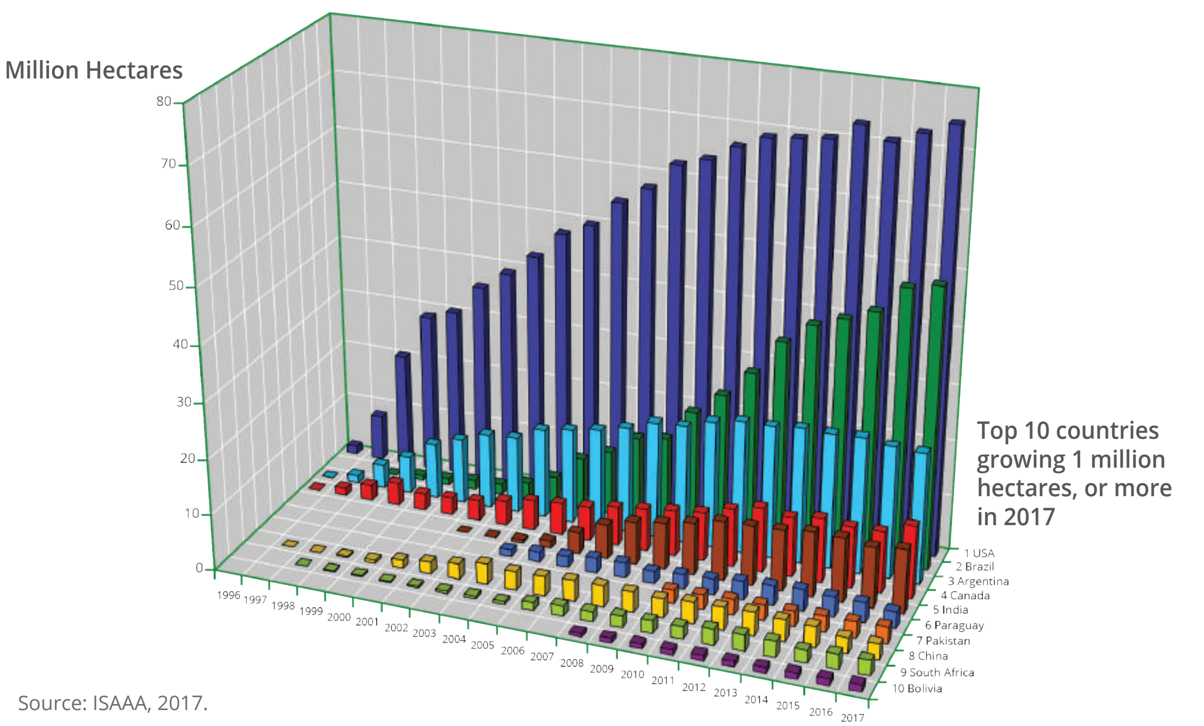
In 2017, global area of biotech crops was 189.8 million hectares, representing an increase of 3% from 2016, equivalent to 4.7 million hectares.

Source: ISAAA, 2017.

50,000 hectares, or more		
1.	USA	75.0 million
2.	*Brazil**	50.2 million
3.	*Argentina**	23.6 million
4.	Canada	13.1 million
5.	*India**	11.4 million
6.	*Paraguay**	3.0 million
7.	*Pakistan**	3.0 million
8.	*China**	2.8 million
9.	*South Africa**	2.7 million
10.	*Bolivia**	1.3 million
11.	*Uruguay**	1.1 million
12.	Australia*	0.9 million
13.	*Philippines**	0.6 million
14.	*Myanmar**	0.3 million
15.	*Sudan**	0.2 million
16.	Spain*	0.1 million
17.	*Mexico**	0.1 million
18.	*Colombia**	0.1 million

Less than 50,000 hectares	
*Vietnam**	Portugal
*Honduras**	*Bangladesh**
*Chile**	*Costa Rica**

** Developing countries*



Source: ISAAA, 2017.

a strong wave of endorsement of technology benefits through increased expressions of political goodwill and budget allocations by various governments.

The two EU countries, Spain and Portugal continued to plant biotech crops in 2017 at 131,535 hectares, indicating a slight decrease of 4% from 136,363 hectares in 2016. Czech Republic and Slovakia did not plant biotech crops in 2017 as mentioned above.

ECONOMIC BENEFITS OF BIOTECH CROPS

The six principal countries that have gained the most economically from biotech crops, during the first 21 years of commercialization of biotech crops, 1996 to 2016 were, in descending order of magnitude, the USA (US$80.3 billion), Argentina (US$23.7 billion), India (US$21.1 billion, Brazil (US$19.8 billion), China (US$19.6 billion), Canada (US$8 billion), and others (US$13.6 billion) for a total of US$186.1 billion.

In 2016 alone, the six countries that gained the most economically from biotech crops were: the USA (US$7.3 billion), Brazil (US$3.8 billion), India (US$1.5 billion), Argentina (US$2.1 billion), China (US$1 billion), Canada (US$0.82 billion), and others (US1.8 billion) for a total of US$18.2 billion (Brookes and Barfoot, 2018, Forthcoming).

The global economic benefits of US$18.2 billion in 2016 were divided between the developing countries at US$10 billion and US$8.2 for industrial countries.

TOP TEN BIOTECH CROP COUNTRIES

The top ten biotech crop planting countries include the USA (75.0 million hectares), Brazil (50.2 million hectares), Argentina (23.6 million hectares), Canada (13.1 million hectares) India (11.4 million hectares), Paraguay (3.0 million hectares), Pakistan (3.0 million hectares), China, (2.8 million hectares), South Africa (2.7 million hectares) and Bolivia (1.3 million hectares), which planted a total of 186.1 million hectares or 98% of the total 189.8 million hectares biotech crop area. Details on the biotech crops planted, adoption trends, country situations and future prospects for each country are discussed below.

UNITED STATES OF AMERICA

As in the past 21 years, the area of biotech crops planted in 2017 in the United States of America (USA) remains the highest globally. A total of 75 million hectares of biotech crops were planted comprised of 34.05 million hectares biotech soybeans, 33.84 million hectares biotech maize, 4.58 million hectares biotech cotton, 1.22 million hectares biotech alfalfa, 876,000 hectares biotech canola, 458,000 hectares biotech sugar beet, 3,000 hectares biotech potato, and some 1,000 hectares each of biotech apples, squash, and papaya (Figure 3). The biotech crop area in the USA was 40% of the global biotech crop area of 189.8 million hectares, confirming the country's leadership in biotech crop farming.

The United States Department of Agriculture (USDA) estimates indicate that each of the percentage adoption of the three principal biotech crops was at, or close to maximum adoption: soybean at 94% (similar to 2016), maize at 93.4% (an increase of 1.4% from 2016), and biotech cotton at 96% (a 2% increase from 2016). The average adoption rate for the three crops is 94.5%, higher by 1.5% than 93% in

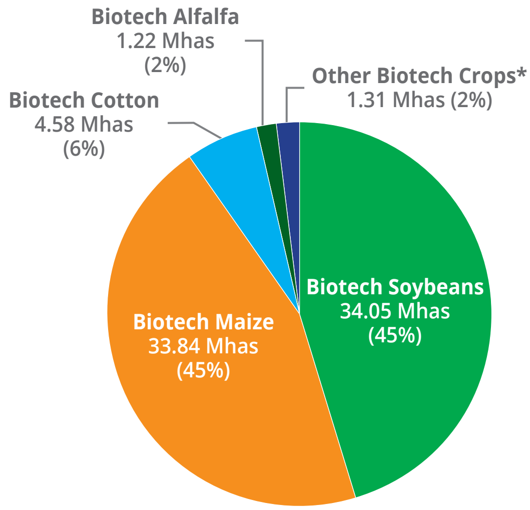


Figure 3. Biotech Crops Planted in the USA, 2017

* Biotech canola, biotech sugar beets, biotech potato, biotech apples, biotech squash, and biotech papaya.

Source: ISAAA, 2017

2016. The 2017 biotech crop area in the USA of 75 million hectares is 3% higher than the 2016 planting of 72.92 million hectares.

Since 1996, USA has approved 197 single trait events in 19 crop species: alfalfa (3), apple (3), Argentine canola (21), chicory (3), cotton (28), creeping bentgrass (1), flax (1), maize (43), melon (2), papaya (3), plum (1), potato (43), rice (3), soybeans (25), squash (2), sugar beets (3), tobacco (2), tomato (8), and wheat (1). In 2017 alone, the USA approved drought tolerant soybean for food, creeping bentgrass with glyphosate tolerance trait for food and cultivation, and glufosinate tolerant canola for food, feed, and cultivation.

In the 21 years of commercialization of biotech crops (1996-2016), the USA accrued the highest economic benefits of US$80.3 billion, and US$7.3 billion in 2016 alone (Brookes and Barfoot, 2018, Forthcoming) with more than

420,000 farmers cultivating these biotech crops. Biotech products from the USA are exported globally contributing to global food stability.

Biotech maize adoption increased to 93.4%

For 2017, the USDA National Agricultural Statistical Service (USDA NASS) reported that the total maize area was 36.8 million hectares, a decrease of 3% from 38.1 million in 2016. The biotech maize area was reported at 33.84 million hectares, a 3.5% decrease from 2016. The adoption rate, however, increased from 92% in 2016 to 93.4%. The biotech maize area of 33.84 million hectares was comprised of 1.1 million hectares insect resistant (IR), 4.4 million hectares herbicide tolerant (HT) and 28.34 million hectares stacked varieties with insect resistance and herbicide tolerance (IR/HT) traits (Table 4).

By December 2017, a total of 43 single biotech maize events have been approved in the USA for food, feed, and cultivation use, with insect resistance, herbicide tolerance, and drought tolerance (DT) traits. The 33.84 million hectares of biotech maize also include various stacked traits of IR, HT, and DT in addition to improved nutritional content and maize breeding related traits.

Low maize market price, high ending maize stocks in 2016, and elevated inventory levels of ethanol, affected maize planting in the USA in 2017. The low international and local price of maize prompted farmers to shift from maize to soybean which received higher market price in 2017. Prices for maize fell sharply after the USDA issued its monthly crop production and supply and demand reports, with maize down by 2.5% (Reuters News Service, August 10, 2017). The bountiful harvest in the past two consecutive years resulted to high U.S. maize ending stocks of 2.4 billion bushels, a 36% increase from 2015 and had pushed prices to below break-even levels.

Maize is the primary feedstock for ethanol production in the country. The US Energy Information Authority reported that during the first half of 2017, domestic E10 gasoline demand and export growth were outpaced by ethanol production rates, leading to elevated ethanol inventory levels. By mid-2017, weekly ending stocks of ethanol reached 2.1 million barrels, 5% higher than stocks at around the same time in 2016 and 13% higher than the previous five-year average (US Energy Information Agency, July 21, 2017). However, the continuous growth of US fuel ethanol production could boost maize planting in the near future.

Table 4. Total and Trait Hectares of Biotech Maize in the USA, 2016-2017

	Area Planted (MHa)		% Trait Hectares	
	2016	**2017**	**2016**	**2017**
Total Maize	38.10	36.79		
IR	1.14	1.10	3.3%	3.3%
HT	4.95	4.41	14.1%	13.0%
IR/HT**	28.96	28.34	82.6%	83.7%
Total Biotech Maize	**35.05**	**33.84**	**92.0%**	**93.4%***

* Adoption rate ** Includes 1.4 million hectares with drought tolerance trait

Source: ISAAA, 2017

Biotech soybean area increased by 7%

Soybeans are the second important crop in the USA, with a total planted area of 36.22 million hectares in 2017, 94% of which or 34 million hectares were biotech. Both total and biotech soybean areas increased by 6.9% (~7%) in 2017 compared to 2016, and adoption rate remained at 94%, similar to 2016. Biotech soybeans contain the herbicide tolerant traits that control various kinds of weeds depending on the genes deployed. Other traits incorporated in HT soybeans include consumer traits such as event 260-05 (approved in 1997) with high monounsaturated oleic acid; event DP 305423-1 (2009) and Vistive Gold MON87705-6 (2011); and omega3-fatty acid enriched soybean MON 87769 (2011).

Since 1996, 37 single events were approved in the USA for food, feed, and cultivation. In 2017, a drought tolerant soybean event was also approved in the country.

The high increment of soybean planting in the past four years was due in part to the shortfall in South American production in 2016 (FarmdocDaily, September 12, 2016). Total soybean usage for 2016-2017 was estimated at just over 4.1 billion bushels, up from near 3.9 billion bushels in both 2015-16 and 2014-2015. This is due to projected increases in both the export and soybean crush levels. In 2016-2017, the market year average soybean price was US$9.45 per bushel, 5% higher than the MYA in 2015-2016, that provided incentives to plant more soybeans in 2017.

Biotech alfalfa HarvXtra™ area increased by 75%

Alfalfa is the third most planted crop in the USA at 8.5 million hectares, with 14.4% or 1.2 million hectares being biotech. Since 2015, biotech alfalfa has offered herbicide tolerance and low lignin traits (HarvXtra™) to livestock farmers. Herbicide tolerant alfalfa was planted on 1.14 million hectares and 80,000 hectares to HarvXtra™ in 2017. The area planted to HarvXtra™ increased by 300% from 20,000 hectares in 2016 to 80,000 hectares in 2017, a manifestation of acceptance by US cattle producers for a product that is highly digestible and offers a 15 to 20% increase in yield. Since 1996, five biotech alfalfa events were approved in the USA for herbicide tolerance and low lignin traits.

Biotech cotton area increased by 20%

Upland cotton planted in the USA increased by 20% in 2017 at 4.8 million hectares from 3.9 million hectares in 2016. The biotech cotton area also increased by 24% from 3.7 million hectares in 2016 to 4.6 million hectares in 2017. Notably, adoption of biotech cotton in 2017 was 96%, an increase of 3% from 93% in 2016. The 4.6 million hectares of biotech cotton were comprised of 239,000 hectares insect resistant, 525,000 hectares herbicide tolerant, and 3.8 million hectares stacked IR and HT traits (Table 5). There were 59 biotech cotton single events that were approved in the USA since 1996 to control various weeds that affect cotton fields.

The total and biotech cotton area in the USA increased in 2017 due in part to the 6%, or 9 cents per pound increase in cotton price, from 68 cents per pound (0.45kg) in 2016 to 75.48 cents per pound. In addition, the world 2017-18 cotton projections show a decline in stocks of 2.4 million bales as consumption exceeds production for the third consecutive season. There is also a production forecast to increase in major cotton producing countries, as the global consumption is projected to rise by 23% when a growing economy drives mill use higher around the world (DeltaFarm Press, May 10, 2017).

Table 5. Total and Trait Hectares of Biotech Cotton in the USA, 2016-2017

	Area Planted (MHa)		% Trait Hectares	
	2016	2017	2016	2017
Total Cotton	3.98	4.78		
IR	0.16	0.24	4.30%	5.2%
HT	0.36	0.53	9.68%	11.5%
IR/HT	3.18	3.82	86.02%	83.3%
Total Biotech Cotton	**3.70**	**4.58**	**93.0%**	**96.0%***

* Adoption rate

Source: ISAAA, 2017

Biotech canola area increased by a remarkable 41%

The area covered by canola increased by 27% (from 690,000 hectares in 2016 to 876,000 hectares) with an accompanying increase in biotech canola of 41.1% (from 621,000 hectares to 876,000 hectares). Adoption rates likewise increased from 90% in 2016 to 100% in 2017. Since 1996, 40 single biotech events were approved for canola with different herbicide tolerance genes to control various weed species in canola fields. In addition, some biotech canola events have improved oil content for the health-conscious public, such as high lauric acid canola (Laurical Canola™), Event 18 and Event 23 approved in 1994. Event MPS 963 Phytaseed™ (1998) with high lauric acid approved in 1994 that contains an enzyme that breaks down plant phytases, making phosphorous available to monogastric animals. In 2017, glufosinate tolerant canola was approved for food, feed, and cultivation.

Farmers in the USA planted more canola and other alternate crops for wheat due to low wheat prices, as well as the increasing local market for canola in the country. Canola prices ranged from US$7.26 per hundredweight, while soft wheat averaged US$4.65 per bushel (Capital Press, April 6, 2017). This is a positive incentive for biotech canola farmers in the USA.

Biotech sugar beets remain at 100% adoption rate

Sugar beets were planted in the USA at 458,000 hectares, 100% of which was biotech herbicide tolerant. In 2017, biotech sugar beets had a minimal decrease of 3%. Across the country, the sugar beet growing season faced variability in sugar content and yield which affected the area planted and the amount of sugar harvested per area from year to year. The high price of sugar beets in 2016, which averaged US$45 to US$48 per ton compared to the US$46 per ton average in 2015, resulted in increased area and bountiful harvest in 2016. Thus, ending stocks of sugar beet sugar in 2016, as well as the competing sugar from cane could have resulted to a minimal decrease in sugar beet area in 2017 (Idaho Farm Bureau Federation, October 12, 2017). Since 2009, three herbicide tolerant sugar beet events have been approved for food, feed, and commercialization in the USA.

Virus resistant papaya and squash sustains small hectarage

Virus resistance traits deployed in papaya and squash have been in the US market since the mid-90's. Papaya ringspot virus is a potyvirus and resistant papaya was developed through the insertion of the coat protein genes of the virus. Papaya ringspot virus resistant (PRSV-R) Rainbow papaya was developed by public research institutions Cornell University and University of Hawaii in 1997 which was commercialized in the USA since 1998. USDA estimated that 77% (405 hectares) of 526 hectares of papaya in Hawaii in 2017 was PRSV-R papaya.

Similar to PRSV-R, the yellow crookneck squash (*Cucurbita pepo* L.) varieties were developed by Seminis Vegetable Seeds Inc. through the insertion of the viral coat protein genes of potyviruses watermelon mosaic virus 2 and zucchini yellow mosaic virus. Biotech squash resistant to mosaic and yellow mosaic virus diseases was planted in an estimated 1,000 hectares in the USA in 2017.

Biotech non-browning Arctic®Apples area increased to 101 hectares

Three non-browning Arctic® apple varieties (Golden, Granny, and Fuji) developed by Okanagan Specialty Fruits were approved by the US FDA and APHIS since 2015. The research team led by Neal Carter used gene silencing to produce less polyphenol oxidase (PPO), the enzyme that causes the flesh to turn brown. Apple slices with the trait does not brown for as long as three weeks. The US agency assessment documents concluded that these apples are just as safe as any other apple, they are unlikely to pose a plant pest risk, and deregulation is not likely to have a significant impact on human environment. In 2016, some 80 hectares of Arctic® apples were planted which increased to 101 hectares in 2017. The company plans to reach 567 hectares planted to Arctic® apples by 2019, out of the approximately 132,000 hectares of apple trees in the USA (Technology Review, October 7, 2017).

The product was launched as slices of Arctic® Golden apple in 10 oz packs in retail stores across the United States market from October to December 2017. This comes after a consumer research was conducted in early 2017 in six US cities, where primary grocery shoppers tried Arctic® apples. Notably, 95% were satisfied or very satisfied with the product and 92% said they would buy them if available in their local stores. Arctic® Granny and Fuji apples will also be marketed soon after. In the long term, commercial availability of non-browning apples could significantly reduce food waste since half of all apples produced end up in waste due to superficial bruising (Fresh Plaza, November 7, 2017).

Biotech potatoes Innate® generations 1 and 2 planted in the USA

Four Innate® generation 1 potato varieties (Russet Burbank, Ranger Russet, Atlantic, and Snowden) that are non-browning, resistant to bruising and black spots, and with less asparagine were deregulated successively since 2014. Having less asparagines in potatoes was found to reduce formation of acrylamide by 58-72% when exposed to high temperatures during cooking (Innate® potato website, retrieved December 2017). Generation 1 potatoes were planted on 160 hectares in 2015, 2,500 hectares in 2016, and 1,618 hectares in 2017. White Russet potatoes are available in supermarkets around the country. Consumers prefer these potatoes due to its reduced browning benefits as they can be prepared ahead of time because off-site peeling or dicing is possible, as they can stay fresher-looking longer.

Innate® generation 2 potato varieties that have late blight resistance genes and lower reducing sugars in addition to generation 1 traits were deregulated since 2016. Late blight trait in these potatoes addresses the major disease of potato, protecting farmers' fields and reducing fungicide spray of up to 45% to control late blight. Furthermore, the lowered reducing sugars in generation 2 potatoes contribute to the reduction in acrylamide while enhancing cold storage capability. In March 2017, the three generation 2 potatoes (Russet Burbank, Ranger Russet, Atlantic) were given approvals for planting, by the USA EPA (Innate potato website, retrieved December 2017). Generation 2 potatoes were planted on 809 hectares for the first time in 2017.

Researchers estimated that potato waste incurred in field, during storage, packing, retail and foodservice for fresh potatoes could be reduced by 447 million kilograms (986 million pounds) using Innate® potato varieties in the food industry. In addition, the presence of late blight resistance in these potatoes could reduce CO_2 emissions by 66 million kilograms (146 million pounds), reduce water usage by 64 billion liters (17 billion gallons), and a total of 200,000 fewer pesticide-hectare applications (495,000 fewer pesticide acre-applications) needed (Simplot, January 13, 2016).

Benefits of Biotech Crops

According to Brookes and Barfoot (2018, Forthcoming), in the 21 years of commercialization of biotech crops (1996-2016), the USA accrued the highest benefits of US$80.3 billion and US$7.3 billion for 2016. The USA, one of the first six countries to commercialize biotech crops, has been benefiting from the technology and is expected to retain its position with the most new biotech crops and traits being developed and commercialized.

Country Situationer

The USA has been in the forefront of biotechnology research, development, and commercialization. Since biotech crop commercialization started in 1996, the global community benefited from scientific innovations and its products that pass through the science-based regulation implemented by the US Food and Drug Administration, USDA-Animal and Plant Health Inspection Service, and the US Environmental Protection Agency. With the fast evolution of science and technology, the country has to be ready to regulate and assess future biotech products. Hence, the US National Academies of Sciences, Engineering, and Medicine Committee on Future Biotechnology Products and Opportunities to Enhance the Capabilities of the Biotechnology Regulatory System has released a Report on Preparing for Future Products of Biotechnology. The Report proposed three recommendations for action "to enhance the ability of the biotechnology regulatory system to oversee the consumer safety and environmental protection required for future biotechnology products" (Crop Biotech Update, March 22, 2017).

Provisions in each of the Agency biotechnology regulation were revised and comments were solicited from stakeholders. Various industry stakeholders had mixed reactions to the proposal with comments on the need to streamline the review process so as not to hamper research, innovation, and commercialization and consult foreign markets and international regulators in preparing for the implementation of the proposed rule. On the other hand, a provision for the exclusion of certain genome-edited products from undergoing pre-market approvals since they are low risk and similar to products of traditional mutation breeding was acceptable (Crop Biotech Update, July 19 and June 21, 2017).

In a similar vein, a letter by a group of independent scientists and members of the Information Technology and Innovation Foundation (ITIF) to Secretary Ryan Zinke of the Department of the Interior, appealed for the reversal of a Fish and Wildlife Service policy that phased out the use of genetically-modified (GM) seeds and neonicotinoid pesticides. The letter stressed that ***"It would appear to be a major***

federal action that should have been adopted through a notice-and-comment rulemaking process under the Administrative Procedure Act. But even setting aside this apparent procedural irregularity, the policy is at odds with the conservation objectives of the NWRS, which has a long and praiseworthy history of welcoming innovation in management practices for the betterment of wildlife and the environment." The Foundation appealed for the reversal of the directive (ITIF, October 3, 2017).

On the other hand, support to biotechnology and its products continued in the USA, as former President Barack Obama and the current President Donald Trump have each issued statements of support. In a speech in Milan, Italy, President Obama said, ***"The approach that I took when I was President of the United States is in the same way that I would let the science determine my policies around climate change. I try to let the science determine my attitudes about food production and new technologies."*** He also said that small and medium-sized farmers would be happy to adopt technologies that will help them do things better without much additional expense (Crop Biotech Update, May 17, 2017).

Current President Donald Trump in the American Farm Bureau Federation's 2018 Annual Convention in Nashville said to 7,400 farmers, ***"We are streamlining regulations that have blocked cutting-edge biotechnology, setting free our farmers to innovate, thrive, and to grow."*** His address decried the costs of excessive regulation, and touched on issues of particular importance to agriculturists such as regulations, labor, and trade. Furthermore, he signed two executive orders that fund and streamline the expansion of rural broadband access (Crop Biotech Update, January 16, 2018). The US government also took actions to counter the misinformation on agri-biotech products, as the U.S. House Committee on Appropriations considers to provide for consumer outreach to promote the understanding and acceptance of agricultural biotechnology and its products. US$3 million was proposed to be used by FDA and USDA to make various initiatives through publication and distribution of science-based educational information on environmental, nutritional, food safety, economic, and humanitarian benefits of biotechnology food and feed products (Crop Biotech Update, May 10, 2017).

Summary and Future Prospects

Generally, the area planted to biotech crops increased in the USA except for maize and sugar beets. The lesser drought incidence and lesser storms that bypassed the crop growing areas across the country as well as the favorable and profitable prices for soybeans, cotton, and canola were enough incentives for farmers to increase area of these three biotech crops. Average near saturation biotech adoption rates of 94.5% from the three major crops: maize, soybeans, and cotton may mean minimal increases expected in the coming years. Thus, expansion in biotech crop area will rely on other biotech crops: canola, alfalfa, sugar beets, potato, and apple. Other crops in the pipeline are the biotech chestnut tree with resistance to chestnut blight, biotech citrus greening resistant citrus, and an upcoming potato enriched with beta carotene developed by Italian and American scientists.

Animal biotechnology has also gained ground in the USA with biotech salmon that matures half the time compared to the non-biotech counterpart. Biotech salmon met some regulatory net with regards to food labeling, but has been commercialized in Canada in 2017. Aquabounty, the company that developed the biotech salmon, plans to begin sales in the USA in the second half of 2019. Genetically modified mosquito (*Aedes aegypti*), the vector of Dengue, Zika, Chikungunya, and other viral diseases, were developed by Intrexon to control mosquito breeding. The biotech insect has been placed under the US Environmental Protection Agency's responsibility to gain approval as a pesticide. This could lead to pilot releases of the mosquitos in the USA by 2018 (The Scientist, October 13, 2017). Other biotech animals include other fishes that mature early, goats that produce nutritive compounds in their milk and various disease-resistant livestock.

The USA leads the bandwagon in the discovery, development, and commercialization of biotech crops. The current revamp on biotech regulations of the three government regulatory agencies should reflect the country's leadership in acceptance and recognition of the scientific basis of the technology. Expeditious approval of new products of agri-biotechnology benefits not only the USA, but also the global community.

BRAZIL

Brazil planted the second largest area of biotech crops globally in 2017 at 50.2 million hectares compared to 49.1 million hectares in 2016, a 2% increase or 1.1 million hectares, and represents 26% of the global biotech area of 189.8 million hectares. The biotech crops planted in the country include soybean at 33.7 million hectares, maize (summer and winter) at 15.6 million hectares, and cotton at 940,000 hectares. The total planted area of these three crops in Brazil was 53.4 million hectares, a 1% increase from 52.6 million hectares in 2016. The 50.2 million hectares biotech crop area is a 94% adoption rate, a 1% increase from 2016 (Figure 4).

From 2013 to 2017, Brazil has approved 68 biotech events for food, feed, processing, and cultivation for bean (1), cotton (15), eucalyptus (1), maize (39), soybean (11), and sugarcane (1). In 2017, Brazil approved two cotton events: stacked GHB614 x T304-40 x GHB 119 x COT102 with insect resistance (IR) and stacked

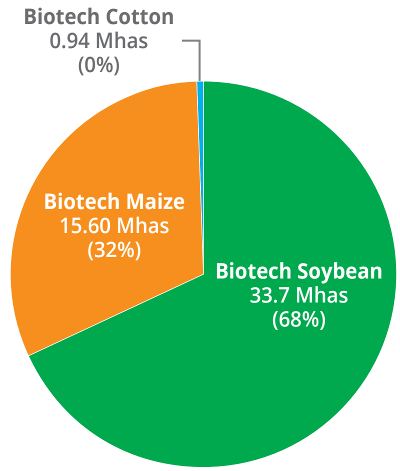


Figure 4. Biotech Crops Planted in Brazil, 2017

Source: ISAAA, 2017

glyphosate/glufosinate traits, as well as event MON88701 with stacked herbicide tolerance (HT) traits for glufosinate and dicamba; one stacked IR maize event MIR162 x MON89034; stacked IR/HT soybean event DAS-81419-2 and DAS-44406-6 that have two genes for insect resistance and three genes for herbicide tolerance to glyphosate, glufosinate and 2,4-D; and one sugarcane event CTB141175/01-A with insect resistance.

According to Brookes and Barfoot (2018, Forthcoming), the estimated economic benefits from biotech crops covering 2003 to 2016 in Brazil was US$19.8 billion, and US$3.8 billion in 2016 alone. These benefit some 300,000 farmers in the country whose economic status have improved since they adopted biotech crops.

Biotech soybean adoption rate increased to 97%

Biotech soybeans were planted on 33.7 million hectares at 97% adoption rate (compared to 96.5% in 2016), of the total 34.7 million hectares soybeans in 2017. Both the total soybean area and the biotech soybean area increased by 3% in 2017 compared to 2016. The 33.7 million hectares of biotech soybean were comprised of 40% (13.6 million hectares) HT and 60% (20.1 million hectares) stacked IR/HT. The stacked trait IR/HT (Intacta™), which was first introduced in 2013 on 2.2 million hectares, increased to 20.2 million hectares in 2016 and was planted on 20.1 million hectares in 2017, a slight decrease due to lower pest incidence.

Soybeans are still the preferred crop by farmers in Brazil due to profitability and market demand, both domestically and internationally. In 2017, economic and climatic conditions in the country increased investment in the technology, as well as the lower incidence of pests during the cropping season, contributed to the increased yield and area planted to soybeans. Brazil has a steady export market with China's strong demand for food and animal meat industry. Brazil's future soybean area is likely to increase with the local demand for feedstock for biodiesel production, which is expected to increase with the implementation of higher blending mandates. Soybean meal used for livestock is likewise estimated to increase with the growing animal protein consumption globally (USDA FAS GAIN Report, Oilseeds and Products Update-Brazil , 2017).

Biotech maize adoption rate increased to ~90%

The total summer and winter maize planted in Brazil decreased slightly by 1% (180,000 hectares) from 17.73 million hectares in 2016 to 17.55 million hectares in 2017 (Table 6). However, biotech maize adoption rate increased slightly from 88.4% (at 15.7 million hectares) in 2016 to 88.9% (15.6 million hectares) in 2017. The 15.6 million hectares biotech maize were comprised of 3.3 million hectares IR, 656,000 hectares HT and 11.7 million hectares IR/HT. The stacked trait maize had a significant increase of 3.2% or 367,000 hectares in 2017.

The slight decrease in biotech maize area was a consequence of low current prices and the expansion of soybean area in the country. Future increases in biotech maize area may come with the continued expansion of the soybean area where the second crop is maize. The increased maize area is needed to provide feed for the growing beef, pork (expected at 2.5% increase in 2018), and poultry sectors for export and domestic use, as well as plans to use maize in ethanol production. Brazil has

Table 6. Total and Trait Hectares of Biotech Maize in Brazil, 2016-2017

	Area Planted (MHa)		% Trait Hectares	
	2016	**2017**	**2016**	**2017**
Total Maize	17.73	17.55		
IR	3.67	3.26	23.4%	20.9%
HT	0.68	0.66	4.3%	4.2%
IR/HT	11.32	11.69	72.2%	74.9%
Total Biotech Maize	**15.67**	**15.60**	**88.4%***	**88.9%***

* Adoption rate

Source: ISAAA, 2017

been using sugarcane as a feedstock in ethanol production and maize may be an important option for maize producers in Brazil's Center-West region (USDA FAS GAIN Grain and Feed Uptake Report-Brazil, 2017).

Biotech cotton adoption increased to 84%

The total cotton area in 2017 increased by 100,000 hectares from 1 million hectares in 2016 to 1.1 million hectares in 2017 (Table 7). The increased total cotton area contributed to the 19% increase of biotech cotton area from 790,000 hectares in 2016 to 940,000 hectares in 2017. The 940,000 hectares of biotech cotton were comprised of 11% IR (102,000 hectares), 30% HT (282,000 hectares) and 59% IR/HT (556,000 hectares). The adoption rate of biotech cotton increased significantly in 2017 at 84% compared to 78.2% in 2016. The notable increase in cotton production area is due to the expected higher prices by producers in 2018 and a shift in some second crop maize area to cotton production as a result of lower maize prices. In addition, excellent seed technologies available in the market, as well as favorable weather conditions in cotton producing areas of Mato Grosso and Bahia (which experienced severe drought in the previous year) contributed to increase in cotton production area in 2017 (USDA FAS GAIN Cotton and Products Update-Brazil, 2017). Increasing local consumption and global exports to Indonesia, Turkey, Vietnam, South Korea, and Bangladesh will drive the expansion of biotech cotton area in the future.

Benefits of Biotech Crops

Brazilian farmers planting soybeans, maize, and cotton adopted biotech crops in 2003, or 12 years ago. Brookes and Barfoot (2018, Forthcoming) estimated that benefits from biotech crops covering 2003 to 2016 in Brazil was US$19.8 billion, and US$3.8 billion in 2016 alone. These are immense economic benefits for some 300,000 biotech farmers and their communities that contributed to improvements in their economic well-being.

Celeres in 2016 published the economic benefits of biotechnology with data collected from rural producers and the industries that developed the technology from 1996-1997 to 2012-2013 crop period. The economic benefits to users of the technology have reached US$24.8 billion.

Country Situationer

Brazil is one of the world's leading exporters of biotech soybeans, maize, and cotton.

Table 7. Total and Trait Hectares of Biotech Cotton in Brazil, 2016-2017

	Area Planted (MHa)		% Trait Hectares	
	2016	**2017**	**2016**	**2017**
Total Cotton	1.01	1.12		
IR	0.12	0.10	15.2%	10.9%
HT	0.24	0.28	30.4%	30.0%
IR/HT	0.43	0.56	54.4%	59.1%
Total Biotech Cotton	**0.79**	**0.94**	**78.2%***	**84.0%***

* Adoption rate

Source: ISAAA, 2017

Soybeans and cotton are exported to China and the European Union, while maize is exported to countries in Asia including Iran. This fact drives the increasing biotech crop adoption, as well as the high public acceptance, farmer satisfaction, and enabling government regulation in Brazil. In a survey conducted by Brazil's Biotechnology Information Council (CIB) on 1,250 rural producers, 90% recognized the importance of insect resistance and herbicide tolerance technologies. However, there is a need to introduce management steps among the producers to preserve the technology (Crop Biotech Update, April 6, 2017).

As the leader of biotech crop adoption in Latin America, Brazil hosted the 34th Regular Meeting of the Southern Agricultural Council in Sao Paulo on August 29, 2017. The Brazilian Agriculture Minister, together with counterparts from Argentina, Bolivia, Chile, Paraguay, and Uruguay signed a joint statement with three points: World Trade Organization (WTO) negotiation, joint actions for the control and prevention of Avian influenza, and new technologies for improving and accessing GM products to third markets. The third statement referred to new technologies for the improvement and access of biotech crops to third markets through intensification of information exchange in the approval of biotech products, reduction of asynchronous approval in the region, and promotion of biotech events in the third market that are of regional interest. In addition, the six countries emphasized the need to urge the European Union and China, which are big importers of biotech products from these countries to stop delaying GMO import authorization (Crop Biotech Update, September 6, 2017).

Brazilian multinational seed companies and public sector research institutions are developing various biotech crops. Currently, there are a number of biotech crops in the pipeline waiting for commercial approval, of which the most important are sugarcane, 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. For example, biotech dry edible beans approved in 2011 could be commercially cultivated starting 2019-2020 crop season; biotech eucalyptus will be commercially available starting 2019-2020; and recently approved sugarcane will be available in 2020.

Biotech sugarcane event CTC20BT was recently approved by CTNBio in 2017. The first biotech sugarcane approved for cultivation has resistance to the country's main insect pest, the sugarcane borer (*Diatrarea saccharalis*) which can cause losses of up to some Real $5 billion (US$1.6 billion) annually. CTC20BT was developed by a local technology company Centro de Tecnologia Canavieira (CTC) to contain the same Bt gene widely used for more than 20 years in soybean, maize, and cotton, and for three years in eggplant. Studies by CTC also confirmed that sugar and ethanol obtained from biotech and conventional sugarcane are identical. Recently conducted environmental studies revealed no effects on soil composition, sugarcane biodegradability, or insect populations, with the exception of the target pests (mainly the borer). CTC plans to work closely with producers, starting with the distribution of 20 Bt sugarcane seedlings, followed by closely-monitored field planting (Crop Biotech Update, June 14, 2017).

Brazil has revolutionized the use of biotechnology beyond biotech crops as exemplified by its adoption of biotech/GM mosquito (*Aedes aegypti*) to combat malaria, dengue, Zika, and Chikungunya. Trial releases of Oxitec's biotech mosquito were conducted from 2011 and 2013 in northeastern Brazil. Male mosquitoes harbor a lethal gene that disrupts the protein synthesis such that when they mate with wild females, their offsprings do not survive. Another strategy called Eliminate Dengue (ED) carry the *Wolbachia pipientis* parasite that protects the mosquito from infection with dengue, Zika, and Chikungunya viral infections. Female ED mosquitoes mate with wild males and pass on *Wolbachia* in their eggs. Thus, offspring mosquitoes can no longer serve as vectors of the viral disease (Science, October 13, 2016). Since 2016, ED mosquitoes have been released in several countries, including Brazil, and in 2017, another batch was released in the country. Effectiveness of these releases to an incidence of the viral diseases can be evaluated after three to five years (Crop Biotech Update, September 13, 2016).

Summary and Future Prospects

Brazil continues to lead biotech crop adoption in Latin America with its average adoption rate of 94% (a 2% increase compared to 2016) for biotech soybeans, maize, and cotton in 2017. Soybeans are still the major biotech crop in Brazil at 33.7 million hectares, followed by maize at 15.6 million hectares, and cotton at 150,000 hectares. The area grown to biotech soybeans and cotton increased significantly in 2017 compared to 2016 due to profitability, higher prices, high market demand both domestically and internationally, and available seed technologies. Slight reduction in biotech maize was due to low current prices and the expansion of soybean area in the country. Future expansion of these three biotech crops may come with the increasing domestic and global demand for protein for food, animal feeds, and biofuel production – biodiesel from soybeans and ethanol from maize – and raw cotton materials. Acceptance of biotech crops in Brazil is exemplary and could influence adoption in neighboring countries. With the joint statement of the six agriculture ministers in Latin American countries (Argentina, Bolivia, Brazil, Chile, Paraguay, and Uruguay), trade of biotech crops and products to third markets can be enhanced. Various biotech crops in the pipeline include sugarcane, potato, papaya, rice, and citrus. New biotech products such as biotech dry edible beans, biotech eucalyptus, and the recently approved sugarcane will be commercially available by 2019-2020. Biotech/GM mosquitoes are also being utilized to control viral diseases that have afflicted millions of Brazilians. With the increasing adoption of biotech crops in the country, knowledge on protecting the technology among farmers and crop producers is essential and steps have to be taken to this end.

ARGENTINA

Argentina, one of the leading exporters of biotech soybean, cotton, and maize, planted a total of 23.6 million hectares, 12% of the global biotech crop area of 189.8 million hectares in 2017. Argentina had a slight decrease of biotech crop area in 2017 compared to 2016 at 23.82 million hectares. The slight decrease is due to reduced planting of biotech soybean at -3% (from 18.7 million hectares in 2016 to 18.1 million hectares in 2017), and -38% (from 380,000 hectares in 2016 to 250,000 hectares in 2017) for biotech cotton (Figure 5). However, biotech maize area increased by 10% from 4.7 million hectares to 5.2 million hectares. The average adoption rate of the three biotech crops is close to 100% indicating the country's reliance on the technology to drive its economy.

Argentina is one of the pioneer countries which planted biotech crops in 1996. Currently, 62 biotech events from three crops: cotton (7 events), maize (42), and soybean (13), have been approved for food, feed, and processing. In 2017, one biotech soybean event, SYHT0H2, with resistance to glufosinate herbicide, was approved for food, feed, and cultivation in the country.

Some estimated 130,000 farmers, their families and communities have been benefiting

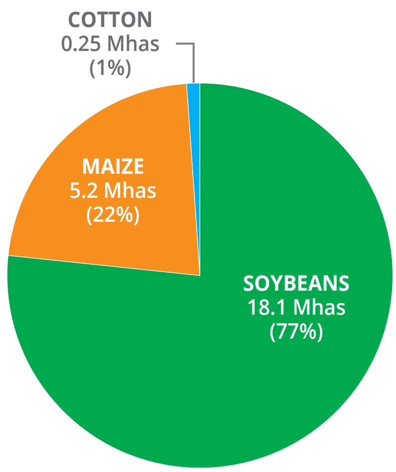


Figure 5. Biotech Crops Planted in Argentina, 2017

Source: ISAAA, 2017

from the increased economic benefits from planting biotech crops. Brookes and Barfoot (2018, Forthcoming) estimates the economic benefits of planting biotech crops to Argentina to be US$23.7 billion hectares in 21 years of commercialization (1996-2016), and the economic benefits for 2016 alone are estimated at US$2.1 billion.

Biotech soybean IR/HT stacked Intacta™ increased area planted by 25%

Soybeans were planted on 18.1 million hectares in 2017, a 3% slight reduction from 18.7 million hectares in 2016. Soybeans grown in the country was 100% biotech, 83% of which or 15 million hectares were herbicide tolerant and 17% or 3.1 million hectares were stacked IR/HT (Table 8). Soybean stacked trait Intacta™ introduced to farmers in 2015 was launched on 70,000 hectares, increased to 2.5 million hectares in 2016, and 3.1 million hectares in 2017, a 25% increase – an indication of farmers adopting a technology that reduces costs and profits. Stacked soybean event SYHT0H2, which has resistance to mesotrione and glufosinate herbicides, was approved for planting for food, feed, and cultivation in 2017. The approval of this event increases the available herbicide tolerant technologies to farmers to control various weed species in soybean fields. It is worth mentioning that Argentina approved a drought and salinity tolerant soybean event developed by the Institute of Agriculture Biotechnology of Rosario in 2015.

The 2017 planting season was mired with erratic weather patterns. Heavy rains and flooding at the beginning of the season and excessive heat in Northern Argentina and the province of Buenos Aires in late December/ early January resulted in a decrease in soybean area. However, with the 2015 policy changes by Argentina's President Mauricio Macri, the agriculture sector will be revitalized and is expected to deliver higher returns, greater access to credit and more stable economic conditions. Notable of the policy changes is the plan to reduce further the export tax on soybeans from the current 30% to 18% and soybean oil from 29% to 15% by the end of December 2019, which could provide incentives to farmers to plant more soybeans (USDA FAS GAIN, Oilseeds and Products Update-Argentina, 2017).

Biotech maize increased by 10% in 2017

The total maize area in 2017 increased by 10% from 4.9 million hectares in 2016 to 5.4 million hectares, and was comprised of 382,000 hectares IR, 521,000 hectares HT, and 4.3 million hectares stacked IR/HT. Compared to 2016, maize with stacked traits increased by 17% from 3.7 million hectares to 4.3 million hectares. Consequently, IR and HT maize area were reduced by 10% and 15%, respectively. The adoption rate of biotech maize remains at 97%, similar to 2016 (Table 9).

Table 8. Total and Trait Hectares of Biotech Soybeans in Argentina, 2016-2017

	Area Planted (MHa)		% Trait Hectares	
	2016	**2017**	**2016**	**2017**
Total Soybeans	18.70	18.10		
HT	16.23	15.02	86.8%	83.0%
IR/HT	2.47	3.08	13.2%	17.0%
Total Biotech Soybeans	**18.70**	**18.10**	**100.0%***	**100.0%***

* Adoption rate

Source: ISAAA, 2017

Table 9. Total and Trait Hectares of Biotech Maize in Argentina, 2016-2017

	Area Planted (MHa)		% Trait Hectares	
	2016	**2017**	**2016**	**2017**
Total Maize	4.90	5.40		
IR	0.43	0.38	9%	7%
HT	0.62	0.52	13%	10%
IR/HT	3.70	4.32	78%	83%
Total Biotech Maize	**4.74**	**5.22**	**97%***	**97%***

* Adoption rate

Source: ISAAA, 2017

Farmers in Argentina have been adopting biotech maize technology because of proven stability and higher yields. In 2017, the increase in biotech maize area was a result of having a second maize crop after a winter crop instead of soybeans, and the positive returns from the crop. In addition, President Macri announced in 2015 the elimination of the 20% export tax on maize and the lowering of soybean's export tax from 35% to 30%. Consequently, the area planted to maize increased in 2016 by 1 million hectares, the soybean area decreased by an equivalent amount, and a similar trend was observed for the 2017 planting season. Hence, after several years of low returns in planting maize, farmers started to profit by 2016 compared to planting soybeans. Export tax, however, will continue to decrease for soybean to as low as 18% in December 2019 which could negatively impact maize planted area once again (USDA FAS GAIN, Grain and Feed Annual-Argentina, 2017).

Domestic consumption of maize is expected to increase, which could provide incentives for maize farmers to increase production, and hence, also increase the maize area in the coming years. Maize is being used for livestock, dairy sector, poultry, and pork production, which are all projected to increase in the near future. In addition, local production of high fructose corn syrup expanded in 2016 and operationalized in 2017. Maize, which is also being used in the bioethanol sector, may not increase its demand for feedstocks, pending additional quota for the domestic fuels mandate.

IR biotech maize was introduced in Argentina in 1998 and HT maize in 2004. Stacked trait varieties became available in 2007, and by 2017, 83% of the biotech maize area was planted with stacked varieties.

Biotech cotton increased to 100%

The total cotton area in Argentina was reduced by 38% from 400,000 hectares in 2016 to 250,000 in 2017. Adoption rate, however increased from 9% to 100%, and all are stacked IR/HT traits. The country stopped planting HT cotton in 2017 and IR (Bt) cotton was not planted since 2015.

Cotton planting in 2017 was affected by too much rain in the cotton-producing areas of the northern part of the country, primarily in the provinces of Chaco, Santiago del Estero and Formosa. In addition, cotton competed with soybeans and maize for land use because of higher profitability with the reduction of export tax for these two crops. The increased cotton area can be achieved in Argentina with the expected increase of global consumption by an estimated 400,000 bales each year, as well as the lower ending stocks for cotton at the end of 2017 (Cotton Grower, November 9, 2017).

Benefits of Biotech Crops

Recent data on the economic benefits from biotech crops by Brookes and Barfoot (2018, Forthcoming) estimates that Argentina has enhanced farm income from biotech crops by US$23.7 billion in 21 years of commercialization (1996-2016), and the benefits for 2016 alone are estimated at US$2.1 billion. This is a huge economic benefit for the 130,000 farmers, their families and their communities.

Another comprehensive study published by Trigo (2016) on the benefits of biotech crops (soybeans, maize, and cotton) in Argentina for 21 years of its commercialization (1996-2016) indicated a gross benefit of US$126.97 billion (Table 10). This is an unprecedented increase of 75% in benefits from the previous US$72.4 billion determined by Trigo (2011) for 1996-2010. In a social context, the study estimated that – considering the surplus generated from these technologies – over a 20-year period, this surplus should have created a total of 2,052,922 jobs.

Table 10. Economic Benefits of Biotech Crops in Argentina (Billion US$ and percentage)

Crop and Trait	Total Benefits (Billion US$)	Amount (Percentage) of Benefits Accrued to		
		Farmers	National Government	Technology Developers
HT Soybeans	118.36	77.94 (65.9%)	32.41 (27.4%)	8.01 (6.7%)
IR/HT Maize	5.51	2.49 (45.2%)	0.98 (17.7%)	2.04 (37.1%)
IR/HT Cotton	3.10	2.50 (95.0%)	0	0.16 (5.0%)
Total	**126.97**			

Source: Trigo, 2016

Trigo also mentioned some environmental impacts related to GM crops, and emphasized the synergy between the adoption of these technologies and no-till farming practices, considering the positive impact the latter has on the conservation of soil, the emission of greenhouse gases, carbon sequestration, and the energetic efficacy of crop management. The author also warned about other issues that should be addressed, considering the competitiveness and sustainability of agriculture, as well as the need for rotating crops and active principles, recycling nutrients and implementing refuges in the case of insect resistant crops. The study highlighted the importance of keeping agricultural biotechnology as a Policy of the State to be able to sustain agricultural production in the path of expansion that it has gone through in the last decades. This entails respect for intellectual property, solid, science-based regulatory frameworks, as well as effective international negotiation, to encourage investments in R&D and to sustain long-term biotechnology policies.

Country Situationer

Farmers in Argentina have been reaping the benefits of biotech crops with the government supporting their approval through the National Commission on Biotechnology (Conabia). Biotechnology research and development focus on drought tolerance and resistance to viruses, fungi, bacterial diseases, as well as for improved nutrition in important crops such as potato, wheat, and sugarcane. Argentina is one of the countries that signed the joint statement crafted by five Latin American countries to streamline trade with third markets in August 2017 (see Brazil Chapter). Regional collaboration among the Latin American countries can boost biotech crop adoption as there are plans to intensify information exchange in the approval of biotech products, reduction of asynchronous approval in the region, and the promotion of biotech events in the third market that are of regional interest.

Summary and Future Prospects

It is notable that the average adoption rate of the three biotech crops, soybeans, maize and cotton was close to 100% in 2017. However, Argentina experienced climatic problems during the 2017 planting season for soybeans, maize, and cotton. This affected the total biotech crop area which, similar to 2016, was about -3% and was contributed by the decline in soybean and cotton areas. The maize area, however increased by 10%. With the government's plan to revolutionize agriculture accompanied by a reduction in export tax, as well as the increasing protein demand for food and feeds, both locally and internationally, the soybean and maize areas are expected to increase in the very near future. Cotton area declined in two successive years, but the increasing global demand for cotton could revive cotton production in the country.

CANADA

Canada planted six biotech crops in 2017 at 13.12 million hectares, an unprecedented 18% increase from 11.1 million hectares in 2016, with a corresponding increase in total crops by 17% from 12.38 million hectares in 2016 to 14.49 million hectares in 2017. The biotech crops were comprised of 2.50 million hectares soybeans, 1.78 million hectares maize, 8.83 million hectares canola, 15,000 hectares sugar beets, 3,000 hectares alfalfa, and 40 hectares potato, for a total of 13.12 million hectares. The average adoption rate for the four major crops of soybeans, maize, canola and sugar beets was similar to 2016 at 95%. For the first time, Canada planted biotech potato generations 1 and 2 (Figure 6).

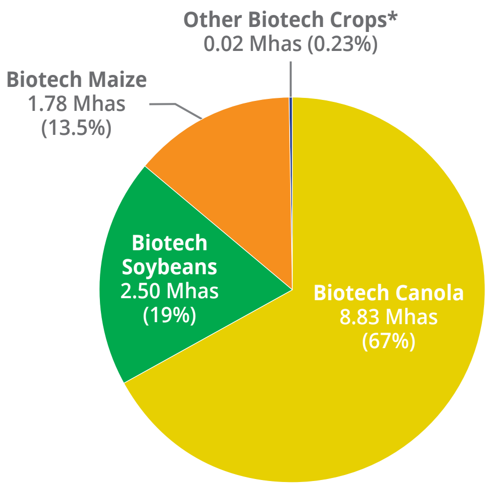


Figure 6. Biotech Crops Planted in Canada, 2017

* Biotech sugar beets, biotech alfalfa, and biotech potato

Source: ISAAA, 2017

Canada is a member of the group of six "founder biotech crop countries," having commercialized biotech tolerant canola in 1996, the first year of commercialization of biotech crops. Since 1996, Canada has approved 177 biotech events for food, feed use, and cultivation of various crops: alfalfa (3), apple (2), Argentine canola (18), cotton (25), flax (1), maize (67), papaya (1), Polish canola (4), potato (27), rice (1), soybeans (21), squash (1), sugar beets (2), and tomato (4). In 2017, Canada approved six biotech events comprised of three stacked trait IR/HT maize events and three stacked potato events. The biotech maize events were Bt11 x MIR162 x MIR604 x MON89034 x 5307 x GA21; MON87427 x MON89034 x TC1507 x MON87411 x 59122 x DAS40278; and MON89034 x TC1507 x NK603 x MIR162. The potato biotech events W8, X17, and Y9 all contain stacked traits for reduced acrylamide potential, black spot bruising tolerance, and fungal disease resistance.

From 1996 to 2016, some 50,000 farmers and their families have been benefiting from enhanced farm income from biotech canola, maize, soybeans, cotton, and sugar beets by US$8.04 billion and the economic benefits for 2016 alone is estimated at US$817 million (Brookes and Barfoot, 2018, Forthcoming).

Biotech canola adoption rate soared to 95%

Canada was the first country to commercialize biotech herbicide tolerant canola in 1996. In 2017, canola was planted on 9.31 million hectares in Canada, 95% of which was biotech herbicide tolerant canola at 8.93 million hectares. Both the area planted to total and biotech canola increased by 15% in 2017: total canola from 8.1 million hectares to 9.31 million hectares and biotech canola from 7.53 million hectares to 8.83 million hectares in 2017.

Canada, the leader in canola production, research, and development, continue its support of canola farmers by providing new biotech canola varieties with improved traits. In 2017, event MS11 with glufosinate-ammonium herbicide tolerance and male sterility traits, as well as a canola variety that contains long chain omega-3 fatty acids that could provide EPA/DHA omega-3, are in the pipeline for possible release in 2018.

Of the canola produced in the country, 10% is consumed domestically and close to 90% are exported. Expansion of herbicide tolerant canola area depends on the increasing global consumption of edible oil with the increasing population and varied food preferences (USDA FAS GAIN, Canada Agricultural Biotechnology Annual, 2017).

Biotech soybean area increased by 20%

Soybeans are the next important crop in Canada planted on 2.95 million hectares, 85% of which or 2.5 million hectares were herbicide tolerant. The total soybean area in 2017 increased by 33% or 735,000 hectares, from 2.21 million hectares to 2.95 million hectares, and biotech soybean area was increased by 20% from 2.08 million hectares to 2.50 million hectares. In 2017, soybeans were planted in Ontario, Saskatchewan, and Manitoba, with the latter state planting more soybeans compared to previous years. The increase in soybean area was due to the relatively attractive returns compared to alternate crops.

Several nutritionally-improved biotech soybean events with high oleic acid have been approved in Canada for food, feed, and cultivation. Expansion of the soybean area depends on the approval of these events in the global market. China, an importer of Canadian biotech soybean, has approved in 2017, event MON87705 or Vistive Gold soybeans, and preparation for full-scale launch is expected in Canada in 2018. Meanwhile, Canada and the US are waiting for the approval of high oleic acid soybean event of DP305423 by the European Union for import which can also drive biotech soybean production in Canada (USDA FAS GAIN, Agricultural Biotechnology Annual-Canada, 2017).

Biotech maize area increased by 19% and adoption rate to 100%

Biotech insect resistant (IR) maize has been grown commercially in Canada since 1996 and herbicide tolerant (HT) maize since 1999. Throughout the 22-year period, biotech adoption has increased significantly and by 2017, the adoption rate of biotech maize reached 100% of the 1.78 million hectares of total maize planted. This is a significant increase of 19% from 92% adoption rate in 2016. The 1.78 million hectares were comprised of 18,000 hectares (1%) IR, 280,000 hectares (16%) HT, and 1.48 million hectares (83%) stacked IR/HT. IR maize was reduced by 60% from 45,000 hectares in 2016 to 28,000 hectares in 2017, HR maize increased by 35% and the stacked IR/HT increased by 20% from 2016 (Table 11).

Similar to soybeans, the total and biotech maize area expanded in Manitoba and Saskatchewan, largely due to the commercialization of new biotech varieties that are better adapted to prairie growing conditions. In addition, farmers in Quebec and Ontario continued to plant maize. Further expansion of the maize area in the country is expected with the demand from the USA

Table 11. Total and Trait Hectares of Biotech Maize in Canada, 2016-2017

	Area Planted (MHa)		% Trait Hectares	
	2016	**2017**	**2016**	**2017**
Total Maize	1.62	1.78		
IR	0.05	0.05	3.0%	1%
HT	0.21	0.28	14.0%	15.8%
IR/HT	1.23	1.48	83.0%	83.2%
Total Biotech Maize	**1.49**	**1.78**	**92.0%***	**100.0%***

* Adoption rate

Source: ISAAA, 2017

and other export destinations for beef and pork from Canada, that would need feeds and by-products for livestock derived from maize (USDA FAS GAIN, Agricultural Biotechnology Annual Canada, 2017).

Biotech sugar beet area increased by a remarkable 82%

On the ninth year of sugar beet commercialization in Canada in 2017, some 14,569 hectares of sugar beets were planted, estimated to be 100% herbicide tolerant. The area planted to sugar beets increased by 82% from 8,000 hectares in 2016 to 15,000 hectares in 2017. Sugar beet growing regions in Canada include Ontario in Eastern Canada and Taber, Alberta in Western Canada.

Alberta sugar beets are processed and refined locally from some 400 sugar beet farmers. The facility has an annual production capacity of approximately 150,000 metric tons or refined sugar for local consumption and export to the USA (USDA FAS GAIN, Agricultural Biotechnology Annual-Canada, 2017). Hence, expansion of the sugar beet planting area depends on sugar demand, new technologies, and sometimes, favorable weather.

Biotech alfalfa HarvXtra™ area increased by 200%

Canadian regulatory agencies authorized planting of HarvXtra™ alfalfa developed by Forage Genetics with Roundup Ready® (RR) technology in December 2014 (Monsanto Canada, March 29, 2016). Through RNA interference, the endogenous S-adenosyl-L-methionine: trans-caffeoyl CoA 3-O-methyl transferase (CCOMT) gene was suppressed reducing the content of guaiacyl (G) lignin in alfalfa, making it more digestible to livestock, and will allow farmers to delay harvest of up to 7-10 days to attain greater yield without sacrificing quality. In 2016, Canada planted for the first time 809 hectares of HarvXtra™ alfalfa, and in 2017, this area increased by 200% at 3,000 hectares. In March 2016, the company announced that it will offer commercial seed sales of HarvXtra™ alfalfa with RR® technology to farmers in Eastern Canada, but no planting has been recorded as of this writing. Current adoption of biotech alfalfa was 0.7% of the potential 445,000 hectares alfalfa in the country. This is a big room for expansion, as more and more farmers realize the benefits of the technology in livestock production and farm management.

Biotech potato generations 1 and 2 planted for the first time on 20 hectares

Four Innate® biotech potato events developed by J.R. Simplot were given approval by the Canadian Food Inspection Agency and Health Canada in March 2016. The four generation 1 events possess traits to improve the quality of the produce such as reduced levels of reducing sugars, reduced acrylamide potential, and black spot bruising tolerance. In August 2017, three generation 2 Innate® potatoes have been approved for import, planting, and commercialization in Canada, complementing the four varieties of Innate® first generation potatoes (Russet Burbank, Ranger Russet, Atlantic, and Snowden) that received regulatory approval in 2016. The generation 2 potatoes contain the generation 1 traits plus protection against the late blight pathogen. In 2017, Innate® potatoes generations 1 and 2 were planted in Canada on 20 hectares each, with plans to expand in the coming years.

The increasing acceptance and adoption of biotech potatoes fits well with the global concern on food waste. A study conducted in Canada indicated that if all fresh potatoes had Innate® generation 2 traits, potato waste (in-field, during storage, packing, retail, and food service for fresh potatoes) could be reduced by 93 million kilograms; CO2 emissions reduced by 14 million kilograms; water usage reduced by 13 billion liters; and a total of 154,000 fewer pesticide hectare-applications would be needed (Simplot, retrieved January 2018).

Benefits of Biotech Crops

Canada is estimated to have enhanced farm income from biotech canola, maize, soybeans, cotton, and sugar beets by US$8.04 billion in the period 1996 to 2016 and the benefits for 2016 alone is estimated at US$817 million (Brookes and Barfoot, 2018, Forthcoming).

Country Situationer

Canada, similar to the USA has the key ingredients for successful acceptance and adoption of biotech crops. Biotech crops are continuously developed by both the public and private sectors and are regulated by capable government agencies such as the Canadian Food Inspection Agency, Health Canada and Environment and Climate Change Canada for safety before commercialization. As a manifestation of government support of biotech crops, Canadian parliament voted against mandatory labeling of biotech/GM foods in the country on May 17, 2017. The C-291 bill, an Act to amend the Food and Drugs Act (genetically modified food), sponsored by Mr. Pierre-Luc Dusseault, the New Democratic Party MP for Sherbrooke, Québec, was defeated by a significant margin, with 67 yes, and 216 nays.

The bill specified that the Food and Drugs Act be amended, such that "No person shall sell any food that is genetically modified unless its label contains the information... to prevent the purchaser or the consumer of the food from being deceived or misled in respect of its composition." However, the term genetically modified lacked description in the bill, which generated enormous discussion during the second reading. Opponents argued that the wording was too vague, but supporters said that such vagary provided important 'latitude' (Crop Biotech Update, May 24, 2017).

New biotech products are planned to be commercialized in the country, including the non-browning apple. The Canadian Food and Inspection Agency (CFIA) and Health Canada approved the unconfined environmental release for commercial planting purposes, livestock feed and food use for apple (*Malus domestica*). Arctic® apple events GD743 and GS784 have been genetically engineered to be non-browning. The two approved varieties will be marketed under the name Arctic® Golden Delicious and Arctic® Granny Smith. As of this writing, no planting of Arctic® apple has been recorded.

Biotech/genetically engineered (GE) salmon has passed Canadian regulations after 25 years of long wait since its first application for Food and Drugs Administration approval. Canadian consumers were the first to taste commercialized biotech salmon. GE salmon is a variety of Atlantic salmon that needs half the time (18 months only) of its non-GE counterpart to mature. According to the developer AquaBounty Technologies, they have sold about 4.5 tons of GE salmon in Canada as of August 4, 2017. AquaBounty's chief executive, Ron Stotish, said they sold the first commercial batch for US$5.30/lb ($11.70/kg) (Crop Biotech Update, August 9, 2017).

Summary and Future Prospects

In 2017, Canada had an unprecedented increase of biotech crop area by 18% compared to 5% in 2016. Six biotech crops were planted in the country including canola, soybeans, maize, sugar beets, alfalfa, and the newly introduced biotech potatoes. Large increases in biotech crop area were obtained for reduced lignin alfalfa, HT soybeans and HT sugar beets. Biotech/GE salmon has also been introduced to Canadian consumers in August 2017, while biotech apple will be in the consumer market and in the orchards in the very near future. All these indicate the Canadian government's support to farmers and consumers by providing enabling and efficient regulatory system. Expansion of biotech crop adoption in Canada is therefore expected with the increasing global demand for food, feed, and feedstocks for ethanol and biodiesel, strong research and development in the country, excellent public acceptance of the technology, and the exemplary support of the government for biotech crops.

INDIA

In 2017, the area under IR(Bt) cotton in India increased by 600,000 hectares, from 10.8 million hectares in 2016 to 11.4 million hectares, equivalent to 93% of the total cotton area of 12.24 million hectares grown in the country. The significant increase in the total cotton area of over 1 million hectares was due to favorable market price and supportive weather conditions for cotton cultivation in Kharif 2017. Unfortunately, a large number of cotton farmers planted unauthorized stacked trait IR/HT cotton in major cotton growing areas in Central and Southern zones in Kharif 2017.

In 2017, the Genetic Engineering Appraisal Committee (GEAC) of the Ministry of Environment, Forests & Climate Change (MOEF&CC) thoroughly assessed the safety and performance of GM mustard and recommended the environmental release of transgenic mustard hybrid Dhara Mustard Hybrid -11 (DMH-11) and parental lines containing events bn 3.6 and modbs 2.99 developed using barnase, barstar, and bar genes developed by the Centre for Genetic Manipulation of Crop Plants (CGMCP) of the University of Delhi on May 11, 2017 (GEAC, 2017). Consequently, on October 26, 2017, the MOEF&CC decided to keep the matters related to environmental release of transgenic mustard pending further review based on receipt of various representations from different stakeholders (MOEF&CC, 2017). Similarly, the GEAC of MOEF&CC kept in abeyance applications related to import of crude and processed soybean oil derived from different herbicide tolerant soybean events; soybean for food and feed purposes and import of distillers dried grains with solubles (DDGS) derived from biotech maize in 2017.

Biotech cotton area increased by 6% in 2017 to reach 93% adoption

In 2017-2018, approximately 7.5 million cotton farmers rebounded cultivation of IR cotton to 11.4 million hectares, an increase of 6% compared to 2016, and showed resilience to overcome constraints such as infestation of pink bollworm spurred by poor quality and unauthorized sale of IR/HT cotton hybrids. Unfortunately, cotton farmers in Maharashtra saw an unusual outbreak of pink bollworm in 2017-2018 cotton seasons (Figure 7). The mismanagement of IR cotton technology has been responsible for erosion of resistance to pink bollworm, which was successfully achieved through development of host resistance by IR gene incorporation. The IR cotton technology has delivered its benefits for 16 years and could have prolonged its life provided the protocols of technology management were followed. Widespread cultivation of substandard and spurious IR cotton and illegal IR/HT cotton is spoiling IR cotton technology as the management of such improved technology needs proper supervision and control. These account for obvious loss or erosion of host resistance and ultimately the outbreak of pink bollworm in some areas of Maharashtra in 2017-2018 including lack of crop rotation; use of unapproved, unauthorized IR/HT seeds for cultivation; cultivation of long duration hybrids that serve as continuous host to PBW; non-compliance of refugia; and lack of understanding of farmers about IR technology.

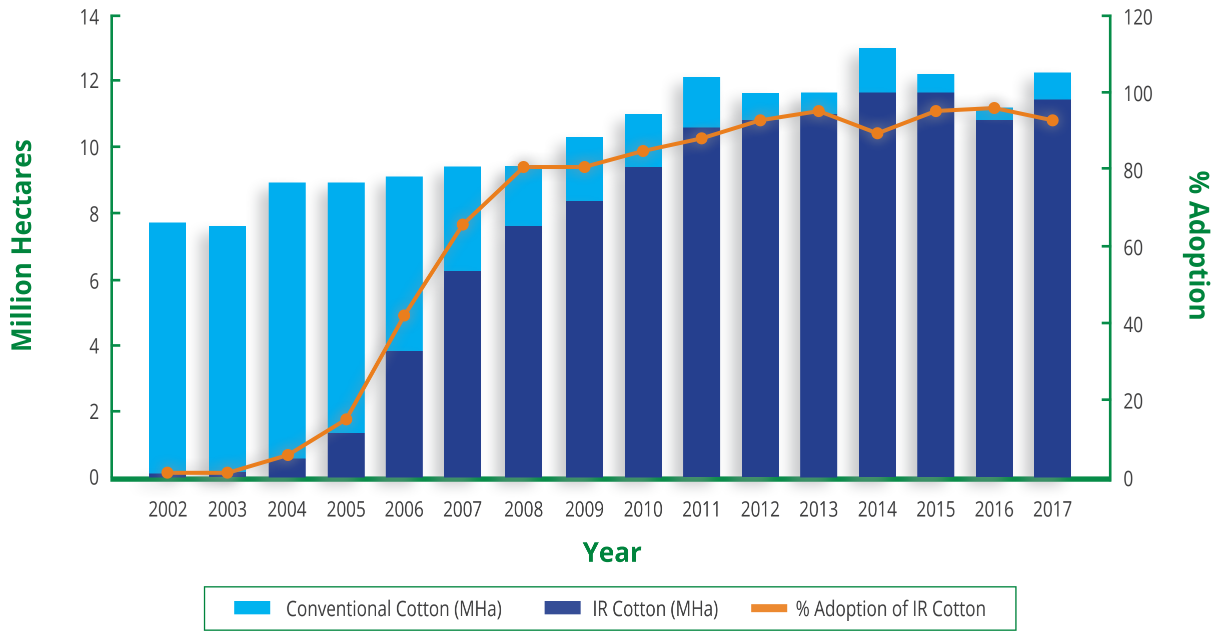


Figure 7. Sixteen Years of Adoption of IR (Bt) Cotton in India, 2002 to 2017

Source: ISAAA, 2017

It was estimated that around 3.5 million packets occupying approximately 800,000 hectares of illegal IR/HT cotton expressing both Roundup Ready® event MON1445 and Roundup Ready® Flex (RRFlex) event MON88913 (Damodaran, 2017; Fernandes, 2017) were planted in 2017. Unauthorized sale of IR/HT cotton hybrids marked a major controversy due to infestation of pink bollworm and failures of the cotton crop in some areas of Maharashtra. The veracity of cultivation of unauthorized IR/HT cotton is under investigation by the DBT's Field Inspection and Scientific Evaluation Committee (FISEC) in India (The Hindu, 2018). Notably, India remained a major producer of cotton in the world with estimated cotton production pegged at 37.7 million bales in 2017, higher than 34.5 million cotton production in 2016-2017 (CAB, 2017).

The adoption rate of IR cotton was overwhelming as nearly 93-96% of the total cultivable cotton area was occupied by IR cotton since 2012-2013 to 2017-2018 (Figure 7). On the production side, the cotton year 2014-2015 was excellent, achieving cotton production of 39 million bales which subsequently declined to 33.8 million bales and rebounded in 2017-2018 to 37.7 million bales (Figure 8).

The unauthorized cultivation of IR/HT cotton was a wake-up call for the regulatory agencies and authorities at the state and national levels. Notably, it reaffirmed the demand by farmers for improved cotton technologies at the grassroots level. Importantly, the illegal sale of unapproved IR/HT cotton of substandard quality may express varied levels and duration of *cp4epsps* protein at different reproductive stages of the cotton crop cycle with decreased efficiency of weed control, resulting in damage of the cotton crop and imminent losses for farmers. Moreover, the proliferation of illegal sale of IR/HT cotton technologies may also give rise to introduction of counterfeit seeds of other

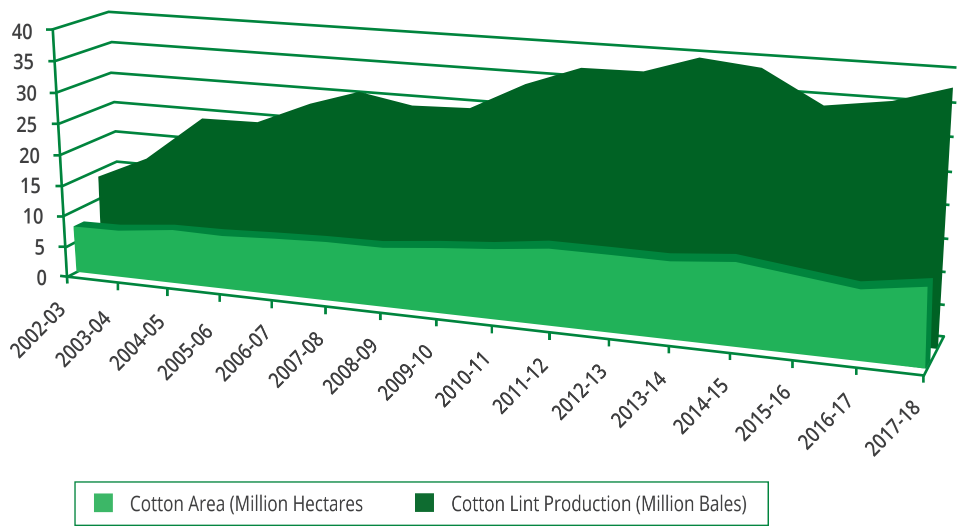


Figure 8. Cotton Area and Production in India, 2002 to 2017

Source: CAB, 2017; Compiled by SABC & ISAAA, 2017

biotech cotton traits, including those officially imported for biosafety evaluation, some of which are undergoing regulatory review (Table 12). The short term gains with unauthorized IR/HT cotton is not only a gross violation of the national and state laws and regulations, but also poses major challenges of seed quality, refuge management, weed resistance management, and technology stewardship. In a nutshell, such unlawful activities should be curbed in order to circumvent the deterioration of already ailing biotech sector and diminishing R&D efforts in agriculture sector particularly in the cotton crop.

Biotech mustard field trials confirm high potential yield

Biotech Indian mustard developed by Delhi University South Campus is India's first state-of-the-art farm innovation that will allow Indian mustard farmers to produce more mustard per unit area. The barnase-barstar technology of GE mustard will accelerate the mustard breeding programs of both public and private sectors, resulting in the introduction of high-yielding and superior mustard hybrids capable of revolutionizing mustard farming and edible oil production in the country. The development of biotech mustard is a classic example of India's scientific capability to harness the science of biotechnology and farm innovation in agriculture. More so, India faces a huge deficit in edible oil production and imported 15 million tons of edible oil in 2016-2017 including oil extracted from biotech soybean and biotech canola (SEA, 2017). The imported edible oil accounts for over 70% of total edible oil consumption pegged at 21 million tons. Annually, India spends over US$12 billion on edible oil imports that is growing at double digits to meet the burgeoning domestic requirement (SABC, 2016). It is estimated that the edible oil deficit will continue to widen with the increase in population, dietary changes and per capita income. To address this, India needs to critically look into ways and means

Table 12. Biotech Cotton under Regulatory Consideration in India, 2017

Developer	Trait(s)	Technology	Status
Mahyco	IR/HT	BG-IIRRF	Regulatory process completed (temporarily withdrawn)
Dow AgroSciences	IR	WideStrike	Pending approval
Bayer CropSciences	IR/HT	TwinLink/Glytol	BRL-II trial
Mahyco	HT	RRF	BRL-II trial
JK Agri Genetics	IR	–	BRL-II trial
Monsanto	IR/HT	BG-IIIRRF	BRL-I trial
Mahyco	NUE	–	BRL-I trial
Mahyco	DST	–	BRL-I trial
Nuziveedu	IR	–	BRL-I trial
CICR, DU, TNAU, NRCPB, NBRI, UASD, Rasi, Dow, Bayer & Mahyco	IR/HT/DR/VR/ NUE/DST	–	Laboratory & Greenhouse Stage

Source: GEAC, 2016 & 2017; Analyzed by SABC, 2017

to increase productivity of oilseed crops, including mustard, soybeans, and other important edible oil crops. Biotech mustard hybrid DMH-11 is one of the promising technologies to improve mustard yields in India. The GEAC had thoroughly assessed the safety and performance of GM mustard and successfully completed the process of inviting public comments on the biosafety dossier of GM mustard followed by a rigorous scrutiny by the Sub-Committee constituted to review the dossier and application of GM mustard for Environmental release in 2016.

The Assessment of Food and Environmental Safety (AFES) on GM mustard, prepared by Biosafety Support Unit of the Department of Biotechnology (DBT) noted that biotech mustard hybrid DMH-11, a cross between varuna bn 3.6 and EH-2 mod bs 2.99, is superior compared to the parents, showing proof-of-concept of the technology, exhibiting heterosis and hybrid vigor. Table 13 shows the yield advantage in each trial year, including two years of multi-location trials in 2010-2011 and 2011-2012 as part of the BRL-I trial conducted at different mustard growing centers under the supervision of the Indian Council of Agriculture Research (ICAR), and subsequently, BRL-II multi-location field trial in 2014-2015 carried out by the Punjab Agricultural University (PAU), Ludhiana and the Indian Agricultural Research Institute (IARI), New Delhi. The multi-location field trials showed a yield advantage in each year trial, across each location with the yield advantage of DMH-11 over national and zonal checks by more than 25% (DBT, 2016).

The Assessment of Food and Environmental Safety report concluded that the presence of transgenes including bar, barnase, and barstar genes in the hybrid DMH-11, does not lead to any unintended effect on the agronomic parameters, and the efficacy evaluation provided evidence of hybrid vigor in the hybrid DHM-11.

Table 13. Seed Yield (Kg/ha) of Biotech Mustard Hybrid DMH-11 During BRL-I in 2010-2011 and 2011-2012

Entry	*Mean Yield 2010-2011	%Yield Increase Over Checks	**Mean Yield 2011-2012	%Yield Increase Over Checks	*8*Mean Yield 2014-2015	%Yield Increase Over Checks
Varuna (Barnase)	2,096	24	2,291	32	1,861	28
EH-2 (Barnase)	2,009	29	1,611	88	1,558	53
Varuna	2,093	24	2,272	33	1,887	26
EH-2	1,897	37	1,741	74	1,378	73
RL1359	2,037	28	2,016	50	1,776	34
DMH-11	2,600	–	3,025	–	2,386	–

* Conducted in Kumber, Navgaon, and Sriganganagar
** Conducted in Kumber and Navgaon
*** Conducted in Ludhiana, Bhatinda, and IARI

Source: DUSC, 2016; Analyzed by SABC and ISAAA, 2017

Socioeconomic Benefits and Impact of IR cotton in India

The summary and key findings of fourteen studies conducted by public institutes on cost-benefits of IR cotton were included in previous briefs, ISAAA Brief 26 to 52 released from 2002 to 2016. Moreover, estimates by Brookes and Barfoot (2018, Forthcoming) indicate that India has enhanced farm income from IR cotton by US$21.1 billion in the 13-year period 2002 to 2016 and US$1.5 billion in 2016 alone. These immense benefits have been enjoyed by more than 7.5 million farmers and their families and have contributed greatly to the improvement of economic status in the community.

Country Situationer

During its meeting in 2016, GEAC approved a large number of events of different crops, primarily focusing on cotton, maize, pigeonpea, and chickpea and issued permits for the conduct of event selection trials and biosafety research trials in 2016. The majority of the field trials could not take place in the absence of the no-objection certificate (NOC) from the States. In 2017, GEAC kept in abeyance applications related to import of crude and processed oil derived from Dicamba tolerant soybean (Event MON 87708) from USA for consumption purposes in India by M/s Monsanto Holdings Pvt. Ltd; permission for import of soybean grain and oil derived from herbicide tolerant soybean (Event DAS-68416-4) for food and feed purpose by M/s Dow AgroSciences India Pvt. Ltd; permission for import of soybean grain and oil derived from herbicide tolerant DAS-44406-6 soybean for food and feed purposes by M/s Dow AgroSciences India Pvt. Ltd and import of distillers dried grains with solubles (DDGS) derived from biotech maize for use in animal feed (Table 14).

Summary and Future Prospects

India achieved a great stride in cotton production with a quarter of market share

Table 14. Applications pending for Import of GM Food/Feed Products

Product	Trait/Event(s)	Importer	Purpose
Crude and processed soybean oil	Dicamba tolerant Event MON87708	Monsanto Holdings Pvt. Ltd	Food & feed
Soybean grain & oil	Herbicide tolerant Event DAS-684164	Dow AgroSciences India	Food & feed
Soybean grain & oil	Herbicide tolerant Event DAS-44406-6	Dow AgroSciences India Pvt. Ltd	Food & feed
Distillers dried grains and solubles (DDGS)	–	Godrej Agrovet Ltd	Animal feed

Source: GEAC, 2017; Analyzed by SABC, 2017

in global cotton production in 2017. Biotech cotton area increased by 6% from 10.8 million hectares in 2016 to 11.4 million hectares in 2017. Insect resistant (Bt) technology in cotton hybrids delivered broad based benefits by saving losses caused by American bollworm and boosting cotton yield to 500 kg lint per hectare. However, the next level of cotton yield targeting to achieve the yield level equal to global average cotton yield of 700+ kg lint per hectare, cannot be achieved without the introduction of new generation biotech traits including stacked traits, smart agronomy, and high yielding cotton cultivars. Stewardship and resistance management strategies need to be implemented rigorously to maintain current yield level in existing IR cotton hybrids. The unauthorized cultivation of unapproved IR/HT cotton varieties should be curbed and the infestation of pink bollworm should be properly managed at farmers' field level. The recommendation of the regulatory agency GEAC on GM mustard, which was based on a thorough assessment of the safety and performance of GM mustard shall not go into oblivion. The moratorium on IR brinjal by MOEF&CC in 2010 has not yielded any outcome in the last seven years, and thus a careful consideration of the recommendation of the regulatory agency on GM crops by MOEF&CC is immensely needed at this time.

PARAGUAY

Adoption of biotech crops in Paraguay started in 2004 with the commercialization of Roundup Ready (RR®) soybeans. In 2017, the area planted to biotech crops were reduced by 16% − from 3.60 million hectares in 2016 to 2.96 million hectares in 2017, along with a 15% reduction in the total crop area in Paraguay. Biotech crop area was 2.96 million hectares and was comprised of soybeans (2.68 million hectares), maize, (270,000 hectares), and cotton (10,000 hectares) (Figure 9). Since 2004, a total of 20 events were approved in Paraguay for food, feed, and cultivation use, including cotton (20), maize (14), and soybean (3) events.

Some 10,000 farmers have benefited from adopting biotech crops: soybeans, maize, and cotton since 2004 to 2016 with economic benefits of US$1.38 billion. The benefits for 2016 alone were estimated at US$176 million (Brookes and Barfoot, 2018, Forthcoming). The insurmountable year-on-year increases of economic benefits accrue to farmers, their families, and the whole community.

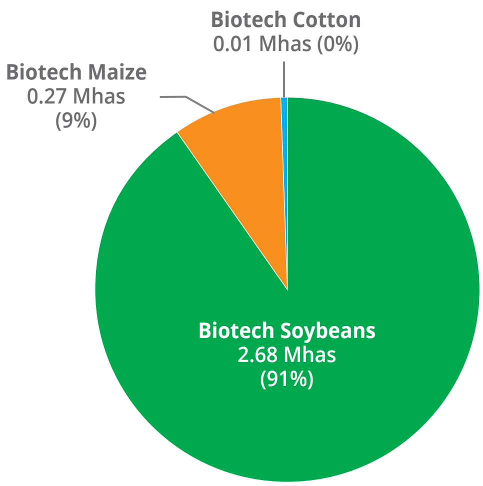


Figure 9. Biotech Crops Planted in Paraguay, 2017

Source: ISAAA, 2017

Biotech stacked IR/HT soybean area increased by 73% in 2017

Paraguay has planted biotech soybeans in the last 13 years. In 2017, there were 2.79 million hectares planted to soybeans, 96% of which or 2.68 million hectares were biotech. This was comprised of 1.73 million hectares HT and 951,000 hectares stacked IR/HT soybeans. The 96% adoption rate of biotech soybeans in 2017 was similar to 2016. The area of HT soybeans decreased in 2017 from 2.66 million hectares in 2016 to 1.73 million hectares, with a commensurate increase in the stacked IR/HT soybean area from 551,000 hectares to 951,000 hectares (Table 15). Since the introduction of Intacta™ in 2013, the area planted to the stacked trait gradually increased, and in 2017 an increase of 73% was achieved from 2016. The stacked trait event occupied 35% of the total biotech soybean area in 2017.

The decline in total and biotech soybean area was due to the lesser Zafrina soybean crop (2nd crop of soybean during the year) and to agronomic pressures and greater incentives to grow alternative crops. Soybeans are consumed as food, oil, feed, and biofuels. Demands for soybeans for these purposes are stable and may not affect the expansion of biotech area in the near future. The possible push for increased production and area are the exportable supplies and greater demand for soybean from Argentina, Brazil, and Mexico (USDA FAS GAIN Report: Oilseeds and Products Annual, Argentina, 2017).

Biotech stacked IR/HT maize accounts for 83% of all biotech maize

Similar to soybeans, the area planted to total maize and biotech maize declined by 10% and 13%, respectively. There was also a decrease of 2% in biotech maize adoption rate, from 44% in 2016 to 42% in 2017. The 270,000 hectares biotech maize was comprised of 35,000 hectares IR (13%), 10,000 hectares HT (4%), and 225,000 hectares stacked IR/HT (83%) (Table 16). The reduction in maize area is a reflection of high end stocks in the previous year and the prevailing unfavorable climatic conditions in Latin America. Boost in biotech maize production and area may come from the booming livestock industry which is expected to expand over the next few years from the current 300,000-500,000 heads of cattle. The use of grains (maize and soybean) accelerates production of beef, improves its quality, and provides greater meat consistency (USDA FAS GAIN Report, Livestock and Products Annual-Paraguay, 2017).

Biotech cotton maintains area and adoption at 100%

Paraguay approved IR cotton for commercial production in 2011. In 2013, the IR/HT cotton was approved for planting and by 2017, 10,000 hectares of cotton were planted, 100% of which was IR/HT, similar to 2016. Paraguay will benefit from biotech cotton, which is also being

Table 15. Total and Trait Hectares of Biotech Soybean in Paraguay, 2016-2017

	Area Planted (MHa)		% Trait Hectares	
	2016	2017	2016	2017
Total Soybean	3.33	2.79		
HT	2.66	1.73	82.8%	64.5%
IR/HT	0.55	0.95	17.2%	35.5%
Total Biotech Soybean	**3.21**	**2.68**	**96.4%***	**96.1%***

* Adoption rate

Source: ISAAA, 2017

Table 16. Total and Trait Hectares of Biotech Maize in Paraguay, 2016-2017

	Area Planted (MHa)		% Trait Hectares	
	2016	2017	2016	2017
Total Maize	0.71	0.64		
IR	0.05	0.03	16.2%	13.0%
HT	0.01	0.01	3.2%	3.7%
IR/HT	0.25	0.23	80.6%	83.3%
Total Biotech Maize	**0.31**	**0.27**	**43.5%***	**42.2%***

* Adoption rate

Source: ISAAA, 2017

successfully grown in the neighboring countries of Argentina and Brazil.

Benefits from Biotech Crops

Paraguay is estimated to have enhanced farm income from biotech soybean, maize, and cotton by US$1.7 billion planted from 2004 to 2016. The benefits for 2016 alone are estimated at US$328 million (Brookes and Barfoot, 2018, Forthcoming).

Country Situationer and Future Prospects

Paraguay has been included in the top 10 countries planting more than 1 million hectares of biotech crops. In 2017, a slight decline in the area planted to biotech soybeans, maize, and cotton were due to various factors, including unfavorable weather conditions, greater incentives to grow alternative crops, agronomic problems and high year-end stocks for maize. With the government support to farmers in terms of farm capital, approval of new biotech crops and traits, and the country's acceptance of biotech crops, Paraguay can maintain its biotech crop country standing. Future expansion of biotech area and increase in biotech crop adoption may come with a good market price for the basic commodity crops used for food, oil, livestock feed, and biofuels, expansion of the livestock industry, and demand from export markets. Paraguayan farmers are large holder farmers and have been benefiting from the economic gains of using biotech soybean, maize, and cotton.

PAKISTAN

In 2017-2018, the area planted to biotech cotton in Pakistan increased by 100,000 hectares from 2.9 million to 3 million hectares. The cotton production is expected to be as high as 14.04 million bales in 2017. Coincidentally, Pakistan also achieved an all-time high maize production of 6.13 million tons in 2017, up by 16.3% from last year's 5.27 million tons. Furthermore, Pakistan successfully conducted several farmers' field demonstrations of biotech maize hybrids which exhibited its performance to maize farmers. Single and stacked IR(Bt)/HT maize – expressing insect resistance and herbicide tolerance traits were officially approved for commercial cultivation by the National Biosafety Committee (NBC) of the Ministry of Climate Change (MOCC) in 2016. In 2017, the field performance trials of IR/HT maize hybrids were conducted as part of the regulatory requirement for varietal registration by the Federal Seed Certification and Registration Committee, Ministry of National Food Security and Research. It is expected that maize farmers of Pakistan will, for the first time, grow IR/HT maize developed by Monsanto Pakistan and Dupont Pioneer in the autumn maize growing season from mid-May to August 2018.

Biotech cotton area reached an all-time high of 3 million hectares equal to 96% of total cotton

IR cotton has been consistently adopted by cotton farmers in Pakistan since 2010, when the first commercial cultivation was officially reported by the NBC of MOCC of the Government of Pakistan (Figure 10). Punjab province was the first to adopt large IR cotton area, followed by Sindh, Khyber Pakhtunkhwa, and Balochistan in the subsequent years. In 2017, IR cotton cultivation reached an all-time high of 3 million hectares, equivalent to 96% of total cotton area of 3.11 million hectares planted by ~725,000 smallholder cotton farmers in the eighth year of its commercialization. The significant increase in IR cotton area to 3 million hectares in 2017 was possible because of the introduction of a substantial support package for farmers including subsidy on fertilizers, reducing interest rates on loans, and other support measures introduced in the budget 2017-2018 by the Government of Pakistan. Other factors include training of farmers for the management of pink bollworm, as well as leaf burning syndrome and competitive market price for cotton (Ministry of Commerce and Textile, 2017).

The Punjab provincial Seed Council (PSC) approved only those IR cotton varieties that express *cry1Ac* gene (MON 531 event) for which the waiver of commercial certificate was granted by the NBC on the basis of decision at paragraph 7(a) of minutes of the 14th meeting of NBC held on March 31, 2016 and April 22, 2016. All the PSC approved IR cotton varieties were also subjected to the issue of classification/notification by the National Biosafety Committee (NBC) of the Ministry of Climate Change, Islamabad. The provincial PSC has not approved any new crop/event that was not approved by the Federal NBC and thus maintains the supremacy of the Federal NBC for the approval of new gene/event/crop in Pakistan. Although the legal battle over the regulatory oversight has been fought in the courts, there is an unwritten understanding about the approval of biotech crops developed between the Federal and the provincial government in 2016-2017, which needs to be clearly spelled out so as to spur the growth of biotech approval, adoption, and acceptance in

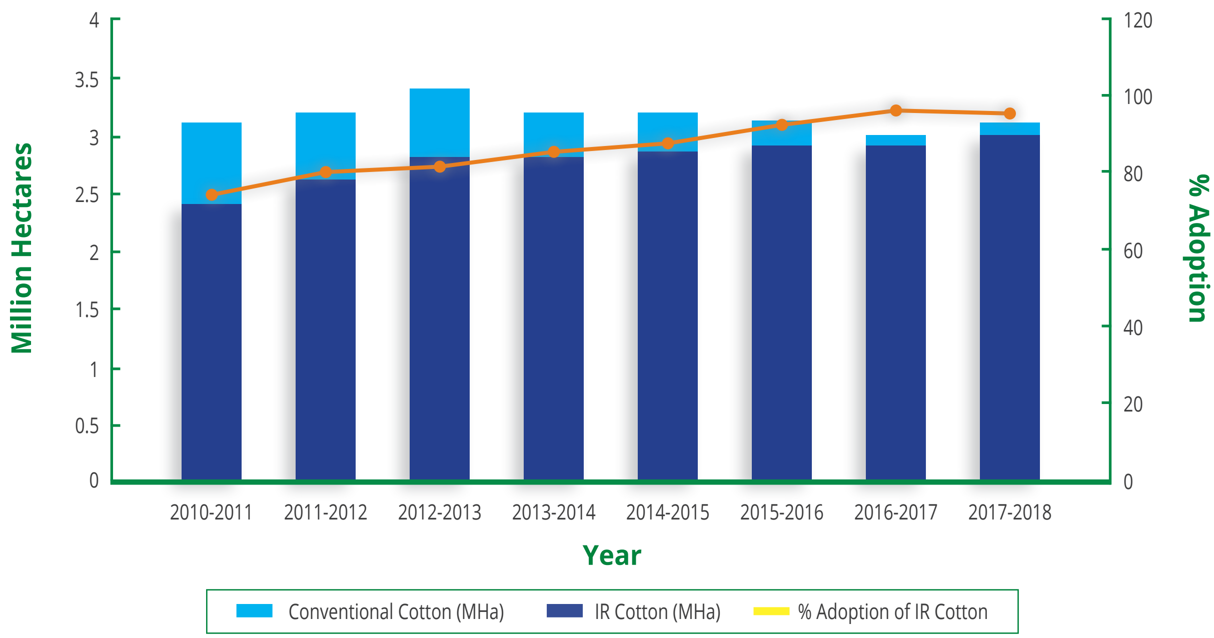


Figure 10. Adoption of IR Cotton in Pakistan, 2010 to 2017

Source: Analyzed by South Asia and Biotechnology Centre (SABC) and ISAAA, 2017.

the country. The biotech crops approved by the NBC and the PSC in 2016 and 2017 are listed in Tables 17 and 18.

In 2017, four additional varieties of IR cotton expressing *cry1Ac* gene including event Mon 531 were approved for commercial planting in the 48th meeting of the PSC in March 2017. Other IR cotton varieties and hybrids expressing single and double gene(s) such as *cry1Ac* or pyramided *cry1Ac* and *cry2A* genes developed by both public and private sector institutions were awaiting commercial approval but deferred due to non-provision of commercialization certificate by the NBC. Many of these IR cotton varieties and hybrids possess higher ginning turn out percentage, better fiber qualities, and spinning performance compared with all the existing commercial IR varieties (Khan et. al, 2017). The most prominent of them include IR cotton varieties including IR CIM-600 and IR CYTO-177 developed by Central Cotton Research Institute (CCRI) Multan; IR NIBGE-4 and IR NIBGE-6 developed by National Institute of Biotechnology and Genetic Engineering (NIBGE), Faisalabad and TARZEN-3 by M/s Four Brothers Group of Pakistan, Lahore.

Efforts were also directed to develop inter- and intra- specific varieties and hybrids of IR cotton that exhibit high tolerance to cotton leaf curl virus, pink bollworm, and sucking pests to overcome emerging challenges and significantly contribute to the overall cotton production. In the past seven years from 2010 to 2016, the NBC and PSC have approved 34 varieties of IR cotton which were made available to cotton farmers in four important cotton growing provinces including Punjab, Sindh, Khyber Pakhtunkhwa, and Balochistan. However, it was reported that a number of IR cotton varieties have become susceptible to insect pests for which those IR cotton varieties were derived. It was also noticed that the fiber parameters

Table 17. Commercial release of IR/HT maize events by Federal NBC in Pakistan, 2016

Gene(s)/Event	Traits	Developer
MON 89034 x NK603	Insect Resistant and Herbicide Tolerant	Monsanto Pakistan
NK603	Herbicide Tolerant	Monsanto Pakistan
TC1507 x MON810 x NK603	Insect Resistant and Herbicide Tolerant	Dupont Pioneer Pakistan
TC1507 x NK603	Insect Resistant and Herbicide Tolerant	Dupont Pioneer Pakistan

Source: PSC/NBC/PCCC, Compiled by SABC and ISAAA, 2017

Table 18. List of PSC approved and FSC&RD registered New IR Cotton Varieties with *cry1Ac* gene in Pakistan in 2017, subject to certification by National Biosafety Commission (NBC) of Pakistan

	Cotton variety	Developer
1	IR.CYTO-177	Central Cotton Research Institute (CCRI) Multan
2	IR.CYTO-179	Central Cotton Research Institute (CCRI) Multan
3	IR CIM-600	Central Cotton Research Institute (CCRI) Multan
4	CRIS-508	Central Cotton Research Institute (CCRI) Multan
5	FH-326	Cotton Research Station, AARI, Faisalabad
6	IR NIBGE-4	NIBGE, Faisalabad
7	IR NIBGE-6	NIBGE, Faisalabad
8	NIAB-878 B	Nuclear Institute for Agriculture & Biology (NIAB), Faisalabad
9	Koonj	ARI, Tandojam
10	BPC-11	M/s Biocentury Seeds, Lahore
11	BS-15	M/s Bandesha Seed Co, Jahanian
12	Leader-3	M/s Suncrop Group Multan
13	Sahara-120	M/s Patron Seed Company
14	Weal AG “SHAHKAR”	M/s Weal AG Corporation, Allah Din Group of Companies, Multan

Source: PSC, 2017; FSC&RD, 2017; Compiled by SABC and ISAAA, 2017

of all the prevailing IR cotton varieties were not up to standard. Therefore, new IR cotton varieties were developed with the objective of conferring resistance against bollworm along with desirable fiber quality (USDA FAS GAIN Report, Agricultural Biotechnology Annual-Pakistan, 2017).

Pakistan imports approximately 2.5 to 3 million bales of cotton worth US$1 billion every year to meet the demand of the textile industry. Most of the imported raw cotton was from India, Brazil, and the United States (USDA FAS GAIN Report, Cotton and Products Annual-Pakistan, 2017). In order to meet the growing requirement of cotton by the textile industry, the Pakistan Cotton Ginners’ Association (PCGA) and other key stakeholders urged the government to introduce a Five-Year Cotton Policy to raise production to 22 million bales by increasing cotton cultivation to 4.2 million hectares from 3.11 million hectares in 2017 and by giving incentives of crop insurance and quality premium for farmers (The Nation, 2017). Similarly, the Ministry of Textile Industry introduced a series of measures to boost cotton production by providing equal support measures including the establishment of the National Textile University in all the four provinces, Cotton Ginning Factory in D.I. Khan and restructuring the Pakistan Central Cotton Committee (PCCC) in the sector (Ministry of Textile, 2017 & Pakistan Observer, 2017).

On the technology development front, researches in the public sector institutions led by the Pakistan Atomic Energy Commission (PAEC), National Institute for Biotechnology and Genetic Engineering (NIBGE), Nuclear Institute of Agriculture and Biology (NIAB), Agricultural Biotechnology Research Institute Faisalabad, Cotton Research Institute Faisalabad, Cotton Research Institute Multan, Centre of Agricultural Biotechnology and Biochemistry (CABB), and National Center of Excellence in Molecular Biology (NCEMB) at Punjab University Lahore have been geared to tackle major problems of sap-sucking pests, cotton leaf curl virus, and pink bollworm, and have been developing local biotech cotton varieties (Kang and Saeed, 2017). In 2017, the NCEMB of Punjab University has claimed to develop the country's first three herbicide tolerant and insect resistant GM cotton varieties, including CEMB-33, CEMB-Klean Cotton, and CA-12 (Business Recorder, 2017). A list of IR cotton varieties developed by public sector institutions is presented in Table 18, and there are others which have pending regulatory approvals due to non-functioning of the NBC.

Biotech maize field trials exhibited top performance in farmers' fields

In 2017-2018, Pakistan successfully conducted the farmers' field demonstrations of biotech maize and exhibited its performance to maize farmers (Pakistan Today, 2017). Single and stacked IR/HT maize varieties were officially approved for commercial cultivation by the NBC of MOCC of the Government of Pakistan in 2016. Table 17 lists the approval of IR/HT maize events for commercial cultivation by Federal NBC in Pakistan in 2016. In 2017, the field performance trials of IR/HT maize hybrids –expressing insect resistance and herbicide tolerance were conducted as part of the regulatory requirement for varietal registration by the Federal Seed Certification and Registration Committee, Ministry of National Food Security and Research. It is expected that the maize farmers of Pakistan will, for the first time, grow IR/HT maize developed by Monsanto Pakistan and Dupont Pioneer in the autumn maize growing season from mid-May to August 2018. The commercial release of IR/HT maize in 2016 was a significant milestone in the regulatory approval of GM crops in Pakistan since it deregulated IR cotton in 2010. The commercial authorization of four events of IR/HT maize developed by both Dupont Pioneer Pakistan and Monsanto Pakistan will spur the tremendous growth of adoption of IR/HT maize and will drive adoption of maize hybridization in the country.

Coincidentally, Pakistan also achieved an all-time high maize production of 6.13 million tons in 2017, up 16.3 percent from last year's 5.27 million tons. However, the domestic prices of maize remained much higher, approximately US$55 per ton than the price of imported maize. The Government of Pakistan imposed a 30% regulatory duty and 10% customs duty on the import of maize, thus shielding maize producers from imports. On the contrary, the Pakistan Poultry Association has reportedly sought a tariff reduction to access cheaper maize feed from the international market (USDA FAS GAIN Report, Grain and Feed Annual-Pakistan, 2017). In order to further increase the supply of maize, it is expected that the approval of four events of IR/HT maize, will spur the growth of maize production by increasing the area under hybridization in Khyber- Pakhtunkhwa, as well as replace the existing maize hybrids with IR/HT maize hybrids in Punjab province. Similarly, it is estimated that the rapid adoption of IR/HT maize in Pakistan beginning 2018 will deliver around US$1 billion additional benefits to farmers in the next 10-year period.

Benefits of Biotech Cotton

For the last eight years, an estimated 725,000 smallholder Pakistani farmers have been benefiting from the economic gains in using biotech cotton. It is provisionally estimated that the economic gains from biotech crops for Pakistan for the period 2010 to 2016 was US$4.8 billion and US$483 million for 2016 alone (Brookes and Barfoot, 2018, Forthcoming).

In 2017, two new research studies were published to examine the effectiveness of IR cotton by Spielman et al. (2017) and to evaluate the impacts of IR cotton on profitability, productivity, and farm inputs in Pakistan. Spielman et al. (2017) carefully looked at the concerns about the prevalence of IR cotton varieties possessing weak or non-performing insect-resistance traits conferred by the cry gene. Analysis drawn from a 593 sampled cotton households data, collected from six agroclimatic zones spanning 28 districts in Pakistan in 2013, as well as measurements of Cry protein levels in cotton tissue samples collected from the sampled households' main fields, revealed a wide variability both in farmers' beliefs about presence and absence of cry gene and its adequate expression to effectively control insect pests (Spielman et al., 2017). Another study on the impacts of IR cotton on profitability, productivity, and farm inputs in Pakistan that relied on the panel modeling approach estimated the benefits from adopting IR cotton seeds in Punjab, Pakistan over two cropping seasons – 2008 and 2009. Results indicate that, on average, IR adopting farmers receive 9% higher yields per hectare, reduce per hectare pesticide use by 21.7%, and increase per hectare use of irrigation water by 6%. The study concluded that allowing more IR cotton varieties and ensuring the availability of quality IR cotton seeds in the market is likely to lead to further benefit increases (Bakhsh, 2017).

Country Situationer

In 2017, Pakistan successfully concluded the USDA supported "Pakistan-US Cotton Productivity Enhancement Program", which was implemented by ICARDA to transfer cutting-edge integrated pest management (IPM) techniques spread through farmer field schools (Dawn, 2017). The provincial Punjab government was reportedly planning to acquire two more advanced gene technologies including double gene, *cry1Ac* and *cry2Ab*, Bollgard®-II and stacked trait, insect resistant and herbicide tolerant, popularly known as Roundup Ready® Flex (RRF) event from Monsanto under the Kissan Package 2016-17 for better seed quality resisting pests and effective weed control (Dawn, 2017a). The Punjab provincial government and the World Bank announced a US$300 million project to modernize agriculture in Punjab to raise farmers' incomes, give consumers better quality and safer food at lower prices, create jobs on farms and agribusinesses, and improve the use of irrigation water (The Nation, 2017a).

As a part of the China Pakistan Economic Corridor (CPEC) – a Long-Term Plan (LTP) prepared by Pakistan National Reform Commission (NDRC), the People's Republic of China, and China Development Bank in December 2015, the Sino-Pak agriculture expert worked out a plan to strengthen agriculture including the transfer of biotechnology from China to boost cotton production in Pakistan (The Nation, 2017b). Strengthening cotton-textile supply chain, the Prime Minister of

Pakistan Mr. Nawaz Sharif also announced an Rs 180 billion package to boost the country's textile and apparel exports including tax-free import of cotton and man-made fiber, and duty drawback on exports of fabrics, made-ups and garments against realization of import proceeds in January 2017 (Tribune, 2017).

Summary and Future Prospects

Pakistan increased its IR cotton area by 3.4% or 100,000 hectares from 2.9 million hectares to 3 million hectares. This is expected to increase cotton production by 14.04 million bales. The delayed approval and commercialization of new generation biotech cotton, double gene(s) and stacked traits, has marred the prospects of cotton and textile industry after the 18th Constitutional Amendment that decentralized roles and responsibilities to regulate biotech products to provincial government in 2010. In the meantime, a series of litigation as to who should regulate biotech products, the federal or provincial government has hindered the pace of approval of biotech products for R&D, field trials, and commercial release. Evidently, the approval for commercial planting of stacked Bt/HT maize by the NBC in 2016 was a clear indication of the roles and responsibilities of biotech regulation between the Federal and provincial governments, wherein the biosafety approval lies with the Federal government whereas the release of biotech varieties rests on the provincial government. The process of approval of IR/HT maize and subsequent varietal registration and farmers' field demonstration of stacked IR/HT maize in 2017 was a step forward in this direction, which will not only spur the tremendous growth of adoption of IR/HT maize but also drive the approval and adoption of next generation biotech crops in the country in 2018 onward.

CHINA

China has been one of the leaders in planting IR cotton since 1997, as well as a small area of biotech papaya. IR cotton was planted in the last 21 years in China, with the highest recorded area in 2013 at 4.2 million hectares. In 2017, 95% of the total cotton area of 2.8 million hectares was biotech, similar to 2016 and planted by some estimated 6 to 7 million farmers. The 2.78 million hectares of cotton harbor the insect resistant gene Bt to resist lepidopterous insect pests. Biotech papaya resistant to papaya ringspot virus (PRSV) disease was planted on 7,130 hectares at 86% adoption rate.

Since 1997, China has approved 64 biotech events for food, feed, and cultivation: Argentine canola (12), cotton (11), maize (18), papaya (1), petunia (1), poplar (2), rice (2), soybeans (12), sugar beets (1), sweet pepper (1), and tomato (3). In 2017, China granted import approval for biotech maize event 5307 which has resistance to corn rootworm. The approval covers corn grain and processing co-products, including dried distiller's grains, for food and feed use.

Biotech cotton maintains 95% to 96% adoption rate

Since biotech cotton has been introduced in China in 1998 at 0.26 million hectares, the area increased to 4.6 million hectares in 2013 and slowly decreased to the current area of 2.78 million hectares. The total cotton area in 2017 was similar to 2016 at 2.9 million hectares, despite the high cotton end stocks since 2015. This is due to the stable cotton policy and high global cotton prices in 2017 (ICAC, May 1, 2017). The adoption rate of biotech cotton was similar to 2016 at 95%, the highest adoption rate reached by IR cotton in China was 96% in 2015.

Biotech papaya adoption maintained at 86%

Biotech papaya has been planted in China since 2006, with the approval of China's National Biosafety Committee. Papaya is consumed in China largely as a fruit and dish ingredient. Papaya was planted on a total of 7,130 hectares, 17% lower than the 2016 planting of 8,550. Papaya is planted in Guangdong province, Hainan Island, and Guangxi province as shown in Table 19.

Benefits from Biotech Crops in China

China has been planting biotech cotton since 1997 and some 6 to 7 million farmers have benefited from the technology through high yields and significant cost savings on insecticide application, as well as on labor use in spray application. It is estimated that China has enhanced farm income from biotech cotton by US$19.64 billion from 1997 to 2016 and by US$990 million in 2016 alone (Brookes and Barfoot, 2018, Forthcoming).

The benefits of IR cotton were extensively studied by Quiao et al. (2017) using seven unique waves of panel data collected between 1999 and 2012. The study revealed that Bt cotton has not only caused a reduction of the mean value of pesticide use, but also reduced the standard deviation of pesticide use as well as the stability of pesticide use in cotton production. The reduction of the standard deviation of pesticide use indicates that the benefit of Bt cotton adoption is not only enjoyed by adopters, but also by non-Bt adopters. The stability of pesticide due to Bt cotton adoption contributes to the stability of cotton yields and economic benefits as no farmers, especially non-adopters, spray too less or too much.

A 15-year study from 1999 to 2012 by Qiao et al. (2017) further explained the sustainability of Bt crops in the long run. Using seven unique waves of panel data collected during 1999-2012, results revealed that pesticide use against bollworms has not increased significantly over time, indicating that the buildup of pest resistance is not a concern at the moment due to the existence of natural refuge areas. There was no outbreak of secondary pests during Bt adoption, and that both Bt and non-Bt adopters benefit from the widespread adoption of the technology, suppressing the density of the pest population regionally. The benefit of Bt cotton adoption continues 15 years after its introduction, albeit with evidence of a decline in the comparative advantage over non-Bt cotton in late adoption since pesticide use categorized were for controlling bollworms and for controlling secondary pests.

Bt technology adoption also has an impact on the health of Chinese farmers. A study by the Beijing Institute of Technology (Zhang et al., 2016) revealed that adoption of biotech crops in China could improve the health of Chinese

Table 19. Area of Biotech Papaya Planted in China, 2017 (Hectares)

Location	Total papaya Area	Biotech Papaya Area	% Adoption
Guangdong Province	3,000	2,850	95%
Hainan Island	3,800	3,230	85%
Guangxi Province	1,500	1,050	70%
Total	8,300	7,130	86%

Source:

farmers. The results indicated that biotech crops not only increased glyphosate use, but also reduced the use of non-glyphosate herbicides, while adoption of insect resistant biotech crops significantly reduced insecticide use. Farmers used glyphosate herbicides, chemical lepidopteran insecticides, biological lepidopteran insecticides, non-lepidopteran insecticides, and fungicides. The report also revealed that none of the examined health indicator was associated with glyphosate, while the use of non-glyphosate herbicides was found to induce renal dysfunction, inflammation, and severe nerve damage. The result of this study indicates that adoption of biotech crops will cause the replacement of other herbicides with glyphosate, which may actually benefit farmers' health in China and around the world, and has positive implications for biotech crops (Crop Biotech Update, October 19, 2016).

Country Situationer

China, being a member of the six founding biotech crop countries, continues its science-based regulation and adoption of biotech cotton and papaya. Poplar is not included in the report because of lack of information on its planting. Approval of various biotech products for food and feed have been going on, but with the recent protests on biotech crops in the country, regulation is affected and hinders the widespread utilization of biotech crops. The country's National Biosafety Committee monitors biotech imports on a case-by-case basis and does not endorse synchronous approval of biotech crops. To date, there are estimated ten biotech events awaiting the Ministry of Agriculture approval, some of which have been under regulatory review for over 5 years. With the US-China Cooperation 100-day plan which started in 2015, new collaborations between China and the USA are hoped to spur future biotech crop development that could offer ways to address public fears and reduce regulatory barriers (USDA FAS GAIN Agriculture Biotechnology Annual, China, 2017).

President Xi Jinping has been actively supporting "strong research and innovation" on biotech crops, providing some US$3 billion funds to research institutes and domestic companies to develop home-grown disease and drought resistant wheat, disease resistant rice, drought resistant maize, soybeans that produce more and nutritious oil, and biotech peanuts. Recent new initiatives also include biotech cabbage with resistance to diamondback moth, HT cotton with low glyphosate residues, and high antioxidant purple rice. Furthermore, ChemChina's acquisition of Syngenta in June 2017 has made substantial contributions to shifting China's GMO policy, facilitating the re-approval of 14 biotech crops by the Ministry of Agriculture and extended the review process to 2020. The US-China Comprehensive Economic Dialogue could elevate agricultural biotechnology at the high level bilateral interactions, and influence biotech crop approval. As a case in point was China's agreement to expedite the approval of two US biotech crops after one meeting was concluded.

One important consideration could be the commercialization of biotech maize and soybeans in the country. Speculations that home-grown-biotech maize (Bt or phytase maize) will be commercialized in the next three years could open enormous potential markets of 35 million hectares of maize. Biotech maize and soybean could help China become less dependent on increasing imports of these crops, over 90% of which is biotech. In 2017-2018, 95.5 million metric tons of soybeans were imported by China, up by 14% compared to 2016/17 (AgriCensus, January 12, 2018).

In relation to this, an economic impact assessment of commercializing insect-resistant biotech maize was conducted in China by Xie et al. (2017). The study used production trials of insect resistant maize and expert interviews to determine impact of commercializing biotech maize at farm level, under three severity levels of insect pest attack in maize. Results indicate that in farm terms, insect resistant biotech maize increases crop yield and reduces both pesticide and labor inputs. China will likely increase its GDP by US$8.6 billion and maize self-sufficiency by about 2% given normal insect pest attacks. Additional benefits will also accrue to consumers and the livestock industry, as a result of cheaper feedstocks and land saving for farmers.

Two Bt rice lines, Bt Shanyou 63 and Huahui-1, were developed by Huazhong Agricultural University in Wuhan and had been given phytosanitary certificates in August 2009, but has not been renewed. Issues on ecological risk, food safety, and biosafety regulation surfaced influencing adoption by farmers and public acceptance. Various experiments and related literature point to the fact that Bt rice showed effective control of the target pest and pose negligible risks to the environment and human health. A recent publication by the Chinese Academy of Agricultural Sciences, Huazhong Agricultural University in China and Agroscope in Switzerland detailed a study to assess the risk of the technology to 13 non-target organisms in Central and Southern China. The level of exposure to the plant-produced Cry2A-protein was evaluated in the field in the period 2011 to 2012. Results indicate that the protein was not present in parasitoids, spiders, and beetles before rice anthesis, at trace amounts of the Bt protein in planthoppers, and 2.5 times higher in meadow katydids. As expected, lacewings and beetles contained significant amount of Cry2A-protein during anthesis. This confirms the safety of Cry2A protein in Bt rice to non-target organisms, similar to field studies of other transgenic Bt crops with different Cry proteins (Crop Biotech Update, June 14, 2017).

With the proven safety of Bt rice, and successful adoption of Bt cotton and virus resistant papaya, farmers are likely to accept and adopt it. Acceptance of Bt rice may also be expedited by enhancing communication of GM crop science-related issues on safety and benefits to government officials and the general public (Li et al., 2016).

Summary and Future Prospects

China has been one of the leaders in IR (Bt) cotton planting since 1997 with IR cotton area increasing until 2013 and declined slowly, after a bountiful harvest in 2015 increased year-end stocks, and global cotton prices went down. Thus in 2017, biotech cotton was planted on 2.78 million hectares by some 6 to 7 million farmers, at 95% adoption rate. Biotech papaya ringspot virus resistant papaya was adopted since 2007 and planted on 7,130 hectares in 2017. The country has been in the forefront of research and development of biotech crops as various biotech products have been developed, but are still undergoing regulation including IR rice, phytase maize, HT cotton, HT soybeans, and many others. Studies by noted local scientists attest to the safety (environment and health) of the Bt gene which is currently deployed in cotton, maize, rice, and soybeans. Due to China's vocal biotech critics, biotech products, although proven safe to the environment and to humans, are being unnecessarily scrutinized by the Chinese regulatory bodies. This hinders approval by the Ministry of Agriculture which currently holds an estimated 10 biotech events awaiting approval, some of which have been under regulatory review for over five years. China relies heavily on soybean and maize imports for their increasing livestock and poultry industry, and adoption of these biotech crops will contribute to the reduction of imports and can make farming profitable and competitive. Acceptance of the technology may not be regarded as a problem with over 20 years of IR cotton planting and 10 years of virus resistant papaya planting.

In 2017, the US-China Comprehensive Economic Dialogue and the ChemChina's acquisition of Syngenta could influence synchronous and efficient approval of biotech crops.

SOUTH AFRICA

The year 2017 marked two decades of successful commercialization of biotech crops in South Africa, having planted its first biotech crop in 1998. To date, the country grows three biotech crops: cotton, maize, and soybeans on a combined area of 2.73 million hectares. This is a 2.6% increase from the 2.66 million hectares of biotech crops planted in 2016. The area per biotech crop comprised of maize (1.96 million hectares), soybeans (736,535 hectares), and cotton (37,406 hectares) (Figure 11). Average biotech crop adoption went up to 93%. The total area planted to maize, soybeans and cotton was 3.1 million hectares, a 7% increase from the last report in 2016 when 2.9 million hectares were planted. The increase was mainly from soybeans and cotton.

Since 1998, the 70 events have been approved for food, feed, and planting in South Africa including 5 Argentine canola events, 10 cotton, 42 maize, 1 rice, and 12 soybean events.

Biotech maize adoption rate marginally declined to 85% even with low maize price and high year-end stocks

Maize is the main field crop in South Africa and is used for both human consumption (mainly white maize) and animal feed (mainly yellow maize). In 2017, estimated GM/biotech maize area was 85%, against the 90% recorded in 2016. A total of 1.96 million hectares of biotech maize were grown against total maize area of 2.3 million hectares. This was 9% lower than the 2.2 million hectares planted in 2016. About 1.3 million hectares (54.69%) was biotech white maize and 1.0 million hectares (45.31%) was

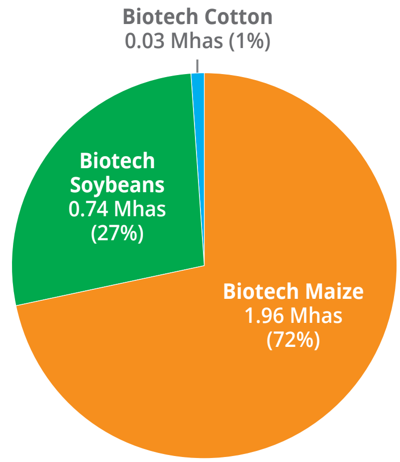


Figure 11. Biotech Crops Planted in South Africa, 2017

Source: ISAAA, 2017

biotech yellow maize. It is estimated that out of the biotech maize planted, some 66% was stacked IR(Bt)/HT), and the rest contain single IR and HT traits in equal proportions.

Low maize price at the end of 2017 planting season running through to 2018 may indicate that some farmers may have opted for the less expensive non-GM seed to caution against a glut that would not help in paying back for technology fees and other inputs. A weak global market for white maize also limited South Africa's export opportunities, leaving a relatively large carry-over stock for the 2018 marketing year.

Favorable rainfall during the critical pollination and early grain-filling stages from January 20 through the end of February 2018 has led to a yield forecast of above average for maize in the coming season. The satellite-derived Normalized Difference Vegetation Index (NDVI) shows that all major dryland maize-producing provinces experienced a dry spell in early January, but NDVI was above average in mid-February after croplands recovered following abundant rains starting late January 2018 (USDA FAS, World Agricultural Production Report 2018).

Maize remains a vital staple food in South Africa and the South African Development Community (SADC) region. White maize is primarily used as food for humans, while yellow maize has been considered as animal feed and primarily used for processing. More than 80% of maize production in South Africa is situated in three provinces, namely the Free State, Mpumalanga, and the North West. However, farmers in the Free State (especially in the western side of the province) and North West provinces plant more white maize and almost 80% of the total commercial white maize crop originates from these two provinces. Mpumalanga is the major yellow maize production region with 35 percent of the national yellow maize crop harvested from this province. Approximately 64% of the subsistence maize crop is planted in the Eastern Cape.

Significantly, the fall armyworm infestation which devastated tracks of maize fields in most parts of Africa had much less impact in South Africa. This was attributed to the more than 85% of biotech maize planting that protected the crop against the noxious pest. In addition, many commercial pesticides to control fall armyworm have been legally registered since the first detection, and were available for producers to control the pest. Genetic engineering is thus an additional intervention that other countries struggling with fall armyworm can explore alongside other integrated pest management practices being employed in the region.

South Africa, in partnership with Kenya, Mozambique, Tanzania, and Uganda is also involved in the development and deployment of drought tolerant biotech maize under the Water Efficient Maize for Africa (WEMA) project. In 2017, small amounts of maize varieties with stacked drought tolerance and insect resistance were made available to a limited number of smallholder farmers for demonstration. The trait was approved in 2015 and official wide-scale release to commercial farms is expected in 2018.

Maize production in South Africa indicates the long-term trend of producing more maize on less area with the use of more efficient and effective farming methods and practices. This is accompanied by the use of less marginal land in the maize production systems, better seed cultivars with the adoption of biotechnology. As a result, maize yield has doubled over the past 20 years in South Africa (USDA, Agri-biotechnology Annual-South Africa, 2017).

Biotech soybean area increased by 37% in 2017

Soybeans have been planted in South Africa since 2001, and in 2017, 787,200 hectares have been planted indicating a 37% increase (213,250 hectares) from 573,950 hectares planted in 2016. Biotech soybeans were planted on 736,535 hectares or 95% of the total soybean area in South Africa. The country has seen an increase in production and 2017 was remarkable with a quick recovery from the dip experienced in 2015/2016 season due to drought. This increase was mainly due to increasing feed and food requirements even though it is still below the annual requirements. Soybeans for human consumption are also expected to increase from 23,800 tons in the previous season to 25,000 tons. Rising domestic demand for soybeans provide an incentive for expansion with farmers being advised to consider soybeans during crop planning in order to meet the rising local demand and subsequently reduce the import requirements over time. Furthermore, the oilseeds industry supported, promoted, and funded research on soybeans to the extent that their target crop size of one million metric tons was reached before the target date and yielded over 1.2 million MT.

Resolving the Farm-Saved Seed Problem in Soybean

Retention by farmers of harvested plant material for re-using as seeds material in the next season has been a major issue, wherein the case of soybeans, rate of retention is about 80%. In 2017, a non-profit company - the South African Cultivar and Technology Agency (SACTA) was formed to mediate the process. The initiative was supported and driven by several leading farmers, Grain SA as farmer association, Agri-business Chamber and SANSOR (*South African National Seed Organization*), with the blessings of Department of Agriculture, Forestry and Fisheries (DAFF). The final Agreement was released on 17 November 2017 and contains the following key elements:

- The basis for an end-point levy is a levy at the point of sale of farm-saved seed.
- Implementation of levies in 2017 will commence with wheat and soybeans, then barley and some canola varieties and may extend to all other open- or self-pollinated crops.
- Collected levies will be re-allocated to variety owners of farm-saved seed on a pro-rata basis related to the market share of variety concerned. The levy collecting and allocating party will be eligible for a 20% commission.
- The levy for soybeans has been set at R65 per MT for 2017 to February 2018 and at R80 per MT for 2018-2019.
- Twenty percent of collected levies/ royalties must go to transformation i.e. disadvantaged black farmers.
- At the request of stakeholders, these requirements will be registered as statutory measures. DAFF has complied and the measures have been published in the Government Gazette.

As costs associated with plant breeding, seed production, and marketing continuously increase, so has the tendency to retain more harvested grain to be used as seed. This is not a unique scenario and farmers make the decision based on economies of scale. Technology stewardship, however may become a big challenge in the future and the practice should be discouraged.

Biotech cotton area reached 37,406 hectares compared to 9,000 hectares in 2016, a 315% increase

Cotton with insect resistance (Bt) has been planted in South Africa since 1998. In 2017, a record 37,406 hectares, a 315% increase from the 9,000 hectares planted in 2016, was reported. Dryland and irrigated cotton areas recorded increases of 68% and 170%, respectively, over the previous year mainly due to the more favorable prices of cotton in relation to competitive crops as well as to renewed interest in cotton production. All cotton was 100% biotech with 95% stacked Bt-Bt+HT and 5% of HT used as refugia. Acceleration of consumer demand for textiles and rising environmental and production costs for synthetics is expected to ignite further expansion in the near to long-term. It is also expected that cotton prices will increase as global prices stabilize, leading to increased prospects for cotton in the 2017-2018 season.

Country Situationer

Permits Issued for Biotech Crops

The GMO Act and applicable implementing regulations and biosafety framework govern the regulation of GMOs in South Africa. The Department of Agriculture houses the GMO Secretariat and all decision-making is managed by the Executive Council comprising Agriculture, Environment, Labour, Health, Trade & Industry, and Science & Technology.

The GMO Act requires applications and approval of permits for all GMO activities, from plants to animals, microbes and vaccines, and cover imports/exports, contained field trials, seed and commodity trade, food and animal feed. Also included are 12 types of permits to assess biosafety standards for research. Apart from meeting standard phytosanitary requirements, a GM seed import permit is required, and a second permit to plant or to multiply such seed. Commodity grain imports are subject to Commodity Clearance approval, then a permit for import, followed by a permit for commodity use as food, feed, and/or processing. Previous biosafety assessments of application documentation are carried out by a scientific team comprised of 10 experts, the GMO Advisory Committee (AC) and its sub-committees on a case-by-case basis. The AC opinion is presented to the official Executive Committee, the chairman and senior representatives from six government departments, to reach a consensus decision.

In 2016-2017, 723 permits were granted for biotech crops, an increase from 628 in 2016. GM maize had the highest at 694 (96% of total permits), which was comprised of 18 permits for food and feed, 20 permits for processing, and other permits covering import for planting, contained use, field trials, exports, commodity clearance. GM soybeans had 15 permits, 2% of total permits comprised of permits for planting, imports of seed of current cultivated HT soybeans, and four soybean Commodity Clearance approvals for imports: two with stacked traits for contained use and one stacked traits intended for feed, and one new stacked soybean trait for modified fatty acid composition having less risk to human health. GM cotton had 14 permits (2% of total permits) approved.

Public Perceptions about Biotechnology in South Africa

According to Gastrow et al. (2018), South Africans are more positive about the health implications of GM food, less critical about the environmental impact of GM food, and more positive about the economic consequences of GM food than Europeans. From a nationwide survey conducted in 2017, the South Africans' familiarity with the concept of biotechnology and awareness of GM food, have increased over the last decade, although these changes have occurred from a low base. Knowledge about biotechnology is positively correlated with younger age, higher educational attainment, and higher living standards. It was found that engaging on the basis of indigenous knowledge systems may prove to be the most effective platform for communication. The concepts of DNA and genes are far better understood than those of genetic modification or GM food, and would, therefore, present a better starting point for engagement and knowledge transfer in the future. Together, these considerations point towards new strategic imperatives for public engagement in the South African biotechnology sector. Public policy and broader sectoral engagement strategies need to take into account: (1) the highly dynamic nature of public perceptions, (2) the diversity of views held by different demographic groups and (3) the diversity of sources of information utilized and preferred by different demographic groups. These considerations would support a strategically targeted engagement approach that would leverage the rapidly growing public awareness of biotechnology in a constructive manner.

Economic Benefits of Biotech Crops in South Africa

It is estimated that the economic gains from biotech crops for South Africa for the period 1998 to 2016 was ~US$2.3 billion and US$330 million for 2016 alone (Brookes and Barfoot, 2018, Forthcoming).

A study focusing on gender-aggregated benefits by Gouse et al. (2016) found that female smallholder farmers and household members value GM herbicide tolerant maize higher than their male counterparts because of the labor-saving benefit the technology brings. The researchers found that females in HT maize seed adopting households were able to save 10-12 days of manual weeding per hectare, compared to their conventional and GM insect resistant maize planting, and traditional manual weeding counterparts. Interestingly, females spent most of their extra time doing housework (cleaning and cooking) and working in their own or community vegetable gardens.

In summary, the increase in biotech crop planting in South Africa was spurred by increased planting of soybean and cotton. For soybean, favorable weather, increasing feed and food requirements, and rising domestic demand for soybeans provided incentives for expansion for farmers. In the case of cotton, the impetus for growth was spurred by more favorable prices of cotton in relation to competitive crops, renewed interest in cotton production, acceleration of consumer demand for textiles and rising environmental and production costs for synthetics. Farmers have been advised to consider further expansion of both crops to meet the rising local demand and reduce the import requirements over time. The WEMA maize is expected to address the water deficiency that affects South Africa periodically. This is expected to be distributed widely to farmers from the 2018 plantings. There are also prospects for introduction of drought tolerant soybean that will be available from Argentina.

BOLIVIA

Bolivian farmers have planted biotech soybean event GTS 40-3-2 (the only approved event) since 2008, and had been regarded as the most treasured crop in Bolivia. The crop is planted largely in Santa Cruz which is the center of agricultural development, especially in commodity crops as well as commercial livestock. In 2017, Bolivia experienced the worst drought episode in 25 years that reduced soybean planted area to 1.283 million hectares, a marginal decrease of 1% from 1.3 million hectares in 2016. The adoption rate of biotech soybeans increased however from 91% in 2016 at 1.2 million hectares to the current 100% (1.3 million hectares), an increase of 7%.

Country Situationer

Some 300 large holder farmers felt the combined impact of El Niño's weather cycle, poor water management and climate change, which caused the country's worst drought in 25 years. Drought had affected 125,000 families and threatened 280,000 hectares (716,605 acres) of agricultural land. In addition, a swarm of locust of up to 10 kilometers long and traveling up to 100 kilometers per day had spread across Santa Cruz in February 2017. More than 1,500 hectares of the total 1.5 million hectares of agricultural land have been devastated by the locust attack, which were planted to soybeans, maize, wheat, sunflower, and sorghum (theguardian.com, May 5, 2017). As a consequence, in 2017, Bolivia imported some 113,320 tons of biotech maize from Argentina and the USA for livestock use. Bolivian farmers were not in agreement with the government's decision to import maize from Argentina which was biotech – the very technology these farmers were not allowed to use. If given the chance to plant biotech maize, these farmers will be more competitive with Argentina and Brazil.

A report from the Association of Producers and Oilseeds and Wheat (ANAPO), the Bolivian Foreign Trade (IBCE), and the Agricultural Chamber of the East (CAO) has indicated that biotech soybean and maize can generate US$150 million in Bolivia. The report titled *Socioeconomic Impact and Environment in Bolivia from Genetically Improved Soy and Maize*, was based on the 10-year experience and research on the use of glyphosate resistant soybean which was the first biotech crop adopted in Bolivia in 2005. This biotech crop helped the country to accumulate US$177 million savings from 2005-2015. Biotech maize production in the last four seasons was also studied and compared to the production of Paraguay. According to IBCE, biotech soybean adoption helped reduce the use of insecticides and saved US$66 million per year, in addition to the increase of 200,000 tons in production which translates to US$50 million profit per year. On the other hand, biotech maize adoption would help reduce pesticide use, and an additional 87,000 tons in production could lead to income of US$11 million. There will also be 7,000 tons of reduction in carbon dioxide emissions and 120 million liters of water savings (Crop Biotech Update, March 8, 2017).

A similar recent study commissioned by several agricultural institutions pointed out that maize production could be more than doubled by 2025 if the government authorizes the use of the GM maize. According to ProyectAgro, domestic demand for maize of 850,000 tons per year may rise with the increasing demand of feeds for pork, poultry, and cattle industry in the country. The only way that this demand is met is through the use of biotech maize (Genetic Literacy Project, October 17, 2017). The government therefore must understand the importance of this problem and should open policies and measures to enable farmers to plant biotech maize.

Bolivia intends to implement an ethanol blend mandate in gasoline, which will begin at 10% and would increase gradually as the Bolivian biofuel industry increases production capacity. This mandate will potentially benefit the Bolivian industry with US$1.5 billion in investments and the creation of 100,000 jobs in upcoming years. Since Bolivia produces ethanol out of sugarcane, the approved biotech insect resistant sugarcane in Brazil and the soon to be approved drought tolerant sugarcane in Indonesia will be suitable materials in building up the sugarcane industry in Bolivia. Sugarcane is planted on 150,000 hectares with an average yield of 50 MT per hectare. These extremely low yields are the result of inadequate genetics, low levels of mechanization, and poor agricultural practices. If the Bolivian industry were to fully supply the demand generated by a ten percent ethanol blend mandate, it would have to increase the planted area by 180,000 hectares and increase its yields to 80 MT per hectare. (USDA FAS GAIN Report, Possible E10 Mandate in 2018– Bolivia, 2017). The potential of Bolivia to become a biotech sugarcane country is not far from being a reality.

Benefits from Biotech Soybeans

It is estimated that the economic gains from biotech soybeans for the period 2008 to 2016 was US$776 million and US$54 million in 2016 alone (Brookes and Barfoot, 2018, Forthcoming), benefiting the more than 300 biotech soybean farmers and their families in Bolivia.

Summary and Future Prospects

It is unfortunate that Bolivia is still experiencing the effects of extreme drought and the attack of a swarm of locusts during the planting season. These conditions affected thousands of families and some 280,000 hectares of agricultural lands planted with soybeans, cotton, and maize. Thus, the soybean area was reduced marginally by 1%, at 1.28 million hectares, and was all biotech. The area planted to biotech soybean increased by 9% or 103,000 hectares in 2017. In addition, a large amount of maize was imported in 2017 to provide feeds for the poultry, pork, and beef industry. Two independent studies on the impact of increasing biotech soybean adoption and possible maize adoption were conducted at different time periods. One study conducted by ANAPO with its partners IBCE and CAO indicated that biotech soybeans and maize can generate US$150 million in Bolivia, and that adoption of biotech maize could lead to an income of US$11 million on top of the savings in carbon dioxide emissions and reduction of insecticide and harmful herbicide use. Sugarcane is also another candidate biotech crop that can be adopted in the country with the plan to implement an ethanol blending mandate of 10% in the very near future.

LATIN AMERICA

Ten countries in Latin America planted biotech crops in 2017, led by Brazil and followed by Argentina, Paraguay, and Bolivia (included in the top 10 biotech countries), Uruguay, Mexico, Colombia, Honduras, Chile, and Costa Rica in decreasing order of biotech crop area. Details on the biotech crops planted, adoption trends, country situations and future prospects for respective countries and the region are discussed below.

URUGUAY

Biotech soybeans were introduced in Uruguay in 2000, followed by IR (Bt) maize in 2003. In 2017, the biotech soybean area in Uruguay was 1.09 million hectares while biotech maize was 50,000 hectares for a total of 1.14 million hectares, indicating a 13% reduction from 1.29 million hectares in 2016. However, biotech crops adoption rate increased from 97% in 2016 to 98% in 2017, with 100% adoption rate of biotech maize. The reduction in the soybean and maize areas, similar to neighboring countries Brazil, Argentina, and Paraguay were due to low prices, unfavorable weather conditions, and local and international trade issues.

Brookes and Barfoot (2018, Forthcoming) estimated that Uruguay farmers numbering more than 3,000 had enhanced farm income from biotech soybean and maize of US$284 million from 2000 to 2016, and the economic benefits for 2016 alone is estimated at US$60 million. These farmers, their families, and the community have been benefiting immensely from biotech crops since its introduction in 2000. It is also notable that Uruguay planted 17 biotech events: 10 for maize and 7 for soybean. There was no new approval granted in 2017.

Biotech stacked IR/HT Intacta™ soybean area increased by 64%

The area planted to biotech soybeans was reduced by 11% from 1.23 million hectares in 2016 to 1.09 million hectares in 2017, while the adoption rate of biotech soybean was 98% of the total soybean area of 1.11 million hectares, similar to 2016. This reduction in biotech area comes with the decrease in national soybean area from 1.26 million hectares in 2016 to 1.11 million hectares in 2017, which is a 12% reduction. The biotech soybean area was comprised of 811,000 hectares HT (74%) and 279,000 hectares IR/HT (26%) (Table 20). The area planted to stacked IR/HT soybean event Intacta™ increased from 171,000 hectares in 2016 to 279,000 hectares, an increase of 64%, indicating the preference of farmers for stacked trait soybean events.

According to the USDA FAS GAIN report on Uruguay's oilseeds and products (2017), the reduction of planted area to soybean was affected by a recent phytosanitary protocol implemented between Uruguay and its primary export market, China. This led to a great uncertainty in the country's soybeans sector. There were speculations that if the flow of soybean exports to China will not be interrupted by the new protocol, soybean area could increase to 1.3 million in the next planting season. If China declines the soybean shipment from Uruguay, export markets in Russia, Southeast Asia, and the European Union will be strengthened. The soybean growing areas were

Table 20. Total and Trait Hectares of Biotech Soybeans in Uruguay, 2016-2017

	Area Planted (MHa)		% Trait Hectares	
	2016	**2017**	**2016**	**2017**
Total Soybean	1.26	1.11		
HT	1.06	0.81	86.1%	74.4%
IR/HT	0.17	0.28	13.9%	25.6%
Total Biotech Soybean	**1.23**	**1.09**	**97.6%***	**98.2%***

* Adoption rate

Source: ISAAA, 2017

in the Departments of Rio Negro, Soriano, and Colonia, a region known for prime soybean crop production area.

The reduction of demand for soybeans for biodiesel production during the year also affected soybean planted area. This is because canola is being considered as a substitute for soybean feedstocks in Uruguay's primary biodiesel blender, Alcohols of Uruguay (ALUR). The company believes that canola is an excellent substitute and is expected to assist them in reaching greater efficiency and improved profitability. This strategy will open doors for the introduction of biotech canola for biodiesel, as the country planted 40,000 hectares of conventional canola in 2017.

Expansion of the soybean area may be influenced by the estimated increase of 2% in the domestic soybean meal consumption due to the growth of the poultry and pork sectors. Domestic consumption of soybean oil is expected to increase slightly from 1,000 tons to 37,000 tons based on greater demand from the food sector.

Soybeans are being exported as whole beans due to the high upstart and operating costs for soybean crushing in Uruguay. It is noteworthy that Argentina has become a significant importer of Uruguayan soybeans after the Argentine government permitted the importation of soybeans in January 2016. These additional soybean supplies are a great boon to Argentine processors as they help increase utilization of their excess crush capacity.

Biotech maize adoption soared to 100%

The area planted to maize in 2017 was 50,000 hectares, indicating a 29% reduction from 70,000 hectares in 2016. Adoption of biotech maize increased, however from 86% in 2016 to 100%, thus all 50,000 hectares were biotech maize compared to 60,000 hectares in 2016. The 50,000 hectares of biotech maize were comprised of 2,000 hectares HT and 48,000 hectares stacked IR/HT (Table 21).

Reduction in maize planting similar to soybean was also brought by unfavorable weather conditions during the planting season, as there was dryness in spring and minimal rain during the winter season. In addition, maize cultivation requires higher input costs and with lower producer prices due to the appreciation of the local currency, the price of maize in 2017 was not competitive with ample maize crops in South America.

Local consumption of maize and by-products

Table 21. Total and Trait Hectares of Biotech Maize in Uruguay, 2016-2017

	Area Planted (MHa)		% Trait Hectares	
	2016	**2017**	**2016**	**2017**
Total Maize	0.070	0.050		
HT	0.003	0.002	4.8%	4.0%
IR/HT	0.057	0.048	95.2%	96.0%
Total Biotech Maize	**0.060**	**0.050**	**85.7%***	**100.0%***

* Adoption rate

Source: ISAAA, 2017

in poultry and egg industry has not changed and may not influence an increase in maize planted areas. However, according to USDA FAS GAIN Livestock and Products Annual-Uruguay (2017), importation of maize from Uruguay for domestic production of animal feeds came regularly from Paraguay and Argentina. The area planted to maize may somehow increase with demand for cattle feed for beef exports to the EU, as well as the probable utilization of maize in ethanol production similar to 2016. New international markets for beef may also open in Japan, Turkey, and some small portions of Brazil and the Russian Federation.

Benefits from Biotech Crops

In the study by Brookes and Barfoot (2018, Forthcoming), Uruguay is estimated to have enhanced farm income from biotech soybean and maize of US$284 million from 2000 to 2016, and the benefits for 2016 alone is estimated at US$60 million.

In 2016, SerAgro, an agricultural consultancy firm, reported the results of an economic study on the impact of the adoption of biotech maize and soybeans, associated with the no-tillage system from 2003 to 2015. According to the lead author and agronomist Nicolas Lussich, the no-till technology represented a strong impact on production and a direct financial return for the sector. There were also indirect forms of gains obtained from the technology that were indirectly used with other sectors, creating between 20,000 and 40,000 well-paid jobs during the period. Benefits gained from the biotech crops were as much as US$12.08 billion compared to conventional crops. The adoption of biotech crops during the period 2004 and 2015 corresponds to an increase of 1.7% in Uruguay's GDP, when the economy grew by 5%.

The use of herbicide tolerant soybeans alone generated an additional income of US$4.4 billion from 2004-2015, particularly during 2012-2013 when exports reached US$1.9 billion. The extra income from biotech maize during the 12-year period was US$305 million. For both biotech soybeans and biotech maize, the direct impact on the economic sector generated US$4.3 billion during 2014-2015. The indirect income represented US$7.7 billion because of the jobs generated not only in the agricultural sector but also in the trade and industry sectors (AgroPages.com, November 21, 2016). However, since 2012, there were no new biotech events approved in Uruguay while neighboring countries in Latin America continue to incorporate more biotech crops, varieties, and traits in food production. This puts the country at a disadvantage, especially with the global trade competition of these products.

Summary and Future Prospects

Biotech soybeans and biotech maize were planted at a lower rate in Uruguay in 2017 at 1.14 million hectares compared to 1.29 million hectares in 2016 due to the reduction of total soybean and maize area in the country. These biotech crops have been planted since 2000 and contributed to the increase in GDP, provided enormous jobs and contributed to the improvement of the Uruguayan economy. The reduction in area of these biotech crops was due to unfavorable weather conditions and specific local and international trade issues. In addition, the phytosanitary protocol agreement with China led to uncertainty in the soybean sector. For maize, the high cost of production, and lower price of the produce due to the appreciation of the local currency made the price of maize not competitive with the ample maize crops in the region. Possible area expansion of these crops may come with the demand for feeds of the livestock and poultry sectors and the opening of new export markets for beef. Canola is being regarded as a bioethanol feedstock and with the herbicide resistance technology in soybeans by farmers since 2000, adoption of HT canola will revolutionize and boost biotech crop adoption in Uruguay.

MEXICO

Mexico has been planting biotech crops (cotton and soybean) since 1996 and is one of the six pioneer biotech planting countries. In 2017, biotech cotton was the only crop planted in the country at 110,000 hectares by some 8,000 farmers, all of which was biotech, compared to 2016, when Mexico planted 101,000 hectares of biotech crops (97,000 hectares of biotech cotton and 4,000 hectares of biotech soybeans). Biotech soybean planting was suspended in the country following a court injunction. At the same time, a court injunction against biotech maize field trials continues to affect producers and the scientific community.

Since 1996, Mexico has approved 170 events for food, feed and cultivation: alfalfa (5), Argentine canola (13), cotton (31), maize (75), potato (13), rice (1), soybeans (26), sugar beets (1), and tomato (5). In 2017, Mexico approved the following biotech events for food approvals: five maize events (IR stacked -Bt 11 x MIR163, and IR/HT stacks - Bt11 x MIR162 x MON89034 x GA21, Bt11 x TC1507 GA21, MON89034 x TC1507 x NK603 x MIR162, and MON87427 MON89034 x MIR162 x MON87411) and two soybean events (glufosinate/dicamba tolerant MON87708 x MON89789 x A5547-127 and modified oil/dicamba tolerant MON87705 x MON87708 x MON89788).

Biotech cotton was planted on 110,018.54 hectares comprised of 3,681.04 hectares HT (3%) and 106,337.5 hectares stacked IR/HT (97%). The increase in biotech cotton area was 13% from 97,000 hectares in 2016 to 110,000 hectares in 2017 (Table 22). This increase was expected because of the return to cotton planting after a year of crop rotation with other feed crops such as sorghum and maize. Cotton is being planted in Baja California, Chihuahua, Coahuila, Durango, Sonora, and Tamaulipas in Mexico in two seasons: spring (April to July and harvested in August to January) and fall-winter (planted from November to January, and harvested mainly in April and May). Most of the cotton-growing areas have adopted the use of biotech seed varieties and high density planting, however, the difference in production levels can be explained on how the technology is used.

Expansion of the cotton area may come with the increasing domestic consumption of cotton in the coming years, estimated at 1.82 million bales. In addition, the government supports programs to increase domestic use of cotton produce. Hence, with the implementation of various government support programs

Table 22. Total and Trait Hectares of Biotech Cotton in Mexico, 2016-2017

	Area Planted (MHa)		% Trait Hectares	
	2016	**2017**	**2016**	**2017**
Total Cotton	0.099	0.110		
HT	0.004	0.004	4.1%	3.3%
IR/HT	0.093	0.106	95.9%	96.7%
Total Biotech Cotton	**0.097**	**0.110**	**98%***	**100%***

* Adoption rate

Source: ISAAA, 2017

and other measures taken by the Mexican government, the Mexican textile and clothing industries grew nearly 6% in the past year, 3% by 2016, and is expected to expand in the coming years, according to the national Chamber of Textile industry and the National Chamber of the Clothing Industry (CANAIVE) (USDA FAS GAIN Report, Agricultural Biotechnology Annual-Mexico, 2017).

Currently, there are pre-commercial evaluation trials for cotton events: Bollgard III x Dicamba/ Glufosinate tolerant (DGT) cotton x Roundup Ready Flex® (RRF) at 107.2 hectares and DGT x RRF at 39.66 hectares.

The planting of biotech soybeans in Mexico was stalled in 2017 due to the complaint of the Yucatan tribe on the probable presence of pollen from biotech crops in their produced honey that will be exported to the EU. The state of Yucatan exports over 90% of its honey production to Europe. In 2012, honey producers initiated eight court injunctions against the permits and filed a complaint with the National Commission on Human Rights (NCHR). In 2015, the Mexican Supreme Court and the NCHR established that there is no evidence of any damage to the trade of honey, the environment or health, but recommended a consultative process with the indigenous communities before continuing with the permit for commercial production. The Inter-secretarial Commission on Biosafety of Genetically Modified Organisms (CIBIOGEM) and the National Commission for the Development of Indigenous Peoples (CDI) coordinated the transparent consultations. Some communities expedited the process and were willing to accept the use of biotech soybean, but others were not as agreeable (USDA FAS GAIN Oilseeds and Products-Mexico, 2017).

Mexico has a large deficit of maize for animal feed and starch industry and imports largely from the USA, Brazil, and Argentina, which are global leaders in the production of biotech yellow maize. Maize imports for 2018 are estimated to be substantially higher than the historical import average of the last few years. This can be attributed to continued high demand for feed by poultry and livestock sectors. The hope of farmers and 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 new challenges, such as more frequent and severe droughts associated with climate change.

Benefits from Biotech Cotton and Soybeans

Mexico is estimated to have enhanced farm income from biotech cotton and biotech soybeans planted from 1996 to 2016 of US$553 million and the benefits for 2016 alone is estimated at US$62 million (Brookes and Barfoot, 2018, Forthcoming). Some 8,000 farmers and their families are benefiting from economic gains derived from these biotech crops.

In summary, Mexico, being one of the pioneer biotech crop planting countries, has been steadfast in ensuring that Mexican farmers are provided with new seed technologies to increase production and improve the country's economy. Mexico has been developing agricultural biotechnology products with its strong team of scientists, which can make the country gain more opportunities to enter into sustainable agriculture. It has also established its regulatory system to assess the safety and benefits of biotech products. However, there are negative propaganda and cultural prejudices that opponents use to confuse the public about the technology. These influence the ongoing delays in the release of permits, such as the injunctions that have suspended the planting of biotech maize and soybean, for example. This is an ongoing situation where farmers are not allowed to plant these products while importing large amounts from neighboring countries that produce the same biotech products. Only biotech cotton was allowed to be planted in the country, which increased by 13% in 2017. The increase in planted area for cotton was expected because of the return to cotton planting after a year of crop rotation with other feed crops such as sorghum and maize. Possible expansion of the cotton area may be in the offing with the increasing local and domestic demand for cotton, as well as the high global prices.

COLOMBIA

Colombia started planting biotech cotton in 2002 and biotech maize in 2007. Since then, the biotech maize area surpassed biotech cotton area. In 2017, biotech maize was planted on 86,000 hectares and biotech cotton on 9,000 hectares for a total of 95,000 hectares, a 7% increase from 89,000 hectares in 2016. Small areas of blue carnation and blue roses were planted under controlled greenhouse conditions since 2000 for export to Japan.

Since 2002, 94 biotech events were approved for food, feed, and cultivation in Colombia: carnation (8), cotton (14), flax (1), maize (49), rice (2), rose (2), soybean (16), sugar beets (1) and wheat (1). In 2017, six biotech events were approved for food, including: three biotech maize events (stacked IR/HT MON87427 x MON89034 x MIR162 x NK603 and Bt11 x MIR162; and stacked IR/HT with high amylose content Event 3272 x Bt 11 x MIR604 x TC1507 x Event 5307 x GA21) and three biotech soybean events (IR MON87751, HT and modified oil DP305423, and stacked HT SYHT0H2). It is noteworthy that these newly approved biotech events were mostly stacked traits with improvement in product quality for livestock and human consumption.

Biotech maize area increased by 15%

A total of 86,000 hectares of biotech maize were planted in 2017, an increase of 15% from 73,000 hectares in 2016. Biotech IR maize was planted on 12,000 hectares (14%) and 74,000 hectares (86%) stacked IR/HT, for a total of 86,000 hectares (Table 23). The total area of maize remains at 375,000 hectares with yellow and white maize being planted interchangeably depending on the local demand and prices. The rate of adoption of biotech maize is at 23%, which is the highest rate achieved so far. The increased biotech area was due to favorable weather conditions as well as substitution of maize in areas intended for sorghum planting (USDA FAS GAIN Report, Agricultural Biotechnology Annual-Colombia, 2017).

Biotech cotton adoption rate increased to 91%

Biotech cotton area decreased in 2017 to 9,000 hectares from 16,000 hectares in 2016. The 9,000 hectares biotech cotton was comprised of 544.5 hectares HT and 8,530.5 hectares stacked IR/HT (Table 24). The reduction in biotech cotton area was due to the decrease in total cotton planted area from 18,000 hectares in 2016 to 10,000 hectares in 2017, which was affected by low domestic cotton demand and low price of cotton in the region. The adoption rate of biotech cotton increased by 1% from 89% in 2016 to 91% in 2017 (USDA FAS GAIN Agricultural Biotechnology Annual-Colombia, 2017).

Benefits from Biotech Maize and Cotton

Colombia is estimated to have enhanced farm income from biotech crops of US$182 million in the period 2002 to 2016 and the benefits for 2016 alone is estimated at US$29 million (Brookes and Barfoot, 2018, Forthcoming). Some 80,000 farmers and their families in Colombia have been benefiting from biotech

Table 23. Total and Trait Hectares of Biotech Maize in Colombia, 2017

	Area Planted (MHa)		% Trait Hectares	
	2016	**2017**	**2016**	**2017**
Total Maize	0.375	0.375		
HT	0.010	0.012	14%	14%
IR/HT	0.063	0.074	86%	86%
Total Biotech Maize	**0.073**	**0.086**	**19%***	**23%***

* Adoption rate

Source: ISAAA, 2017

Table 24. Total and Trait Hectares of Biotech Cotton, 2017

	Area Planted (MHa)		% Trait Hectares	
	2016	**2017**	**2016**	**2017**
Total Cotton	0.018	0.010		
HT	0.001	0.001	5%	6%
IR/HT	0.015	0.009	95%	94%
Total Biotech Cotton	**0.016**	**0.009**	**89%***	**91%***

* Adoption rate

Source: ISAAA, 2017

crops in the last 14 years of commercialization, improving their economic conditions and social status.

A similar study carried out in Colombia from 2003 to 2015 by the Brazilian agro-consultant Celeres for the Agricultural Plant Biotechnology Association (Agro-Bio), found that biotechnology is an invaluable tool to achieve greater productivity, capable of contributing to better agricultural practices, which reduce pressure on natural resources and the environment. The environmental benefits through biotech come from millions of gallons of water saved, the savings in fossil fuel use, and reduction of CO2 emission. From 2002 to 2015, there was a reduction of 55.1 million gallons (208.6 million liters) of water, where 56.9% of the reduction was due to planting biotech cotton and 43.1% from planting biotech maize. If and when Colombia becomes self-sufficient in maize, cotton, and soybeans through biotechnology, the total water savings over a 10-year period is estimated at 600 million gallons (2.3 billion liters) of water, enough to supply 57,700 people in the indicated period. Since there will be less application of agricultural pesticides (insecticide and herbicides) some 820,000 gallons (3.1 million liters) of diesel were saved from 2003 to 2015, equivalent to taking out 1,290 vehicles for 12 years and reducing carbon emission by as much as 8,200 tons, equivalent to preserving 60,600 trees.

The total economic benefits achieved from 2003 to 2016 were US$237 million, 68% or US$171 million of which accrue to rural producers. The US$171 million farmer benefits come from US$138.5 million increased productivity and US$22.8 million reduced production costs. The seed industry on the other hand only receives US$75 million or 32% of the accumulated economic benefits during the period.

On the farmer level, biotech cotton farmers obtained a 55% increase in operating margin while biotech maize farmers obtained a 35% increase compared to non-biotech farmers. Some 77% of Colombian farmers also attested that it is worth paying more for biotech seeds because of the final increase in crop productivity and the added value of biotech seeds. If in case Colombia becomes self-sufficient in cotton, maize, and soybeans through biotech crops, the economic benefit from the adoption of biotech crops will reach US$1.05 billion (Genetic Literacy Project, July 20, 2017).

In summary, Colombia in its current quest to obtain political and economic stability is making strides within the agricultural sector. Although the majority (92%) of Colombia's farmland is still used as permanent pastures, 4% of agricultural land is used for growing coffee, maize, rice, sugarcane, and bananas. However, farmers adopted biotech crops early on with cotton and maize and have gained both directly and indirectly the economic and environmental benefits of biotech crops. In 2017, the 7% increase in biotech crop area primarily from maize and the increased adoption rate of biotech crops were a manifestation of how farmers recognize the potential of the technology to generate benefits throughout the value chains of cotton and maize. In addition, Colombia will most likely embark into the use of sugarcane in biofuel production. In late 2016, the Ministry of Mines and Energy (MME) lifted all restrictions on fuel ethanol imports by May 2017, as long as the biofuel complies with quality and carbon footprint standards that will allow Colombia to achieve its climate change commitments. In 2016, imports of maize-derived ethanol from the USA reached a record 30.8 million liters, well above the full year record of 18.6 million liters in 2016, a manifestation of the increasing need of the country for ethanol (USDA FAS GAIN Agricultural Biotechnology Annual-Colombia, 2017). This will open doors for the possible adoption of biotech sugarcane, the preferred ethanol raw material in Colombia in the very near future.

To support the interest of farmers, consumers, and the industry, the government will need to continue to provide agricultural biotechnology with favorable institutional and regulatory conditions for the investment and R&D of new technologies tailored for Colombia. It is expected that adoption of biotech maize and cotton will continuously increase in the future with the local demand for feed and fiber stocks.

HONDURAS

Biotech maize is the only biotech crop commercialized in Honduras since 2002. In 2017, 32,000 hectares of biotech maize were planted at 3% higher than 31,000 in 2016. The biotech maize area was composed of 2,733 hectares HT and 29,293 hectares stacked IR/HT. In 2016, IR (Bt) was planted in Honduras but not in 2017. Instead, the area planted to HT maize increased from 1,000 hectares in 2016 to 3,000 hectares in 2017. Similarly, the stacked trait IR/HT maize increased from 28,000 hectares in 2016 to 29,000 hectares in 2017 (Table 25).

Since 2002, Honduras approved eight biotech events for food, feed consumption, and environmental release for maize (7 events) and rice (1 event). There was no recorded biotech crop approval in 2017.

The 42% increase in total maize area in 2017 was due to farmers decision to compensate for the decreased area and yield losses in 2014 and early 2016 because of drought episodes. However in 2017, El Niño forecasts for the first and second season planting in some maize producing areas of the north and in the Gulf of Fonseca prompted farmers to reduce adoption rate of biotech maize from 100% to 73%. The commercial cultivation of biotech crops is for food/feed consumption and seed production. Honduras' production of biotech maize seeds is sold within the domestic market for agro-industry and is exported to Colombia (USDA FAS GAIN Report, Agricultural Biotechnology Annual-Honduras, 2017).

Increase in biotech maize area can be influenced by the strong demand from the feed sector as manifested by the high level of maize imports which remain above the five-year average. Honduras imports biotech maize seeds, which is distributed within the domestic market for agro-industry to supply its poultry, livestock, shrimp, and tilapia industries. In 2016, Honduras imported biotech yellow maize valued

Table 25. Total and Trait Hectares of Biotech Maize in Honduras, 2016-2017

	Area Planted (MHa)		% Trait Hectares	
	2016	**2017**	**2016**	**2017**
Total Maize	0.031	0.044		
IR	0.002	0	6%	
HT	0.001	0.003	3%	9%
IR/HT	0.028	0.029	90%	91%
Total Biotech Maize	**0.031**	**0.032**	**100%***	**73%***

* Adoption rate

Source: ISAAA, 2017

at US$106 million and soybean meal worth US$87.6 million from the USA. These large imports can be reduced or totally eliminated if the country will expand biotech maize area and adopt biotech soybean.

Benefits from Biotech Maize

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 countries particularly those in the Central American region. It is estimated that Honduras has enhanced farm income from biotech maize of US$11.5 million from 2002 to 2016 and US$1.1 million in 2016 alone (Brookes and Barfoot, 2018, Forthcoming), benefiting some 7,000 farmers and their families.

In summary, Honduras is the only country in Central America, and one of seven countries in Latin America, that allows the commercial cultivation of GE crops. Since September 2017, the Honduras National Service of Food Safety, Animal and Plant Health (SENASA) oversee the functions of the National Committee of Biotechnology and Biosecurity (NCBB), from the Environmental Ministry. This is hoped to expedite monitoring and approvals of new biotech crops and traits. Biotech maize is planted in Honduras since 2002, but the area planted needs expansion with the increasing demand for food/feed consumption and seed production. Adoption of biotech soybeans in the future may also be an excellent option to reduce soybean imports for domestic consumption.

CHILE

Biotech crops in Chile has been planted under strict field conditions for export since 1996. In 2017, a total of 13,143 hectares were planted in the country, 23% higher than 2016's biotech crop area of 10,667 hectares. The biotech crops planted in 2017 were comprised of 7,634 hectares IR/HT maize (58.1%), 4,051 hectares canola (30.8%), and 1,458 hectares HT soybeans (11.1%). For this year, weather conditions, productivity and stocks at the Northern hemisphere, which are the export markets of biotech seeds, caused a decrease in the sown area.

Chile maintains its fifth position as the largest global producer/exporter of biotech and non-biotech seeds, and the USA is the largest market for biotech seeds. Growing of biotech seeds had been under the guidance of a biotechnology framework and strict regulations of the Livestock and Agricultural Service of the Ministry of Agriculture and risk assessment from the Ministry of Environment. The Ministry of Health, on the other hand, registers food products that contain biotech ingredients and requires a label that the biotech component is substantially different from its conventional counterpart. Therefore, since there is no commercial biotech crop production, Chile does not require biotech products to be labeled.

Interest groups have been lobbying for government approval to allow farmers to plant biotech crops. Currently, planting is prohibited and farmers will be fined. A bill that would allow farmers to plant biotech seeds was submitted to the Congress 10 years ago, but nothing has been done about it. This weighs heavily on the farmers and consumers since Chilean imports of maize and food ingredients have been increasing. Maize imports went up by 13.3% in 2016 over 2015. Furthermore, Chile has imported agricultural and other food products and ingredients at a cost of US$13 million in 2017, the highest recorded so far.

Maize production has not been profitable in the country with the use of conventional seeds as current prices barely cover production costs because the price of seeds and chemical products increased since 2015. Consequently, the area planted to maize decreased to 90,000 hectares in 2017 and market conditions are very competitive. This will further increase maize imports, which are used for animal feed, and the case may be true for soybean and canola (USDA FAS GAIN Grain and Feed Annual-Chile, 2017). It is thus imperative that commercial planting of biotech maize, soybean, and canola could contribute economically and agriculturally in Chile with the proven contributions of biotech crops for increasing yield and farmers' profits and decreasing production costs in the midst climate change.

Chile has varied biotech research and development of plants, trees, and animals, including grapes, stone fruit, apples, pine tree, and salmon. Government research funding for these projects comes from copper mining royalties. In addition, public sector funding of research and development include the consortia on fruit plants through Biofrutales and in the forestry sector such as the Genomica Forestal. Since 2009, research collaborations with different universities in the USA, Australia, and Canada have improved research capacities of local Chilean educational and research institutions.

COSTA RICA

Similar to Chile, Costa Rica has been planting biotech crops for export since 1996. In 2017, approximately 250 hectares of biotech IR/HT cotton (91%) and 25 hectares of pink pineapple (9%) with high anthocyanin were planted for a total of 275 hectares, an increase of 22% from 226 hectares in 2016. Biotech soybeans planted in 2016 was not planted in 2017. Since 1996, 21 biotech events have been approved for seed production in the country including 19 cotton events, 2 soybean events, and 1 pineapple event. Six stacked IR/HT cotton events were approved for seed export production in 2017, which could increase cottonseed production area in 2018. Moreover, companies involved in biotech seed production in Costa Rica are influenced by the demand of these products in the USA.

Although Costa Rica has implemented legislation to regulate the import and cultivation of biotech crops, no planting has ever been conducted in the country. In addition, no requirement that foods containing biotech components needs to be labeled. Procedures to obtain permission from the Costa Rican government to plant biotech varieties for human and animal consumption did not represent an obstacle in the past. However, the process to register new products was halted in 2013 due to a court case involving a multinational seed company. It is noteworthy that the National Biosafety Commission, the government agency that reviews and approves the entry of biotech crops as food, feed, or for cultivation has started to meet regularly since October 2016 – this could be an indication that the government is considering cultivation in the very near future (USDA FAS GAIN Report Agricultural Biotechnology Annual, Costa Rica, 2017).

Costa Rica has been importing biotech maize and soybeans in large quantities to provide food and feed for the animal industry, and a small volume of cotton for processing. Imports of these biotech products come from biotech planting countries such as the USA, Brazil, and Argentina. For example, the country's maize production of 10,000 tons in 2017 – 11% higher than the previous year – was still not sufficient to provide for domestic demand for maize feed. Furthermore, with the effect of drought in 2017, it may be imperative that adoption of biotech maize and soybean in Costa Rica could contribute to the reduction of imports of both crops and make farming profitable in the country.

A move to eliminate restriction on biotech crops was proposed by the agricultural chambers in the region in 2015. Representatives from the Central Federation of Agricultural Chambers (FECAGRO) unanimously supported the use of agricultural biotechnology. The representatives, in a meeting held in 2015 prepared law proposals to be presented in the Central American regions to remove restrictions on growing biotech crops. The group supports the use of agricultural biotechnology to enable farmers to benefit from high productivity seeds that reduce agrochemical use, create more drought resistant crops, tolerant to salt water, and are completely safe for human consumption. (Central America Data, 2015). As of this writing, there has not been any information about this move.

Biotech researches conducted by Costa Rican scientists include the development of herbicide tolerant rice and bananas with resistance to black Sigatoka. Some of the products are already in the field trial stage, approved under biosafety regulations which conform to international standards, and are likely to be commercialized in the future.

Future Prospects For Latin America

Ten countries in Latin America planted biotech crops in 2017 including Brazil (50.2 million hectares), Argentina (23.6 million hectares), Paraguay (2.96 million hectares), Uruguay (1.14 million hectares), Bolivia (1.3 million hectares), Mexico (110,000 hectares), Colombia (95,000 hectares), Honduras (32,000 hectares), Chile (13,000 hectares) and Costa Rica (275 hectares) for a total of 79.4 million hectares, which is 42% of the global biotech area of 189.8 million hectares. In 2016, a total area of 79.6 million hectares biotech crops were planted in Latin America which declined marginally in 2017 by 110,000 hectares to 79.4 million hectares. The decline in biotech crop area occurred in Paraguay (-16%), Uruguay (-13%), Argentina (-3%), and Bolivia (-1%) due to water stresses (drought and flooding), low prices of specific commodities, and local and international trade issues. Large percentage increases in biotech crop area were recorded in Chile (23%), Costa Rica (22%), Mexico (13%), Colombia (7%), Honduras (3%), and Brazil (2%). Increases in biotech crop areas in these countries were due to profitability, higher prices, high market demand both domestically and internationally, and presence of available seed technologies in the country. Future expansion of the major biotech crops soybeans, maize, and cotton may come with the increasing domestic and global demand for protein in food, animal feeds and biofuel production (biodiesel from soybeans and ethanol from maize), and raw cotton materials. New biotech crops which can be adopted by particular countries in the future are maize and sugarcane for Bolivia, maize and resumption of soybean planting in Mexico, and soybeans for Honduras. As the leader of biotech crop adoption in Latin America, Brazil hosted the 34th Regular Meeting of the Southern Agricultural Council in Sao Paulo on August 29, 2017. The Brazilian Agriculture Minister together with counterparts from Argentina, Bolivia, Chile, Paraguay, and Uruguay signed a joint statement with three points, one of which was the adoption of new technologies for improving and accessing GM products to third markets. The third point referred to new technologies for improvement and access of biotech crops to third markets through intensification of information exchange in the approval of biotech products, reduction of asynchronous approval in the region, and promotion of biotech events in the third market that are of regional interest. In addition, the six countries emphasized the need to urge the European Union and China, which are big importers of biotech products from Latin American countries to stop delaying GMO import authorization.

Finally, over half a million biotech farmers in the developing countries of Latin America have been benefiting immensely in the last 21 years of biotech crop commercialization. Economic benefits estimated by Brookes and Barfoot (2018, Forthcoming) from respective country start year of planting until 2016 is over US$46.9 billion, and US$6.5 billion is for 2016 alone. These are enormous benefits that can only be derived from biotech crops, and non-adoption of biotech crops in these countries will result to huge opportunity cost that will escalate poverty, hunger, malnutrition, and political instability.

ASIA AND THE PACIFIC

There were eight countries in Asia and the Pacific that planted and consumed biotech crops in 2017. Three of them: India, Pakistan, and China planted more than 1 million hectares of biotech cotton and belong to the top 10 countries. The five countries which planted less than 1 million hectares in descending order were Australia (biotech cotton and canola), Philippines (biotech maize), Myanmar (biotech cotton), Vietnam (biotech maize), and Bangladesh (biotech eggplant). Details on the biotech crops planted, adoption trends, country situations and future prospects for the country and the region are discussed below.

AUSTRALIA

Australia was one of the first six countries that commercialized biotech crops in 1996. In 2017, Australia ranked 12th in the list of biotech crop planting countries with 924,000 hectares, 8% higher than 852,000 hectares in 2016. The biotech crop area was comprised of 432,000 hectares biotech cotton (47%) and 492,000 hectares biotech canola (53%) for a total of 924,000 hectares. The total area planted to these two crops increased by 8% from 2.37 million hectares in 2016 to 2.54 million hectares in 2017.

Since 1996, Australia has approved 129 biotech events for food, feed, and cultivation, including: alfalfa (3), Argentine canola (22), carnation (12), cotton (26), maize (27), potato (17), rice (1), rose (1), soybeans (17), sugar beets (2), and wheat (1). In 2017, eight biotech crops were approved for food in Australia, including one stacked canola event MS11 with HT/male sterility/fertility restoration gene,and four potato events: J3, E56, E12, and F10 with generation 1 traits (reduced acrylamide potential and reduced black spot bruising tolerance, and three potato events: W8, X17, and Y9, with generation 1 traits plus late blight resistance.

Biotech canola area increased by 10%

Australia has planted biotech canola since 1996, and in 2017, there were 491,528 hectares grown to biotech canola, indicating a 10% increase from 446,226 hectares planted in 2016. Biotech canola was planted in New South Wales on 68,163 hectares, Victoria with 56,900 hectares, and in Western Australia with 366,466 hectares, for a total of 491,528 hectares. The adoption rate of biotech cotton was 24% of the total 2,080,000 hectares planted to canola in the three states, compared to 21% adoption rate in 2016. The total canola area (biotech and non-biotech) decreased by 5% from 2,125,000 hectares in 2016 to 2,080,000 hectares in 2017 (Table 26).

The reduction in canola area was due to unfavorable weather conditions during the canola planting season. Areas sown with canola in Western Australia failed to germinate and were eventually substituted with cereal crops. In addition, there was a temporary problem with the availability of hybrid biotech canola seeds, which could have increased adoption up to 34%. More canola farmers are shifting to biotech

Table 26. Area of Biotech Canola Planted in Three States in Australia, 2017

State	Hectares		% of Total Canola per State	
	2016	2017	2016	2017
New South Wales	54,970	68,163	10	10
Victoria	47,069	56,900	13	13
Western Australia	344,188	366,466	28	28
Total Biotech Canola Area	446,226	491,528	21	24
Total Canola Area	**2,125,000**	**2,080,000**	**21%***	**24%***

* Adoption rate

Source: Agricultural Biotechnology Council of Australia

canola because of the proven benefits on yield, profit, and production cost (The Weekly Times, July 11, 2017). A biotech canola event with high omega-3 oils is being tested in Australia from 2017 to 2022. The biotech event was developed by Nuseed, a private company, and the Commonwealth Scientific and Industrial Research Organization (CSIRO). The biotech canola will not enter the human food or animal feed supply, but some biotech material may be used for small-scale experimental feeding studies. Once approved, this biotech canola will make omega-3 oils more accessible and affordable, and competitive in the global market (Australian Department of Health – Office of the Gene Technology Regulator, 2017).

Biotech cotton area increased by 6.7% and adoption rate to 100%

Biotech cotton has been grown in Australia since 1996, and in 2017, 432,000 hectares were planted with biotech cotton, comprised of 16,416 hectares HT, 415,584 hectares IR/HT for a total of 432,000 hectares. The adoption rate of biotech cotton increased to 100% in 2017, as compared to the adoption rate in 2016. The area planted to biotech cotton increased by 6.7% in 2017 compared to 405,000 hectares in 2016. The total area planted to cotton also increased by 4.6% to reach 432,000 hectares in 2017 from 413,000 hectares in 2016 (Table 27).

Cotton production in 2017 was still low considering the available land throughout the country, coupled with some degree of regional variability in cotton area planted. In Western Australia, the presence of favorable growing conditions boosted cotton production across the regions. In northern and central east cropping regions, there were crop failures due to drought at the start of spring, but favorable conditions prevailed towards the end of the season producing good harvest.

In addition, the observed increase in biotech cotton area of 6.7% was partly due to the increase in the number of farmers that signed to grow the biotech crop. A 30% increase in the number of farmers was estimated in NSW Riverina, and in Murrumbidgee, Lachlan, and Murray Valleys, 50-60 new cotton growers signed. The industry reported that a total of 57 new growers planted biotech cotton in these areas. Some 80% of these growers made future contracts, indicating their confidence in the technology. The farmers'

Table 27. Total and Trait Hectares of Biotech Cotton in Australia, 2016-2017

	Area Planted (MHa)		% Trait Hectares	
	2016	**2017**	**2016**	**2017**
Total Cotton	0.413	0.432		
HT	0.012	0.016	3.1%	3.8%
IR/HT	0.392	0.416	96.9%	96.2%
Total Biotech Cotton	**0.405**	**0.432**	**98.0%***	**100.0%***

* Adoption rate

Source: ISAAA, 2017

choice for 2017 planting season was to grow cotton based on returns per megaliter of water, good marketing option, and better varieties for the cooler southern region (The Weekly Times, August 13, 2017). Currently, farmers are able to produce one ton of cotton lint in 33% less land compared to 10 years ago, according to Cotton Australia. In addition, the Australian cotton industry has achieved a 40% increase in water productivity since 2003 (Primacy, 2018).

Benefits from biotech canola and cotton

Australia is estimated to have enhanced farm income, benefiting some 250 farmers in the period 1996 to 2016 by as much as US$1.16 billion and the benefits for 2016 alone is estimated at US$73 million (Brookes and Barfoot, 2018, Forthcoming).

A review by Brookes and Barfoot (2016) on ***GM crops: global socio-economic and environmental impacts 1996-2015***" reported that cotton farmers had a net farm income of more than US$55.8 million in 2015, and cumulatively since 1996, the gains have been US$949 million. For canola farmers, biotech canola in 2015 had an average net increase in gross margins of US$38 per hectare, which is a national gain of nearly US$17 million in farm income.

Country Situationer

Australia has grown biotech cotton since 1996 and biotech canola since 2008 in New South Wales and Victoria, and in Western Australia since 2010. The government supports use of modern biotechnology through its enabling regulatory machinery and assesses genetic traits on a case by case basis through the Office of Gene Technology Regulator (OGTR, Food Standards Australia New Zealand (FSANZ), and the Australian Pesticides and Veterinary Medicines Authority (APVMA). In 2017, CSIRO released the *Food and Agribusiness Roadmap*, which shows detailed action plans for new products and innovation to ensure future success in the sector. The new technologies include algae-based protein, allergenic-free nuts, tolerable varieties of lactose and gluten, and edible packaging to reduce environmental impact. The Roadmap centers on the themes of keeping a greater share of food processing onshore and better differentiating Australian food product (Crop Biotech Update, July 19, 2017).

In 2017, Australia's OGTR approved field trials of biotech wheat and barley, which have abiotic tolerance and yield enhancement traits, biotech potato with improved agronomic trait and resistance to potato virus X, biotech bananas with resistance to Panama Tropical Race 4 (TR4), and biotech safflower with about 92% oleic acid, to name a few. Genetic improvement of various crops is continuously being conducted, including golden bananas enriched with beta carotene. Initial field tests were conducted with Cavendish bananas in Queensland, Australia and on highland and East African cooking banana variety, in collaboration with Uganda National Agricultural Research Organization.

Summary and Future Prospects

Over the years, yield gains in biotech cotton and canola in Australia were attributed to plant breeding and use of modern seed technology with continued farmer compliance with the recommended technology management procedures. Biotech cotton, canola, and carnation varieties are still the only agricultural crops approved for commercial release in Australia. Biotech cotton and canola area in 2017 soared to 924,000 hectares, 8% higher than 2016. In 2006, biotech carnation events became the first biotech product to be assessed by the OGTR and found to pose minimal risks to people or the environment, and are sufficiently safe. It had been placed on the GMO Register to be used by anyone without the need for a license. Since the lifting of a moratorium on biotech crop planting in New South Wales, Victoria, and Western Australia in 2007, planting of biotech canola has increased rapidly. In 2017, biotech canola was planted on 491,528 hectares, showing a 10% increase from 446,226 hectares planted in 2016. Future adoption of biotech canola which was at 24% in 2017 is possible as more farmers see the benefits of the technology, as well as the increasing demand of canola oil in the global market. Adoption of biotech cotton in Australia was close to 99%, but the area planted varies depending on the weather conditions. It is noteworthy that in 2016, there was an increase of 89% in the area planted to biotech cotton compared to 2015, while in 2017, an increase of 6.7% was achieved. Furthermore, the introduction of Bollgard III® and its stack with Roundup Ready Flex® in 2015, considerably influenced biotech cotton planting without the unfavorable weather conditions.

The government is continually improving its regulation, and in 2017, the Australian Productivity Commission completed an inquiry into the regulatory burden on farm businesses focusing on regulations that have a material impact on the competitiveness and productivity of Australian agriculture, including the impact of GE regulations. Technical reviews of the Gene Technology Regulations 2001 and the relevant Standard of the Food Standards Code were also conducted to provide clarity regarding regulatory capture of new technologies.

Biotech maize and soybeans have not received approval for cultivation in the country. Conventional maize is planted around 70,000 hectares all over Australia from North Queensland, down to Victoria and Tasmania, and across to the Northern Territory and the southern regions of Western Australia. Maize is used as a component of feedstock for cattle as a finisher. With stiff competition for beef from the USA, Brazil, and Uruguay, the cattle industry in Australia has slowed down. This is due to a shortage of pasture during dry season and the cost of maize and other grains for cattle fattening/finishing (USDA FAS GAIN Livestock and Products-Australia, 2017). Thus, the cultivation of biotech maize in Australia could revive or boost the country's cattle industry.

Another important crop is soybeans, planted all over Australia from the northern Queensland to the inland cropping regions of southern New South Wales and Victoria. Soybeans grow in irrigated areas and where there are adequate levels of summer rainfall. It is an important part of Australia's US$2.5 billion oilseed industry. Australia's reliance on imported soybean meal has been increasing, reaching 730,000 tons in 2014-2015 and expected to increase further as the poultry and pig industries continue to expand. Although canola meal production has been increasing, the inability of Australia to supply protein sources to replace imported soybean meal continues to be a limitation to the supply chain. Growing and processing soybean in Australia would be a welcome respite to this problem (USDA FAS GAIN Livestock and Products-Australia, 2017).

Lastly, in Australia, farmers are given access and opportunity of growing biotech crops to a certain extent, full support of the government to access other biotech crops would enable farmers to grow more on less land, increase crop yields, contribute to international competitiveness, and reduce agriculture's environmental impact.

PHILIPPINES

Biotech maize commercialization in the Philippines started in 2003, following the strict regulations set by the Department of Agriculture for biotech cultivation approved and signed in 2002. Through this, the Philippines became the first country to plant a biotech crop in Southeast Asia, and has become a model for science-based and thorough regulatory policy in the region. The Philippines ranked 13th in biotech crop commercialization in 2017, with 642,000 hectares planted to biotech maize, indicating a decline of 21% from 812,000 hectares in 2016. This area was comprised of 35,000 hectares HT (5.5%) and 607,000 hectares IR/HT (94.5%) (Table 28). The increase in percentage stacked traits was phenomenal from 83.6% in 2016 to 94.5% in 2017, proving that the more than 470,500 Filipino biotech maize farmers know the value and potential of stacked traits in obtaining significant profits.

Since 2002, there were 88 events approved for food, feed, and processing for the following crops: alfalfa (2), Argentine canola (2), cotton (8), maize (52), potato (8), rice (1), soybeans (14), and sugar beets (1). Since the Philippine Supreme Court ruled in December 2015 that the Administrative Order no. 8 (DA-AO8) is invalid, no new approval has been granted by the Department of Agriculture Bureau of Plant Industry (DA-BPI) for cultivation.

Total maize area increased by 10% from 1.25 million hectares in 2016 to 1.38 million hectares in 2017, due to favorable weather conditions for growing maize. However, biotech maize area and adoption rate (based on actual seed sales and farm surveys) decreased (Table 28) because according to industry analysts, there was a proliferation of counterfeit biotech maize

Table 28. Total and Trait Hectares of Biotech Maize in the Philippines, 2016-2017

	Area Planted (MHa)		% Trait Hectares	
	2016	**2017**	**2016**	**2017**
Total Maize	1.248	1.378		
HT	0.133	0.035	16.4%	5.5%
IR/HT	0.679	0.607	83.6%	94.5%
Total Biotech Maize	**0.812**	**0.642**	**65.1%***	**46.5%***

* Adoption rate

Source: ISAAA, 2017

seeds. In a press briefing, Monsanto Philippines representative said that the presence of counterfeit seeds account for close to 10% of market share of biotech maize. The Bureau of Plant Industry has already published the seven companies engaged in counterfeit seed production, which have not undergone the rigorous process for technology approval of the DA-BPI, and neither have they invested into technology development. They also published the list of authorized biotech maize suppliers for farmers reference in seed procurement.

Counterfeit seeds in the Philippines include the so called *"ukay-ukay"*, where pilferage seeds from production areas were used to develop counterfeit seeds and sold at a cheaper price. This accounts for 6% of market share in Mindanao and 2% nationwide. The *"sige sige"* seeds on the other hand, are second generation or the offspring of F1 seeds which has reduced vigor and efficiency of the Bt maize technology. Thus, aside from the negative impact on seed developers, counterfeit seeds have serious and dangerous effects as they threaten effectivity and longevity of the technology. They also dangerously cheat farmers into buying cheap seeds that do not perform as excellently as the original seeds. Farmers still need to incur as much pesticides similar to non-biotech seeds, making maize farming unreasonably costly and unprofitable.

To this end, Bt maize developer Monsanto Company has developed a refuge system in a package of 8-10 kg seeds (35,000 seeds) that contains 5% non-Bt maize seeds, sufficient for one hectare planting. The seeds also go through tests of dryness (11% moisture), germination (at least 90%), and vigor (Manila Bulletin, February 2, 2018). This product doubly ensures that the purchased seeds are of high quality and has efficient and reliable IR trait that farmers can depend on to obtain high yield and clean produce.

Country Situationer

Regulation of biotech crops in the Philippines was challenged in 2012 when a lawsuit was filed to halt the commercialization of Bt eggplant. The case was elevated to the Supreme Court (SC), which ruled on December 8, 2015 that existing GE regulations as embodied in DA Administrative Order No. 8 (DA-AO 8) did not sufficiently cover the minimum requirements of the principles of risk assessment embodied in the National Biosafety Framework (NBF). The SC permanently enjoined the field testing of Bt eggplant (which had already been completed) and declared DA-AO 8 null and void. Hence, it halted the processing of applications for contained use, field testing, propagation and commercialization, as well as the importation of GE products. In 2016, a new regulation was drafted by scientists and a new set of regulators were installed on April 2016. A Joint Departmental Circular entitled *Rules and Regulations for the Research and Development, Handling and Use, Transboundary Movement, Release into the Environment, and Management of Genetically-Modified Plant and Plant Products Derived from the Use of Modern Biotechnology* will be implemented by five government departments: Agriculture, Environment and Natural Resources, Health, Interior and Local Government, and Science and Technology. The Department of Science and Technology (DOST) remains the lead agency for evaluation and monitoring of regulated articles (i.e., approved GE events) intended for contained use, while the Department of Agriculture (DA) continues to take the lead in the evaluation and monitoring of regulated articles. The DA, through the Bureau of Plant Industry (BPI) is still tasked to evaluate and issue all permits such as field trials, propagation, and direct use for food or feed. Food safety assessment is given to BPI-Plant Product Safety Services Division, while feed safety assessment was assigned to the Bureau of Animal Industry (BAI) in accordance with the Food Safety Act of 2013. As of October

17, 2017, there have been 39 applications for direct use, 2 for propagation, and one for field testing for processing (USDA FAS GAIN Agricultural Biotechnology Annual-Philippines, 2017).

Biotech Crops in the Pipeline

The fruit and shoot borer resistant Bt eggplant research is led by the Institute of Plant Breeding of the University of the Philippines Los Baños (IPB-UPLB), and was also a royalty-free technology donated by the Maharashtra Hybrid Seed Company (Mahyco) through a sublicense agreement. As discussed previously, on July 26, 2016, the Supreme Court unanimously reversed its December 2015 decision and granted all motions for reconsideration by Bt eggplant proponents and other interested parties. Since then, the Bt eggplant team has continued its collaboration with Cornell University through USAID's Feed the Future Biotechnology Partnership (FtFBP) project. In the past two years, the Philippine Bt eggplant team has published results from field trials which showed the high trait efficacy of the Bt technology with negative effect on non-target organisms. The team has also been collaborating with regulatory experts and Mahyco in preparing the regulatory package and IRM plan for submission according to the new set of regulatory guidelines under the Joint Department Circular Series 1 (2016). At the same time, farmers, extension workers, policy makers, and the general public are being prepared for the possible commercialization of Bt eggplant through various outreach and communication activities conducted in collaboration with SEARCA BIC, ISAAA, and other partners. These activities also became a venue for introducing the new set of regulatory guidelines as well as stressing the fact that Philippine biotech crops are scientifically regulated (Philippine Bt eggplant team, Personal Communication).

Golden Rice (GR) is a biotech rice biofortified with pro-vitamin A beta carotene that is being developed by the Philippine Rice Research Institute (PhilRice) and the International Rice Research Institute (IRRI), with support from the Bill and Melinda Gates Foundation. There is also support from the Rockefeller Foundation, USAID, and the Philippine Department of Agriculture's (DA) Biotechnology Program. The project aims to develop Golden Rice varieties suitable for farmers in the Philippines and partner countries, Indonesia and Bangladesh; help assess the biosafety of Golden Rice; evaluate whether consumption of Golden Rice improves vitamin A status; and explore how Golden Rice could reach those most in need.

Two seasons of confined field testing (CFT) of Golden Rice event GR2E for: 1) selection of breeding lines; and 2) grain production for compositional analysis and food, feed, processing (FFP) have been completed under the strict monitoring of the Department of Science and Technology-Biosafety Committee (DOST-BC), DA-Bureau of Plant Industry (BPI) and local Institutional Biosafety Committee (IBC). The CFTs were concluded in early 2016. The next step will be to forward a few of the best GR-PSB Rc 82 lines to a season of confined field trials in two sites in the Philippines once DA-BPI approves the application based on the new Joint Department Circular of 2016. The proponents have also filed an application at DA-BPI towards securing a Food, Feed, Processing (FFP) permit for direct use. FFP application was also sent to the US FDA, Health Canada, and Food Standards Australia New Zealand (FSANZ). So far, FSANZ already released a statement that there are no public health or safety concerns with Golden Rice. In 2018, the Golden Rice Project will be transitioning to the Healthier Rice Project to include high iron rice and high zinc traits. Golden Rice will be released first, followed by other micronutrient-enriched biotech rice with Iron and Zinc (PhilRice Golden Rice team, Personal Communication).

Biotech papaya with delayed ripening and papaya ringspot virus resistance is also being developed by IPB-UPLB, and had undergone contained test in 2012, and the confined field trial in 2014. The technical advisory team of the DA Biotech Program Office recommended backcrossing of the F1 hybrid to the transgenic line instead of preparing a second field trial in 2017. The dossiers are currently being prepared for the contained trial and its eventual varietal registration.

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, and multi-location field trials in 2012 and 2013. The data to complete the required regulatory dossiers were obtained in 2015, as well as some related laboratory experiments in 2017. The evaluation further confirmed the bioefficacy of the Bt cotton hybrids against the cotton bollworm. The proponents will apply for the commercial propagation as soon as the certificate of satisfactory completion of the multi-location test is received.

Benefits from Biotech Maize

The farm level economic benefit of planting biotech maize in the Philippines in the period 2003 to 2016 was estimated to have reached US$724 million. For 2016 alone the net national impact of biotech maize on farm income was estimated at US$82 million (Brookes and Barfoot, 2018, Forthcoming). These immense economic gains are continuously benefiting more than 406,000 farmers and their families in the last 14 years of biotech maize commercialization in the Philippines

In summary, biotech maize was planted on 642,000 hectares in 2017, a decrease of 21% compared to 2016. Adoption rate went up to 65% in 2016, but down again in 2017 at 46.5% due to the huge problem of counterfeit seeds. In addition, the newly approved biosafety guideline makes the approval process a little complicated. There are currently some applications which have not been approved which were already over the prescribed review and assessment period of 85 days. Nevertheless, the science community in the Philippines and farmer groups are fully supportive of the technology and are working together to improve the JDC to make it more transparent and efficient. The biotech crops that are in the pipeline may take some years before they are commercialized, but the overwhelming benefits target the developing countries to tackle problems such as vitamin A deficiency (for Golden Rice), rampant use of harmful pesticides and low yield (for Bt eggplant and Bt cotton), and delayed ripening and viral disease (for papaya ringspot virus resistant papaya).

MYANMAR

Myanmar planted 320,000 hectares of IR (Bt) cotton, equivalent to 92% of 349,000 hectares of the total cotton area in 2017-18 (Figure 12). The majority of the cotton area was occupied by two long staple insect resistant Bt cotton varieties *"Ngwe chi-6"* and *"Ngwe chi-9"*, demonstrating the preference of smallholder farmers for Bt cotton technology. Both Bt cotton varieties *Ngwe chi-6* and *Ngwe chi-9* were developed by the Department of Industrial Crops Development (DICD) of the Ministry of Agriculture, Livestock and Irrigation (MOALI) and registered by Myanmar's National Seed Committee (NSC) for commercial sale in Myanmar in 2010 and 2015, respectively. Approximately 455,000 smallholder farmers (average of 0.7 hectare of cotton farm per farmer) planted the long staple Bt cotton variety in the 12th consecutive year of cultivation, 2006 to 2017. Over the years, the field testing and approval of new biotech cotton varieties and other biotech crops relevant to

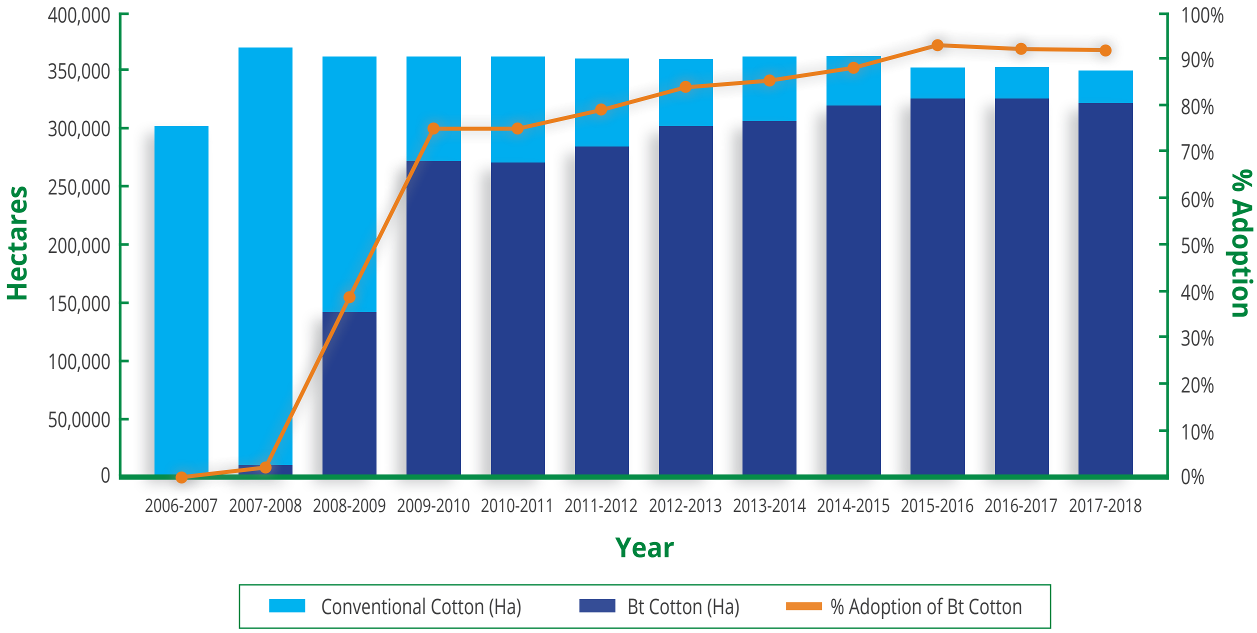


Figure 12. Adoption of IR (Bt) Cotton in Myanmar, 2006 to 2017

Source: Analyzed by South Asia and Biotechnology Centre (SABC) and ISAAA, 2018

Myanmar could not take place in the absence of the biosafety regulatory regime. Myanmar is the only country in South Asia without a legal national biosafety framework, which is not only affecting in-house research and development on cutting edge crop technology but also hampering trade and transboundary movement of GMOs. The third draft of the national biosafety framework which was completed in 2008 was pending for enactment into the biosafety law.

In 2017-2018, Myanmar produced approximately 500,000 metric tons of cotton from 349,000 hectares with average cotton productivity of 1,432 kg per hectare (USDA, 2018; USDA FAS GAIN Report, Agricultural Biotechnology Annual-Burma, 2017). In the past, the average yield for Bt cotton variety *Ngwe Chi 6* was recorded at 2,000 kg per hectare. Over the years, the availability of good quality Bt cotton variety of *Ngwe chi 6* has become a big challenge for public sector institutions that are engaged in production and distribution of cotton led by the DICD. The growth of cotton production, which at one time reached an all time high of 618,220 metric tons in 2012-2013 is either stagnant or decelerating. Myanmar also recorded the highest cotton yield of 1,719 kg per hectare in 2012-2013 from 770 kg per hectare in 2006-2007 after the commercial release of Bt cotton variety *Ngwe chi 6*.

In the past year, the supply of quality cotton has diminished with cotton farmers facing problems accessing good quality seeds (Myanmar Times, 2017). One of the prime reasons for the short supply of quality cotton seeds was the lack of resources of the State-run seed distribution system. Poor quality seeds also hindered the agricultural sector's ability to reach its full potential (EuroChem Myanmar, 2017). In the past, the World Bank reported that Myanmar had a short supply of certified paddy seeds which only meets about 1% of the demand (World Bank, 2016). The situation for cotton was no different. The Myanmar Times (2017) reported that the volume and quality of the cotton seeds provided by government cotton seed distributors in Mandalay, Myanmar have weakened in recent years.

However, the demand for cotton has risen due to increasing need for cotton by the domestic textile sector. In 2017-2018, the Government of Myanmar has re-opened the government run textile mills and factories, which were non-operational for the last couple of years (Myanmar Times, 2017a). Increasing demand for textile made-in-Myanmar after the US re-designated Myanmar as eligible for the General System of Preference (GSP) program in November 2016. With this, Myanmar may export almost 5,000 different products including textile and apparels to the United States duty-free (USTR, 2016). As a result, the textile and garment sector have become Myanmar's second largest export sector achieving US$2.2 billion export in 2017-2018 from US$900 million in 2012-2013 (MGMA, 2017; Gartex, 2017). Uninterrupted supply of cotton, at least the similar level of cotton production of 600,000 metric tons in 2013-2014, is necessary to meet the growing demand as many textile factories are now turning to locally produced cotton instead of procuring from abroad (Myanmar Times, 2017a). Therefore, the supply of quality cotton seeds is paramount to boost cotton production and farmers will no longer rely on the government run-seed distribution system. However, the World Bank opined that the private seed providers have not been able to produce enough to meet demand, nor import the required amounts of quality seeds due to a poor enabling environment in Myanmar. As a result, many Myanmar farmers use saved seeds, thus producing low yields (World Bank, 2016).

Enactment of the Biosafety Law

Myanmar has been a member of the Convention of Biological Diversity (CBD) since 1994 and the World Trade Organization (WTO) since 1995, and is bound by the WTO's Trade Related Aspects of Intellectual Property Rights (TRIPs) agreement (Lwin Oo, 2016). In addition, Myanmar has also recognized the ASEAN guidelines on risk assessment of agriculture-related GMOs. Moreover, Myanmar signed the Cartagena Protocol on Biosafety (CPB) on May 11, 2001 in order to harmonize with international regulatory requirements for the products of modern biotechnology.

Table 29 shows the enactment of different laws to regulate and promote agriculture inputs including seeds, pesticides, and fertilizer in Myanmar. Myanmar has to enact the draft Biosafety law to facilitate the introduction of improved seeds and biotechnology in the country. The Ministry of Agriculture, Livestock and Irrigation (MOALI) realized the shortcomings in the existing policy as well as rules and regulations and have made significant progress to create conducive environment for investment by multinational and national seed companies. Policy and legislative reforms in the agriculture sector undertaken by the Government of Myanmar were geared to attract foreign direct investments, particularly in the seed industry development (Kyi, 2016). The enabling policy and regulatory environment is fundamental for Myanmar's five-year Agriculture Development Strategy (ADS) to enhance the government's capacity to design, create, and implement policies, and plans to increase agricultural productivity and income of smallholder farmers, and enhanced market linkages and competitiveness of Myanmar farmers and agro-enterprises (ADB, 2017). Notably, Myanmar has the potential to become the hybrid seed production center in the near future, not only to cater to the ASEAN Economic Community (AEC) but also to neighboring

Table 29. Legislative Framework in Agriculture in Myanmar, 2017

Legislative system	Scope of activities	Status
The Biosafety Law	To regulate GM crops	Draft prepared in 2008, Pending Enactment
New Plant Variety Protection Law 2016	To protect plant breeders right	Enacted on January 20, 2016 Enforced on January 20, 2017
The Seed Law	To maintain quality and supply of seeds	Enacted on January 7, 2011 Enforced on January 7, 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 August 31, 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 December 1, 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 February 25, 1992
The Pesticide Law	To regulate the use of pesticides	Enacted on May 11, 1990

Source: Compiled by South Asia Biotechnology Centre and ISAAA, 2017

countries of the South Asian Association for Regional Cooperation (SAARC).

Benefits of IR (Bt) Cotton in Myanmar, 2010-2017

Brookes and Barfoot (2018, Forthcoming) estimated that the farm income in Myanmar was enhanced due to the large scale adoption of IR cotton varieties *Ngwe chi-6* and *Ngwe chi-9*, estimated at US$358 million for the period 2006 to 2016 and the benefits for 2016 alone was at US$50 million, which will benefit the families and communities of the 455,000 IR cotton farmers.

In summary, a near optimal adoption of IR cotton at 92-93% was a testimony of smallholder farmers's appreciation for IR cotton technology in Myanmar. Two long staple Bt cotton *Ngwe chi-6* and *Ngwe chi-9*, expressing the insect resistance trait, replaced majority of short staple cotton varieties in Myanmar in the last decade. In 2017, there was a slight decrease of 1.5% in IR cotton area from 325,000 in 2016 to 320,000 hectares planted by 455,000 smallholder farmers. Adequate cotton production has revived domestic cotton processing and textile industry, and has great potential to transform the livelihood of millions of people involved in the cotton-textile value chain. However, the introduction of new generation, multiple gene(s), and stacked trait cotton will not reach farmers in the absence of a functional biosafety regulatory system in Myanmar. Therefore, it is paramount for Myanmar to prioritize the implementation of the draft national biosafety framework by enacting into the biosafety law, which can spur the growth of indigenous R&D, field testing, export-import, and transboundary movement of grain, edible oil, and food products containing ingredients derived from biotech crops.

VIETNAM

Biotech maize, the first biotech crop commercialized in Vietnam in 2015, was planted on 45,000 hectares in 2017. This is a considerable increase of close to 13-fold since 2015 at 3,500 hectares. The 45,000 hectares planted by 37,500 farmers is a sizeable increase of 29% from 35,000 hectares in 2016. The biotech maize varieties planted since 2015 were essentially those with stacked IR/HT maize traits. Since 2015, there were 22 events approved for food, feed, and cultivation: 14 events for maize and 8 events for soybean. Five biotech events: 1 single herbicide tolerant event and 4 stacked IR/HT events were approved for commercialization in the country.

Biotechnology has been identified as an essential tool to achieve the country's national goals and has become the focus of research and development to modernize agriculture and to contribute to rural development. The country's Outlook for 2020 aims to make 70% of agricultural products be derived from biotechnology: whereby 30-50% of the cultivated crops should be biotech/transgenic crops, 70% of freely distributed seedlings will come from micropropagation, 80% of the fruit and vegetable areas are supplied with biofertilizer and biopesticides, and finally biotechnology as a component of science and technology will contribute up to 50% of the growing agricultural value in the country (Vietnam Biotechnology Information Service, Personal Communication).

Registration procedures for GE events for food/feed use is regulated by the Ministry of Agriculture and Rural Development's Circular 02/2014/TT-BNNPTNT dated April 14, 2014, entitled the Approval Process of Issuing and Withdrawing Certification for Genetically Modified Plants for use as Food and Feed. Under Circular 02/2014, the deadline for submission of registration dossiers for biotech events (that were present in products exported to Vietnam) was March 10, 2015. However, per requests from animal feed industry and to avoid trade interruption, MARD issued Circular 6/2015 on February 14, 2015, amending Clause 2, Article 18 of Circular 02/2014 and extending the deadline for submission of food/feed approval dossiers for all GE events to March 10, 2016. Furthermore, MARD continues to receive applications from biotech companies, despite the passing of the March 2016 deadline. As of November 2017, there were 51 submissions for approval of biotech events for food/feed use, of which 21 submissions have been approved and 30 applications are still pending. All approved applications were for maize and soybean biotech events while pending biotech events were for different crops such as cotton, canola, sugar beets, alfalfa, and some maize and soybean events. Between December 2016 and December 2017, eight applications to register new hybrid maize varieties for cultivation have not been acted upon by the end of the year. Analysts believe that the current reorganization at MARD with the change in leadership in July 2016 had somehow affected the review and approval process of new varieties and registrations of biotech events (USDA FAS GAIN Agricultural Biotechnology Annual-Vietnam, 2017).

Benefits from Biotech Maize

The Vietnamese government had policies to help expand the cultivation of biotech maize in view of the country's increasing demand for pork and poultry feeds. Average maize productivity was low at 4.5 tons per hectare, and with high production cost, domestic production of maize was unable to compete with maize from other countries. Maize produced in the country was able to meet only 40% to 50% of market demand, with maize import volume increasing significantly in the past years. The government had also issued policies to encourage farmers to shift rice areas with low productivity to maize and soybeans. However, the low profits from maize cultivation have somehow discouraged farmers to do so. To meet the country's demand for maize, maize yield must reach at least 5 tons per hectare, reduce production cost, and raise the income of farmers.

Speaking at a seminar organized by the Crop Production Department, Graham Brookes of PG Economics said that increasing biotech maize adoption to 20% could boost the rural economy by US$16.9 million per year, in the worst scenario. It is thus imperative that with biotech maize, farmers could increase output to meet growing demand from the feed sector and improve the balance of payments in Vietnam (Vietnam News, September 11, 2017).

Research by Brookes and Barfoot (2018, Forthcoming) estimated that benefits from biotech maize from 2015 to 2016 has reached US$5.45 million and from 2016 alone was US$5 million. With the unprecedented increase in biotech maize adoption in Vietnam more than the current 37,500 farmers will benefit from these economic gains which can help the families and the communities.

Country Situationer

Vietnam remains as a major importer of key biotech plant products such as maize, distillers dried grains with solubles (DDGS), soybeans for animal feed production, and cotton for the textile industry. Maize is the major ingredient in locally sourced-feed as well as cassava bits, broken rice and rice bran. In the past few years, feed demand continued to outpace local maize production, increasing the volume of imported maize brought into Vietnam. For instance, in 2017, the total feed demand has gone up to 29.1 million tons and expected to increase to 29.6 million tons in 2018. Hence, to provide for this demand, the country imported some 9.0 million tons in 2016-2017 and estimates for 2017-2018, maize imports is 9.5 million tons (USDA FAS GAIN Report, Grain and Feed Update Quarterly-Vietnam, 2017). Adoption of biotech maize, which started in Vietnam in 2015, is slowly contributing to profitability, based on Brookes and Barfoot (2018, Forthcoming), and expected to contribute to the lowering of maize imports. However, the government's policy to shift rice cultivation to maize still needs more push because only a few farmers in the Mekong River where rice is planted three times a year have shifted to maize. In addition, the current lower-priced maize import is more accessible than producing it locally at a more expensive production cost. It is thus imperative that in order to increase biotech maize area in Vietnam, a need to increase farmer acceptance and adherence to the technology package provided by the developers are essential.

For protein source, animal and aquaculture feed, and food industries rely heavily on the imported fresh full fat soybean meal, which is comprised of 20% soybean meal for animal feeds, and 25% for aquaculture feed. Demand for soybean meal is estimated to increase from 3-5 million metric tons in 2017 to 5.6 million metric tons by 2020. The production of soybean in the country is decreasing because farmers switch to more profitable rice and maize, and thus continue to fall short of domestic demand. To provide for the domestic needs, the country will have to import around 5 million metric tons annually. Moreover, possible increases in the amount of imports depend on the expansion of the existing soybean crushing plants or the construction of new ones (USDA FAS GAIN Reports, Oilseeds and Product Update-Vietnam, 2017). Some eight biotech soybean events have been approved in the country for food, feed, and processing, but not for cultivation. The area of biotech soybeans planted globally has been increasing since 1996 and is more than 50% of the global biotech area. Benefits in the form of increased yield, low cost of production, and excellent product quality have inspired farmers to plant an increasing area through the years. Vietnam has a potential soybean area of more than 100,000 hectares which can provide the needed soybean products for domestic use if biotech soybean is adopted.

Vietnam has a huge potential to be a biotech cotton adopting country because it is the fastest growing cotton spinning country for yarn, which is imported at an increasing rate, to China, Turkey, and South Korea. The country had also made free trade agreements with these trading partners. With the increasing growth of the textile sector, the country will have to continue to import more cotton in the short to medium term. In 2016-2017, cotton imports reached 1.2 million tons (5.5 million bales), up by 20% over 2015-2016, while the 2017-2018 imports is estimated to be 1.4 million tons, up by 15% over 2016-2017. Domestic cotton supply from local producers can only reach up to less than 1% of the market demand, and the country may even be a 100% cotton importer in the very near future. This is due to low global cotton price while local cotton production is high; farm competition for more profitable cash crops and cattle raising; less incentive from the state and commitments by cotton ginning mills (USDA FAS GAIN Report, Vietnam Cotton and Products Update-Commodity Report, 2017). Cultivating biotech cotton, similar to its neighbor, China, may still be far-fetched because of the above reasons. However, the global price of cotton is slowly going up and farmers can choose to plant biotech cotton and reduce the cotton imports in the future.

In summary, Vietnam showed its commitment to decrease maize imports in the last three years by planting biotech maize, which in 2017 went up by 29% from 35,000 hectares in 2016 to 45,000 hectares. Country regulations are in place and 22 biotech events for food and feed were approved since 2015, five of which were for cultivation. In 2016 and 2017, no new events were approved, and by the end of 2017, 30 applications for food, feed, and cultivation for various crops such as cotton, canola, sugar beets, alfalfa, and some maize and soybean events have pending approvals. The slow approval process may be due to the reorganization of the agriculture ministry. Expansion of the biotech maize area may be achieved in the future with the country's dependence to maize for animal feeds. Similarly, soybeans is an important component of aquaculture and animal feeds. Imports of these two products not only for human consumption, but also for animal feeds are estimated to increase by as much as 8% yearly. Vietnam is also keen on producing its own cotton because of the all important cotton yarn that they mill and export. The big markets of China, Turkey, and South Korea have made the textile sector a strong revenue earner, albeit using imported cotton. Cotton-growing areas are slowly diminishing with stiff competition from other crops and livestock. But with the slowly increasing global price of cotton, it may soon be the preferred crop by farmers.

BANGLADESH

About 27,000 smallholder farmers planted IR (Bt) brinjal (eggplant) in the winter season of 2017 – the fourth year of commercial cultivation of IR brinjal in Bangladesh. The winter season of 2017 was the turning point of the large scale adoption of IR brinjal in Bangladesh, from 700 hectares by 2,500 farmers in winter 2016 to ~2,400 hectares by 27,000 farmers in the winter 2017 season, which was a 242% increase in adoption of IR brinjal in Bangladesh (Table 30). The Bangladesh Agricultural Research Institute (BARI) and Feed the Future South Asia Eggplant Improvement Partnership in Bangladesh

Table 30. Adoption of IR Brinjal in Bangladesh, 2017

Year	Adoption of IR brinjal (ha)	Total brinjal area (ha)	No. of IR brinjal farmers	% Adoption
2014	12	50,000	120	<1
2015	25	50,000	250	<1
2016	700	50,000	2,500	2
2017	2,400	50,000	27,000	5

Source: Analyzed by South Asia Biotechnology Centre & ISAAA, 2018

conducted a two-year trial period in 2016 and 2017 in Bogra district of Rajshahi division, Bangladesh and reported an almost zero infestation of fruits of IR brinjal, which varied from 0-2.27% in 2016 and 0% in 2017, whereas the percent infested fruits in the non-IR brinjal isolines reached 36.7% in 2016 and 45.5% in 2017, even with weekly spraying.

The adoption of IR brinjal reached 5% of the total brinjal area in Bangladesh in its fourth year of commercialization. Four IR brinjal varieties including IR Uttara (BARI IR brinjal-1), IR Kazla (BARI IR brinjal-2), IR Nayantara (BARI IR brinjal-3), and IR ISD-006 (BARI IR brinjal-4) were grown by 27,000 farmers in around 64 districts of Bangladesh in 2017. In 2017, IR brinjal seeds were supplied free of cost to around 7,000 farmers by the Department of Agricultural Extension (DAE) of the Government of Bangladesh in winter 2017 season. Each of the 7,000 farmers received 20 grams of IR brinjal seeds along with the prescribed amounts of fertilizers for growing IR brinjal on each *bigha* (0.2529 hectare) of land as part of the Government of Bangladesh's support to flood affected farmers in 2017 (USDA FAS GAIN Report, Grain and Feed Uptake-Bangladesh, 2017; New Age, 2017). The remaining 20,000 farmers purchased IR brinjal seeds at a nominal rate from the commercial outlets of the Bangladesh Agricultural Development Corporation (BADC), a public sector enterprise of the Government of Bangladesh.

IR brinjal is the country's first genetically modified crop that protects brinjal from the deadly fruit and shoot borer (FSB). The brinjal fruit and shoot borer (*Leucinodes orbonalis*), also known as BFSB, is one of the major insect-pests of brinjal, which causes losses of up to 70% in commercial plantings of 50,000 hectares of brinjal grown by almost 150,000 smallholder farmers in three brinjal growing seasons –summer, winter and spring. Eggplant (*Solanum melongena* Linn.), or brinjal as it is called in Bangladesh, is an important and popular vegetable in Southeast Asia. As an alternative to intense use of insecticides to control BFSB, Mahyco inserted the *cry1Ac* gene from *Bacillus thuringiensis* and donated the transformed line (EE-1 event) to BARI. The gene was introgressed into nine popular brinjal varieties developed by BARI, consequently.

Four of the nine IR brinjal varieties were approved for commercial planting in 2013, while three IR brinjal varieties, including BARI IR begun-5 (IR Dohazari), BARI IR begun-6 (IR Khatkhatia), and BARI IR begun-7 (IR Singnath), were recommended by the NTCCB Core Committee for the commercial approval in 2017 (BARC, 2017; Daily Star, 2017). Thus, in response to the growing interest by smallholder farmers in IR brinjal, BARI produced breeder seeds of IR brinjal varieties namely BARI IR begun-1 (IR Uttara); BARI IR begun-2 (IR Kajla); BARI IR begun-3 (IR

Nayantara); and BARI IR begun-4 (IR Iswardi or ISD006). In total, BARI produced 90 kilograms of IR brinjal breeder seeds in 2014-2015, 875 kilograms in 2015-2016, and around 1,500 kilograms of IR brinjal seeds in 2016-2017, which were made available for distribution to smallholder farmers through the BADC and the Department of Agricultural Extension (DAE) of the Government of Bangladesh in the winter of 2017.

The IR brinjal varieties were evaluated in 2016 and 2017 by a team of researchers led by Dr. Md. Zulfikar Haider Prodhan, of the Farm Research Division of BARI, supported by USAID Feed the Future South Asia Eggplant Improvement Partnership. A full report of the trials is being prepared for a peer-reviewed publication but preliminary analysis indicated the IR varieties had increased fruit production and very little fruit infestation by BFSB, compared to their respective non-IR isolines. The number of infested fruit for IR brinjal varieties varied from 0 to 2.27% in 2016 and was 0% in 2017, and was not significantly affected by the spray regime in either year. In contrast, the percent infested fruit in the non-IR isolines reached 36.7% in 2016 and 45.5% in 2017, even with weekly spraying. However, maximum fruit yield was obtained from sprayed plots compared to non-sprayed plots, indicating that other insects such as whiteflies, thrips, and mites can reduce plant vigor and subsequent fruit weight. Statistically, similar number of non-target arthropods, including beneficial arthropods, were observed in both IR and non-IR varieties in most cases. An additional trial that focused on a single IR variety and its isoline provided similar results on infestation levels, with and without sprays, and similar trends of non-target arthropods. Together, these studies indicate that IR brinjal is extremely effective at controlling BFSB in Bangladesh without affecting other arthropods. However, to achieve maximum yield of IR brinjal, other pest arthropods including whiteflies, thrips, mites, and aphids need to be controlled (Prof. Anthony M. Shelton, Personal Communication).

In 2017, BARI scientists led by Dr. M.M. Khatun et al. published the article *Quantification of Cry1Ac Protein in IR Eggplant Fruits* that quantifies the Cry1Ac proteins in the fruits of newly released four IR eggplant varieties such as BARI IR brinjal-1 to -4. The experiment was conducted at the Molecular Genetics and Genetic Engineering Laboratory of Biotechnology Division of BARI in which the mature fruits of four IR brinjal varieties were used. The Cry1Ac protein in brinjal fruit extracts was determined through Enzyme Linked Immunosorbent Assay (ELISA) method. The expression of the protein was found among the fruits of the IR brinjal varieties, which varied from 29.53 to 33.99 μg per gram (Khatun et al., 2017). The expression of Cry protein in IR brinjal varieties was found to be similar to the reported 30-40 micrograms per gram (ppm) in fruits and leaves in India. This is sufficient to kill BFSB effectively as the moult inhibitory concentration was 1.7 ppm for Cry1Ac (Dr. Bharat Char, Personal Communication, 2018). As reported by Prof. Anthony M. Shelton of the Feed the Future South Asia Eggplant Improvement Partnership and Dr. Md. Prodhan, On Farm Research Division of BARI, Bangladesh, the IR brinjal varieties in commercial farmers' fields were found free from the infestation of the fruit and shoot borer, whereas the counterpart non-IR isolines were affected by the insects at the experimental field. Fruit infestations in non-IR isolines were recorded at 36.70% in 2016 and 45.51% in 2017, even with weekly spraying. This indicates that the prevailing levels of IR protein are effective to control the fruit and shoot borer (FSB).

As the adoption of IR brinjal increases, the need for product stewardship becomes extremely vital to prolong the life of IR technology. The IR protein controls the main pest – BFSB, but does not affect other brinjal pests such as leafhoppers, whiteflies, aphids, and thrips, therefore studies are being conducted as part of the IR eggplant improvement partnership to develop thresholds for these other pests. Shelton et al. (2017) recommends that refuge planting must be practiced in farmers' fields and IR brinjal must be incorporated within an Integrated Pest Management (IPM) program to ensure the long-term benefit of this technology. Similarly, Khatun et al. (2017) emphasized on the post release monitoring as well as extensive research should be carried out on IR eggplant, considering the influence of external environmental factors on the expression of IR protein, optimization of minimum standard value of IR protein & quantification of IR protein and study of IR protein at molecular levels (Khatun et al., 2017).

In 2017, Bangladesh Ministry of Agriculture commissioned the IR brinjal impact assessment study to be implemented by the DAE, Agricultural Policy Support Unit (APSU), and BARI. International Food Policy Research Institute's Policy Research and Strategy Support Program (PRSSP) was requested to design an experimental study to assess the impact of growing IR brinjal on brinjal yields, pesticide use, and farmers' health outcomes. This IR brinjal impact assessment study would generate definitive evidence on how IR brinjal may affect farmers' income and pesticide use and exposure, and would be released sometime in 2018 (APSU, 2017).

Biotech Crops in the Pipeline

Late Blight Resistant Potato. In 2017, the Michigan State University (MSU) in collaboration with the Bangladesh Agricultural Research Council (BARC) and BARI launched a USAID's US$5.8 million project "Feed the Future Biotechnology Potato Partnership" to produce and commercialize 3R gene potato technology to tackle devastating losses caused by late blight fungal disease – *Phytophthora infestans*, which causes significant losses. Farmers in Bangladesh spend US$60.27 (Bangladeshi Takka 5,000 per hectare or Takka 80-100 crore) annually spraying 400-500 metric tons of fungicide to control late blight disease. In the past, BARI's Tuber Crop Research Center in collaboration with ABSPII developed a late blight resistant (LBR) potato variety BARI Potato-8 popularly known as Diamant by introgressing RB gene sourced from *Solanum bulbocastonum* in 2007. BARI has conducted backcrossing, contained and confined multi-location field trials of LBR potato between 2008 and 2016. In 2017, the National Technical Committee on Crop Biotechnology (NTCCB) Core Committee has recommended the commercial release of first generation RB gene BARI Potato-8 popularly known as Diamant to the Bangladesh National Committee on Biosafety of the Ministry of Environment & Forests.

Biotech Golden Rice. In 2017, the Bangladesh Rice Research Institute (BRRI), in collaboration with IRRI has successfully conducted multi-location field trials of Golden Rice variety "GR2E BRRI dhan29" − a biotech rice that produces beta (β) carotene, a source of vitamin-A. Two years of multi-location trials of "GR2E BRRI dhan29" in Boro seasons of 2015-2016 and 2016-2017 in Bangladesh resulted in the superior yield level while producing a desired level of β-carotene, 10-12 μg/g beta carotene, enough to meet 50% of vitamin-A daily dietary requirement of people consuming rice. The Golden Rice variety GR2E BRRI dhan 29 is expected to undergo field trials for varietal registration in Boro season 2017-2018 and 2018-2019 before it is commercialized in Bangladesh in the near future. The BRRI plant breeding group was awarded the prestigious Bangabandhu National Agriculture Award 2017 in recognition of its significant work in climate-smart, high-yielding rice varieties and the significant progress in Golden Rice research on "GR2E BRRI dhan 29" (BRRI, 2017).

In 2017, FSANZ approved the food products containing traces of Golden Rice event GR2E − and such food products can be sold in Australia and New Zealand (FSANZ, 2017). This approval was a significant milestone in the commercialization of Golden Rice which is either field tested or nearing commercial approval for planting in Bangladesh, Philippines, and Indonesia. In addition, the NTCCB core committee has accorded permission for import of iron and zinc-enriched "IRS495-274" event of BRRI dhan 29 from IRRI for conducting greenhouse trial by BRRI. Underscoring the urgent need for a food secure Bangladesh, Agriculture Minister Matia Chowdhury has laid greater emphasis on R&D, demonstrated political will and forged partnership with institutions working on cutting edge technological innovations such as IRRI and alluded that **"the purposeful investment in agricultural research and development is a high priority of the Bangladesh government to achieve sustainable and inclusive development. We hope that IRRI will continue to provide the technical support we need through collaborative programs for our vision of a food- and nutrition-secure future"** (IRRI, 2017).

Biotech Cotton. In 2017, the NTCCB Core Committee has given import approval to IR cotton having X-gene (Cry1Ac Truncated Event 1) to be imported from JK Agri Genetics Limited for contained trial by the Cotton Development Board (CDB) of the Ministry of Agriculture. Bangladesh is the second largest importer of cotton fiber and uses approximately 4 to 4.5 million bales of cotton to spin a product for the textile sector. Domestic raw cotton production is abysmally low, with an annual production of 150,000 bales from a total cotton area of 40,000 hectares planted by 70,000 farmers. Bangladesh can only meet 2-3% of the total raw cotton demand of the textile sector and hence relies heavily on imported raw cotton and fiber from India, USA, and Uzbekistan. The CDB estimates that the demand for cotton fiber will increase three-fold from 800,000 tons in 2014 to 2,500,000 tons by 2020 driven by the global demand for clothing and textiles manufactured in Bangladesh. In order to increase the domestic supply of raw cotton, the Government of Bangladesh has shown commitment to increase cotton production by introducing new and improved varieties of cotton hybrids and genetically modified IR cotton. In the past, the CBD has field tested single gene IR cotton hybrid sourced from Chinese Hubei Seeds in 2015-2016. However, the confined field trial of IR cotton hybrid in 2015-2016 hasn't shown adequate protection against *Helicoverpa armigera* and delivered insignificant yield advantage over non-IR cotton hybrid. In 2016-2017, the Cotton Development Board of Bangladesh sought the import permit from the Ministry of Agriculture to import seeds of IR cotton variety expressing X-gene (cry1Ac truncated Event 1) from JK Agri Genetics Limited from India. It is expected that the Cotton Development Board would conduct contained field trial of X-gene Event 1 at BARI facility in 2018.

Country Situationer

The progress of biotechnology in Bangladesh in 2017 is a reflection of the attitude and sufficient understanding of professionals towards biotechnological products in Bangladesh. The opinion of professionals in the country is valuable in the further acceptance of biotech products in the country. A study on the "Attitude and consumption of Bangladeshi professionals of biotechnological products" by Abdullah et al. (2018), reveals that introduction and expansion of biotechnological products in Bangladesh are phenomenal and has been strongly supported by the government. The study confirms that **"Bangladesh has successfully introduced a GM food crop, IR brinjal, nationwide without any sensitivity from the consumers, indicating the higher prospects**

for the expansion of other biotechnological products in Bangladesh" (Abdullah et al., 2018).

When asked specifically about IR brinjal, which is the first commercial GM food crop in Bangladesh, 90% of the respondents opined that IR brinjal could be helpful to reduce the attack of the fruit and shoot borer (FSB) – the target pest. A vast majority (83%) of respondents preferred biotechnology to traditional breeding to develop new varieties, noted the study. In addition, **"Bangladeshi professionals understand the effectiveness and consequences of IR brinjal and they consider that it is beneficial for the production of brinjal in Bangladesh."** Majority of the respondents showed a higher level of understanding on the principles and mechanisms of biotechnology in the development of crops to ensure food security. The study also estimates that **"about 65,000 farmers all over the country cultivated IR brinjal in 2017, which improved marketable yield by at least 30%, and reduced the number of insecticide applications by a massive 70–90% resulting in a net economic benefit of US$1,868 per hectare."**

Inspired by the success of the country's first commercially released biotech crop − IR brinjal − Bangladesh is currently field testing three more crops developed through genetic engineering, which are late blight resistant potato, IR cotton, and Golden Rice, noted the study. The authors concluded that **"Bangladeshi professionals have an optimistic outlook about biotechnology and its products."**

In summary, Bangladesh is all set to reap a bountiful harvest in the near future from Bt brinjal and other biotech crops which have pending approvals for commercial release. A well designed and timely executed projects under the public-private partnership coupled with the political will has allowed Bangladesh to enhance its scientific and regulatory capacity and nurture innovative crop improvement technologies to achieve higher level of food production. Golden Rice, LBR potato, and IR cotton can pave the way for highly productive, nutritious and efficient agriculture production system. Bangladesh, a country of 166 million people in 2018 who largely depends on food produced from a meagre 8 million hectares of arable land, had 27,000 farmers plant Bt brinjal in 2,400 hectares of land.

Future Prospects for Asia and the Pacific

Biotech countries in the Asia and Pacific region are led by India with the largest area of biotech crops at 11.4 million hectares cotton followed by Pakistan (3 million hectares cotton), China (2.78 million hectares cotton), Australia (924,000 hectares cotton and canola), the Philippines (642,000 hectares maize), Myanmar (320,000 hectares cotton), Vietnam (45,000 hectares maize) and Bangladesh (2,400 hectares eggplant). This region planted 19.11 million hectares of biotech crops, 10% of the global biotech crops of 189.8 million hectares. The region increased biotech crop area by 3.34% and contributed mainly by the increase in biotech cotton area in India (6%) and Pakistan (3.4%); Australia (8%) for biotech cotton and canola; Vietnam (29%) for biotech maize; and most notably Bangladesh (242%) for biotech eggplant. Increases in biotech crops in these countries were mainly due to farmers' acceptance of the technology because of the savings on insecticide application and labor cost for India, Pakistan, Vietnam, and Bangladesh; more clarified regulatory guideline and new biotech cotton varieties available in Pakistan and Myanmar; and favorable weather and increasing global demand for canola in Australia. The decrease in biotech maize area in the Philippines of 21% was due to the problem of counterfeit seeds in the country, which had occupied 10% of the market share. China's biotech cotton area remained at 2.78 million hectares due to the country's high end stocks that are still supplying the domestic needs for cotton.

The expansion of biotech crops in Asia and the Pacific Region depends on a number of factors specific to each country. Biotech cotton-growing countries of India, Pakistan, China, and Myanmar have various new biotech cotton varieties in the pipeline pending approval in their respective regulatory systems, as well as various crops and traits. In India, biotech mustard and brinjal have been assessed to be safe and offers high yield and insect protection respectively, but have not been given final approval by the government. Thus, a careful consideration of the recommendation of the MOEFF&CC is essential. The presence of counterfeit Bt cotton seeds in India is having a big negative impact to farmer profitability and technology efficiency which needs to be solved immediately.

Biotech maize has been approved in Pakistan, and field testing has resumed for commercialization in farmers' field by 2018. This will drive approval and adoption of next generation biotech crops in the country. In Myanmar, biotech crop regulation is being put in place to expedite approval and commercialization of new biotech cotton varieties and other crops/traits. Biotech research in China has produced various biotech crops with important agronomic traits including IR rice, phytase maize, HT cotton, HT soybean and many others. However, the approval process in China has been unreasonably slow affecting possible benefits that the farmers may gain from the improved traits. Biotech crop acceptance in Australia has been commendable with the increasing adoption of biotech cotton and canola, and the many field trials of other crops including banana, maize, wheat, sugarcane, barley, grapevines, to name a few with various traits for improved nutrition, disease resistance, and drought tolerance. In Vietnam, biotech maize commercialization had been well accepted in the country and farmers are looking forward to more biotech maize varieties and new crops such as biotech cotton and soybean. The government of Bangladesh believes and supports adoption of biotech crops with the proven benefits derived from Bt eggplant. Thus, field trials of Golden Rice, late blight resistant potato, and biotech cotton are being conducted for commercialization in the near future. The large decline of biotech maize area in the Philippines due to counterfeit seeds needs immediate attention because if not attended to, this will jeopardize the longevity and efficiency of the technology that will weigh heavily on farmer profitability and economic benefits. Field trials of public sector biotech crops are positively progressing under the new biosafety guidelines with commercialization opportunities in the future.

Finally, the estimated over 15 million biotech farmers in the developing countries of Asia have been benefiting immensely in the last 21 years of commercialization. Economic benefits estimated by Brookes and Barfoot (2018, Forthcoming) from the respective countries since the start year of planting until 2016 is over US$46.7 billion and for 2016 alone, was US$3.1 billion. These are enormous benefits that can only be derived from biotech crops, and non-adoption of biotech crops in these countries will result in huge opportunity cost that will escalate poverty, hunger, malnutrition, and political instability.

THE AFRICAN CONTINENT

The African continent remains the region with the biggest potential to reap from the benefits associated with modern agricultural biotechnology. Close to 70% of the population, the majority of whom are smallholders, derive their livelihood from farming with average farm sizes of 2 hectares or less. The sector employs 65% of Africa's labor force and accounts for 32% of gross domestic product. Thus, with agriculture propelling the economies of the majority member countries, unlocking the sector holds the key to addressing the much-needed transformation in all spheres from socio-economic, environment to geopolitical. The continent bears more than half of the world's unused arable land and as a late adopter of modern biotechnology, it has unlimited opportunities to interrogate and harness the immense knowledge gathered over the last two decades and avoid some of the pitfalls experienced by early adopters. In the words of fallen gallant Harvard scholar Prof. Calestous Juma: "Sub-Saharan Africa is well-poised to benefit from those advantages that accrue to late adopters of new technologies."

In 2017, global and African leaders continued their call for increased investments in modern farming technologies to make the sector more productive and competitive especially for her youthful population. The importance of creating enabling environments for the technology to thrive increased. At a regional meeting on agricultural biotechnologies for sub-Saharan Africa co-organized by the African Union Commission and FAO in November 2017, the African Union Commissioner for Department of Rural Economy and Agriculture, Sacko Josefa Leonel Correa, acknowledged the application of science, technology, and innovation in the agricultural sector as key in combating food insecurity and malnutrition. She called on African governments to create a favorable policy environment and invest more resources in order for the region to benefit from the safe applications of proven biotechnologies so as to lift vulnerable communities out of extreme food insecurity (FAO, November 4, 2017).

South Africa and Sudan maintained the lead in the planting of biotech crops, with South Africa remaining among the top 10 countries that planted more than 1 million hectares of biotech crops. In Sudan, exceptional performance of the IR cotton program gained top attention by the Prime Minister and ministers of the economic sector of Cabinet as it was the only crop that achieved the target in the country's economic remedy program. Biotech cotton was grown on 192,000 hectares, with an adoption rate of 95%. South Africa continued to lead the adoption of biotech crops in the African continent with a combined planting of biotech maize, soybeans, and cotton totaling 2.73 million hectares in 2017 – a 2.6% increase from the reported biotech crop area of 2.66 million hectares in 2016.

SUDAN

In its sixth year of commercialization of biotech crops, a total of 192,000 hectares of IR (Bt) cotton were planted in Sudan, up from the previous 120,600 hectares grown in 2016, an impressive 59% or 71,400 hectares increase. An estimated 90,000 farmers grew the crop on average farm sizes of 2.1 hectares. The adoption rate of biotech cotton remained high at 98% and only 2,520 hectares were grown to conventional cotton.

Sudan approved its first biotech crop — IR cotton for commercial planting in 2012 with a single variety under the trade name Seeni-1. Continuous research over the last six years has resulted in approval of two new IR hybrids, gradually increasing the acreage from an initial modest launch of 20,000 hectares in 2012 to 192,000 hectares in 2017, a cumulative 549,353 hectares over six years (Figure 13).

In Sudan, seeds are provided by the public and private sectors (Table 31). Two companies provided the technology: the Chinese Center and JK Agri-Genetics of India through a local company Elaeena. Seeds are produced annually in the irrigated schemes for the open pollinated varieties (OPVs) while Elaeena

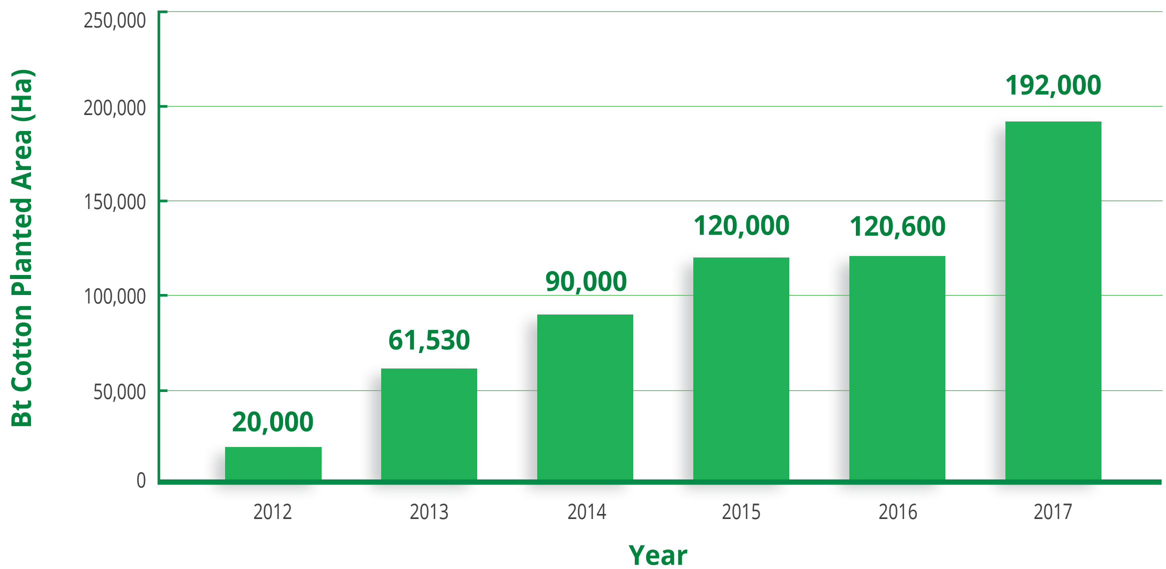


Figure 13. IR Cotton Adoption in Sudan 2012-2017

Source: ISAAA, 2017

Table 31. Commercial Production of IR Cotton, 2017 (Hectares)

District/State	Irrigated	Rainfed	Flood Irrigated Area	Total
Gezira	48,300			48,300
Rahad	28,560			28,560
New Halfa	13,020			13,020
Suki	10,500		900	10,500
Sennar	14,050	7,500		21,550
South Kordofan	–	410	–	410
West Kordofan	–	320		320
Blue Nile		14,700		14,700
White Nile	9,580	–	–	9,580
Gadarif		41,110		41,110
Dalta Toker			1,390	1,390
Khor Abu Habil			2,940	2,940
Private Sector	18,000			18,000
	124,028	**64,040**	**5,230**	**192,380**

Source: ISAAA, 2017
Note: In 2017, seed production area was included in the scheme areas.

handles distribution of the hybrid seed in accordance with quotas as required by the different companies or farmers. It is noteworthy that there has been a change in the cotton financing policy, with the Government leaving it more to the private sector. The emergence of local markets through cotton collection points where the farmers can sell their cotton directly after determination of cost by the financing company has contributed to a drastic cotton expansion. Companies and farmers remain highly enthusiastic and are prepared to almost double the planting area over the coming season due to satisfaction with the performance of IR cotton. Several companies have started introducing ginneries and cottonseed oil extraction factories. Others are engaged in negotiations with neighboring countries to export seeds and cotton lint. Evidently, the IR cotton program is spurring positive change in all spheres from farmers, field laborers, collectors, transporters, local market operators, ginneries, and cottonseed oil extraction plants. To safeguard these gains, the government, through the Ministry of Agriculture, intends to put a strong stewardship program to ensure farmers have easy access to certified seeds instead of the current practice where some still use uncertified seed from ginneries or produced by other farmers.

This demonstrates strong political goodwill out of satisfaction with the IR cotton technology from demonstrated benefits accrued by farmers and other stakeholders along the cotton sub-sector value chain.

Benefits of Biotech Cotton in Sudan

The use of IR cotton hybrids has drastically raised yields by 2-3 times higher than that of conventional varieties and significantly higher than the initially released IR variety (Seeni1). The use of IR cotton hybrids will provide an added assurance of seed purity and optimize farmer harvests. Other significant benefits will arise from the introduction of ginneries and cottonseed oil extraction factories which are underway. Evidently, the IR cotton program is stimulating positive change in all spheres of the cotton sub-sector value-chain. There are also prospects for exporting seeds, spinning, and textile production in neighboring countries and negotiations have begun in a win-win venture. Ultimately, environmental and health gains from the reduction of hazardous chemical sprays for bollworm control in the cotton fields will lead to general wellness and a more productive citizenry. A strong stewardship program and sustainable seed production and distribution system need nurturing to ensure that the country reaps technology benefits sustainably.

Progress with Biotech Crops Research in Other African Countries

In 2017, a total of 13 countries sustained various activities from planting, evaluating trials or granting approvals for the general release of various biotech crops. Figures 14a and 14b and Table 32 capture these developments alongside the two countries – South Africa and Sudan – that sustained commercial planting of biotech crops in 2017. Progress was observed at several levels:

- Swaziland completed the evaluation of an environmental release application for IR cotton, which now awaits endorsement by Swazi Environment Authority for the issuance of seed import permit and commencement of commercial planting.
- Mozambique planted the first field trial of genetically modified (GM) maize as part of the Water Efficient Maize for Africa (WEMA) program. This is a stacked trait and the trial will test the tolerance of GM maize to drought and insect pests.
- Six countries continue to conduct multi-location trials in preparation for general release. They are Burkina Faso (cowpea), Ethiopia (cotton), Ghana (cowpea), Kenya

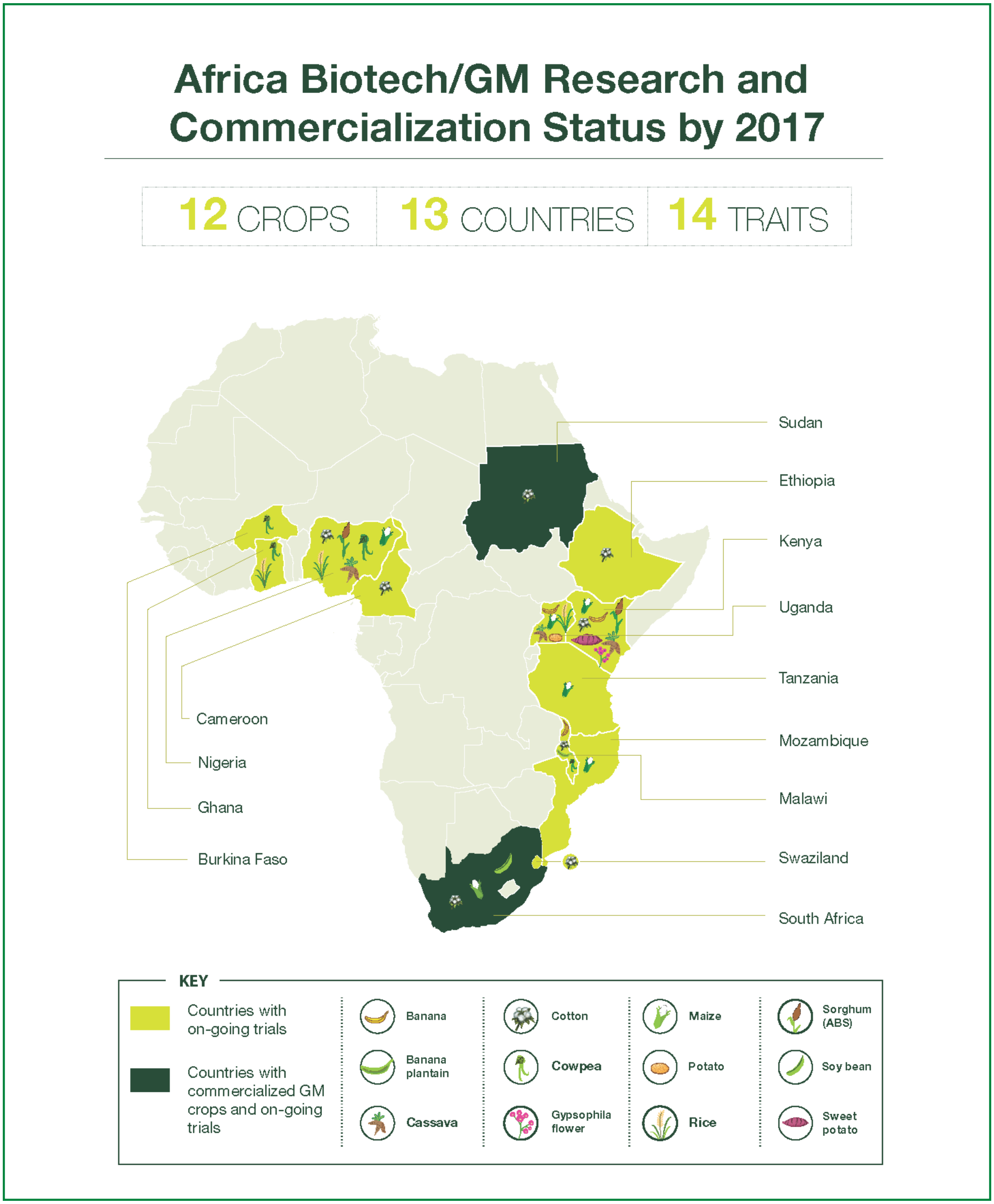


Figure 14a. Africa Biotech/GM Research and Commercialization Status in 2017

Figure 14b. Crop Traits Under Various Stages of Research in Africa in 2017

Table 32. Crop Traits under various stages of research in Africa by 2018

Crop	Country	Traits
Banana	Uganda, Malawi, Kenya	Biofortified Black sigatoka Banana bacterial-*Xanthomonas* wilt (BXW) resistance
Banana Plantain	Malawi	Bunchy top virus resistance
Cassava	Kenya, Nigeria, Uganda	Cassava mosaic Disease Cassava brown streak Disease Delayed postharvest starch deterioration
Cowpea	Burkina Faso, Ghana, Malawi, Nigeria	Maruca resistance (insect resistance)
Cotton	Ethiopia, Kenya, Nigeria, Swaziland	Insect (bollworm) resistance
Gypsophila Flower	Kenya	Pink coloration of petals
Maize	Kenya, Mozambique, Tanzania, South Africa, Uganda, Nigeria	Insect resistance (IR) Drought tolerance (DT) Stacked IR/DT
Potato	Uganda	Late blight
Rice	Burkina Faso, Ghana, Nigeria, Uganda	Nitrogen Use Efficiency Water Use Efficiency
Sorghum	Kenya, Nigeria	Biofortified
Sweet potato	Kenya	Sweet potato virus disease resistance
Soybean	South Africa	Stacked trait with modified fatty acid composition

Note: 12 Crops; 13 Countries; 14 Traits

(maize), Nigeria (cowpea and cotton), and Uganda (banana, maize, and potato).
- Two countries, Mozambique and Tanzania, approved a stacked trait — insect-resistant and drought tolerant maize under the WEMA project, demonstrating a growing interest in the continent to incorporate more traits in various crops.
- Malawi planted the second season of national varietal trials of IR cotton in eight agro-ecological sites as it aims to commercialize the crop by 2019.
- Nigeria granted a permit for GM cassava modified for delayed post-harvest starch deterioration.
- Nigerian and Swaziland governments issued import permits for GM maize to meet food and feed deficits. Approval for nine GM maize events was granted to WACOT Nigeria Limited for feed processing.

In Burkina Faso, where IR cotton was suspended in 2016, cotton farmers rallied their call on the Government to quickly resolve the short fiber length concern in order to reinstate the IR cotton program. A 70% increase in chemical use has been reported in the control of bollworm resurgence while many farmers are withdrawing from growing the country's top foreign exchange earner.

Elsewhere, the Kenyan Government formed a taskforce to fast-track the commercialization of IR cotton and eight sites in different agro-ecological sites were identified to conduct the National Performance Trials (NPTS) earmarked for 2018. Discussions are still on-going to initiate IR maize NPTs following the conditional approval for general release granted for IR-WEMA maize in 2016. This is particularly urgent for the country and the continent given significant levels of control of the devastating fall armyworm (FAW) have been observed in the IR maize experimental trials even though this particular trait is not for FAW control. Promising results with specific FAW control are already at advanced stages of research in South Africa.

Biosafety Policy Developments

In 2017, the biggest milestone was the passage of Uganda's long-awaited National Biosafety Bill by Parliament in October 2017. The law now awaits assent once a number of issues raised by President Yoweri Museveni are addressed. It may be noted, that it is not unusual for a President to seek clarification over Bills voted by Parliament, and Ugandan researchers are hopeful this would not delay their quest to move completed research to the next level – farmers' fields. The country has been conducting a number of multi-location experimental trials to improve main staple and food security crops, key among them are bacterial wilt, black sigatoka, and beta carotene-enhanced banana; virus resistant cassava; drought tolerant and insect resistant maize; nitrogen and water efficient and salt tolerant rice; and late blight resistant potato. A proof of concept experiment for herbicide tolerant soybean is also underway.

The Government of Ghana made provisions in the national budget for the National Biosafety Authority operations with biosafety activities factored in the National Small-to-Medium Term Development Plan (NSMTDP-2017 – 2021).

In Nigeria, the National Biosafety Management Agency approved a set of National Biosafety Regulations, revised and approved the National Biosafety Policy 2017, and recruited additional staff to strengthen its operations in the country.

In South Africa, the Academy of Science of South Africa (ASSAf) published a consensus report on the Regulatory Implications of New Breeding Techniques (NBTs). The main message from the report was an acknowledgement of the importance of NBTs for the region and called upon policymakers to ensure regulatory processes are able to accommodate their application as a matter of urgency. The report pointed out that South Africa has a robust and experienced regulatory system for GMOs, which can, without much change, be applied to also effectively regulate the products of NBTs and any genome modifying techniques that may still be developed in the future. Furthermore, the GMO Act (Act 15 of 1997), as it stands, has a product-based trigger and sets genetic variation beyond what may also occur naturally as the threshold for regulation.

Technology Demand

Throughout 2017, African farmers were at the frontline in dismissing misinformation that has resulted in fear of GM technology and delayed its adoption in the continent. They continued relented demand for the technology, urging their governments to remove hurdles that deny them access to biotech products. In Nigeria, the national president of *All Farmers Association of Nigeria (AFAN)* Arc Kabir Ibrahim, demanded deployment of GMO technology, arguing it would help cushion seeds from drought due to climate change, resist disease, and deliver higher yield to mitigate hunger and poverty. This will bring about prosperity in the country. ***"In Nigeria we view ourselves as the giant of Africa, therefore in order to walk***

the talk, it has become necessary to embrace this technology regardless of the endless diversions from the anti-GMO activists," he said.

Kenyan farmers reiterated their call on the government to lift the ban on GM food imports that was imposed by a cabinet decision in 2012, arguing that the ban was affecting the conduct of National Performance Trials, thus delaying selection of suitable GM seed varieties for their use. On behalf of newly formed Society for Biotechnology Farming in Kenya (SOBIFAK), the chairman Mr. Mugo Magondu had a clear message to Government: ***"We can clearly see that these drought tolerant varieties work, we demand that the government releases the WEMA-IR maize to avert the crop failure that we face. We know that the research on these genetically engineered varieties is now complete,"*** he remarked. While expressing his excitement about the technology, another farmer, Paul Musui, wondered why the government is preventing a technology that is being practiced elsewhere from benefiting Kenyan farmers. ***"We have continued to suffer heavy losses from perennial droughts and insect pests, yet a technology that can address these issues exist,"*** said Mr. Musui. More than 50 farmer leaders representing thousands of farmers from various regions across the country supported his sentiments.

In North Eastern Tanzania, farmers urged their government to hasten delivery of biotech crops, which, they said, will save them from crop failure. The maize, cassava, and cotton farmers whose crops had been severely affected by stalk borer pests, cassava mosaic disease, and African cotton bollworm, respectively, said they had applied chemical and cultural control methods against the pests and diseases with little success over the years. Mr. Chongo Ngundamira, a farmer from Buchosa District in the area pointed out that high cost of inputs to control pest and disease had decreased production capacity. ***"We have heard that scientists are working on biotech maize, cassava, and cotton that will need less spraying as the crops are self-protected against pests and diseases. We urge the government to hasten delivery of these crops as they will help us save on the cost of production and eliminate crop failure,"*** said Mr. Chongo. He added that in the current circumstances, the farmers face perennial food shortages as a result of the challenges, yet their land is highly productive.

In Burkina Faso, farmers called for the reinstatement of IR cotton, citing poor harvests and intense spraying that has further impoverished them. They predicted the collapse of the cotton farming industry in the next two years unless something drastic is done about the pest attacks and mass crop failure. Others threatened to abandon growing of the country's major foreign exchange earner. Kuraogo Salifu, a 65-year-old farmer lamented, ***"I have been growing cotton for the last 30 years but I have not seen anything like what I am seeing this year. Since they brought back these conventional seeds two years ago, the pressure from the pest has been serious. We spray 6 to 7 times a season. You spray today and return the following day to see more pests on the field... If the government wants to help farmers, they need to bring back GM cotton,"*** he said.

Partnerships Emerging in Africa

A new trend emerging in the continent is the forging of south-south collaboration to diversify the range of technology providers with Asian tigers (India and China) reaching for such partnerships. Brazil and Australia have also been providing valuable capacity-strengthening opportunities in the regulatory, research, and experience-sharing with biotech crops. These efforts will no doubt expand current portfolio of efforts all aimed at accelerating access to cutting-edge technologies and tools to the African farmer. As a late adopter, this will ultimately lead to a quantum jump as the continent harnesses the immense knowledge gathered over the last two decades to her benefit without re-inventing the wheel.

In summary, the continent is poised to deliver new biotech crops into the global basket in the coming years, given the vibrant research and advanced multi-location trials nearing commercialization for food security crops such as banana, cassava, and cowpea. There is also a strong wave of endorsement of technology benefits through increased expressions of political goodwill and budget allocations by various governments. In Kenya for example, the government is spearheading Bt cotton commercialization to revive the textile and apparel sector, which is among the Government's 'Big Four Agenda' for socio-economic growth. Others like Ethiopia and Nigeria Governments have clearly outlined priority areas for technology application. Increased area of biotech crops from South Africa and Sudan further confirms that the technology is delivering benefits. Stacked traits appear to be gaining popularity with more countries opting for them even for new entrants like Mozambique and Tanzania. Importantly, South Africa is leading the continent in providing guidance on the regulatory narrative for new breeding techniques in order to expand the innovation platform and quickly reap benefits from these precise tools. South-South collaboration and diversification of technology providers will further boost confidence in decision-making and build courage among policymakers for hastening sound science-based decisions about the technology for Africa's benefit.

EUROPEAN UNION

Two countries, Spain and Portugal, in the European Union (EU), have consistently planted the biotech IR maize event MON810, the only biotech event approved in the EU. The total biotech crop area planted in 2017 was 131,535 hectares, a slight decrease of 4% from the 2016 biotech maize area of 136,363 hectares (Figure 15). Spain planted 124,227 hectares and Portugal planted 7,308 hectares.

Czechia and Slovakia did not plant biotech maize in 2017. Czechia had supported the science-based approach to biotechnology and started planting biotech crops in 2005 at 250 hectares and peaked in 2008 at 8,380 hectares. From then on, farmers planted a decreasing area with 75 hectares in 2016, and none in 2017 (Figure 15). The country also planted 147 hectares of Amflora potato in 2010 which stopped after BASF transferred its operations from Germany to the USA in 2012 due to the hostile political climate towards biotech crops in the EU. Slovakia on the other hand, grew its first biotech maize in 2006, when 30 hectares were grown for commercial production by several farmers, and peaked in 2008 at 1,900 hectares. Farmers have opted not to plant due to the inconvenience of stringent reporting requirements for IR maize, as well as the difficulty in marketing biotech crops. This resulted in less incentives for farmers and all stakeholders seeking to capture the benefits offered by IR maize. In Czechia and Slovakia, biofuel production and cattle feeding rely mostly on biotech maize. Some strong retailer groups in these countries have negative campaigns against cattle fed with biotech maize. Thus, with the sudden decision not to plant biotech maize, the two industries that rely mostly on maize imports, which were biotech maize anyway, suffered tremendous losses. Resumption of cultivation of biotech maize and approval of other biotech crops for environmental release may take some time to be realized because of the influence of neighboring non-biotech planting countries. However, science-based regulation is still strong and there is no ban for planting biotech crops in these countries. There is an active biotech

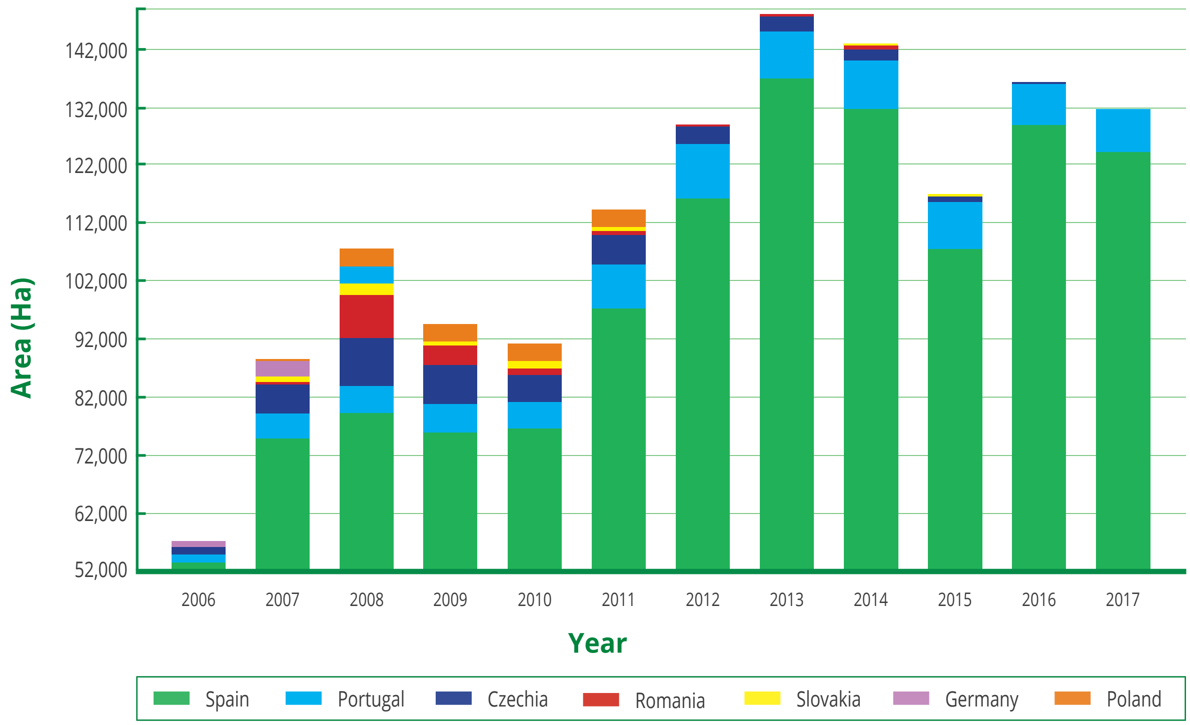


Figure 15. Biotech Maize Area in the European Union, 2006-2016, Hectares

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: ISAAA, 2017

research in Czechia, such as the consortium with USDA's Agricultural Research Service and several EU new member state research institutions (such as the French INRA) that has developed a bioengineered plum tree called HoneySweet that is resistant to the Plum Pox virus. Many field trials have been successfully completed. However, commercialization is still not possible with the current status of biotech acceptance and regulation in the EU (USDA FAS GAIN Report, EU Agricultural Biotechnology Annual, 2017).

The EU has been importing biotech crops for use in livestock and poultry industry. Since 1998, 104 biotech events have been approved for food, feed, and cultivation: Argentine canola (13), carnation (7), cotton (13), maize (50), potato (1), soybean (19), and sugar beets (1). In 2017, nine biotech events have been approved for food and feed including: 1 canola event MON88302 x MS8 x RF3 (stacked glufosinate, glyphosate, male sterility/fertility; 2 for cotton, event GHB119 (IR/HT) and event 3006-210-23 x 281-24-235 x MON88913 (IR/HT); 2 for maize, event DAS40278 (single HT) and event BT11 x 59122 x MIR164 x TC1507 x GA21 (stacked IR/HT); and 4 for soybean, event DP 305423 x GTS 40-3-2 (stacked HT and modified oil), event DAS44406-6 (stacked HT for glyphosate, glufosinate and 2,4-D, event DAS68416-4 (stacked HT for glufosinate and 2,4-D), and event FG72 x A5547-127 (stacked HT for glyphosate, glufosinate and sulfonylurea).

SPAIN

Spain has been planting biotech maize for 19 years since 1998, and in 2017 has contributed 91% of the 131,535 hectares in the total biotech maize area in the EU (Figure 15). The highest biotech maize area was recorded in Spain in 2013, when 136,962 hectares were planted, corresponding to 92% of the biotech maize area in the EU. Fluctuations in the area of biotech maize followed in the next few years, depending on past season's incidence of European corn borer and market conditions for biotech and conventional maize. In 2017, there was a decline of 4% in biotech maize area from 129,081 hectares to 124,227 hectares, and all were IR (Bt) maize event MON810. The slight decline was due to poor crop margins, and the EU-wide move to eliminate ingredients sourced from biotech crops so as not to be labeled "Contain GMOs".

There were 13 regions in Spain that cultivated biotech maize. The autonomous regions of Aragon and Catalonia had the highest share of Spain's biotech maize area at 71%, because the insect pest European corn borer is endemic in these areas (Table 33).

Spain continues to defend a science-based and pragmatic approach to agricultural biotechnology with regards to both cultivation and imports. Despite the counter-productive efforts of the EU, Spain has steadfastly and successfully grown IR (Bt) maize after opting not to ban growing of biotech crops in the country in 2015. Field trials are also permitted in Spain, although they are subject to prior notice and authorization. According to the Joint Research Center in 2017, notifications for deliberate release into the environment of GE plants but not for commercialization purposes include:

- Multiplication of biotech wheat event IND-ØØ412-7 with glufosinate tolerance and water stress tolerance

Table 33. Area of Biotech Maize by Region in Spain (Hectares)

Region	2013	2014	2015	2016	2017
Aragon	54,451	54,041	42,612	46,546	49,608
Catalonia	33,996	36,381	30,790	41,567	39,092
Extremadura	16,979	13,815	9,827	15,039	13,976
Navarra	7,013	7,264	6,621	8,066	7,778
Castile-La Mancha	8,766	7,973	5,734	5,932	5,069
Andalucia	12,862	10,692	11,471	10,919	8,013
Others*	2,895	1,371	695	1,011	691
Total	**136,962**	**131,538**	**107,749**	**129,081**	**124,227**

*Castilla Leon, Comunidad de Madrid, Comunidad Valencia, Islas Baleares, La Roja, Region de Murcia, Islas Canarias

Source: Ministerio de Agricultural Y Pesca Alimentacion Y Medio Ambiente, 2017

- Validation of flowering time and life cycle of biotech Westar canola lines under field conditions
- Biomass production assay in tobacco with adrenomedullin gene for vasodilation
- Biotech potato plants with plastidial glucose 6P dehydrogenase for increased starch content
- Biotech maize lines A188 with high starch content by the action of sucrose synthase activity.

The increasing maize demand for food and feed consumption in Spain has increased throughout the years, with some 7 million metric tons of maize imported in 2015-2016. The bulk of the imports came from the US, Ukraine, Brazil, and Canada (USDA FAS GAIN Report, Agricultural Biotechnology Annual, Spain, 2017).

Benefits from Biotech Maize

Some 5,500 farmers have benefited from growing biotech maize in the period 1998 to 2016, at an estimated US$275 million and are estimated to have reached US$23 million in 2016 alone (Brookes and Barfoot, 2018, Forthcoming). These are enormous benefits continuously being enjoyed by farmers in Spain in the last 18 years of Bt maize adoption.

PORTUGAL

Portugal is the second country that planted biotech maize in the EU, starting in 2005. Maize area has increased since then, peaking in 2013 at 147,000 hectares, but has steadily declined since 2014, along with the biotech maize area. However, in 2017, the total maize area declined slightly by 2% but the biotech maize area increased by 3%, from 7,069 hectares in 2016 to 7,308 hectares in 2017. The adoption rate in 2017 also increased from 6% in 2016 to 6.3% in 2017.

Biotech maize used to be planted in six regions in 2012. However, in 2017, only four regions planted biotech maize. Alentejo and Lisboa were the regional leaders in biotech maize area, at 44% and 34%, respectively (Table 34). Maize grown for grain were planted in these areas compared to Norte region where maize was grown for silage, and the use of biotech maize was limited.

This historical reduction in total maize area and the marginal increase in adoption rate of biotech maize area were due to the severe drought that discouraged maize planting as well as the demand for biotech-free maize by the food industry. The EU has a policy to label consumer products derived from biotech crops as “Contains GE products”, but most of the food industry uses biotech raw materials. However, some industries have changed to using ingredients from non-biotech raw materials. In addition, there was a tight crop margin in maize cultivation, compared to alternate crops, but the area planted to IR maize remained fairly stable. IR maize was planted only in areas affected by European corn borer (ECB), and with a small crop margin scenario, only farmers forecast to have ECB threats would invest in the seed technology. With only the IR event MON810 available, biotech maize planting was only limited in these areas.

Portugal follows the EU directives and regulations on biotechnology, including crop distance during co-existence. With the small farm size that prevails throughout the country, following the crop distance between biotech and non-biotech crop was difficult. In Alentejo and Lisboa where average farm size is bigger, this can be followed as directed.

Annually, Portugal imports some 1.5 million tons of maize from various sources, but shifted to non-biotech planting countries including Ukraine and Russia, and lesser from the USA, Argentina, and Brazil. Biotech soybean is

Table 34. Area of Biotech Maize by Region in Portugal, 2011-2017 (Hectares)

Region	2012	2013	2014	2015	2016	2017	% of Total Biotech (2017)
Total Maize	143,000	147,000	137,000	126,000	118,000	115,667	
Norte	165	85	78	60	100	46	1%
Centro	774	853	933	1,013	1,485	1,609	22%
Lisboa	2,322	2,215	2,074	2,002	2,138	2,466	34%
Alentejo	5,796	5,041	5,457	4,942	3,346	3,187	44%
Algarve	13	8	0	0	0	0	
Açores	208	0	0	0	0	0	
Total Biotech	**9,278**	**8,202**	**8,542**	**8,017**	**7,069**	**7,308**	
Adoption Rate	**6.5%**	**5.6%**	**6.2%**	**6.4%**	**6.0%**	**6.3%**	

Source : Dados Nacionais, 2017. Republica Portuguesa.

another potential biotech crop in Portugal with annual imports of 875,000 metric tons soybeans and 170,000 metric tons soybean meal for livestock and animal industry. With the exception of special market niches, these imports were mostly biotech sourced from Brazil, USA, and Argentina.

The majority of Portuguese feed and food chain industry are keen to support and utilize biotech crops as a means of achieving higher competitiveness. The annual increases in the import of biotech maize and soybeans may somehow influence biotech crop adoption and approval in the country. Additionally, feed producers and livestock breeders are aware that to be able to be competitive globally, they should have access to the technology, similar to their main competitors. To prove this point, the government of Portugal was one of the signatories to the 13 European Member States that did not sign the European Soya Declaration submitted by the German and Hungarian delegations (USDA FAS GAIN Report, Agricultural Biotechnology Annual, Portugal, 2017).

Challenges of Biotech Crops in the EU

EU Rely Heavily on Biotech Crop Imports

Provision of food and feed in the EU rely heavily on imports of raw materials. USDA FAS, EU Agricultural Biotechnology Annual (2017) reports that the EU imports 33 million metric tons (MMT) soybeans, 62 MMT maize, and more than 3.8 MMT rapeseeds and by-products in 2017. It estimated that these imports are 92% biotech soybeans, 95% soybean meal, just over 20% maize, and close to 20% rapeseed. These raw materials are used as ingredients for livestock and poultry industry. However, with the EU directive on labeling food products which are sourced from biotech crops as "Contains GE" products, food producers are forced to import non-biotech source which are non-existent as the global cultivation of biotech soybeans, maize, and rapeseed expand. Moreover, prices of products with non-biotech ingredients are more expensive because the imported raw materials are priced higher. Non-biotech crops undergo extensive non-biotech licensing or certification procedures, crops have low yield and practice labor-intensive production methods.

Slow and Strict Regulatory Procedures

The regulatory procedures for biotech crop approval in the EU have been characterized as a slow and strict process. Biotech crop developers are facing five to seven years delay in getting new varieties approved. This has led to asynchronous approval of biotech crops where a certain biotech crop event produced outside the EU can already be marketed to other countries years before approval is made in the EU. There were instances when commodity product shipments were stopped at the EU border if they contain traces of products which have not yet been approved in the EU. Trading of biotech crops is made more difficult in the EU with the zero tolerance to the non-approved biotech event, even if the event has been used and marketed for a long time and had been proven to be safe in other countries. This practice is a big challenge for domestic commodity trading companies, since sourcing options are limited and risky, products become more expensive and hence, less globally competitive.

According to the USDA FAS GAIN, Agribiotech Annual, EU (2017), 28 applications for cultivation, import, and renewal for maize, soybean, or rapeseed are being tracked for scientific review by the European Food Safety Authority (EFSA) while an additional 14 applications await EU commission's approval. A study by Smyth et al., (2017) reveals that these regulatory delays are greatly reducing returns on investment for developers of biotech crops, which cost an average of US$136 million to develop and commercialize.

Change of Face? – Public Acceptance of Biotech Crops in Europe

The 28 countries in the EU have varied acceptance of biotech crops and were categorized into three. The first set of countries has governments and industries favoring biotech crops and would plant biotech crops, or would do so if more biotech events were approved for cultivation in the EU. These ten countries were: Denmark, The Netherlands, Finland, Estonia, Romania, Spain, Portugal, Czechia and England in the United Kingdom, and Northern Belgium. The second set is composed of seven countries which are willing to adopt the technology and have a strong push from the scientists and professionals. While the third set is composed of countries which reject the technology. However, this categorization can be regarded as loosely based on acceptance studies and farmers choice.

Independent studies carried out since 2008 and summarized by Lucht (2015) highlighted the fact that in the EU, what the public says is not what they do in purchasing food products. A real marketing study conducted by Lusk et al. (2005) where identical fruits were labeled "organic", "conventional" or "spray-free GM" at real roadside fruit stalls in type 2 countries Germany, Sweden, and France, and type 1 countries Belgium, the UK and Germany. Consumers preferred organic, but the "spray-free GM" fruits achieved a market share of around 20% when the prices for the three varieties were identical. When "organic" fruits were priced 15% higher and "spray free GM" fruits were cheaper by 15%, the share of biotech fruits soared to 43% in Sweden, 33% in France, 30% in the UK, and 36% in Germany. When the preference study was conducted via questionnaires, only 12% of respondents in Germany indicated that they would buy the biotech fruits, likewise with 31% in Sweden. Hence, this study indicated that consumers say something different from what they do in a real purchase situation. In the survey study, the decision of the respondents was influenced by a negative connotation and socially-charged issue on biotech crops.

Switzerland is not an EU member state, but trades actively with the EU. Swiss consumers can be influenced by the neighboring type 2 countries Germany and France, and type 3 countries Italy and Austria. Buyers choice in Switzerland also provided a clear indication that when given the chance to choose among bread made with organic, conventional, or biotech, the total market share of the latter was 20%, and 23% of shoppers bought at least one loaf. Average sales were about 30% higher when all three kinds of bread were offered (Aerni et al., 2011). All these studies indicate that despite a voiced negative attitude toward GM food by a majority of European consumers, over 50% of respondents did not actively avoid the purchase of biotech food products, even in EU countries where a small number of such products is on the market.

Farmers in Italy, a country averse to biotech crops, have already started to voice out their preference to farm biotech crops, which the European Union Court of Justice (CJEU) supported. Farmer Giorgio Fidenato, with farmers from northeast Italy, decided to grow biotech maize event MON810 in 2015, despite Italy's ban against planting the biotech crop in 2013. These farmers were convinced that the extra yield and reduced pesticide application would benefit him and the community. However, the fields were vandalized by anti-biotech activities and the Italian government fined and took him to court. The CJEU in Luxembourg ruled that the banning of MON810 was illegitimate on the grounds of the "precautionary principle" because the safety of MON810 has been well proven not to pose food safety threat. Italy had banned the cultivation of biotech crops despite two rulings by the EFSA stating no new scientific evidence has been presented to support the use of the safeguard clause. Thus, on March 30, 2017, following a request for a preliminary ruling from the Italian District Court of Udine, CJEU advocate general Michal Bobek proposed that member states can adopt emergency measures concerning genetically modified food and feed only if they can establish, in addition to urgency, the existence of a situation which is likely to constitute a clear and serious risk for human, animal health, and the environment, as set out in Article 34 of EU Regulation No. 2003/1829 on genetically modified food or feed. The CJEU Judges have begun their deliberations in this case, and judgment will be given at a later date (Crop Biotech Update, June 28, 2017).

Two other European countries have started to import biotech crops for food and feed. The government of Turkey has started approving biotech events in various crops. On May 11, 2015, the Turkish Poultry Meat Producers and Breeders Association (BesdBir) submitted dossiers to the Biosafety Board to request approval for 37 traits for feed use: 9 soybeans, 15 corn, 4 canola, and 10 cotton. Five traits and their products were approved on July 16, 2015 for feed use, including 3 corn (MIR604, MON863, T25) and 2 soybeans (MON87701 and MON87701 x MON89788). Eight events (6 corn (MON863 x NK603, MON863 x MON810, MON89034 x MON88017, MIR604 x GA21, Bt11 x MIR604, MIR162) and 2 soybean (A5547-127, 356043) events) were approved on November 5, 2015 and an additional four events given above were approved on August 2, 2017. The remaining 20 traits are still undergoing assessments by the Biosafety Board. With these new approvals, there are currently 36 approved GE events for feed in Turkey (Crop Biotech Update, August 9, 2017), signifying Turkey's acceptance of the biotech products.

The Russian Ministry of Agriculture, on the other hand, has drafted nine regulatory documents regarding safety assessment and testing of genetically engineered products used in food, feed additives, and veterinary pharmaceuticals. It also drafted documents for GE animals and microorganisms. The functions of the Federal Service for Veterinary and Phytosanitary Surveillance (VPSS) in the assessment and testing were also drafted in a regulatory document. Once the drafted documents are adopted, these will have an impact on the development and trade of agricultural biotechnology products and veterinary pharmaceuticals in Russia (Crop Biotech Update, July 26, 2017).

The United Kingdom has been supportive of biotechnology, and research has been quite outstanding leading to field testing of various improved crops. For example in 2017, Defra (UK's Department for Environment, Food and Rural Affairs) has approved The Sainsbury Laboratory's (TSL) application to conduct field trials of GM potato crops on a designated trial site at the Norwich Research Park between 2017 and 2021. The field trials are part of TSL's Potato Partnership Project to develop a Maris Piper potato that is blight and nematode resistant, bruises less, and produces less acrylamide when cooked at high temperatures. The project is funded by the Biotechnology and Biological Sciences Research Council (BBSRC) with additional funding from BioPotatoes (UK) and Simplot (US) (Crop Biotech Update, May 17, 2017). Defra also approved the field trials of wheat with increased efficiency to convert energy from sunlight into biomass developed by Rothamsted Research Institute. The trial will be carried out between 2017 and 2019.

It is noteworthy to mention that Great Britain's Princess Anne is supportive of biotech/ genetically modified crops. In an interview on BBC Radio 4's Farming Today on March 23, 2017, she said that biotech crops provide important benefits for providing food and she would be open to growing them on her own land. Speaking from Buckingham Palace, the Princess Royal said she saw no problem with modifying crops if it improved their ability to grow. ***"Gene technology has got real benefits to offer,"*** she said and added that she would be happy to use GM for crops and livestock on her own farming estate. In the interview, Princess Anne also told Farming Today that ***"GM is one of those things that divide people."*** She said, ***"Surely, if we're going to be better at producing food of the right value, then we have to accept that genetic technology... is going to be part of that."*** She also discussed biofuels, the use of science in farming and what kind of subsidies could help farmers in the future (Crop Biotech Update, March 29, 2017).

The countries in the European Union, in partnership with research institutions around the EU and in the Americas, are also actively conducting biotech research but will not likely lead to the commercialization of new biotech crops in the short term. These include, among other things, tomatoes with vitamin E, provitamin A, and lycopene content – nutrients claimed to have anti-aging properties (Chinese-French collaboration), biotech plum with virus resistance (Czech-French), cisgenic late-blight resistant potatoes (three Flemish institutions) and many others.

With the current focus on innovative biotechnologies (IBs), most of the regulatory status and legal analysis on products produced from IBs in the EU member countries are still on hold until the CJEU rules on important issues raised by the French Supreme Court. In the meantime, the European Seed Association (ESA) puts plant breeding innovations at the heart of a sustainable EU Agri-Food policy. The seed sector launched the campaign #EmbracingNature to emphasize and explain the essential role that plant breeding innovation plays in tackling Europe's agri-food challenges, including meeting consumer demands and contributing to a highly productive and more sustainable agriculture and food production system. Nigel Moore, ESA President, representing the seed sector in the conference panel on *Modern Biotechnologies in Agriculture and Societal Challenges* said that Europe cannot afford to miss out on the opportunity to develop new varieties more quickly, more efficiently, and address the needs of farmers, consumers, and the environment in a more targeted way. The European seed sector calls upon the EU to ensure a supportive public policy that enables plant breeding innovation, and to consider the latest plant breeding methods as essential components of the plant breeders' toolbox, concludes Garlich von Essen, Secretary-General of the ESA (Crop Biotech Update, October 4, 2018).

Benefits from Biotech Maize in the EU

The EU planting countries in 2016 (Portugal, Czechia, and Slovakia, not including Spain) were estimated to have enhanced farm income from biotech maize by US$25 million in the period 2006 to 2016 and the benefits for 2016 alone was estimated at US$2 million (Brookes and Barfoot, 2018, Forthcoming).

Summary and Future Prospects in the EU

For the first time in the history of biotech crop adoption in the EU, only two countries planted biotech maize: Spain and Portugal. Biotech event MON810 was the only one planted since 2006 and adoption is limited to areas where the target pest, European corn borer wreaks havoc. The Czechia and Slovakia have stopped planting in 2017 due to difficulty in marketing their biotech maize to feed millers who demand non-biotech maize. Hence, the future of biotech crop adoption within the EU maybe dim, but there are movements among the farmers, researchers and regulatory sectors that indicate a possible change in acceptance and perception in the near future.

DISTRIBUTION OF BIOTECH CROPS: BY CROP

In 2017, the four major biotech crops (soybeans, maize, cotton, and canola) occupied some 99% of the global biotech crop area, similar to 2016 (Table 35). The adoption trend provided in Figure 16 shows the large increases in soybeans, cotton, and canola and a slight decrease in biotech maize. Favorable weather and market prices as well as increased demand for biofuels and feedstocks encouraged soybean planting, with area increases in the USA (2.2 million hectares), Brazil (2.0 million hectares), South Africa (0.24 million hectares), and Bolivia (0.103 million hectares). Unfavorable weather conditions in Latin America, low global market prices, coupled with high year-end stocks in the USA, and counterfeit seeds in the Philippines had slightly affected biotech maize area negatively in 2017. High global cotton prices and farmers acceptance for biotech cotton increased global cotton area exceptionally at 8% led by USA, India, and Pakistan. Biotech canola had the highest percentage increase of 19% and was grown in the USA, Canada, and Australia because of favorable weather and high global prices. There were also small increments for biotech alfalfa, sugar beets, papaya, squash, potato, eggplant, and apple.

Biotech soybean area is 50% of the global biotech area

Soybeans occupied 50% (94.1 million hectares) of the global biotech crop area of 189.8 million hectares, an increase of 3% or 2.7 million hectares from 2016 (Table 35). The 94.1 million hectares was comprised of 69.7 million hectares HT and 24.4 million hectares stacked IR/HT (Intacta™) soybeans — an increase of 4% or 979,000 hectares in 2017. The stacked trait soybeans were deployed successfully in Argentina, Paraguay, and Uruguay, and with almost no change in Brazil.

Biotech soybeans were planted in the USA (34 million hectares), Brazil (33.7 million hectares),

Table 35. Global Area of Biotech Crops, 2016 and 2017: by Crop (Million Hectares)

Crops	2016	%	2017	%	+/–	%
Soybeans	91.4	50	94.1	50	+2.7	3
Maize	60.6	33	59.7	31	-0.9	-1
Cotton	22.3	12	24.1	13	+1.8	8
Canola	8.6	5	10.2	5	+1.6	19
Alfalfa	1.2	<1	1.2	<1	+<1	<1
Sugar beet	0.5	<1	0.50	<1	-<1	<1
Papaya	<1	<1	<1	<1	-<1	<1
Others*	<1	<1	<1	<1	+ <1	<1
Total	**185.1**	**100**	**189.8**	**100**	**4.7**	**+3%**

*Others include biotech squash, potato, eggplant and apples

Source: ISAAA, 2017

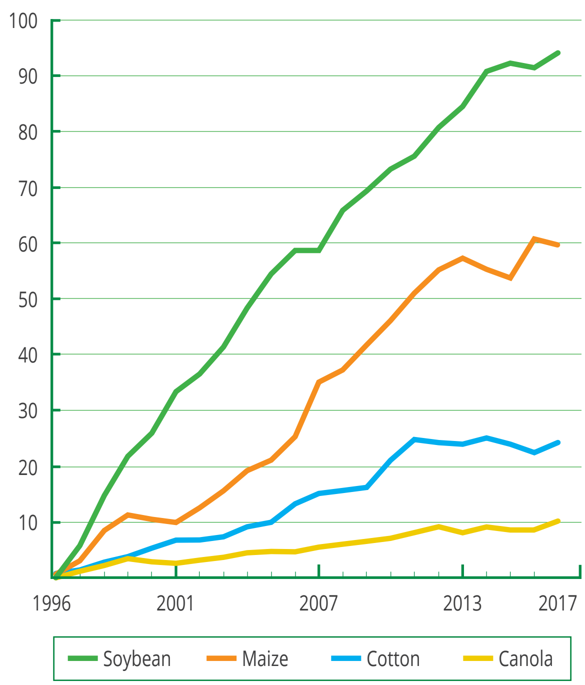


Figure 16. Global Area of Biotech Crops, 1996 to 2017: by Crop (Million Hectares)

Source: ISAAA, 2017

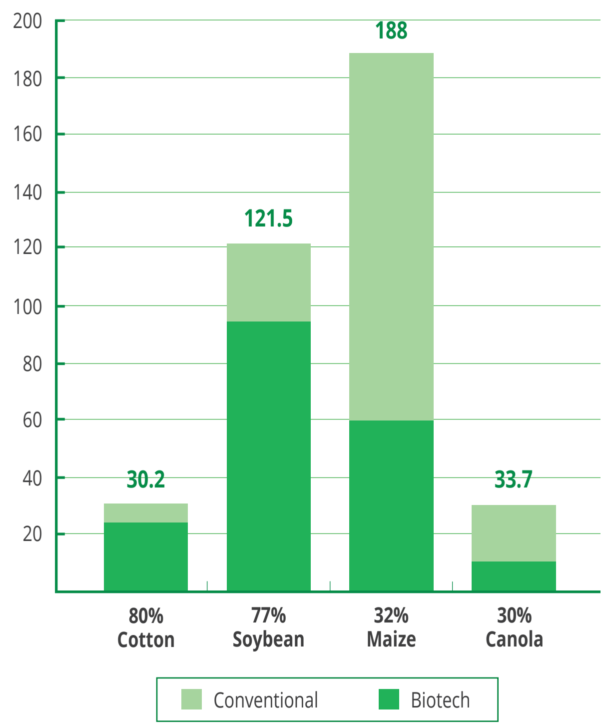


Figure 17. Global Adoption Rates (%) for Principal Biotech Crops, 2017 (Million Hectares)

Source: ISAAA, 2017

Argentina (18.1 million hectares), Paraguay (2.7 million hectares), Canada (2.5 million hectares), Bolivia (1.2 million hectares), Uruguay (1.1 million hectares), Chile (1,000 hectares), and South Africa (243,000 hectares). The biotech soybean area increased in the USA, Brazil, South Africa, and Bolivia but was not planted in Mexico due to a court injunction. In 2017, biotech soybean was not planted in Costa Rica which used to plant the crop for export depending on seed demand. Of the global hectarage of 121.5 million hectares (2016 data of FAOSTAT, 2018), 77% (94.1 million hectares) was biotech soybean in 2017 (Figure 17). It is noteworthy that in 2017, Brazil approved four biotech soybean events for cultivation including a stacked IR/HT soybean event (IR (lep)/HT (glyphosate)), and 3 HT traits (glyphosate, glufosinate, and methozone resistance) stacked with IR (lep). There were 14 biotech soybean events approved for food and feed in 2017.

The increase in income benefits for farmers growing biotech soybeans during the 21-year period 1996 to 2016 was US$59.7 billion and for 2016 alone, US$6.9 billion (Brookes and Barfoot, 2018, Forthcoming).

Biotech maize area slightly decreased in 2017

Biotech maize occupied 59.7 million hectares in 2017, a slight decrease of 1% from 2016 (Table 35). The 59.7 million hectares was comprised of 5.3 million hectares IR, 6.3 million hectares HT, and 48.1 million hectares stacked IR/HT. The area planted to biotech maize fluctuated in 2017 due to the unfavorable weather conditions in Latin America, low market price, lesser pest incidence, high year-end stocks and the problem of counterfeit seeds in the Philippines. Biotech maize was planted in 14 countries, including the USA (33.8 million hectares), Brazil (15.6 million hectares), Argentina (5.2 million hectares), Canada (1.5 million hectares), South Africa (1.9 million hectares), and countries with less than 1 million hectares planted include the Philippines, Paraguay, Uruguay, Spain, Colombia, Vietnam, Honduras, Chile, and Portugal. Czechia and Slovakia, which are member states of the EU, did not plant biotech maize in 2017 due to the inconvenience of stringent reporting requirements for IR maize resulting in less incentive for farmers and all stakeholders seeking to capture the benefits offered by IR maize, as well as the difficulty in marketing biotech crops. The same reason made Romania stop planting biotech maize in 2016. An important feature of biotech maize is stacking, which is discussed in each country sections, trait distribution of biotech crops, and in the benefits section.

Of the global 188 million hectares maize area (2016 update, FAOSTAT, 2018), 32% or 59.7 million hectares were biotech maize in 2017 (Figure 17). 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. In addition, the continuing beneficial adoption of drought tolerant maize in the USA that reached 1.4 million hectares in 2017, which will be commercialized in 2018 in Africa, biotech maize adoption will likely increase with more countries facing drought stress due to climate change. Maize continued to be used for ethanol production in the US, and other countries in the Americas.

The increase in income benefits for farmers growing biotech maize during the 21 years (1996 to 2016) was US$63.7 billion and US$ 6.9 billion for 2016 alone (Brookes and Barfoot, 2018, Forthcoming).

Biotech cotton adoption increased by 8%

The area planted to biotech upland cotton globally in 2017 was 24.1 million hectares, an unprecedented increase of 8% from 22.3 million hectares in 2016 (Table 35). The 24.1 million hectares were comprised of 18 million hectares IR, 828,000 hectares HT, and 5.2 million hectares IR/HT. The 8% increase in total biotech cotton area globally was due mainly to the improved global market value and the high adoption rate of IR/HT cotton in 2017. Biotech cotton was planted in 14 countries led by India (11.4 million hectares), USA (4.6 million hectares), Pakistan (3 million hectares), China (2.8 million hectares), and less than 1 million hectares planted in Brazil, Australia, Myanmar, Argentina, Mexico, South Africa, Paraguay, Colombia, Sudan, and Costa Rica. The highest year-on-year increment in the biotech cotton area was obtained in the USA at 24%, followed by Brazil at 19%. Based on the latest 2016 FAOSTAT data (2018), cotton was planted on 30.2 million hectares globally, a high of 80% (24.1 million hectares) of which was biotech (Figure 17).

The increase in income benefits for farmers growing biotech cotton during the 21-year period 1996 to 2016 was US$59.9 billion and US$3.8 billion for 2016 alone (Brookes and Barfoot, 2018, Forthcoming).

Biotech canola area increased by 19%

The global area of biotech canola increased by 19% from 8.6 million hectares in 2016 to 10.2 million hectares in 2017 (Table 35). Notably, two-digit percentage increases in biotech canola area were in the canola-growing countries: USA (42%), Canada (17%), and Australia (10%). These three countries support the technological needs of canola farmers in their country. Since 1996, various varieties with multiple HR genes for glufosinate, glyphosate, and oxynil tolerance were developed and made available to the farmers. Chile grew biotech canola on 4,000 hectares, similar to 2016, for seed export. Farmers in these countries planted more biotech canola due to the increasing local and international markets for canola oil at an excellent price, as well as the increasing demand for biodiesel production. Of the global hectarage of 33.71 million hectares of canola grown in 2016 (FAO, 2018), 30%, or 10.2 million hectares were biotech canola grown in Canada, the USA, Australia, and Chile (Figure 17).

The increase in income benefits for farmers growing biotech canola during the 21-year period 1996 to 2016 was US$6 billion and US$0.51 billion for 2016 alone (Brookes and Barfoot, 2018, Forthcoming).

Biotech alfalfa HarvXtra™ area increased by 295%

Biotech alfalfa varieties are available as Roundup Ready® herbicide tolerant or low-lignin HarvXtra™. Herbicide tolerant RR®alfalfa was first approved for commercialization in the USA in 2005. In 2017, the USA planted 1.14 million hectares RR®alfalfa and 80,000 hectares HarvXtra™, while Canada planted 3,000 HarvXtra™, for a total of 1.2 million hectares similar to 2016. Remarkably, on the second year of planting HarvXtra™ alfalfa, the area increased from 21,000 hectares in 2016 to 83,000 hectares in 2017. HarvXtra™ alfalfa has less lignin, higher digestibility, and was claimed to also offer a 15 to 20% increase in yield, and hence is likely to be in high demand by farmers. The adoption rate of biotech alfalfa in these two countries are still low but is likely to increase as more and more farmers realize the benefits of the technology in livestock production and farm management.

Other biotech crops

The total area of HT biotech sugar beets planted in the USA and Canada at 100% adoption in 2017 was 472,000 hectares, a slight reduction of 2% compared to 2016. This reduction was largely due to the unfavorable growing season in the USA, while in Canada, there was a slight increase in the biotech sugar beets area. The most remarkable increase in biotech crop area was obtained in IR (Bt) eggplant in Bangladesh at 242%, from 700 hectares in 2016 to 2,400 in 2017. This was largely due to huge government support and farmer acceptance. Biotech sweet corn in the USA is very conservatively estimated at a minimal nominal hectarage of 1,000 hectares 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-R papaya in Hawaii (1,000 hectares) continued to be grown in the USA in 2017; China also grew a total of 7,130 hectares PRSV-R papaya in 2017 compared to 8,550 hectares in 2016, a 17% reduction. In the USA, biotech Generation 1 Innate™ potatoes were grown on 160 hectares in 2015, 2,500 hectares in 2016, and 1,618 hectares in 2017. In addition, Generation 2 potatoes were planted on 809 hectares for the first time in 2017. In 2016, some 80 hectares of non-browning Arctic® apples were planted which increased to 101 hectares in 2017. And lastly, the anthocyanin-rich biotech pink pineapple was grown in Costa Rica at 25 hectares in 2017, an increase from 14.76 hectares in 2016.

DISTRIBUTION OF BIOTECH CROPS, BY TRAIT

During the 22-year period of 1996 to 2017, herbicide tolerance has consistently been the dominant trait of biotech crops planted (Table 36 and Figure 18), but is slowly declining through the years with the increasing prominence of the stacked traits. In 2017, stacked IR/HT traits deployed in soybean, maize, and cotton had the highest increase in year-on-year increment of 3% and occupy 41% of the global area (Table 36). In 2017, there were percentage increases in area planted to stacked IR/HT cotton (22%), soybeans (4%), and maize (1%). Stacked trait products were preferred by farmers due to its cost saving technology, especially the Intacta™ soybean and BolgardIII/RR®flex cotton. Various IR/HT products were approved for food/feed and commercialization in 2017 for soybeans, maize, and cotton.

In terms of year-over-year increases, the highest growth was notable for stacked traits at 3%, followed by single trait herbicide tolerance at 2% and insect tolerance at 1%, 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 for farmer's use in the market such as the BolgardIII/RRFlex® cotton from Australia. Stacking is a very important feature of the technology with SmartStax™ comprising eight genes coding for three traits, launched in the USA and Canada in 2010, as well as the Innate™ potato generation 2 which was approved for cultivation in 2015 in the USA and in Canada in 2016.

The deployment of stacked traits of different Bt genes and herbicide tolerance is becoming increasingly important and is most prevalent in the USA and Brazil. Of the 77.7 million hectares of biotech crops with stacked traits, USA and Brazil contributed 41% each, with small contributions from countries which planted IR/HT soybeans, maize, and cotton. In 2017, a total of 14 countries deployed biotech crops with stacked traits: USA (32.1 million hectares), Brazil (32.4 million hectares), Argentina (7.6 million hectares), Canada (1.5 million hectares), South Africa (1.3 million hectares), Paraguay (1.2 million hectares), and smaller areas in the Philippines, Australia, Uruguay, Mexico, Colombia, Vietnam, Honduras, Chile, and Costa Rica. 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.

Herbicide tolerance (HT) deployed in soybean, maize, canola, cotton, sugar beet, and alfalfa occupied 88.7 million hectares or 47% of the 189.8 million hectares of biotech crops planted by up to 17 million farmers globally (Table 1). This is an increase of 2% or 2.1 million hectares

Table 36. Global Area of Biotech Crops, 2016-2017: by Trait (Million Hectares)

Traits	2016	%	2017	%	+/–	%
Herbicide Tolerance	86.6	47	88.7	47	2.1	2%
Stacked Traits	75.4	41	77.7	41	2.3	3%
Insect Resistance	23.1	12	23.3	12	0.2	1%
Virus Resistance/ Other	<1	<1	<1	<1	<1	<1
Total	**185.1**	**100**	**189.8**	**100**	**4.7**	**+3%**

Source: ISAAA, 2017

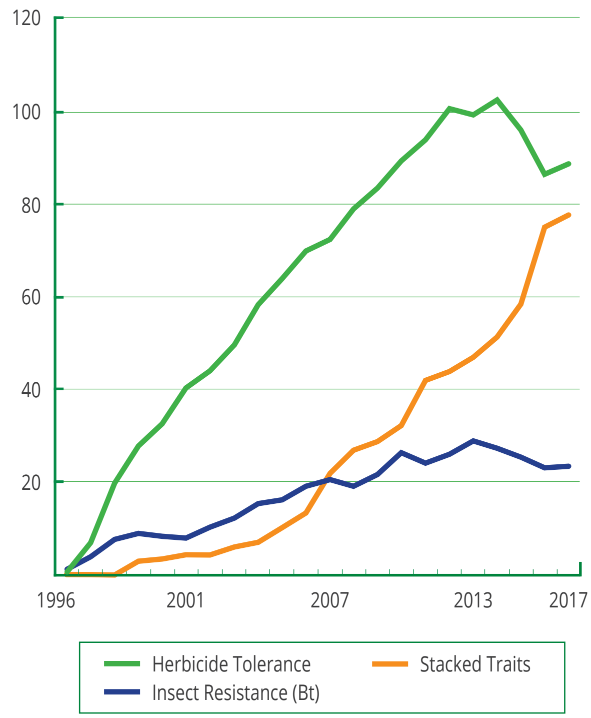


Figure 18. Global Area of Biotech Crops, 1996 to 2017: by Trait (Million Hectares)

Source: ISAAA, 2017

compared to 2016. The herbicide tolerance trait used in the no-till technology is still the most popular trait for farmers because of the ease in field preparation for crop rotation. Various HT genes have been discovered and used in single or in combination to prevent the build-up of HT in these biotech crops. HT crops were commercialized in the USA (41.5 million hectares), Argentina (15.5), Brazil (14.5), Canada (11.6), Bolivia (1.8), Paraguay (1.7), South Africa (1.1), and less than 1 million hectares in Uruguay, Australia, Philippines, Colombia, Chile, and Honduras.

The area of biotech crops with the insect resistance trait increased by a minimal 1% from 23.1 million hectares in 2016 to 23.3 million hectares in 2017. The global increase in cotton prices and the available new insect resistant traits in cotton slightly favored IR cotton adoption in India, the USA, and Pakistan. Biotech crops with insect resistance traits were planted in India (11.4 million hectares), Brazil (3.4 million hectares), Pakistan (3.0 million hectares), China (2.8 million hectares), USA (1.3 million hectares), and less than 1 million hectares grown in Argentina, South Africa, Myanmar, Sudan, Spain, Paraguay, Canada, Portugal, and Bangladesh.

Generally, the changes in trait hectarage were mainly due to changes in the key countries of the USA, Brazil, Argentina, Canada, China, and India. In addition, countries such as South Africa, Australia, Philippines, and Honduras continued to report changes. The stacked traits for herbicide tolerance and insect resistance are deployed in cotton and soybean (IR/HT), maize (Bt/Bt/IR, Bt/HT, and Bt/Bt/HT) but not in sugar beets, canola, and alfalfa. The Bt/Bt/IR stack refers to different Bt or other IR genes that code for different insect resistance traits, for example for maize, above ground pests and below ground pests and herbicide tolerance are all stacked in the same maize product.

Distribution of economic benefits at the farm level by trait, for the 21 years of commercialization of biotech crops 1996 to 2016, were as follows: all herbicide tolerant crops at US$89.02 billion and all insect resistant crops at US$97.4 billion, with the balance of US$0.4 billion for other minor biotech crops for a total of US$186.1 billion. For 2016 alone, the economic benefits were: all herbicide tolerant crops US$8.44 billion, and all insect resistant crops US$9.73 billion plus a balance of US$0.03 billion for the minor biotech crops for a total of ~US$18.2 billion (Brookes and Barfoot, 2018, Forthcoming).

TRENDS IN GM CROP APPROVALS 1992-2017

The number of countries that issued approvals for food, feed, and cultivation reached its peak in 2014 at 22 countries and declined slightly to only 18 countries in 2017 (Figure 19). As of December 2017, 176 approvals were granted by these countries. The USA, one of the

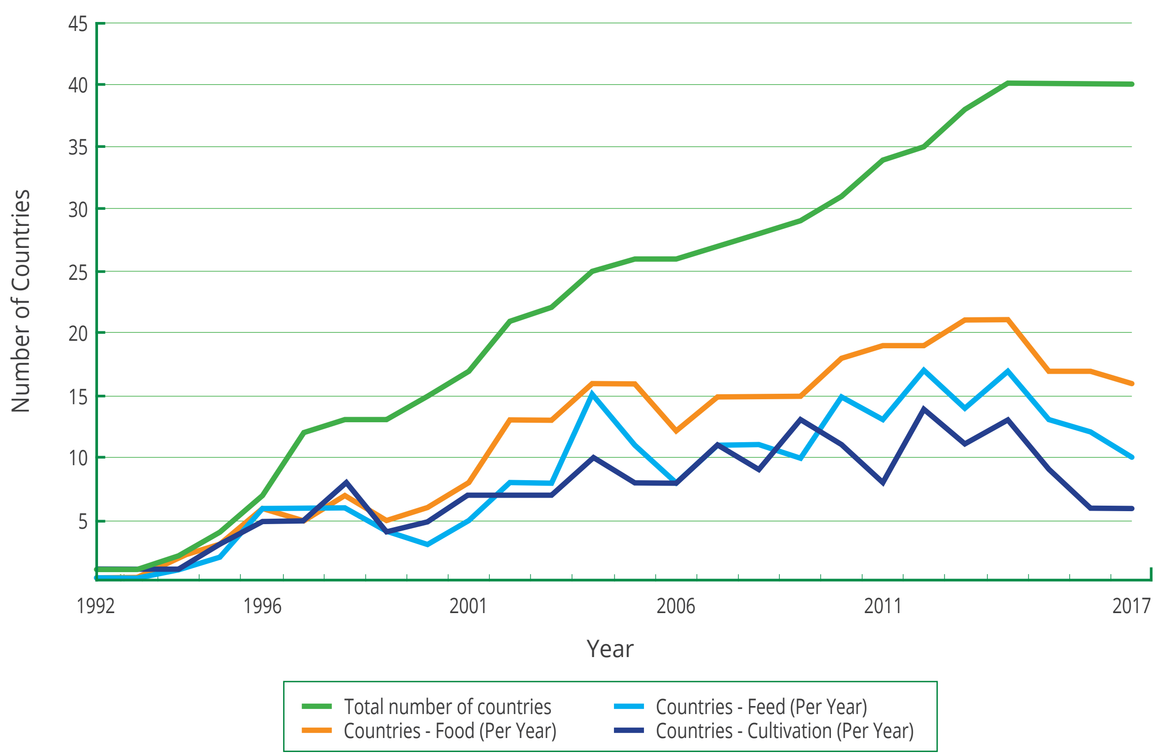
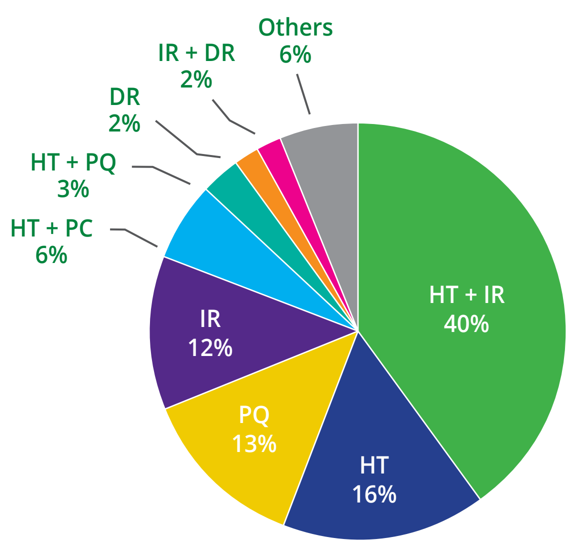


Figure 19. Number of countries that issued food, feed and cultivation approvals 1992-2017
Source: ISAAA, 2016

Figure 20. Number of GM Events Approved per Year

Source: ISAAA, 2016



HT - Herbicide Tolerance; IR - Insect Resistance; DR - Disease Resistance; PC - Pollination Control; PQ - Modified Product Quality: Anti-allergy; Delayed Fruit Softening; Delayed Ripening; Enhance Vitamin A Content; Modified Alpha-Amylase; Modified Amino acid; Modified oil/fatty acid; 8) Modified starch/carbohydrate; Nicotine Reduction; Non-Browning Phenotype; Phytase production; Reduced Acrylamide Potential; Reduced Black Spot Bruising

Figure 21. Distribution of Traits of Approved GM Events

Source: ISAAA, 2016

leading countries in GM approvals, only had six individual event approvals in 2017, their lowest since 2010. Approvals in other countries include both individual and stacked trait events.

In 2017, 70.8% of the approved events were stacked or pyramided. This trend of stacked events outnumbering the single events started in 2008 and peaked in 2013 (Figure 20). This is an indication that technology developers respond to farmers' preference for biotech events/varieties with more traits to offer for cost reduction and better economic profit. Another evidence of this is in Figure 21, in which events with both herbicide tolerance and insect resistance comprised 40% of the events approved, while events with more than one trait (HT + PC, IR + DR, and HT + PQ) make up at least 51% of the approved events. This trend will likely continue into the future since farmers demand more traits in an event, especially in maize.

Maize still has the most number of approved events. This is probably due to numerous single maize events which can be combined with other events to form a desired stacked traited event.

The overall total number of approvals for 2017 was 176, wherein 101 were for food, 52 for feed, and 23 for cultivation. These approvals are divided among 72 events from eight crops and were granted by 18 countries. Brazil had the highest number of approvals, including the new insect resistant sugarcane event, CTB141175/01-A, developed by Centro de Tecnologia Canavieira. Malaysia and South Korea were tied for second most number of approvals, while the USA and Argentina have six and three approvals, respectively, in 2017.

From 1992 to 2017, 40 countries (including EU 28, counted as one) have given 1,995 food approvals, 1,338 feed approvals, and 800 cultivation approvals (not including approvals for ornamentals such as carnation, rose, and petunia), scattered among 498 events of 29 crops.

BIOTECH CROP IMPORTING COUNTRIES

Globally, there are countries that adopt biotech crops through import for food, feed, and cultivation. Since commercialization began in 1996, countries have set up biosafety regulations in order to facilitate entry of biotech crops from outside sources. Laboratories were geared up to efficiently detect entry of non-approved biotech products into the country. Biotech crop approval had never been synchronized globally, as each country approves new crop events based on country needs and priorities. This disrupts trade and is a huge disadvantage to farmers in the country of origin. Measures should be set up to effectively synchronize approvals for the benefit of the farmers, consumers, and technology developers (ISAAA, 2016).

Since 1996, a total of 43 non-planting countries (17 + 26 countries from the EU) have approved biotech crops for import food, feed, and processing (FFP) (Table 37). Japan approved the most number of crops with 12, for import for food, feed, processing, and cultivation, but has not cultivated yet. However, farmers in Hokkaido have expressed their intention to conduct field trials of RR® sugar beets through a petition submitted by the Agricultural Academy of Japan (Crop Biotech Update, March 15, 2017).

The most number of import approvals was granted to biotech maize events given by 14 countries, followed by soybeans (10), cotton (8), and canola (7). In 2017, 33 countries (7 + 26 EU countries) approved new biotech events of these crops, plus biotech potato with the non-browning, non-bruising low acrylamide, and late blight resistance traits.

Overall, a total of 67 countries (24 planting and 43 non-planting countries) have formally adopted 29 biotech crops for food, feed, and cultivation in 2017. These biotech crops possess various traits with stacked HT/IR traits comprising 40% (Figures 20 and 21) of the total 4,133 approvals from 1992 to 2017, broken down into 1,995 food, 1,338 feed, and 800 cultivation approvals. Recorded economic benefits from biotech crops provide incentives to farmers to adopt an increasing area of biotech crops, technology developers to continue research and development for new crops and traits, and governments to approve these biotech crops for the use by farmers and consumers.

BIOTECHNOLOGY ADDRESSES GLOBAL FOOD INSECURITY: NOW AND INTO THE FUTURE

Call to Revitalize Efforts to Increase Food Production by 70%

Global food insecurity is still a leading problem in the developing world. According to the Global

Table 37. Non-planting Countries which Granted Approvals for Import (Food, Feed, and Processing) from 1996 to 2017

	Countries	Crops Approved for Import	
		1996-2016	2017
1	Burkina Faso	Cotton	
2	Cuba	Maize	
3	Egypt	Maize	
4	Indonesia	Maize, soybeans, and sugarcane	
5	Iran	Rice, soybeans and rapeseed	
6	Japan	Alfalfa, canola, carnation, cotton, maize, papaya, potato, rice, rose, soybeans, and sugar beets	Maize
7	Malaysia	Canola, carnation, cotton, maize, potato and soybeans	Cotton, maize, soybeans
8	New Zealand	Alfalfa, canola, cotton, maize, potato, rice, sugar beet, and wheat	Canola and potato
9	Norway	Carnation	
10	Panama	Maize	
11	Russian Federation	Maize, potato, rice, soybeans, and sugar beets	
12	Singapore	Alfalfa, canola, cotton, maize, soybeans and sugar beet	
13	South Korea	Alfalfa, canola, cotton, and maize	Canola, cotton, maize, and soybeans
14	Switzerland	Maize and soybeans	
15	Taiwan	Canola, cotton, maize, soybeans and sugar beets	Canola, cotton, maize, and soybeans
16	Thailand	Maize and soybeans	
17	Turkey		Maize and soybeans
18	26 EU countries	Canola, carnation, cotton, maize, potato, soybeans, and sugar beets	Canola, cotton, maize, and soybeans

Source: ISAAA GM Approval Database.

Report on Food Crises 2017, around 108 million people in 48 food crisis-affected countries are still at risk or in severe acute food insecurity in 2016. This is even amidst massive and collective efforts of international organizations to address food challenges. The report was an outcome of a study by collaborating organizations in the European Union, USAID's Famine Early Warning Systems Network (FEWSNET), regional food security institutions, UN agencies including the Food and Agriculture Organization (FAO), the World Food Prize and the UN International Children's Fund (UNICEF). The 108 million people experiencing food insecurity in 2016 is a significant increase from the 80 million people in 2015, and reflects the enormity of the problem that these people face in terms of accessing food due to conflict, the record-high food prices in local markets, and extreme weather conditions such as drought and erratic rainfall caused by El Niño. In nine out of ten worst humanitarian crises, civil conflict was found to be the driving force, indicating a strong link between peace and food security (FAO, July 3, 2017).

Furthermore, according to FAO Director-General Jose Graziano da Silva, sadly, the number of hungry people has reversed years of progress accomplished at the end of the Millenium Development Goals of 2015. About 60% of the hungry people are located in 19 countries facing conflict and climate change crisis situations. High risk of famine was recorded in northeast Nigeria, Somalia, South Sudan, and Yemen, where 20 million people were severely experiencing hunger. The FAO Director-General opined that in these situations, **"Strong political commitment to eradicate hunger is fundamental, but it is not enough. Hunger will only be defeated if countries translate their pledges into action, especially at national and local levels. Peace is of course the key to ending these crises, but we cannot wait for peace to take action. It is extremely important to ensure that these people have the conditions to continue producing their own food. Vulnerable people cannot be left behind, especially the youth and women."**

Global population in 2017 reached 7.6 billion and is expected to reach 8.6 billion in 2030, 9.8 billion in 2050 and 11.2 billion in 2100, according to the United Nations (2017). Roughly 83 million people are added to the world's population every year, and the upward trend is expected to continue, even if the fertility levels will continue to decline. Food experts for a long time believed that food production must double by 2050 to feed the world's growing population. However, researchers at Pennsylvania State University (2017) suggest that production likely will need to increase from 25% to 70% to meet the 2050 food demand. The authors, supported by data, believe that in the coming decades, agriculture will not only feed people, but must also ensure a healthy environment. To attain the agriculture for the 2050 population, quantitative targets need to be set both for food production and environmental impacts, and they must be treated as equal parts of agriculture's grand challenge. According to the researchers, in the need to increase food production to feed the 2050 population, agriculture's environmental impact has been increasing and it has to drop dramatically in order to maintain clean water and stabilize climate. In addition, farmers will need to ramp up efforts to hold nutrients in their fields, reduce greenhouse gas emissions, and improve soil health; this is where biotech crops will contribute immensely to agriculture that is sustainable, bountiful and profitable.

Decline in Food Production due to Climate Change

Climate change is another challenge that can cause a 23% decline in major crop production from maize, wheat, rice, and soybean by 2050. The Center of Development Research at the University of Bonn, Germany analyzed the price and production of the major crops from 1961 to 2013, and found that a significant decrease of 9% in the global output of major crops is expected to be evident by the 2030s. This decline in the 2030s will be manifested in several countries but will be more pronounced in all countries by 2050s. Furthermore, the increase in average temperatures during the growing season does not have much effect on staple crops until they hit a particular "tipping point", which is around 89^{o}F (32^{o}C). Aside from temperature, extreme weather conditions such as drought or too much rainfall could also decrease the production of crops (The Daily Climate, May 24, 2017).

Moreover, according to research conducted at Harvard University, the damage to crops will be worse than previous estimates when crops are exposed to projected atmospheric concentrations of carbon dioxide in 2050. Not just food quantity but food quality will be affected. The team found that the protein content of crops will be reduced considerably in major staple crops: barley (14.6%), rice (7.6%), wheat (7.8%) and potatoes (6.4%). This situation is more worrisome since 150 million people across 47 different countries will be at risk of protein deficiency by 2050, hugely impacting countries whose populations consume purely vegetables, such as India and other countries in South Asia. Other studies also point out that the zinc and iron content of staple crops will likewise be affected, whereby iron concentrations will drop by as much as 10% in maize for example, putting around 1.4 billion children at risk of major iron deficiencies by 2050 (Phys.org, August 2, 2017).

These forecasts are compelling as the reports show the extent of food and nutrient scarcity that the 2050 population could be facing. Thus, improvements in modern crop technology and agronomic practices have to be fully utilized because they have the capacity to reduce annual fluctuations in food availability as well as maintain nutritive contents of crops. Both mitigation and adaptation technologies are crucial in combating climate change. Adoption of biotech crops is one of the most effective crop adaptation technologies to combat climate change because crop varieties may be developed through modern methods of molecular biology and biotechnology to cope with salinity, submergence, and drought, as well as more virulent newly emergent insect pests and plant pathogens.

A New Call for Urgent Action to Reverse the Rise in Hunger

With the recent increase in the number of hungry people globally, urgent actions are needed to overturn this condition, according to Jose Graziano da Silva, Director-General of the Food and Agriculture Organization of the United Nations (FAO). He stressed that the latest hunger figure of 815 million people is the first increase after over ten years of steady decrease. Furthermore, obesity and overweight statistics are also growing, in developed and developing countries, which is another area of concern in current food systems. Thus, FAO calls for new and more investments from the public and private sector in order to build the resilience of poor people to face the impacts of conflicts and climate change. Current humanitarian assistance should be combined with development actions to chart a course towards the eradication of hunger by 2030 (FAO, December 4, 2017).

The FAO also sought more support from G20 countries so that family farmers can contribute more to meet food demand. The FAO Director General da Silva emphasized that millions of small family farmers need access to technical information and financial assistance to be more resilient and adapt to the impacts of climate change. He opined also that the rural areas are the key battleground in accomplishing the 2030 sustainable development agenda because the highest incidences of poverty and hunger are in rural areas. Furthermore, the increases in agricultural yield are needed in such locations because of the population boom. Thus, small family farmers need much support. Initiatives on Information and Communication Technologies (ICT) should be exhaustively utilized to provide farmers with tools to monitor and manage natural resources while promoting sustainable agriculture, and strengthening food security. More support to family farmers is needed to meet the world's rising food demands, FAO tells G20. (FAO, January 22, 2017).

The private sector also plays a big role in the quest for food security through their capacity to innovate. The global seed industry is one such entity which can immediately respond and adapt to global challenges. The seed industry has been the initiator in the development of innovations that will address global challenges such as food security. This call was made by the President of the ISF, Mr. Jean-Cristophe Gouache during the World Trade Congress Opening on May 22, 2017 in Budapest Hungary (International Seed Federation, May 22, 2017).

Optimum Biotech Crop Adoption to Benefit Global Population

Agricultural innovations such as biotechnology crops have been regarded as the fastest growing agricultural technology adopted by farmers in the last two decades. The area planted to biotech crops has increased in the last 22 years, with continuous growth in year-to-year increments, to reach close to optimum adoption rates of 94% and above, in the top five countries: USA (94.5%), Brazil (94%), Argentina (~100%), Canada (95%) and India (95%) in 2017. The number of countries increased from 6 in 1996 to around 30 countries and yearly fluctuations were due to various factors related to trade, domestic regulation, and product marketing. The number of countries planting and importing biotech crops increased to 67 indicating that there may be challenges in planting biotech crops, but more people accept, utilize and consume imported biotech products.

Benefits to the environment, consumers and the food industry, and more so, the livestock, pork and poultry industries from biotech crops have been documented in the last two decades. These are proofs that since 1996, biotech crops have contributed to sustainability, helped mitigate the effects of climate change, and helped alleviate poverty and hunger. To understand and appreciate the enormous economic gains of biotech crops, some essential data from the forthcoming report on the economic gains in the last 21 years by Brookes and Barfoot (2018, Forthcoming) are discussed below. This is in relation to the global area of biotech crops in 2016 and 2017, the biotech products in the pipeline, and some key messages to effectively convey the benefits of biotech crops and products.

Biotech crops increased productivity by 657.6 million tons and economic gain of smallholder farmers by US$186.1 billion

In the last 21 years (1996-2016), biotech crops and products have contributed to food, feed, and fiber security and self-sufficiency through increased productivity and economic gain. An economic gain of US$186.1 billion was obtained from 1996 to 2016, an 11% increase from the US$167.8 million recorded in 1996-2015 (Table 38). This economic benefit value was obtained from reduced production cost of 28% valued at US$52.1 billion and 72% due to yield gain, valued at US$134 billion. Through the 21 years of biotech crop commercialization, the yield gain has been increasing minimally compared to reduction of production cost due to less ploughing, fewer pesticide sprays and less labor. Similarly in 2016 alone, 17% (US$3.1 billion) of the economic value of US$18.2 billion was for reduced production cost, a 35% increase from the US$2.3 billion in 2015 alone (Table 38).

The productivity of the four major crops contributed to the 657.6 million tons gained from 1996 to 2016, with soybean having the highest year to year increment at 18%, followed by maize at 13%, canola at 10%, and cotton lint at 9% (Table 38). For 2016 alone, productivity gain was 82.2 million tons, a 25% increase from the 65.8 million hectares in 2015. The productivity gain in 2016 was contributed by the four major crops with year-to-year increments of 44% for soybeans, 18% for maize, 5% for cotton lint, and a 29% reduction for canola.

In 2016, the global soybean area was 91.4 million hectares which covered 50% of the total biotech crop area (ISAAA, 2016). Although there was a 1% reduction in the global soybean area between 2015 and 2016, productivity that accrued at the farm level of 31.6 million tons (Table 38) was mainly due to the global adoption of the no-till technology, as well as the high adoption of stacked IR/HT trait soybean Intacta™ which was adopted widely in Brazil, Argentina, Paraguay, and Uruguay. In 2017, there was a 3% increase in the global biotech soybean area despite the unfavorable planting conditions in some countries in Latin America (Argentina, Paraguay and Uruguay) that resulted in reduced soybean planting. This was balanced by increased total and biotech soybean area in the USA, Brazil, Canada, South Africa, and Bolivia.

A three-year *ex-ante* study on how biotech soybean will yield in 2050 conducted by University of Illinois researchers indicates that biotech soybeans will yield more than conventional soybeans in 2050. Biotech soybeans can harness genetic changes to help offset the detrimental effects of rising temperatures and carbon dioxide levels that can hit 600 parts per million – a 150% increase over today's levels (phys.org. May 3, 2017). The year 2050 is when the population is predicted to reach some 9.8 billion, an increase of 2 billion mouths to feed from today's 7.6 billion people). Biotech soybeans can contain various stacked traits to increase yield and be resistant to pests and diseases. Gene stacking is one of the many tools that can be used to improve cultivated crops in response to future problems of population growth and depleting natural resources.

The global area of maize in 2016 was 60.6 million hectares, which gained 13% from 2015 (ISAAA, 2016). The absolute incremental productivity increase of 7.4 million tons in 2016 from 40.3 million hectares in 2015 to 2016 was due to various maize seed technologies that farmers used in 2016, that increased yield. In 2016, the increased biotech maize area was due

Table 38. Economic Benefit Gains and Productivity at the Farm Level

	1996-2015	1996-2016	% Diff	2015 alone	2016 alone	% Diff
Economic Benefits						
Total (Billion, US$)	167.8	186.1	11%	15.4	18.2	18%
a. Reduced Production Cost* (billion, US$, %)	46.9 (28%)	52.1 (28%)	11%	2.3 (15%)	3.1 (17%)	35%
b. Yield Gain (billion US$, %)	120.9 (72%)	134 (72%)	11%	13.1 (85%)	15.1 (83%)	15%
Productivity (Million Tons)						
Total	574.0	657.6	15%	65.8	82.2	25%
a. Soybean	180.3	213.5	18%	21.9	31.6	44%
b. Maize	358.0	404.9	13%	40.3	47.7	18%
c. Cotton lint	25.2	27.5	9%	2.2	2.3	5%
d. Canola	10.6	11.7	10%	1.4	1	-29%

* Less ploughing, fewer pesticide sprays, and less labor
Source: Brookes and Barfoot, 2018, Forthcoming

to favorable market prices, demand for biofuel and animal feeds, as well as the increased corn borer infestations in parts of Europe which encouraged farmers to grow insect-resistant corn. In 2017, there was a minimal decrease of 2% in the biotech maize area because of reduced maize planting in the USA, unfavorable weather conditions in the maize-growing countries of Latin America and some regulatory problems in Asia and Europe.

The area planted to biotech canola in 2016 was 8.6 million hectares, a 1% increase from 8.5 million hectares in 2015 (ISAAA, 2016). The production from herbicide tolerant canola in 2016 alone declined by 29% from 1.4 million tons in 2015 to 1 million tons in 2016 due to reduced yield associated with climate change problems. The area planted to biotech canola increased by 19% in 2017 (Table 35) due to the adoption of new biotech canola varieties with nutritious oil content and various types of herbicide tolerant traits.

Biotech cotton yield increased by 5% from 2.2 million tons in 2015 to 2.3 million tons in 2016 (ISAAA, 2016) because of the new biotech cotton varieties introduced in 2016 such as BollgardIII/RR Flex™. This enabled cotton crops to have high yield despite a reduced area planted to biotech cotton in 2016, as well as high insect pressure in some cotton-growing areas. Global cotton prices increased in 2017 that provided more incentives for farmers to increase the planting area for biotech cotton by 8%.

Three staple crops: rice, wheat, and potato have been improved to resist pests and diseases, increase yield and reduce wastage. These three biotech staple crops, once commercialized, have huge potential to be adopted in developing countries and play a big role in ensuring food security. This is a major challenge, given the projected need to increase world food production by 40% in the next 20 years, and 70% by 2050.

Biotech crops conserve biodiversity and saved 183 million hectares of land

The rapid growth of human population as well as anthropogenic activities has a huge impact on the agricultural landscape. To provide for food and shelter to the burgeoning population, lowlands of tropical, subtropical and temperate regions have been stripped off more than half of their original vegetation, with the remaining natural habitats persisting only in relatively small patches. In many ways, agriculture has contributed to a loss of biodiversity, but with modern forms of agriculture, including genetic engineering, loss of biodiversity has slowed down. This is because existing crop varieties have been improved with new economic traits including improved yield and resistance to biotic and abiotic stresses so that the optimum amount of food can be produced in the same or smaller area of about 1.5 billion hectares, saving biodiversity in land areas and forest sanctuaries.

In the last 21 years, (1996-2016), the 657.6 million tons of productivity gained through biotechnology has saved 183 million hectares of land from being ploughed and cultivated (Table 39). This is a 5% increase from the amount of land saved in 1996-2015 at 174 million hectares. For 2016 alone, the 82.5 million tons of productivity gained through biotechnology has saved 22.5 million hectares of land. The no-till technology or herbicide tolerance technology has provided farmers the option not to plough and cultivate the soil. From 1996 to 2015, herbicide tolerance has consistently been the dominant trait grown by farmers, but has declined in 2016 with the increasing prominence of the stacked IR/HT traits (ISAAA, 2016). In 2016, herbicide tolerance deployed in soybeans, maize, canola, cotton, sugar beets and alfalfa occupied 86.6 million hectares or 47% of the 185.1 million hectares of biotech crops planted (ISAAA, 2016). In addition, the increased yield and reduced use of hazardous chemical using this technology also benefited up to 17 to 18 million farmers globally.

Table 39. Land Savings through Biotech Crops

	1996-2015	1996-2016	% Diff	2015 alone	2016 alone	% Diff
Productivity (Million Tons)	574.0	657.6	14%	65.8	82.5	26%
Area Saved (Million Hectares)	174.0	183.0	5%	19.4	22.5	16%

Source: Brookes and Barfoot, 2018, Forthcoming

Furthermore, the land saved to produce the 657 million tons also prevents deforestation for agricultural purposes. The World Carfree Network (SciTechDaily, April 26, 2018) indicated that cars and trucks account for about 14% of global carbon emissions, while most analysts attribute upwards of 15% to deforestation. Logging contributes greatly to global warming because when trees are felled the stored carbon is released into the atmosphere, and together with other greenhouse gases from other sources, contributes to global warming accordingly.

Biotech crops reduce agriculture's environmental footprint by 671 million kgs active ingredient

Before the commercialization of biotech crops, farmers used to endlessly rip up or till the soil to remove weeds that affect growth and yield of food crops. With the introduction of herbicide tolerant soybeans, farmers used a variety of herbicides, 68% of which had high toxicity scores. Weeds account for about 20-40% decrease in global food production. However, indiscriminate use of herbicides had a negative impact on the environment. By 2006, the majority of soybean farmers had switched to the less toxic herbicide glyphosate as the active ingredient (a.i.). Glyphosate is the most widely used and successful herbicide on the market to date (Fernandez-Cornejo et al., 2017).

Recent attention by critics of biotech crops to the seemingly increased glyphosate use has again stirred criticisms about the environmental safety of the herbicide. However, various scientific accounts in the past 40 years on the use of glyphosate in biotech and non-biotech crops prove that it poses no threat to human health (FAO/WHO, 2016). In addition, the reported increase in the volume of herbicide use in agricultural systems is a poor measure of environmental impact because glyphosate is less harmful to the environment than the herbicides it has replaced. The increase in amount is therefore inconsequential because the safety of consumers and the environment is the net effect of the change.

On the other hand, reports from University of Wyoming indicate that herbicide use has increased more rapidly over the last 25 years in non-biotech crops than in biotech crops. Herbicide use intensity increased over the last 25 years in maize, cotton, rice and wheat. Thus, even if GM crops were perceived to cause an increase in herbicide use, the actual increases in herbicide use were faster in non-GM crops. **The results showed that even as herbicide use increased, chronic toxicity associated with herbicide use decreased in two out of six crops, while acute toxicity decreased in four out of six crops. In the last year of the study, glyphosate accounted for 26% of maize, 43% of soybeans, and 45% of cotton herbicide applications. However, due to the relatively low chronic toxicity of glyphosate, it contributed only 0.1, 0.3, and 3.5% of**

the chronic toxicity hazard in those crops, respectively (Kniss, 2017).

In fact, the Committee for Risk Assessment (RAC) of the European Chemicals Agency (ECHA) has concluded that the available scientific evidence did not meet the criteria for the classification, labeling and packaging regulation to classify glyphosate as a carcinogen, as a mutagen or as toxic for reproduction. The RAC assessed glyphosate's hazardousness against these parameters and considered extensive scientific data to reach this conclusion. The committee also had a full access to the original report of studies conducted by industry, apart from the published studies of glyphosate. RAC assessed all the scientific data, including any scientifically relevant information received during the public consultation in 2016 (European Chemicals Agency, March 15, 2017).

Furthermore, in November 2017, EU's European Commission's Appeal Committee voted for the renewal of glyphosate for five years, after the 15-year license for glyphosate expired in December 2017. The current renewal entered into force from December 16, 2017, and the regulation is binding in its entirety and directly applicable in all the EU Member States. According to a noted plant ecologist Jonathan Storkey, from Rothamsted Research in the UK, **"I believe the renewal of the approval of glyphosate is to be cautiously welcomed and is the right decision. In terms of direct toxicity on non-target organisms, it is relatively benign, and it is an important mainstay of weed control. Some weed species that have evolved resistance to other herbicides would become extremely difficult to control without glyphosate and it is particularly useful in cropping systems that minimize soil disturbance which itself brings environmental benefits"** (Rothamsted Research, November 27, 2017).

Moreover, contrary to biotech critics, reports by Brookes and Barfoot (2018, Forthcoming) revealed that by using biotech crops, the environmental footprint from agriculture was reduced over the last 21 years by 671 million kgs active ingredient (a.i), an 8% increase from the period 1996-2015 at 619 million kgs (Table 40). In 2016 alone, there was 48.5 million kgs reduction in pesticides a.i., an increase of 30% from 2015 alone. In addition, with the prolonged use of the technology, the reduction of environmental impact quotient (EIQ) increases, protecting the agricultural environment of soil and water. EIQ is a numerical representation of the risks a pesticide poses to the environment, consumers and farm workers. During the two time periods, pesticide savings and reduction

Table 40. Reduction in Pesticides and Environmental Impact Quotient

	1996-2015	1996-2016	% Diff	2015 alone	2016 alone	% Diff
Reduction in pesticides (Million kgs. active ingredients [a.i.])	619.0	671.0	8%	37.4	48.5	30%
Pesticides savings (%)	8.1%	8.2%	1.2%	6.1	8.1	33%
Reduction in EIQ*	19.0%	18.4%	-3%	18.5	18.3	-1%

*Environmental Impact Quotient (EIQ) = a composite measure based on the various factors contributing to the environmental impact of an individual active ingredient.
Source: Brookes and Barfoot, 2018, Forthcoming

in EIQ were 8.2% and 18.4%, respectively. The corresponding values in 2016 increased over 2015 by 30% for a reduction in pesticide, 33% for pesticide savings and 1% for a reduction in EIQ.

Biotech crops with stacked IR/HT traits increased in 2016 by 29% from 58.5 million hectares in 2015 to 75.4 million hectares in 2016 (ISAAA, 2016). This increased global adoption brought immense impact to the environment through reduced active ingredients, increased pesticide savings and reduction in EIQ in 2016 as indicated in Table 40. Farmers adopting these technologies therefore contribute to the reduction of agricultural footprint in the course of producing food for the increasing global population. In 2017, the area planted to stacked traits increased by 3%, proving that farmers accept and enjoy the benefits of the technology.

Biotech crops mitigate climate change with savings of 27.1 billion kgs of CO2

Conventional breeding is losing the battle against climate change. The rate at which temperatures across the globe are increasing the frequency of climate-change related stresses occur are outpacing the speed at which new adapted crop varieties are developed and deployed. Biotech crops contribute to a reduction of greenhouse gases and help mitigate climate change by permanent savings in carbon dioxide emissions. This is achieved through reduced use of fossil-based fuels associated with fewer insecticide and herbicide applications, and reduction in farm operations such as ploughing (Tables 39 and 40) in no-till agriculture associated with the use of herbicide tolerant crops.

It is noteworthy that reduced ploughing/tilling contributes greatly to minimize CO2 emission. Tilling mechanically turns over and breaks up soil to prepare for planting. It incurs the use of fossil fuels and at the same time leaves soil vulnerable to erosion and contributes to increased pollution and sedimentation in streams and rivers and loss of land to desertification. According to the World Wildlife Foundation, half of the topsoil on the planet has been lost in the last 150 years. Less tilling results in less erosion, more water retention, and fewer greenhouse gas emissions due to less soil disturbance as farm machineries make the field rounds, and lowered fuel costs as well as decreases machinery maintenance costs. In 2016, total savings of 27.1 billion kgs of CO2 was obtained, an increase of 1% from the 26.7 billion kgs saved in 2015 (Table 41). In addition, with the use of biotech crops, the total CO2 emissions saved from reduced sprays and ploughing of 27.1 billion kgs is equivalent to taking 16.7 million cars off the road. Since there was an increase by 1% in the CO2 emissions saved, the corresponding number of cars removed from the road increased by 40% from 11.9 million cars in 2015 to 16.7 million cars in 2016.

CO2 accumulation in the atmosphere contributes to global warming that affects agricultural productivity. With biotech crops, the 183 million hectares of land saved to produce the 657.6 million tons of food (Table 39) also prevents deforestation to make way for food production. Thus, adoption of biotech crops not only contribute to food security and sustainability, but also provide adaptive technologies such as improved seeds, which also serve as mitigation measures to manage problems associated with climate change.

Biotech Crops with Traits to Benefit Farmers and Consumers

Products of biotechnology were developed in response to the needs of farmers for traits that will lessen cost of production, provide enormous yield, and are nutritious to consumers. The development and market release of biotech crops follows a borderless trend for new crops and traits from 1992 to

Table 41. Savings on CO2 Emissions Equated with Number of Cars off the Road

	2015	2016	%
Savings in CO2 emissions due to reduced use of fossil-based fuels (Billion kgs)			
a. Due to reduced insecticide and herbicide sprays	2.8	2.9	4%
b. Due to reduced ploughing	23.9	24.2	1%
Total CO2 emissions	26.7	27.1	1%
Reduction in number of cars off the road (Million)			
a. Due to reduced insecticide and herbicide sprays	1.2	1.8	50%
b. Due to reduced ploughing	10.6	14.9	41%
Total cars off the road	**11.9**	**16.7**	**40%**

Source: Brookes and Barfoot, 2018, Forthcoming

2017. The commercialization of first generation biotech crops started in 1996 and featured agronomic input traits in HT soybean and canola, IR maize and cotton. These were followed by HT maize and cotton in 1997, virus resistant papaya and squash in 1999, and HT sugar beets in 2008. Second generation input traits consisted of stacked IR/HT soybeans, maize, and cotton commenced in early 2000s (most notably the HT/CRW (corn root worm-resistant) maize, IR/HT soybeans in 2013), and the drought tolerant maize launched in 2013.

Third generation output products with improved product quality and nutrition for livestock and food, started to be commercialized in the mid-2000s. These include modified oil in canola and soybeans, lysine content in maize, nicotine reduction in tobacco, delayed ripening in melon and tomato, phytase production in canola and maize, anti-allergy rice, altered lignin production in alfalfa, potatoes with black spot bruising tolerance, non-browning, and reduced acrylamide potential, as well as non-browning apple.

The increased adoption of biotech crops which is currently at the optimum rate in major biotech growing countries reflect farmer satisfaction and reliability in providing food and feed globally. Benefits that accrue to farmers and the communities are mounting since these crops were commercialized. Selected biotech crops which provided billions of benefits were single-traited products HT soybean, IR cotton, IR maize, HT maize, and HT canola, as well as stacked traits soybeans (Intacta) and CRW maize

Economic benefits of HT soybeans increased by 14% in 2016

HT soybeans, the dominant biotech crops commercialized since 1996, have provided insurmountable benefits to HT soybean farmers by as much as US$4.3 million in 2016 alone, a 14% increase from US$3.8 million in 2015 (Table 5). In 2016, HT soybean was planted by soybean farmers on 67.9 million hectares, a reduction of 14% in 2015 by 11 biotech farming countries of the USA, Brazil, Argentina, Canada, Paraguay, Uruguay, South Africa, Bolivia, Mexico, Chile and Costa Rica. HT soybean farmers in these countries have benefited largely due to the cost-savings and less labor requiring no-till technology deployed in high yielding soybean varieties even at a reduced biotech soybean area. With the increasing adoption of biotech soybeans in its 21 years of commercialization, an accumulative US$54.5 billion dollars worth of benefits were enjoyed by soybean farmers. This is a 40% increase compared to the period 1996 to 2015 at US$50 billion (Table 42). Biotech soybean farming in small developing countries such as South Africa, Paraguay, Uruguay, Bolivia and Mexico has been generating additional income to the country. In Bolivia for example, biotech soybean and biotech maize (if planted in the country) could generate US$150 million additional income for the country (see Bolivia chapter), according to the report released by the Association of Producers of Oilseeds and Wheat (Anapo) and other partners. The biotech crop helped the country to accumulate US$177 million in savings from 2005-2015, reduced the use of pesticides and saved US$66 million per year. This is in addition to the increase of 200,000 tons in production which translates to US$50 million profit per year – immense and huge benefits for a small country with 70% of farmers planting biotech soybeans in small scale (less than 50 hectares per farmer).

Since 1996, new biotech soybean events have been approved for food and feed imports, and cultivation globally which consequently increased biotech soybean area and its benefits. The market release of Intacta™ soybean in 2013 was welcomed by countries in Latin America: Brazil, Argentina, Paraguay and Uruguay. It is notable that recorded benefits in the last 21 years were US$5.2 billion, a 117% increase from US$2.4 billion from the period 1996 to 2015. For 2016 alone, the benefits increased by 103% from US$1.2 billion in 2015 to US$2.6 billion in 2016 (Table 42). This amplified benefits

Table 42. Economic Benefits by Crop Traits (Million US$)

Crops by Trait (Start of Planting)	2015	2016	% Diff	Start Year to 2015	Start Year to 2016	% Diff
Single Traits						
HT Soybean (1996)	3,822.0	4,373.0	14%	50,039.7	54,524.0	9%
IR Cotton (1996)	3,267.0	3,6950	13%	50,274.8	53,986.0	7%
IR Maize (1996)	3,356.0	3,722.0	11%	33,401.0	36,908.0	10%
HT Maize (1997)	1,788.0	2,105.0	18%	11,103.8	13,103.0	18%
HT Canola (1996)	655.0	510.0	-22%	5,479.6	5,971.0	9%
HT Cotton (1997)	117.0	130.0	11%	1,722.7	1,917.0	8%
HT Sugar beets (2008)	54.0	49.7	-8%	410.6	466.0	13%
VR Papaya (1999)	1.4	1.3	-7%	27.9	29.2	5%
VR Squash (1999)	10.4	10.4	0%	278.8	289.2	4%
DT Maize (2014)		20.0			33.3	
Stacked Traits						
Intacta Soybeans (2013)	1,227.0	2,491.0	103%	2,405.2	5,212	117%
CRW Maize (2003)	1,107.0	1,067.0	-4%	12,557.0	13,624.0	8%
Totals	**15,404.8**	**18,174.4**	**18%**	**167,751.1**	**186,062.7**	**10%**

Source: Brookes and Barfoot, 2018, Forthcoming

coincided with the expanded area for Intacta™ from 12.9 million hectares in 2015 to 23.4 million hectares in 2016 – an 81% increase. These economic benefits are enjoyed by most soybean farmers in this part of Latin America, which can also be beneficial to other farmers planting soybean in the world.

It is noteworthy that in 2017, Brazil approved four biotech soybean events for cultivation that included stacked IR/HT soybean event (IR (lep)/HT (glyphosate), and 3 HT traits (glyphosate, glufosinate and methozone resistance) stacked with IR (lep). Brazil is one of the leading countries in biotech soybean area, which is estimated to surpass the USA – not an impossibility – with the national approval of these products in the country.

Economic benefits of IR cotton increased by 13% in 2016

IR cotton accumulated the second highest economic benefits since it was planted in 1996. The total benefits for 21 years (1996-2016) amounted to US$54 billion, 7% higher than IR cotton in the period 1996-2015. For 2016, the economic benefits amounted to US$3.7 billion, a 13% increase from US$3.3 billion in 2015 (Table 42). Biotech IR cotton has been planted in 2016 by 8 countries, with the highest area planted in India followed by Pakistan, China, Myanmar, USA, Brazil, Sudan, and Costa Rica. The IR cotton area decreased by 11% in 2016 from 19.4 million hectares in 2015 to 17.2 million hectares in 2016, as farmers opted to plant more of the stacked trait IR/HT cotton. In India, the leading IR cotton adopting country, some 7.2 million smallholder farmers holding only at most 1.5 hectares planted 11.4 million hectares of IR cotton in 2017. Biotech cotton farmers in Pakistan, China, and Myanmar also have smallholder cotton farmers with less than 2 hectares farmed per farmer. Thus, the bulk of the IR cotton benefits are enjoyed mostly by farmers and families in these developing countries with accumulated benefits of US$21.1 billion for India, US$4.8 billion for Pakistan, US$19.6 billion for China and US$358 million for Myanmar (Brookes and Barfoot, 2018, Forthcoming). These monetary benefits were accompanied by increases in yield, improvements in cotton quality, reduced insecticide use applications and hazardous exposure, as well as benefits to the environment and non-target organisms. New IR cotton varieties with resistance to lepidopterous insects were approved in Costa Rica in 2017. Although Costa Rica plants biotech IR cotton seeds for export only, these new approvals increased the IR cotton technologies available to IR cotton planting countries.

Economic benefits of IR maize increased by 11% in 2016

IR maize was planted starting 1996 and had accumulated US$36.9 billion in the last 21 years, higher by 10% in the period 1996 to 2015. In 2016 alone, economic benefits were US$3.7 million, an increase of 11% from 2015, valued at US$3.3 billion (Table 42). IR maize was planted on 5.9 million hectares in 2016, similar to 2015 and occupied 10% of the total biotech maize planted in 2016 (ISAAA, 2016). Biotech maize farmers have been increasingly using the stacked trait IR/HT maize such as CRW maize, which is a cost reducing technology. Since 1996, IR maize farmers in 11 adopting-countries Brazil, USA, Argentina, Canada, Paraguay, South Africa, Spain, Honduras, Portugal, Czech Republic and Slovakia (ISAAA, 2016) have benefited from the savings due to reduced insecticide use and applications, increases in yield, improved maize quality associated with fungal infection, reduced hazardous pesticide exposure, as well as the benefits to the environment and non-target organisms. It is noteworthy that EU countries Spain, Portugal, Czech Republic and Slovakia have been steadfast in their support of the technology in 2016 because IR maize is the only technology that can combat the devastating European corn borer. Developing countries Brazil, Argentina, Paraguay, South Africa, Philippines, and Honduras have been consistently growing IR maize and also slowly adopting the more profitable stacked trait IR/HT events such as HT/CRW maize. Recorded economic benefits from HT/CRW maize from 2003 to 2016 were US$13.6 billion hectares, an increase of 8% from US$5.6 billion in 2003 to 2015. However, in 2016, economic benefits gained from this stacked maize slightly reduced with the approval and market release of other IR/HT maize events. In 2017, Brazil approved a pyramided IR resistant maize to control lepidopterous insects through three genes encoding insecticidal proteins: *vip3Aa* variant, *cry2Ab* delta-endotoxin, and *cry1A.105* gene (a gene fusion comprised of *cry1Ab*, *cry1F*, and *cry1Ac*).

Accumulated benefits of HT maize increased by 18% over a 19-year period

HT maize has been commercialized since 1997 with accumulative economic benefits of US$13.1 billion over a 19 year period. This is 18% higher than the accumulated economic benefits of US$11.1 billion from 1997 to 2015. In 2016, economic benefits of planting HT maize were at US$2.1 billion, a 17% increase from 2015 at US$1.8 billion (Table 42). HT maize in 2016 was planted by 10 countries: USA, Brazil, Argentina, Canada, South Africa, Paraguay, Philippines, Uruguay, Colombia, and Honduras. HT maize comprised 11.6% of the biotech maize area in 2016, higher by 1.1 million hectares compared to IR maize. Similar to HT soybean, the no-till technology in HT maize provides control to the obnoxious weeds in maize fields initially through single gene products, and with multiple herbicide tolerance genes, soon after. Biotech maize varieties resistant to the tandem of glufosinate and glyphosate herbicides have been available since the mid 2000s. Moreover, farmers have started using maize varieties with multiple HT and multiple IR genes due to profitability, reduced labor use and more trait efficiency. In 2017, various IR/HT stacked traits were approved for cultivation in the USA, Brazil, Canada, and Paraguay. These new technologies can effectively control weeds through tolerance against glufosinate, glyphosate, and 2,4-D, as well as resist various insects such as lepidopterans, and coleopterans.

Accumulated benefits of HT canola increased by 9%

HT canola is the fifth most important biotech crop trait commercialized in 1996, which has been adopted largely in Canada, the USA, and Australia. In the last 20 years (1996-2016), economic benefits from this biotech crop have reached US$5.9 billion, a 9% increase from US$5.5 billion recorded in 1996-2015. In 2016 however, a 22% reduction in economic benefits was observed, from US$655 million in 2015 to US$510. Although the area of biotech canola increased marginally by 1% in 2016, yield declined due to unfavorable growing conditions in Canada and Australia. These three canola growing countries support the technological needs of canola farmers in their country. Since 1996, various varieties with multiple HR genes for glufosinate, glyphosate, and oxynil tolerance were developed and made available to farmers. Increasing adoption of HR canola is expected with the approval in the USA of a new canola event with glufosinate and pollination control in 2017. In addition, global area and adoption of canola could increase significantly in the near term in response to the likely increased use of canola for vegetable oil and biodiesel.

Other biotech crops presented in Table 42 all showed an increasing trend compared to the previous time period. HT cotton increased by 8%, HT sugar beets by 13%, virus resistant (VR) papaya by 5% and VR squash by 4% (Table 42). From the year these biotech crops were first cultivated, the size of the area varied from year-to-year depending on the global market price and demand, the prevailing weather conditions during the planting season, and the internal regulatory issues in the planting countries.

For 2016 alone, the economic benefits of HT cotton went up by 11% at US$130 million compared with US$117 million in 2015. This increase in economic benefits coincides well with the increase by 38% of HT cotton area in 2016 compared to 2015, a manifestation that farmers which planted HT cotton benefited largely from the no-till technology and lesser cost of production.

The decline in economic benefits in 2016 of HT sugar beets by -8% from US$54 million to US$49.7 million, even if the biotech sugar beet area was similar, was due to the unfavorable conditions during the planting season affecting yield, sugar quality, and low sugar market price. Economic benefits of virus resistant squash and papaya, which are planted at small scale in China and the USA derive the benefits from high yield and high quality of the produce that demand higher price, as well as the reduced chemical applications to control the aphid vector of the virus.

Biotech drought tolerant maize planted on a commercial scale at ~1.2 million hectares in 2016 generated US$20 million economic benefits in 2016 and US$33.3 million for the period 2014 to 2016 (Table 42). Drought tolerant maize can reduce transpiration by 175% under stress conditions. This allows for better moisture retention to reduce drought conditions without additional irrigation. The economic benefits were therefore derived from lower production cost due to reduced water application, labor and fuel use. Farmers in developing countries who have smaller farms and less capital will gain immensely using this technology. In addition, stacked trait maize events with drought, herbicide tolerance, and insect resistance have been deployed since 2014. In 2017, a total of 1.4 million hectares of these drought tolerant stacked maize events were planted. This technology will also be beneficial to farmers in other countries where extreme drought occurs such as in Africa, Europe, and some parts of Latin America and Asia.

GLOBAL VALUE OF BIOTECH CROP SEEDS SOARED TO US$17.2 BILLION, GMO CROPS AND SEEDS MARKET REVENUE TO INCREASE BY 10.5% IN 2025

Biotech crops have delivered insurmountable economic benefits in the last 22 years and are continuously contributing to food sustainability and security, alleviation of poverty and hunger, environmental and food safety, as well as in adaption and mitigation of the harmful effects of climate change. Cropnosis, an independent provider of market research, industry analysis and strategic consulting in agrochemical and agribiotechnology, as well as various international economic analysts provide the current and future forecast of the global value of biotech crops, respectively.

In 2017, the global market value of biotech crop seeds, estimated by Cropnosis was US$17.2 billion (up by 9% from US$15.8 billion in 2016) and in an increasing trend from 1996 at US$93 million, a 185-fold increase (Figure 22); this represents 23.9% of the US$70.9 billion global crop protection market in 2017, and 30% of the US$56.02 billion global commercial seed market (Global Seeds Industry, 2017). The US$17.2 billion biotech crop seed market comprised of maize, soybeans, cotton, canola, and other crops (Table 43). Biotech maize had the highest seed sale value at US$8.72 billion, which is 51% of the total market value of US$17.2 billion. The highest year-on-year increase in value however, was obtained by biotech soybeans at 14%. The biotech seed sales for biotech soybean and maize are reflective of the biotech crop areas in 2017 – biotech soybean area increased by 2.7% while biotech maize was reduced by 1%.

The global GMO seed and total seed market will display moderate growth for the forecast

Table 43. The Global Biotech Seed Sales, 1996 to 2017, (US$ Billion)

	2016	2017	% Diff	% of Total
Maize	8.38	8.72	4%	51%
Soybean	5.53	6.33	14%	37%
Cotton	1.27	1.42	12%	8%
Canola	0.40	0.46	13%	3%
Sugar Beet & Others	0.23	0.25	6%	1%
Total	**15.80**	**17.18**	**9%**	**100%**

Source: Cropnosis, 2018, Personal Communication

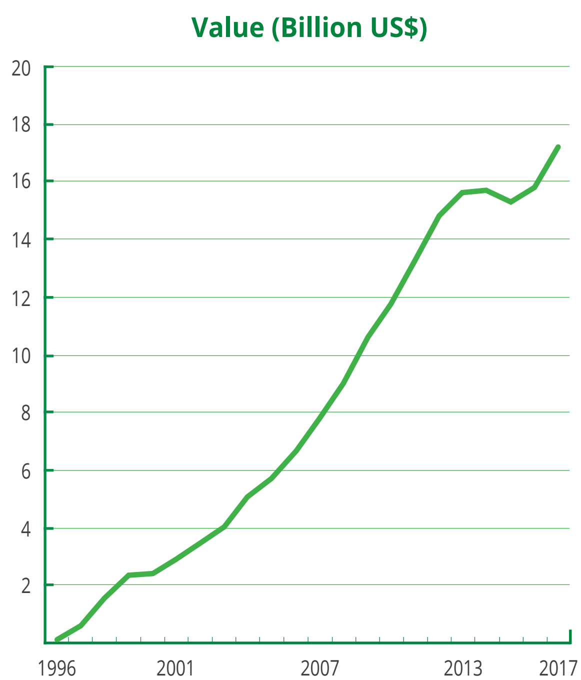


Figure 22. The Global Value of the Biotech Crop Market, 1996 to 2017

Source: Cropnosis, 2018, Personal Communication

period between 2017 and 2022, according to Transparency Market Research (Sept. 6, 2017). The global combined GMO seed and non-GMO seed market revenues are expected to be worth US$36,653.2 million by the end of 2022, expanding at a compounded average growth rate (CAGR) of 8.3% between 2017 and 2022. A summary of the forecast shows that:

1. Maize will account for a significant share of the GMO seed and total seed market (37.8%) valued at US$9.3 billion in 2017, and is expected to expand by 8.2% between 2017 and 2022 to attain a value of US$13.8 billion at the end of 2022 with a slight reduced share of 37.6% of the market. The year-on-year growth of the maize segment is estimated at US$890.6 million, the largest of the crop type segment.
2. North America will remain the leading regional market for GMO seed and total seeds at CAGR of 7.6% between 2017 and 2022, and is anticipated to attain a value of US$13.9 billion by the end of 2022 from US$9.6 billion in 2017.
3. Europe is expected to have CAGR of 9.2% between 2017 and 2022 and expected to attain a valuation of US$11.2 billion by the end of 2022.

4. The Asia Pacific except for Japan (APEJ) accounts for a substantial revenue at a CAGR of 7.6% between 2017 and 2022, and is anticipated to reach a valuation of US$5.1 billion by the end of 2022. On the other hand, Japan GMO crops and seeds market is anticipated to present an opportunity of US$773.5 million.
5. The Middle East and Africa GMO seed and total seeds market are projected to be worth US$1.2 billion by the end of 2022, expanding at a CAGR of 7.4% between 2017 and 2022.

Another similar forecast was reported by the Progressive Markets (2017) on "Global Seed Market – Size, Trend, Share, and Opportunity Analysis and Forecast for 2014-2025" indicating that the global biotech crop industry is predicted to increase at a CAGR of 10.5% during the period 2017-2025.

Thus, the positive forecasts of the two reports with an increase of 8.3% to 10.5% by the end of 2022 and 2025, respectively, provide forward looking information for seed developers and the food industry the enormous economic benefits that can be obtained in the seed market if biotech crops are continuously planted globally. However, if the global community decides to somehow stop planting biotech crops regionally or globally, a huge opportunity costs are estimated to be at stake.

OPPORTUNITY COSTS WITHOUT GLOBAL BIOTECH CROPS

Despite all the documented benefits discussed above, critics of biotech crops have been raising non-scientific allegations that may affect country regulations and approvals of biotech crops. Governments are concerned about the safety, access, and profitability of biotech crops, as well as local interests on biodiversity protection and trade competitiveness. Hence, regulations become stringent which stifle access of farmers to the technology and its economic benefits.

The benefit, profit, or value of something that must be given up to acquire or achieve something else is called opportunity cost. These are fundamental costs in economics, and are used in computing cost benefit analysis of a project. Some of the most recent studies on opportunity cost if and when biotech crops and traits are not planted either regionally or globally are discussed below.

Restrictive regulation could cost low-and lower middle-income nations up to US$1.5 trillion in foregone economic benefits through 2050.

In Europe, where there is massive biotech crop importation, long standing campaigns against biotech crops have hindered development and adoption of biotech crops. The policies and practices impose considerable costs on the economies of the exporting countries as well as deny developing countries which have the greatest need of the technology and its benefits. According to the Information Technology and Innovation Foundation (ITIF) study led by L. Val Giddings (2016), the current restrictive regulatory climate for agricultural biotech innovations could cost low- and lower middle-income nations up to US$1.5 trillion in foregone economic benefits through 2050. Furthermore, it is estimated that for African agricultural economies alone, the continued suppression of biotech innovations in agriculture had cost at least US$2.5 billion from 2008-2013. Thus, according to the authors, GMO critics have erected sufficient barriers to the development of the poorest nations on earth who mainly rely on agriculture for subsistence, which is a moral disaster.

Delayed approval of biotech canola due to SEC-based moratoria resulted to a foregone

output of 1.1 million metric tons of canola and US$377.9 million economic loss in Australia

In Australia, opportunity cost for the economic and delayed adoption of biotech canola between 2004 and 2014 was estimated in a report by Biden et al (2018). The report indicated that the incorporation of socio-economic considerations (SECs) into the national biosafety regulations regarding biotech crops have opportunity costs. Biotech canola has been approved by the Government of Australia after a thorough science-based risk assessment in 2003, however, state moratoria were allowed based on potential trade impact over the period 2004 to 2008, and 2010 in the main canola growing states. Farmers in Victoria and New South Wales started planting biotech canola in 2008 and in Western Australia in 2010. The area of biotech canola increased year-on-year with the highest recorded area of 432,000 hectares in 2017. The total farm income gain of US$16.7 million was reported in 2015, when the area of biotech canola was 444,000 hectares, and the accumulated total farm income gain from 2008 was US$73.9 million (Brookes and Barfoot, 2017).

Biden et al. (2018) on the other hand conducted a counterfactual assessment using the Canadian biotech canola adoption data to measure the environmental and economic opportunity costs of Australia's SEC-based moratoria between 2004 and 2014. The report indicated "that the environmental opportunity costs from delaying the adoption of biotech canola in Australia include an additional 6.5 million kgs of active ingredients applied to canola farm; 8.7 million liters of diesel fuel burned; and an additional 24.2 million kilograms of greenhouse gas (GHG) and compound emissions released." The economic opportunity cost of the SEC-based moratoria resulted in foregone output of 1.1 million metric tons of canola, and a net economic loss to canola farmers of AU$485.6 million (US$377.9 million). Farmers in South Australia are still suffering from the current moratorium on biotech crop commercialization, which farmers in other parts of Australia are benefiting from since 2008. Opportunity cost is expected to mount as this moratorium is extended until 2025 without a price premium given to non biotech canola products (Genetic Literacy, March 7, 2018). These data provide evidence on the negative impacts of not adopting GM crops in a timely manner, on the economy and the environment. The frequent use of more toxic herbicides, increase in GHG emissions, and loss of biodiversity are the negative consequences in not adopting biotech crops. It also limits farmers' abilities to choose what is best for them and their farmland. This is a form of Western colonialism that prevents food insecure developing countries and the world's poorest communities to use the technology that will lift them out of poverty and hunger.

Loss of US$6.8 billion without glyphosate-tolerant biotech crops

As previously discussed, the herbicide tolerant trait deployed in soybeans, maize, and canola covered the highest biotech crop area of 86.6 million hectares in 2016. Accumulated benefits provided by Brookes and Barfoot (2018, Forthcoming) from 1996 to 2016 indicate that economic benefits by farmers reached US$89.0 billion, and for 2016 alone was US$8.4 billion. Even so, various reports on the negative impact of glyphosate application have surfaced in recent years to discredit the use of the technology (see discussion on HT soybean above). Thus, Brookes et al. (2017) analyzed the contribution of glyphosate to agriculture and potential impact of restrictions on use at the global level. In other words, they responded to the question, *What will happen if herbicide tolerant crops are no longer available because glyphosate is banned?* According to the paper, the initial impacts include loss of global farm income amounting to US$6.76 billion, and decrease in the production of soybeans, corn, and canola by around 18.6 million tons, 3.1 million tons, and 1.44 million tons, respectively. The environment would be directly affected as well, due to the increase in the use of other herbicides with 8.2 million kg of active ingredient, and larger net negative environmental impact quotient of 12.4%. Furthermore, there will be an increase in carbon emissions due to fuel usage and reduced soil carbon sequestration, equivalent to adding 11.77 million more cars on the roads. Other effects on global welfare were also predicted using Computable General Equilibrium (CGE) model GTAP-BIO, which showed that most impacts are negative. World prices of all grains, oilseeds, and sugars are expected to rise. Land use area for crops is also expected to increase by 762,000 ha, which may further lead to deforestation, and increase in more carbon dioxide emissions.

The above-described study confirmed the analysis conducted earlier in 2016 by Purdue University economists that assessed the economic and environmental value of GM crops when biotech maize, soybeans, and cotton are replaced with conventionally-bred varieties worldwide. The study by Mahaffey et al. (2016) revealed that there will be a price hike on food by as much as 0.27% to 2.2%, depending on the region. Poorer countries will be most burdened by the price increase because as much as 70% of their income goes to food, compared to about 10% in the USA. In addition, countries that export crops, such as the USA, would gain economically due to the increase in food prices, while countries that import crops, such as most of the developing countries, China, and parts of the EU will suffer. Therefore, total welfare losses associated with loss of GMO technology total up to US$9.75 billion.

A global ban on biotech crops will also have an environmental impact on land use change owing to the loss of GM traits and the associated GHG emissions. There will be forest and pasture conversion to clear 3.1 million hectares of land which is an environment-costly process. This expansion of cropland would add the equivalent of 0.92 billion tons of CO_2 to the atmosphere. On the other hand, if the global rate of biotech crop planting is patterned after the USA, global greenhouse emissions would fall by 0.2 billion tons of CO_2 and would allow 0.8 million hectares of cropland to be converted back to forests and pastures. Thus, a global ban on biotech crops would result in an insurmountable toll on food affordability and accessibility, as well as on environmental impact. These elements should be included in discussions with critics of biotech crops whose concerns have no scientific basis, depriving others, especially the poor people in the developing world, of bountiful and nutritious biotech food.

Finally, global economic gains contributed by biotech crops in the last 21 years (1996-2016) have provided some US$186.1 billion of economic benefits to more than 16 to 17 million farmers, 95% of whom come from developing countries. Opportunity costs could rise above the reported data of US$1.5 trillion in foregone economic benefits through 2050 especially in developing countries when the restrictive regulatory climate prevails.

DELAYED BENEFITS OF PUBLIC SECTOR BIOTECH CROPS

Golden Rice- delayed approval of GR in India alone could result to a perceived cost of US$199 million per year

Since Golden Rice (GR), a biotech/GM crop developed to contain beta-carotene (lycopene, a precursor of Vitamin A) in the seed, was first developed by co-inventors Ingo Potrykus and Peter Beyer in 2004, the project had been under the watchful eyes of critics. Golden Rice development was aimed to benefit young children and lactating mothers of impoverished developing countries, but has been the target of many debates and protests. Hence, 17 years after the first prototype was developed by Ye et al., (2000), the product is still not close to commercialization and illnesses associated with vitamin A deficiency (VAD) such as xerophthalmia (night blindness), susceptibility to infectious diseases of infants, and malnutrition in mothers are becoming more prevalent. This is especially so in South Asia and Sub-Saharan Africa where VAD was 44% and 48%, respectively, in children aged 6-59 months old (Stevens et al., 2015). These were compared with children in East and Southeast Asia and Oceania which fell from 39% to 29%, and in Latin America and the Caribbean from 21% to 11% in a survey study from 1991 to 2013. The usual prescribed procedure to alleviate VAD such as delivery of supplementary vitamin A capsule with serum retinol, food fortification, and dietary modification to include vitamin A-rich green and leafy vegetables, were not as successful in South Asia and Sub-Saharan Africa. Thus, a more effective method of alleviating VAD is needed, and Golden Rice could contribute immensely to this effort.

The first generation Golden Rice which contains 1.6 μg/g beta carotene in 2000 was improved to contain 31μg/g beta-carotene (Paine et al., 2005), after Al-babili and Beyer (2005) found out that the *psy* gene is the rate-limiting step. Paine and colleagues (2005) changed the *psy* gene source from daffodil to maize. Thus, according to Paine et al., (2005), GR generation 2 was determined to contain significant beta-carotene levels, equivalent to 50% of the vitamin A Recommended Dietary Allowance (RDA). This means that RDA for children aged 12 to 36 months could be met with 300 μg GR based on the 12:1 conversion factor of beta-carotene to vitamin A.

In 2014, the disability-adjusted life year (DALY) framework (Wesseler and Zilberman, 2014), a measure of the estimates of the cost-effectiveness of better nutrition has been used by the World Bank and the United Nations World Health Organization (WHO) to determine the health gap in developing countries. This then became a standard evaluation tool for estimating the burden of micronutrient malnutrition and cost-effectiveness of related interventions, expressed in the number of DALYs lost. It describes both mortality and disability-weighted morbidity of a health condition. The cost to deliver effective intervention in international dollars is also estimated relative to the disease/illness (Marseille et al., 2015).

Various scientists determined the cost-effectiveness of including GR in the daily diet in poor and populated countries of India, China and Bangladesh using DALYs (Table 44). As expected, China and India, the most populated countries in Asia have comparable cost effectiveness (C-E) per DALY, while Bangladesh has the highest at US$1,285 per DALY. Bangladesh is one of the target countries for GR deployment because of the technology's impact in reducing VAD and the estimated monetary benefits that can be derived as a result of GR intervention.

De Steur et al., (2017) also provided a comprehensive paper on the social and economic impact of biofortification through genetic modification for Golden Rice, Bt eggplant, folate-enriched rice, biofortified sorghum, multi-biofortified 'Biocassava', multi-biofortified rice, and high provitamin A and high-iron banana. For Golden Rice alone, Table 45 provides the potential and cost-effectiveness in the Philippines, India, and Bangladesh.

With GR in the pipeline in developing countries of Bangladesh, Philippines and Indonesia, regulations in these countries are the only

Table 44. Disability-adjusted life year (DALY) Saved and Monetary Benefits after Golden Rice Intervention

India	***Stein et al., 2006***			
DALYs lost with VAD	DALYs saved with GR (HIS)	C-E per DALY saved with GR	DALYs saved with GR (LIS)	C-E per DALY saved with GR
2.3 million	1.4 million (59.4%)	US$3.06	0.20 million (8.8%)	US$19.40

China	***De Steur, 2012***	
DALYS lost with VAD	Cost-effectiveness per DALY saved with GR	
1.9 million	US$5 at optimistic circumstances	US$18 at pessimistic circumstances

Bangladesh	***Deb, 2016***					
DALYS lost with VAD	1% Increase in GR coverage			5% Increase in GR coverage		
	DALYs saved with GR	C-E per DALY saved with GR	Monetary Benefits	DALYs saved	Monetary benefits (Total)	
25,065 under 5 y.o.	251	US$1,285	US$3 million	1,255	US$25 million (CS)	US$40 million (OS)

Legend: HIS = High Impact Scenario, LIS= Low Impact Scenario, C-E = Cost-effectiveness per DALY saved by GR intervention, CS = Conservative Scenario, OS = Optimistic Scenario

limiting step before the benefits can reach target beneficiaries – young infants and pregnant and lactating mothers. It was estimated by Wesseler and Zilberman (2014) that delayed approval of GR in India could result in a perceived cost of US$199 million per year to overcompensate the benefits of the technology. This value can also be easily perceived in other developing countries in Asia, Africa and Latin America, where VAD-related illnesses occur. This opportunity cost is mounting with each year that GR is not released to the target beneficiaries.

IR (Bt) Eggplant in India - 1.4 million eggplant farmers denied of the more than US$500 million annual economic benefits

Eggplant or brinjal (local name used in India and Bangladesh) has been planted in India for more than 4,000 years by smallholder farmers. More than 550,000 hectares of eggplant are being grown by 1.4 million smallholder farmers in eight growing zones in the country (Choudhary and Gaur, 2009). Hybrid eggplant varieties have been successfully farmed in the country which provided enormous harvest until the fruit and shoot borer insect pest started to wreak havoc on eggplant fields. This lepidopteran pest can damage as much as 80% of the eggplant field, especially during high pest incidences. Farmers resort to various less effective biological control measures and cocktails of hazardous insecticides to control the pest, applied two to three times daily throughout the growing season which expose farmers, their families, and the community to toxic and nerve-damaging chemicals. Therefore, the

Table 45. Potential Impact and cost-effectiveness of Golden Rice

Biofortified crop (Country)	Impact	Cost-effectiveness	Profitability
Dawe et al., 2002			
First Generation (Phils)	VA intake increases by 2-8% of current intake	US$4-7 million RAE provided (VA supplementation = US$30-75 per million RAE	
Zimmerman and Qaim, 2004			
First generation (Philippines)	Burden of VAD decreases by 6-32%	15000-85000 DALYs saved per year	66-133% rate of return on R&D investments
Stein et al, 2006 and Stein et al., 2008			
Second generation GR (India)	Burden of VAD decreased by 9-59%; 204,000 – 1,382,000 DALYs saved per year	US$3-19 DALY saved (other VA interventions = US$84-11860 per DALY saved)	29-93% rate of return (international agricultural R&D investments = 17-35%)
De Moura et al., 2016			
Second generation (Bangladesh, Indonesia, Philippines)	Prevalence of VAD decreases by 71-78% in Bangladesh and by 30-60% in Indonesia and the Philippines		

RAE = retinol activity equivalents

development of biotech IR (Bt) eggplant is a welcome respite for farmers from low quality produce and chemical exposure.

IR (Bt) eggplant was developed by Maharashtra Hybrid Seed Company (Mahyco) – a leading Indian seed company – to contain the *cry1Ac* gene that is expressed throughout the plant. This gene is similar to the *cry* gene used in Bt cotton and Bt maize where only the lepidopteran insects were controlled through toxin production in the insect gut at alkali pH. Various studies to determine the efficacy of the gene and its economic benefits have been conducted, concluding that: Bt eggplant is a cost-saving and profitable technology due to savings on insecticides and labor cost from reduced spraying of up to 77.2%; manifold increase in yield per unit area by saving fruits from FSB damage, significant quality improvement in marketable fruits thereby increasing income per unit area; and reduction in direct exposure to insecticides leading to lesser health problems. According to Kumar et al., (2011), the estimated annual economic gains from the Bt brinjal hybrids were US$126 million, assuming adoption rate of 15%, US$255 million at 30% adoption rate, and US$500 million with 60% adoption rate in India. Yield increases of up to 116% over conventional hybrids and 155% over popular open-pollinated varieties can be achieved, which can lower brinjal market price by 15%, increasing its accessibility and affordability (Kumar et al., 2011; Choudhary and Gaur, 2009).

Despite these benefits, cultivation of Bt brinjal was stalled even after India's scientific regulatory body, the Genetic Engineering Approval Committee (GEAC), approved its cultivation in October 2009. This is because after environment minister Jairam Ramesh announced an indefinite moratorium on the cultivation of Bt eggplant on February 9, 2010, no other action has been made to repeal the decision. Thus, Bt eggplant cultivation in India may look bleak, but to the advantage of Bangladesh which had continued the field trials and eventual commercialization in 2015. The strong Bangladeshi government support was led by agriculture minister Matia Chowdhury, who distributed the Bt eggplant seedlings in a launching ceremony in 2015. In 2017, 27,000 farmers have planted 2,400 hectares of Bt brinjal, a 242% increase from 700 hectares in 2016.

The 1.4 million smallholder eggplant farmers and their communities in India have been denied the benefits that they would have enjoyed if Bt eggplant were planted upon its approval in 2009. If eggplant farmers in India adopt biotech eggplant at 90% adoption rate similar to Bt cotton, annual gains will definitely be higher than the half a billion dollars estimated annual economic benefits at 60% adoption rate (Kumar, 2011). This will come from a reduction in pesticide application and labor use, pesticide cost and increased yield.

Biotech Bean in Brazil – 25,000 small farmers being denied of increased yield and virus resistance with delayed commercialization

Bean (*Phaseolus vulgaris*) is an essential feature of Brazilian cuisine providing protein, carbohydrates, and micronutrients not only in Brazil but also the neighboring Latin American countries. It was grown on 2.5 million hectares in 2016 with a mean yield of 10.1 kg/ha (FAOSTAT, 2016 data). Local production varied from 2.9 and 3.7 million tons annually, but is not sufficient for local demand, needing some 100,000 to 300,000 tons of bean imports. Bean production in Brazil is affected by various diseases, insect pests, drought, and low soil fertility, but since the 1970s, the incidence of bean golden mosaic virus (BGMV) has made it the most devastating viral disease of common beans. The virus is transmitted by whitefly *Bermicia tabaci* and, depending on the time of infection, may cause up to 100% yield losses in a single field, and annual average losses have been estimated at 20% or some 200,000 tons, which is enough to feed 5-10 million people (Aragao et al., 2009). BGMV has been an annual incidence in Brazil and can only be controlled through chemical sprays to control the whitefly vector. Various breeding strategies including mutagenesis using gamma radiation and ethyl methane sulfonate mutation, and the use of moderately resistant parental genotypes and other candidate lines did not yield any promising BGMV-resistant advance lines.

Thus, using the last technological option, BGMV-resistant beans were developed through transgenesis via RNA Interference (RNAi) of the *rep* viral gene to prevent viral DNA replication and the appearance of symptoms. The generated homozygous plants showed 100% immunity under field conditions while non-transgenic plants showed severe symptoms (Aragao and Faria, 2009). A transgenic bean event line 5.1 was selected and biosafety analyses were carried out by the Biosafety Network of EMBRAPA, whereby the proponents concluded that line 5.1 is safe for the environment and human consumption. By 2011, the Brazilian Biosafety Committee (CTNBio) approved the line for cultivation and human consumption in Brazil. Transgenic line 5.1 in Carioca seed type was further evaluated in 2012, simultaneously with the seed production process. Some 31 field trials were conducted which proved that the transgenic lines maintained up to 100% BGMV resistance across all tested field conditions. Comparing agronomic traits across all tested transgenic lines, one cultivar BRS FC401 RMD was selected as the first BGMV-resistant cultivar with up to 174.3% grain yield increase over the two conventional parental cultivars (Faria et al., 2016).

It has been more than a decade since BGMV-resistant bean was developed and 7 years had passed since it got approved for commercialization, but it is not in the farmers' hands yet. In Brazil, beans are cultivated by an estimated 25,000 smallholder farmers with nearly 80% of the production cultivated in less than 100 hectares, which is classified as small in Brazil. Once commercialized, the proven resistance of the transgenic line BRS FC401 RMD to the virus and the increased grain yield discussed above, the biotech BGMV-resistant bean will confer significant socio-economic and environmental advantages, including reduced waste, a stable and reliable harvest, and reduced use of pesticides beneficial to the farmers and the communities in the region.

Water Efficient Maize for Africa – 300 million Africans denied of sufficient food with the delay in DT/Bt maize approval

Many countries in Africa annually experience long drought spells that affect crop production resulting to malnutrition and famine. The staple crop maize, consumed by more than 300 million Africans, is susceptible to drought and affected by corn borer resulting to crop failure and famine in the worst scenario. Africa grows 90% of its maize under rainfed conditions and up to 25% of the area suffers from frequent droughts. Sub-Saharan Africa (SSA) has 25 million hectares of maize, largely run by smallholder systems that produce 38 million tons for food. Average yield losses due to drought alone in SSA are estimated at about 33% which translates into substantial income losses for farmers in the region. On the other hand, corn stem borer damage has been estimated at about 13.5% within the East African region, further reducing farmer's income (Wamatsember et al., 2017). Reports also indicate that corn borer infestation increases when crops suffer from drought or water stress (Moyal, 1995). It is thus imperative that drought tolerance and insect resistance are the two most important traits needed by maize in order to reach the potential yield in the region.

Water Efficient Maize for Africa (WEMA) was established in SSA countries of South Africa, Kenya, Uganda, Tanzania and Mozambique in March 2008 under the leadership and management of the African Agricultural Technology Foundation (AATF-Africa) in Kenya. The project collaborators include Monsanto Co. and the International Maize and Wheat Improvement Center (CIMMYT) for technology development, and supported by the Gates Foundation, the Howard G. Buffet Foundation and USAID. The drought tolerant (DT) maize technology (MON 87460) and insect resistant maize event (MON 810) were donated by Monsanto Co. to the project. Partner countries are gearing up for the immediate release of DT/BT maize hybrids as described in the Africa section of the Brief. Biosafety regulations have to be put in place and farmer and consumer acceptance of the technology should be strengthened in the partner countries.

The SSA population is at the greatest risk of food insecurity because by 2050, it will increase 2.5-fold and demand for cereals will approximately triple. It is estimated that the socio-economic impact of DT maize alone can be deduced from the 12.6% increase in average yields in 10 SSA countries. Yield gaps can be closed by up to 24.2% in sub humid areas in SSA. Maize production can be increased by up to 2 to 5 million tons under moderate drought which can feed about 14 to 21 million people (Cenacchi and Koo, 2011). Wamatsembe et al. (2017) indicated in a survey study that drought and stem borer damage were on average 54.7% and 23.5%, respectively, with corresponding estimated yield losses of 36.5% and 15.6% in Uganda. If and when Bt maize and DT maize are grown in Uganda, the ex-ante partial budget analyses for profitability of the two individual traits reveal an average value/cost ratio of 2.1 for hybrid Bt maize and 1.5 for drought tolerant maize (Wamatsembe et al., 2017). It is imperative that combining the two traits together in one hybrid such as DT/Bt could increase this average value/cost ratio. Thus, countries in SSA whose staple crop is maize would be largely benefited with this technology. It has been a decade since the WEMA project got started and DT/Bt maize is still far from being commercialized. Farmers are waiting earnestly for the technology since overcoming food shortage in Africa is in the offing with biotech DT/Bt adoption. This is especially so if the estimated more than 88 million hectares of land suitable for maize in SSA is utilized. This could mean the end of the hunger and poverty era in Africa.

CLOSING COMMENTS AND CONCLUSION

On the 22nd year of biotech crop commercialization, 24 countries grew 189.8 million hectares of biotech crops with economically important traits such as insect resistance, herbicide tolerance, and stacks thereof, disease resistance, product quality traits such as anti-allergy, delayed fruit softening, modified oil/fatty acid content, and many more, as well as pollination control traits.

The accumulated biotech crop area (planted since 1996) surged to a record 2.3 billion hectares or 5.8 billion acres. Of the total 24 countries planting biotech crops, 19 were developing countries and 5 were industrial countries. The increase between 2016 and 2017 of 3% is equivalent to 4.7 million hectares or 11.6 million acres. Developing countries grew 53% of the global biotech area compared to 47% for industrial countries. Soybeans occupied 50% (94.1 million hectares) of the global biotech crop area, a 3% increase compared to 2016. Herbicide tolerance has consistently been the dominant trait at 47% of the global area, similar to 2016. Stacked traits increased from 75.4 million hectares in 2016 to 77.7 million hectares in 2017 – an increase of 2.3 million hectares or 3%. Based on the global crop area planted to the major crops, 77% of soybean, 80% of cotton, 32% of maize, and 30% of canola were biotech crops in 2017.

In addition to the 24 planting countries, 43 non-planting countries (17 + 26 EU countries) have approved the import of biotech crops for food, feed, and processing, for a total of 67 countries adopting biotech crops globally. The total biotech crop approvals from 1992 to 2017 was 4,133 comprised of 1,995 approvals for food, 1,338 for feed, and 800 for cultivation.

A total of US$186.1 billion economic benefits were gained by countries planting biotech crops from 1996 to 2016. The highest gain was obtained by USA (US$80.3 billion), Argentina (US$23.6 billion), India (US$21.1 billion, Brazil (US$19.8 billion), China (US$19.6 billion), Canada (US$8 billion), and others (US$13.6 billion). For 2016 alone, six countries gained the most economically from biotech crops, namely USA (US$7.3 billion), Brazil (US$3.8 billion), Argentina (US$2.1 billion), India (US$1.5 billion), China (US$1 billion), Canada (US$ 0.7 billion), and others (US1.8 billion) for a total of US$18.2 billion. For 2017, the US$18.2 billion comprised of US$10 billion for developing countries and US$8.2 for industrial countries.

In 2017, the global market value of biotech crop seeds, estimated by Cropnosis was US$17.2 billion, representing 23.9% of the US$70.9 billion global crop protection market in 2016, and 30% of the US$56.02 billion global commercial seed market (Cropnosis, 2018, Personal Communication). Two industry sources projected an increase of 8.3% to 10.5% in the global value of biotech seed market by the end of 2022 and 2025, respectively. These are enormous benefits that can be obtained in the seed market if biotech crops are continuously planted globally.

The continued increase in biotech crop area of 3% in 2017 was as predicted by James (2015), **that the slight decline in biotech crop area in 2015 due to the low global commodity price would immediately reverse when the crop prices revert to higher levels.** Remarkably, the average biotech crop adoption rate in the top five biotech crop-growing countries increased in 2017 to reach close to saturation, with the USA at 94.5%, Brazil (94%), Argentina (~100%), Canada (95%), and India (93%). Year-on-year fluctuations in biotech crop area depend on various factors and situations that interplay in different countries.

In the USA, the close to saturation biotech crop adoption rate (94.5%) does not leave much room for expansion in the three major biotech crops of soybeans, maize, and cotton, so area expansion will depend more on the other biotech crops such as canola, alfalfa, sugar beets, papaya, potato, and apple. The expansion of biotech crop area in the USA by 2.1 million hectares in 2017 was mainly due to the bigger area planted to soybeans, cotton, alfalfa and canola. The reasons being: soybean farmers have to compensate for the short fall of soybean production in South America; increased cotton price in the global market; more farmers grew biotech alfalfa for ease in feedlot farming; and canola became the alternate crop for the low priced wheat. The decrease in maize area was because of the low market price and the high ending maize stocks in 2016.

In Canada, the 2 million hectare increase in biotech crop area was due to the expansion of areas planted to canola, soybeans, maize, sugar beets, alfalfa, and the newly introduced biotech potato. Large increases in biotech crop area were obtained for reduced lignin alfalfa, HT soybeans and HT sugar beets, mainly because of the ease in livestock production and farm management, more profitable soybean crop compared to alternate crops, and sugar demand, respectively.

In Brazil, the area grown to biotech soybeans and cotton area increased significantly by 1.1 million hectares in 2017 compared to 2016 due to profitability, higher prices, high market demand both domestically and internationally, and available seed technologies. The slight reduction in biotech maize was due to low current prices and the expansion of soybean area in the country. Future expansion of these three biotech crops may come with the increasing domestic and global demand for protein for food, animal feed, and biofuel production – biodiesel for soybeans and ethanol for maize – and raw cotton materials.

In South Africa, the increased biotech crop area of 2.6% in 2017 was because of favorable weather conditions for soybean growing, and the competitive price for cotton in relation to other crops. Overall, the impetus for growth was spurred by more favorable prices for renewed interest in cotton production in relation to competitive crops, acceleration of consumer demand for textiles, and rising environmental and production costs for synthetics. The WEMA maize is expected to address the water deficiency that affects South Africa periodically. This is expected to be distributed widely to farmers from the 2018 plantings. There are also prospects for further expansion of traits with introduction of drought tolerant soybean underway.

In biotech cotton-planting countries of India, Pakistan, Mexico, and Sudan, increases in biotech IR cotton area were due to the favorable global market price of cotton. New biotech cotton varieties with resistance to other insect pests and diseases could increase biotech cotton adoption in these countries.

In Bolivia, the expansion of biotech soybean was in part due to the huge demand for livestock and poultry feeds. With the worst drought and locust infestation during the growing period, the total soybean area was marginally reduced, but it was all biotech. **In Australia,** biotech crop area increased due to favorable cotton prices, but total canola area decreased marginally due to unfavorable weather conditions and lack of biotech seeds, while the adoption rate increased.

In Vietnam, the increase in biotech maize area was due to farmers' benefits and ease in farming no-till and insect resistant stacked IR/HT maize varieties. While in Honduras, the increase in biotech maize area was a way to recover the losses in biotech maize planting in the previous year due to drought.

In Colombia, there was some expansion of biotech maize area because of favorable weather conditions, however, low domestic cotton demand and low price in the region reduced the biotech cotton area. The increased demand for seeds by countries in the Northern hemisphere increased biotech crop area **in Chile**.

Countries which had decreased biotech crop area include **Argentina, Paraguay and Uruguay –** neighboring countries which experienced unfavorable climatic conditions during the planting season for soybeans, maize, and cotton. In Argentina, the government's plan to revolutionize agriculture accompanied by a reduction in export tax, as well as the increasing demand for protein for food and feed, locally and internationally, suggests that the soybean and maize areas are expected to increase in the very near future. Cotton area declined in two successive years, but the increasing global demand for cotton could revive cotton production in the country. The government planned to revolutionize agriculture by reducing export tax which could be an incentive for farmers to grow more biotech crops in the future. The **Philippines'** biotech maize area had a marginal reduction due to farmers' preference for high priced rice and the problem of counterfeit seeds. Biotech crop area in **China, Myanmar, Portugal, and Spain** had marginal to no change in area compared with the previous year. It is unfortunate that the **Czech Republic and Slovakia** did not plant biotech crops in 2017 because of the EU's stringent reporting requirements for IR maize and the difficulty in marketing biotech crops because of the "contain GMO labeling" requirement in products. This resulted in less incentive for farmers and all stakeholders seeking to capture the benefits offered by IR maize.

Biotech crops are being adopted globally because of the enormous benefits to the environment, human and animal health, and contribution for the improvement of socioeconomic conditions of farmers and the general public. Global economic gains contributed by biotech crops in the last 21 years (1996-2016) have provided US$186.1 billion economic benefits to more than 16 to 17 million farmers, 95% of whom come from developing countries. However, critics continue various non-scientific allegations that somehow affect country regulations and approvals of biotech crops. Many studies confirm the immense economic losses and opportunity costs once approvals and release of biotech crops are delayed or stopped. Studies showed that restrictive regulations could cost low- and lower middle-income nations up to US$1.5 trillion to a forgone economic benefits through 2050 if biotech crops are not planted (Giddings, 2016). In Australia, it was estimated that the delayed approval of biotech canola resulted to foregone output of 1.1 million tons of canola and US$377.9 million economic losses (Biden, et al, 2018). In addition, losses amounting to US$6.8

billion and negative environmental effects will be incurred if all glyphosate tolerant biotech crops (soybeans, maize and canola) are not planted globally (Brookes et al., 2017).

Moreover, commercialization of some public sector biotech crops has been affected by stringent regulations in their respective countries or regions, including Golden Rice (GR), Bt eggplant, bean golden mosaic virus (BMGV)-resistant beans, and the stacked drought tolerant and insect resistant maize in Africa. The delay in approval of GR in India could result to a perceived cost of US$199 million per year to overcompensate the benefits of the technology. This could be similar in other developing countries of Asia, Latin America, and Africa, with high incidence of vitamin A deficiency. Around 1.4 million IR (Bt) eggplant farmers in India are being denied of the more than US$500 million annual economic benefits because of the long standing impasse on the commercialization of Bt eggplant. It is ironical that the same product is being commercialized in Bangladesh for three consecutive years and farmers are already benefiting from 70-90% reduction in pesticide use and economic benefits of US$1,868 per hectare. The approval of the biotech BGMV-resistant bean in Brazil in 2011 gave hope to the 25,000 small farmer holders in the country to use a technology that would effectively control the devastating viral disease and recover from their previous big losses. Unfortunately, as of this writing, there is no clear indication that the technology will be at the farmers' hands in the very near future which can stifle its economic and agricultural benefits. The Water Efficient Maize for Africa (WEMA) project, which started in 2008, is focused on the development of stacked drought tolerant and insect resistant (Bt) maize for countries in Sub Saharan Africa: South Africa, Kenya, Uganda, Tanzania, and Mozambique. This private-public collaboration hoped to solve the two most devastating problems in the region: drought and insect pest in maize the soonest time possible to prevent further hunger and malnutrition in Africa. These four public sector products target the impoverished, malnourished, and hungry people in the developing countries. Critics who somehow get to influence government regulatory bodies have no right to stop the technology due to idealism and fanaticism because millions of lives are at stake.

Finally, the continuing immense growth of biotech crop adoption for cultivation and import globally is a manifestation of farmer and consumer satisfaction of the agricultural, socio-economic, and environmental benefits as well as food safety and nutritional improvement brought by biotech crops. Ensuring that these benefits will continue now and in the future depends on the diligence and forward-looking regulatory steps based on science, critically looking at the benefits instead of risks, agricultural productivity with a sense of environment conservation and sustainability, and most importantly taking into consideration the millions of hungry and impoverished populace needing and waiting for their lives to improve.

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REFERENCES

Abdullah, AHMd, MdSI Afrad, AKMAH Bhuiyan, MdE Haque and T Islam. 2018. Attitude and consumption of Bangladeshi professionals toward biotechnological products, Agric & Food Secur (2018) 7:2, 2018. https://agricultureandfoodsecurity.biomedcentral.com/articles/10.1186/s40066-017-0155-z.

ADB, 2017. Myanmar: Country Partnership Strategy (2017-2021), the Asian Development Bank, 2017.

Aerni, P. 2011. Do political attitudes affect consumer choice? Evidence from a large-scale field study with genetically modified bread in Switzerland. Sustainability 2011(9) 1555-1572.

agriCensus. January 12, 2018. China December soybean imports hit 9.5 million mt, 2017 imports up 14%. https://www.agricensus.com/Article/China-December-soybean-imports-hit-9-5-million-mt-2017-imports-up-14-568.html.

agroPages.com. November 21, 2016. GMO crops contribute to a third of Uruguayan economy. http://news.agropages.com/News/NewsDetail---20158.htm.

Al-babili, S and P Beyer. 2005. Golden Rice – five years on the road – five years to go. Trends in Plant Science. 10(12):565-573. http://www.goldenrice.org/PDFs/Al-Babili_Beyer_TIPS_2005.pdf.

APSU, 2017. Ministry Organizes Bt Brinjal Monitoring Training, Agricultural Policy Support Unit (APSU), Ministry of Agriculture, Bangladesh, August 8, 2017.

Aragão FJ and JC Faria. 2009. First transgenic geminivirus-resistant plant in the field. Nature Biotechnology. 2009;27(12):1086–1088. doi: 10.1038/nbt1209-1086.

Aung Pa Pa. 2017. Current Status of Biosafety Assessment in Myanmar, June 5, 2017.

Australian Department of Health – Office of the Gene Technology Regulator. 2017. http://www.ogtr.gov.au/internet/ogtr/publishing.nsf/Content/fact-gmcanola-htm.

Bakhsh, K. 2017. Impacts of Bt cotton on profitability, productivity and farm inputs in Pakistan: use of panel models, Journal of Environment and Economic Development. 22(4): 373-391.

BARC. 2017. BARC Annual Report 2016-17, Bangladesh Agricultural Research Council (BARC), Dhaka, Bangladesh.

Biden, S, S J Smith, and D Hudson. 2018. The economic and environmental cost of delayed GM crop adoption: The case of Australia's GM canola moratorium. https://www.tandfonline.com/doi/full/10.1080/21645698.2018.1429876.

Brookes, G, F Taheripour, and WE Tyner. 2017. The contributions of glyphosate to agriculture and potential impact of restrictions on use at the global level. GM Crops & Food, 8:4, 216-228. https://www.tandfonline.com/doi/pdf/10.1080/21645698.2017.1390637.

BRRI. 2017. Plant Breeding Division of BRRI gets Bangabandhu National Agriculture Award, the Bangladesh Rice Research Institute (BRRI), July 17, 2017.

Business Recorder. 2017. PU scientists create genetically-modified cotton seed varieties, Business Reconder, September 8, 2017.

CAB. 2017. Minutes of CAB meeting held on 12.12.2017, Cotton Advisory Board, Office of the Textile Commissioner, Government of India.

Capital Press. April 6, 2017. NASS: Pulse, canola acres on the rise in PNW. http://www.capitalpress.com/Nation_World/20170406/nass-pulse-canola-acres-on-the-rise-in-pnw.

Cenacchi, N and J Khoo. 2011. Effects of drought tolerance on maize yield in Sub-Saharan Africa. Presented during the conference on Increasing agricultural productivity and enhancing food security in Africa: New challenges and opportunities. Addis Ababa, Ethiopia. http://addis2011.ifpri.info/files/2011/10/Paper_4C_Nichola-Cenacci.pdf

Central America Data.com. 2015. Proposal to eliminate restrictions on GMOs. https://www.centralamericadata.com/en/article/home/Proposals_to_Eliminate_Restrictions_on_GMOs.

Chemicals Agency. March 15, 2017. Glyphosate not classified as a carcinogen by ECHA/PR/17/06. https://echa.europa.eu/-/glyphosate-not-classified-as-a-carcinogen-by-echa.

Choudhary, B. and Gaur, K. 2009. The Development and Regulation of Bt Brinjal in India (Eggplant/Aubergine). ISAAA Brief No.38. ISAAA: Ithaca, NY. http://www.isaaa.org/resources/Publications/briefs/38/default.asp.

Cotton Grower. November 9, 2017. Cotton highlights from November WASDE Report. http://www.cottongrower.com/cotton-production/production-outlook-acreage/cotton-highlights-from-november-wasde-report-2/.

Crop Biotech Update, 2017. http://www.isaaa.org/kc/cropbiotechupdate/default.asp

DAC. 2017. Agricultural Statistics at Glance 2017, Department of Agricultural and Cooperation, Ministry of Agriculture and Famers' Welfare, Government of India.

Daily Star, 2017. Bangladesh to release 3 more Bt brinjal varieties, the Daily Star, March 23, 2017.

Damodaran, H. 2017. Grey Market: When nearly a million Indian farmers plant 'unapproved' GM cotton, Indian Express, Sept 28, 2017.

Dawn, 2017b. Capitalizing on record maize production, Dawn, June 19, 2017.

Dawn. 2017. Govt looks to continue US-assisted cotton project, the Dawn, May 17, 2017.

Dawn. 2017a. Punjab plans to buy more GM cotton seed varieties, Dawn, December 15, 2017.

De Steur H, M Demont, X Gellynck, AJ Stein. 2017. The social and economic impact of biofortification through genetic modification. Curr Opin Biotechnol. 44:161-168. https://www.ncbi.nlm.nih.gov/pubmed/28231514.

De Steur, H, X Gellynck, D Blancquaert, W Lambert, D Van Der Straeten, and M Qaim. 2012. Potential impact and cost-effectiveness of multi-biofortified rice in China. New Biotechnology. 29(3):432-442. https://www.ncbi.nlm.nih.gov/pubmed/22154941.

Deb, U. 2016. Returns to Golden Rice Research in Bangladesh: An Ex-ante Analysis. Copenhagen Consensus Center. 36 pp. http://www.copenhagenconsensus.com/sites/default/files/deb_golden_rice.pdf.

DeltaFarm Press. May 10, 2017. 2017-18 U.S. cotton crop could be biggest in 11 years. http://www.deltafarmpress.com/cotton/2017-18-us-cotton-crop-could-be-biggest-11-years.

DUSC. 2016. Assessment of food and environmental safety for environmental release of genetically engineered mustard (Brassica juncea) hybrid DMH-11 and use of parental events (Varuna bn 3.6 and EH2 modbs 2.99 for developing of new generation hybrids, CGMCP, University of Delhi South Campus (DUSC), 2016.

EuroChem Myanmar. 2017. Agriculture Guide 2017. European Chambers of Commerce in Myanmar, December 2017.

FAO/WHO. 2016. Joint FAO/WHO Meeting on Pesticide Residues. Geneva. Summary Report. 9-13 2016. http://www.who.int/foodsafety/jmprsummary2016.pdf?ua=1.

Faria, J, F Aragão, T Souza, E Quintela, E Kitajima, and S Ribeiro. 2016. Golden Mosaic of Common Beans in Brazil: Management with a Transgenic Approach. APS Features. doi:10.1094/APSFeature-2016-10. http://www.apsnet.org/publications/apsnetfeatures/Pages/GoldenMosaic.aspx.

FarmdocDaily. September 12, 2016. Weekly Outlook: Large U.S. Corn and Soybean Production Prospects Confirmed. http://farmdocdaily.illinois.edu/2016/09/large-us-corn-soybean-production-prospects-confirmed.html.

Fernandes, V. 2017. Widespread use of unapproved GM cotton shows official tolerance of illegality. The Economic Times, October 18, 2017.

Food and Agriculture Organization, November 4, 2-017. AU and FAO speak loud and clear: biotechnologies can be decisive in bridging the food deficit gap in Africa. http://www.fao.org/africa/news/detail-news/en/c/1069475/.

Food and Agriculture Organization. December 4, 2017. Much more investment to reverse the rise in hunger. http://www.fao.org/news/story/en/item/1070840/icode/.

Food and Agriculture Organization. January 22, 2017. More support to family farmers needed to meet world's rising food demand, FAO tells G20. http://www.fao.org/news/story/en/item/463804/icode/.

Food and Agriculture Organization. July 3, 2017. World hunger on the rise again, reversing years of progress. http://www.fao.org/news/story/en/item/902489/icode/.

Food and Agriculture, January 22, 2017. More support to family farmers is needed to meet world's rising food demands, FAO tells G20 (http://www.fao.org/news/story/en/item/463804/icode/..

Fresh Plaza. Nov. 7, 2017. Arctic apples now available in US stores. http://www.freshplaza.com/article/183745/Arctic-apples-now-available-in-US-stores.

FSANZ, 2017. Food derived from Provitamin A Rice Line GR2E, Approval report – Application A1138, the Food Standards Australia and New Zealand (FSANZ), December 20, 2017.

Gartex. 2017. Garment exports from Myanmar rise, Gartex, Myanmar, 2017.

Gastrow M, B Roberts, and IS Reddy. 2017. Public Perceptions of Biotechnology in South Africa. S Afr J Sci. 2018: 114(1/2).Art. #2017-0276, http://dx.doi.org/10.17159/ sajs.2018/20170276.

GEAC. 2017. Minutes of the 133rd meeting of the Genetic Engineering Appraisal Committee (GEAC) held on 11.05.2017, Genetic Engineering

Appraisal Committee (GEAC), Ministry of Environment, Forests and Climate Change (MOEF&CC), Government of India.

Genetic Literacy. July 20, 2017. 15 years after debuting GMO crops, Colombia's switch has benefited farmers and environment. https://geneticliteracyproject.org/2017/07/20/15-years-debuting-gmo-crops-colombias-switch-benefited-farmers-environment/.

Genetic Literacy. March 7, 2018. Non-GMO crops don't earn farmers more, report on South Australia GMO ban shows. https://geneticliteracyproject.org/2018/03/07/non-gmo-crops-dont-earn-farmers-report-south-australia-gmo-ban-shows/.

Genetic Literacy. October 17, 2017. Utilization of GMO crops could double Bolivia's corn yields. https://geneticliteracyproject.org/2017/10/17/utilization-gmo-crops-double-bolivias-corn-yields/.

Giddings, LV, RD Atkinson, and J Wu. 2016. Suppressing growth: How GMO opposition hurts developing nations. https://itif.org/publications/2016/02/08/suppressing-growth-how-gmo-opposition-hurts-developing-nations.

Global Seeds Industry. 2017. Seed Industry – Global Trends, Market Advancements and Forecasts to 2022. https://www.mordorintelligence.com/industry-reports/seeds-industry.

Gouse, M, D Sengupta, P Zambrano, and JB Falck-Zepeda. 2016. Genetically modified maize: Less drudgery for her, more maize for him? Evidence from smallholder maize farmers in South Africa. World Development 83(2016): 27-38 38. http://dx.doi.org/10.1016/j.worlddev.2016.03.008.

Idaho Farm Bureau Federation. October 12, 2017. Beet crop nearly as sweet as '16. https://www.idahofb.org/News-Media/2017/10/2017-beet-crop-nearly-as.

IFPRI. 2017. Bt Brinjal Census Training, IFPRI, Dhaka, Bangladesh, 2017.

Information Technology and Innovation Foundation (ITIF) October 3, 2017. Independent Scientists Call on Interior to Reverse Policy Against GM Seeds. https://itif.org/publications/2017/10/03/itif-independent-scientists-call-interior-reverse-policy-against-gm-seeds.

Innate potato website. retrieved Dec 2017, http://www.innatepotatoes.com/gen-one.

International Cotton Advisory Committee. May 1 2017. High Prices in 2016/2017 Encourages Cotton Area Expansion in 2017/18. https://www.icac.org/Press-Release/2017/PR-16-17-High-Prices-in-2016-17-Encourages-Cotton.

International Seed Federation (ISF). May 22, 2017. World Seed Congress delegates urged to respond to global challenges. A Press Release. http://www.worldseed.org/wp-content/uploads/2017/05/WSC_-Press-Release_1.pdf.

IRRI. 2017. Bangladesh Agriculture Minister hopes for "new era of collaboration" for rice sector during IRRI visit, the International Rice Research Institute (IRRI), the Philippines, November 28, 2017.

ISAAA, 2016. Global Status of Commercialized Biotech/GM Crops: 2016. ISAAA Brief No. 52. ISAAA: Ithaca, NY. http://www.isaaa.org/resources/publications/briefs/52/download/isaaa-brief-52-2016.pdf

Khan, MI, K Hussain, M Akbar, and HA Haq. 2017. Evolution of Cotton Variety Bt.CIM-598 / J. Agric. Basic Sci. Vol. 2(1):28-36.

Khatun, MM, MK Hasan, MK Jamil and D Khanam. 2017. Quantification of Cry1Ac Protein in Bt Eggplant Fruits, Int. J. Appl. Sci. Biotechnol. Vol 5(3): 356-360, 2017. file:///C:/Users/olah/Downloads/18292-59203-2-PB.pdf.

Kniss, AR. 2017. Long-term trends in the intensity and relative toxicity of herbicide use. Nature 8:14865. https://www.nature.com/articles/ncomms14865.

Kumar, S, A Misra, AK Verma, R Roy, A Tripathi, KM Ansari, MK Das and PD Dwivedi. 2011. Bt Brinjal in India: A long way to go. GM Crops 2:2, 92-98, April/May/June 2011. https://www.tandfonline.com/doi/pdf/10.4161/gmcr.2.2.16335

Kumar, S, PAL Prasanna and S Wankhade. 2011. Potential benefits of Bt brinjal in India – An economic assessment. Agricultural Economics Research Review. 24: 83-90. https://ideas.repec.org/a/ags/aerrae/109420.html.

Kyi, MM. 2016. Textile Association Formed to Bolster Domestic Production, Myanmar Biz Today. Vol 4, Issue 24.

Li, Y, EM Hallerman, Q Liu, K Wu and YPeng. 2016. The Development and status of Bt rice in China. Plant Biotechnol J. 14(3):839-48. https://www.ncbi.nlm.nih.gov/pubmed/26369652.

Lucht, JM. 2015. Public acceptance of plant biotechnology and GM crops. Viruses 7(8):4254-4281. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4576180/.

Lusk, J.L, M Jamal, L Kurlander, M Roucan, and L Taulman. 2005. A meta-analysis of genetically

modified food valuation studies. Journal of Agricultural and Resource Economics. 30(1):28-44. https://ageconsearch.umn.edu/bitstream/30782/1/30010028.pdf.
Lwin, O0. 2016. Current Situation of PVP System in Myanmar, 9 th EAPVP Forum Meeting in Vietnam, 2016.
Mahaffey, H, F Taheripour, and WE Tyner. 2016. Evaluating the economic and environmental impacts of a global gmo ban. Presented at the 2016 Agricultural and Applied Economics Association Annual Meeting, Boston, Massachusetts, July 31-Aug 2. 2016. https://ageconsearch.umn.edu/bitstream/235591/2/AAEA%20paper%20Mahaffey%20Taheripour%20Tyner2.pdf.
Manila Bulletin. February 2, 2018. Monsanto asks government to regulate proliferating counterfeit Bt corn seeds. https://business.mb.com.ph/2018/02/02/monsanto-asks-government-to-regulate-proliferating-counterfeit-bt-corn-seeds/.
Marseille, E, B Larson, DS Kazi, JG Kahn, and S Rosen. 2015. Thresholds for the cost–effectiveness of interventions: alternative approaches. Bulletin of the World Health Organization, 93(2), 118-124. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4339959/.
MGMA. 2017. Garment Export Data, Myanmar Garment Manufacturer' Association (MGMG), 2017.
Ministry of Commerce and Textile. 2017. Press release by Textile Division, Ministry of Commerce and Textile, Government of Pakistan, November 2, 2017.
Ministry of Textile. 2017. 1st Meeting of Cotton Crop Assessment Committee held on August 10, 2017, Ministry of Textile, Government of Pakistan, 10 August 2017.
MOEF. 2017. Decision of Government with regard to Agenda Item No. 5.1 of 133rd Meeting of GEAC held on May 11, 2017 regarding "Application for Environmental release of Transgenic Mustard Hybrid DMH-11 and Parental lines containing events bn 3.6 and modbs 2.99 developed using barnase, barstar and bar genes by M/s. Centre for Genetic Manipulation of Crop Plants (CGMCP), University of Delhi, Ministry of Environment, Forests and Climate Change (MOEF&CC), Government of India, October 28. 2017.
Moyal, P. 1995. Borer infestation and damage in relation to maize stand density and water stress in the Ivory Coast. International Journal of Pest Management 41, 1995 Issue 2. Published online: https://www.tandfonline.com/doi/abs/10.1080/09670879509371934.
Myanmar Times. 2015. US agricultural giant ramps up in Myanmar, Myanmar Times, October 27, 2015.
Myanmar Times. 2017. Quality cotton seeds running out even as demand rises, Myanmar Times, August 15, 2017.
Myanmar Times. 2017a. Cotton demand expected to rise as textile plants reopen, September 27 2017.
Myanmar Times. 2018. Garment industry must raise value proposition to stay sustainable. January 2, 2018.
New Age. 2017. Bt brinjal to be grown in 64 districts with incentives from govt, New Age Bangladesh, Sept 18, 2017.
Paine, JA, CA Shipton, S Chagger, RM Howells, MJ Kennedy, G Vernon, SY Wright, E Hinchliffe, J L Adams, AL Silverstone and R Drake. 2005. Improving the nutritional calue of Golden Rice through increased pro-vitamin A content. Nature Biotechnology 23:482-487. https://www.nature.com/articles/nbt1082.
Pakistan Observer. 2017. Re-structuring committee of PCCC proposes open auction of seed varieties, Pakistan Observer, October 1, 2017.
Pakistan Today. 2017. Crop Technology Annual farmer Expo 2017 held in Lahore, Pakistan Today, October 31, 2017.
Pennsylvania State University. 2017. Widely accepted vision for agriculture may be inaccurate, misleading. http://news.psu.edu/story/452218/2017/02/22/widely-accepted-vision-agriculture-may-be-inaccurate-misleading.
phys.org. August 2, 2017. Global warming reduces protein in key crops: study. https://phys.org/news/2017-08-millions-protein-deficiency-result-human-caused.html
phys.org. May 3, 2017. Modified soybeans yield more in future climate conditions. https://phys.org/news/2017-05-soybeans-yield-future-climate-conditions.html.
President Office. 2012. Enforcement of Farmland Law designated Notification No. 62/2012, Notification No. 62/2012, President Office, Republic of the Union of Myanmar, 2012.
Primacy. 2018. 2017 Highlights: the year in Australian agriculture. https://www.pum.com.au/blog/2017-highlights-the-year-in-australian-agriculture/.

Progressive Markets. March 2017. Size, trend, share, opportunity analysis and forecast for 2014-2025. https://www.progressivemarkets.com/industry-research/seed-market.

PSC, 2017. 48th Meeting of the Punjab Seed Council (PSC) held on Friday, March 6, 2017, Lahore, Pakistan.

Qiao, F, J Huang, C Zhang. 2016. The sustainability of the farm-level impact of Bt cotton in China. Journal of Agricultural Economics. 67(3): 602-618. https://onlinelibrary.wiley.com/doi/full/10.1111/1477-9552.12182.

Reuters News Service. August 10, 2017. USDA pegs US maize, soybean, wheat crops above trade forecasts, https://www.producer.com/2017/08/usda-pegs-u-s-corn-soybean-wheat-crops-above-trade-forecasts/.

Rothamstead Research. November 27, 2017. Viewpoint. Glyphosate Renewal Approved. https://www.rothamsted.ac.uk/news/glyphosate-renewal-approved.

SABC. 2016. Submission of representation on the Barnase-Barstar mustard technology to Genetic Engineering Appraisal Committee (GEAC) of Ministry of Environment, Forests and Climate Change, South Asia Biotechnology Centre (SABC), New Delhi, August 8, 2016.

ScienceMag. October 13, 2016. Brazil will release billions of lab-grown mosquitos to combat infectious disease. Will it work? http://www.sciencemag.org/news/2016/10/brazil-will-release-billions-lab-grown-mosquitoes-combat-infectious-disease-will-it.

SciTechDaily. April 26, 2018. Deforestation adds more atmospheric CO2 than the sum of total cars and trucks on the world's roads. https://scitechdaily.com/deforestation-adds-more-atmospheric-co2-than-the-sum-total-of-cars-trucks-on-the-worlds-roads/.

SEA. 2017. Import of Vegetable Oils during Nov.'16 to Oct.'17 – Up by 5%, Solvent Extractors' Association of India, Mumbai, Nov 14, 2017.

Shein, UHA. 2013. Seed Industry Development in Myanmar, Developing Viable Seed Industries in Cambodia, Lao PDR, Myanmar and Vietnam, Asian Development Bank Institute (ADBI), Asian Development Bank (ADB), Mekong Institute, Khon Kaen, Thailand, December 11-15, 2012.

Shelton, AM, KE Hokanson, DM Hautea, MJ Hossain, MA HOssain, V Paranjape, RA Hautea, L McCandless, and SH Sarwer. 2017. Bt Eggplant: A Genetically Engineered 'Minor' Crop Comes of Age in Bangladesh and the Philippines, ISB News Report, August 2017 https://www.scribd.com/document/360396074/Bt-Eggplant-a-Genetically-Engineered-Crop-Comes-of-Age-in-BD-PH.

Simplot. January 13, 2016. Innate® second generation potato receives FDA safety clearance. http://www.simplot.com/news/innate_second_generation_potato_receives_fda_safety_clearance.

Simplot. retrieved January 2018. http://www.innatepotatoes.com/newsroom/view-news/innate-second-generation-potato-receives-canadian-government-clearance.

Spielman DJ, F Zaidi, P Zambrano, AA Khan, S Ali, HMN Cheema, N Hina, RSA Khan, A Iqbal, MA Zia and GM Ali. 2017. What are farmers really planting? Measuring the presence and effectiveness of Bt cotton in Pakistan. PLoS ONE 12(5): e0176592. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0176592.

Stein, AJ, H Sachdev, and M Qaim. 2006. Potential impact and cost-effectiveness of Golden Rice. Nature biotechnology. 24(10):1200-1201. https://www.ncbi.nlm.nih.gov/pubmed/17033649.

Technology Review. Oct. 7, 2017. GM apples that don't turn brown to reach US shelves this fall. https://www.technologyreview.com/s/609080/gm-apples-that-dont-brown-to-reach-us-shelves-this-fall/.

Thant, H. 2017. Myanmar must establish cultivation of new plant species and seeds, Myanmar Times, September 13, 2017.

The Daily Climate. May 24, 2017. Report: Climate change estimated to slash major crop production worldwide by 23% over next 30 years. https://theoldspeakjournal.wordpress.com/2017/05/.

The Hindu. 2018. Centre urged to check spread of BG-III cotton, the Hindu, January 20, 2018.

The Nation. 2017a. World Bank approves $300 million loan for Punjab to modernize agriculture, The Nation, December 16, 2017.

The Nation. 2017b. Sino-Pak moot focuses on cotton production, the Nation, November 23, 2017.

The Scientist. October 13, 2017. GM mosquitoes closer to release in the U.S. https://www.the-scientist.com/?articles.view/articleNo/50636/title/GM-Mosquitoes-Closer-to-Release-in-U-S-/.

The Weekly Times. August 13, 2017. Monsanto accredits 57 new GM cotton growers.

The Weekly Times. July 11, 2017. Genetically modified canola edges up. https://www.

weeklytimesnow.com.au/agribusiness/cropping/genetically-modified-canola-edges-up/news-story/377f7d450ebf50e9a95bf72c1a3fe59d.

theguardian.com. May 5, 2017. Brown and barren land: Bolivia's historic drought-in pictures. https://www.theguardian.com/global-development-professionals-network/gallery/2017/may/05/bolivia-historic-drought-water-in-pictures.

Transparency Market Research. Sept. 6, 2017. Global GMO cros and seeds market driven by leap in agricultural practices. https://www.transparencymarketresearch.com/pressrelease/gmo-crops-seeds-market.htm.

Tribune. 2017. PM Nawaz announces Rs180 billion package for exporters, Tribune, January 10, 2017.

Trigo, EJ. 2011. Quince Años de Cultivos Genéticamente Modificados en la Agricultura Argentina. (Fifteen Years of GM Crops in Argentine Agriculture). http://www.argenbio.org/adc/uploads/15_anos_Estudio_de_cultivos_GM_en_Argentina.pdf. English news release at http://www.argenbio.org/index.php?action=notas&note=5884.

Trigo, EJ. 2016. Veinte Años de Cultivos Genéticamente Modificados en la Agricultura Argentina. http://argenbio.org/index.php?action=novedades&note=747.

UN Department of Economic and Social Affairs, 2017. World Population Prospects: The 2017 Revision. https://www.un.org/development/desa/publications/world-population-prospects-the-2017-revision.html

United Nations. 2017. World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100. https://www.un.org/development/desa/en/news/population/world-population-prospects-2017.html.

US Energy Information Agency. July 21, 2017. https://www.eia.gov/todayinenergy/detail.php?id=32152.

USDA FAS GAIN Reports, https://www.fas.usda.gov/data.

USDA. 2018. Cotton: World Markets and Trade, United State Department of Agriculture Foreign Agricultural Service, February 2018.

USTR. 2016. Myanmar and the U.S. Generalized System of Preferences (GSP) Program, The United State Trade Representative (USTR), November 13, 2016.

Vietnam News. September 11, 2017. Experts urge use of biotech corn. http://vietnamnews.vn/society/393514/experts-urge-use-of-biotech-corn.html#i6HsCPGP2Kw0pwSE.97.

Wamatsembe IM, A Godfrey and SM Haefele. 2017. A Survey: Potential impact of genetically modified maize tolerant to drought or resistant to stem borers in Uganda. Agronomy. 7(24). https://digital.library.adelaide.edu.au/dspace/bitstream/2440/104571/3/hdl_104571.pdf.

Weekly Times. August 13, 2017. Monsanto accredits 57 new GM cotton growers. https://www.weeklytimesnow.com.au/news/national/monsanto-accredits-57-new-gm-cotton-growers/news-story/a3a762368b839f0217a7037886122b22

Wesseler, J and D Zilberman, 2014, The economic power of the Golden Rice opposition. Environment and Development Economics 19: 724-742. https://pdfs.semanticscholar.org/0c41/d80a75cadbb2e98b2c62698e22d1ad178d0a.pdf.

World Bank. 2016. Unleashing Myanmar's agricultural potential, the World Bank, June 27, 2016.

Xie, W, T Ali, Q Cui, J Huang. 2017. Economic impacts of commercializing insect-resistant GM maize in China. China Agricuyltrueal Economic Review. 9(3):340-354. pp.340-354, https://doi.org/10.1108/CAER-06-2017-0126.

Ye, X, S Al-Babili, A Kloti, J Zhang, P Lucca, P Beyer and I Potrykus. 2000. Engineering the provitamin A (beta-carotene) biosynthetic pathway into carotenoid-free) rice endosperm. Science. 287(5451):303-5. https://www.ncbi.nlm.nih.gov/pubmed/10634784.

Zhang, C, R Hu, J Huang, X Huang, G Shi, Y Li, Y Yin, Z Chen. 2016. Health effect of agricultural pesticide use in China: implications for the development of GM crops. Nature Reviews. http://www.nature.com/articles/srep34918.

Appendix 1. Global Crop Protection Market, 2017

US$M	Herbicides	Insecticides	Fungicides	Others	Biotech	Total
North America	5,772	2,287	2,298	442	12,398	23,197
Europe	5,312	1,672	4,412	396	10	11,622
Japan	1,100	1,089	880	62	0	3,131
Australia	562	196	150	22	35	965
Industrial Countries	**12,566**	**5,244**	**7,740**	**922**	**12,443**	**38,915**
Latin America	5,317	3,048	4,054	461	3,664	16,364
Rest of Far East	3,612	2,751	2,648	401	398	9,810
Rest of World	1,692	1,966	1,238	215	676	5,787
Developing Countries	**10,441**	**7,765**	**7,940**	**1,077**	**4,738**	**31,961**
Total	**23,007**	**13,009**	**15,680**	**1,999**	**17,181**	**70,876**

Source: Cropnosis Agrochemical Service, 2017

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