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ISAAA Briefs

BRIEF 54

GLOBAL STATUS OF COMMERCIALIZED BIOTECH/GM CROPS IN 2018:

Biotech Crops Continue to Help Meet the Challenges of Increased Population and Climate Change

In 2018, 191.7 million hectares of biotech crops were grown in 26 countries by up to 17 million farmers.

Over the last 22 years, ISAAA has devoted considerable effort to consolidate all the available data on the adoption of officially approved biotech crops 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 Food and Agriculture Organization of the United Nations (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 October biotech reports of Celeres are used; similarly, for the US, the US Department of Agriculture National Agricultural Statistics Service (USDA NASS) crop acreage reports published in 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 database, 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 crops, 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 sum 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, sum, 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 2018 information for Argentina, Brazil, Australia, South Africa, and Uruguay is hectares usually planted in the last quarter of 2018 and harvested in the first quarter of 2019, 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 2018 and more intensively through January and February 2019, is classified as a 2018 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 the United Nations Conference on Trade and Development (UNCTAD), when necessary.

ISAAA Briefs

BRIEF 54

Global Status of Commercialized Biotech/GM Crops in 2018:

Biotech Crops Continue to Help Meet the Challenges of Increased Population and Climate Change

No. 54 – 2018

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

Email: publications@isaaa.org

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INTRODUCTION

The first 22 years of commercialization of biotech crops (1996 to 2017) has confirmed that biotech crops have delivered substantial agronomic, environmental, economic, health, and social benefits to farmers, and increasingly to the consumers (ISAAA, 2017). The rapid adoption of biotech crops reflects the substantial multiple benefits realized by both large and small farmers in industrial and developing countries who have commercially grown biotech crops. In 22 years, an accumulated 2.34 billion hectares of biotech crops have been grown commercially, comprised of 1.13 billion hectares of biotech soybean, 0.7 billion hectares of biotech maize, 0.36 billion hectares of biotech cotton, and 0.14 billion hectares of biotech canola. Biotech products derived from 2.34 billion hectares significantly contributes food, feed, fiber, and fuel to the current world population of almost 7.7 billion people. Hence, feeding the world population, which is continuously increasing and predicted to be 9.9 billion in 2050 and 11.2 billion in 2100 (UN, 2018), is indeed a daunting task.

The Global Report on Food Crises 2017 revealed that the targets of the United Nations (UN) Millennium Development Goals (UN-MDG) that ended in 2015 were not achieved, and that around 108 million people in 48 food crisis-affected countries are still at risk or in severe acute food insecurity since 2016 (FAO, 2017). Moreover, the 2018 UN report on the State of Food Security and Nutrition in the World indicated that for three years in a row (since 2016), there was a continuous increase of hunger worldwide, with current levels equivalent to records a decade ago. The report also emphasized that there was a slow progress in addressing the multiple forms of malnutrition which includes child stunting and adult obesity, making the health of hundreds of millions of people at risk. These findings translate into a clear warning that more efforts must be done rapidly to achieve the Sustainable Development Goal of Zero Hunger by 2030 (Crop Biotech Update, September 19, 2018).

It was also emphasized that the main drivers that slow down economic growth and incite hunger were climate variability, impacting rainfall patterns and agricultural seasons, and extreme climate conditions such as drought and floods. There were also countries whose people are affected by conflict and were hungry.

Climate change, as predicted by studies in the early 2000s, cause significant reduction in crop yields directly and indirectly as climate warms. A report by the Food and Agriculture Organization of the United Nations (FAO) revealed that among the natural disasters that cause agricultural losses, drought is the most destructive (Crop Biotech Update, March 28, 2018). The report titled *The Impact of Disasters and Crises on Agriculture and Food Security* highlights that natural disasters, including drought, floods, forest fires, storms, plant pests, animal disease outbreaks, chemical spills, and toxic algal blooms, have cost developing countries US$96 billion losses from 2005 to 2015. About 50 percent of the damages (US$48 billion worth) occurred in Asia. Drought was found to be the leading threat among all the natural disasters. Around 80 percent of the economic losses caused by drought were absorbed by agriculture, amounting to US$29 billion.

Indirectly, climate change and its accompanying warming temperature result to crop losses caused by insect pests. According to the researchers of the University of Vermont, losses in staple crops rice, maize, and wheat are projected to rise by 10-25 percent per degree of increase in temperature. These losses are due to the increase in insect metabolism and population growth rates. When it becomes hotter, the insects' metabolism increases, and they tend to eat more, leading to an eventual rise in insect population. The losses will be greatest in temperate areas, but less severe in the tropics where temperature is close to optimal for survival of insect pests (Crop Biotech Update, September 5, 2018).

One important example is the fall armyworm which was native to the Americas. It has spread across Africa and expected to spread to India and to other countries in Southeast Asia and South China, putting food security and farmer livelihoods at risk, according to FAO (Crop Biotech Update, August 15, 2018). Its population has reached an epidemic size with the warming temperatures. The insect has the ability to fly over long distances (100 km per night) and destroy staple crops such as maize, rice, vegetables, groundnut, and cotton.

In the midst of climate change, there is an urgent and united call to reverse the reported increasing hungry people. As José Graziano da Silva, FAO Director-General said, ***"There is no time to lose, poverty will not be eradicated, natural resources will continue to degrade, and forced migration will continue to rise…if every person is sustainably food secure in 2030, that will be the most consequential turning point in history"*** (Crop Biotech Update, October 17, 2018).

In a study conducted by Lancaster University and Small World Consulting, the researchers stressed that if the world population continues a "business-as-usual" dietary trajectory, a 119% increase in edible crops grown will be necessary by 2050. Moreover, the current production of crops could be sufficient to provide enough food for the projected global population if radical changes are made on the dietary choices of most (replacing most meat and dairy with plant-based alternatives, and greater acceptance of human-edible crops currently fed to animals, especially maize, as directly-consumed human food) would be necessary, under all scenarios (Crop Biotech Update, July 25, 2018).

Since biotech crops were commercialized in 1996, it has contributed to:

- 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.

The current problem on fall armyworm can be solved by biotech crops that contain insect resistant (IR) genes, according to a study conducted at the Iowa State University. Bt maize could help farmers in Africa to combat this emerging pest capable of devastating their crops, but fear of GM crops has slowed adoption of the technology in the continent. Bt maize could fight the pest immediately compared to developing resistant varieties through traditional breeding which takes several years. Thus, delaying the adoption of biotech crops such as IR (Bt) maize in the developing world presents risks to both humans and the environment (Crop Biotech Update, December 19, 2018).

New biotech crops and traits have been developed to tolerate extreme weather conditions. The drought tolerant maize was released to drought-stricken farmers in 2013, and drought tolerant sugarcane and soybean have been commercialized or are undergoing final stages of evaluation before eventual release to the farmers. The contribution of this technology and accompanying cultural management could offset the effects of climate change in the long run (Crop Biotech Update, November 21, 2018).

Biotech crops are safe for humans and the environment and risks associated with biotech crops have proven to be low to non-existent. Two 2018 Nobel Laureates in chemistry Prof. Frances Arnold from the US and Sir Gregory Winter from Great Britain believe in biotechnology. ***"We've been modifying the biological world at the level of DNA for thousands of years,"*** Arnold said at a news conference, citing examples such as new dog breeds. ***"Somehow there is this new fear of what we already have been doing and that fear has limited our ability to provide real solutions."*** Arnold opined that biotech crops could make food production more environmentally sustainable and help feed the world's growing population. Genetic modifications can make crops drought and disease resistant. Winter said that current regulations on biotech crops needed to be "loosened up" (The Guardian, December 7, 2018).

Other international bodies such as the World Health Organization, the American Medical Association, the U.S. National Academy of Sciences, the British Royal Society, and many other respected organizations support biotechnology. They unanimously stated in many different ways that "consuming foods containing ingredients derived from biotech crops is no riskier than consuming the same foods that contain ingredients from crop plants modified by conventional plant improvement techniques. Despite this, there are still skeptics and a widening perception gap between scientific knowledge and the general public's views.

For instance, a 2015 Pew Research Center study found that 88% of American Association for the Advancement of Science member scientists consider GM foods safe to consume, while only 37% of the general public consider them safe and 57% deem GM foods unsafe to eat. The resulting 51% gap between the views of scientists and those of the public on GMO food safety amounts to an opinion difference greater than divisions over other controversial issues such as climate change, childhood vaccines, and human evolution, the study authors reported (Crop Biotech Update, February 11, 2015).

Biotechnology can be used to develop stress-tolerant and more nutritious crop varieties and to protect natural resources and human health. Each biotech crop is evaluated on a case-by-case basis, approved commercial products in the market have been subjected to rigorous scientific scrutiny. Biotech crops should be considered as a tool for improving crop yields, food safety, and income for food-insecure farmers. 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-decisions on 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.

The International Service for the Acquisition of Agri-biotech Applications (ISAAA) strongly supports the above statements and the scientific truths underpinning them with the publication of *Global Status of Commercialized Biotech/GM Crops in 2018* (ISAAA Brief 54). 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 adopting 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 2018, the global area of biotech crops increased from 189.8 million hectares to 191.7 million hectares, a 1% increase from 2017 equivalent to 1.9 million hectares, and planted by 26 countries. 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, 2017, and a slight increase in 2018, with changes in global prices of commodities, demand for biofuels, need for livestock and poultry feeds, environmental stresses, disease/pest pressure, country policies, political situations, and consumer perception. Thus, adoption of biotech crops in 2018, detailed in each country chapter was a result of an interplay of these various factors, but it is noteworthy that the majority has reached 90% saturation 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.

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. We also dedicate this Brief to the late Dr. Randy A. Hautea, former ISAAA Global Coordinator and *SEAsia*Center Director for more than two decades. They have been great advocates of biotechnology and biotech products and believe that ISAAA can make a difference in enhancing the knowledge and capacities of the global community in order to benefit from the technology, especially the poor and marginalized people of the world.

GLOBAL AREA OF BIOTECH CROPS IN 2018

In 2018, the accumulated biotech area (planted since 1996) surged to a record 2.5 billion hectares or 6.2 billion acres (Table 1). Of the total number of 26 countries planting biotech crops in 2018, 21 were developing countries and 5 were industrialized countries (Table 2, Figure 1). The 1.1% increase between 2017 and 2018 is equivalent to 1.9 million hectares or 4.7 million acres (Table 1). This is a manifestation of how fast the technology has been adopted in an increasing number of countries and expanded area, contributing benefits to the global community and preserving the environment.

DISTRIBUTION OF BIOTECH CROPS IN INDUSTRIAL AND DEVELOPING COUNTRIES

Developing countries continued to outperform industrialized countries since 2012. Prior to 2011, industrial countries consistently exceeded the adoption of 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 their planting area and by 2018, there was a difference of 14.5 million hectares between developing and industrialized countries. Developing countries grew 54% of the global biotech hectares compared to 46% for industrialized countries (Table 2, Figure 1). Moreover, developing countries increased by 2.5% in 2018, compared to 2017, while industrialized countries decreased by 0.7%.

Table 1. Global Area of Biotech Crops, 23 Years, 1996 to 2018

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
2018	191.7	473.7
Total	**2,531.2**	**6,254.5**

*Global area of biotech crops in 2018 slightly increased to 191.7 million hectares compared with 189.8 million hectares in 2017, equivalent to 1.0% or 1.9 million hectares (4.7 million acres).

Source: ISAAA, 2018

The 14.5 million hectares increment between the developing countries and industrialized countries in 2018 is due mainly to increases in areas in Brazil (1.1 million hectares), Paraguay (800,000 hectares), Argentina (300,000 hectares), India, and Uruguay (200,000 hectares each), and China and Mexico (100,000 hectares each) and small increases in Sudan, Honduras, and Vietnam.

The largest percentage expansion was obtained by Mexico at 100% increase in biotech cotton area, followed by Paraguay and Sudan (27%), Uruguay (18%), and small increases in China (4%), India and Brazil (2% each), and Argentina (1%). There were minimal decreases in industrialized countries area wise: Canada with 400,000 hectares, Australia with 100,000 hectares, and small decreases in Spain and Portugal.

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, especially in Africa and Asia 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 26 countries, 21 developing and 5 industrialized countries, planted biotech crops in 2018. The top ten countries, each of which grew over 1 million hectares, was led by the USA which grew 75 million hectares (39% of global total), Brazil with 51.3 million hectares (27%), Argentina with 23.9 million hectares (12%), Canada with 12.7 million hectares (7%), India with 11.6 million hectares (6%), Paraguay with 3.8 million hectares (2%), China with 2.9 million hectares (2%), Pakistan with 2.8 million hectares (1%), South Africa with 2.7 million hectares (1%) and Uruguay with 1.3 million hectares (1%), for a total of 188.0 million hectares. An additional 16 countries grew a total of approximately 3.7 million hectares in 2018 (Table 3 and Figure 3).

Table 2. Global Area of Biotech Crops, 2017 and 2018: Industrialized and Developing Countries (Million Hectares)

	2017	%	2018	%	+/–	%
Industrialized countries	89.2	46	88.6	46	-0.6	-0.7
Developing countries	100.6	54	103.1	54	2.5	2.5
Total	**189.8**	**100**	**191.7**	**100**	**1.9**	**1.0**

Source: ISAAA, 2018

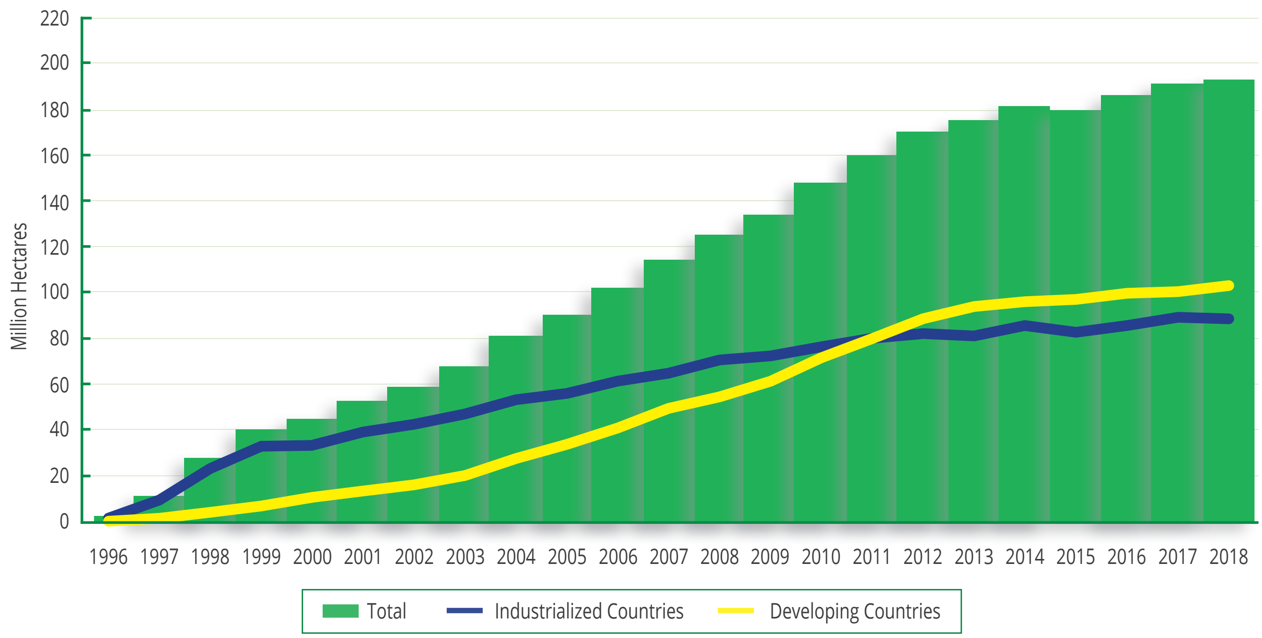


Figure 1. Global Area of Biotech Crops, 1996 to 2018: Industrialized and Developing Countries (Million Hectares)

Source: ISAAA, 2018

Two new developing countries planted biotech crops in 2018: Indonesia (Southeast Asia) with 1,315 hectares of drought tolerant sugarcane planted in a government owned corporation and few farmers fields, and 250 hectares of Bt cotton in eSwatini (formerly Swaziland in Africa).

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) were developing countries, with Brazil, Argentina, India, Paraguay, China, South Africa, Pakistan, and Uruguay, compared with only two industrialized countries, USA and Canada.

A total of 18 biotech mega-countries (countries which grew 50,000 hectares, or more, of biotech crops) was recorded in 2018, the same as 2017.

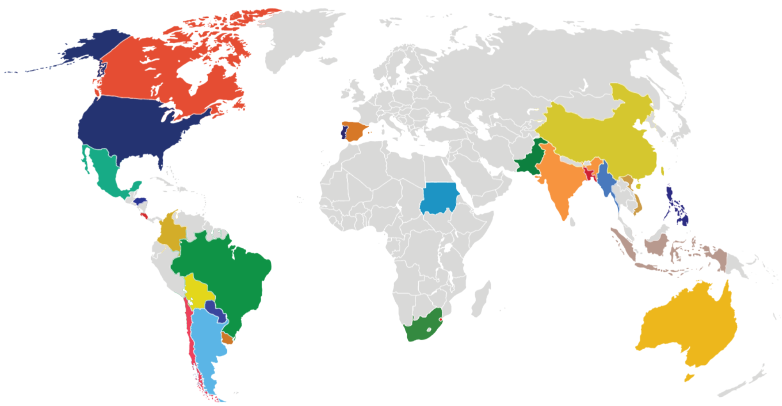
Table 3. Global Area of Biotech Crops in 2017 and 2018: by Country (Million Hectares)**

	Country	2017	%	2018	%	+/–	%
1	*USA**	75.0	39	75.0	39	0	0
2	Brazil*	50.2	26	51.3	27	1.1	2
3	Argentina*	23.6	12	23.9	12	0.3	1
4	*Canada**	13.1	7	12.7	7	-0.4	-3
5	India*	11.4	6	11.6	6	0.2	2
6	Paraguay*	3.0	2	3.8	2	0.8	27
7	China*	2.8	1	2.9	2	0.1	4
8	Pakistan*	3.0	2	2.8	1	-0.2	-7
9	South Africa*	2.7	1	2.7	1	0	0
10	Uruguay*	1.1	1	1.3	1	0.2	18
11	Bolivia*	1.3	1	1.3	1	0	0
12	*Australia**	0.9	<1	0.8	<1	-0.1	-11
13	Philippines*	0.6	<1	0.6	<1	0	0
14	Myanmar*	0.3	<1	0.3	<1	0	0
15	Sudan*	0.2	<1	0.2	<1	0	27
16	Mexico*	0.1	<1	0.2	<1	0.1	100
17	*Spain**	0.1	<1	0.1	<1	0	0
18	Colombia*	0.1	<1	0.1	<1	<0.1	0
19	Vietnam	<0.1	<1	<0.1	<1	<0.1	0
20	Honduras	<0.1	<1	<0.1	<1	<0.1	0
21	Chile	<0.1	<1	<0.1	<1	<0.1	0
22	Portugal	<0.1	<1	<0.1	<1	<0.1	0
23	Bangladesh	<0.1	<1	<0.1	<1	<0.1	0
24	Costa Rica	<0.1	<1	<0.1	<1	<0.1	0
25	Indonesia	--	--	<0.1	<1	--	--
26	eSwatini	--	--	<0.1	<1	--	--
	Total	**189.8**	**100**	**191.7**	**100**	**1.9**	**1.0**

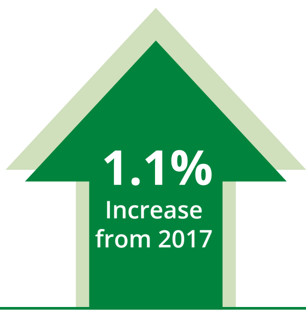
* Biotech mega-countries growing 50,000 hectares or more
** Rounded-off to the nearest hundred thousand or more

Source: ISAAA, 2018

Figure 2. Global Area (Million Hectares) of Biotech Crops, 1996 to 2018, by Country, Mega-Countries, and for the Top Ten Countries



26 countries which have adopted biotech crops



In 2018, global area of biotech crops was 191.7 million hectares, representing an increase of 1.1% from 2017, equivalent to 1.9 million hectares.

Source: ISAAA, 2018

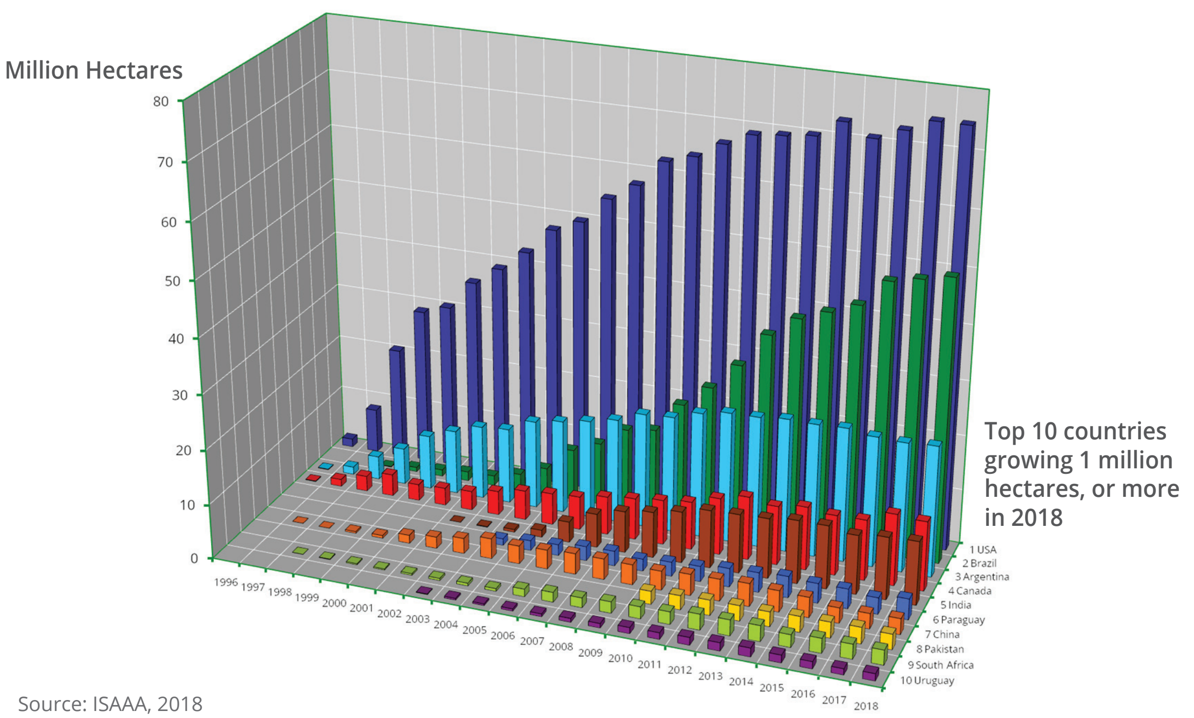
50,000 hectares, or more

1.	*USA*	75.0 million
2.	Brazil*	51.3 million
3.	Argentina*	23.9 million
4.	*Canada*	12.7 million
5.	India*	11.6 million
6.	Paraguay*	3.8 million
7.	China*	2.9 million
8	Pakistan*	2.8 million
9.	South Africa*	2.7 million
10.	Uruguay*	1.3 million
11.	Bolivia*	1.3 million
12.	*Australia*	0.8 million
13.	Philippines*	0.6 million
14.	Myanmar*	0.3 million
15.	Sudan*	0.2 million
16.	Mexico*	0.2 million
17.	*Spain*	0.1 million
18.	Colombia*	0.1 million

Less than 50,000 hectares

Vietnam*	Bangladesh*
Honduras*	Costa Rica*
Chile*	Indonesia*
Portugal	eSwatini*

* *Developing countries*



Source: ISAAA, 2018

Notably, 14 of the 18 mega-countries were developing countries from Latin America, Asia, and Africa. The high proportion of biotech mega-countries in 2018, 18 out of 26, equivalent to 69%, reflects the significant broadening, deepening, and stabilizing in biotech crop adoption that has occurred within the group of more progressive mega-countries adopting more than 50,000 hectares of biotech crops, on all six continents.

Of the 26 countries that planted biotech crops in 2018, 12 (46%) of the countries were in the Americas, 9 (35%) were in Asia, 2 (8%) were in Europe, and 3 (11%) were in Africa. In terms of biotech crop area, of the 26 countries that planted biotech crops in 2018, 88.5% of the area was in the Americas, 10% in Asia, 1.5% in Africa, and 0.1% 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, Uruguay, Bolivia, Mexico, Colombia, Honduras, Chile, and Costa Rica. There were nine countries that planted biotech crops in Asia and the Pacific led by India, China, Pakistan, Australia, Philippines, Myanmar, Vietnam, Bangladesh, and Indonesia. For the sixth year since its approval, Japan grew blue carnation and blue rose which are commercial biotech flowers. They were grown on 12 hectares under partially covered conditions and not in “open field” conditions like the food, feed, and fiber biotech crops grown in other countries listed in this Brief. Australia and Colombia also grew biotech carnation.

In Africa, Sudan, South Africa, and eSwatini grew a total of 2.9 million hectares of biotech crops; South Africa for 2.7 million hectares of biotech soybean, maize, and cotton, Sudan for 243,000 hectares of biotech cotton, and eSwatini with 250 hectares of biotech cotton. Africa currently has 13 biotech crops in 13 countries and 13 traits under different stages of planting and research. There is also a strong wave of endorsement of technology benefits through increased expressions of political goodwill and budget allocations by various governments.

Two EU countries, Spain and Portugal, continued to plant biotech crops in 2018 at 120,733 hectares, a slight decrease of 9% from 131,535 hectares in 2017.

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 (Brookes and Barfoot, 2018).

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 (US$1.8 billion) for a total of US$18.2 billion (Brookes and Barfoot, 2018).

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

In 2018, the top 10 biotech crop planting countries included the USA (75 million hectares), Brazil (51.3 million hectares), Argentina (23.9 million hectares), Canada (12.7 million hectares), India (11.6 million hectares), Paraguay (3.8 million hectares), China (2.9 million hectares), Pakistan (2.8 million hectares), South Africa (2.7 million hectares), and Uruguay (1.3 million hectares), which planted a total of 188.0 million hectares or 98% of the total 191.7 million hectares biotech crop area. Details on the biotech crops planted, adoption trends, country situations, and future prospects are discussed below.

UNITED STATES OF AMERICA

As in the past 22 years, the area planted to biotech crops in 2018 in the United States of America (USA) remained the highest globally. A total of 75 million hectares of biotech crops were planted comprised of 34.09 million hectares biotech soybeans, 33.14 million hectares biotech maize, 5.1 million hectares biotech cotton, 1.26 million hectares biotech alfalfa, 0.9 million hectares biotech canola, 491,000 hectares biotech sugar beets, 1,700 hectares biotech potato, and some 1,000 hectares of biotech apples, squash, and papaya (Figure 3). The biotech crop area in the USA was 39% of the 191.7 million hectares global biotech crop area, confirming the country's leadership in biotech crop farming.

Estimates from the United States Department of Agriculture (USDA) indicate that each of the percentage adoption of the three principal biotech crops was at, or close to maximum penetration: soybeans at 94% (similar to 2017), maize at 92% (decrease of 1.4% from 2017), and biotech cotton at 94% (2% decrease from 2017). The average adoption rate for the three crops is 93.3%, 1.2% lower than in 2017. The 2018 biotech crop area in the USA of 75 million hectares is the same as 2017.

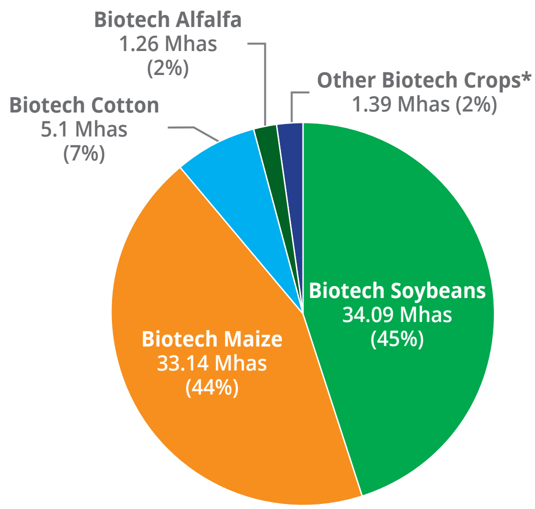


Figure 3. Biotech Crops Planted in the USA, 2018

* Canola, sugar beets, potato, apples, squash, and papaya.

Source: ISAAA, 2018

Biotech maize adoption slightly decreased to 92%

For 2018, the USDA National Agricultural Statistical Service (USDA NASS) reported that the biotech maize area slightly decreased to 33.17 million hectares at 92% adoption rate. The 33.17 million hectares biotech maize was comprised of 721,000 hectares insect resistant (IR), 3.61 million hectares herbicide tolerant (HT), and 28.85 million hectares stacked insect resistant and herbicide tolerant (IR/HT) traits (Table 4).

Biotech soybean adoption rate remained at 94%

Soybeans are the second most important crop in the USA, with a total planted area of 36.26 million hectares in 2018, 94% (similar to 2017)

Table 4. Total and Trait Hectares of Biotech Maize in the USA, 2017-2018

	Area Planted (MHa)		% Trait Hectares	
	2017	**2018**	**2017**	**2018**
Total Maize	36.79	36.059		
IR	1.10	0.72	3.3	2
HT	4.41	3.61	13.0	11
IR/HT**	28.34	28.85	83.7	87
Total Biotech Maize	**33.84**	**33.17**	**93.4***	**92***

* Adoption rate ** Includes 2 million hectares with drought tolerance trait

Source: ISAAA, 2018

or 34.08 million hectares were biotech, a slight increase of 0.11% from 2017. Biotech soybeans contain herbicide tolerant traits that control various kinds of weeds depending on the genes deployed. The 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 omega-fatty acid enriched soybeans MON 87769 (2011).

Biotech alfalfa HarvXtra™ area increased slightly at 50% adoption

Alfalfa is the third most planted crop in the USA at 8.5 million hectares, with 15% or 1.26 million hectares were 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 120,000 hectares to HarvXtra™ in 2018. The area planted to HarvXtra™ increased by 6-fold from 20,000 hectares in 2016—when it was first planted—to 120,000 hectares in 2018, a manifestation of acceptance by US cattle producers for a product that is highly digestible and offers a 15 to 20% increase in yield. In addition, with HarvXtra™ alfalfa, growers have the option to achieve a 25% higher yield potential by delaying harvesting to 35-day cutting intervals. This is based on three cuttings at 35-day intervals compared to four cuttings at 28-day intervals, with the three-cut system yielding more over the life of the stand. Futhermore, delaying the cutting leads to huge benefits such as soil preservation, savings in equipment like custom choppers, and less time used (Hay & Forage Grower, 2018).

Biotech cotton area increased by 10%

Upland cotton planted in the USA increased by 12.7% in 2017, equivalent to 161,000 hectares, from 4.8 million hectares in 2017 to 5.4 million hectares in 2018. The biotech cotton area also increased by 10.4% from 4.6 million hectares in 2017 to 5.1 million hectares in 2018. Notably, adoption of biotech cotton in 2018 was 94%, 2% less than 2017. The 5.06 million hectares of biotech cotton was comprised of 161,000 hectares insect resistant, 484,000 hectares herbicide tolerant, and 4.4 million hectares stacked IR/HT (Table 5).

Biotech canola adoption rate remained at 100%

The area covered by canola increased by

Table 5. Trait Hectares of Biotech Cotton in the USA, 2017-2108

	Area Planted (MHa)		% Trait Hectares	
	2017	2018	2017	2018
Total Cotton	4.78	5.38		
IR	0.24	0.16	5.2	3
HT	0.53	0.48	11.5	10
IR/HT	3.82	4.42	83.3	87
Total Biotech Cotton	**4.58**	**5.06**	**96.0***	**94.0***

* Adoption rate

Source: ISAAA, 2018

2.5% (from 876,000 hectares in 2017 to 898,000 hectares). Adoption rate of 100% was maintained since 2017. 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 also 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$15.76 to US$18.76 per hundredweight, while soft wheat averaged US$4.49 to US$4.80 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

In 2018, sugar beets were planted in the USA at 491,000 hectares, which is 100% biotech herbicide tolerant (American Sugar Beet, personal communication, 2018). This year, the area planted to sugar beets increased by 7.2%.

Across the country, the sugar beet growing season faces variability in sugar content and yield which affect 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 sustain 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 in 1997 by two public research institutions Cornell University and University of Hawaii, and commercialized in the USA since 1998. USDA estimated that 77% (405 hectares) of 526 hectares of papaya in Hawaii in 2018 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 2018.

Biotech non-browning Arctic®Apples area increased 2.4-fold

In 2018, Arctic® apples (varieties ®Golden Delicious, ®Granny, and ®Fuji) were planted on 240 hectares, a 2.4-fold increase from 101 hectares in 2017, when it was first planted. This is comprised of 912,000 trees of the three apple varieties. The total volume of the 2017 harvest was close to 200,000 lbs of fruit and sold in 2018, including fresh market product as sliced Arctic ®Golden apples plus dried Arctic ApBitz™ apple snacks (dehydrated, fruit-cut apples). The fresh slices were test marketed in conventional retail outlets in limited quantities. Arctic®ApBitz™ dried apples were sold through Amazon.com from late March until product was sold out in late summer. There was positive market acceptance for the 2018 limited release of Arctic® apples fresh slices in select grocery stores and with Arctic ApBitz™ dried apples. Thus, the availability of the product is being expanded in US retail market in 2019. It is projected that approximately 10,000 bins of Arctic® apples will be available from the 2019 harvest, which will be composed of Arctic® Golden and Arctic® Granny (Okanagan Specialty Fruits, personal communication, 2019).

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

Biotech 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 and planting commenced in 2015 on 160 hectares. In 2018, a total of 1,700 hectares of Innate® potatoes comprised of 800 hectares of Generation 1 and 900 hectares of Generation 2 (with additional late blight resistance trait) were planted (J.R. Simplot Co., personal communication, 2019).

Benefits of Biotech Crops

According to Brookes and Barfoot (2018), 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 alone. 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 number of new biotech crops and traits being developed and commercialized.

Summary and Future Prospects

In 2018, the biotech area in the USA was 75 million hectares, covering 39% of the global biotech area, with an average adoption rate of 93% for major crops. The biotech crops planted were soybeans (34.08 million hectares), maize (33.17 million hectares), cotton (5.06 million hectares), canola (900,000 hectares), sugar beets (491,000 hectares), alfalfa (1.26 million hectares), and some 1,000 hectares or so of papaya, squash, potatoes, and apples.

Weather patterns in the beginning of spring 2018 characterized by cold April to warm May, the over supply of water in some parts in California and some drought in the southwestern and south central USA contributed to reduced yield. There were also late spring downpours in the middle and southern Atlantic states that curtailed fieldwork and caused local flooding. Despite the reduced drought in some parts of the USA, a core drought area persisted across the southern High Plains and South West. These, among other things contributed to the reduced planting of biotech crops in the USA.

The USA has been a leader in the discovery, development, and commercialization of biotech crops. Under the US President Donald J. Trump's administration, various initiatives have been put in place to expedite and make regulations transparent including the conscious effort of biotech food labelling.

During the American Farm Bureau Federation's 2018 Annual Convention held in Nashville, Tennessee on January 5-10, 2018, President Trump said, ***"We are streamlining regulations that have blocked cutting edge biotechnology, setting free our farmers to innovate, thrive and to grow."*** His remarks were delivered to 7,500 farmers and ranchers gathered at the Convention. Moreover, he decried the costs of excessive regulation, and touched on issues of particular importance to agriculturists such as regulations, labor, and trade (Crop Biotech Update, January 17, 2018). The USDA and FDA are committed to modernize the Coordinated Framework for the Regulation of Biotechnology and the U.S. agricultural biotechnology regulatory system to develop efficient, science-based regulatory practices for products of biotechnology with assistance from other federal agencies, as part of the National Strategy for Modernizing the Regulatory Systems for Biotechnology Products (Crop Biotech Update, February 7, 20018).

New and impactful regulatory approvals for controversial biotech crops were conducted in 2018 including USA FDA's approval of China's biotech IR (Bt) rice developed by Huazhong Agricultural University. US FDA ruled that the biotech event Huahui No.1 rice are not materially different in composition, safety and other relevant parameters from rice-derived human and animal food currently on the market, and that genetically engineered Huahui No.1 grain does not raise issues that would require premarket review or approval by FDA (Crop Biotech Update, January 24, 2018). US FDA also approved the biosafety of Golden Rice GR2E, a rice genetically engineered to produce provitamin A carotenoids. The agency concurs with the assessment of the International Rice Research Institute (IRRI), regarding the safety and nutrition of Golden Rice. This is the third positive food safety evaluation of Golden Rice, after the approval granted by Food Standards Australia New Zealand (FSANZ) and Health Canada in February and March 2018 (Crop Biotech Update, May 30, 2018). In addition, US FDA approved Bt sugarcane developed from Brazil which produces raw and refined sugar not materially different in composition from raw and refined sugar from other sugarcane varieties (Crop Biotech Update, August 15, 2018).

USDA APHIS on the other hand, approved for environmental release biotech cotton with resistance to herbicides glyphosate and isoxaflutole from Bayer (Crop Biotech Update, July 25, 2018); a canola variety developed by Nuseed Americas Inc. that contains high levels of docosahexaenoic acid (DHA), an omega 3-fatty acid (Crop Biotech Update, August 29, 2018); and a GE low-gossypol cotton developed by Texas A&M, which reduces refining cost of cottonseed oil (to get rid of cotton protectant gossypol) and expands the application of cottonseed in the livestock and aquaculture feed industries (Crop Biotech Update, October 24, 2018).

Biotech crops that are in the pipeline and in field trials include triple stack trait biotech rice with better yield amidst abiotic stresses, 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, among others.

Animal biotechnology has also gained ground in the USA with biotech salmon that matures half the time compared to the non-biotech counterpart. Aquabounty, the US-based company that developed the biotech salmon, sold some 7 tons of the GM fish in Canada since 2017, and has been given approval by the US FDA for its commercialization in the USA in 2019 (AquaBounty, 2019).

BRAZIL

Brazil planted the second largest area of biotech crops globally in 2018 at 51.3 million hectares compared to 50.2 million hectares in 2017, a 2% increase or 1 million hectares, and represents 27% of the global biotech area of 191.7 million hectares. The biotech crops planted in the country include soybeans at 34.86 million hectares; maize (summer and winter) at 15.38 million hectares; cotton at 1.0 million hectares; and 400 hectares sugarcane, the first time in Brazil. The total planted area of soybeans, maize, and cotton (conventional and biotech) in Brazil was 54.88 million hectares, a 1% increase from 53.39 million hectares in 2017. The 51.3 million hectares of biotech crop area is a 93% adoption rate, a 1% reduction from 2017 (Figure 4).

Biotech soybean adoption rate was ~96%

Biotech soybeans were planted on 34.86 million hectares at 96% adoption rate (compared to 97% in 2017), of the total 36.39 million hectares soybeans in 2018. The total soybean area increased by 4.8%, while biotech soybean area increased by 3.4% in 2018

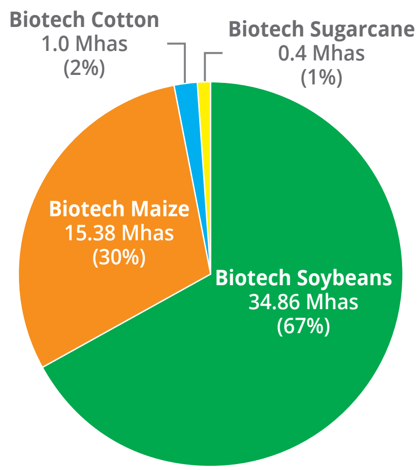


Figure 4. Biotech Crops Planted in Brazil, 2018

Source: ISAAA, 2018

compared to 2017. The 34.86 million hectares of biotech soybeans was comprised of 42% (14.6 million hectares) HT and 58% (20.2 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 2018, compared to 20.1 million hectares in 2017, a slight increase due to lower pest incidence.

In a study by Brookes and Barfoot (2018), the increased use of stacked IR/HT soybeans (Intacta™) in the whole of South America has benefitted farmers with an increase in income of US$7.64 billion for the first five years of adoption. The study highlighted the benefits that accrued over the five-year period with 73.6 million total hectares. For every additional US$1 spent on Intacta™ soybean seed, farmers have gained US$3.88 additional profit. This income gains are due to increase in yields and reduced expenses for weed and pest control. The technology has decreased pesticide spraying by 10.44 million kg and reduced greenhouse gas emissions equivalent to removing 3.3 million cars off the roads (Crop Biotech Update, August 29, 2018).

Biotech maize adoption rate was 89%

The total summer and winter maize planted in Brazil decreased slightly by 1.5% (279,000 hectares) from 17.6 million hectares in 2017 to 17.3 million hectares in 2018. However, biotech maize adoption rate increased slightly from 88.9% (at 15.6 million hectares) in 2017 to 89% (15.4 million hectares) in 2018. The 15.4 million hectares biotech maize was comprised of 4.4 million hectares IR, 646,000 hectares HT and 10.3 million hectares IR/HT. The stacked trait maize decreased by 1.4 million hectares (-11%) (Table 6).

Biotech cotton adoption was 84%, similar to 2017

The total cotton area in 2018 increased by 100,000 hectares from 1.1 million hectares in 2017 to 1.2 million hectares in 2018. The increased total cotton area contributed to the 19% increase of biotech cotton area from 940,000 hectares in 2017 to 1.025 million hectares in 2018. The 1.025 million hectares of biotech cotton was comprised of 9.6% IR (98,000 hectares), 16.9% HT (173,000 hectares) and 73.6% IR/HT (754,000 hectares). The adoption rate of biotech cotton was similar to 2017 at 84% (Table 7).

Biotech insect resistant sugarcane planted in Brazil for the first time

In 2018, 100 sugar mills in Brazil planted some 400 hectares of insect resistant biotech sugarcane variety, developed by Centro de Technologica Canavieira (CTC) (Reuters, March 3, 2018). The National Biosafety Technical Commission approved Bt sugarcane after proving that the sugar and ethanol obtained from it are identical to conventional sugarcane. The biotech sugarcane is one of the best solutions against the cane borer which costs US$1.5 billion losses and insecticide expense annually. This first planting of Bt sugarcane is projected to improve yields, reduce production costs, and increase profits. Studies also showed that the Bt gene and protein were completely eliminated from sugarcane products after processing. Environmental studies further showed that Bt sugarcane does not cause negative effects.

Table 6. Total and Trait Hectares of Biotech Maize in Brazil, 2017-2018

	Area Planted (MHa)		% Trait Hectares	
	2017	2018	2017	2018
Total Maize	17.55	17.28		
IR	3.26	4.43	20.9	28.8
HT	0.66	0.65	4.2	4.2
IR/HT	11.69	10.30	74.9	67.0
Total Biotech Maize	**15.60**	**15.38**	**88.9***	**89.0***

* Adoption rate

Source: ISAAA, 2018

Table 7. Total and Trait Hectares of Biotech Cotton in Brazil, 2017-2018

	Area Planted (MHa)		% Trait Hectares	
	2017	**2018**	**2017**	**2018**
Total Cotton	1.12	1.219		
IR	0.10	0.098	10.9	9.6
HT	0.28	0.173	30.0	16.9
IR/HT	0.56	0.754	59.1	73.6
Total Biotech Cotton	**0.94**	**1.025**	**84.0***	**84.1***

* Adoption rate

Source: ISAAA, 2018

Benefits of Biotech Crops

Brazilian farmers planting soybeans, maize, and cotton adopted biotech crops in 2003, or 13 years ago. Brookes and Barfoot (2018) 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.

In 2018, Brazil has completed 20 years since biotech crops were adopted in agriculture. Throughout this period, what stands out are the benefits for farmers resulting from planting biotech soybeans, maize, and cotton. There has been, for example, a reduction in the application of pesticides per hectare and there have been fewer losses caused by pests. Consequently, the productivity and yield of the biotech crops have been, on average, higher than conventional crops. The data is part of a study, *20 Years of GMOs in Brazil: Environmental, Economic, and Social Impacts*, which was conducted by the Agroconsult consultancy with support from the Council for Information on Biotechnology (Crop Biotech Update, October 31, 2018).

Throughout the period analyzed, the profit obtained per hectare from biotech soybeans was up to 26% higher than the conventional variety. For maize, the performance differential reached 64% in the summer harvest and 152% in the winter harvest. In the case of cotton, GM seeds have a margin of 12% higher than non-modified ones. ***"The positive effect of this technology on agriculture and on the quality of life, level of education and profit for the population is unquestionable,"*** said Executive Director of the CIB, Adriana Brondani.

Summary and Future Prospects

Brazil continues to lead biotech crop adoption in Latin America with its average adoption rate of 93% (a slight decrease from 2017) for biotech soybeans, maize, and cotton. Soybeans is still the major biotech crop in Brazil at 34.9 million hectares, followed by maize at 15.4 million hectares, cotton at more than 1 million hectares and biotech Bt sugarcane at 400 hectares.

The area grown to biotech soybeans and cotton increased significantly in 2018 compared to 2017 due to profitability, higher prices, high market demand both domestically and internationally, and available seed technologies. China was the main export market for soybeans and cotton. In 2018, 80% of Brazil soybean exports was sent to China, estimated to have hit a record of 83 million tonnes in total.

The availability of subsidized credit for farmers and foreign investments from large agricultural companies has supported the widespread adoption of biotech crops in the foreseeable future. Moreover, the Brazilian court has issued a ruling that lifts the ban on glyphosate in the country. The decision ensures growers continued access to glyphosate-based herbicides. This court decision comes in favor of a remedy filed by the Federal Government to overturn a previous injunction before it took effect and ensure that Brazilian growers can continue to use glyphosate-based products (Crop Biotech Update, September 9, 2018).

Various biotech crops in the pipeline include sugarcane, potato, papaya, rice, and citrus. New biotech products such as biotech dry edible beans, and biotech eucalyptus have been approved but are not ready to be commercialized. 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.

Biotech/GM mosquitoes are also being utilized to control viral diseases that have afflicted millions of Brazilians. On October 4, 2018, the National Technical Biosafety Commission (CTNBio) determined that genome-edited hornless cows are conventional animals. With this determination, genome-edited cows and their derived products may enter the market soon.

ARGENTINA

Argentina ranked third in the top 10 countries planting biotech crops in 2018 with a total of 23.9 million hectares biotech crops, 12% of the global total of 191.7 million hectares and at close to 100% adoption rate. The biotech crop area was comprised of 18 million hectares soybeans, 5.5 million hectares maize, and 370,000 hectares cotton (Figure 5). There was an increase of 309,540 hectares or 1.3% from 23.6 million hectares of biotech crops planted in 2017.

Biotech soybean IR/HT stacked Intacta™ increased area planted by 40%

Soybeans were planted on 18 million hectares in 2018, a slight reduction from 18.1 million hectares in 2017 (Table 8). Soybeans grown in the country was 100% biotech, 76% of which or 13.68 million hectares were herbicide tolerant and 24% or 4.3 million hectares were stacked IR/HT. Soybean stacked trait Intacta™ introduced to farmers in 2015 was launched on 70,000 hectares, increased by 40.2% from 2017 (3.08 million hectares)– an indication of farmers adopting a technology that reduces costs and increases profits. A severe drought during the peak summer months reduced the area planted to biotech soybean and resulted to importation

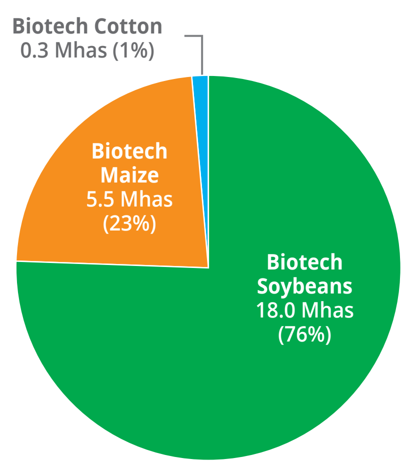


Figure 5. Biotech Crops Planted in Argentina, 2018

Source: ISAAA, 2018

of US soybeans to Argentina for the first time in decades.

In March 2018, Argentina approved Bayer's soybean events MST-FG072-2 and MST-FG072-2xACS-GM006-4 tolerant to isoxaflutole, glyphosate, and glufosinate herbicides, as well as soybeans with salt tolerance and herbicide tolerance.

Biotech maize increased by ~6% in 2018

The total maize area in 2018 increased by 5.6% from 5.4 million hectares in 2017 to 5.7 million hectares. The biotech maize area was 5.51 million hectares (an increase of 6% from 2017), comprised of 42,000 hectares IR, 526,000 hectares HT, and 4.9 million hectares stacked IR/HT. Compared to 2017, maize with stacked traits increased by 14.5% from 4.3 million hectares to 4.9 million hectares in 2018. The adoption rate of biotech maize remains at 97%, similar with 2017 (Table 9).

Four new maize events which are herbicide tolerant and insect resistant stacked traits were approved in 2018 in Argentina (Table 10).

Biotech cotton adoption rate was 93%

The total cotton area in Argentina increased by 60% from 250,000 hectares in 2017 to 400,000 in 2018. Adoption rate however declined to 93%,

Table 8. Total and Trait Hectares of Biotech Soybeans in Argentina, 2017-2018

	Area Planted (MHa)		% Trait Hectares	
	2017	**2018**	**2017**	**2018**
Total Soybeans	18.10	18.000		
HT	15.02	13.680	86.8	76.0
IR/HT	3.08	4.320	13.2	24.0
Total Biotech Soybeans	**18.10**	**18.00**	**100.0***	**100.0***

* Adoption rate

Source: ISAAA, 2018

Table 9. Total and Trait Hectares of Biotech Maize in Argentina, 2017-2018

	Area Planted (MHa)		% Trait Hectares	
	2017	**2018**	**2017**	**2018**
Total Maize	5.40	5.70		
IR	0.38	0.04	7	1
HT	0.52	0.53	10	10
IR/HT	4.32	4.94	83	90
Total Biotech Maize	**5.22**	**5.51**	**97***	**97***

* Adoption rate

Source: ISAAA, 2018

Table 10. Maize Events Approval in Argentina in 2018

	Event Name	Traits	Developer
1	DAS-40278-9 MON-89034-3 x DAS-01507-1 x MON-00603-6 x DAS-40278-9 and all the stacks	Tolerate herbicides base of 2,4-D and herbicides of the family, ariloxypheonoxypropionate, ammonium glufosinate and glyphosate, as well as insect resistance.	Dow Agrosciences
2	SYN-05307-1 and SYN-BT011-1xSYN-IR162-4xSYN-IR604-5xDAS-01507-1xSYN-05307-1xMON-00021-9 and all the stacks.	Tolerance to glyphosate and ammonium glufosinate and resistance to lepidopteran and coleopteran pests.	Syngenta
3	MON-87427-7, MON-87411-9, MON-87427-7 × MON-89Ø34-3 × SYN-IR162-4 × MON-87411-9 and all the stacks	Tolerance to glyphosate and resistance to lepidopteran and coleopteran pests.	Monsanto
4	MON-87427-7 MON-89Ø34-3 x MON-88Ø17-3	Tolerance to glyphosate and resistance to lepidopteran and coleoptera.	Monsanto

Source: ISAAA, 2018

and all are stacked IR/HT traits. The country stopped planting HT cotton in 2017 and IR (Bt) cotton was not planted since 2015.

Benefits of Biotech Crops

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

A comprehensive study 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. 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 in over a 20-year period, this surplus should have created a total of 2,052,922 jobs considering the surplus generated from these technologies.

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 by noting the positive impact of the latter 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 which are 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.

Summary and Future Prospects

A minimal increase of 309,540 hectares of biotech crops were planted in Argentina in 2018, from 23.6 million hectares in 2017 to 23.9 million hectares in 2018. Argentina covers 12% of the global total of 191.7 million hectares in 2018. The biotech crop area was comprised of 18 million hectares soybeans, 5.5 million hectares maize, and 370,000 hectares cotton, at an average adoption rate of close to 100%.

After the previous years' low number of approvals, the Argentinian government through the Argentine National Advisory Committee on Agricultural Biotechnology (CONABIA) approved eight biotech crop applications in 2018: seven full approvals comprised of four maize insect tolerant and herbicide tolerant stacked events, two herbicide tolerant soybeans, and alfalfa event, plus one soybean event for food, feed, and processing only. The newly approved alfalfa stacked herbicide tolerant and low lignin event MON-ØØ179-5 x MON-ØØ1Ø1-8, and intermediates MON-ØØ179-5 (HarvXtra™) and MON-ØØ1Ø1-8 (RR™) will be available to farmers in 2019. Since China is the most important market for Argentinian agricultural products, the government includes a statement in every final approval of a biotech event that the event must be approved in China before being commercialized.

Other products in the pipeline for commercialization, and are in the final stages of evaluation are: a) HB4 wheat with drought tolerance trait awaits commercial approval by the National Direction of Agricultural Food Markets (DNMA) under the Ministry of Agro-Industry; b) INDEAR HB4, a drought resistant soybean event, developed by local researchers from INDEAR that has 30% increase in under extremely dry conditions; c) Chinese soybean event DBN 09004-6 with tolerance to glyphosate and glufosinate-ammonium herbicides; and d) the Intrexon company's non-browning apples which has started field trials in Argentina.

CANADA

Canada planted a total of 12.75 million hectares of six biotech crops in 2018, a ~3% decrease from 13.11 million hectares in 2017. Canada covers 7% of the global biotech crop area with 2.4 million hectares soybeans, 1.6 million hectares maize, 8.7 million hectares canola, 15,000 hectares sugar beets, 4,000 hectares alfalfa, and 65 hectares potatoes. Except for potatoes, the major biotech crops planted had an average adoption rate of 92.5%, a 2% increase from 2017 (Figure 6).

Biotech canola maintained at 95% adoption rate

Canola was planted on 9.2 million hectares in Canada, mostly herbicide tolerant (95% or 8.7 million hectares). Both the area planted to total and biotech canola marginally decreased by 1% in 2018: total canola from 9.31 million hectares to 9.2 million hectares and biotech canola from 8.83 million hectares to 8.74 million hectares.

A new canola variety, MS 11 developed by Bayer CropScience, was approved in 2018 for environmental release This will facilitate the breeding work in canola. Monsanto's TruFlex canola containing the Roundup Ready® technology was approved by the Canadian Food Inspection Agency (CFIA) and Health Canada in 2012 but still awaiting approval in key export

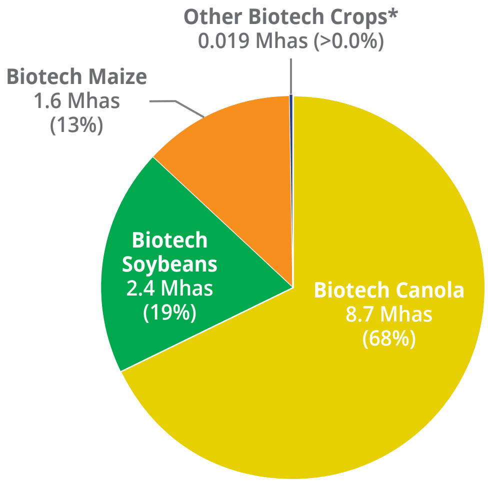


Figure 6. Biotech Crops Planted in Canada, 2018

* Biotech sugar beets, biotech alfalfa, and biotech potato

Source: ISAAA, 2018

market in China. Priority traits for canola in 2018 to 2023 include disease resistance, plant fertility, and high oleic oil. High oleic varieties now account for roughly 12% of the area seeded in Canada, but closer to one third of the domestic crush.

Biotech soybean adoption rate increased to 95%

Soybeans are the next important crop in Canada planted on 2.6 million hectares, 95% of which or 2.4 million hectares were herbicide tolerant. The total soybean area in 2018 decreased by 13% or 735,000 hectares, from 2.9 million hectares to 2.6 million hectares. Biotech soybean area decreased by 3.2% from 2.5 million hectares to 2.4 million hectares in 2018. However, adoption rate increased from 86% in 2017 to 95% in 2018.

The drop in the soybean area was a result of farmers' apprehension of low yield due to dry weather and relatively attractive wheat prices that shifted farmers to plant more wheat. Moreover, soybean prices went down during the growing season. Soybeans were planted in Manitoba, Saskatchewan, and Ontario.

Biotech maize area adoption rate maintained at close to 100%

Biotech insect resistant (IR) maize has been grown commercially in Canada since 1996 and herbicide tolerant (HT) maize since 1999. Throughout the 23-year period, biotech adoption has increased significantly and by 2017 and 2018, the adoption rate of biotech maize reached close to 100% at 1.57 million hectares: 267,000 hectares (17%, HT) and 1.3 million hectares (83% stacked IR/HT). There was no insect resistant maize planted in 2018 (Table 11). Biotech maize in Canada are planted in Manitoba and Quebec.

Other biotech crops planted in Canada

Similar to 2017, the area planted to biotech sugar beets in 2018 was 15,000 hectares which is 100% herbicide tolerant. Sugar beet growing regions in Canada include Ontario in Eastern Canada and Taber, Alberta in Western Canada. Expansion of sugar beet planting area depends on sugar demand, new available technologies, and favorable weather.

HarvXtra™ alfalfa planted in Canada increased 5-fold since it was first planted in 2016 – from 809 hectares to 4,000 hectares in 2018. Farmer acceptance of the technology has been increasing because of the benefits to livestock rearing: more digestibility and allows farmers to delay up to 7-10 days to attain greater yield without sacrificing quality.

In 2018, the area planted to the Four Innate® biotech potato events developed by J.R. Simplot increased to 65 hectares: 15 hectares for generation 1 and 40 hectares for generation 2.

Table 11. Total and Trait Hectares of Biotech Maize in Canada, 2017-2018

	Area Planted (MHa)		% Trait Hectares	
	2017	**2018**	**2017**	**2018**
Total Maize	1.78	1.570		
IR	0.02		1.0	
HT	0.28	0.27	15.8	17
IR/HT	1.48	1.30	83.2	83
Total Biotech Maize	**1.78**	**1.57**	**100.0***	**100.0***

* Adoption rate

Source: ISAAA, 2018

Generation 1 events possess traits to improve the quality of the produce such as decreased levels of reducing sugars, reduced acrylamide potential, and black spot bruising tolerance. Generation 2 Innate® potatoes contain the generation 1 traits plus protection against the late blight pathogen.

Benefits of Biotech Crops

Canada had 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 were valued at US$817 million (Brookes and Barfoot, 2018).

Summary and Future Prospects

The biotech crop area in Canada declined slightly in 2018 by ~3% from 13.11 million hectares in 2017 to 12.75 million hectares due to reduction in planted areas of soybean, maize, and canola. The other biotech crops planted: alfalfa, sugar beets, and potatoes planted in smaller area increased slightly as compared to 2017. However, the average adoption rate of 92.5% was an increase of 2% from 2017.

Biotech adoption in Canada has shown an increasing trend in the last few years and follows the US example. In 2018, up to three varieties of biotech apples: (Arctic® Golden Delicious, Arctic® Granny Smith, and Arctic® Fuji) were approved for commercial planting purposes, livestock feed, and food use (Crop Biotech Update, January 31, 2018). It is estimated that the increasing demand of Arctic® apple slices in the USA could influence planting and commercialization in Canada.

Biotech Golden Rice with provitamin A Event GR2E has been given approval from Health Canada. This decision coincides with the approval from Food Standards Australia New Zealand (FSANZ) in 2017. In the decision, Health Canada stated that the changes made in the rice variety did not pose a greater risk to human health than rice varieties currently available on the Canadian market. Moreover, the biotech event would have no impact on allergies and that there were no differences in the nutritional value of GR2E compared to other traditional rice varieties available for consumption except for increased levels of provitamin (Crop Biotech Update, March 16, 2018).

Health Canada also approved the insect resistant sugarcane and decided that the sugar produced was as safe as produced from conventional sugarcane. The biotech sugarcane was developed by the Centro de Tecnologia Canavieira, a publicly-owned national company focused on research, development, and marketing of varieties of sugarcane and other disruptive technologies (Health Canada, April 18, 2018).

Aside from biotech crops, public acceptance of biotech animals in Canada has also been exemplary. In 2018, US-based AquaBounty Technologies have sold 7 tonnes of biotech salmon fillet in Canada (MacLean's, June 5, 2018). Health Canada and the Canadian Food Inspection Agency have approved the sale of the biotech salmon in 2016. AquaBounty's salmon contains genetic material from ocean pout and Chinook salmon to help it reach adult size faster.

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 exemplary support of the government to biotech crops.

INDIA

Due to the successful control of the spread of unapproved IR(Bt)/HT cotton, India achieved higher planting of the officially approved IR cotton to 11.6 million hectares in 2018-19, an increase of 200,000 hectares over 2017-18 and planted by over 6 million farmers (Figure 7). In 2017-18, the adoption of officially approved IR cotton represents 95% of 12.24 million hectares of cotton planted in India. IR cotton is the only biotech crop planted in India since 2002.

Since India's adoption of IR cotton in 2002, adoption rate has increased exponentially reaching 95% in 2013. This indicates farmer's acceptance that is a manifestation of the benefits they derive from the technology. The fluctuations in the adoption rate after 2013 was due to instability of global cotton prices and market demand. However, in 2017 Kharif cotton season, adoption rate went down to 93% after an all-time high of 96% in 2016 when India reported the cultivation of unapproved IR/HT cotton, estimated at 3.5 million packets planted over approximately 760,000 hectares. Thus, the current 95% adoption rate and 6% biotech crop area indicate the restoration of farmers' confidence on the Bt cotton technology and a sign of demand for the approval of next generation biotech cotton technology including stacked IR (Bt)/HT cotton.

Socioeconomic Benefits and Impact of IR cotton in India

The summary and key findings of 14 studies conducted by public institutes on cost-benefits of IR cotton were included in previous briefs, ISAAA Brief 26 to 53 released from 2002 to 2017. Moreover, estimates by Brookes and Barfoot (2018) indicated that India had 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.

Summary and Future Prospects

A large number of cotton farmers planted unauthorized stacked trait IR (Bt)/HT cotton in major cotton growing areas in Central and Southern zones in Kharif 2017. In order to contain the spread of unapproved IR/HT cotton, the Prime Minister's office in India ordered a probe on the illegal IR/HT cotton which was carried out by Field Inspection and Scientific

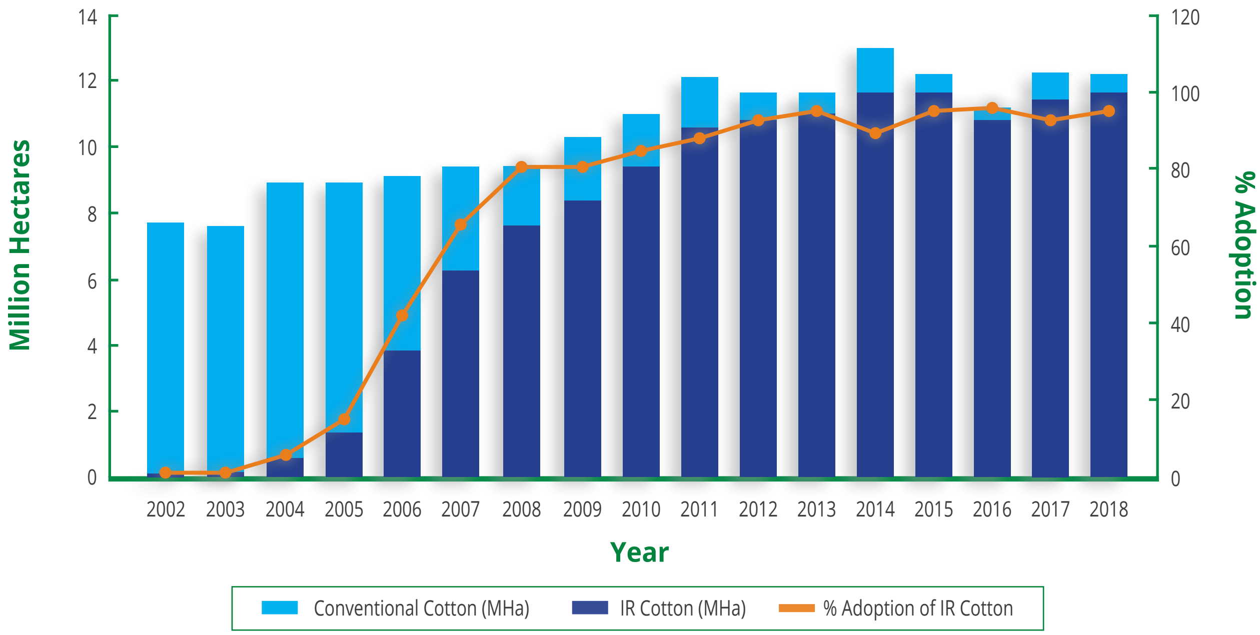


Figure 7. Seventeen Years of Adoption of IR (Bt) Cotton in India, 2002 to 2018

Source: Analyzed and Compiled by South Asia Biotechnology Centre, 2018

Evaluation Committee (FISEC) of the Department of Biotechnology, Government of India in 2018 (PIB, 2018a). A six-month probe nailed down the perpetrators of illegal Bt/HT cotton resulted in curbing of illegal trade activities in Kharif 2018-19 (LiveMint, 2018). In addition, the successful management of pink bollworm contributed to the rebound in cotton planting and production in 2018-19. Cotton farmers in Maharashtra saw an unusual outbreak of pink bollworm in 2017-18 cotton seasons due to the widespread cultivation of substandard, counterfeit and unapproved Bt cotton, non-compliance of refugia and, more importantly, lack of understanding of farmers about Bt technology. The nationwide management of pink bollworm campaign, which was implemented in cotton growing States, focused on dryland farmers in Maharashtra in 2018. The campaign included farmers educational programs, workshops, and awareness and training programs involving key stakeholders. This contributed to increasing farmer's awareness resulting to a significant control of pink bollworm in 2018 Kharif season (Times of India, 2018).

In 2018-19, the dispute between Monsanto and Indian seed company Nuziveedu on intellectual property rights of patented biotech innovation rattled the policy making, innovation ecosystem and biotechnology landscape in India. However, the Supreme Court of India, which heard the case in 2018, delivered a landmark judgment on January 8, 2019 which ruled that the Monsanto patent on novel nucleotide sequence of IR cotton is valid and overturns the earlier decision made by the Delhi High Court that invalidated patenting biotech innovation (Reuters, 2019). India grants patent on biotech innovation under Patents (Amendment) Act 2005 and the protection of plant variety, in this case the seeds under the Protection of Plant Variety & Farmers Rights Act (PPVFRA) 2001. In 2018, the Department of Biotechnology has undertaken a major overhaul of biotechnology regulations by consolidating existing three recombinant DNA safety guidelines of 1990, 1994, and 1998, and released an updated and comprehensive "Regulations and Guidelines for Recombinant DNA Research and Biocontainment- 2017" (DBT, 2018).

The 2017 guidelines address a range of biosafety concerns from research, contained/laboratory use, import/export, storage and handling, manufacturing, disposal, and emergency procedures, and facility certification. Similarly, the Food Safety and Standards Authority of India (FSSAI) proposed labeling of packaged food products containing GM ingredients with a threshold of 5% or more. The FSSAI released a draft "Food Safety and Standards (Labeling and Display) Regulations 2018 that aimed at enforcing labeling of GM products as "Contains GMO/Ingredients derived from GM." Rationalizing the access and benefit sharing under the National Biodiversity Act 2002, the National Biodiversity Authority (NBA) has allowed the applicants for retroactive permission of access to biological material on account of any unintentional contraventions under sections 3, 4, and 6 of Biological Diversity Act, 2002, which allowed the institutions and companies to comply with the provisions of the NBA and contribute to conservation, sustainable use and fair and equitable sharing by December 17, 2018 (NBA, 2018). In order to boost domestic agriculture production, the Ministry of Commerce and Industry, Government of India announced the "Agriculture Export Policy" as part of PM Narendra Modi's target of doubling farmers' income by 2022. The salient features of Agriculture Export Policy are to double agricultural exports from present ~US$30+ Billion to ~US$60+ Billion by 2022 and reach US$100 Billion in the next few years thereafter, with a stable trade policy regime (PIB, 2018b).

Notwithstanding numerous policy initiatives, the Government of India has not made that much progress on commercialization of home-grown GM mustard developed by the Centre for Genetic Manipulation of Crop Plants (CGMCP) of the University of Delhi. In 2017, the Genetic Engineering Appraisal Committee (GEAC) of the Ministry of Environment, Forests, and 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 (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). In 2018, the GEAC instructed the developer of GM mustard to assess the safety of GM mustard on honeybee and other pollinators, however, the studies were not initiated due to lack of study protocols and uncertainty about the approval process. While urging the society to take a considerate view on this home-grown innovation of GM mustard, Dr. K. Vijay Raghavan, Principal Scientific Adviser to the Prime Minister said *"GM mustard is safe and useful but commercial release of the seed is a socio-political issue"* (The Hindu, 2018). 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 2018.

In the meantime, India reported the infestation of invasive pest fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Insecta: Lepidoptera), in maize fields in Karnataka state in July 2018. The pest incidence noted in the field was more than 70%. The populations of fall armyworm collected from different regions of Karnataka were tested for molecular identification of larvae confirming 100% match with populations from Canada and Costa Rica (NBAIR, 2018). Reports from different maize growing States of India indicated the devastating infestation of fall armyworm on maize, causing heavy damages in maize growing States of Southern India in both Kharif and Rabi seasons (Economic Times, 2018).

PARAGUAY

Since 2004, Paraguay has been planting biotech soybeans, maize, and cotton, and in 2018, 3.8 million hectares has been planted to these biotech crops, an increase of 26% (in absolute value) compared to 2.96 million hectares in 2017. The 3.8 million hectares of biotech crops was comprised of 3.35 million hectares soybeans, 392,000 hectares maize, and 10,000 hectares cotton with an average adoption rate of 90%, 4% higher than 2017 (Figure 8).

Some 10,000 farmers have benefited from adopting biotech 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). The insurmountable year-on-year increases of economic benefits accrue to farmers, their families, and the whole community.

Biotech stacked IR/HT soybean area increased by 76% in 2018

Paraguay has planted biotech soybeans in the last 14 years. In 2018, there were 3.4 million hectares planted to soybeans, 99% of which or 3.35 million hectares were biotech, with 1.68 million hectares HT and 1.67 million hectares IR/HT stacked traits. The area of HT soybean declined by 3% in 2018 from 1.7 to 1.68, and the area of IR/HT stacked traits increased by 76% from 951,000 hectares (Table 12).

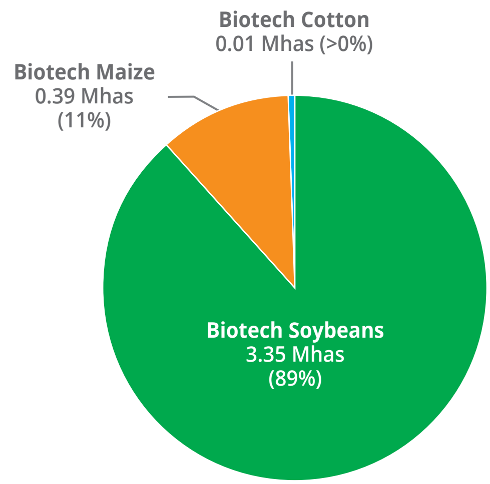


Figure 8. Biotech Crops Planted in Paraguay, 2018

Source: ISAAA, 2018

The increasing adoption of Intacta™ soybeans in South America was due to the benefits enjoyed by the farmers since its adoption in 2013. Brookes and Barfoot (2018) highlighted that for every additional US$1 spent on Intacta™ soybean seed, farmers have gained US$3.88 additional profit. The technology has decreased pesticide spraying by 10.44 million kg and reduced greenhouse gas emissions equivalent to removing 3.3 million cars off the roads (Crop Biotech Update, August 29, 2018).

Biotech stacked IR/HT maize accounts for 80% of all biotech maize

Biotech maize area increased by 45% in 2018 from 270,000 hectares in 2017 to 392,000 hectares, with an adoption rate of 52%, an increase of 10% from 2017. The 392,000 hectares was comprised of 9,000 hectares IR, 68,000 hectares HT and 315,000 hectares IR/HT stacked traits. The area planted to stacked IR/HT traits increased by 40% and was >80% of the biotech maize planted. HT maize increased by 580%, and was 17.3% of the biotech maize

Table 12. Total and Trait Hectares of Biotech Soybeans in Paraguay, 2017-2018

	Area Planted (MHa)		% Trait Hectares	
	2017	**2018**	**2017**	**2018**
Total Soybean	2.79	3.400		
HT	1.73	1.688	64.5	50
IR/HT	0.95	1.666	35.5	50
Total Biotech Soybeans	**2.68**	**3.35**	**96.1***	**99***

* Adoption rate

Source: ISAAA, 2018

Table 13. Total and Trait Hectares of Biotech Maize in Paraguay, 2017-2018

	Area Planted (MHa)		% Trait Hectares	
	2017	**2018**	**2017**	**2018**
Total Maize	0.64	0.76		
IR	0.03	0.01	13.0	2.3
HT	0.01	0.07	3.7	17.3
IR/HT	0.23	0.32	83.3	80.4
Total Biotech Maize	**0.27**	**0.39**	**42.2***	**52.0***

* Adoption rate

Source: ISAAA, 2018

planted, while IR maize declined by 74% (Table 13).

Biotech cotton maintains area and adoption at 100%

Similar to 2018, biotech cotton was planted on 10,000 hectares and maintained its 100% adoption rate.

Benefits from Biotech Crops

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

Summary and Future Prospects

The biotech crop area in Paraguay increased by 26% with the largest increase obtained from biotech soybean at 25%. Moreover, both the total and biotech area of maize and soybean increased in 2018 contributing to the year's high adoption rate. Intacta™ soybean area increased by 76% and is expected to continue with the benefits reported by Brookes and Barfoot (2018) in the first five years of adoption.

The prevailing environment to increase biotech adoption including financing and price incentives for soybean and maize motivated farmers to plant more. In addition, the weather was favorable for planting these biotech crops compared to the drought experienced in 2017 (USDA FAS, 2018). Producers partnered with local contacts by supplying inputs to producers in exchange for a negotiated volume of soybeans or its monetary equivalent based on negotiated cost. It is estimated that 80% of production came from land owned by producers and 20% from land that was rented. Paraguay farmers are big-holder farmers with small farm size of 100-200 hectares, medium farm at 500 hectares, and large farm at 1,000 hectares.

Expansion of biotech maize and soybean areas may compete with the recent rise in domestic meat prices that is making livestock production more profitable.

CHINA

China has been one of the leaders in planting biotech crops since 1997. In 2018, two biotech crops were planted in China: 2.93 million hectares insect resistant cotton and 9,600 hectares of virus resistant papaya, for a total of 2.94 million hectares. China had a 5% increase of biotech crop area from 2017 at 2.8 million hectares.

Since biotech cotton was 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 2.94 million hectares. The total cotton area in 2018 increased to 3.83 million hectares, a ~31% increase from 2.9 million hectares in 2017. The adoption rate of biotech cotton was the same as 2017 at 95%. The highest adoption rate reached by IR cotton in China was 96% in 2015.

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 9,600 hectares, a 26% increase from 7,130 hectares in 2017, and an adoption rate of 78% (Table 14). Papaya was planted in Guangdong province, Hainan Island, Guangxi province, and Yunnan province.

This technology developed by South China Agricultural University in Guangzhou, Guangdong, China, features the viral replicase gene that made it highly resistant to all the local strains of PRSV.

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. China had 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).

The benefits of IR cotton were extensively studied by Quiao et al. (2016) 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. (2016) 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

Table 14. Area of Biotech Papaya Planted in China, 2018 (Hectares)

Location	Total papaya Area	Biotech Papaya Area	% Adoption
Guangdong Province	4,500	4,300	95.6
Hainan Island	4,400	3,700	84.1
Guangxi Province	1,900	1,300	68.4
Yunnan Province	1,500	300	20
Total	12,300	9,600	78

Source: (Li, Huaping, personal communication, 2018).

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 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 (Crop Biotech Update, October 19, 2016).

Summary and Future Prospects

China's biotech crop area planted to insect resistant cotton and virus resistant papaya have expanded in 2018 and is expected to increase with the local and international demand for quality products. China is a large exporter of biotech cotton products including cotton fiber, cottonseed meal, and cottonseed oil. Although China is a large importer of biotech soybeans, cotton, maize, Distiller's dried grains with solubles (DDGs), and sugar beet pulp for feed and processing, trade has been affected because of China's slow and unpredictable approval process.

The newly named Ministry of Agriculture and Rural Affairs (MARA) oversees the GMO Safety Office. The roadmap released by MARA prioritized non-food use biotech crops (such as cotton), biotech crops for indirect food use (such as soybeans and maize), and lastly biotech food crops (such as rice and wheat) for commercialization and cultivation. In 2018, MARA added supplementary in-country testing and studies to the battery of evaluations required to progress through the Chinese regulatory process. China's National Biosafety Committee (NBC) review and approval process has delayed import approval for developers. Thus, since 2017, only five new events were given approvals by MARA in January 2019. Domestic technology developers who have been facing severe financial pressure due to slow regulatory approval sought overseas regulatory approval such as the insect resistant rice Huahui-1 developed by Huazhong Agricultural University (USDA FAS, 2018).

To learn the economic impact of these delays in China, a study was conducted by Informa and supported by CropLife International. The report, *The Impact of Delays in Chinese Approvals of Biotech Crops*, quantifies the significant economic impact due to the delayed availability of new biotech products for farmers in major biotechnology cultivation countries, including the United States, Brazil, Argentina, and China. According to the report, the approval delay between 2011 and 2016 cost U.S. farmers nearly US$5 billion in farm income. Beyond the farm gate, the study estimates that nearly 34,000 potential jobs were prevented, as well as US$4.6 billion in wage growth (CropLife International, May 30, 2018). These findings confirm the fears farmers have carried for years: restrictions in technology have a direct, negative, and significant impact on their bottom line. Farmers benefit from adopting GM seeds that produce more yields with less input and can better adapt to climate change conditions. On the other hand, importers benefit from the timely approvals by having more and diversified availability of food/feed crops, which leads to a safe and stable food supply, improved consumer choice, and lower food prices in some areas.

Soybean exporters to China belonging to the International Soybean Growers Alliance (ISGA) made up of soy growers and industry representatives from Argentina, Brazil, Canada, Paraguay, the USA, and Uruguay have been frequently sending delegations to China to ensure a more efficient biotech approval process (Feed Navigator, April 30, 2018). It is important to note that approval to commercialize new biotech and soybean products in the country developers requires China approval first to ensure that farmers do not incur losses.

Currently, the Chinese public remains to be uninformed about the science and potentials of the technology. Activists who are not even farmers and food producers easily mislead them. It is therefore essential that knowledge of transgenic biotechnology, the benefits derived and biosafety issues be imparted to the general public in order to enhance acceptance, adoption, and utilization of biotech crops.

PAKISTAN

In 2018-19, the area under Bt cotton declined to 2.8 million hectares due to overall reduction in total area under cotton to 2.96 million hectares. The Cotton Crop Assessment Committee (CCAC) estimated a steep decline in cotton production at 10.85 million bales from earlier projections of 14.2 million bales for 2018-19, and an absolute decline of almost 0.75 million bales from the production of 11.58 million bales in 2017-18. Pakistan peaked cotton production of 14.9 million bales in 2013-14 (PCCC, 2018). The reduction in area and production of cotton was mainly due to uncertainty in approval of new generation biotech traits and high yielding cotton varieties including IR/HT cotton, shortage of water for timely irrigation, and infestation of pink bollworm and cotton leaf curl virus (CLCuV).

In the past, the significant increase in IR cotton area was possible because of the introduction of a substantial support package for farmers including subsidy on fertilizers, reducing interest

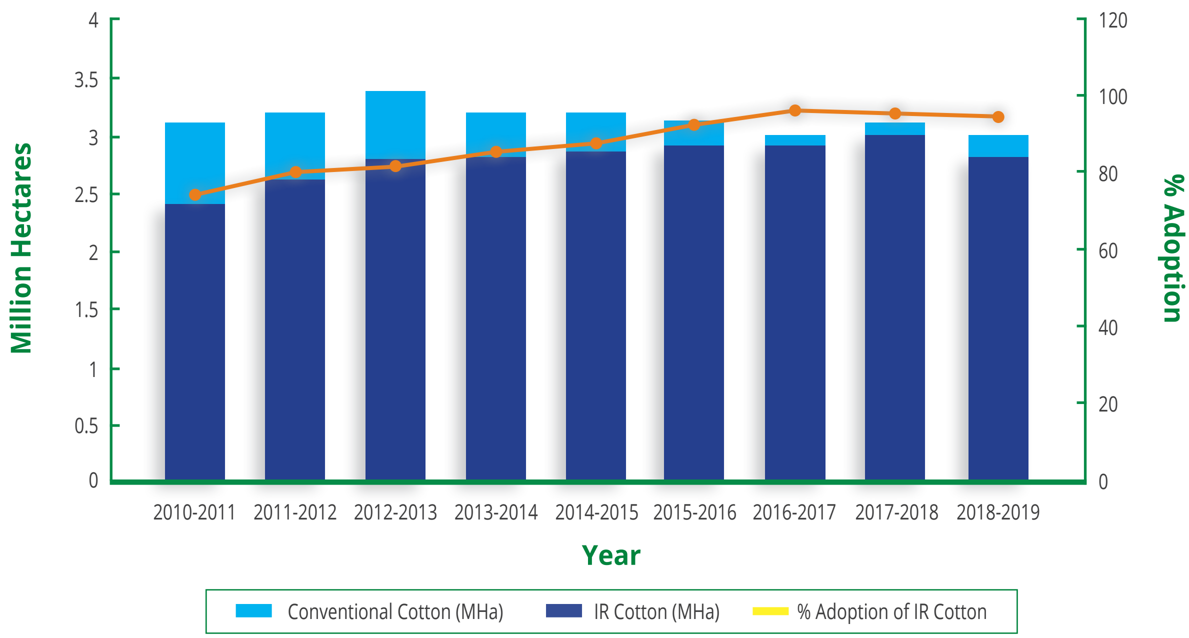


Figure 9. Adoption of IR Cotton in Pakistan, 2010 to 2019

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

rates on loans, and other support measures introduced in the budget 2017-18 by the Government of Pakistan. Other factors include training of farmers for the management of pink bollworm and leaf burning syndrome. and competitive market price for cotton (Ministry of Commerce and Textile, 2017). Figure 9 shows the adoption of Bt cotton in Pakistan from 2010 to 2018, with the highest adoption rate obtained in 2016-2017.

Benefits of Biotech Cotton

For the last 8 years, an estimated 725,000 smallholder Pakistani farmers have been benefiting from the economic gains in using biotech cotton. The economic gains from biotech crops for Pakistan for the period of 2010 to 2016 was US$4.8 billion and US$483 million for 2016 alone (Brookes and Barfoot, 2018).

In 2017, two research studies were conducted 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 (Bakhsh, 2017). 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 *cry1* 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 *cry1* 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 increases in the private benefits from IR cotton (Bakhsh, 2017).

The International Food Policy Research Institute and University of Guelph researchers conducted a study (Nazli, 2018; Crop Biotech Update, November 28, 2018) to determine the impact of Bt cotton adoption on the well-being of cotton farmers in Pakistan. The researchers used propensity score matching method and found that Bt cotton adoption has positive impacts on the well-being of the farmers. However, the extent of impacts depends on the agro-climatic conditions and farm size. For instance, the impact of Bt cotton adoption on yield for small farmers is about 50% of the same for large farmers. Furthermore, the impact of Bt cotton adoption on household income was positive and significant for medium and large farmers, but not for small farmers. The impacts of Bt cotton on yield and income are larger under hot and humid conditions compared to those under hot and dry climatic conditions.

Summary and Future Prospects

In 2018-19, the National Biosafety Committee (NBC) of Ministry of Climate Change resumed regular functioning after the 18th Constitutional Amendment that decentralized roles and responsibility of biotech products to provincial government in 2010. In the meantime, a series of consultation and discussion as to who should regulate biotech products, the federal or provincial government stimulated approval of biotech products for R&D, field trials, and commercial release. Evidently, the approval for commercial planting of stacked IR/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 with the Provincial Government. In 2018-19, the Plant Breeders Rights (PBR) Rules 2018 was introduced, which was pending since 2017. Consequently, the Ministry of National Food Security and Research (MNFSR) would initiate a process of establishing a registry to enforce the plant breeders' rights in the near future which will provide the legal protection to new varieties, promote R&D and encourage seed industry in Pakistan (MNFSR, 2018). In 2016, Pakistan introduced the Plant Breeders' Right Act 2016 that allowed the notification of the PBR Rules 2018.

The resumption of meeting of the National Biosafety Committee (NBC) in 2018 was an indication of the timely implementation of three key regulations including the Biosafety Rules 2005, the Seed Amendment Act 2015 and subsequent Rules, and the Plant Breeders Rights Act 2016 and Rules 2018. Not only it would promote R&D of new varieties and traits but also facilitate commercialization of crops pending approval and varietal registration including IR/HT cotton and IR/HT maize (USDA FAS, 2018). In 2017, the Federal Seed Certification and Registration Committee (FSCRC) of the Ministry of National Food Security and Research approved the field performance trials of IR/HT maize hybrids as part of the regulatory requirement for varietal registration (Table 15). For the last two years, 2016-17 and 2017-18, the different biotech events of IR/HT maize developed by Monsanto (now Bayer) and Dupont Pioneer (now Corteva) have been undergoing the hybrid registration approval process with an expected commercialization in 2019 (Table 16). It is expected that maize

Table 15. Approval of Field Trials of Maize Events by FSCRC, 2018

Gene(s)/Event	Traits	Developer
IR	Insect Resistance	CEMB, NIGAB
cry1F, cry1Ab and cp4epsps	Insect Resistance and Herbicide Tolerance	Pioneer
cry1Ab x mESPSPS	Insect Resistance and Herbicide Tolerance	Syngenta
mESPSPS	Herbicide Tolerance	Syngenta

Source: PSC/NBC/PCCC, Compiled by SABC and ISAAA, 2018

Table 16. Biosafety Approval of IR/HT Maize Events by Federal NBC in Pakistan, 2018

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

Source: PSC/NBC/PCCC, Compiled by SABC and ISAAA, 2018

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 2019.

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, 2018). In order to further increase the supply of maize, it is expected that the biotech maize, with 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, and 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 sometime by 2019 will deliver around US$1 billion additional benefits to farmers in the next 10-year period.

Notably, the NBC meeting held in 2018 has also approved R&D and field testing of large number of biotech events of cotton, potato, wheat, and sugarcane. These biotech crops address both biotic and abiotic stresses including insect resistance, heat tolerance, salinity tolerance, biofortification with iron and zinc and increased phosphorus efficiency. In addition, NBC endorsed 48 cases for import approval for seeds, laboratory experimentation, field trials, and commercial release that were approved in 17th NBC meeting and nine cases of genetically modified organisms (GMOs) related activities were on the agenda of the 18th NBC meeting held in 2018. In addition, the

Pakistan Central Cotton Committee (PCCC) has announced that 93 new cotton varieties will undergo National Coordinated Varietal Trials (NCVT) in four provinces in Pakistan before Pakistani authorities make their decision to allow commercial cultivation. Table 17 lists the different biotech crops approved for field testing developed by public sector institution in Pakistan.

SOUTH AFRICA

In 2018, South Africa completed 21 years of successful commercialization of biotech crops with a total acreage of 2.74 million hectares planted with three principal biotech crops: cotton, maize, and soybeans. This is a slight increase from the 2.73 million hectares of biotech crops planted in 2017. The area per biotech crop was comprised of maize (2.0 million hectares), soybeans (693,975 hectares, and cotton (42,654 hectares) (Figure 10). Average biotech crop adoption stands at 96%. The combined area planted to maize, soybeans, and cotton was 3.07 million hectares, a slight decrease from the 2017/18 planting of 3.1 million hectares. The decline was mainly from maize and soybean plantings. A slight reduction in biotech maize area was due to delayed rainfall. Given that the more ideal planting window is around October-December, this forced some farmers in the western parts of the country to postpone planting into 2019. The soybean area went down by 5.8% as large number of farmers used farm-saved seeds. Biotech cotton and maize planting increased by 14% and 0.3% respectively. Stacked IR and HT traits are becoming increasingly popular with farmers due to the multiple benefits offered.

Table 17. Approved Biotech Crops for Field Testing Developed by Public Sector, 2018

Crops	Gene/Trait	Developer
Cotton	Abiotic stress tolerance	NIBGE
	Insect resistance (NIBGE 8)	NIBGE
	Insect resistance (NIAB Bt-1 +NIAB Bt2)	NIAB
	Insect resistance (double Bt) and herbicide tolerance (Klean Cotton)	CEMB
	Insect Resistance	CEMB
	Insect Resistance (181)	AARI
	Insect resistance (Cry 1Ac & Cry 2Ab)	AARI
	Insect Resistance CIM 600 &616; Cyto-177	CRI
	Insect resistance (Eagle1-6)	CRI
Potato	Multiple genes	CEMB
Wheat	Increased salinity & heat tolerance	NIBGE
	Biofortification (Iron, Zinc)	FCCU
	Increased phosphorus use efficiency	FCCU
	Salinity and drought tolerance	CABB/UAF
Sugarcane	Insect resistance & herbicide tolerance	CABB/UAF

Source: PSC/NBC/PCCC, Compiled by SABC and ISAAA, 2018

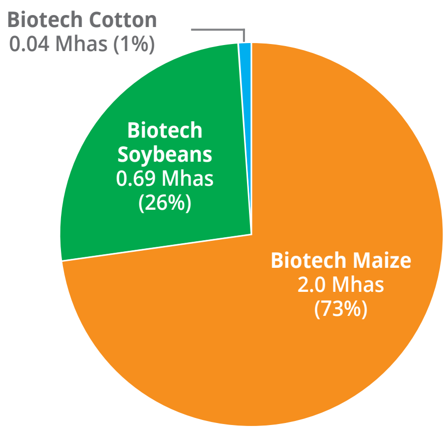


Figure 10. Biotech Crops Planted in South Africa, 2018

Source: ISAAA, 2018

Biotech maize area increased slightly at 87% adoption rate

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 2018, the estimated biotech maize area was 87%, against the 85% recorded in 2017. A total of 2 million hectares of biotech maize were grown against total maize area of 2.3 million hectares. This 2 million hectares of biotech maize is comprised of 207,000 hectares IR, 460,000 hectares HT, and 1.3 million hectares IR/HT. The long-term trend in maize production indicates South Africa is producing more maize on less area due to more efficient and effective farming methods and practices using less marginal land adoption of biotech seeds. GM area decreased from the high of 2016/17, returning to around 85% adoption level. it may be noted that the 2016/17 adoption level was exceptionally high with farmer chasing record high maize prices, caused by the 2015-16 drought. The maize price for 2017/18 was low and farmers tried to limit input cost, and opted to plant single trait or conventional maize than stacked traits.

It is predicted that the late rains will negatively affect yields.

Biotech soybean adoption rate maintained at 95%

Soybeans have been planted in South Africa since 2001, and in 2018, 731,000 hectares have been planted indicating a decrease of 6% (45,000 hectares) from 775,000 hectares planted in 2017. Biotech soybean was planted on 694,000 hectares or 95% of the total soybean area in South Africa. The country had an increase in production in 2017, and the bumper produce reduced soybean area and biotech soybean area marginally. Rising domestic demand for soybeans provide an incentive for future 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. The soybean sector is considering introducing a technology and breeding levy to encourage investment in R&D, which has been low for soybeans. This is projected to increase the purchase of 'new' seed by farmers.

Biotech cotton increased by 14%

Cotton with insect resistance (Bt) has been planted in South Africa since 1998. In 2018, 43,000 hectares were planted, which is a 14% increase from the 37,000 hectares planted in 2017. 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 IR/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 2018-2019 season.

Economic Benefits of Biotech Crops

The economic gains from biotech crops for South Africa for the period 1998 to 2016 were ~US$2.3 billion and US$330 million for 2016 alone (Brookes and Barfoot, 2018).

Summary and Future Prospects

South Africa was the 8th biotech crop country in 2018 with 2.73 million hectares in 2018 a slight increase of some approximately 7,000 hectares compared in 2017. Most African farmers have adopted plant biotechnology with 87% adoption of biotech maize, 95% biotech soybean, and 100% of biotech cotton. The country's Agricultural Research Council's Biotechnology Platform established in 2010 aims to create high throughput resources and technologies for vegetables, ornamental plants and indigenous crops. Biotech crops and products being developed include improved grapevine and wine microorganisms by the Institute for Wine Biotechnology at Stellenbosch University (IWBT). Improved sugarcane which are drought tolerant, disease resistant, herbicide tolerant (imazapyr herbicide), and improved nitrogen efficiency are being explored at the South African Sugarcane Research Institute.

URUGUAY

Uruguay is the 10th country planting biotech crops in 2018 with 1.32 million hectares, a 15% increase from 2017 which was 1.14 million hectares. Biotech soybeans and maize reached adoption rates of 97% and 88%, respectively.

The area planted to soybeans increased by 17% from 1.1 to 1.3 million hectares with an accompanying increase of 16% in biotech soybean area from 1.09 to 1.26 million hectares. The 1.26 million hectares was comprised of 70% HT and 30% stacked IR/HT trait, which increased by 36% from 279,000 hectares to 379,000 hectares (Table 18). The reductions in 2017 was due to drought that necessitated soybean seed imports from Paraguay and Argentina. The 2018/19 season weather was favorable to the country's soybean crop especially to those areas that were sowed early. Moreover, there were new seed purchases and high fertilizer application rates. Analysts have estimated profits of around US$100-US$200 depending on the farm holdings.

The area planted to maize in 2018 was 60,000 hectares, a 20% increase from 50,000 hectares in 2017. Adoption of biotech maize was 88%, with 3,000 hectares HT, and 50,000 stacked IR/HT traits (Table 19). Growing demand for maize increased in 2018 due to the losses incurred in the drought of 2017. Moreover, improved maize prices contributed to the increased area planted. Maize harvest is mainly used for cattle feed followed by the poultry industry and feedlots. It is also used by local balanced feed manufacturers, grain ethanol plants and operations that export live cattle to Turkey and the Middle East. Farmers conduct crop rotation throughout the year with 1.2-1.3 million hectares planted with soybeans in Uruguay, a ratio of 17 hectares of soybeans for every hectare of maize.

Uruguay does not normally export corn. Imports for MY 2018/19 was forecasted at 440,000 tons; lower than the record of the previous year as production is expected to rebound but still the second highest in history as local production cannot meet domestic demand. Brookes and Barfoot (2018) indicate that Uruguay farmers numbering more than 3,000 had enhanced farm income from biotech soybean and maize

Table 18. Total and Trait Hectares of Biotech Soybeans in Uruguay, 2017-2018

	Area Planted (MHa)		% Trait Hectares	
	2017	**2018**	**2017**	**2018**
Total Soybean	1.11	1.30		
HT	0.81	0.88	74.4	70.0
IR/HT	0.28	0.38	25.6	30.0
Total Biotech Soybean	**1.09**	**1.26**	**98.2***	**97.1***

* Adoption rate

Source: ISAAA, 2018

Table 19. Total and Trait Hectares of Biotech Maize in Uruguay, 2017-2018

	Area Planted (MHa)		% Trait Hectares	
	2017	**2018**	**2017**	**2018**
Total Maize	0.050	0.060		
HT	0.002	0.003	4.8	6.0
IR/HT	0.048	0.050	95.2	94.0
Total Biotech Maize	**0.050**	**0.053**	**85.7***	**100.0***

* Adoption rate

Source: ISAAA, 2018

of US$284 million from 2000 to 2016, and the economic benefits for 2016 alone was US$60 million. These farmers, their families, and the community have been benefiting immensely from biotech crops since its introduction in 2000.

LATIN AMERICA

Ten countries in Latin America planted biotech crops in 2018, led by Brazil, and followed by Argentina, Paraguay, Uruguay (included in the top 10 biotech countries), Bolivia, Mexico, Colombia, Honduras, Chile, and Costa Rica in decreasing order of biotech crop area. Details on the biotech crops planted, adoption trends, and future prospects for respective countries and the region are discussed below.

BOLIVIA

After a huge drought that hit South America and affected Bolivia in 2017, herbicide tolerant biotech soybean area in 2018 remained lower than the potential area of 1.3 million hectares. Biotech soybean event GTS 40-3-2, the only approved event in Bolivia since 2008, has been regarded as the country's most treasured crop. The province of Sta. Cruz, the center of agricultural development in commodity crops as well as commercial livestock has been planting biotech soybeans. Some 1.26 million hectares of 100% biotech soybean has been planted in Bolivia in 2018 compared to 1.28 million hectares in 2017, a marginal 200,000 hectare difference or -1.2%. Farmers have not fully recovered from the 2017 drought incidence that affected 300 large holder farmers. It was the country's worst drought in 25 years.

Benefits from Biotech Soybeans

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), benefiting the more than 300 biotech soybean farmers and their families in Bolivia.

One study conducted by ANAPO with its partners IBCE and CAO indicated that biotech soybean 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 (ANAPO, 2017).

Summary and Future Prospects

Aside from planting biotech soybeans since 2008, Bolivia imports various food products derived from biotech crops from neighboring biotech crop countries of Brazil, Argentina, Paraguay, and Uruguay. This dependency to increasing biotech crop import confuses food producers since the government prohibits the production, importation, and commercialization of genetically modified organisms. To date, food producers in Sta. Cruz demand that the central government authorize the use of more biotech crops that resist climate change, pests, and weeds in maize, cotton, and sugarcane to improve yields and lower production costs (Genetic Literacy Project, March 23, 2018).

Fortunately, the government has considered domestic ethanol production to replace increasing imports of gasoline. Bolivian President Evo Morales announced in March 2018 that beginning 2018, the country would start blending 10% ethanol to gasoline that will rise to 25% in 2025. Ethanol feedstocks will be sugarcane and sorghum (USDA FAS, 2018). However, more recently, President Morales announced that Bolivia allows cultivation of biotech soybean to produce ethanol (Biofuels Digest, March 21, 2019). This government move is timely to reduce fossil fuel importation costing the government US$900 million annually, and will open up a biofuel industry to increase GDP, accompanied with some 27,000 new direct jobs, as well as reduction of carbon dioxide emissions by 6%.

Drought tolerant soybean with *HB4* gene has been approved in the USA and Brazil, and can be adopted by farmers in Bolivia who are experiencing continuous drought. Moreover, drought tolerant biotech soybeans can boost yields between 20% and 30% from the current average of 2,500 kgs per hectare. The technology will be a welcome respite from continuous droughts, floods, and other causes that generated more than US$168 million in losses.

The meeting in March 2019 of various associations of small farmers and large producers in Santa Cruz welcomed the new challenge of planting 250,000 hectares of biotech soybeans to be used exclusively for biodiesel and includes roughly US$2 billion in public funds for infrastructure and machinery.

Parallel to this, the approved biotech insect resistant sugarcane in Brazil and the recent commercialization of 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 10% ethanol blend mandate, it would have to increase the planted area by 180,000 hectares and increase its yields to 80 metric tons per hectare (USDA FAS, 2017).

MEXICO

Mexico has been planting biotech crops (cotton and soybeans) since 1996 and is one of the six pioneer biotech crop planting countries. Biotech soybean planting was suspended in the country in 2017 following a court injunction. At the same time, a court injunction against biotech maize field trials continues to affect producers and the scientific community. Biotech cotton was the only biotech crop planted in Mexico since 2017 at 110,000 hectares that increased to 218,000 hectares in 2018, an enormous increase of 100%. Biotech cotton traits planted include 92,000 hectares HT and 127,000 hectares stacked IR/HT traits.

The increase in biotech cotton cultivation was due to the preference to plant cotton over other crops (sorghum and maize used for silage) and is attributable to attractive prices and good integrated pest management with biotech seeds. In Mexico, domestic cotton production accounts for only 50 to 75% of the country's cotton consumption and relies on US importation of cotton. Oilseed crops (soybeans and canola) and feedstock maize are also imported from the USA, Canada, and South American countries. Adoption of biotech soybeans, canola, and maize can therefore ease the annual increasing importation of these raw materials (USDA FAS, 2018).

Benefits from Biotech Cotton and Soybeans

Mexico had 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). Some 8,000 farmers and their families are benefiting from economic gains derived from these biotech crops.

Summary and Future Prospects

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. Only biotech cotton is allowed to be planted in the country, which has increased by 100% in 2018. 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.

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. Current research focuses on drought tolerance in maize, and other traits beneficial to agriculture including reduction in fertilizer and herbicide use in soybean and cotton. 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 injunctions that have suspended the planting of biotech maize and soybeans, 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. Moreover, scientists opt to conduct experimental trials in Argentina because of the onerous Mexican requirement which makes the process time consuming and costly.

COLOMBIA

Colombia started planting biotech cotton in 2002 and biotech maize in 2007. Since then, the biotech maize area surpassed biotech cotton area. In 2018, biotech maize was planted on 76,000 hectares and biotech cotton on 12,000 hectares for a total of 88,000 hectares, an 8% decrease from 95,000 hectares in 2017 (Figure 1). The slight reduction in the total area planted to biotech crops was due to a 12% reduction in biotech maize area, from 86,000 hectares to 76,000 hectares in 2018. This was comprised of 14% HT (11,000 hectares) and 86% (65,000 hectares) stacked IR/HT traits. The reduction in biotech maize area was in turn due to the overall decrease in maize planting because domestic maize prices are highly affected by international prices and high production costs. The international market supplies 80% of the domestic maize supply.

For cotton, an increase of 26% was obtained in 2018 from 10,000 hectares in 2017 to 12,000 hectares in 2018. The biotech cotton adoption rate was 100% with an area comprised of 1,000 hectares HT and 11,000 hectares stacked IR/HT traits. The average global cotton price in 2018 was relatively high with accompanying favorable weather conditions and reduced production cost, which contributed to a 26% increase in biotech cotton area.

Since 2000, 12 hectares of blue carnations and blue roses are planted in Colombia annually under controlled conditions for export to Japan (USDA FAS, 2018).

Benefits from Biotech Maize and Cotton

Colombia had enhanced farm income from biotech crops of US$182 million in the period 2002 to 2016 and the benefits for 2016 alone were US$29 million (Brookes and Barfoot, 2018). Some 80,000 farmers and their families in Colombia have been benefiting from biotech crops in the last 14 years of commercialization, improving their economic condition 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 emissions. From 2002 to 2015, there was a reduction of 55.1 million gallons (208.6 million liters) of water, where 56.9% of the decrease 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 (insecticides 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 off the road for 12 years; and reducing carbon emissions 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 received 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).

Summary and Future Prospects

Colombian farmers have adopted biotech cotton and maize and have gained both directly and indirectly the economic and environmental benefits from these biotech crops. In 2018, the 8% decrease in biotech crop area was primarily due to reduction in maize area, and the low global price and high production cost for maize. 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.

To support the interests 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. The government has been importing maize-derived ethanol from the USA which could increase maize production in the future. Moreover, sugarcane, which is an important ethanol feedstock may be tapped by Colombia, with the recent approval and commercialization of insect resistant biotech variety in the US and Brazil and drought tolerant variety in Indonesia.

Public sector technology developers in Colombia are improving economically important crops to contain new traits to target food production problems in the country. These include sugarcane varieties resistant to yellow leaf virus, pest and disease resistant rice, cassava and fodder grass, sacha inchi and castor bean with high oleic acid content, coffee borer resistant coffee, and insect resistant potato, among others.

HONDURAS

Honduras first planted biotech maize (the only biotech crop in Honduras) in 2002. In 2018, 36,000 hectares of biotech maize were planted at 10% higher than 32,000 hectares in 2017. The biotech maize area was composed of 1,000 hectares IR, 5,000 hectares HT and 29,000 hectares stacked IR/HT, similar to 2016. IR (Bt) maize was not planted in 2017 but was planted again in 2018. The minimal increase in biotech maize was a rebound from the drought that affected some planting areas (USDA FAS, 2018). Biotech maize is used for food/feed consumption and seed production, with a few biotech maize seeds exported to Colombia.

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. Honduras had 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), benefiting some 7,000 farmers and their families.

Future Prospects

It is noteworthy that Honduras government approved two maize IR/HT stacked traits MON87427-7 x MON89034-3 x SYN-IR162-4 x MON87411-9 and BT11 x MIR162x GA21 (Agrisure VIP3) for field testing.

On January 10, 2018, the Honduras National Service of Food Safety, Animal and Plant Health (SENASA) published a Guide of Processes and Procedures of the Regulatory System for Genetically Engineered (GE) Seed Products in the official gazette. This strengthened the regulatory system by publishing the process as an official regulation. The guide provides users with the general outline to follow in the requests and approval of field test, pre-commercialization, and commercialization of new biotech events.

Honduras imported yellow maize valued at US$85.5 million and soybean meal at US$86.3 million from the USA for its poultry, livestock, shrimp, and tilapia industries in 2018. These imports are needed since local production is not enough to meet domestic needs. The area of biotech maize can be increased if farmers in Honduras who are planting traditional non-hybrid maize varieties which covers 175,000 hectares begin planting biotech maize. Non-biotech maize yields 1.5 metric tons to 5.5 metric tons per hectare (especially hybrids), as compared to the improved biotech maize varieties which yield 7.6 metric tons per hectare (USDA FAS, 2018). The increasing annual imports could motivate the government to allow cultivation of more maize varieties and biotech soybean.

CHILE

Biotech crops have been planted in Chile under strict field conditions for export since 1996. In 2018, a total of 10,454 hectares were planted in the country, a 20% decrease compared to the 13,143 hectares planted in 2017. The biotech crop area was comprised of 5,351 hectares IR/HT maize (51%), 3,351 hectares canola (32%), and 1,752 hectares HT soybeans (17%). For this year, weather conditions, productivity, and countries at the Northern hemisphere, which are the export markets of biotech seeds, caused a decrease in the sown area.

Chile remains the 10th largest producer of seeds (including biotech) in the world. Planting biotech seeds was mainly for research and propagation purposes, and there has never been a commercial biotech crop production. Moreover, Chile does not have a biotechnology framework and only allows biotech seed planting for export. For imports however, the Ministry of Environment (MOE) requires a risk assessment study, while the Ministry of Health (MOH) requires the producer or importer to register the products containing biotech ingredients, and for products to be labeled only if the biotech product is substantially different from its conventional counterpart.

During his second term, Chilean President Sebastian Piñera led the discussion of the implementing regulations that would ratify the law he signed during his first term (2010-2014), the International Union for the Protection of New Varieties of Plants 1991 (UPOV 91). The Law ensures seed quality, distinctiveness and stability of traits, as well as the uniformity of seed lots, and a number of safety parameters for certain plant species. This ratification could open doors for the development of a biotechnology/biosafety law and possible commercialization of biotech crops (USDA FAS, 2018). If biotech crops will be allowed for commercialization, Chile can be an excellent producer of biotech sugar beets, maize, and alfalfa.

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. Biotech cotton and biotech pink pineapple have been planted in Costa Rica since 2017. In 2018, a total of 139.15 hectares of biotech cotton and pink pineapples were planted in Costa Rica. These were comprised of 115.45 hectares of biotech cotton (105.45 hectares stacked IR/HT and 10 hectares were HT) in addition to 23.7 hectares biotech pink pineapple. This 2018 biotech area declined by 44% (250 hectares) from the 2017 biotech area. This could indicate that demand for these biotech seeds in the Northern Hemisphere was small after a favorable harvest in 2017.

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.

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, Costa Rica does not require foods containing biotech components 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.

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. 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.

SUMMARY AND FUTURE PROSPECTS FOR LATIN AMERICA

Ten countries in Latin America planted biotech crops in 2018 including Brazil (51.3 million hectares), Argentina (23.9 million hectares), Paraguay (3.8 million hectares), Uruguay (1.3 million hectares), Bolivia (1.3 million hectares), Mexico (218,000 hectares), Colombia (88,000 hectares), Honduras (35,500 hectares), Chile (10,454 hectares), and Costa Rica (139 hectares) for a total of 81.93 million hectares, which was 42.7% of the global biotech area of 191.7 million hectares. Increases in absolute number of hectares and percent area were recorded in several countries in Latin America, led by Brazil at 1.1 million hectares (2%), Paraguay (800,000 hectares, 27%), Argentina (300,000 hectares, 1%), Uruguay (200,000 hectares, 18%), Mexico (100,000 hectares, 100%), and a small increase of 4,000 hectares (10%) in Honduras. The increase in biotech crop area in most of the Latin American countries compensated for the losses from the extensive drought in 2017. In addition, profitability, high prices, and high market demand in local and international markets, and available seed technologies for soybeans and cotton; available subsidized credit for farmers and foreign investments from the industry; favorable weather and improved agronomic practices with efficient fertilizer applications encouraged farmers in Brazil, Argentina, Paraguay, Uruguay, and Honduras to plant biotech crops. In Mexico, the 100% increase in cotton area was due to the return to cotton planting after a year of crop rotation as well as the favorable climate and price of cotton.

It is noteworthy that the International Soybean Growers Alliance (ISGA) composed of growers and industry representatives from Argentina, Brazil, Canada, Paraguay, the United States, and Uruguay have been actively collaborating in negotiations to ensure that farmers are provided access to modern biotechnology, and that consumers will benefit from affordable and nutritious biotech food products. The team has been visiting China and the EU to facilitate transparent and expeditious biotech crops approvals and remove the global trade barriers for grains and oilseed crops.

On the other hand, decreases in number of hectares were obtained in some countries including Bolivia that decreased biotech soybean by 200,000 hectares (-1.2%) because of the slow recovery from drought. The use of approved drought tolerant soybeans and drought tolerant sugarcane by farmers may be an option to solve the drought problem. Colombia had reduced biotech maize planting due to lower domestic and international prices and high production cost for maize, that consequently decreased total biotech crop area by 7,000 hectares, -8%). The favorable weather in the northern hemisphere (to which biotech ornamental seeds are exported) allowed for more productive yield of ornamental flowers reducing the demand for such. Thus, Chile had reduced planting hectares by 2,689 hectares (-20%) and Costa Rica by 110.8 hectares (-44%).

The prospect for future expansion of biotech area in Latin America looks positive as more technologies come with different crops and traits. In Brazil insect resistant sugarcane has been planted in 400 hectares for the first time. In Argentina, the government approved the herbicide tolerant and low lignin alfalfa for commercialization (the third in the world after the USA and Canada), and approved the field trials of drought tolerant wheat and soybeans, new generation herbicide tolerant soybean and non-browning apples. The other Latin American countries may follow Brazil and Argentina as they enhance their capacity and increase the awareness on biotechnology in these countries. 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) from respective country start year of planting until 2016 was over US$46.9 billion, and US$6.5 billion was 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

Eight countries in Asia and the Pacific planted and consumed biotech crops in 2018. Three of them, India, Pakistan, and China planted more than 1 million hectares of biotech cotton and belong to the top 10 countries that planted biotech crops. The five countries that planted less than 1 million hectares of biotech crops in descending order were Australia (biotech cotton and canola), Philippines (biotech maize), Myanmar (biotech cotton), Vietnam (biotech maize), Bangladesh (biotech eggplant), and Indonesia, which planted biotech sugarcane for the first time. 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 (biotech cotton and canola) in 1996. In 2018, Australia maintained its 12th rank in the list of biotech crop planting countries with 793,000 hectares, a reduction of 14% from the 924,000 hectares planted in 2017. This area was comprised of 294,000 hectares biotech cotton and 499,000 hectares biotech canola.

Biotech canola was planted by 1,100 more growers in 2018

With the destructive drought incidence of 2018, Australian canola growers planted biotech canola at 499,000 hectares, a marginal increase of 7,400 hectares from 491,000 hectares in 2017. Western Australia planted the largest area at 498,897 hectares, followed by New South Wales at 66,045 hectares and Victoria at 63,825 hectares. The total area planted to canola was 2,222,000 hectares and biotech adoption was marginally reduced at 22%, compared to 24% in 2017 (Table 20).

The reduction in canola area was due to unfavorable weather conditions during the canola planting season, characterized by lack of rain, delayed break, and significant wind events. Some 179 new growers planted biotech canola for the first time, 51 of these were from New South Wales and 80 were from Western Australia. In total, more than 1,100 growers were estimated to plant RR® canola, with more than 700 from Western Australia (Monsanto Australia, 2018).

In Australia, the adoption of biotech canola in NSW has already delivered a net benefit of US$300 million to farmers because of increased yields and improved resilience in drier areas. In the long run, developing fast-growing, pest and drought resistant crops is easily the most promising tool to scale the challenges of climate change and a growing world population (USDA FAS, 2019).

Biotech cotton adoption rate maintained at 100%

Biotech cotton area was reduced by 32% or 138,000 hectares in 2018 due to the extended drought that occurred in some cotton growing areas of southern, central, and northwestern New South Wales, southern and central Queensland, and northern Victoria. All the

Table 20. Biotech Canola Area in Three States in Australia, 2018

State	Hectares		% of Total Canola per State	
	2017	2018	2017	2018
New South Wales	68,163	66,045	10	13
Victoria	56,900	63,825	13	15
Western Australia	366,466	369,027	28	28
Total Biotech Canola Area	491,528	498,897	24*	24*
Total Canola Area	**2,080,000**	**2,222,000**		

* Adoption rate

Source: Agricultural Biotechnology Council of Australia cotton planted in Australia was biotech, at 294,000 hectares, comprised of 4% or 12,000 hectares HT and 96% or 282,000 stacked IR/HT (Bollgard 3/RRF).

The use of this stacked cotton event in Australia in the 2018 planting season allowed growers to effectively control Helicoverpa caterpillars and get rid of weeds. Moreover, Bollgard 3 cotton technology also allows flexibility to cotton planting until farms have adequate soil moisture levels. Cotton growers can now plant from August 1 to December 1. The 2018 planting season recorded 78 new cotton growers, half of these are growing dryland cotton (Bayer/Monsanto, 2019).

Biotech safflower planting set for 2019

For many years, biotech cotton, canola, and carnation varieties (in confined areas) have been the only agricultural crops approved for commercial release in Australia. It is noteworthy that in June 2018, the Australian Office of the Gene Technology Regulator (OGTR) approved the commercial release of biotech safflower modified for high oleic acid composition. Commercial safflower production occurs mainly in NSW, Victoria, and South Australia (OGTR, June 27, 2018). The GE safflower has been developed by scientists at the Government Research and Development Center and Commonwealth Scientific and Industrial Research Organization (CSIRO) through gene silencing technology. The *CtFATB* gene that codes for palmitoyl-ACP thioesterase and *CTFAD2.2* gene fragment associated with Δ 12 desaturase that control processes within the safflower seed and limit the level of oleic acid, thereby causing a build-up of the highly desirable oil were switched off. The specific genes were targeted in the developing seeds only to enable build-up of very high oleic acid, up to 92%, without compromising plant performance. After five successive field trials the biotech safflower oil was found to have higher stability than conventional oils and performs as well or better than synthetic oils derived from fossil reserves. Biotech safflower is the only plant-based source of oil suitable for a large number of high-value industrial applications.

In 2018, 68 hectares of biotech safflower was grown predominantly as research and development, market development, and seed production. In 2019, commercialization of biotech safflower event 26 and event 40 is being handled by the Go Resources Pty Ltd. An estimated 3,500 hectares will be planted under a Closed Loop Identity Preservation Stewardship program (Carl Ramage, personal communication, 2019).

Table 21. Total and Trait Hectares of Biotech Cotton in Australia, 2017-2018

	Area Planted (MHa)		% Trait Hectares	
	2017	**2018**	**2017**	**2018**
Total Cotton	0.432	0.29		
HT	0.016	0.012	3.8%	4.0%
IR/HT	0.416	0.28	96.2%	96.0%
Total Biotech Cotton	**0.432**	**0.29**	**100.0%***	**100.0%***

* Adoption rate

Source: ISAAA, 2018

Benefits from biotech canola and cotton

Australia had 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 was US$73 million (Brookes and Barfoot, 2018).

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.

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 on the recommended technology management procedures. Because of the extensive drought in Australia, biotech cotton area was reduced by 32% and biotech canola increased by a marginal 1%. Adoption of biotech cotton in Australia was close to 99%, but the area planted varies depending on the weather conditions. Furthermore, the introduction of Bollgard III® and its stack with Roundup Ready Flex® in 2015 considerably influenced biotech cotton planting even during unfavorable weather conditions. 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 2018, biotech canola was planted at 22% adoption rate. Future adoption of biotech canola is possible as more farmers see the benefits of the technology, as well as the increasing demand for canola oil in the global market. The approval of the first biotech safflower with high oleic acid for industrial purposes in 2018 will provide a suitable and plant-based substitute for petroleum, a finite source and contributor of greenhouse gas emission.

In early 2018, Food Standards Australia New Zealand (FSANZ) approved a ProVitamin A rice line GR2E applied by the International Rice Research Institute, to be sold in Australia and New Zealand. The approval was meant to prevent trade disruptions should GR2E be inadvertently present in imported shipments of milled rice, and that GR2E is not intended to be used in the Australian or New Zealand food supplies. Australia's OGTR approved the commercial release of biotech cotton (COT102 developed by Syngenta) and biotech canola (DHA canola from Nuseed PTY Ltd.) with omega-3 oil content. Products derived from these biotech crops can be commercialized for use in food and animal feed, and do not pose negligible risks to people and the environment and does not require specific risk assessment measures. Other approvals include biotech herbicide tolerant (HT) canola for commercialization developed by Monsanto; field trial of HT biotech canola developed by Nuseed Pty Ltd.; field trials of biotech wheat with altered iron content, developed by the University of Melbourne; and field trials of biotech wheat with rust disease resistance developed by CSIRO (OGTR, 2018).

The opportunity cost due to delayed adoption of biotech canola in Australia between 2004 and 2014 was estimated in a report by Biden et al (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. Loss of 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 Project, 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 of not adopting biotech crops. It also limits farmers' ability to choose what is best for them and their farmland.

South Australia, Tasmania, and the Australian Capital Territory (ACT) have maintained their moratoria and NSW maintains a moratorium on planting biotech crops. Major farm groups and the Commonwealth government's science organizations do not support this position and have argued openly for acceptance of biotech crops. As a result of the change of State government in the March 2018 elections, an independent review of the moratorium in South Australia was announced in September 2018 and is currently underway. The review will assess the available evidence on the market benefits of South Australia's moratorium on the commercial cultivation of biotech crops. It will also quantify where possible the economic costs and benefits of maintaining, modifying, or removing the moratorium, not limited to but including on-farm impacts, food manufacturing, supply chain costs, and impacts on research and development investment in South Australia (Crop Biotech Update, September 26, 2018).

PHILIPPINES

The Philippines is 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. Since the Department of Agriculture Administrative Order No. 8 (DA-AO 8) was enforced at the end of 2002 to oversee biotech crop commercialization, farmers started planting biotech maize in 2003. In 2018, 630,000 hectares of biotech maize were planted in the maize-growing areas of the Philippines, a minimal decrease from 642,000 hectares in 2017. It is noteworthy that farmers are shifting from single trait HT varieties to stacked IR/HT varieties, currently at 97.5% adoption rate compared to 94.5% in 2017 (Table 22).

The total area planted to maize was projected to increase in 2018, however, severe drought in January and February and the damages caused by typhoon Ompong in May to June reduced maize planting area by 8% from 1.38 million hectares to 1.27 million hectares. Consequently, the biotech maize area was also reduced by 2%. Moreover, counterfeit seeds accounted for a 10-12% in the market share reducing the area planted to authorized biotech varieties.

One of the measures to overcome the problem of counterfeit seed in the Philippines is the passing of the draft amendment to RA Seed Act (final draft dated November 26, 2018) prepared by the Philippine National Seed Industry Council. The draft defines what “unlawful seeds” are, and states that production and sale of these without legal required permits and in unacceptable form and identity is punishable by applicable laws. The amendments will ensure that any person, corporation, partnership, firm, establishment, association, or any juridical entity who willfully violates any provision of the Act or any rule or regulation promulgated to the Act will be punished with a fine of not more than P500,000 and/or imprisonment of not more than five years or both in the discretion of the court.

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). These immense economic gains are continuously benefiting more than 470,500 farmers and their families in the last 14 years of biotech maize commercialization in the Philippines.

Future prospects and products in the pipeline

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-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 the country.

Table 22. Total and Trait Hectares of Biotech Maize in the Philippines, 2017-2018

	Area Planted (MHa)		% Trait Hectares	
	2017	**2018**	**2017**	**2018**
Total Maize	1.378	1.268		
HT	0.035	0.016	5.5	2.5
IR/HT	0.607	0.614	94.5	97.5
Total Biotech Maize	**0.642**	**0.630**	**46.5***	**49.7***

* Adoption rate

Source: ISAAA, 2017

In April 2016, a new regulation was drafted by scientists and a new set of regulators. 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* was 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 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.

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. 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 without an 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 Biotechnology Information Center, ISAAA, and other local 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, 2018).

Eggplant farmers in the Philippines have been waiting for the IR(Bt) eggplant to be commercialized soon. In 2012, when the Supreme Court stopped the field trials, the experimental side of the project was almost complete. After the Supreme Court reversed its decision in 2015, farmers have been wondering when they can use the technology that will allow no pesticide spraying to control the pest fruit and shoot borer. A study by Dr. Cesar Quicoy, associate professor at the University of the Philippines Los Baños (UPLB), studied the cost of delaying the commercialization of Bt eggplant in the country in three different adoption rate scenarios: 15%, 30%, and 50%. Results showed that farmers are losing as much as PhP33.85 billion (US$65 million) annually due to non-commercialization of IR eggplant in the last ten years. Furthermore, the additional revenue that eggplant farmers would get from planting Bt eggplant would offset additional costs they would incur. Bt eggplant seeds would drastically cut the farmers' spending for pesticides as the GM crop is 100% resistant to fruit borer (Business Mirror, 2018).

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 DA's 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 testing (CT) of Golden Rice event GR2E for the selection of promising breeding lines and for production of grains for compositional analysis have been completed in 2016 under the strict monitoring of the DOST-Biosafety Committee (DOST-BC), DA-BPI, and the local Institutional Biosafety Committees (IBC) of respective test sites.

In February 2017, the project submitted an application for field trial to DA-BPI based on the new Joint Department Circular (JDC) No. 1 series of 2016. This field trial will generate the last environmental data that will allow PhilRice to apply for propagation approval. The biosafety permit required for the field trial is yet to be released by DA-BPI. So far, PhilRice has already satisfied the public participation requirements of the JDC. These include the posting of Public Information Sheets (PIS), conduct of two public consultations in Munoz, Nueva Ecija (July 18, 2018) and Batac, Ilocos Norte (July 19, 2018), and the acquisition of local resolutions of support from the respective local government units (LGU).

Application for Food, Feed and Processing (FFP) approval was also submitted in the Philippines, United States Food and Drug Administration (US FDA), Food Standards Australia New Zealand (FSANZ) and Health Canada in early 2017. In February 2018, FSANZ completed a thorough assessment of the application and determined that there are no public health or safety concerns for GR2E Golden Rice. Health Canada also released a positive assessment of Golden Rice in March 2018, followed by a similar declaration from US FDA in May 2018. Meanwhile, FFP application in the Philippines is still under review. FFP approval is necessary for the conduct of an independent nutrition study to determine the effectiveness of Golden Rice in improving vitamin A status of humans (PhilRice Golden Rice team, personal communication, 2018).

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 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 Industry Development Authority (PhilFIDA), 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 commercial propagation as soon as the certificate of satisfactory completion of the multi-location test is released.

MYANMAR

Two long staple insect resistant Bt cotton varieties "*Ngwe chi-6*" and "*Ngwe chi-9*" were planted over 310,000 hectares, a slight decline from 320,000 hectares in 2017, representing 89% of total cotton area of 350,000 hectares in 2018. Around 430,000 smallholder farmers grew Bt cotton demonstrating their preference to pest resistant cotton varieties (Figure 11). Two new varieties, *Shwe Taung 10* and *Ngwe Chi 11* developed by Lungyaw Cotton Research Farm & Technology Development Farm of Ministry of Agriculture, Livestock & Irrigation (MOALI) have been tested for agronomic performance and will be released sometime in 2019-20. On average, Bt cotton variety "*Ngwe chi-6*" and "*Ngwe chi-9*" yield almost 2,000 kg per ha, estimated to produce 500,000 metric tons (MT) of cotton in 2018-19. Both Bt cotton varieties "*Ngwe chi-6*" and "*Ngwe chi-9*" were registered by Myanmar's National Seed Committee (NSC) for commercial sale in Myanmar in 2010 and 2015, respectively.

After 13 years of commercialization of Bt cotton, Myanmar has not enacted comprehensive biosafety legislation, guidelines and protocols to underpin biotech R&D in agriculture, animal and health sector. Myanmar has drafted a Biosafety Law in 2008, but has not enacted it in the absence of major R&D projects and experimentations, and field trials of biotech products. However, realizing the potential of R&D and product development, Myanmar recognizes the need for biotech research and revises the draft biosafety guidelines, strengthens research and manpower capacity,

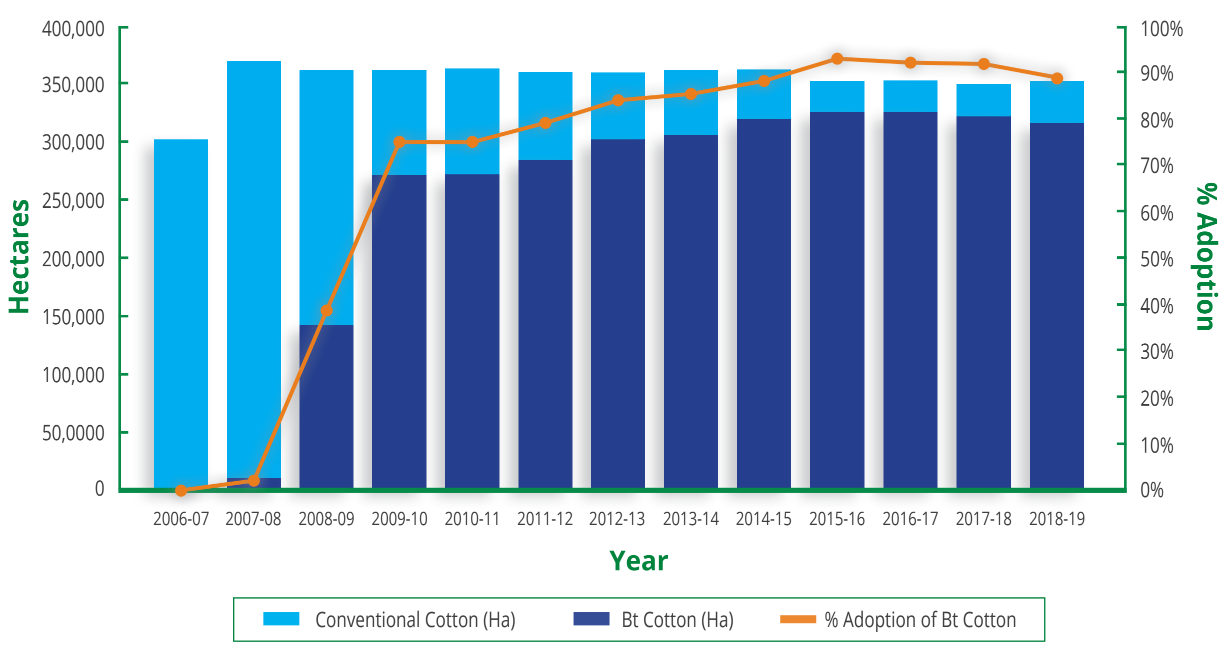


Figure 11. Adoption of IR (Bt) Cotton in Myanmar, 2006 to 2018

Source: Analyzed by South Asia and Biotechnology Centre, 2019 and forges international partnerships to strengthen agriculture in the country in 2018. A functional biosafety framework is essential as the country needs to comply with CBD's Cartagena Protocol on Biosafety (CPB), and boosts ongoing biotech research including tissue culture, molecular marker-aided breeding, and Bt gene introgression to other cotton varieties. In 2018, Myanmar deliberated on revising the draft biosafety law, which is pending review and enactment to facilitate research and development, planting, selling or importing of biotech products for food, feed, and processing (USDA FAS, 2018).

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

Brookes and Barfoot (2018) 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 benefited the families and communities of the 455,000 IR cotton farmers.

VIETNAM

Vietnam is on its fourth year of commercializing biotech maize in 2018 and planted 49,000 hectares, a minimal increase from 45,000 hectares planted in 2017. This figure is insignificant compared to the planting area of biotech maize of 1 million hectares in 2018, similar to 2017. The slow minimal increase in biotech maize area in Vietnam was due to the low price of imported maize and overall production trend of switching from maize to other higher value crops such as fruits and vegetables. Stacked IR/HT trait varieties were preferred by farmers since they started planting in 2015. At that time, five biotech events: 1 single herbicide tolerant event and 4 stacked IR/HT events were approved for commercialization in the country. Unconfirmed industry sources report that there were 18 maize varieties that were approved for cultivation in 2018. However, since 2016, the Ministry of Agriculture and Rural Development (MARD) continued its delay in the review and approval of biotech crops for cultivation. As of December 2018, MARD approved 28 out of the 51 application dossiers for food and feed use. Some 30 cases are still outstanding pending approval for maize, soybeans, canola, cotton, alfalfa, and sugar beets (Le Huy Ham, personal communication, 2018).

According to the USDA FAS GAIN Report-Vietnam (2018), the delay in review and approval of new varieties and registrations of biotech crops could have resulted from a policy shift encouraging the production of agricultural commodities in which Vietnam has a competitive advantage to meet the demands of both domestic consumption and export. Moreover, the government has prioritized the production of organic crops, as well as solutions to address consumers' food safety concerns relating to the overuse of chemicals in Vietnamese agricultural systems. The Government of Vietnam issued Decree 109 on Organic Agriculture on August 29, 2018, to promote organic production, and which does not permit the use of biotechnology crops and products in organic production.

The increasing imports of maize, cotton, and soybeans is an offshoot of high demand for domestic food and feed industry. Moreover, the Government of Vietnam has initiated a Biofuel Plan since 2016. These two drivers would definitely influence cultivation of biotech maize and soybeans for feedstocks.

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 soybean fields. However, the low profits from maize cultivation have somehow discouraged farmers to do so. To meet the country's demand for maize, the 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 Vietnam's rural economy by US$16.9 million per year, in the worst-case 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) estimated that benefits from biotech maize from 2015 to 2016 had 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 their families and communities.

BANGLADESH

In 2018, smallholder brinjal farmers increased planting of insect resistant IR(Bt) brinjal (eggplant) to 2,975 hectares from 2,400 hectares in 2017. About 7,500 additional farmers totaling 34,500 farmers planted Bt brinjal in 2018– the fifth year of commercial cultivation of Bt brinjal in Bangladesh. The winter season of 2017 was the turning point of the large scale adoption of Bt 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 to 34,500 farmers in 2018 (Table 23).

The adoption of IR brinjal reached 6% of the total brinjal area in Bangladesh in its fifth 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 34,500 farmers in around 64 districts in Bangladesh in 2018. Three Bt 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 commercial approval in 2017, and consequent planting in 2018. Bt brinjal seeds 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 2018. Increased adoption of Bt brinjal is a testimony of farmers' trust in insect resistant Bt seeds that delivered round-the-clock protection against voracious fruit and shoot borer (FSB).

A summary of important research studies, released in 2018, to assess the performance of Bt brinjal in farmers' fields is presented below.

A most comprehensive study "Socio-economic performance of Bt eggplant cultivation in Bangladesh" by Rashid et al. (2018) published in the *Journal of Agricultural Research* in 2018 concluded a very favorable socio-economic benefits of Bt brinjal in Bangladesh. On average, smallholder farmers growing Bt brinjal reported 13% higher yield, significantly higher

Table 23. Adoption of IR Brinjal in Bangladesh, 2018

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
2018	2,975	50,000	34,500	6

Source: Analyzed by South Asia Biotechnology Centre, 2018

gross return by 21% (Table 24) and net income by 83% as compared to farmers growing counterpart non-Bt brinjal varieties (Table 25).

The socio-economic study was conducted in 35 districts of Bangladesh during 2016-2017 winter season to assess the farm level performance of Bt brinjal in reducing pesticide use and cultivation cost, and increasing farm income. Rashid et al. randomly selected 505 Bt brinjal farmers and 350 non-Bt brinjal farmers for the study and concluded that:

- Pesticides were applied 11 times to Bt brinjal while 41 times to non-Bt brinjal for controlling sucking pests.
- Bt brinjal farmers saved 61% of the pesticide cost compared to non-Bt brinjal farmers.
- Net returns per hectare were Tk. 179,602 (US$2,122.45)/ha for Bt brinjal as compared to Tk. 29,841 (352.65)/ha for non-Bt brinjal.
- All Bt and 86% non-Bt farmers wanted to cultivate Bt brinjal next year if they can obtain the seeds/seedlings from the research station.
- Bt brinjal farmers experienced no losses due to fruit and shoot borer and received higher net returns.

Another new peer-review study "Bt eggplant (*Solanum melongena* L.) in Bangladesh: Fruit production and control of eggplant fruit and shoot borer (*Leucinodes orbonalis* Guenee), effects on non-target arthropods and economic returns" by Prodhan et al. (2018), published in *PLOS* in 2018 reconfirms the major impact of Bt brinjal on cost of production and marketable yield. Two years' data from farmers' fields (2016–2017) indicated Bt varieties had increased fruit production and minimal FSB fruit infestation compared with their respective non-Bt isolines. Fruit infestation for Bt varieties varied from 0–2.27% in 2016, 0% in 2017, and was not significantly affected by the spray regime in either year. In contrast, fruit infestation in non-Bt lines reached 36.70% in 2016 and 45.51% in 2017, even with weekly spraying. Spraying Bt begun-1 improved the gross margin to US$2,962.94 /ha compared to not spraying Bt begun-1 (US$939.42/ha), despite the increased cost of production. Likewise, in 2017 spraying Bt begun-1 improved the gross margin from US$1,289.78 to US$3,654.59. An economic analysis revealed that all Bt lines had higher gross returns than their non-Bt isolines (Table 26).

Products in the Pipeline

Golden Rice

In 2018, Bangladesh advanced R&D of Golden Rice variety "GR2E BRRI dhan29" − a biotech rice that produces beta (β) carotene, a

Table 24. Yield Difference Between Bt and Non-Bt Eggplant Varieties During Winter 2016-17 in the Study Areas

Variety	Yield (t/ha)	Difference in yield between Bt and non-Bt varieties (t/ha)	Yield difference (%)
BARI Bt Begun-1	17.68	3.29	18.61
BARI Begun-1 (Uttara)	14.39		
BARI Bt Begun-2	26.00	2.48	9.53
BARI Begun-4 (Kazla)	23.52		
BARI Bt Begun-3	21.10	3.33	15.78
BARI Begun-5 (Nayantara)	17.77		
BARI Bt Begun-4	22.68	3.77	16.62
BARI Begun-6 (ISD006)	18.91		

Source: Adapted from Rashid et al. (2018)

Table 25. Per Hectare Return from Eggplant Production in the Study Areas

Items	Return (Tk./ha)	
	Bt eggplant	Non-Bt eggplant
Fresh eggplant yield (ton/ha)	23.21	20.19
Gross return	39,4570	312,945
Gross margin	24,8651	101,590
Net return	179,602	29,841
Benefit cost ratio	1.84	1.11
Production cost (Tk./kg):		
Total cost basis	9.26	14.02
Variable cost basis	6.29	10.47

Source: Adapted from Rashid et al. (2018)

source of Vitamin A and expects approval for commercialization in 2019. The incumbent agriculture minister, Dr. Abdur Razzak, who replaced Mrs. Matia Chowdhury, an ardent supporter of biotech, has prioritized agri-biotech as an important tool for crop improvement in Bangladesh. Both former and current agriculture ministers view Golden Rice as an important innovation to cope with Vitamin A deficiency (VAD) in Bangladesh where an estimated 20% of children suffer from the condition. In 2017, the Bangladesh Rice Research Institute (BRRI), in collaboration with IRRI, successfully conducted multi-location field trials of Golden Rice variety "GR2E BRRI dhan29." Two years of multi-location trials of

Table 26. Mean Yields and Economic Returns in Brinjal by Fruit and Shoot Borer (BFSB) Relative to Insecticides and Varieties

Year	Spray Schedule	Variety*	Fruit Yield (t/ha)		Gross Return ($/ha²)	Gross Margin ($/ha²)
			Non-infested	Infested		
2016	Spray	Bt	17.55 (0.64) a	0.06 (0.05) c	5,2221.1 (189.92) a	2,962.94 (189.92) a
		Non-Bt	9.29 (0.29) b	4.55 (0.53) a	2,872.45 (86.31) b	614.27 (86.31) b
	No Spray	Bt	6.99 (0.72) c	0.0006 (0.0006) c	2,078.62 (213.78) c	939.42 (213.78) b
		Non-Bt	2.59 (0.29) d	1.59 (0.08) b	807.23 (88.69) d	-331.97 (88.69) c
2017	Spray	Bt	19.88 (1.25) a	0.00 (0.00) c	5,912.77 (371.76) a	3,654.59 (371.76) a
		Non-Bt	8.73 (0.80) b	8.48 (0.71) a	2,799.82 (252.03) b	541.64 (252.03) bc
	No Spray	Bt	8.16 (0.66) b	0.00 (0.00) c	2,428.99 (195.26) b	1,289.78 (195.26) b
		Non-Bt	2.63 (0.32) c	2.55 (0.16) b	844.61 (99.34) c	-294.59 (99.34) c

*Variety BARI Bt begun-1

1 Figures in parenthesis are SE values; means followed by the same letter in a column within a year do not significantly differ from each other at 5% level by HSD.
2 Market price of brinjal: Non-infested BARI Bt begun-4 $0.36/kg, others $0.30/kg and infested $0.02/kg. Cost of spray: two laborers/spray/ha Tk. $3.56/labour; Urea $0.19/kg, TSP $0.26/kg, MP $0.18/kg, Zypsum $0.07/kg, Boric acid $1.78/kg, Zn $3.96/kg. Cowdung $0.01/kg. Admire $17.8/250 ml and Proclaim $26.77/500 ml. US$ = 84.05 Bangladeshi Taka (29 March 2018).

"GR2E BRRI dhan29" in Boro seasons of 2015-2016 and 2016-2017 produced superior yield and the desired level of β-carotene (10-12 μg/g beta carotene) which is enough to meet 50% of Vitamin A daily dietary requirement of people consuming rice. The field trials of "GR2E BRRI dhan 29" in Boro season 2017-2018 showed higher yield than its non-GM rice counterpart, and no significant difference in other traits and insect pest infestation between transgenic Golden Rice and non-transgenic rice was observed (BRRI, 2018). In 2018, BRRI completed the biosafety evaluation of Golden Rice line "GR2E BRRI dhan 29" and submitted to the National Committee of Biosafety (NCB) through the National Technical Committee of Crop Biotechnology (NTCCB) an application for environmental release and use in food and feed under Bangladesh Biosafety Rules, 2012. The Biosafety Core Committee (BCC), which provides the NCB with technical comments and recommendations on GE applications and advises on other GE issues has been reviewing all relevant data on Golden Rice submitted by BRRI and would submit its technical report to NCB for commercial release in 2019 (USDA FAS, 2018).

Biotech Cotton

In 2018, the Cotton Development Board (CDB) of the Ministry of Agriculture successfully carried out the first year of contained trial of two Bt hybrid varieties JKCH 1974 Bt and JKCH 1050 Bt. 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). In early 2018, CDB signed a material transfer agreement (MTA) with JK Agri-Genetics and subsequently imported two Bt cotton hybrid JKCH 1947 Bt and JKCH 1050 Bt in July 2018. In August 2018, CDB carried out contained trials of two Bt cotton JKCH 1947 Bt and JKCH 1050 Bt to assess its biosafety including a bioassay test, efficacy and performance, and compare yield and fiber quality of two Bt cotton hybrids with a popular local variety. The CDB would undertake second year of field trials of two Bt cotton hybrids in 2019 and approval on its commercial application is expected early 2020. 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 against the domestic cotton demand of approximately 4.5 million bales per year (CBD, personal communication, 2018).

INDONESIA

Indonesia planted a biotech drought tolerant sugarcane NX1-4T in 2018, putting the country back on the map after it stopped planting IR(Bt) cotton in 2002. Some 1,342.59 hectares were planted within the government-owned sugarcane company PT. Perkebunan Nusantara XI (PTPN-11) farm and in some farmer fields. Drought tolerant sugarcane was developed to overcome the problem of sugar supply in the country. Indonesia is the number 1 sugar importing country around the world valuing at US$1.8 billion, which is 7.7% of total sugar imports. Sugarcane is a crop sensitive to drought and high temperature yielding thin and short stems when stressed. The development of drought tolerant sugarcane was conducted to address the increasing domestic sugar demand in the face of climate change.

PT. Perkebunan Nusantara XI produces 16% of the country's sugarcane on around 83,000-ha estate. Nearly 40% of that land is non-irrigated and receives a limited amount of rainwater. The drought-tolerant biotech sugarcane variety named Cane PRT Drought Tolerant NX1-4T was developed by PTPN-11 in collaboration with Jember University in East Java and PT. Ajinomoto Company International, Japan in 1999 (Rijzaani, 2013). This biotech sugarcane contains choline dehydrogenase gene (*betA*) obtained from a nitrogen-fixation bacteria *Rhizobium meliloti*. The biotechnology laboratory of PTPN-11 developed gene construct pM LH2113 (under the control of CaMV35S promoter followed by successful genetic transformation of elite sugarcane variety TP2V through *Agrobacterium tumefaciens* strain LBA 4404.

Several studies were conducted to assess food safety and environment assessment in the period 1999 to 2013 (PTPN XI, 2014). The genetically modified sugarcane lines were found to contain elevated levels of betaine, a compound which stabilizes the plant cells when there is lack of water in the field. Selected transgenic sugarcane lines were able to withstand water stress for 36 days. It was reported that sugar production during drought stress in NX1-4T yield substantially higher than the conventional non-GM sugarcane counterpart (Waltz, 2014). The drought tolerant sugarcane varieties are comparable with the non-GM isoline on various agronomic traits including percentage germination, number of stalks, number of tillers, biomass and higher percentage sugarcane content and yield (Sugiharto, 2017). The green house confined trial proved that the transgenic sugarcane survived longer time and developed longer root profile during water stress. The transgenic sugarcane has been assayed for environmental, food, and feed safety and approved by Indonesian Biosafety Commission for commercialization. The drought-tolerant transgenic sugarcane has been released by Indonesian ministry of agriculture, named NXI-4T cultivars and used for sugar production in PTPN-11. Sugar production during drought condition in the transgenic sugarcane is 20-30% higher than in conventional parental line. In 2018, the transgenic sugarcane has been used by sugarcane farmers, especially in the non-irrigated planting area of PTPN-11 at 1,341.59 hectares. The company assisted farmers in planting the biotech sugarcane with an undetermined number as of this writing.

Indonesia imported biotech IR cotton, HT soybeans and meal, IR maize, and a variety of food products derived from biotech crops for use in livestock and poultry industry. There is an ongoing strong research on biotech crops including virus resistant tomato, rice, potato, and sugar cane. Moreover, there are also studies on livestock and animal genotyping that includes sheep, Balinese cattle, poultry, and fish; identification of rapid growth and disease resistance in catfish and common carp.

The government of Indonesia follows an agricultural biotechnology policy based on science along with the "precautionary approach" on issues surrounding environmental safety, food safety, and/or feed safety. The policy also considers religion, ethical, socio-cultural, and esthetic norms in regulating biotech crops. In 2018, there were 10 biotech maize varieties, eight biotech soybean varieties, three biotech sugarcane varieties, and one biotech potato variety that have undergone risk assessment for either food, feed or environmental safety.

Several public research institutions are developing improved crops and animals through biotechnology. The Indonesian Institute of Science (LIPI) has completed confined field trials for stem borer resistant rice in four locations and have completed food and feed safety studies. Dossiers are being completed for submission for environmental safety assessment to the Ministry of Environment and Forestry. In addition, LIPI is also conducting research on tungro virus resistant rice, drought tolerant rice, salinity tolerant rice, blast resistant rice, and shelf life extended cassava.

The Indonesian Center for Agricultural Biotechnology and Genetic Resources (ICABIOGRAD) has conducted confined field trials for virus resistant tomato in four locations. In 2019, they are preparing an application for environmental safety assessment and conducting the food safety study. There are also studies on late blight resistant potato for variety registration purposes and a plan to conduct confined field trials for GE nitrogen use efficient rice. Research on IR rice and genome editing for geminivirus resistant chili, greening disease resistant citrus, and low cadmium absorbent rice have also been started.

The University of Jember, in collaboration with PTPN-11, is developing a high glucose content sugarcane and has applied for environmental safety and food safety of this biotech sugarcane. Research on mosaic virus resistant sugarcane has also been completed, pending further assessment for possible commercialization. There is also an ongoing research on Golden Rice in IR36 background and will extend this research to include IR64 rice, with the expectation that these crops will be ready for risk assessment in two years.

There is a strong partnership between the public and private sector in Indonesia. For example, the biotech late blight resistant potato is being carried out in partnership with Michigan State University, the University of Minnesota, University of Idaho, the JR Simplot Company and ICABIOGRAD, and organized under USAID Feed the Future Biotechnology Partnership Project. Another collaboration is with Arcadia Biosciences Inc. and MOA on biotech nitrogen use efficient rice.

Indonesia is once again planting biotech crop, a drought tolerant sugarcane in a government-owned facility and a few farmer fields for a total of 1,342.59 hectares. There are several biotech crops in the pipeline and the government is supportive to move these products to commercialization in 2020.

SUMMARY AND FUTURE PROSPECTS IN ASIA AND THE PACIFIC

In 2018, the cultivation of biotech crops in the Asia and Pacific region was led by India with the largest area of 11.6 million hectares cotton followed by China (2.9 million hectares cotton and papaya), Pakistan (2.8 million hectares cotton), Australia (793,000 hectares cotton and canola), Philippines (630,000 hectares maize), Myanmar (310,000 hectares cotton), Vietnam (49,000 hectares maize), Bangladesh (2,975 hectares eggplant), and a returning biotech crop country, Indonesia (1,342.59 hectares drought tolerant sugarcane). This region planted 19.13 million hectares (the same as in 2017) of biotech crops, or 10% of the global biotech crop area of 191.7 million hectares.

Increases in biotech area were obtained in India (200,000 hectares, at 2%), China (100,000 hectares, 4%), Vietnam (4,000 hectares, 9%), and Bangladesh (575 hectares, 24%). The favorable global cotton price has positively impacted biotech cotton adoption in India and China, while public acceptance of clean and hazard free production of biotech eggplant motivated more farmers in Bangladesh. In Vietnam, the low price of imported maize and overall production trend of switching from maize to other higher value crops has minimally increased biotech maize area.

However, this expansion of biotech crop area was made almost even by the decrease in Pakistan (decrease of 200,000, at -7%), Australia (decrease of 100,000 hectares, -11%), Philippines (decrease of 12,000 hectares -2%), and Myanmar (decrease of 10,000 hectares, -3%). In Pakistan, the slight reduction in area was due to the uncertainty in approval of new generation biotech traits and high yielding IR/HT cotton varieties, shortage of water for timely irrigation, and infestation of pink bollworm and cotton leaf curl virus (CLCuV). Australia's extended extreme drought during the growing season in 2018 affected canola and cotton (biotech and total) areas. Similarly, in the Philippines, the unfavorable weather conditions—drought in planting months of January and February and typhoon in May and June when farmers cannot plant due to water-soaked fields—reduced the biotech maize area. Moreover, the counterfeit seed problem in the Philippines persists, which has occupied 10-12% market share.

Indonesia, a returning biotech country, has planted a new biotech drought tolerant sugarcane that can yield 20-30% higher than its parents during drought conditions. The biotech drought tolerant sugarcane was developed to close the gap between domestic supply and demand for sugar, as Indonesia is the world's largest importer of sugar. The drought tolerant trait would allow farmers to plant even at periods with low rainfall which seems to become worse and frequent due to climate change.

The expansion of biotech crops and traits in the Asia and the Pacific region is still a challenge. There are new biotech crops and traits in the pipeline for commercial release, including the staple crops Golden Rice, late blight resistant potato, various biotech traits for wheat, and IR (Bt) eggplant; biotech soybean and maize for livestock and poultry feed; and varieties of cotton which contain stacked IR/HT traits. The planting of biotech drought tolerant sugarcane by Indonesia, the 25th biotech crop country, has increased the plethora of drought tolerant biotech crops which can be adopted by countries embarking into biofuel production that experience severe drought such as Brazil and Argentina.

One of the most important problems in Asia and the Pacific was the delay in approving new biotech crops and traits in China, Vietnam, and the Philippines. Regulatory guidelines in these countries have been in place and have been used to regulate biotech products efficiently for more than a decade, but the changing political climate and the loud voice of critics have become a strong barrier to trade and commercialization of biotech crops. Strengthening the already sensitized groups in these parts of the world such as academics, researchers, and students and using them to expand knowledge on the technology and the benefits to reach the policy makers and regulators is vital in moving forward biotechnology in the region.

Finally, the estimated over 16 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) 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 costs that will escalate poverty, hunger, malnutrition, and political instability.

THE AFRICAN CONTINENT

The African continent remains the region with the biggest potential to reap the benefits associated with modern agricultural biotechnology. In 2018, the continent recorded impressive records with South Africa planting biotech crops in the last 21 years and belongs to the top 10 biotech crop countries in the last two decades. Moreover, Nigeria became the first country in the world to approve biotech cowpea thus adding a new biotech crop to the global biotech crops basket. The Kingdom of eSwatini (former Swaziland) started commercial planting of IR (Bt) cotton on an initial launch of 250 hectares, making it the third African country to plant biotech crops. This brought the number of African countries currently growing biotech crops to 3 again – South Africa, Sudan, and eSwatini. Two more countries – Ethiopia and Nigeria gave environmental release approvals for Bt cotton (Ethiopia) while Nigeria approved cotton and cowpea. Earlier, Kenya and Malawi had also given environmental release approvals and working towards commercialization of biotech cotton in the short-term (Figures 12 and 13).

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 such as 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 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.

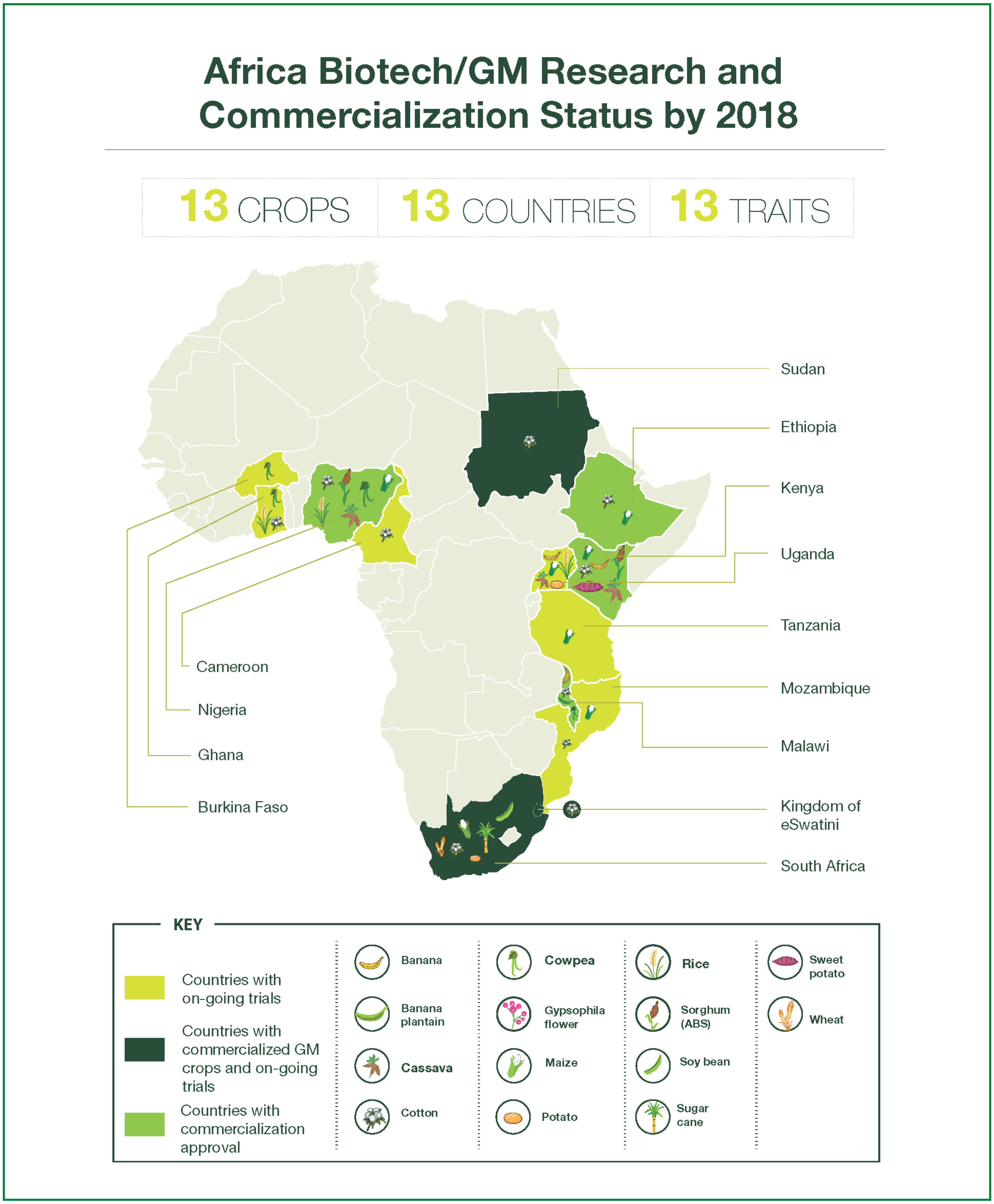


Figure 12. Africa Biotech/GM Research and Commercialization Status in 2018

Figure 13. Crop Traits Under Various Stages of Research in Africa in 2018

SUDAN

In its seventh year of commercialization of biotech crops, a total of 243,000 hectares of IR (Bt) cotton were planted in Sudan, up from the previous 192,000 hectares grown in 2016, an impressive 26% or 51,000 hectares increase. An estimated 150,000 farmers grew the crop on average farm sizes of 2.1 hectares. The adoption rate of biotech cotton remained high at 98% and only 9,311 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 22,000 hectares in 2012 to 243,000 hectares in 2018, a cumulative 831,400 hectares over six years (Figure 14).

In Sudan, seeds are provided by the public and private sectors. Two companies provided the technology: the Chinese Centre 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 handles distribution of the hybrid seed in accordance with quotas as required by the different companies or farmers. Companies and farmers remain highly enthusiastic and are prepared to almost double the planting area over the coming years due to satisfaction with the performance of IR cotton.

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

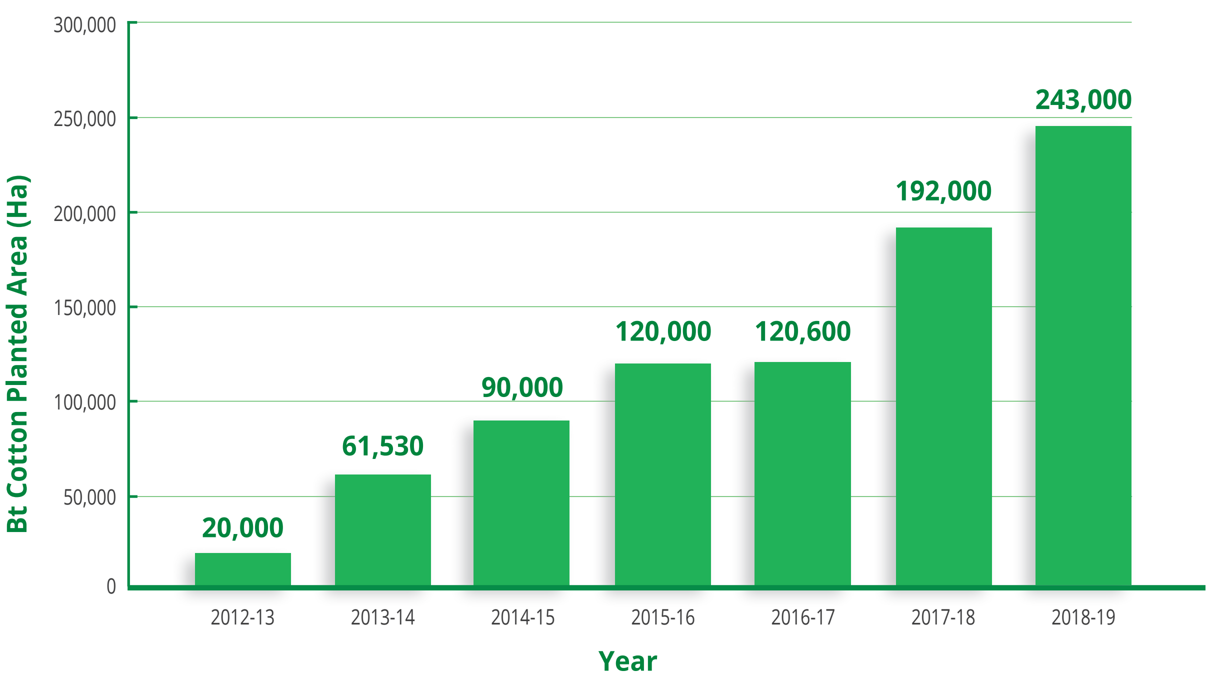


Figure 14. IR Cotton Adoption in Sudan 2012-2018

Source: NBSC

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 gain 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.

ESWATINI

In 2018, the Kingdom of eSwatini planted Bt cotton for the first time on a modest launch of 250 hectares with two Indian hybrids - JKCH 1050 and JKCH 1947. The seed was only supplied to large-scale cotton growers who planted the crop under irrigation. Three farms engaged in this initial launch of Bt cotton growing namely; Nisela Farms, SD Citrus, and Canterbury Estate, all based in the Lubombo region. The area, which used to be a sugarcane zone has been hit by severe drought and farmers are looking for alternative crops. Bt cotton is showing great promise to fill this void. License to sell the technology was issued to the eSwatini Cotton Board as per Cotton Act of 1967, which grant the Board permission to manage all cotton issues in eSwatini. The eSwatini Cotton Board remains the sole importer and distributor of the technology and aims to supply both small scale and large scale growers through national distribution outlets. Small scale growers continued to produce conventional cotton mainly due to unavailability of seeds, which had to be imported from India for the time being

In 2018, more African countries have indicated their support on biotechnology in crops and animals to improve the lives and livelihood of farmers and the marginalized people. Table 27 lists some of the articles which indicate progress in African countries in terms of approvals, biosafety framework, biotech research, policy environment, safety of biotech crops, and most especially farmers voices to expedite approvals and adoption of biotech products.

EUROPEAN UNION

The European Union's (EU) complex and lengthy policy framework for biotechnology continuously creates a challenging environment for research and limits access to innovative tools for EU farmers. Since 2016, only Spain and Portugal have planted biotech maize event MON 810, and in 2018, the total biotech maize area declined by 8% from 131,535 in 2017 to 120,990 hectares.

The EU produces biotech maize but imports large amounts of biotech crops for feed. In 2018, the EU has imported 30 million metric tons (MT) of soybean products (90-95% biotech), 10 to 15 million MT of maize products (20 to 25% biotech), and 2.5 to 4.5 million MT of rapeseed products (less than 20% biotech) per year, mainly for feed. The production of EU soybeans was low, estimated to be 2.7 million MT in 2018, compared to the more than 30 million MT of soybean products imported every year (USDA FAS, 2018). For maize, imports account for 10% supply. The EU imports these products from Argentina, Brazil, and the United States, and may likely not to change in the medium-term.

Table 27. List of Articles on Biotech Developments in Africa

Focus Area	Country	Title	Date	Link
Approvals	Burkina Faso	GE Mosquitoes to be Released in Africa for the First Time	12/09/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16812*
	Ethiopia	Ethiopia Approves Environmental Release of Bt Cotton and Grants Special Permit for GM Maize	06/06/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16515*
	Nigeria	Nigeria Registers Biotech Cotton Varieties for Access to Farmers	01/08/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16671*
	Nigeria	Nigeria's Federal High Court Ruling Permits Bt Cotton Commercialization	22/08/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16743*
	Swaziland	Swaziland Approves Importation and Environmental Release of Bt Cotton	16/05/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16455*
Biosafety Regulatory Framework	Kenya	Kenya Developing Animal Biotech Regulatory Guidelines	07/03/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16246*
	Uganda	High Hopes as Uganda's Biotech Bill Gets 'Second Chance'	04/04/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16320*
	Uganda	Biotech Discussed at National Plant Variety Protection Dialogue in Uganda	01/08/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16674*
	Uganda	Farmers and University Students Call for Urgent Action on Biotech Legislation in Uganda	07/11/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16999*
	Uganda	Uganda Parliament Passes GMO Bill	05/12/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=17058*
Biotech Research Progress	Africa	AATF Receives Multi-million Grant for Bt Maize Commercialization in Africa	20/06/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16466*
	Africa	High-protein Maize Shows Resistance to Parasitic Weed	20/06/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16548*
	Cameroon	Adoption of GM Crops in Cameroon Imminent, Says Expert	17/10/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16925*
	Kenya	Kenya Starts Planting Biotech Cotton Under National Performance Trials	13/06/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16540*
	Mozam-bique	WEMA Maize Shows Promising Resistance to Fall Armyworm in Mozambique	02/05/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16419*
	Nigeria	IITA Begins Confined Field Trials of Transgenic Cassava	10/01/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16097*

Table 1 Continued

Table 27. List of Articles on Biotech Developments in Africa

Focus Area	Country	Title	Date	Link
Policy Environ-ment	Ethiopia	Ethiopian Government Banking on Agri-biotech to Help Steer Economic Development	24/10/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16959*
	Kenya	Kenyan Government Banks on Bt Cotton to Revive Textile Industry	18/04/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16383*
	Kenya	African Women for Biosciences Platform Launched	16/05/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16456*
	Kenya	Kenyan Policy Makers Vouch for Commercialization of Bt Cotton	26/09/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16864*
	Kenya	Kenyan President Okays Planting of Bt Cotton	24/10/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16958*
	Malawi	Malawi Releases New Seed Policy	06/06/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16514*
	Namibia	Agriculture Minister Proposes a Law to Regulate Seeds and Seed Varieties in Namibia	20/06/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16560*
	Uganda	Science Enthusiasts Call for Science-based Biotech Policies in Uganda	18/04/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16379*
Safety of GM Foods	Ghana	Ghana CSIR Affirms Safety of GM Crops	28/02/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16229*
Farmer Voices	Burkina Faso	Burkina Faso Farmers Call for Return of Bt Cotton	19/09/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16846*
	Ghana	Farmer Leader in Ghana Shifts Support to Agri-biotech After Getting Facts	05/09/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16780*
	Kenya	Scientists Recommend Bt Maize as Solution to Fall Armyworm Infestation in Kenya	24/01/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16136*
	Kenya	Farmers and Experts Look Forward to Bt Cotton Adoption to Revive Textile Industry in Kenya	23/05/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16478*
	Uganda	Ugandan Farmers' Demand for Biotech Intensifies	24/10/2018	*http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16955*

Source: ISAAA, 2018

SPAIN

Spain has been planting biotech maize for 20 years since 1998, and in 2018 has contributed 95% of the 120,990 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 previous season's incidence of European corn borer and market conditions for biotech and conventional maize. In 2018, there was a decline of 7% in biotech maize area from 124,227 hectares to 115,246 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 12 regions in Spain that cultivated biotech maize in 2018. The autonomous regions of Aragon and Catalonia had the highest share of Spain's biotech maize area at 33% and 12%, respectively (Table 28), because the insect pest European corn borer is endemic in these areas. The region of La Roja did not plant in 2018.

It is noteworthy that the reduction in biotech maize is also due to the reduction of total maize area from 332.7 million hectares in 2017 to 326.6 million hectares in 2018 caused by less water availability, crop margins, competition from alternative crops, and maize domestic price. The incidence of European corn borer was also lower in 2018, thus, a reduction in biotech maize area. Approvals of new traits could raise the interest in biotech crops by other growers.

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 the cultivation of biotech crops in the country in 2015. Field trials are also allowed in Spain, although they are subject to prior notice and authorization.

The increasing demand for maize for food and feed consumption in Spain has increased throughout the years, with some 8 million metric tons of maize imported in 2017-2018. The bulk of the imports came from the US, Ukraine, Brazil, and Canada (USDA FAS, 2018).

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 reached US$23 million in 2016 alone (Brookes and Barfoot, 2018). These are enormous benefits continuously being enjoyed by farmers in Spain in the last 18 years of Bt maize adoption.

PORTUGAL

Portugal planted biotech maize since 2005 and reached its peak total maize planting in 2013 at 147,000 hectares. However, this has steadily declined over the years, and in 2018, only 118,220 hectares of maize was planted in Portugal. Simultaneously, there was a decline in biotech maize area by 21% from 7,308 hectares to 5,733 hectares. The food industry's demand for biotech-free maize has decreased the biotech maize area in Portugal.

Biotech maize used to be planted in six regions in Portugal in 2012 which was reduced to five regions in 2013, and since 2014, only four regions planted biotech maize. Alentejo and Centro were the regional leaders in biotech maize area, at 58% and 23% adoption rates, respectively (Table 29). Maize grown for grain were planted in these areas compared to Norte region where maize was grown for silage, and

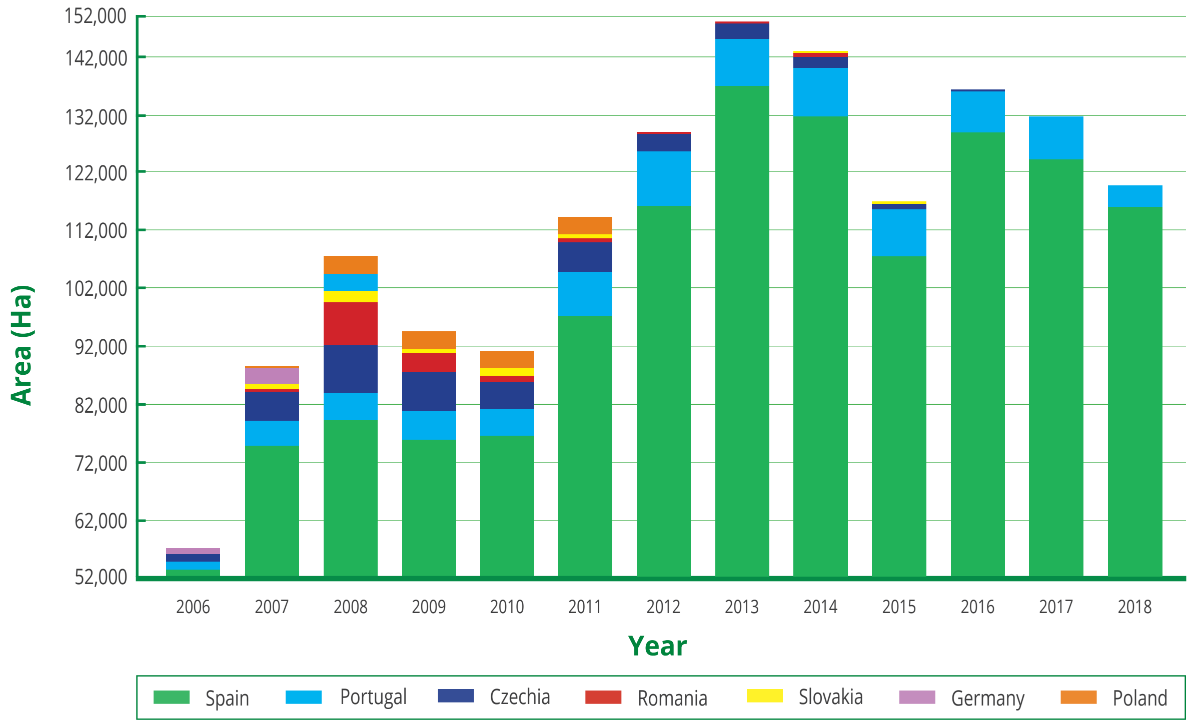


Figure 15. Biotech Maize Area in the European Union, 2006-2018, Hectares

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, 2018

Table 28. Area of Biotech Maize by Region in Spain (Hectares)

Region	2013	2014	2015	2016	2017	2018
Aragon	54,451	54,041	42,612	46,546	49,608	44,932
Catalonia	33,996	36,381	30,790	41,567	39,092	38,752
Extremadura	16,979	13,815	9,827	15,039	13,976	14,138
Navarra	7,013	7,264	6,621	8,066	7,778	8,101
Castile-La Mancha	8,766	7,973	5,734	5,932	5,069	3,805
Andalucia	12,862	10,692	11,471	10,919	8,013	4,972
Others*	2,895	1,371	695	1,011	691	547
Total	**136,962**	**131,538**	**107,749**	**129,081**	**124,227**	**115,246**

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

Source: Ministerio de Agricultural Y Pesca Alimentacion Y Medio Ambiente, 2018 the use of biotech maize was limited. With only the IR event MON810 available, biotech maize planting was only limited in these areas.

Historically, the total area planted to maize varies every year depending on water availability, price, and competition from alternative crops. Since 2015, the continuous decline was due to extensive crop diversification brought about by the EU's greening measures. Moreover, there was a severe drought in 2017 and 2018 growing season that discouraged maize planting.

Annually, Portugal imports some 1.7 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 soybeans is another potential biotech crop in Portugal with annual imports of 875,000 metric tons soybeans and 170,000 metric tons of 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 industries 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 globally competitive, 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, 2017).

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 were estimated at US$2 million (Brookes and Barfoot, 2018).

Table 29. Area of Biotech Maize by Region in Portugal, 2011-2018 (Hectares)

Region	2012	2013	2014	2015	2016	2017	2018	% of Total Biotech (2018)
Total Maize	143,000	147,000	137,000	126,000	118,000	115,667	118,220	
Norte	165	85	78	60	100	46	46	1
Centro	774	853	933	1,013	1,485	1,609	1,311	23
Lisboa	2,322	2,215	2,074	2,002	2,138	2,466	1,023	18
Alentejo	5,796	5,041	5,457	4,942	3,346	3,187	3,338	58
Algarve	13	8	0	0	0	0	0	
Açores	208	0	0	0	0	0	0	
Total Biotech	**9,278**	**8,202**	**8,542**	**8,017**	**7,069**	**7,308**	**5,733**	
Adoption Rate	**6.50%**	**5.60%**	**6.20%**	**6.40%**	**6.00%**	**6.30%**	**4.85%**	

Source : Dados Nacionais, 2018. Republica Portuguesa.

Summary and Future Prospects

The acceptance of biotech crops in the EU is still far from improving. Two countries planted biotech maize, because of the infestation brought by the European corn borer. There was less motivation to plant biotech maize since the market calls for non-biotech raw materials. Imports of feedstocks from Argentina, Brazil, and the United States were mostly biotech. There were up to 30 million metric tons soybean products, 10 to 15 million metric tons of maize, and 2.5 to 4.5 million metric tons canola that have been exported to the EU. This situation was expected to continue as there is no change in the EU regulation, there was no approval for cultivation in sight, and movement against biotech crops was still strong. In the beginning of 2018, six biotech crops were authorized for entry into the EU for food and feed uses including four soybean events, one oilseed rape, and one renewal for maize. Before the end of the year, two new varieties of maize and renewal of three existing authorizations for maize and sugar beets were approved for food and feed uses.

DISTRIBUTION OF BIOTECH CROPS: BY CROP

Of the 31 crops approved for food, feed, and environmental release recorded at the ISAAA GM Approval Database, only 13 crops have been planted in 26 countries in 2018. There were four major biotech crops: soybeans at 95.9 million hectares, followed by maize (58.9 million hectares), cotton (24.9 million hectares) and canola (10.1 million hectares), occupying 99% of the total biotech crop area. Other crops planted in smaller scale were alfalfa, sugar beets, papaya, squash, brinjal, apples, potatoes, pineapple, and sugarcane, which is first planted in 2018 (Table 30). Cotton has been planted in the most number of countries (15), followed by maize (14), and soybeans (8).

The adoption trend provided in Figure 16 and Table 31 indicates the increase in area planted to biotech soybeans, cotton, and alfalfa were almost equaled with decrease in area planted to maize and canola, thus, only a 1.9 million hectare difference from 2017 to 2018.

Biotech soybean area is 50% of the global biotech area

Biotech soybeans has been planted on 95.9 million hectares, which is 50% of the global area planted to biotech crops (Table 31) and have been planted in eight countries: USA (34.1 million hectares), Brazil (34.9 million hectares), Argentina (18.0 million hectares), Paraguay (3.35 million hectares), Canada (2.42 million hectares), Uruguay (1.26 million hectares), Bolivia (1.26 million hectares, and South Africa (694,000 hectares). There were increases in biotech soybean area in 2018 compared to 2017 in Brazil, Paraguay, Uruguay, and the USA, and slight decreases in Argentina, Canada, Bolivia, and South Africa due to unfavorable climatic conditions such as drought in most of these countries, and low soybean prices especially in Canada.

In 2018, three new soybean events were approved in Japan: DP305423 x MON87708 (high oleic acid and dicamba tolerant, for food and processing), DP305423 x MON87708 x MON89788 (high oleic acid, glyphosate and dicamba tolerant for food, feed, processing, and cultivation) and DP305423 x MON89788 (high oleic acid and glyphosate tolerant, for food and processing). Soybean stacked event HB4 x GTS 40-3-2 with salt tolerance and glyphosate tolerance were approved in Argentina for food, processing, and cultivation.

The total biotech soybean area of 95.9 million hectares was comprised of 69.3 million hectares HT and 26.6 million hectares stacked IR/HT (Intacta™) – an increase of 2% or 1.8 million hectares in 2018. The stacked trait soybeans

Table 30. Global Area of Biotech Crops, 2017-2018: by Trait (Million Hectares)

Countries	Soybean	Maize	Cotton	Canola	Alfalfa	Sugar beets	Papaya	Squash	Brinjal	Apples	Pota-toes	Sugar-cane	Pine-apple	Total
USA	34.08	33.17	5.06	0.90	1.26	0.49	<0.01	<0.01	0	<0.01	<0.01	0	0	**75.00**
Brazil	34.86	15.38	1.02	0	0	0	0	0	0	0	0	<0.01	0	**51.26**
Argentina	18.00	5.51	0.37	0	0	0	0	0	0	0	0	0	0	**23.89**
Canada	2.43	1.57	0	8.74	<0.05	0.02	0	0	0	0	<0.01	0	0	**12.75**
India	0	0	11.60	0	0	0	0	0	0	0	0	0	0	**11.60**
Paraguay	3.35	0.39	0.01	0	0	0	0	0	0	0	0	0	0	**3.75**
China	0	0	2.93	0	0	0	0.01	0	0	0	0	0	0	**2.94**
Pakistan	0	0	2.80	0	0	0	0	0	0	0	0	0	0	**2.80**
South Africa	0.69	2	0.04	0	0	0	0	0	0	0	0	0	0	**2.73**
Uruguay	1.26	0.05	0	0	0	0	0	0	0	0	0	0	0	**1.31**
Bolivia	1.26	0	0	0	0	0	0	0	0	0	0	0	0	**1.26**
Australia	0	0	0.29	0.50	0	0	0	0	0	0	0	0	0	**0.79**
Philippines	0	0.63	0	0	0	0	0	0	0	0	0	0	0	**0.63**
Myanmar	0	0	0.31	0	0	0	0	0	0	0	0	0	0	**0.31**
Sudan	0	0	0.24	0	0	0	0	0	0	0	0	0	0	**0.24**
Mexico	0	0	0.22	0	0	0	0	0	0	0	0	0	0	**0.22**
Spain	0	0.12	0	0	0	0	0	0	0	0	0	0	0	**0.12**
Colombia	0	0.07	0.01	0	0	0	0	0	0	0	0	0	0	**0.08**
Vietnam	0	0.05	0	0	0	0	0	0	0	0	0	0	0	**0.05**
Honduras	0	0.04	0	0	0	0	0	0	0	0	0	0	0	**0.04**
Chile	0	<0.1	0	<0.1	0	0	0	0	0	0	0	0	0	**0.01**
Portugal	0	<0.1	0	0	0	0	0	0	0	0	0	0	0	**<0.1**
Bangladesh	0	0	0	0	0	0	0	0	<0.01	0	0	0	0	**<0.1**
Costa Rica	0	0	<0.01	0	0	0	0	0	0	0	0	0	<0.01	**<0.1**
Indonesia	0	0	0	0	0	0	0	0	0	0	0	<0.01	0	**<0.1**
eSwatini	0	0	<0.01	0	0	0	0	0	0	0	0	0	0	**<0.1**
Total	**34.08**	**34.08**	**34.08**	**34.08**	**34.08**	**34.08**	**34.08**	**34.08**	**34.08**	**34.08**	**34.08**	**34.08**	**34.08**	**34.08**

Source: ISAAA, 2018

Table 31. Global Area of Biotech Crops, 2017 and 2018: by Crop (Million Hectares)

Crops	2017	%	2018	%	+/–	%
Soybeans	94.1	50	95.9	50	1.8	2
Maize	59.7	31	58.9	31	-0.8	-1
Cotton	24.1	13	24.9	13	0.8	3
Canola	10.2	5	10.1	5	-0.1	-1
Alfalfa	1.2	<1	1.3	1	0.1	5
Sugar beets	0.5	<1	0.5	<1	0.0	<1
Papaya	<1	<1	<1	<1	<1	<1
Others*	<1	<1	<1	<1	<1	<1
Total	**189.8**	**100**	**191.7**	**100**	**1.9**	**1.0**

*Others include biotech squash, potato, eggplant, sugarcane, and apples

Source: ISAAA, 2018

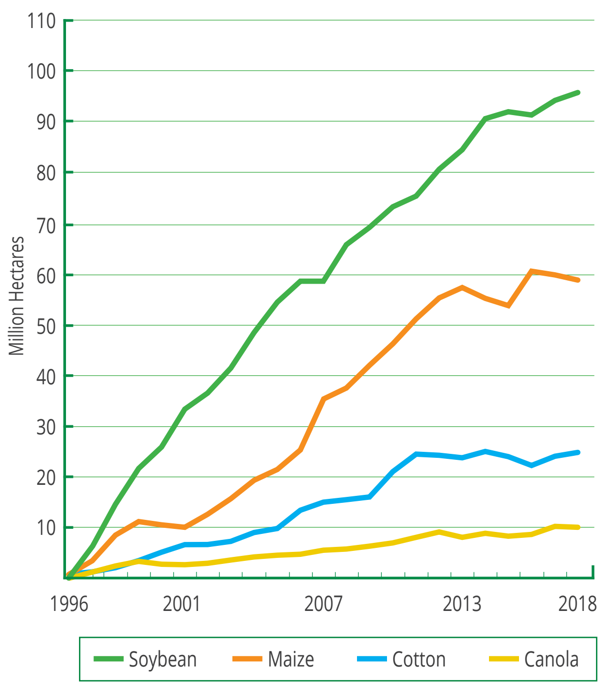


Figure 16. Global Area of Biotech Crops, 1996 to 2018: by Crop (Million Hectares)

Source: ISAAA, 2018

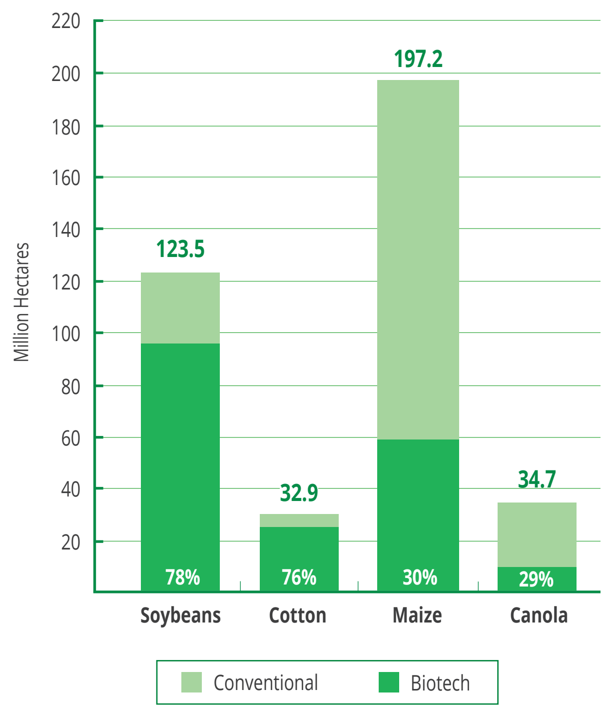


Figure 17. Global Adoption Rates (%) for Principal Biotech Crops, 2018 (Million Hectares)

Source: ISAAA, 2018

were deployed successfully in Brazil, Argentina, Paraguay, and Uruguay.

The global area planted to soybeans in 2018 was 123.5 million hectares (2017 data of FAOSTAT, 2018), 78% (95.9 million hectares) was biotech soybeans (Figure 17).

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).

Biotech maize area slightly decreased in 2018

Biotech maize occupied 58.9 million hectares in 2018, a slight decrease of 1% from 2017 (Table 31). The 58.9 million hectares was comprised of 5.5 million hectares IR, 5.6 million hectares HT, and 47.8 million hectares stacked IR/HT. Biotech maize was planted in 14 countries, including the USA (33.17 million hectares), Brazil (15.4 million hectares), Argentina (5.5 million hectares), South Africa (2.0 million hectares), Canada (1.57 million hectares), Philippines (0.63 million hectares), Paraguay (0.39 million hectares), Spain (0.12 million hectares), and less than 0.1 million hectares in Uruguay, Colombia, Vietnam, Honduras, Chile, and Portugal. Similar to 2017, the area planted to biotech maize fluctuated in 2018 due to the favorable weather conditions in Latin America, low market price in the USA and Canada, lesser pest incidence in Europe, and the problem of counterfeit seeds which accounted for 10-12% of the market share in the Philippines. It is noteworthy that Vietnam had a marginal increase in biotech maize adoption, in the midst of the current controversies of the technology in the country. Moreover, three new stacked IR/HT events with various gene combinations for glufosinate, glyphosate, and dicamba herbicide tolerance, coleopteran and lepidopteran insect resistance, were approved for food, feed, processing (FFP) and cultivation in Japan in 2018.

Of the global 197.2 million maize area (FAOSTAT, 2018), 30% or 58.9 million hectares were biotech maize in 2018 (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 the demand for feed maize to meet higher meat consumption in diets, as people gain more income with surplus to spend for meat. In addition, the continuing beneficial adoption of drought tolerant maize in the USA that increased to 2 million hectares in 2018, and its possible adoption 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 first 21 years of biotech adoption (1996 to 2016) was US$63.7 billion and US$ 6.9 billion for 2016 alone (Brookes and Barfoot, 2018).

Biotech cotton adoption increased by 3%

The area planted to biotech upland cotton globally in 2018 was 24.9 million hectares, an increase of 3% from 24.1 million hectares in 2017 (Table 31). The 24.9 million hectares were comprised of 18.14 million hectares IR, 757,000 hectares HT, and 5.97 million hectares IR/HT. Four new biotech cotton events were approved in 2018, including Event 281-24-236 x 3006-210-23 x COT102 with IR stacked traits and T304-40 x GHB119 x COT102 in Brazil, GHB811 HT event in Australia, Canada, Japan, New Zealand, and the USA, and MON88702 single IR trait in Australia, Canada, New Zealand, and the USA.

The 3% 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 2018.

Biotech cotton was planted in 15 countries led by India (11.6 million hectares), USA (5.06 million hectares), China (2.93 million hectares), Pakistan (2.8 million hectares), Brazil (1.0 million hectares), Argentina (370,000 hectares), Myanmar (310,000 hectares), Australia (290,000 hectares), and small areas in Sudan, Mexico, South Africa, Paraguay, Colombia, Costa Rica, and eSwatini. eSwatini planted 250 hectares of biotech cotton in 2018, and is the newest addition to the list of countries planting biotech cotton. Large percentage increases in the area planted to biotech cotton were observed in Mexico (108,000 hectares, 98%), Argentina (120,000 hectares, 48%), USA (476,000 hectares, 10.6%), China (1.49 million hectares, 5.4%), and India (200,000 hectares, 2%), and small increases in Brazil, Sudan, South Africa, Colombia, and Costa Rica. These increases were due to the favorable global cotton prices and the more conducive weather conditions in Latin America that allowed them to rebound from losses due to drought in 2017. Biotech cotton area in Canada decreased in 2018 because of drought. In Pakistan and Myanmar, overall reduction in total cotton area was due to uncertainty in approval of new generation biotech traits and high yielding cotton varieties including IR/HT cotton, shortage of water for timely irrigation, and infestation of pink bollworm and cotton leaf curl virus.

Based on the 2016 FAOSTAT data (2018), cotton was planted in 32.9 million hectares globally, 76% (24.9 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, wherein US$3.8 billion was for 2016 alone (Brookes and Barfoot, 2018).

Biotech canola area decreased by 6%

The global area of biotech canola decreased by 6% from 10.2 million hectares in 2017 to 10.1 million hectares in 2018. USA and Canada had reduced areas planted to biotech canola by 61% and 9.5%, respectively. These coincide with reduced area of total canola in these countries. On the other hand, Australia had an increase of 1.5%. In 2018, biotech docosahexaenoic acid (DHA) canola with high oleic acid and herbicide tolerance was approved for food in New Zealand, and for food, feed, and processing in Australia and the USA in 2018.

These three countries support the technological needs of canola farmers. Since 1996, various canola varieties with multiple HR genes for glufosinate, glyphosate, and oxynil tolerance were developed and made available to the farmers. Chile grew biotech canola on 3,350 hectares in 2018 for seed export, a reduction of 650 hectares from 2017. Farmers in these countries planted lesser biotech canola because of lesser demand from growers in the northern hemisphere.

Of the global hectarage of 34.7 million hectares of canola grown in 2017 (FAOSTAT, 2018), 29%, or 10.1 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).

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 commercial planting in the USA in 2005. In 2018, the USA planted 1.14 million hectares RR®alfalfa and 120,000 hectares HarvXtra™, while Canada planted 4,000

HarvXtra™, for a total of 1.26 million hectares, 3.3% higher than 2017. Thus, area planted to HarvXtra™ alfalfa increased by almost 6-fold since 2016 when it was planted on 21,000 hectares only. HarvXtra™ alfalfa has less lignin, higher digestibility, and was claimed to also offer a 15 to 20% increase in yield, and 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 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 increased to 506,000 hectares in 2018 from 472,000 hectares in 2017, close to 7% increase.

The area planted to Bt eggplant increased by 40,000 hectares in 2018 and planted by 430,000 farmers in Bangladesh. This was largely due to huge government support and farmer acceptance. 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 9,600 hectares PRSV-R papaya in 2018 compared to 7,130 hectares in 2017, an increase of 34%, at 78% adoption rate in four provinces of Guangdong, Hainan, Guangxi, and Yunnan.

In the USA, Innate™ biotech potatoes increased by 82 hectares from 2017 to 1,700 hectares in 2018 wherein 800 hectares were planted with Generation 1 and 900 hectares were with Generation 2. In Canada, 15 hectares were planted for Generation 1 and 40 hectares of Generation 2 for the first time. In 2018, a new biotech potato with resistance to potato virus Y was approved in Argentina for FFP and cultivation.

Arctic® apples (®Golden, ®Granny, and ®Fuji) were planted on 240 hectares, a 2.4-fold increase from 101 hectares in 2017, when it was first planted. The anthocyanin-rich biotech pink pineapple was grown in Costa Rica at 23.7 hectares in 2018, a slight decrease from 25 hectares in 2017.

In 2018, two new biotech crops with new traits were planted. In Indonesia, a new biotech drought tolerant sugarcane was planted inside a government-owned facility, the Perkebunan Nusantara XI, and some farmer fields at a total of 1,241.6 hectares in 2018. Australia planted biotech safflower with high oleic acid on 68 hectares for research and development, market development, and seed production. Plans to release them to farmers in 2019 will be for 3,500 hectares, under a Closed Loop Identity Preservation Stewardship program.

DISTRIBUTION OF BIOTECH CROPS, BY TRAIT

During the 23-year period of 1996 to 2018, herbicide tolerance has consistently been the dominant trait of biotech crops planted (Table 32 and Figure 18), but is slowly declining through the years with the increasing prominence of the stacked traits. In 2018, stacked IR/HT traits deployed in soybean, maize, and cotton had the highest increase in year-on-year increment of 4% and occupy 42% of the global area (Table 32). In 2018, there were percentage increases in area planted to stacked IR/HT cotton (15%) and soybeans (9%). Stacked trait products were preferred by farmers due to their cost-saving technology, especially the Intacta™ soybean and BolgardIII/RR®flex cotton. Various IR/HT products were approved for food/feed and commercialization in 2018 for soybean, maize, and cotton.

In terms of year-over-year increases, the highest growth was notable for stacked traits at 4%, followed by single trait insect tolerance at 2% and a decline in herbicide tolerance trait at -1% most of which was the net result of a mix of

Table 32. Global Area of Biotech Crops, 2017-2018: by Trait (Million Hectares)

Traits	2017	%	2018	%	+/–	%
Herbicide Tolerance	88.7	47	87.5	45	-1.2	-1
Stacked Traits	77.7	41	80.5	42	2.8	4
Insect Resistance	23.3	12	23.7	12	0.4	2
Virus Resistance/ Other	<1	<1	<1	<1	<1	<1
Total	**189.8**	**100**	**191.7**	**100**	**1.9**	**1.0%**

Source: ISAAA, 2018

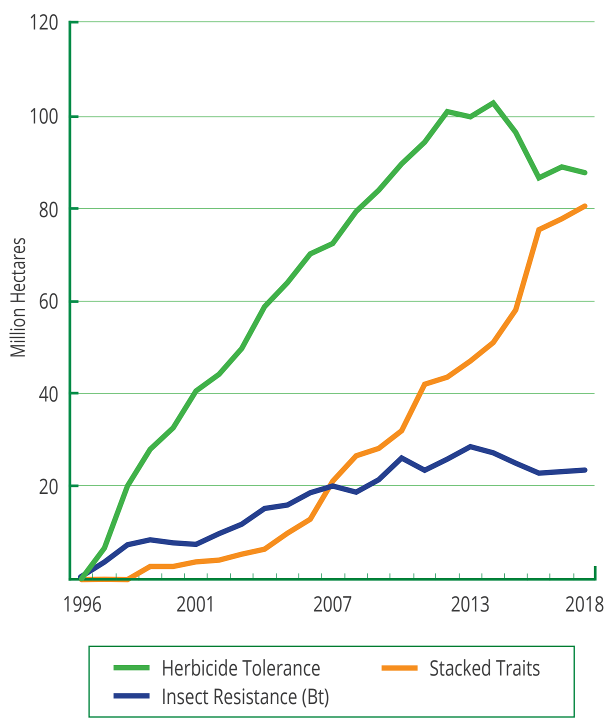


Figure 18. Global Area of Biotech Crops, 1996 to 2018: by Trait (Million Hectares)

Source: ISAAA, 2018

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 the USA in 2015 and in Canada in 2016.

The stacking of different Bt genes and herbicide tolerance is becoming increasingly important as new trait combinations come. Of the 80.86 million hectares of biotech crops with stacked traits, USA and Brazil contributed 41% and 38%, respectively, with small contributions from other countries which planted IR/HT soybeans, maize, and cotton. In 2018, a total of 15 countries adopted biotech crops with stacked traits: USA (33.3 million hectares), Brazil (31.3 million hectares), Argentina (9.6 million hectares), Paraguay (2.0 million hectares), Canada (1.3 million hectares), South Africa (1.4 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 adopting stacked products because productivity constraints at the farmer level are related to multiple biotic and abiotic stresses.

Herbicide tolerance (HT) deployed in soybeans, maize, canola, cotton, sugar beets, and alfalfa occupied 87.3 million hectares or 45% of the 191.9 million hectares of biotech crops planted by up to 17 million farmers globally (Table 32). This is a decrease of 1% or 1.2 million hectares compared to 2017. 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 tolerant crops were commercialized in the USA (40.7 million hectares), Brazil (15.5 million hectares), Argentina (14.2 million hectares), Canada (11.4 million hectares), Paraguay (1.7 million hectares), Bolivia (1.3 million hectares), South Africa (1.2 million hectares) 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 2% from 23.3 million hectares in 2017 to 23.7 million hectares in 2018 (Table 32). 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 (11.6 million hectares, cotton only), Brazil (4.5 million hectares), China (2.9 million hectares, cotton only), Pakistan (2.8 million hectares, cotton only), and less than 1 million hectares grown in the USA, Argentina, Myanmar, South Africa, Sudan, Spain, Paraguay, Portugal, and Bangladesh.

Generally, the variation 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 progress. The stacked traits of herbicide tolerance and insect resistance were deployed in cotton and soybeans (IR/HT) and 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 a number of Bt or other IR genes that code for different insect resistance traits. For example in maize, resistance genes against above ground pests and below ground pests are stacked in the same maize product.

Distribution of economic benefits at the farm level by trait, for the first 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 value of 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).

TRENDS IN GM CROP APPROVALS 1992-2018 (Based on ISAAA GM Approval Database)

The number of countries that issued approvals for food, feed, and cultivation reached its peak in 2012 at 23 countries then declined to 20 in 2015. However, in 2018, it reached a total of 23 countries which includes Ethiopia, Nigeria and eSwatini (formerly Swaziland). Ethiopia and eSwatini both approved the same cotton event, Event1, while Nigeria approved a total of 17 events (1 cotton event, 6 soybean events, 10 maize events) (Figure 19). Nigeria has the most number events approved in 2018 followed by Argentina with 15 events approved.

Accumulated number of countries (1992-2018) reached a total of 43 countries (including EU

28, counted as one) have given 2063 food approvals, 1,461 feed approvals, and 825 cultivation approvals (not including approvals for ornamentals such as carnation, rose, and petunia), scattered among 387 events of 27 crops. On the other hand, if the data will include ornamentals, the details will be: 2,063 food, 1,416 feed, 887 cultivation, total of 4,411 approvals scattered among 409 events of 30 crops.

The total number of approvals for 2018 was 270, wherein 131 were for food, 97 for feed, and 42 for cultivation. These approvals are divided among 91 events from 10 crops including a new GM crop, Safflower, and granted by 23 countries. Argentina issued the greatest number of approvals with 37 approvals followed by Brazil with 36. USA approvals are single events and stacked traits are not counted.

In 2018, a total of 91 events were approved, with 31 single traits and 58 stacked traits. Approval of stacked traits was slow and fluctuating since 1994 but became consistent from 2008 onwards, when stacked trait approvals consistently outnumbered the single events (Figure 20).

Various combinations of stacked trait events are indicated in Figure 3 with stacked herbicide tolerance and insect resistance comprised of 30.5% of the events approved, while other stacked events (HT + PC, IR + DR, and HT + PQ) made up 15% of the approved events. This trend will likely continue into the future since farmers demand more traits in an event, especially in maize.

Biotech Crop Importing Countries

Globally, there are countries that adopt biotech

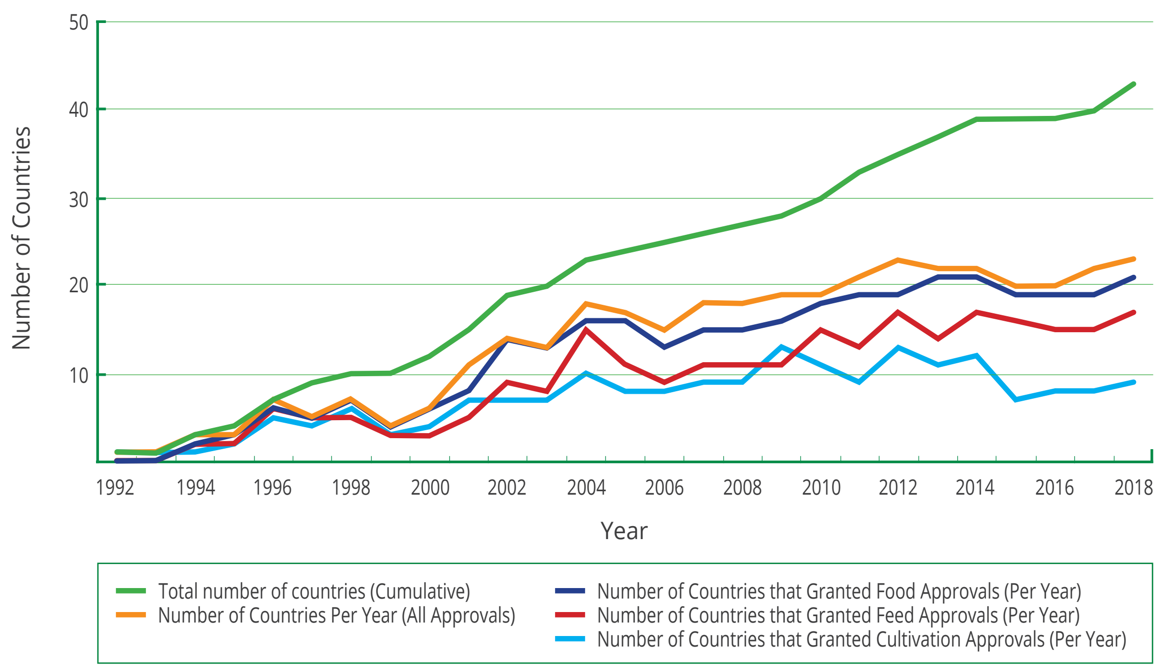


Figure 19. Number of Countries that Issued Food, Feed, and Cultivation Approvals (1992-2018)

Source: ISAAA, 2018

crops through imports 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.

Since 1996, a total of 44 non-planting countries (18 + 26 countries from the EU) have approved biotech crops for import (FFP) (Table 33). Japan approved the most number of crops with 11, 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 beet through a petition submitted by the Agricultural Academy of Japan (Crop Biotech Update, March 15, 2017).

Overall, a total of 70 countries (26 planting and 44 non-planting countries) adopted 30 biotech crops for food, feed, and cultivation in 2018. These biotech crops possess various traits with stacked HT/IR traits comprising 30.5% (Figure 21) of the total 4,349 approvals from 1992 to 2018, broken down into 2,063 food, 1,461 feed, and 825 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 of farmers and consumers.

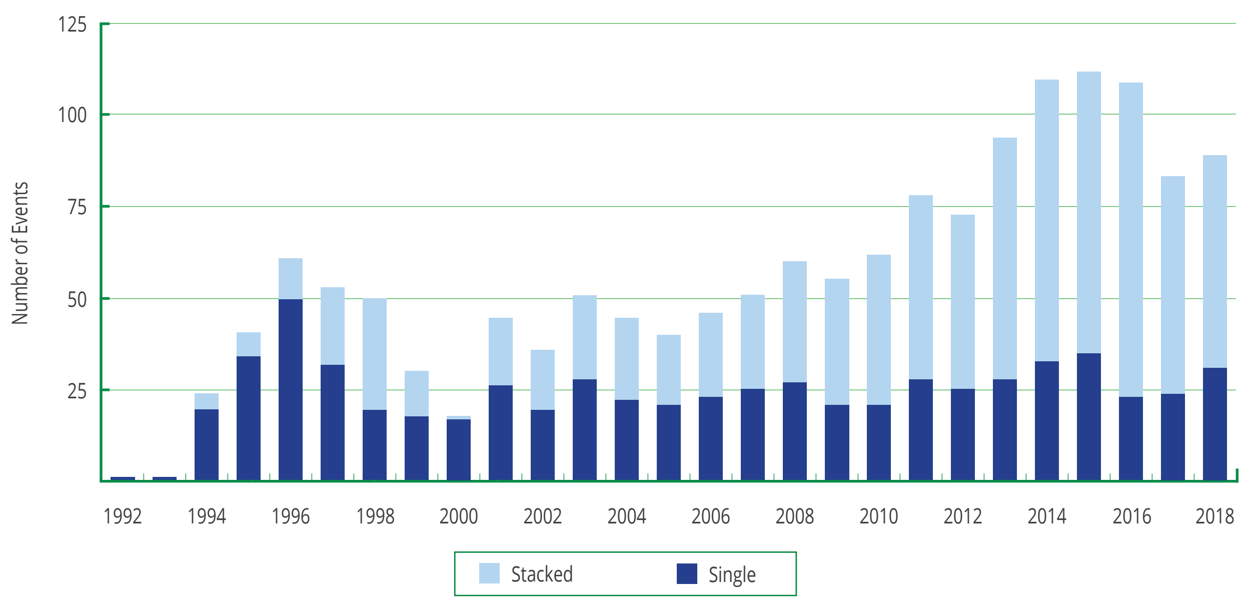


Figure 20. Number of Biotech Events (Single and Stacked) Approved per Year (1992-2018)

Source: ISAAA, 2018

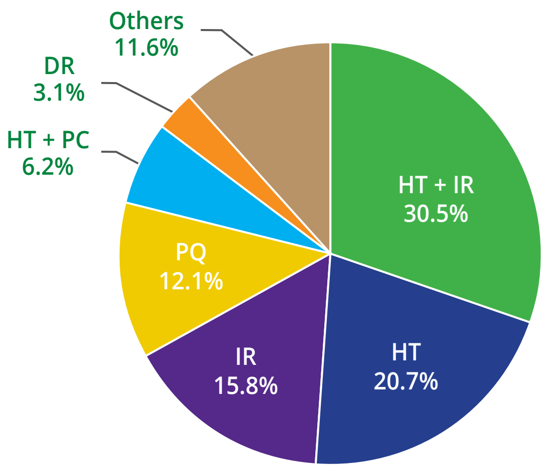
Table 33. Non-planting Countries which Granted Approvals for Import (Food, Feed, and Processing) from 1996 to 2018

	Countries	Crops Approved for Import	
		1996-2017	2018
1	Burkina Faso	Cotton	
2	Cuba	Maize	
3	Egypt	Maize	
4	Ethiopia		Cotton
5	Iran	Rice, soybeans, and rapeseed	
6	Japan	Alfalfa, canola, carnation, cotton, maize, papaya, potato, rice, rose, soybeans, and sugar beets	HT cotton, HT+PQ soybean (3 events), HT maize (3 events)
7	Malaysia	Canola, carnation, cotton, maize, potato, and soybeans	
8	New Zealand	Alfalfa, canola, cotton, maize, potato, rice, sugar beets, and wheat	DHA canola, HT cotton, IR cotton
9	Norway	Carnation	
10	Nigeria		Cotton
11	Panama	Maize	
12	Russian Federation	Maize, potato, rice, soybeans, and sugar beets	
13	Singapore	Alfalfa, canola, cotton, maize, soybeans, and sugar beets	
14	South Korea	Alfalfa, canola, cotton, maize, and soybeans	
15	Switzerland	Maize and soybeans	
16	Taiwan	Canola, cotton, maize, soybeans, and sugar beets	
17	Thailand	Maize and soybeans	
18	Turkey	Maize and soybeans	
19	26 EU countries	Canola, carnation, cotton, maize, potato, soybeans, and sugar beets	

Source: ISAAA GM Approval Database

New Approvals, Events, and Countries

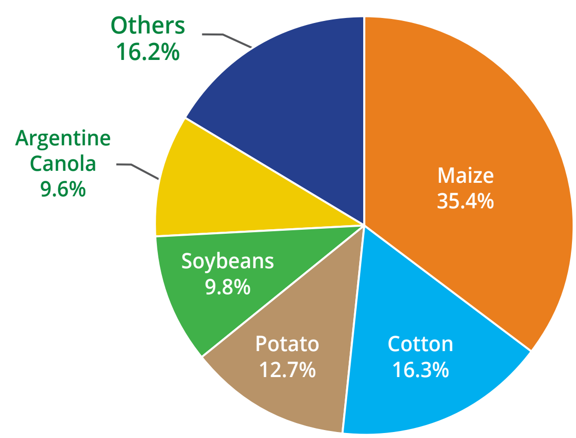
The most number of import approvals was granted to biotech maize events given by 14 countries, followed by soybean (11), cotton (8), and canola (7). In 2018, 7 countries approved new biotech events of these crops, such as DHA canola, stacked IR and IR/HT cotton, drought resistant potato, DHA safflower, HT and PQ soybean, IR sugarcane, single IR cotton, and IR/HT maize. The new countries which approved and planted biotech crops in 2018 were Indonesia (drought tolerant sugarcane) and Kingdom of eEswatini (IR cotton). Ethiopia approved one cotton event for planting in 2020, and Nigeria approved 17 events (1 cotton, 20 maize, and 6 soybean events) for food, feed and processing imports. New traits for 2018 include the hemipteran insect resistance in new cotton event MON88702 approved for



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; Modified starch/carbohydrate; Nicotine Reduction; Non-Browning Phenotype; Phytase production; Reduced Acrylamide Potential; Reduced Black Spot Bruising | Others: DR + IR; HT + PQ; ST; DR + HT + IR; AGY; PC; HT + IR + PQ; HT + IR + ST; DR + PQ; HT + ST; IR + PQ; IR + ST

Figure 21. Distribution of Traits of Approved GM Events (1992-2018)

Source: ISAAA, 2018



Others: Tomato, Rice, Alfalfa, Sugarcane, Papaya, Polish Canola, Apples, Chicory, Sugar beets, Melon, Poplar, Safflower, Squash, Tobacco, Bean, Creeping bentgrass, Eggplant, Eucalyptus, Flax, Plum, Sweet pepper, Wheat

Figure 22. Distribution of Approved GM Crops (1992-2018)

Source: ISAAA, 2018

food in Australia, Canada, New Zealand and the USA; and isoxaflutole herbicide tolerance in new cotton event GHB811 approved for FFP in Australia, Canada, Japan, New Zealand and for cultivation in the USA.

CONTRIBUTION OF BIOTECH CROPS TO FOOD SECURITY, SUSTAINABILITY, AND CLIMATE CHANGE MITIGATION

Biotech crops are being adopted globally because of the enormous benefits to the environment, health of humans and animals, and contributions to the improvement of socio economic conditions of farmers and the general public. Global economic gains contributed by biotech crops in the last 21 years (1996-2016) have amounted to US$186.1 billion economic benefits to more than 16 to 17 million farmers, 95% of whom come from developing countries.

Biotech crops contributed to food security, sustainability and climate change solutions by:

- **increasing crop productivity** by by 657.6 million tons valued at US$186.1 billion in 1996-2016; and 82.2 million tons valued at US$18.2 billion in 2016 alone;
- **conserving biodiversity** in 1996 to 2016 by saving 183 million hectares of land, and 22.5 million hectares of land in 2016 alone;
  providing a better environment
  - by saving on 671 million kg. a.i. of pesticides in 1996-2016, and by 48.5 million kg in 2016 alone from being released into the environment;
  - by saving on pesticide use by 8.2% in 1996-2016, and by 8.1% in 2016 alone;
  - by reducing EIQ (Environmental Impact Quotient) by 18.4% in 1996-2016, and by 18.3% in 2016 alone
- **reducing CO2 emissions** in 2016 by 27.1 billion kg, equivalent to taking 16.7 million

cars off the road for one year; and

- **helping alleviate poverty through uplifting the economic situation of** 16-17 million small farmers, and their families totaling >65 million people, who are some of the poorest people in the world (Brookes and Barfoot, 2018).

Thus, biotech crops can contribute to a "sustainable intensification" strategy favored by many science academies worldwide, which allows productivity and production to be increased on the current 1.5 billion hectares only of global crop land, thereby saving forests and biodiversity. Biotech crops are essential but are not a panacea, and adherence to good farming practices such as rotations and resistance management, are a must for biotech crops as they are for conventional crops.

CLOSING COMMENTS AND CONCLUSION

On the 23rd year of biotech crop commercialization, 26 countries grew 191.7 million hectares of biotech crops with economically important traits such as insect resistance, herbicide tolerance, disease resistance, product quality traits (anti-allergy, delayed fruit softening, modified oil/fatty acid content, and many more) as well as pollination control traits. Two countries commenced planting in 2018: Indonesia for drought tolerant sugarcane and eSwatini for IR(Bt) maize. The two biotech crops and traits introduced in 2018 were biotech drought tolerant sugarcane in Indonesia and biotech high oleic acid safflower in Australia. Various trait combinations were also approved including high oleic acid canola, isoxaflutole herbicide tolerant cotton, stacked herbicide tolerant and high oleic acid soybeans, HT and salt tolerant soybeans, insect resistant sugarcane, and biotech maize with various IR/HT combinations in stack.

The accumulated biotech crop area (planted since 1996) surged to a record 2.5 billion hectares or 6.2 billion acres. Of the total 26 countries planting biotech crops, 21 were developing countries and 5 were industrial countries. The increase between 2017 and 2018 of 1% is equivalent to 1.9 million hectares or 4.7 million acres. Developing countries grew 54% of the global biotech area compared to 46% for industrial countries. Soybeans occupied 50% (95.9 million hectares) of the global biotech crop area, a 2% increase compared to 2017. Herbicide tolerance has consistently been the dominant trait at 46% of the global area, a decline of 1% compared to 2017. Stacked traits increased to 80.5 million hectares in 2018 compared to 77.7 million hectares in 2017 – an increase of 2.8 million hectares or 4%. Based on the global crop area planted to the major crops, 78% of soybeans, 76% of cotton, 30% of maize, and 29% of canola were biotech crops in 2018. In addition to the 26 planting countries, 44 non-planting countries (18 + 26 EU countries) have approved the import of biotech crops for food, feed, and processing, for a total of 70 countries adopting biotech crops globally. The total biotech crop approvals from 1992 to 2018 were 4,349, comprised of 2,063 food, 1,461 feed, and 825 cultivation approvals.

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 the 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, personal communication, 2018). 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.

Remarkably, the average biotech crop adoption rate in the top five biotech crop-growing countries increased in 2018 to reach close to saturation, with the USA at 93.3%, Brazil (93%), Argentina (~100%), Canada (92.5%), and India (95%).

In 2018, the global area of biotech crops increased from 189.8 million hectares to 191.7 million hectares, a 1.1% increase equivalent to 1.9 million hectares, and planted by 26 countries. As predicted by James (2015), the slight decline in biotech crop area in 2015 easily reverted to the increasing trend of biotech crop area in 2016, 2017 and a slight increase in 2018. Trends in global adoption in the planting countries were affected by various factors including but not limited to the following:

- Consumer demand for the commodity and global prices incentives increased biotech cotton and/or soybeans in the USA, Latin American countries, India, China, Paraguay, South Africa, Mexico, and Vietnam;
- Industry demand for biofuels increased adoption in the USA, Brazil, and Indonesia;
- Increased need for livestock and poultry feeds influenced biotech crop adoption in exporting countries in Latin America including Brazil;
- Conducive weather conditions and favorable local and domestic prices of major crops in Brazil, Argentina, Paraguay, Uruguay, and Honduras;
- Farmer/consumer acceptance in India, Bangladesh, and Sudan; and
- Government financing support to farmers in Paraguay.

On the other hand, reduction in area planted to biotech crops were observed in some countries due to:

- Onset of environmental stresses, such as drought and high temperatures in Canada, Pakistan, Bolivia, and Australia;
- Unfavorable domestic and international prices in maize that affected Colombia; and
- Confusing country policies related to biosafety, marketability, and counterfeit seeds in Myanmar, Spain, Portugal, and Philippines.

Once again, in its 23rd year of commercialization, the increase in global biotech crop adoption (cultivation and import for food, feed and processing) manifest the satisfaction of more than 17 million farmers, 95% of whom are small farmers, and consumer acceptance due to 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 environmental conservation and sustainability, and most importantly taking into consideration the millions of hungry and impoverished populace in need of resources.

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

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