ISAAA

International Service for the Acquisition of Agri-Biotech Applications

ISAAA Briefs

BRIEF 55

GLOBAL STATUS OF COMMERCIALIZED BIOTECH/GM CROPS IN 2019:

Biotech Crops Drive Socio-Economic Development and Sustainable Environment in the New Frontier

Over the last 24 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 24 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 2019 information for Argentina, Brazil, Australia, South Africa, and Uruguay is hectares usually planted in the last quarter of 2019 and harvested in the first quarter of 2020, 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 2019 and more intensively through January and February 2020, is classified as a 2019 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 55

Global Status of Commercialized Biotech/GM Crops in 2019:

Biotech Crops Drive Socio-Economic Development and Sustainable Environment in the New Frontier

No. 55 – 2019

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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INTRODUCTION

The first 23 years of commercialization of biotech crops (1996 to 2018) has confirmed that biotech crops have continued to help meet the challenges of increased population and climate change through the substantial agronomic, environmental, economic, health, and social benefits to farmers, and increasingly to the consumers (ISAAA, 2018). The rapid adoption of biotech crops reflects the substantial multiple benefits realized by both large- and small-scale farmers in industrial and developing countries which have commercially grown biotech crops. In 23 years, an accumulated 2.53 billion hectares of biotech crops have been grown comprising 1.23 billion hectares of biotech soybeans, 0.76 billion hectares of biotech maize, 0.39 billion hectares of biotech cotton, and 0.15 billion hectares of biotech canola. Biotech products derived from 2.53 billion hectares significantly contribute to the food, feed, fiber, and fuel needs of the ~7.7 billion world population. Due to reduced fertility, the population is estimated to increase at a slower rate of around 8.5 billion in 2030, 9.7 billion in 2050, and 10.9 billion in 2100 (UN World Population Prospects, 2019). Even so, this continuously increasing population will still need food, feed, clothing, and shelter, which cannot be achieved by conventional methods with dwindling resources.

The Global Food Insecurity Report of 2019 revealed that the targets of the United Nations Millennium Development Goals (UN-MDG) that ended in 2015 were not achieved and that more than 821 million in the world were still hungry in 2018 which highlights the intense challenge of achieving the Zero Hunger target of the Sustainable Development Goals by 2030 (FAO, 2020). The State of Food Security and Nutrition in the World for 2019 also showed that the decline in world hunger that was obtained for over a decade has culminated, and hunger is again on the rise. The global level of the prevalence of undernourishment has stabilized; unfortunately, the absolute number of undernourished people continues to slowly rise.

Regional details show that in almost all African subregions, the highest prevalence of undernourishment is close to 20%. This is followed by Asia, especially the Western Asian region, which shows a continuous increase of more than 12% of its population since 2010. Hunger is also slowly rising in Latin America and the Caribbean at close to 7%. It is disheartening to note that over 2 billion people do not have regular access to safe, nutritious, and sufficient food, including 8% of the population in Northern America and Europe.

The economic slowdowns and downturns have greatly impacted the likelihood of severe food insecurity and undernutrition, and this effect is 20% higher for low-income countries.

Climate change is heavily affecting food production globally. A study by research teams from the University of Minnesota, University of Oxford, and the University of Copenhagen revealed that climate change has already affected production of key energy sources — and some regions and countries are faring far worse than others. The world's top 10 crops — barley, cassava, maize, oil palm, rapeseed, rice, sorghum, soybeans, sugarcane, and wheat — supply a combined 83 percent of all calories produced on cropland. They used weather and reported crop data to evaluate the potential impact of observed climate change. The researchers found that:

- observed climate change causes a significant yield variation in the world's top 10 crops, ranging from a decrease of 13.4 percent for oil palm to an increase of 3.5 percent for soybeans, and resulting in an average reduction of approximately one percent (-3.5 X 10e13 kcal/year) of consumable food calories from these top 10 crops;

- impacts of climate change on global food production are mostly negative in Europe, Southern Africa, and Australia, generally positive in Latin America, and mixed in Asia and Northern and Central America; and
- half of all food-insecure countries are experiencing decreases in crop production — and so are some affluent industrialized countries in Western Europe.

Countries which are negatively affected by climate change should put adaptation strategies in place in agricultural crops to achieve food sufficiency (Crop Biotech Update, June 5, 2019).

In another study by the Australian Centre of Excellence for Climate Extremes, in collaboration with Germany, Switzerland, and the USA, indicate that climate extremes such as droughts or heat waves affect yield variability of staple crops around the world. Overall, year-to-year changes in climate factors during the growing season of maize, rice, soybeans, and spring wheat accounted for 20%-49% of yield fluctuations. Climate extremes, such as hot and cold temperature extremes, characterized by drought and heavy precipitation, by themselves accounted for 18%-43% of these interannual variations in crop yield. The researchers also identified global hotspots – areas that produce a large proportion of the world's crop production yet are most susceptible to climate variability and extremes: North America for soy and spring wheat production, Europe for spring wheat, and Asia for rice and maize production were identified as hotspot agricultural areas (Crop Biotech Update, May 8, 2019).

Indirectly, climate change and its accompanying warming climate increases crop losses due to insect pests. Rising temperatures boost the metabolic rate and population increase of insect pests, according to a study published in Science (Crop Biotech Update, September 5, 2018). According to researchers of the University of Vermont, losses in staple crops rice, maize, and wheat are projected to rise by 10-25% 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 increase in insect population. In extreme temperatures, the population growth is slow. Thus, the losses will be greatest in temperate areas, but less severe in the tropics.

One important example of insect pests is the fall armyworm (FAW) 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 that puts food security and farmer livelihoods at risk, according to FAO (Crop Biotech Update, August 15, 2018). Its population has reached an epidemic size because of 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. For maize, FAW damage is estimated at 80 million tonnes worth US$180 billion per year in Asia, Africa, and the Near East, affecting 600 million people.

With the current concerns related to climate change, there is thus an urgent and united call from the Committee on World Food Security to reverse the increase in the number of hungry people in the midst of climate change. In 2018, José Graziano da Silva, former Director-General of the Food and Agriculture Organization of the United Nations (FAO) already emphasized the urgency of the problem, saying, "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)

Safeguarding food security and nutrition is critical, needing economic and social policies to be in place. Actions to be undertaken should also be bolder and stronger in terms of multisectoral collaboration involving agriculture, food, health, water and sanitation, accompanied by policy domains on social protection, development planning, and economic policy.

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

- increased productivity that promotes 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.

In the last two years, research has been aimed at combating FAW through biotech crops with currently approved multi-insect resistance traits. Once these traits are available, farmers in Africa and Asia will get additional strategies to stop the negative impact of this devastating pest. These biotech insect resistant crops could fight the pest immediately compared to developing resistant varieties through traditional breeding which takes several years. Delaying adoption of biotech crops such as IR (Bt) maize in the developing world presents risks to both humans and the environment due to rampant use of insecticides and food shortage (Crop Biotech Update, December 19, 2018).

Abiotic stresses associated with climate change such as drought are being addressed by the development and commercialization of drought tolerant maize and sugarcane. Drought tolerance in soybeans and wheat are now in the final stages of regulatory approvals to help farmers in drought-stricken parts of the world.

Biotech crops are safe for humans and the environment, and the risks associated with biotech crops have proven to be low to non-existent. A study by the University of Saskatchewan's Stuart J. Smyth detailed the human health benefits from biotech crops, particularly those of small land holder farmers in developing countries. The publication tackled situations such as pesticide reduction, suicide rates, lowered cancer incidences, and mental and nutritional benefits. According to different studies spanning from 2003 to 2016, the use of Bt cotton has resulted in significant reduction in pesticide poisoning in China, India, Pakistan, and South America. The reduction of pesticide-use led to the decreased number of pesticide poisoning-reported cases and contributed to the decreased levels of mycotoxins in maize, a known carcinogen to humans and animals.

Farmer suicide incidences were also found to have plateaued instead of increasing yearly, after Bt cotton was commercialized in India. According to the publication, the cumulative reduced suicide rate related with the Bt cotton adoption represents the prevention of at least 75,000 farmer suicides. Another study also mentioned that the higher yields brought about by GM crops gave farmers confidence that their crop will not fail due to pests, diseases, and drought, resulting in less financial debt. It was recommended that these factors be further investigated to assess and highlight the mental health improvement of GM crop adopters.

Lastly, adoption of biofortified crops have shown to increase micronutrient availability. Consumers in developing countries get their nutrients mostly through a plant-based diet. With biofortified GM crops, consumers are more likely to obtain their nutritional needs through their food in-take alone (Crop Biotech Update, October 2, 2019).

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 over 200 scientific organizations have declared solid and clear consensus about the safety of biotech crops. 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. The release of science-based evidence on the adoption and impact of biotech crops could help bridge this widening gap.

The International Service for the Acquisition of Agri-biotech Applications (ISAAA) strongly espouses these objective and scientific truths with the publication of *Global Status of Commercialized Biotech/GM Crop for 2019* (ISAAA Brief 55). 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 2019, the global area of biotech crops decreased slightly (0.7%, 1.3 million hectares) from 191.7 million hectares in 2018 to 190.4 million hectares and planted by 29 countries. 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, this global area is predicted to increase in due time. Thus, adoption of biotech crops in 2019, detailed in each country chapter was a result of an interplay of these various factors. It is noteworthy that adoption rates of the major biotech crops (soybeans, maize, cotton, and canola) was over 90% of the major products in principal markets in both developing and industrial countries. High adoption rates reflect farmer satisfaction with the products that offer substantial benefits ranging from more convenient and flexible crop management, lower cost of production, higher productivity and/or net returns per hectare, health and social benefits, and a cleaner environment through decreased use of conventional pesticides, which collectively contribute to a more sustainable agriculture.

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. This Brief is also dedicated to the late Dr. Randy A. Hautea, former 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 less fortunate individuals located in poverty-stricken areas of the world.

GLOBAL AREA OF BIOTECH CROPS IN 2019

In 2019, the accumulated biotech area (planted since 1996) surged to a record 2.7 billion hectares or 6.7 billion acres (Table 1). Of the total number of 29 countries planting biotech crops in 2019, 24 were developing countries and 5 were industrialized countries (Table 2, Figure 1). The 0.7% slight decrease between 2018 and 2019 is equivalent to 1.3 million hectares or 3.2 million acres (Table 1). This is a manifestation of how fast the technology has been adopted in an increasing number of countries and expanded areas, 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 2019, there was a difference of 21 million hectares between developing and industrialized countries. Developing countries grew 56% of the global biotech hectares compared to 44% for industrialized countries (Table 2, Figure 1). Moreover, developing countries increased by 2.5% in 2019, compared to 2018, while industrialized countries decreased by 4.4%.

The 21 million hectares increment between the developing countries and industrialized countries in 2019 is due mainly to area increases in developing countries of Brazil (1.5 million hectares), Paraguay (300,000 hectares), India (300,000 hectares), Philippines (246,000 hectares), China (200,000 hectares), Argentina (100,000 hectares), Bolivia (100,000 hectares

Table 1. Global Area of Biotech Crops, 24 Years, 1996 to 2019

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
2019	190.4	470.5
Total	**2,721.6**	**6,725.0**

*Global area of biotech crops in 2019 slightly decreased to 190.4 million hectares compared with 191.7 million hectares in 2018, equivalent to 0.7% or 1.3 million hectares (3.2 million acres).

Source: ISAAA, 2019

Table 2. Global Area of Biotech Crops, 2018 and 2019: Industrialized and Developing Countries (Million Hectares)

	2018	%	2019	%	Diff	%
Industrial countries	88.6	46	84.7	44	–3.9	–4.4%
Developing countries	103.1	54	105.7	56	2.6	2.5%
Total	**191.7**	**100**	**190.4**	**100**	**–1.3**	**–0.7%**

Source: ISAAA, 2019

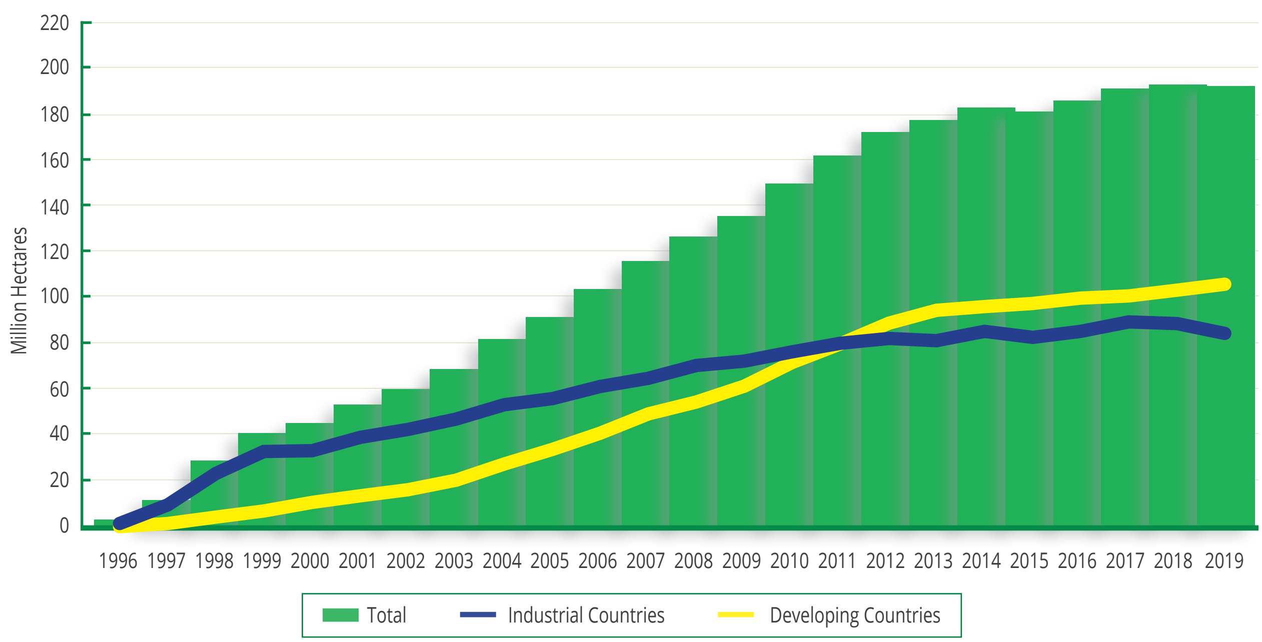


Figure 1. Global Area of Biotech Crops, 1996 to 2019: Industrialized and Developing Countries (Million Hectares)

Source: ISAAA, 2019

each); and small hectare increases in Mexico, Colombia, Vietnam, Honduras, Chile, Indonesia, and Bangladesh. The largest percentage increase was obtained by Vietnam at 86% in biotech cotton, followed by the Philippines (39%) and Colombia (15%).

The 10% reduction in total and biotech soybeans in the USA was instrumental in the reduction of total global biotech crop area. The incremental increases mentioned above was not enough to compensate for the 3.652 million hectares decline in biotech soybeans in the USA in 2019. There were also decreases in the following countries: Pakistan with 287,000 hectares, Canada (281,000 hectares), Australia (178,000 hectares), Uruguay (107,000 hectares); and with decreases of less than 100,000 hectares in South Africa, Myanmar, Spain, Sudan, 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. This trend is expected primarily 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 generation" of biotech crops.

DISTRIBUTION OF BIOTECH CROPS, BY COUNTRY

A total of 29 countries, 24 developing and 5 industrialized countries, planted biotech crops in 2019. The top ten countries, each of which grew over 1 million hectares, was led by the USA which grew 71.5 million hectares (38% of global total), Brazil with 52.8 million hectares (28%), Argentina with 24 million hectares (13%), Canada with 12.5 million hectares (7%), India with 11.9 million hectares (6%), Paraguay with 4.1 million hectares (2%), China with 3.2 million hectares (2%), South Africa with 2.7 million hectares (1%), Pakistan with 2.5 million hectares (1%), and Bolivia with 1.4 million hectares (1%) for a total of 186.6 million hectares (97.9% of 190.4 million hectares global total area). An additional 19 countries grew a total of approximately 3.9 million hectares in 2019 (Table 3 and Figure 3). Three new developing countries in Africa planted biotech cotton for the first time: Malawi (6,000 hectares), Nigeria (700 hectares), and Ethiopia (311 hectares), for a total of 6 biotech planting countries in Africa.

It should be noted that majority (8 out of 10) of the top ten countries, each growing more than 1 million hectares of biotech crops, were developing countries, with Brazil, Argentina, India, Paraguay, China, South Africa, Pakistan, and Bolivia, compared with only two industrialized countries, USA and Canada.

A total of 19 biotech mega-countries (countries which grew 50,000 hectares or more of biotech crops) was recorded in 2019, which is one country more than the 2018 count. Notably, 15 of the 19 mega-countries were developing countries from Latin America, Asia, and Africa. The high proportion of biotech mega-countries in 2019, 24 out of 29, equivalent to 83% of the global biotech crop area, reflects the significant broadening and stabilizing in biotech crop adoption that occurred within the group of more progressive mega-countries adopting more than 50,000 hectares of biotech crops, on all six continents.

Of the 29 countries that planted biotech crops in 2019, 12 (41%) of the countries were in the Americas, 9 (31%) were in Asia, 2 (7%) were in Europe, and 6 (21%) were in Africa. In terms of biotech crop area, of the 29 countries that planted biotech crops in 2019, 88.2% of the area was in the Americas, 10.2% in Asia, 1.5% in Africa, and 0.1% in Europe.

There were 10 countries in Latin America, which benefited from the extensive adoption of biotech crops. Listed in descending order of biotech area, they were Brazil, Argentina, Paraguay, Bolivia, Uruguay, Mexico, Colombia, Honduras, Chile, and Costa Rica. There were 9 countries that planted biotech crops in Asia and the Pacific led by India, China, Pakistan, Philippines, Australia, Myanmar, Vietnam, Indonesia, and Bangladesh. For the seventh year since its approval, Japan grew the 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 other food, feed, and fiber biotech crops grown in other countries listed in this Brief.

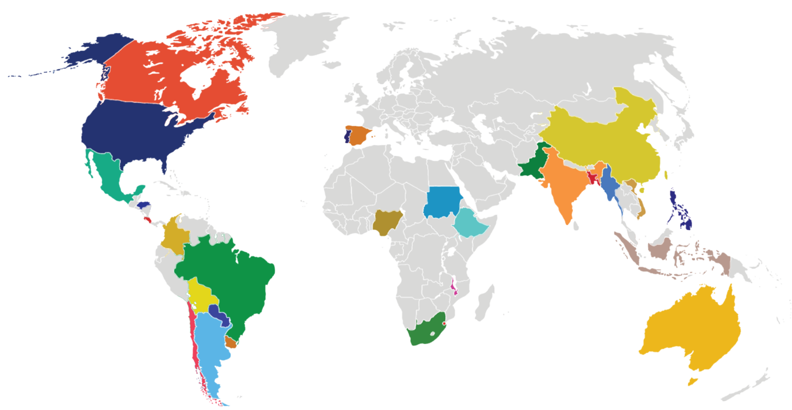
Table 3. Global Area of Biotech Crops in 2018 and 2019: by Country (Million Hectares)**

	Country	2018	%	2019	%	+/–	%
1	*USA**	75.0	39%	71.5	38%	–3.5	–5%
2	Brazil*	51.3	27%	52.8	28%	1.6	3%
3	Argentina*	23.9	12%	24.0	13%	0.1	0.5%
4	*Canada**	12.7	7%	12.5	7%	–0.3	–2%
5	India*	11.6	6%	11.9	6%	0.3	3%
6	Paraguay*	3.8	2%	4.1	2%	0.3	9%
7	China*	2.9	2%	3.2	2%	0.2	8%
8	South Africa*	2.7	2%	2.7	1%	0.0	–1%
9	Pakistan*	2.8	1%	2.5	1%	–0.3	–10%
10	Bolivia*	1.3	1%	1.4	1%	0.1	8%
11	Uruguay*	1.3	1%	1.2	1%	–0.1	–8%
12	Philippines*	0.6	<1	0.9	<1	0.2	39%
13	*Australia**	0.8	<1	0.6	<1	–0.2	–23%
14	Myanmar*	0.3	<1	0.3	<1	<0.1	–3%
15	Sudan*	0.2	<1	0.2	<1	<–0.1	–3%
16	Mexico*	0.2	<1	0.2	<1	<0.1	2%
17	*Spain**	0.1	<1	0.1	<1	<0.1	–7%
18	Colombia*	0.1	<1	0.1		<0.1	15%
19	Vietnam	<0.1	<1	0.1	<1	<0.1	86%
20	Honduras	<0.1	<1	<0.1	<1	<0.1	5%
21	Chile	<0.1	<1	<0.1	<1	<0.1	44%
22	Malawi	--	--	<0.1	<1	--	--
23	*Portugal*	<0.1	<1	<0.1	<1	<–0.1	–18%
24	Indonesia	<0.1	<1	<0.1	<1	<0.1	48%
25	Bangladesh	<0.1	<1	<0.1	<1	<0.1	29%
26	Nigeria	--	--	<0.1	<1	--	--
27	Eswatini	<0.1	<1	<0.1	<1	<0.1	61%
28	Ethiopia	--	--	<0.1	<1	--	--
29	Costa Rica	<0.1	<1	<0.1	<1	<0.1	114%
	Total	**191.7**	**100%**	**190.4**	**100%**	**1.3**	**0.7%**

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

Source: ISAAA, 2019

Figure 2. Global Area (Million Hectares) of Biotech Crops, 1996 to 2019, by Country, Mega-Countries, and for the Top Ten Countries



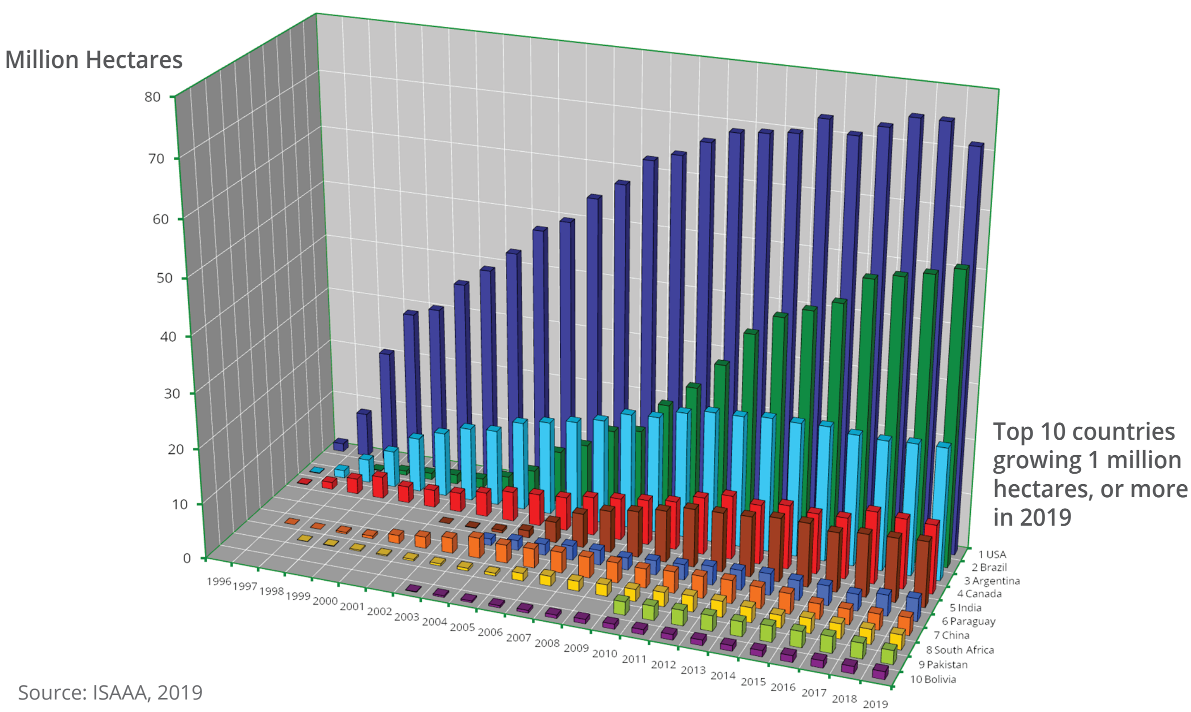
In 2019, global area of biotech crops was 190.4 million hectares, a slight decline of 0.7% from 2018, equivalent to 1.3 million hectares.

Source: ISAAA, 2019

50,000 hectares, or more	
1. *USA*	71.5 million
2. Brazil*	52.8 million
3. Argentina*	24.0 million
4. *Canada*	12.5 million
5. India*	11.9 million
6. Paraguay*	4.1 million
7. China*	3.2 million
8 South Africa*	2.7 million
9. Pakistan*	2.5 million
10. Bolivia*	1.4 million
11. Uruguay*	1.2 million
12. Philippines*	0.9 million
13. *Australia*	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
19. Vietnam*	0.1 million

Less than 50,000 hectares	
Honduras*	Bangladesh*
Chile*	Nigeria*
Malawi*	eSwatini*
Portugal	Ethiopia*
Indonesia*	Costa Rica*

* *Developing countries*



Source: ISAAA, 2019

Australia and Colombia also grew biotech carnation.

In Africa, Malawi, Nigeria, and Ethiopia joined South Africa, Sudan, and Eswatini for a total of six countries planting 2.9 million hectares of biotech crops. The approval of Nigeria's Bt cowpea resistant to pod borers was a major milestone in 2019. Moreover, Kenya approved the commercialization of biotech cotton in 2019 for cultivation in 2020. Other African countries continued to transition from confined field trials to the environmental release phase: Mozambique for drought tolerant maize and Kenya for cassava brown streak disease resistant cassava. Ghana and Niger improved their biosafety regulation to facilitate biotech crop development and adoption. A number of countries also endorsed the trade of biotech crops and vouched for their food safety including Zambia.

Two countries planted biotech maize, because of the infestation brought by the European corn borer. Since 2016, only Spain and Portugal planted biotech Bt maize. In 2019, 107,130 hectares and 4,753 hectares were planted by Spain and Portugal, respectively, for a total of 111,883 hectares, which is 7.5% less than the biotech maize area of 120,980 hectares in 2018. 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.

ECONOMIC BENEFITS OF BIOTECH CROPS

The six principal countries that have economically gained the most from biotech crops during the first 23 years (1996-2018) of its commercialization were, in descending order of magnitude, USA (US$95.9 billion), Argentina (US$28.1 billion), Brazil (US$26.6 billion), India (US$24.3billion), China (US$23.2 billion), Canada (US$9.7 billion), and others (US$23.2 billion) for a total of US$224.9 billion. For 2018 alone, six countries gained the most economically from biotech crops, they were the USA (US$ 7.8 billion), Brazil, (US$3.8 billion), Argentina (US$2.4 billion), India (US$1.5 billion), China (US$1.5 billion), Canada (US$ 0.9 billion), and others (US$1 billion) for a total of US$18.9 billion (Brookes and Barfoot, 2020).

In 2018, developing countries had a higher share (54%), equivalent to US$10.2 billion of the total US$18.9 billion gain, with industrial countries at US$8.7 billion (Brookes and Barfoot, 2020).

TOP TEN BIOTECH CROP COUNTRIES

The top ten biotech crop planting countries include the USA (71.5 million hectares), Brazil (52.8 million hectares), Argentina (24 million hectares), Canada (12.5 million hectares) India (11.9 million hectares), Paraguay (4.1 million hectares), China, (3.2 million hectares), South Africa (2.7 million hectares), Pakistan (2.5 million hectares), and Bolivia (1.4 million hectares), which planted a total of 186.5 million hectares or 98% of the total 190.4 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 24 years, the area of biotech crops planted in 2019 in the United States of America (USA) remained the highest globally. The total area planted with GM crops reached 71.5 million hectares in 2019, with a decrease of 5% from the 75 million hectares recorded in 2018 (Table 3 and Figure 2). This is comprised of 33.17 million hectares biotech maize, 30.43 million hectares biotech soybeans, 5.31 million hectares biotech cotton, 1.28 million hectares biotech alfalfa, 0.8 million hectares biotech canola, 454,100 hectares biotech sugar beets, 1,780 hectares biotech potato, and less than 1,000 hectares each of biotech apples, squash, and papaya (Figure 3). The biotech crop area in the USA was 38% of the global biotech crop area of 190.4 million hectares, thus retaining the country's leadership in biotech crop farming.

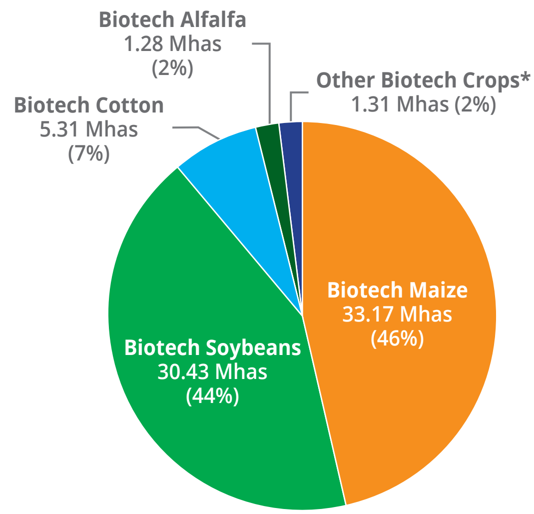


Figure 3. Biotech Crops Planted in the USA, 2019

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

Source: ISAAA, 2019

Estimates by 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 adoption: soybeans at 94% (similar to 2018), maize at 92% (similar to 2018), and biotech cotton at 98% (a 4% increase from 2018). The average adoption rate for the three crops in 2019 was 94.7%, (95%) a marginal increase (1.37%) from 93.3% in 2018. This is due mainly to biotech cotton. In the 24 years of commercialization of biotech crops (1996-2018), the USA accrued the highest economic benefits of US$95.9 billion, and US$7.8 billion in 2018 alone (Brookes and Barfoot, 2020) with more than 420,000 farmers cultivating these biotech crops. Biotech products from the USA are exported globally contributing to the global food supply.

Biotech maize adoption maintained at 92%

For 2019, the USDA National Agricultural Statistical Service (USDA NASS) reported that the biotech maize area was 33.17 million hectares at 92% adoption rate, similar to 2018. The 33.17 million hectares biotech maize area consisted of 1.08 million hectares insect resistant (IR), 3.24 million hectares herbicide tolerant (HT) and 28.85 million hectares stacked insect resistant and herbicide tolerant (IR/HT) traits (Table 4).

Biotech soybean area decreased significantly by 11%

Soybeans were the second most important crop in the USA, with a total planted area of 32.4 million hectares, an 11% decrease compared to 36.26 million hectares in 2018. Consequently, biotech soybean area also decreased by 11%, from 34.08 million hectares in 2018 to 30.43 million hectares in 2019. Biotech soybeans contain herbicide tolerant traits that control various kinds of weeds depending on the genes deployed. Other traits incorporated in HT soybeans include consumer traits such as event 260-05 (approved in 1997) with high monounsaturated oleic acid; event DP 305423-1 (2009) and Vistive Gold MON87705-6 (2011); and omega3-fatty acid-enriched soybean MON 87769 (2011).

The USDA has given its approval to Verdeca for HB4® drought tolerant soybeans which will allow for commercialization in the U.S. market. The USDA approval comes two years after the U.S. Food and Drug administration approved Verdeca's HB4 trait in 2017. With the USDA approval, the HB4 trait now has regulatory approval in more than 80 percent of the global soybean market. The HB4 trait has already been approved in Argentina in 2018 and in Brazil in 2019. Regulatory submissions are currently under consideration by China, Paraguay, Bolivia, and Uruguay. Import approval from China is necessary for commercial launch in Argentina, which is expected in 2020 (Crop Biotech Update, August 19, 2019).

Biotech alfalfa HarvXtra™ area increased by 32%

Alfalfa was the third most planted crop in the USA at 8.4 million hectares, with 15% or 1.27 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 1.12 million hectares and 158,000 hectares to HarvXtra™ in 2019, an increase of 32% from 2018. HarvXtra alfalfa is highly digestible and offers a 15 to 20% increase in yield. 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. Moreover, delaying the

Table 4. Total and Trait Hectares of Biotech Maize in the USA, 2018-2019

	Area Planted (MHa)		% Trait Hectares	
	2018	2019	2018	2019
Total Maize	36.059	36.059		
IR	0.72	1.08	2%	3%
HT	3.60	3.24	11%	10%
IR/HT**	28.85	28.85	87%	87%
Total Biotech Maize	**33.17**	**33.17**	**92%***	**92%***

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

Source: ISAAA, 2019

cutting leads to huge savings in equipment such as custom choppers, soil preservation, and time (Hay and Forage Grower, 2018).

Biotech cotton adoption rate increased to 98%

Upland cotton planted in the USA increased slightly to 5.42 million hectares in 2019 from 5.38 million hectares in 2018. The biotech cotton area also increased by 5% from 5.01 million hectares in 2018 to 5.3 million hectares in 2019. Notably, adoption of biotech cotton in 2018 increased significantly to 98%, compared to 94% in 2018. The 5.4 million hectares of biotech cotton consisted of 162,700 hectares insect resistant, 324,000 hectares herbicide tolerant, and 4.8 million hectares stacked IR and HT traits (Table 5).

In 2019, the U.S. Food and Drug Administration (FDA) has approved an ultra-low gossypol cottonseed, ULGCS, to be utilized as human food and animal feed. ULGCS is derived from a transgenic cotton variety TAM66274 developed by plant biotechnologist Dr. Keerti Rathore and his team at Texas A&M AgriLife Research. TAM66274 is a unique biotech cotton event with ultra-low gossypol levels in the seed, which makes the protein from the seeds safe for food use, but also maintains normal plant-protecting gossypol levels in the rest of the plant, making it ideal for the traditional cotton farmer. ULGCS has the potential to make a significant impact on food security especially in poor, cotton-growing countries, according to Rathore. The amount of protein locked up in the annual output of cottonseed worldwide is about 10.8 trillion grams, that is more than what is present in all the chicken eggs produced globally, and enough to meet the basic protein requirements of over 500 million people. The human food ingredients from TAM66274 cottonseed can be roasted cottonseed kernels, raw cottonseed kernels, cottonseed kernels, partially defatted cottonseed flour, defatted cottonseed flour and cottonseed oil. For animal feed, the low-gossypol cottonseed can be used in the aquaculture and poultry industries. A non-regulated status for TAM66274 was secured from the U.S. Department of Agriculture's Animal and Plant Health Inspection Service. The FDA enables cultivation and use of this promising new cottonseed product within the U.S. (Crop Biotech Update, October 16, 2019).

Biotech canola adoption maintained at 100%

The area covered by canola declined slightly from 898,000 hectares in 2018 to 820,000

Table 5. Trait Hectares of Biotech Cotton in the USA, 2018-2019

	Area Planted (MHa)		% Trait Hectares	
	2018	**2019**	**2018**	**2019**
Total Cotton	5.38	5.42		
IR	0.16	0.16	3%	3%
HT	0.48	0.32	10%	6%
IR/HT	4.42	4.83	87%	91%
Total Biotech Cotton	**5.06**	**5.31**	**94%***	**98%***

* Adoption rate

Source: ISAAA, 2019

hectares in 2019. Canola planted in the US is 100% biotech 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™ with high lauric acid and contains an enzyme that breaks down plant phytases, making phosphorous available to monogastric animals, was approved in 1994. In 2017, glufosinate tolerant canola was approved for food, feed, and cultivation.

Canola event LBFLFK with long chain omega-3 polyunsaturated fatty acids was approved in the USA for cultivation. This canola event is intended to provide an additional source of these omega-3 fatty acids to help meet human and food animal dietary needs. LBFLFK also contains resistance to imidazolinone based herbicides which contain active ingredients such as imazamox.

Biotech sugar beets maintained at 100% adoption rate

One hundred percent of the sugar beets planted in the USA was biotech. In 2019, 454,000 hectares biotech sugar beets were planted, with a slight decrease from 491,000 hectares planted in 2018. 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-1990's. Papaya ringspot virus belongs to Potyvirus, which is the largest genus of plant viruses causing significant losses in a wide range of crops. Resistant papaya was developed through the insertion of the coat protein genes of the virus. Papaya ringspot virus resistant (PRSV-R) Rainbow papaya was developed by public research institutions Cornell University and University of Hawaii in 1997 which has been 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 2019.

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

The area of Innate® potatoes increased in 2019, from 1,700 hectares in 2018 to 1,780 hectares in 2019, representing 1% of the total US potato area. The 1,780 hectares was composed of 809.4 hectares Generation 2 Hibernate chips variety, 485.3 hectares Generation 1 (Gen 1) Innate Cultivate, and 485.3 hectares of Innate Acclimate.

Innate® Gen 1 Cultivate and Accelerate potato varieties have reduced black spot, bruising, and acrylamide formation when cooked compared to conventional varieties. Simplot Co. has already obtained approvals for food and feed safety in the USA, Canada, Australia/New Zealand, Japan, Malaysia, Philippines, Singapore, and Mexico.

Innate® Gen 2 potatoes have the Gen 1 trait with the addition of lower sugars and late blight disease protection. The Gen 2 traits were introduced to varieties Acclimate, Hibernate and Elevate. Gen 2 Hibernate were also planted in Canada at 40.5 hectares. Food and feed approvals have been obtained in the US, Canada, Australia, New Zealand, and Singapore.

The company has also developed the Innate® Gen 3 platform which has reduced bruising, sugar control, and low acrylamide through invertase silencing, 3 resistance genes for robust late blight protection and PVT resistance. Gen 3 traits are being introduced into several varieties with anticipated approval in 2023.

Area of biotech non-browning Arctic®Apples increased 2.4-fold

Arctic® apples are known for their non-browning feature, which is a result of genetic engineering. The apple's enzymes responsible for browning were turned off. This means that the Arctic® apple's flesh does not become brown from getting bruised, sliced or bitten which protects the apple's flavor and nutritional value and, at the same time, makes it more appealing to consumers. Apples are the third most-wasted food in America with around 40 percent in the US being thrown away due to bruising and browning.

In 2019, non-browning Arctic®Golden and ®Granny apples were planted on 265 hectares, compared to 240 hectares planted in the USA in 2018. This is a 2.6-fold increase from 101 hectares planted during its launch in 2017. ApBitz™ dried apples are sold through Amazon.com since 2018. In 2019, ~500,000 kg of Arctic® apples were produced and sold in the US retail market. Okanagan Specialty Fruits Inc. (OSF) is also pursuing approvals in Mexico and has initiated quarantine and regulatory approval process in Argentina for southern hemisphere production. USA Arctic®Fuji event NF872 gained approval in Canada in 2019 and initiated regulatory approval for Arctic®Gala in the USA. Research and development plans are currently focused on diversification of product portfolio.

Acceptance of biotech apple was not as anticipated but the sales prove that biotech apple may be the first biotech product that consumers would buy because it is genetically engineered, said Jack Bobo of Intrexon (Genetic Literacy Project, March 15, 2019).

The United States Food and Drug Authority (FDA) has completed its voluntary review on the Arctic® Fuji Apple, according to Okanagan Specialty Fruit Inc. OSF received FDA's notice of review completion on April 26, 2019. This is the last step in the regulatory process that the Arctic® Fuji needs to officially join the commercial orchards, along with Arctic®Golden and Arctic® Granny apples which were previously approved in 2015 (Crop Biotech Update, May 2, 2019).

Benefits of Biotech Crops

According to Brookes and Barfoot (2020), in the 23 years of commercialization of biotech crops (1996-2018), the USA accrued the highest benefits of US$95.9 billion and US$7.8 billion for 2018 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 new biotech crops and traits being developed and commercialized.

Summary and Future Prospects

In 2019, the biotech area planted in the USA was 71.5 million hectares, covering 38% of the global biotech area, with an average adoption rate of 95% for three principal crops, similar to 2018. Biotech crops planted were soybeans (30.43 million hectares), maize (33.17 million hectares), cotton (5.31 million hectares), canola (800,000 hectares), sugar beets (454,100 hectares), alfalfa (1.28 million hectares), 1,780 hectares potatoes, less than 1,000 hectares each of papaya and squash, and 265 hectares apples.

The planting season of 2019 was marked with abundant rain, that has lowered the area planted to soybeans. However, the bumper crop in both soybeans and maize have proven that new improved genetics in biotech crops and the accompanying culture technologies were enough against soggy fields, late planting and bouts of early winter weather.

New biotech crops and traits were introduced in the US in 2019. This includes USDA commercialization approval for Argentina's HB4 drought tolerant soybeans, following the approvals in Argentina in 2018 and Brazil in 2019. Biotech cotton with low gossypol content event TAM66274 received a non-regulated status from USDA APHIS and an FDA approval in 2019, for commercialization and use for human food and animal feed within the USA. Another variety of apple, Arctic®Gala with non-browning trait was approved for commercialization in the US. The non-browning trait has also been successfully introduced to GreenVenus™ Romaine lettuce by the company Intrexon. The transgenic lettuce has improved shelf life of up to two weeks and has no tip burn. It has been assessed by the USDA and is not to be subjected to regulation under 7CFR Part 340 for plants altered or produced through genetic engineering. It is estimated to be commercialized in 2 years and could reduce the US$3.3 billion worth of loss due to lettuce waste.

Biotech crops that are in the pipeline and in field trials include rice with triple stacked traits for better yields amidst abiotic stresses, the biotech chestnut tree with resistance to chestnut blight, biotech citrus greening resistant citrus, and an upcoming potato enriched with beta carotene developed by Italian and American scientists, among others.

Animal biotechnology has also gained acceptance in the USA with biotech salmon that matures half the time compared to the non-biotech counterpart. AquaBounty, the US-based company that developed biotech salmon, sold some 4.5 tons of the GM fish in Canada since 2017 and has been given import and commercial approvals of salmon eggs from Canada by US FDA in 2019 (Salmon Business, 2018).

The US government continued its support to products of biotechnology in crops and animals. President Donald Trump signed a directive in 2019 to make it easier for genetically engineered plants and animals to enter the food supply and to simplify the "regulatory maze" for producers. This comes after USDA made a proposal on the principles of SECURE (Sustainable, Ecological, Consistent, Uniform, Responsible, and Efficient) to modernize biotechnology regulations. The directive is expected to facilitate innovation, ensure coordination across regulatory agencies, and safely enable billions of people across America and the world to reap the benefits of the products of agricultural biotechnology.

BRAZIL

Brazil planted the second largest area of biotech crops globally in 2019 at 52.8 million hectares compared to 51.3 million hectares in 2018, indicating a 3% increase or 1.56 million hectares. Brazil's biotech plantings represent 28% of the global biotech area of 190.4 million hectares. The biotech crops planted in the country include 35.1 million hectares soybeans, 16.3 million hectares maize (summer and winter), 1.4 million hectares cotton, and 18,000 hectares of sugarcane, at a remarkable 45-fold increase from the 400 hectares record when it was introduced for the first time in 2018. The total planted area of these four crops in Brazil was 56.16 million hectares, a 2.3% increase from 54.9 million hectares in 2018. The 52.8 million hectares biotech crop area is a 94% adoption rate, a 1% increase from 2018 (Figure 4).

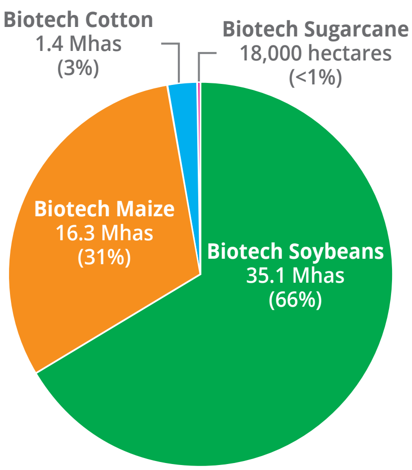


Figure 4. Biotech Crops Planted in Brazil, 2019

Source: ISAAA, 2019

Biotech soybean adoption rate was 96%

Biotech soybeans were planted on 35.1 million hectares at 96% adoption rate (similar in 2018), of the total 36.7 million hectares soybeans in 2019. The total and biotech soybean area increased marginally by 0.7% in 2019. The 35.1 million hectares of biotech soybeans was comprised of 38.3% (13.4 million hectares) HT and 61.7% (21.7 million hectares) stacked IR/HT. The stacked trait IR/HT (Intacta™), which was first introduced in 2013 on 2.2 million hectares, increased to 21.7 million hectares in 2019, compared to 20.2 million hectares in 2018, indicating an increase of 7%.

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. These 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).

In 2019, soybean event HB4 with drought tolerance and HB4 x GTS40-3-2 (glyphosate resistance) were approved for cultivation, and food and feed processing. This approval would motivate farmers to increase soybean cultivation during dry spells in the country, which is becoming more frequent with climate change.

Biotech maize adoption rate was ~91%

The total summer and winter maize planted in Brazil reached 17.94 million hectares in 2019, which indicates a slight increase of 4% (657,000 hectares) from 17.3 million hectares in 2018. Moreover, biotech maize adoption rate increased to ~91% (16.3 million hectares) from 89% at 15.4 million hectares in 2018. The 16.3 million hectares biotech maize was comprised of 3.8 million hectares IR, 565,000 hectares HT, and 11.95 million hectares IR/HT. The stacked trait maize increased by 16% equivalent to 1.65 million hectares (Table 6).

Sixteen biotech maize events were approved in 2019. These include stacked IR/HT events of MIR162 x MIR604 x TC1507 x 5307 x GA21 and intermediates, MIR162 x MON89034 x GA21 and intermediates, MON87427 x MON89034 x TC1507 x MON87411 x 59122 x DAS40278 and intermediates, and BT11 x MIR162 x MIR604 x TC1507 x 5307 and intermediates (ISAAA GM Approval Database). These contain pyramided insect resistance genes to control fall armyworm (*Spodoptera frugiperda*), corn ear worm (*Helicoverpa zea*), sugarcane borer (*Diatraea saccharalis*), and coleopteran insects.

Table 6. Total and Trait Hectares of Biotech Maize in Brazil, 2018-2019

	Area Planted (MHa)		% Trait Hectares	
	2018	**2019**	**2018**	**2019**
Total Maize	17.28	17.94		
IR	4.43	3.79	28.8%	23.2%
HT	0.65	0.56	4.2%	3.5%
IR/HT	10.30	11.95	67.0%	73.3%
Total Biotech Maize	**15.38**	**16.30**	**89.0%***	**91.0%***

* Adoption rate

Source: ISAAA, 2019

Deployment of these biotech maize events would contribute in the control of insect pests especially the fall army worm which has already affected some 600 million people globally, with damage of 80 million tons of maize worth US$180 billion per year in Asia and Africa, and (FAO, 2018).

Biotech cotton adoption increased to ~91%

The total cotton area in 2019 increased by 340,000 hectares from 1.2 million hectares in 2018 to 1.6 million hectares in 2019. The increased total cotton area contributed to the 38% increase of biotech cotton area from 1 million hectares in 2018 to 1.4 million hectares in 2019. The 1.4 million hectares of biotech cotton consisted of 8.7% IR (122,000 hectares), ~13% HT (183,000 hectares) and 78% IR/HT (1.11 million hectares). The adoption rate of biotech cotton increased to ~91% in 2019 (Table 7).

Three new cotton events were approved in 2019 for food, feed, and cultivation including events 281-24-236 x 3006-210-23 x COT102 x 81910 with glufosinate, 2,4-D and glyphosate tolerance plus resistance to lepidopterous insect pests, GHB811 (tolerant to isoxaflutole herbicide), and GHB811 x T304-40 x GHB119 x COT102 (stacked IR/HT [pyramided isoxaflutole and glufosinate herbicides]) (ISAAA GM Approval Database).

Biotech insect resistant sugarcane area increased by 44%

Insect resistant sugarcane CTC93209-4 was introduced in 2018 by some 100 sugar mills in Brazil. The biotech sugarcane variety was developed by Centro de Technologica Canavieira (CTC). The National Biosafety Technical Commission approved Bt sugarcane after proving that the sugar and ethanol obtained from it are identical to the conventional sugarcane. The biotech sugarcane is one of the best solutions to the cane borer which causes US$1.5 billion worth of losses and insecticide expenses annually. It also boasts projected yield increase, reduction of production cost and increased profit. The first planting of Bt sugarcane was conducted on 400 hectares which increased to an estimated 18,000 hectares in 2019. Studies 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 7. Total and Trait Hectares of Biotech Cotton in Brazil, 2018-2019

	Area Planted (MHa)		% Trait Hectares	
	2018	2019	2018	2019
Total Cotton	1.22	1.56		
IR	0.10	0.12	9.6%	8.7%
HT	0.17	0.18	16.9%	~13.0%
IR/HT	0.75	1.11	73.6%	78.3%
Total Biotech Cotton	**1.02**	**1.41**	**84.1%***	**90.5%***

* Adoption rate

Source: ISAAA, 2019

Benefits of Biotech Crops

Brazilian farmers planting soybeans, maize, and cotton started adopting biotech crops in 2003, or 15 years ago. Brookes and Barfoot (2020) estimated that benefits from biotech crops covering 2003 to 2018 in Brazil was US$26.6 billion, and US$3.4 billion in 2018 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, the benefits for farmers resulting from planting biotech soybeans, maize, and cotton were evident. There have been a reduction in the application of pesticides per hectare and fewer losses caused by pests. Consequently, the productivity and yield of the biotech crop have been, on average, higher than conventional crops. These findings are reported in the 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, September 5, 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," says executive-director of the CIB, Adriana Brondani.

Summary and Future Prospects

Brazil maintains its standing as the second country, after the USA, with the largest biotech crop area planted in 2019. The 52.8 million hectares biotech crops include 35.1 million hectares soybeans, 16.3 million hectares maize, 1.4 million hectares cotton, and some 18,000 hectares insect tolerant sugarcane. Brazil's 2019 biotech area had an increase of ~1.6 million hectares or 3% from 2018, at an adoption rate of 94% (1% higher than 2018).

The country has built the necessary enabling environment and machinery for farmers and consumers for research, development, and commercialization of biotech crops. According to Tereza Cristina Corrêa Da Costa Dias, Minister of Agriculture, Livestock and Food Supply, Brazil is dedicating 2,400 scientists for research and development of GM crops. Early in the year, Brazil's CTNBio approved the commercialization of drought tolerant HB4 soybeans developed by Tropical Melhoramento & Genetica and Verdeca. In addition, a soybean stacked event with HB4 and herbicide tolerance traits was also approved. The company revealed through personal communications that the soybean lines are under field trials and the commercial launch is contingent upon approvals by the main soybean grain importing countries, such as the variety registration process. The trait has been approved in Argentina, USA, China, Paraguay, Bolivia, and Uruguay (Crop Biotech Update, May 29, 2019).

The most complete genome sequence of commercial sugarcane has also been released by an international group of researchers led by scientists from Brazil's Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP). The group sequenced the variety SP80-3280, one of the top 20 sugarcane varieties grown in São Paulo and uncovered 373,869 genes, equivalent to 99.1% of the total genome. Researchers from the University of São Paulo (USP) are now developing tools for the genetic improvement of sugarcane and testing several candidate genes in genetically modified (GM) plants. They are also conducting comparative genomic studies on large gene families with the aim of understanding their contributions to the sugarcane varieties used in Brazilian genetic improvement programs. The researchers hope to find genes that can help increase yields, enhance drought resistance, and contribute to the development of novel compounds from sugarcane (Crop Biotech Update, December 4, 2019).

Brazil is looking forward to more cultivation of other biotech crops such as tomato, carrot, and other important vegetables, which are under research and development in the country. The country has the readiness to cooperate with Gulf States on GM food research and development, as well as other agricultural innovations.

To systematize the process for GM authorization, a resolution was made in force in January 2020 to update the rules regarding the authorization and commercial launch of genetically modified organisms (GMOs) by the National Technical Biosafety Commission of Brazil (CNTBIo). The resolution has made the process more flexible and does not weaken food safety in Brazil, according to an industry regulatory officer. More specifically, the procedures were streamlined for more lengthy but accurate decisions by CNTBIo. This will allow applicants to submit any additional information on new data to ensure that application complies with the new conditions (Food Navigator, 2020).

ARGENTINA

Argentina ranked third in the top ten countries planting biotech crops in 2019. A total of ~24 (23.99) million hectares were planted in 2019, 13% of the global total of 190.4 million hectares and at close to 100% adoption rate. The biotech crop area was comprised of 17.5 million hectares soybeans, 5.9 million hectares maize, 485,000 hectares cotton, and more than 1,000 hectares of biotech alfalfa planted for the first time (Figure 5). The 24 million hectares is an increase of 110,000 hectares or 0.5% from 23.88 million hectares planted in 2018.

Biotech soybean IR/HT stacked Intacta™ declined slightly

Soybeans were planted on 17.53 million hectares in 2019, and similar to 2018, soybeans grown in the country was close to 100% biotech, 77% of which or 13.52 million hectares were herbicide tolerant and 23% or 4.01 million

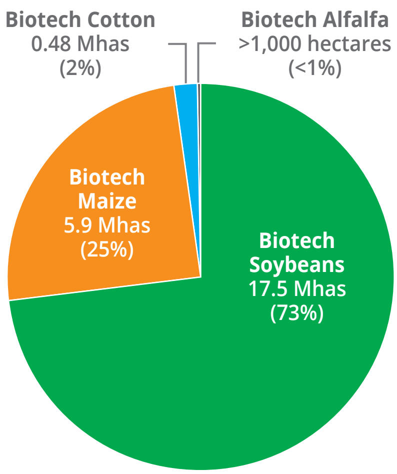


Figure 5. Biotech Crops Planted in Argentina, 2019

Source: ISAAA, 2019

hectares were stacked IR/HT (Table 5). Soybean stacked trait Intacta™ introduced to farmers in 2015 was launched on 70,000 hectares, had a slight decrease in 2019 compared to 2018 - an indication of farmers adopting a technology that reduces costs and profits. A severe drought during the peak summer months reduced the area planted to biotech soybeans and resulted to the importation of US soybeans to Argentina for the first time in decades.

Among the events approved in 2019 is a soybean event, DBN 09004-6, the first Chinese-developed soybean event developed and field-tested under a joint venture with an Argentine company. The soybean event has tolerance to glyphosate and glufosinate-ammonium herbicides.

Biotech maize increased by 8.5% in 2019

The total maize area in 2019 increased by 12% from 5.7 million hectares in 2018 to 6.4 million hectares. The biotech maize area of 5.98 million hectares was an increase of 8.6% from 2018 and was comprised of 598,000 hectares HT and ~5.4 million hectares stacked IR/HT. Compared to 2018, maize with stacked traits increased by 8.9% from 4.9 million hectares to 5.38 million hectares in 2019. The adoption rate of biotech maize reduced slightly to 93% (Table 8).

Argentine farmers have been using stacked maize events for ten years. In 2019, Argentina approved six new stacked IR/HT maize events:

1. DOW Argentina, MON-89O34-3 x DAS-O15O7 x MON OO603 x 6 x DAS-4O278-9 tolerance to herbicides formulated based on products of the family of aryloxiphenoxy and 2,4,-D, ammonium glufosinate and glyphosate, and resistance to Lepidopteran insects
2. MONSANTO + DOW +PIONEER Argentina, MON-89O34-3 x DAS-O1507-1 x MON-88O17-3 x DAS-59122-7 tolerance to glyphosate and glufosinate. resistance to Lepidopteran insects
3. MONSANTO ARGENTINA MON-87427 x MON-89034-3 x DASO15O7-1 x MON-88017-3 x DAS- 59122-7 tolerance to ammonium gluphosinate, glyphosate and resistance to Lepidopteran insects
4. MONSANTO ARGENTINA.MON-87427-7 x MON-89034-3 X MON00603-6 tolerance to ammonium gluphosinate, glyphosate and resistance to Lepidopteran insects
5. MONSANTO ARGENTINA. MON-87427-7 x MON 89034-3 x SYN-IR162-4 x MON-OO603-6 tolerance to ammonium glufosinate, glyphosate and resistance to Lepidopteran insects
6. MON87427 x MON89034 x MIR162 x NK603 tolerance to glyphosate and Lepidopteran insects

Biotech cotton adoption rate was 100%

The total cotton area in Argentina increased by 21% from 400,000 hectares in 2018 to 485,000 in 2019. Adoption rate, however, was 100%, and all are stacked IR/HT traits. The country stopped planting HT cotton in 2017 and IR (Bt) cotton was not planted since 2015.

Table 8. Total and Trait Hectares of Biotech Soybeans in Argentina, 2018-2019

	Area Planted (MHa)		% Trait Hectares	
	2018	**2019**	**2018**	**2019**
Total Soybeans	18.00	18.00		
HT	13.68	13.52	78.0%	77.0%
IR/HT	4.32	4.01	24.0%	23.0%
Total Biotech Soybeans	**18.00**	**17.5**	**100.0%***	**100.0%***

* Adoption rate

Source: ISAAA, 2019

Table 9. Total and Trait Hectares of Biotech Maize in Argentina, 2018-2019

	Area Planted (MHa)		% Trait Hectares	
	2018	**2019**	**2018**	**2019**
Total Maize	5.70	6.40		
IR	0.04	0.00	1%	
HT	0.53	0.59	9%	10%
IR/HT	4.94	5.38	90%	90%
Total Biotech Maize	**5.51**	**5.98**	**97%***	**93%***

* Adoption rate

Source: ISAAA, 2019

In the 2018/19 crop season, the total cotton area was planted with the stacked event (IR/HT). As there is new investment in cotton production after several years without any approvals in cotton, two new traits were approved during 2019:

1. BASF. BCS-GH811-4 Glyphosate tolerance and herbicide inhibitors of HPPD
2. BASF. SYN-IR1O2-7 and BCS-GHOO2-5 x BCS-GHOO4-7 x BCS-GHOO5-8 x SYN-IR1O2-7 the stacked BCS-GHOO4-7 and BCS-GHOO5-8 tolerance to ammonium gluphosinate glyphosate and resistance to lepidoptera.

Biotech alfalfa planted for the first time

It is notable that in 2019, Argentina planted 1,000 hectares of the stacked traits low lignin and herbicide tolerant alfalfa in the Pampa region of the country. The stacked herbicide tolerant and low lignin event MON 179-5 x MON 101-8, and single traits MON 179-5 (HarvXtra™) and MON 101-8 (RR™) were approved for commercialization/propagation in Argentina in 2018. Alfalfa is the most important forage crop in Argentina, where about 4.7 million hectares are grown. Alfalfa is mostly utilized for direct grazing for both beef and dairy production. The demand for more resilient HT alfalfa prompted some farmers to plant unapproved two HT gene pyramided events (one HT event unapproved), estimated at 10,000 hectares (not included in the total biotech area for Argentina). As Argentina is a large exporter of beef and dairy, the area of biotech alfalfa has a potential to expand in the very near future.

Benefits of Biotech Crops

Recent data on the economic benefits from biotech crops by Brookes and Barfoot (2018) estimates that Argentina has enhanced farm income from biotech crops by US$28.1 billion in 23 years of commercialization (1996-2018), and the benefits for 2018 alone are estimated at US$2.4 billion. This is a huge economic benefit for the 130,000 farmers, their families and their communities.

Summary and Future Prospects

A minimal increase of 110,000 hectares of biotech crops were planted in Argentina in 2019, from 23.8 million hectares in 2018 which is 13% of the global total of 190.4 million hectares. The biotech crop area consisted of 17.5 million hectares soybean, 5.9 million hectares maize, 485,000 hectares cotton, and more than 1,000 hectares of biotech alfalfa, at an average adoption rate of close to 100%.

The Argentinian government through the Argentine National Advisory Committee on Agricultural Biotechnology (CONABIA) approved eight biotech applications in 2019: six maize events, two cotton events and one soybean event. 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. A wheat event containing the HB4 gene that confers drought resistance received full technical approval but awaits commercial approval by the National Direction of Agricultural Food Markets (DNMA) under the Ministry of Agro-Industry. The HB4 wheat was developed by the Instituto Agrobiotecnologico Rosario (INDEAR) and has increased yield by 30% under extremely dry conditions. The HB4 gene was originally isolated from sunflower but has been introduced to wheat, soybeans, and maize. Soybeans with the HB4 gene are currently being field-tested in both Argentina and the United States. In the United States, this testing is being conducted as part of a joint venture between INDEAR and Arcadia AgroSciences.

Among the crops in the pipeline are GM potato with resistance to virus Y called SPT TICAR. This new biotech potato variety is expected to provide potato farmers with 10% cost savings, reduction in the use of insecticides, and general improvement of competitiveness across the value chain. Potato virus Y is a common disease problem of potato farmers in all production zones around the country. Development of TICAR biotech potato started 20 years ago by the National Council of Technical and Scientific Research (CONICET), in partnership with Sidus. The developers are currently working on potato varieties with drought tolerance and other virus resistance traits. TICAR potato is expected to be commercially available in Argentina in 2020. CONICET commenced with the registration of the biotech potato variety in Argentina to the National Seed Institute (Crop Biotech Update, October 23, 2019).

Argentinian scientists have developed a transgenic cotton resistant to the cotton boll weevil through gene silencing, minimizing the damage caused by the pest and allowing cotton plants to thrive. Cotton boll weevil (*Anthonomus grandis*) has plagued Argentina's cotton industry for years, causing significant losses during cotton production. The National Institute of Agricultural Technology (INTA) developed transgenic cotton resistant to the pest through RNA interference strategy, wherein a small sequence of the RNA in the cotton plant was taken to block the function of a specific gene in the boll weevil to decrease its ability to cause damage. The researchers then developed an adjusted transformation system using the gene of interest to make the trait more stable. When the cotton weevil eats the floral buds of the transgenic plant, the buds are expected to interfere with the pest's cellular metabolism. In case the pest does not die from eating the buds, it is expected that the pest's reproductive capacity will decrease leading to the control of the pest population. Both outcomes will still be beneficial to Argentina's cotton industry (Crop Biotech Update July 24, 2019).

CANADA

Canada planted a total of 12.46 million hectares of six biotech crops in 2019, showing a ~2% decrease from 12.75 million hectares in 2018. The 12.46 million hectares is 7% of the global biotech crop area (190.4 million hectares) and is comprised of 2.1 million hectares soybeans, 1.6 million hectares maize, 8.8 million hectares canola, 19,000 hectares sugar beets, 4,200 hectares alfalfa, and 40.5 hectares potatoes (Figure 6). Except for potatoes, the major biotech crops planted had an average adoption rate of 90%, with a 2% decrease from 2018.

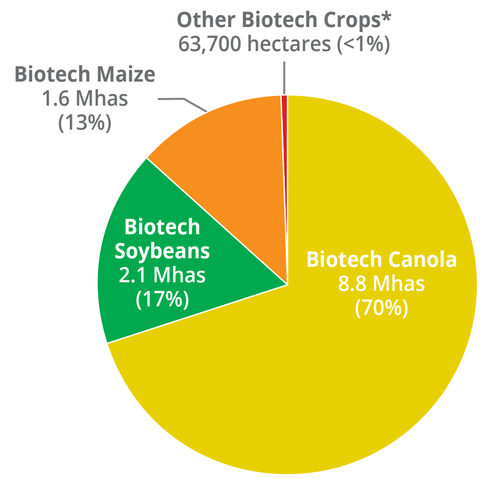


Figure 6. Biotech Crops Planted in Canada, 2019

* Biotech sugar beets, biotech alfalfa, and biotech potatoes

Source: ISAAA, 2019

From 1996 to 2018, some 50,000 farmers and their families have been benefiting from enhanced farm income from biotech canola, maize, soybeans, cotton, and sugar beets by US$9.7 billion and the economic benefits for 2018 alone is estimated at US$865.3 million (Brookes and Barfoot, 2020).

Biotech canola maintained at 95% adoption rate

Total canola was planted on 9.23 million hectares in Canada, 95% (8.77 million hectares) herbicide tolerant canola. Both the area planted to total and biotech canola marginally increased by less than 1% in 2019: total canola increased from 9.20 million hectares to 9.23 million hectares and biotech canola from 8.74 million hectares to 8.77 million hectares.

In 2019, Monsanto commercialized TruFlex™ canola, a new canola trait with Roundup Ready® technology. TruFlex™ was seeded in Canada for the first time at 404,000 hectares.

Biotech soybean area decreased by 16%

Soybeans are the next important crop in Canada planted on 2.5 million hectares, 82% (2.1 million hectares) of which were herbicide tolerant. The total soybean area in 2019 decreased by 1.4% or 36,000 hectares, from 2.56 million hectares to 2.52 million hectares. Biotech soybean area decreased by 16% from 2.42 million hectares to 2.1 million hectares in 2019. Adoption rate decreased from 95% in 2018 to 82% in 2019.

The drop in the soybean area was a result of the farmers' apprehension of low yield due to dry weather and relatively attractive wheat prices. Thus, the farmers shifted to planting more wheat. Moreover, the soybean prices went down during the growing season. Soybeans have been planted in Manitoba, Saskatchewan, and Ontario, and much of the reductions were in the first two areas.

Two varieties of high oleic soybeans are approved in Canada: Corteva's (DowDupont) Plenish soybeans and Monsanto's Vistive Gold soybeans. Both are approved for unconfined environmental release in Canada as well as in China, which is the main export market after the European Union.

Biotech maize area adoption rate maintained at 90%

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 2019, the adoption rate of biotech maize reached 90% at 1.6 million hectares, wherein 155,000 hectares (10%) was planted with HT maize and 1.4 million hectares (90%) was planted with stacked IR/HT (Table 10). There was no insect resistant maize planted in 2019. Biotech maize in Canada are planted in Manitoba, Ontario, and Quebec.

Other biotech crops planted in Canada

The area planted to biotech sugar beets increased in 2019 to 19,000 hectares compared to 15,000 hectares in 2018, 100% of which is herbicide tolerant. Sugar beets growing regions in Canada include Ontario in Eastern Canada and Taber, Alberta in Western Canada. Expansion of the sugar beets planting area depends on sugar demand, new available technologies, and favorable weather.

A total of 4,500 hectares of biotech alfalfa were planted in Canada in 2019, composed of 4,200 hectares HarvXtra™ alfalfa and 300 hectares HT alfalfa which was planted for the first time in Canada. This is an increase of 7% from 4,200 hectares in 2018 of purely HarvXtra™ alfalfa. Canadian farmers started planting biotech alfalfa in 2016 at 809 hectares. Farmers' 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.

Table 10. Total and Trait Hectares of Biotech Maize in Canada, 2018-2019

	Area Planted (MHa)		% Trait Hectares	
	2018	**2019**	**2018**	**2019**
Total Maize	1.784	1.791		
IR				
HT	0.27	0.155	17%	10%
IR/HT	1.30	1.439	83%	90%
Total Biotech Maize	**1.57**	**1.594**	**88%***	**89%***

* Adoption rate

Source: ISAAA, 2019

Innate® potato has received approvals in Canada. These include Generation 1 Cultivate and Accelerate varieties with reduced black spots, bruising, and acrylamide formation when cooked; and Generation 2 Acclimate, Hibernate, and Elevate varieties which have Generation 2 traits as well as lowered reducing sugars and late blight disease protection. Some 40.5 hectares of Generation 2 Hibernate potatoes were planted in 2019. These are processed in Canada but sold in the US.

Benefits of Biotech Crops

Canada is estimated to have enhanced farm income from biotech canola, maize, soybeans, cotton, and sugar beets by US$9.7 billion in the period 1996 to 2018 and the benefits for 2018 alone is estimated at US$865.3 million (Brookes and Barfoot, 2020).

Summary and Future Prospects

Biotech crop area in Canada declined slightly in 2019 by ~2% from 12.75 million hectares in 2018 to 12.46 million hectares due to reduction in planted areas of total and biotech soybeans. The decrease in soybean area was due to the unstable weather conditions during the planting season. Biotech maize, canola, and alfalfa areas had marginal increases, while sugar beets reached its highest increase of 23%. Innate® potato was planted on 40 hectares only in 2019. The average adoption rate of 90% for principal crops (except potato) in 2019 was a decrease of 2% from 2018.

New and upcoming biotech crops and events in Canada include a) Roundup Ready® tolerant Truflex™ canola by Monsanto which was launched in 404,000 hectares and b) approval of two varieties of high oleic acid soybeans: Corteva's Plenish soybeans and Monsanto's Vistive Gold soybeans.

Biotech Golden Rice with provitamin A Event GR2E has been given approval from Health Canada in 2019. This decision coincides with the approval from Food Standards Australia New Zealand (FSANZ) in 2017. The Canadian Food Inspection Agency (CFIA) and Health Canada (HC) approved the use for feedstock of one Bayer CropScience cotton product.

Development of high oleic acid and high linoleic varieties will continue to impact the balance between canola, soybeans, and sunflower within the oilseed industry. Price premiums for high oleic soybeans have not been favorable in the current or previous marketing year, and area planted continues to be less than high oleic canola. Greater production of high oleic soybeans would be needed before Canadian crushing facilities would have a strong incentive to crush high oleic beans. High oleic soybean varieties are shipped to the United States for crushing. High linoleic oil in soybeans on the other hand is being developed to fill the current deficit in linoleic oils.

The Canola Council of Canada in its 2018-2023 plan prioritizes improvements in disease resistance, plant fertility and integrated pest management. Other areas of focus include the evaluation of new antibacterial technologies for canola meal as well as high oleic canola oil. Canadian canola oil production is expected to increase over the longer term in Canada, especially as the Comprehensive and Progressive Trans-Pacific Partnership (CPTPP) trade agreement brings down tariff rates in key markets like Japan and Vietnam.

Aside from biotech crops, public acceptance of biotech animals in Canada has also been exemplary. A land-based facility in Prince Edward Island, Canada produces sterile, pressure-shocked female AquaAdvantage Salmon eggs. Then the eggs are transferred to a grow-out facility in the same island and exported to a land-based, grow-out facility in Albany, Indiana, USA. AquaBounty's salmon contains genetic material from ocean pout and Chinook salmon to help it reach the adult stage two times faster than the wild type. The first commercial harvests for distribution to customers from both the Canadian and American facilities are scheduled to occur in the second half of 2020. Production of AquaAdvantage Salmon in the Canadian facility is projected at 250 MT and in the US facility at 1,200 MT annually.

All these indicate the Canadian government's support to farmers and consumers by providing an enabling and efficient regulatory system. Expansion of biotech crop adoption in Canada is therefore expected with the increasing global demand for food, feed, and feedstocks for ethanol and biodiesel, strong research and development in the country, excellent public acceptance of the technology, and the exemplary support of the government for biotech crops.

INDIA

The biotech cotton area in India increased once again by 313,000 hectares, 3% increase from 2018 at 11.6 million hectares to 11.9 million hectares in 2019. Of the total cotton area of 12.24 million hectares, adoption rate was recorded at 94%, marginally lower than that in 2018.

Record shows (Figure 7) that the adoption of Bt cotton in India has been increasing and nearing saturation, making India the number one cotton producing country in the world, and the second largest exporter of cotton. Estimates for the 2019 growing season yielded 26.5 million bales from a total cotton area of 12.7 million hectares.

The government of India has approved five cotton events and more than 1,400 hybrids for cultivation in various agro-climatic zones for fiber, food, and feed. Some small quantities of cotton were imported (1.8 million bales in 2018/19) to augment the quality requirement by the local textile industry. There are selected biotech food products authorized for import into India that includes soybean oil derived from GM soybeans and canola oil from GM canola. The imported soybean oil in 2018 was obtained from Argentina (1.99 MMT), Brazil (0.7 MMT), and Paraguay (0.2 MMT), and small quantities of canola from Canada.

Research and development on crop improvement through biotechnology have been conducted in India. Among these are the drought tolerant and disease resistant chickpeas, salt tolerant rice variety, and transgenic tomatoes with resistance to root knot nematode, among others.

Socioeconomic Benefits and Impact of IR cotton in India

The summary and key findings of fourteen studies conducted by public institutes on cost-benefits of IR cotton were included in previous briefs, ISAAA Brief 26 to 53 released from 2002 to 2017. Moreover, estimates by Brookes and Barfoot (2020) indicate that India has enhanced farm income from IR cotton by US$24.3 billion in the 17-year period 2002 to 2018 and US$1.5 billion in 2018 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

The IR (Bt) cotton adoption rate in India has almost stabilized in the past five years at more or less 95%. The 94% adoption rate in 2019 by more than 6 million farmers reflects the continuing confidence of the farmers and the benefits they obtain from the technology. Thus, they are in need of other biotech crops that will provide them profit and improvement in their status of living. This encouraged some farmer groups to plant unauthorized stacked trait IR(Bt)/HT cotton

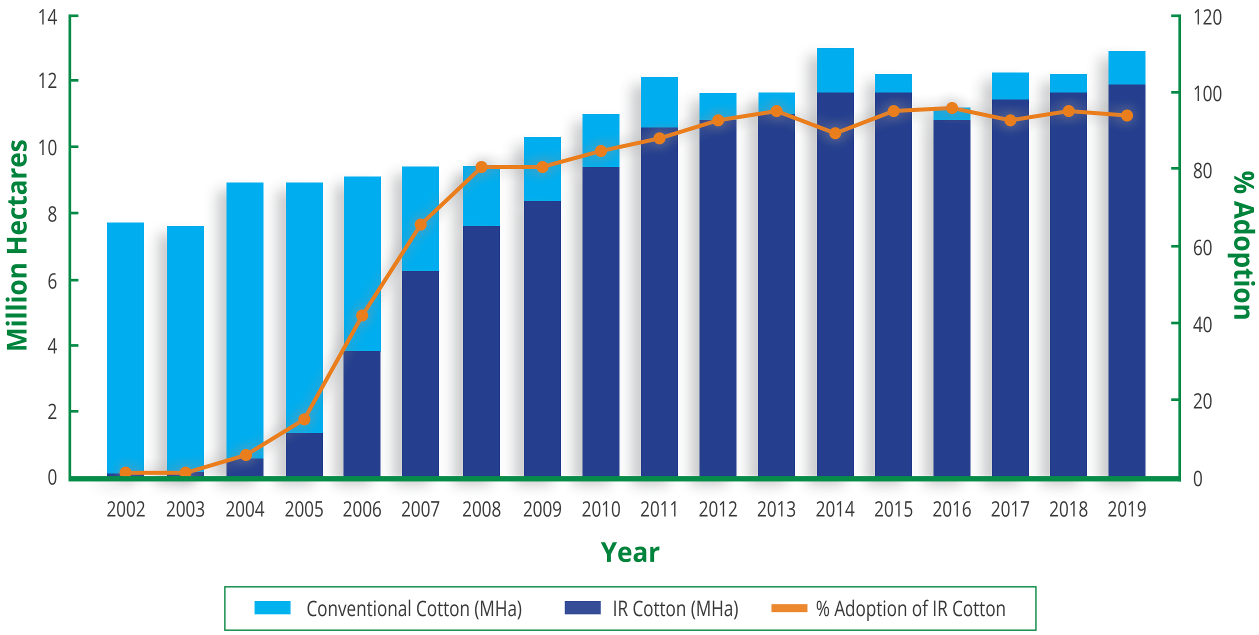


Figure 7. Eighteen Years of Adoption of IR (Bt) Cotton in India, 2002 to 2019

Source: Analyzed and Compiled by South Asia Biotechnology Centre and ISAAA, 2019

in major cotton growing areas in Central and Southern zones in Kharif 2017.

After over a thousand farmers conducted a protest in Maharashtra by planting IR (Bt) brinjal and herbicide tolerant (HT) cotton seeds, which are not yet approved in the country, a farmer organization known as Shetkari Sangathana collected support from peasants to seek free access to biotech seeds, particularly to use herbicide tolerant seeds. However, concerns on the use of glyphosate herbicide, which is used in HT seeds were raised by experts. According to the former director of Central Institute of Cotton Research and head of the technical section of the International Cotton Advisory Council in the U.S., Keshav Sranthi, even if the HT seeds would be allowed in India, glyphosate is only recommended for use in teal plantations and barren land. There are currently 12 glyphosate tolerant cotton events approved for planting in other countries.

Another group of female farmers also joined the protest by planting unapproved biotech cotton with herbicide tolerance and insect tolerance traits at Pusada village in Amravati district. This act also aimed at calling the attention of the government to allow the farmers to plant HT cotton seeds, which help farmers save time and resources for manual weeding (Crop Biotech Update, June 26, 2019).

Similar non-violent protests against government regulations on GM crops were also conducted in Haryana by Bt eggplant farmers despite a national moratorium imposed by the central government in 2010. The Bt brinjal farms in Haryana were destroyed by authorities. During the protest, the farmers demanded the government to compensate the farmers in Haryana and declared that they are currently raising funds to give assistance to the farmers affected by the incident. In the beginning of 2020, biotech critics raised their efforts to stop genetically improved seeds into the nation's Supreme Courts (Crop Biotech Update, January 16, 2020).

In 2018-19, the dispute between Monsanto and Indian seed company Nuziveedu on intellectual property rights of patented biotech innovation rattled 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 8th January 2019 which ruled that the Monsanto patent on novel nucleotide sequence of IR cotton is valid and overturned the earlier decision of 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 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).

Notwithstanding numerous policy initiatives, the Government of India has not made much progress on the commercialization of home-grown GM mustard developed by the Centre for Genetic Manipulation of Crop Plants (CGMCP) of the University of Delhi. In 2018, the Genetic Engineering Appraisal Committee (GEAC) of the Ministry of Environment, Forests & Climate Change (MOEF&CC) 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 the 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).

In July 2018, India reported the infestation of invasive pest fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Insecta: *Lepidoptera*), in maize fields in Karnataka state. 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). Several initiatives were led by the South Asia Biotechnology Centre (SABC), in collaboration with the University of Agriculture and Horticulture Sciences (UAHS), to conduct a mega campaign on fall armyworm provided farmers, dealers, and retailers with information and control measures to contain the pest (Crop Biotech Update, June 13, 2019).

PARAGUAY

Since 2004, Paraguay has been planting biotech soybeans, maize, and cotton. In 2019, 4.1 million hectares has been planted to these biotech crops, with an increase of 9% from 3.8 million hectares in 2018. The 4.1 million hectares of biotech crops comprised of 3.6 million hectares soybeans, 518,000 hectares maize, and 18,000 hectares cotton, with an average adoption rate of 92%, 2% higher than 2018 (Figure 8).

Some 10,000 farmers have benefited from adopting biotech soybeans, maize, and cotton since 2004 to 2018 with economic benefits of US$2.3 billion. The benefits for 2018 alone were

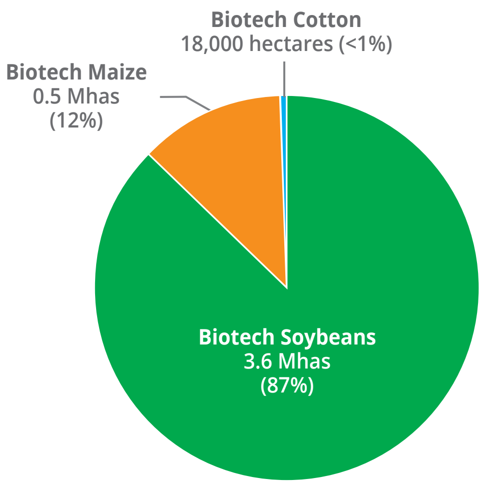


Figure 8. Biotech Crops Planted in Paraguay, 2019

Source: ISAAA, 2019

estimated at US$310.9 million (Brookes and Barfoot, 2020). The insurmountable year-on-year increases of economic benefits accrue to farmers, their families, and the whole community.

Biotech HT soybean area increased by 21% in 2019

Paraguay has planted biotech soybeans in the last 15 years. In 2019, 3.57 million hectares were planted to soybeans and 99% of which or 3.56 million hectares were biotech, with 2.04 million hectares HR and 1.52 million hectares IR/HT stacked traits. The area of HT soybeans increased by 21% in 2019 from 1.68 to 2.04 million hectares, and the area of IR/HT stacked traits decreased by 9% from 1.68 million hectares. The biotech soybean area increased by 6% in 2019 (Table 11).

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 the fact 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 90% of all biotech maize

Biotech maize area increased by 32% in 2019 from 392,000 hectares in 2018 to 518,000 hectares, with an adoption rate of 76%, an increase of 24% from 2018. The 518,000 hectares comprised of 47,000 hectares HT and 471,000 hectares IR/HT stacked traits (Table 12). The area planted to stacked IR/HT traits increased by 50% and was 91% of the biotech maize planted. HT maize area declined by 30% and was 9% of the biotech maize planted, while IR maize was not planted in 2019.

Biotech cotton maintains area and adoption rate at 100%

Similar to 2019, biotech cotton was planted on 18,000 hectares, an 80% increase from 2018 and maintained its 100% adoption rate.

Benefits from Biotech Crops

Paraguay is estimated to have enhanced farm income from biotech soybeans, maize, and cotton by US$2.3 billion planted from 2004 to 2018. The benefits for 2018 alone are estimated at US$311 million (Brookes and Barfoot, 2020).

Summary and Future Prospects

The biotech crop area in Paraguay increased by 9% with increases in area planted to biotech cotton (80%), biotech maize (32%) and soybeans (9%). Thus, biotech adoption rate for 2019 increased to 92% in 2019.

Table 11. Total and Trait Hectares of Biotech Soybeans in Paraguay, 2018-2019

	Area Planted (MHa)		% Trait Hectares	
	2018	2019	2018	2019
Total Soybean	3.40	3.57		
HT	1.68	2.04	50%	57%
IR/HT	1.68	1.52	50%	43%
Total Biotech Soybeans	**3.35**	**3.56**	**99%***	**99%***

* Adoption rate

Source: ISAAA, 2019

Table 12. Total and Trait Hectares of Biotech Maize in Paraguay, 2018-2019

	Area Planted (MHa)		% Trait Hectares	
	2018	2019	2018	2019
Total Maize	0.68	0.68		
IR	0.01	0.00	2.3%	0
HT	0.07	0.05	17.3%	–31%
IR/HT	0.32	0.47	80.4%	50%
Total Biotech Maize	**0.39**	**0.52**	**52.0%***	**73.0%***

* Adoption rate

Source: ISAAA, 2019

The environment for biotech research and biotech adoption including financing and price incentives for soybeans and maize motivated the farmers to plant more. In 2019, The Paraguayan Minister of Agriculture, through the National Commission for Agricultural and Forestry Biosafety, has granted approval to Verdeca's HB4 drought and herbicide tolerant soybeans. The HB4 stack is Verdeca's newest product release from its pipeline of traits developed to benefit soybean producers through quality improvement, stress mitigation, and management practices. With this new approval, the HB4 trait now has regulatory approval in more than 80 percent of the global soybean market. The HB4 trait has already been approved in the US, Argentina, and Brazil, with regulatory submissions currently under consideration by China. Import approval from China is needed for commercial launch in Argentina and is expected in late 2020 (Crop Biotech Update, November 20, 2019).

CHINA

China has been one of the leaders in planting biotech crops since 1997. In 2019, two biotech crops were planted with a total of 3.18 million hectares, indicating an 8% increase from 2018 (2.9 million hectares). The two biotech crops planted in China in 2019 were insect resistant cotton (3.17 million hectares) and virus resistant papaya (12,000 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 3.3 million hectares. The total cotton area in 2019 reached 3.3 million hectares, which is an 8% increase from 3.1 million hectares in 2018. The 95% adoption rate of biotech cotton was similar to 2018. 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 14,200 hectares, which is a 15% increase from 12,300 hectares in 2018. Some 12,125 hectares were planted to papaya ringspot virus (PRSV)-resistant papaya, indicating an adoption rate of 85% (Table 13). The increase in area planted to biotech papaya as well as the adoption rate was due to the addition of Fujian province which planted 800 hectares which is 100% biotech. Five Chinese provinces planted biotech papaya in 2019 including Guangdong, Hainan Island, Guangxi, Yunnan, and Fujian (Table 13).

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. It is estimated that China had enhanced farm income from biotech cotton by US$23.2 billion from 1997 to 2018 and by US$1.5 billion in 2018 alone (Brookes and Barfoot, 2020).

Summary and Future Prospects

China's biotech crop area planted to insect resistant cotton and virus resistant papaya have expanded in 2019 and is expected to increase with the local and international demand for quality cotton and disease-free papaya. The 8% increase in biotech crops, equivalent to 245,000 hectares reflects the continuous benefits and ease in producing cotton and papaya using the technology. 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.

Table 13. Area of Biotech Papaya Planted in China, 2019 (Hectares)

Location	Total Papaya Area	Biotech Papaya Area	% Adoption
Guangdong Province	5,300	5,035	95%
Hainan Island	4,500	4,050	90%
Guangxi Province	2,000	1,600	80%
Yunnan Province	1,600	640	40%
Fujian Province	800	800	100%
Total	**14,200**	**12,125**	**85%**

Source: (Li, Huaping, personal communication, 2019).

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 soluble (DDGs) and sugar beet pulp for feed and processing, trade has been affected because of China's slow and unpredictable approval process. 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 costed 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. These findings confirm the fears farmers have carried for years: restrictions in technology have a direct, negative and significant impact on their bottom line. Industry groups and some US policymakers have been proactive in encouraging the Trump administration to press China to make more transparent and timely regulations for approval of GM crops (Crop Biotech Update, April 17, 2019).

In the beginning of 2019, five biotech crops were approved for import by China, the first after 2017. The Ministry of Agriculture and Rural Affairs approved RF3 canola (Bayer/BASF), MON 88302 canola (Monsanto/Bayer), DP4114 maize (DuPont Pioneer) SYHTOH2 soybeans (Syngenta) and DAS 44406-6 (Dow AgroSciences). The new GM crop event approvals were released after Chinese and U.S. officials had a meeting in Beijing on January 7, 2019 for the first face-to-face talks since U.S. President Donald Trump and Chinese President Xi Jinping agreed in December 2018 to a 90-day truce in a trade war that has affected global markets. The Agriculture Ministry also extended the import approvals for 26 other GM crops by three more years (Crop Biotech Update, January 9, 2019).

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 led to a safe and stable food supply, improved consumer choice, and lower food prices in some areas.

At the close of the year, China approved two new genetically modified crops for import that could boost agricultural purchases from the US including Corteva Agriscience's stacked IR/HT DAS-81419-2 soybeans and PRSV-R 55-1 papaya jointly developed by the USDA and Hawaii University. The approval was a result of the US-China trade talks that emphasized the need for a more transparent and efficient process of approvals. China is a top importer of biotech soybean and canola while the US is the world's top producer. China also renewed permission for imports of 10 other GM products, including BASF developed T25 maize, A5547-127 soybean, T45 canola, Oxy-235 canola, and Ms8Rf3 canola. Bayer-owned Monsanto Far East Ltd's MON89788 soybean, 15985 cotton, and H7-1 beet were also reapproved, along with DuPont subsidiary Pioneer's 305423 soybean and 305423×GTS40-3-2 soybean. All approvals took effect from December 2, 2019 and will last for three years, according to a statement on the agriculture ministry's website (Crop Biotech Update, January 6, 2020).

SOUTH AFRICA

The year 2019 marked South Africa's 22 years of commercial cultivation of biotech crops, planting a total of 2.68 million hectares on the three principal biotech crops: cotton, maize, and soybeans. This was a slight decrease of 2% from 2018 that recorded 2.74 million. The estimated acreage per biotech crop consisted of maize (1.9 million hectares), soybeans (693,975 hectares) and cotton (43,654) (Figure 9). Average biotech crop adoption stood at 84.6% for maize, 95% soybeans and cotton at 100%. The white and yellow total maize hectares for the 2018/19 season (maize planted in 2018 and harvested in 2019) were rather similar to the previous season. For soybeans, it is estimated that 95% of the 730,500 hectares was biotech, hence 693,975 hectares. In cotton the 2018/19 crop year saw an estimated 43,654 hectares planted, out of which, 95% was planted to stacked Bt/HT and the 5% refugia planted to herbicide tolerant only, thus no non-GM cotton was planted in South Africa.

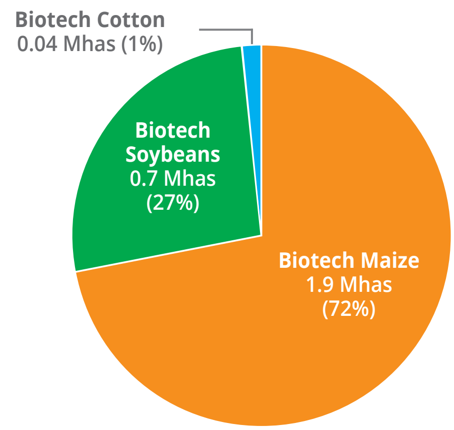


Figure 9. Biotech Crops Planted in South Africa, 2019

Source: ISAAA, 2019

Biotech maize planting decreased by 2.8%

Maize is the main field crop in South Africa and is used for both human consumption (white maize) and animal feed (mainly yellow maize). In 2019, estimated GM/biotech maize area was 84.6% against the 94% record in 2018. A total of 1.94 million hectares were grown against 2.2 million hectares biotech maize grown in 2018. It is estimated that the trait combination did not change and hence out of the biotech maize planted, 80% was stacked IR(Bt)/HT), 12% HT, and 8% IR. Preference for stacked IR and HT traits among farmers continued due to the multiple benefits offered.

The white and yellow total maize hectares for the 2018/19 season (maize planted in 2018 and harvested in 2019) were similar to 2018. White maize area increased slightly from 1.27 million hectares to 1.3 million hectares, while yellow maize decreased from 1.051 million to 1 million. The total maize area decreased slightly to 2.3 million hectares, out of which 1.94 million hectares was genetically modified.

For maize, while there was a slight decrease in area mainly for yellow maize, the season had increased rainfall throughout the 2019/20 maize season. This is expected to result in a yield increase for the 2020 harvest that would compensate for the slight drop in planted area. Industry players have predicted one of the largest main crop tonnages in the history of maize production in South Africa. A combination of high technology adoption, improved agronomic practices especially among small-scale producers and favorable weather all contributed to bumper harvest records.

Biotech soybean adoption rate maintained at 95%

Biotech soybeans was approved for commercial planting in 2001. Out of a total of 730,000 hectares planted on soybeans, 693,975 hectares or 95% was biotech herbicide tolerant soybeans. The country maintained the production as recorded in 2019. Rising domestic demand for soybeans continues to provide an incentive for future expansion with farmers being advised to consider soybeans during crop planning to meet the rising local demand and subsequently reduce the import requirements over time. The soybean sector has introduced a modest technology and breeding levy to encourage investment in R&D, which has been low for soybeans. This is projected to increase purchase of 'new' seed by farmers instead of the farm-saved seed increasingly becoming the trend. A large number of soybean farmers continued to use biotech farm-saved seed with no significant difference noted between the 2018 and 2019 cropping patterns.

Biotech cotton increased by 2.3%

Bt cotton was introduced in South Africa in 1998. Since then, multiple Bt and stacked traits have been introduced and gained popularity among farmers. In 2019, biotech cotton was planted on 43,654 hectares, a 2.6% increase from the 43,000 hectares planted in 2018. All cotton was 100% biotech with 95% stacked IR/HT and 5% of HT used as refugia. The 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 continue to stabilize, leading to increased prospects for cotton in the 2019-2020 season.

Benefits of Biotech Crops in South Africa

It is estimated that the economic gains from biotech crops for South Africa for the period 1998 to 2018 was ~US$2.4 billion and US$153.8 million for 2018 alone (Brookes and Barfoot, 2020).

Summary and Future Prospects

South Africa was the 8th biotech crop country in 2019 with a biotech crop area of 2.68 million in 2019 (Figure 9), compared with the 2.74 million hectares in 2018, indicating a slight decrease of 56,749 hectares. The country is nearing a plateau with average plant biotechnology adoption of 93% of the three principal crops. This is a source of inspiration for other seven African countries in 2019 and expected to increase in the coming years. Lessons learned continue to inform the growth of the sector.

Biotechnology innovation is strongly supported in South Africa. During the National Biosafety Symposium organized by Biosafety South Africa in Pretoria on March 14, 2019, a call for inclusion of biotech innovations in school curricula was made to improve public understanding and appreciation. Moreover, South Africa's Department of Health's Food Control Unit revealed their new findings that residue levels of GMO-associated herbicides in maize products are mostly undetectable and even when detectable, they are more than two orders of magnitude below the national maximum allowable residue levels. Finally, the attending stakeholders called for a policy environment conducive to sustainable innovation and recommended that a multi-disciplinary approach to biotech innovation is critical to ensure success and sustainable growth in the country's biotech sector (Crop Biotech Update, March 20, 2020).

PAKISTAN

In 2019-2020, the area under Bt cotton declined to 2.5 million hectares due to an overall reduction in total cotton area of 2.6 million hectares from the 2.9 million hectares in 2018-2019. The adoption rate was maintained at 95% and has been the same since 2016-2017 when adoption rate reached 97% (Figure 10). A reduction in cotton production was again observed in 2019-20 by the Cotton Crop Assessment Committee (CCAC), with an estimate of 9.45 million bales, a decline of 1.4 million bales from 10.85 million bales for 2018-19. The reduction in area and production of cotton was mainly due to uncertainty in approval of new generation biotech traits and

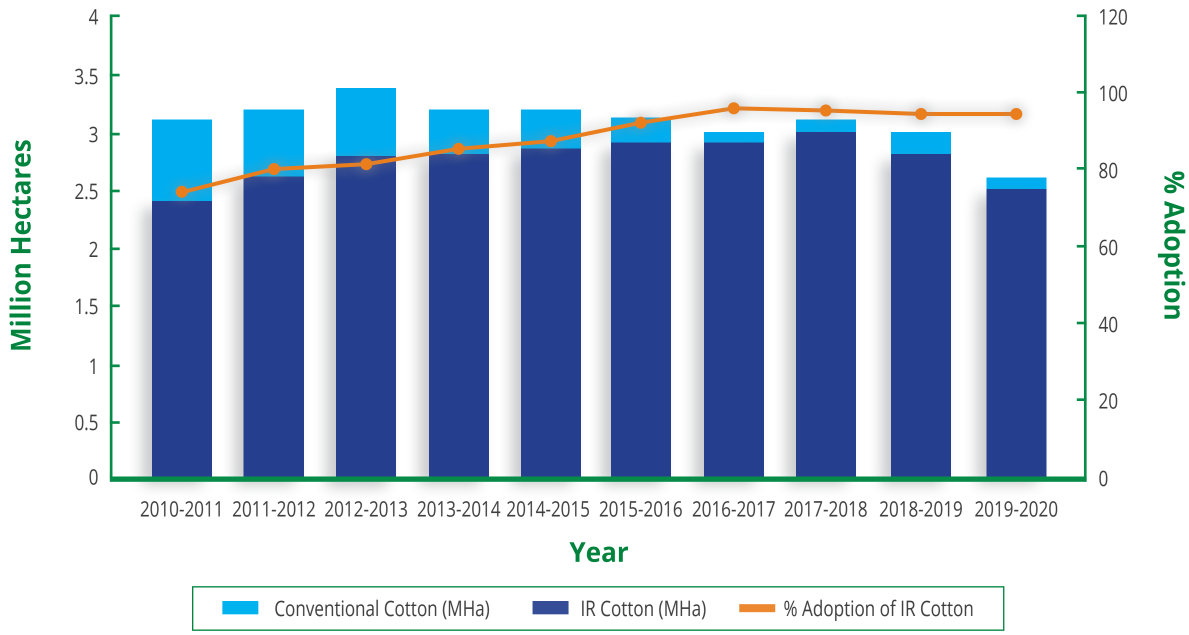


Figure 10. Adoption of IR Cotton in Pakistan, 2010 to 2019

Source: Analyzed by South Asia Biotechnology Centre (SABC) 2018 and ISAAA , 2019

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).

Biotech cotton is the only biotech crop under commercial production in Pakistan. Most of the approved biotech cotton seed varieties contain one of the two released events – MON 531 (Cry1Ac gene) or (Cry1Ab gene) – both of which protect cotton from lepidopterans and were introduced in 2010.

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. It is provisionally estimated that the economic gains from biotech crops for Pakistan for the period 2010 to 2018 was US$5.8 billion and US$515 million for 2018 alone (Brookes and Barfoot, 2020).

David Orden from the International Food Policy Research Institute and Karl Meilke from the University of Guelph' conducted a study 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 half of the benefits gained by the 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 (Crop Biotech Update, November 28, 2018).

Summary and Future Prospects

In 2018-19, the National Biosafety Committee (NBC) of the Ministry of Climate Change resumed regular function after the 18th Constitutional Amendment that decentralized roles and responsibility of biotech products to the 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. 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 will be with the Provincial Government. In 2018-19, the new rules for protection of breeders' rights called 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 support the seed industry in Pakistan (MNFSR, 2018).

In 2019-20, the Federal Minister for Science and Technology announced the revival of the National Biotechnology Commission (NBC). The Technical Advisory Committee and the National Biosafety Committee has approved cotton varieties for commercial release (Table 14).

Moreover, the Pakistan Central Committee (PCCC) has announced that 93 new cotton varieties will undergo National Coordinated Varietal Trials (NCVT) in four provinces in Pakistan. The 93 varieties are composed of 85 Bt and eight non-Bt cotton varieties, 41 of the Bt cotton varieties were developed by the public sector and 44 by the private sector. It is noteworthy that the NCVT aims to assess the cotton varieties' production capability and fiber qualities in accordance with Pakistan's 2018-2019 research plan.

Seed companies have fulfilled all statutory requirements for biotech maize hybrid approvals, starting with the first biosafety trials in 2009, followed by application submission in 2011, secured NBC approval in 2016 (one single HT and three stacked IR/HT events) and completed National Uniform Yield Trials (NYUT), spot examination, as well as distinctness,

Table 14. Approvals for Commercial Release in Pakistan, 2019

	Institute	Crop	Trait
1	CEMB, NIBGE, NARC	Cotton	More than 40 cases of Bt cotton
2	Cotton Research Institute (CRI) Faisalabad	Cotton	Bt cotton variety FH-Lalazar, MNH-988, BH-184
3	Auriga, Lahore	Cotton	Bt cotton Variety Sayban-202
4	Bayer Pakistan	Maize	Roundup Ready corn® NK6 Genuity VT Double Pro (MON89034 x NK603)
5	Corteva Pakistan	Maize	Event 1507 x xNK603; MON 810 x NK603

Source: Annual GAIN Report for Agri-Biotechnology, 2020 uniformity, and stability (DUS) tests in 2018. Field trials of one single HT and two stacked IR/HT events were also conducted in the interim. In January 2019, biotech maize was expected to be approved for commercial cultivation. However, the Ministry of National Food Security and Research halted the approval of commercialization of biotech hybrid maize pending the formulation of biotech policy for the introduction of GM technology in food crops. The National Biosafety Committee subsequently issued a unilateral moratorium on the biotech maize approval process. Consequently, Pakistan temporarily stopped the field trials of biotech maize also. In December 2019, the government alluded to the need of a conducive legal environment for investment in biotech.

Research and development on a variety of biotech crops is ongoing in various public research institutes and a few in collaboration with foreign and domestic firms, that led to field trials. In 2018, field trials were approved for stress resistance (biotic and abiotic) in wheat, cotton, potato, and sugarcane.

BOLIVIA

Biotech soybeans has once again gained acceptance in Bolivia after a drought streak in 2017 that lowered planting area until 2018. In 2019, the total area planted to soybeans was 1.4 million hectares, 97% (adoption rate) of which 1.36 million hectares were biotech herbicide tolerant soybeans. Both total and biotech soybeans increased by ~8%, equivalent to 100,000 hectares more.

Soybean production in 2019 was partly affected by drought in the early part of the year which reduced production by about 450,000 MT. Soybeans is Bolivia's largest agricultural export with total soybean exports in 2018 were US$1.7 billion and soybean meal exports reached 1.6 MMT. It is expected to reduce to 1.4 MMT in CY 2019.

Benefits from Biotech Soybeans

It is estimated that the economic gains from biotech soybeans for the period 2008 to 2018 was US$874 million and US$44.8 million in 2018 alone (Brookes and Barfoot, 2020), 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).

Future Prospects

Soybeans is an important crop in Bolivia which accounts for 45% of the total agricultural land production, the majority of which are found in Sta. Cruz. Producers have been demanding approval for the widespread use of biotech products to increase their productivity and reduce production costs, allowing them to be at par with their competitors in the market. The sole genetically engineered seed approved for cultivation in the country was the glyphosate resistant soybeans. The Bolivian government is also considering the approval to use biotechnology for both maize and cotton, as both crops are also high in demand (Crop Biotech Update, July 3, 2019).

It is noteworthy that in March 2019, the Bolivian government gave its support to the food producers by granting approval to cultivate two new genetically engineered soybean events: Intacta™ (stacked IR/HT), which is already planted largely in Argentina, Paraguay, and Uruguay; and drought tolerant HB4 soybean.

The announcement was made during the meeting of President Evo Morales with private entrepreneurs in Santa Cruz. Also present were Vice President Alvaro Garcia Linera and Minister Luis Alberto Sanchez of the Ministry of Hydrocarbons. The government's decision was based on its commitment to biofuels, which also prompted Bolivia to mass produce bioethanol to replace the importation of gasoline and diesel fuel additives in September 2018 (Crop Biotech Update, March 27, 2019). According to Minister Sanchez, biotechnology will be used in soy production exclusively for the preparation of the new biodiesel green fuel. This initiative is estimated to cost over US$2 million in investments and is predicted to increase Bolivia's soy agricultural production by 250,000 hectares. He also said that work will be done in Bolivia's regulatory framework to regulate the activity through a supreme decree.

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 emission by 6% (Hoy, 2019).

Since the country is always affected by drought, the planting of the newly approved drought tolerant HB4 strain of soybeans approved in the USA and Brazil should be considered in the future. This soybean variety can boost yields between 20-30% from the current average of 2.5 kgs per hectare. The technology will be a welcome respite from a continuous drought, floods and other causes that generated more than US$168 million losses. The National Association of Oilseed and Wheat Producers (ANAPO), Marcelo Pantoja in a recent association meeting revealed that the frequency and regularity of drought in the country has already affected a third of the of the soy crop planted during the current austral summer (Crop Biotech Update, March 27, 2019).

LATIN AMERICA

Ten countries in Latin America planted biotech crops in 2019, led by Brazil and followed by Argentina, Paraguay, Bolivia, (included in the top 10 biotech countries), Uruguay, Mexico, Colombia, Honduras, Chile, and Costa Rica in decreasing order of biotech crop area. Details on the biotech crops planted, adoption trends, and future prospects for respective countries and the region are discussed below.

URUGUAY

Uruguay is the 11th country planting biotech crops in 2019 with 1.21 million hectares, an 8% decline from 2018 at 1.32 million hectares. Biotech soybeans and maize reached adoption rates of 97% and 90%, respectively. The area planted to soybeans was 1.13 million hectares and biotech soybean area decreased by 13% from 1.26 to 1.1 million hectares due to unfavorable weather conditions and lack of new seed technologies. The 1.1 million hectares consisted of 67% HT and 33% stacked IR/HT traits (Table 15).

The area planted to maize in 2019 was 130,000 hectares, a 117% increase from 60,000 hectares in 2018. Adoption of biotech maize was 90% or 117,000 hectares with 10,000 hectares HT, and 107,000 hectares stacked IR/HT traits (Table 16). Growing demand for maize increased in 2019 due to losses incurred in the drought of 2017 and 2018. 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 to 1.3 million hectares planted with soybeans in Uruguay, a ratio of 17 hectares of soybeans for every hectare of corn.

Table 15. Total and Trait Hectares of Biotech Soybeans in Uruguay, 2018-2019

	Area Planted (MHa)		% Trait Hectares	
	2018	**2019**	**2018**	**2019**
Total Soybean	1.30	1.13		
HT	0.88	0.73	70.0%	67.0%
IR/HT	0.38	0.36	30.0%	33.0%
Total Biotech Soybean	**1.26**	**1.09**	**97.1%***	**97.0%***

* Adoption rate

Source: ISAAA, 2019

Table 16. Total and Trait Hectares of Biotech Maize in Uruguay, 2018-2019

	Area Planted (MHa)		% Trait Hectares	
	2018	**2019**	**2018**	**2019**
Total Maize	0.060	0.130		
HT	0.003	0.010	4.8%	9.0%
IR/HT	0.050	0.107	95.2%	91.0%
Total Biotech Maize	**0.053**	**0.117**	**88.3%***	**90.0%***

* Adoption rate

Source: ISAAA, 2019

Brookes and Barfoot (2020) estimated that Uruguay farmers numbering more than 3,000 had enhanced farm income from biotech soybean and maize of US$214 million hectares from 2000 to 2018, and the economic benefits for 2018 alone are estimated at US$32 million. These farmers, their families, and the community have been benefiting immensely from biotech crops since its introduction in 2000.

Maize area has been expanding in the past few years due to positive returns, higher yields, and steady domestic demand. Maize has been taking hectarage from sorghum and seed technology available in maize has improved compared to that of sorghum. Roughly 70% of the maize crop was planted early with the combination of barley followed by a second maize crop resulting in high returns in the past couple of seasons. Maize has produced the best profit margins amongst alternative crops over the last few seasons according to farm owners. Local maize prices are generally higher than those in the region because its price is basically the import parity due to annual imports of 200-400,000 tons from regional neighbors. Most farmers have improved crop management and incorporated technology to increase their returns. Producers who lease land typically prefer to plant soybeans which require lower investment.

MEXICO

Biotech/GM cotton has been cultivated in Mexico for over 23 years, since 1996, and has been increasing in area and adoption. In 2019, the area planted to cotton increased by 1.6% from 235,000 hectares in 2018 to 239,000 hectares in 2019. Likewise, biotech cotton (herbicide tolerant and stacked IR/HT) has increased area of planting from 218,000 hectares to 223,000 hectares (1.9% increase) in 2019 and percentage adoption increased as well from 96% in 2018 to 97% in 2019. The 223,000 hectares biotech cotton consisted of 29% IR and 71% IR/HT. The increasing adoption of the stacked traits (24% in 2019) is a manifestation or farmers' acceptance of the new technology and its profit earning potentials.

The marginal increase in cotton area in 2019 was due to the shortage of seeds available for the increasing number of farmers who decided to plant biotech cotton in 2019. Moreover, the slow approval of biotech cotton seed events by the Mexican government has exacerbated supply challenges. Development of biotech cotton seed typically requires five to six years, and the sharp increase of Mexican production over the past three years was not factored into seed production. The slow biotech cotton event approval has also resulted in a smaller variety of seeds available to companies and producers. The variations in new seed planted in the 2019 planting cycle could result in reduction of cotton yield, due to the unfamiliarity with proper management techniques to optimize yields. Farmers and producers are concerned that gains in production expansion and improved quality (due to public and private investments) over the past two years will be lost if the seed shortage continues.

Benefits from Biotech Cotton and Soybeans

Mexico is estimated to have enhanced farm income from biotech cotton and biotech soybeans (planted from 2013 to 2016) from 1996 to 2018 of US$798.5 million and the benefits for 2018 alone (cotton only) are estimated at US$128.3 million (Brookes and Barfoot, 2020). 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 pioneering 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. 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 help the country gain more opportunities for sustainable agriculture. Current research focuses on drought tolerance in maize, and other traits beneficial to agriculture including reduced 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 the injunctions that have suspended the planting of biotech maize and soybean, for example. This is an ongoing situation, where farmers are not allowed to plant these products while importing large amounts from neighboring countries that produce the same biotech products. Moreover, scientists opt to conduct experimental trials in Argentina because of the onerous Mexican requirement which makes the processing time consuming and costly.

COLOMBIA

Colombia started planting biotech cotton in 2002 and biotech maize in 2007. Since then, the biotech maize area surpassed the biotech cotton area. In 2019, biotech maize was planted on more than 88,268 hectares and biotech cotton on 12,907 hectares for a total of 101,188 hectares, a 15% increase from 88,000 hectares in 2018. An additional 12 hectares were planted to blue carnation and rose. The increase in area planted to biotech crops manifests the continuing acceptance of the farmers for productive and sustainable technology.

The area of biotech maize increased by 16% from 76,000 hectares in 2018 to 88,268 hectares, composed of 11,000 hectares HT and 77,268 hectares stacked IR/HT traits. Of Colombia's 32 departments, 21 cultivate biotech crops, led by Meta department, (28,662 hectares), followed by Tolima (18,453 hectares) and Valle del Cauca (16,052 hectares). Valle del Cauca increased the area planted to biotech maize by 47%. Other departments that showed increased adoption were Cordoba, Cesar, Risaralda, and Quindio.

The area planted to biotech cotton in 2019 increased by 6% from 12,000 in 2018 to 13,000 in 2019. The 13,000 hectares is composed of 1,000 hectares HT and 12,000 hectares IR/HT. Biotech cotton was planted in the departments of Tolima, Cordoba, Huila, Valle del Cauca, Guajira, Cesa, and Sucre. The department of Tolima planted the largest area of biotech cotton at 6,421 hectares followed by Cordoba (3,817 hectares) and Huila (1,831 hectares). Adoption of biotech cotton in 2019 increased by 155% in Huila (Agrobio, 2020).

Annually, some 12 hectares of blue carnation and blue roses were planted in Colombia under controlled greenhouse conditions since 2000 for export to Japan.

Benefits from Biotech Maize and Cotton

Colombia is estimated to have enhanced farm income from biotech crops of US$301.7 million in the period 2002 to 2018 and the benefits for 2018 alone is estimated at US$20.1 million (Brookes and Barfoot, 2020). 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 conditions and social status.

A study conducted by Graham Brookes of PG Economics Ltd. published in the journal *GM Crops and Food* found that since 2003, crop biotechnology has helped Colombian farmers grow more food, feed, and fiber, using fewer resources and farm incomes increased by a total of over US$300 million. Crop biotechnology has enabled Colombian farmers to obtain higher yields from better pest and weed control, reducing the environmental footprint associated with the production of cotton and maize. The study found that since 2003, about 1 million hectares of biotech cotton and biotech maize were planted in Colombia, and in 2018, the technology was used on the equivalent of 90% and 36% respectively of the total cotton and (commercial) maize crops.

The extra production and reduced cost of pest and weed control helped maize farmers attain higher incomes equal to an average of US$294/ha and an average return on investment equal to +US$5.25 for each extra US$1 spent on GM maize seed relative to conventional seed. For cotton farmers, the average increase in income has been +US$358/ha, with an average return on investment equal to +US$3.09 for each extra US$1 spent on GM seed relative to conventional seed. The study also found that crop biotechnology facilitated cuts in fuel use, resulting in a reduction in the release of greenhouse gas emissions from the GM cotton and maize cropping area and contributed to saving scarce land resources (Crop Biotech Update, February 12, 2020).

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 2019, the 15% increase in the biotech crop area was proof of continuous farmer acceptance for a more productive and sustainable agricultural technology. Farmers in the 21 departments who planted biotech maize and cotton seeds have shown that productivity can be increased to impact national production, depend less and less on imports, and be more competitive with neighboring countries. These benefits can greatly contribute to increased profitability and improve the social conditions of the rural population, as well as to attain more environmentally friendly and maintain sustainable food production.

To support the interest of farmers, consumers, and the industry, the government will need to continue to provide agricultural biotechnology with favorable institutional and regulatory conditions for the investment and R&D of new technologies tailored for Colombia. 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, respectively.

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 contents, coffee borer resistant coffee, and insect resistant potato, among others.

HONDURAS

Honduras planted its first biotech maize in 2002, and it is the only biotech crop in the country. In 2019, 37,386 hectares of biotech maize were planted in Honduras, 5% higher than the area planted in 2018 at 36,000 hectares. The biotech maize area was composed of 3,335 (9%) hectares HT and 34,051 (91%) hectares stacked IR/HT. IR (Bt) maize was not planted in 2019 but was planted in 2018. The significant increase in biotech maize planting indicated the continuous higher demand for yellow maize for feeds and white maize for human consumption. Both rainfed and irrigated maize in key producing departments of Francisco Moraga, Olancho, and El Paraiso planted biotech maize in 2019. Honduras' production of biotech maize is mainly for domestic agroindustry purposes and a portion exported to Colombia. Honduras continues its import of yellow maize and soybean meal to supply its poultry, livestock, shrimp, and tilapia industries.

In 2019, Honduras produced stacked commercial events: VTPRO/RR, VT3PRO/RR, and HX1 x RR2 for feed production, and Roundup Ready (RR) and Herculex (HX1) for commercial seed production export 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. It is estimated that Honduras has enhanced farm income from biotech maize by US$20.9 million from 2002 to 2018 and US$4.8 million in 2018 alone (Brookes and Barfoot, 2020), benefiting some 7,000 farmers and their families.

Future Prospects

The National Service for Food Safety, Plant and Animal Health (SENASA) is the responsible agency for agricultural biotechnology regulation and policy. The National Committee on Biotechnology and Biosecurity created in 1998, evaluates and analyzes GE requests. A guideline to update the procedures of the NCBB was published on January 10, 2018, called *Guide of Processes and Procedures of the Regulatory System for Genetically Modified Organisms*. The guideline covers procedures for the field test, pre-commercial, and commercialization stages of new event applications. Genome editing of crops was also considered and in September 2019 when SENASA approved a simplified procedure to shorten the process of approval.

On March 15, 2019, El Salvador, Guatemala, and Honduras Customs Union approved a technical regulation (TR) for the commercial exchange and safe use of agricultural biotechnology. On October 1, 2019, the rule entered into effect for Guatemala and Honduras. The TR applies to plants and the reproduction of animals (such as mosquitoes that cause Dengue fever). The procedural manuals need to be developed for full implementation. These new developments will push biotech crop adoption in Honduras and open for products of genome editing.

CHILE

Biotech crops in Chile have been planted under strict field conditions for export since 1996. In 2019, a total of 41,093 hectares were planted in the country, an increase of 35% compared to 2018. The biotech crop area consisted of 8,016 hectares IR/HT maize, 2,911 hectares HT canola, 3,166 hectares HT soybeans, and 27,000 hectares sweet corn. The 35% increase in biotech crop adoption was a result of increased demand for seeds in the Northern hemisphere, which are export markets of Chile.

Chile became the 9th largest producer of seeds in 2017 (ISF, 2018), with the Netherlands being the top producer. With the 35% increase in biotech crop area for seed exports in 2019, they can move to the next level soon. The planting of biotech seeds is a part of research and development, as well as propagation for export, and there has never been commercial biotech crop production.

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 that produces products that contain biotech ingredients to register the products. Products need to carry a label only if the biotech product is substantially different from its conventional counterpart.

The ratification of the International Union for the Protection of New Varieties of Plants 1991 (UPOV 91) in the country could open doors for the development of a biotechnology/biosafety law and possible commercialization of biotech crops. If biotech crops will be allowed for commercialization, the country 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 the research capacities of local Chilean educational and research institutions.

More recently, Chilean biologist Simón Ruiz from the University of Talca has developed a transgenic maize variety that can withstand 52 days without water. Ruiz and his research team developed the transgenic maize with genes from a tomato that grows in the Atacama Desert. Transgenic variety B73 that are adapted to excessive light, fluctuating temperatures, and pests were tested in the field in summer. During flowering and grain filling, plants with and without resistant genes were planted, and both grew for 52 days without water. The plants without the resistance genes had very few kernels, compared to the transgenic maize. The researchers also found that transgenic plants that were not irrigated maintained 80 percent of their productivity. The plants without the resistance gene and were not irrigated, maintained only 20 percent of their productivity (Crop Biotech Update, October 2, 2019)

COSTA RICA

Similar to Chile, Costa Rica has been planting biotech crops (soybeans and cotton) for export since 1996. Biotech pink pineapple has been planted in Costa Rica since 2017. In 2019, a total of 297 hectares of biotech crops were planted including 182 hectares of stacked IR/HT cotton and 115 hectares of biotech pink pineapple. An increase of 158 hectares of biotech crops was achieved in 2019 indicating the increased demand for these biotech seeds in the Northern Hemisphere.

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, foods containing biotech components do not need 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.

Gene editing technologies, such as the clustered regularly interspaced short palindromic repeats (CRISPR), have been used by many researchers to enhance crop traits such as yield and nutritional qualities. To analyze the perceptions and attitudes of consumers towards the use of CRISPR, scientists from the University of Costa Rica conducted a survey. A total of 1,018 adults from Costa Rica were surveyed and the results indicated that only 7.4% have heard about CRISPR-Cas9. However, the majority are willing to accept its use for nature preservation (84.5%), curing diseases in animals (83.0%), crop improvement (80.9%), and curing human diseases (80.2%). More than half also agreed that CRISPR foods would improve crop production in the country (66.0%), help the economy (63.7%), and bring benefits to their families (60.7%) and the environment (57.4%). They expressed their willingness to consume CRISPR foods if the nutritional quality is improved (70.8%), cheaper than conventional foods (61.0%), and if they are available in the local market (59.4%). Based on the results, the respondents showed favorable attitudes towards CRISPR (Crop Biotech Update, July 17, 2019).

SUMMARY AND FUTURE PROSPECTS FOR LATIN AMERICA

Ten countries in Latin America planted biotech crops in 2019 including Brazil (52.8 million hectares), Argentina (24 million hectares,), Paraguay (4.1 million hectares), Bolivia (1.4 million hectares), Uruguay (1.2 million hectares), Mexico (223,000 hectares), Colombia (101,188 hectares), Chile (41,093 hectares), Honduras (37,386), and Costa Rica (297 hectares) for a total of 83.9 million hectares, covering 44% of the global biotech area of 190.4 million hectares.

Increases in absolute number of hectares and percent area were recorded in several countries in Latin America, led by Brazil at 1.6 million hectares (3%), Paraguay (300,000 hectares, 9%), Argentina (100,000 hectares, 0.5%), Bolivia (100,000 hectares, 8%), Colombia (12,900 hectares, 15%), Mexico (5,000 hectares, 2%), Chile (4,600 hectares, 44%), Honduras (1,900 hectares, 5%) and Costa Rica (158 hectares, 114%).

The increases in biotech crop area in most of the Latin American countries compensated for the losses from the extensive drought incidence of 2017 and 2018. In addition, enabling regulations; profitability, high prices, and high market demand in the local and international market; availability of new seed technologies for maize, soybean, and cotton; subsidized credit for farmers and foreign investments from the industry; favorable weather; and improved agronomic practices with efficient fertilizer applications encouraged the farmers in Brazil, Argentina, Paraguay, Mexico, Colombia, and Honduras to plant biotech crops. In Bolivia, the increase in biotech soybean area was due to favorable conditions in 2019, after two years of extreme drought. Moreover, the Bolivian government gave its support to soybean producers by granting the approval to cultivate two new genetically engineered soybean events to boost their biofuel production. In the future, the adoption of drought tolerant soybean will be useful to overcome the drought incidences in the country in the Latin American countries.

A significant reduction of 9% in area planted to biotech crops in Uruguay was due to unfavorable weather for soybean planting and lack of new soybean technologies.

For Chile and Costa Rica which have planted biotech crops for seed export only since 1996, an increase of 35% (for canola, soybeans, and sweet corn) and ~114% (for cotton and pink pineapple) were obtained respectively, indicating an increasing demand of biotech seeds in the northern hemisphere.

New crops and traits planted for 2019 include low lignin and herbicide resistant alfalfa in Argentina and increasing area of insect resistant soybean introduced in 2018 in Brazil. Upcoming crops and traits include drought tolerant wheat, and virus resistant potato; while approvals for drought tolerant and herbicide tolerant soybean are expected soon.

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 so that consumers will benefit from affordable and nutritious biotech food products.

Finally, over half a million biotech farmers in the developing countries of Latin America sans Chile and Costa Rica have been benefiting immensely in the last 23 years of biotech crop commercialization. Economic benefits estimated by Brookes and Barfoot (2018) from the respective countries' start year of planting until 2018 is over US$59.9 billion, with US$6.4 billion for 2018 alone. These are enormous benefits that can only be derived from biotech crops.

ASIA AND THE PACIFIC

There were nine countries in Asia and the Pacific that planted and consumed biotech crops in 2019. Three of these countries, India, Pakistan, and China, planted more than 1 million hectares of biotech cotton and belong to the top 10 biotech countries. The six countries which planted less than 1 million hectares in descending order were the Philippines (biotech maize), Australia (biotech cotton, canola, and safflower), Myanmar (biotech cotton), Vietnam (biotech maize), Bangladesh (biotech eggplant), and Indonesia (biotech sugarcane). Details about the biotech crops planted, adoption trends, country situations, and future prospects for the country and the region are discussed below.

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 that oversees biotech crop commercialization was enforced at the end of 2002, farmers have been planting biotech maize starting in 2003. In 2019, 875,000 hectares were planted in the yellow maize-growing areas of the Philippines, which is an increase of 245,000 hectares (39%) compared to 2018 (630,000 hectares). Biotech stacked IR/HT occupied 99% of the biotech maize planted, with only 1% for HT. Biotech yellow maize was grown at 62% adoption rate in 2019 compared to 2018 (50%). Total maize area also increased by 13% in 2019, following good global prices and demand for local consumption for feeds.

Regulation of biotech crops in the Philippines was challenged in 2012 when a lawsuit was filed to halt the commercialization of Bt eggplant. The case was elevated to the Supreme Court (SC), which ruled on December 8, 2015 that existing GE regulations as embodied in DA Administrative Order No. 8 (DA-AO 8) did not sufficiently cover the minimum requirements of the principles of risk assessment embodied in the National Biosafety Framework (NBF). The SC permanently enjoined the field testing of Bt eggplant (which had already been completed) and declared DA-AO 8 null and void. Hence, it halted the processing of applications for contained use, field testing, propagation, and commercialization, as well as the importation of GE products. Although motions for reconsideration were filed and the case was later on dismissed in July 2016 on the ground of mootness, a new regulation was still drafted by scientists and a new set of regulators were installed in April 2016 in response to the court case. The 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.

After a few years of implementation, the JDC was reviewed in 2019 to improve efficiency and transparency in the approval of biotech events. A revised JDC may be completed by the end of 2020.

The Department of Science and Technology (DOST) remains the lead agency for evaluation and monitoring of regulated articles (i.e., approved GE events) intended for contained use, while the Department of Agriculture (DA) continues to take the lead in the evaluation and monitoring of regulated articles. The DA, through the Bureau of Plant Industry (BPI) is still tasked to evaluate and issue all permits such as field trials, propagation, and direct use for food or feed. Food safety assessment is given to BPI-Plant Product Safety Services Division, while feed safety assessment was assigned to the Bureau of Animal Industry (BAI), in accordance with the Food Safety Act of 2013.

Benefits from Biotech Maize

The farm-level economic benefit of planting biotech maize in the Philippines from 2003 to 2018 was estimated to have reached US$872.6 million. For 2018 alone, the net national impact of biotech maize on farm income was estimated at US$87.7 million (Brookes and Barfoot, 2020). These immense economic gains are continuously benefiting more than 673,000 farmers (with an average of 1.3 hectares farm size) and their families in the last 16 years of biotech maize commercialization in the Philippines.

Future Prospects

The **fruit and shoot borer resistant Bt eggplant** research is being 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 with no 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, policymakers, judiciary, and the general public are being prepared for the possible commercialization of Bt eggplant through various outreach and communication activities conducted in collaboration with SEARCA BIC, ISAAA, and other partners. These activities also became a venue for introducing the new set of regulatory guidelines as well as stressing the fact that Philippine biotech crops are scientifically regulated (Philippine Bt eggplant team, Personal Communication).

When the Supreme Court ordered the stop of the field trials in 2012, the field trials were already completed. After the Supreme Court reversed its decision in 2015, farmers have since been wondering when they will be able to use the technology that will eliminate the spraying of pesticides to control the fruit and shoot borer pest. A study by Cesar Quicoy, associate professor at the University of the Philippines Los Banos (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 P33.85 billion (US$65 million) annually due to the non-commercialization of IR eggplant in the last ten years. Furthermore, the additional revenue that eggplant farmers would get from using the 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. The project aims to develop Golden Rice varieties suitable for farmers in the Philippines, 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. Golden Rice is also being developed simultaneously in Bangladesh by the Bangladesh Rice Research Institute (BRRI) and IRRI.

In the Philippines, two seasons of confined testing (CT) of Golden Rice Event E (GR2E) for the selection of promising breeding lines and for the production of grains for compositional analysis (for FFP application as mentioned below) have already been completed in 2016 under the strict monitoring of the Department of Science and Technology-Biosafety Committee (DOST-BC), Department of Agriculture-Bureau of Plant Industry (DA-BPI), and the local Institutional Biosafety Committees (IBC) of the respective test sites. This was followed by the application for a field trial to DA-BPI in February 2017, which required informing/consulting the public and securing LGU resolutions as required by the Joint Department Circular (JDC) No. 1 series of 2016. The field trial permit was issued in May 2019 by DA-BPI after more than two years. The field trial was completed in October 2019. After careful evaluation by DA-BPI of the submitted field trial completion report, the certificate of completion was finally issued in August 2020. With this, PhilRice has officially generated the environmental data required for the application for commercial propagation, which is the final regulatory hurdle for Golden Rice.

Application for food, feed, and processing (FFP) approval was submitted to the DA-BPI, United States Food and Drug Administration (USFDA), 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 USFDA in May 2018. As for the Philippines, the FFP permit for Golden Rice was released in December 2019. With the permit, PhilRice was able to conduct a preliminary sensory evaluation of cooked GR2E in December 2019. The FFP approval will also give way to the eventual conduct of an independent nutrition study to determine the effectiveness of Golden Rice in improving the vitamin A status of humans (PhilRice Golden Rice team, Personal Communication).

Biotech papaya with delayed ripening and papaya ringspot virus resistance is also being developed by IPB-UPLB, and has undergone a 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 Development Administration (PFIDA), formerly the Cotton Development Authority. The technology, provided by Nath Biogene Ltd. and the Global Transgene Ltd. from India, was tested for the first time in a confined field trial in 2010, and multi-location field trials in 2012 and 2013. The data to complete the required regulator dossiers were obtained in 2015, as well as some related laboratory experiments in 2017. The evaluation further confirmed the bioefficacy of the Bt cotton hybrids against the cotton bollworm. The proponents will apply for the commercial propagation as soon as the certificate of satisfactory completion of the multi-location field trial is received.

AUSTRALIA

Australia was one of the first six countries that commercialized biotech crops in 1996 with biotech cotton and canola. In 2019, Australia ranked 13th in the list of biotech crop planting countries with 614,446 hectares, a reduction of 22% from the 793,000 hectares planted in 2018. The biotech crop area consisted of 59,850 hectares of biotech cotton, 551,000 hectares of biotech canola, and 1,970 hectares of biotech safflower.

Biotech canola adoption rate increased to 31%

Once again, in 2019, the continuous drought incidence in Australia reduced crop area in the country including total canola area at 21% reduction, which is also the smallest area recorded for biotech canola so far. However, due to the better weed control and profit, farmers' use of biotech canola with herbicide tolerance reached 31% adoption rate, the highest adoption rate achieved so far, which is also a 10% increase from 2018.

Australian canola growers planted biotech canola at 550,656 hectares, an increase of 10%, equivalent to 51,759 hectares (Table 17). As in the past, Western Australia planted the largest area at 433,833 hectares, followed by New South Wales at 50,030 hectares and Victoria at 66,793 hectares. The total area of canola was 1.76 million hectares and biotech adoption rate increased to 31% (Table 18).

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

Table 17. Area of Biotech Canola Planted in Three States in Australia, 2018-2019

State	Hectares		Adoption Rate per State	
	2018	2019	2018	2019
New South Wales	66,045	50,030	13	14
Victoria	63,825	66,793	15	17
Western Australia	369,027	433,833	28	44
Total Biotech Canola Area	498,897	550,656	22*	31*
Total Canola Area	**2,222,000**	**1,760,000**		

* Adoption rate

Source: Agricultural Biotechnology Council of Australia, 2019 canola, with more than 700 from Western Australia (Monsanto Australia, 2019).

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 we have to scale the challenges of climate change and a growing world population (USDA FAS, 2019).

Biotech cotton adoption rate maintained at 100%

Compared with 2018 data, biotech cotton area in Australia was reduced by 79% or 233,572 hectares in 2019 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 cotton planted in Australia is biotech, at 59,000 hectares, comprised of 2% or 1,000 hectares HT and 98% or 58,850 hectares stacked IR/HT (Bollgard3/RRF) (Table 18).

The use of this stacked cotton event in Australia in the 2018 planting season allowed growers to effectively control Helicoverpa caterpillars as well as get rid of weeds. The use of Bollgard 3 cotton technology also allows flexibility to cotton planting until farms have adequate soil moisture levels. Cotton growing season is from August to December each year.

Biotech safflower

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 Gene Technology Regulator approved the commercial release of biotech safflower modified for high oleic acid composition. Commercial safflower production occurs mainly in NSW, Victoria, and South Australia. The GE safflower has been developed by scientists at the Government Research and Development Center and Commonwealth Scientific and Industrial Research Organization through gene silencing technology. The CtFATB gene fragment that codes for palmitoyl-ACP thioesterase and CTFAD2.2 gene fragment associated with Δ 12 desaturase that control processes within the safflower seed and limits 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 the build-

Table 18. Total and Trait Hectares of Biotech Cotton in Australia, 2018-2019

	Area Planted (MHa)		% Trait Hectares	
	2018	2019	2018	2019
Total Cotton	0.29	0.06		
HT	0.012	0.001	4.0%	2.0%
IR/HT	0.28	0.058	96.0%	98.0%
Total Biotech Cotton	**0.29**	**0.059**	**100.0%***	**100.0%***

* Adoption rate

Source: ISAAA, 2019

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. The biotech safflower is the only plant-based source of oil suitable for a large number of high-value industrial applications.

Currently, the commercialization of biotech safflower event 26 and event 40 is being handled by Go Resources Pty Ltd. In 2019, an estimated 3,500 hectares is planted under a Closed Loop Identity Preservation Stewardship program, as compared to 68 hectares planted in 2018.

Benefits from biotech canola and cotton

Australia is estimated to have enhanced farm income, benefiting some 250 farmers in the period 1996 to 2018 by as much as US$1.3 billion and the benefits for 2018 alone are estimated at US$72.1 million (Brookes and Barfoot, 2020).

A review by Brookes and Barfoot (2018) 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. 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

Australia is one of the pioneer countries that started planting biotech crops in 1996. Biotech cotton and canola were planted in designated areas of the country in increasing trends. However, due to extended drought, the area planted to biotech cotton has decreased considerably by 79% in 2019. Biotech canola area on the other hand increased by 10% and the newly approved safflower by 50% in a Closed Loop Identity Preservation Stewardship program.

Farmers in South Australia may soon be planting biotech crops with the lifting of the moratorium. The State Government of South Australia (SA) has introduced legislation to finally lift the GM crop ban in mainland SA. Parliament will be working on the Bill to make sure that SA farmers can plan their 2020 cropping season. The Genetically Modified Crops Management (Designated Area) Amendment Bill 2019 will allow farmers from mainland SA to benefit from GM crops. The lifting of the ban allows SA farmers to have equal choices as those from the neighboring states thereby increasing productivity and job opportunity. On the other hand, the Bill also designates Kangaroo Island as the only place in SA where the GM moratorium will be implemented until September 2025, as the island has an established non-GM canola market with Japan.

Minister Tim Whetstone of the Department of Primary Industries and Regional Development (DPIRD) continues to push for the GM ban to be lifted as he believes that the moratorium denies the SA farmers their right to choose what crop to plant while at the same time costing them more money to produce crops. He also believes that new and improved crop varieties are tools that can help farmers overcome drought and other climate challenges. These statements are consistent with an independent expert review completed by the economist professor Kym Anderson of the University of Adelaide in 2018. According to the review, the GM ban has cost SA farmers at least AUD 33 million since 2004 and will cost farmers at least an additional AUD 5 million if it is extended to 2025 (Crop Biotech Update, February 27, 2019).

The Minister is pleading to fellow lawmakers to set aside their ideology and put their trust in the farmers to grow GM crops in the state. His statement also mentions that if the Bill does not pass parliament this year, the Marshall Liberal Government will reconsider other regulatory options for farmers to have access to more choices (Crop Biotech Update, September 4, 2019).

Some biotech crops in the pipeline include biotech wheat with altered iron uptake, transport, and bioavailability. A field trial has been approved by Australia's Office of the Gene Technology Regulator (OGTR). It will gather research and regulatory data under field conditions. The GM wheat grown in the field trial will not be used in human food or animal feed. The field trial will take place between April 2019 and December 2023 at sites in New South Wales, Victoria, and Western Australia. In the first year, the field trial will be conducted at up to two trial sites, with a maximum combined area of 4 hectares. In the remaining four years, the field trial will be conducted at up to 10 trial sites per year, with a maximum combined area of 20 hectares per year (Crop Biotech Update, April 14, 2019).

Since its discovery in the 1800s, Fusarium Wilt or Panama disease has been a global threat to the banana industry, wiping out entire plantations in Asia, Australia, Middle East, Africa, and Latin America. The economic impact of the disease has been catastrophic, with losses reaching US$18.2 billion to date. One of the major breakthroughs in the industry was the discovery of another variety of banana, known as the Cavendish. This variety was almost entirely resistant to Panama disease. Currently, 99% of exported bananas and about half of the total production worldwide are Cavendish bananas. However, the Panama disease has made a comeback, and not even the Cavendish is immune. Scientists now turn to modern biotechnology to create a new plant resistant to Panama disease. Genetic modification in particular, is seen as a possible solution to protect the plants from Tropical Race 4 or TR4, the strain of fungus that appeared in Taiwan in the early 2000s. For instance, researchers from Australia have discovered that adding two different genes — from a wild banana resistant to TR4 and another one from nematode worms — to the genetic code of Cavendish bananas protects the plants from TR4. Meanwhile, a team from Taiwan has already produced a Cavendish line which can somewhat withstand TR4. Another study shows evidence that some crops can defend bananas against TR4 (Crop Biotech Update, April 24, 2019).

MYANMAR

Two long staple insect resistant Bt cotton varieties *"Ngwe chi-6"* and *"Ngwe chi-9"* were planted over 300,000 hectares in 2019, a slight decrease from 310,000 hectares in 2018, representing 86% of the total cotton area of 350,000 hectares. 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 the 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"* yields 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.

Myanmar has drafted a Biosafety Law in 2008 but has not been able to enact it in the absence of major R&D projects and experimentations,

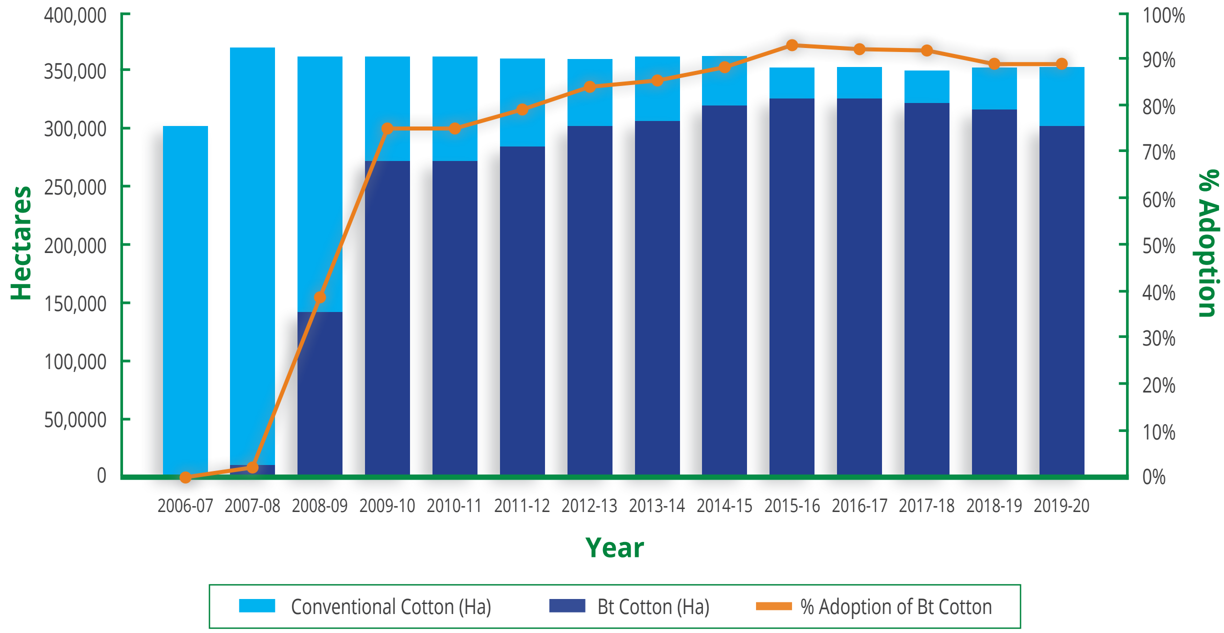


Figure 11. Adoption of IR (Bt) Cotton in Myanmar, 2006 to 2019

Source: Analyzed and compiled by South Asia Biotechnology Centre and ISAAA, 2019

and field trials of biotech products. However, realizing the potential of biotech R&D and product development, Myanmar in 2018 started to review and revise the draft biosafety guideline, strengthened research and manpower capacity, and forged international partnership to revolutionize agriculture in Myanmar. Functioning of biosafety framework is essential as the country needs to comply with CBD's Cartagena Protocol on Biosafety (CPB) and boost ongoing biotech research including tissue culture, molecular marker-aided breeding, and Bt gene introgression to other cotton varieties.

Benefits of IR (Bt) cotton in Myanmar, 2010-2018

Brookes and Barfoot (2020) 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$461.8 million for the period 2006 to 2018 and the benefits for 2018 alone was at US$52.5 million, which will benefit the families and communities of the 455,000 IR cotton farmers.

VIETNAM

Vietnam, on its fifth year of commercializing biotech maize, planted 92,000 hectares in 2019, a notable increase of 88% from 49,000 hectares planted in 2018. This was more than a 26-fold increase from the 3,500 hectares in 2015 when farmers planted for the first time. At that time, biotech stacked (IR/HT) maize events: 1 single herbicide tolerant and 4 stacked IR/HT events were approved for commercialization in Vietnam. A modest annual increase in the planted area was observed due to switching of farmer preference from maize to other higher value fruits and vegetables. The 88% increase in biotech maize area in 2019 is due to the higher local demand for livestock and poultry feeds. Vietnam remains a major importer of key biotech plant products other than maize, with soybeans, distiller's dried grains with solubles (DDGS) and cotton.

The slow approval of biotech maize applications by the Ministry of Agriculture Research and Development (MARD) in 2016 also contributed to the steady increase of biotech maize area. However, from October 2018 to September 2019, MARD issued ten Certificates of Food and Feed Safety Approvals for outstanding biotech events; three maize, five soybeans, and two alfalfa events. Industry reports however are alerted on the 21 applications awaiting approvals since October 2019. These include 17 events for maize, soybeans, canola, cotton, alfalfa, and sugar beets. The delay in approval may be due to the repealed Circular 29/2009 regulating field trials for environmental risk assessment before commercialization causing a gap in regulations on field trials and biosafety certification for biotech crops in Vietnam.

Some issues that may affect future biotech crop approval and adoption may be the banning of glyphosate which will take effect on December 31, 2020 as well as the introduction of the new Cultivation Law (Draft 94) in late 2019. The Law provides detailed regulations on labeling conditions for trading or manufacturing, and administrative procedures related to plant varieties to facilitate the manufacture, trade or import of plant varieties. It is worth noting that the Decree removed the provision prohibiting the import of genetically modified plant varieties into Vietnam that was included in the draft version released in May 2019 (Tilleke and Gibbins, 2020).

The approval of biotech events, which in some cases have been pending approval for almost four years in Vietnam despite being commercially adopted in the United States and other countries, provides a much needed assurance to producers that the trade in these products can continue. Delays in biotech event approvals especially those varieties that contain genes to control fall armyworm could affect feed demand. MARD reported that in August 2019, 15,000 hectares of standing maize crop were infected by FAW in 40 provinces in Vietnam. The affected area increased in April 2020 to 35,000 hectares. Field trials of biotech maize hybrids to control FAW have been started in the country.

Benefits from biotech maize

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

A farmer survey conducted in Vietnam in 2018-2019 revealed that planting biotech maize significantly reduced production cost, increased farmers' income, and decreased pesticide use. The findings support countless studies about the benefits of biotech crops that were previously completed and published. The survey was conducted through personal interviews among 735 maize growers in different regions of Vietnam from 2018 to 2019. The objective of the survey was to assess the farm-level economic and environmental effects of the use of GM maize that is insect resistant and herbicide tolerant.

Among the economic impacts indicated by the results of the study was that the biotech maize varieties yielded +30.4% more than the conventional varieties. The cost of production was also reduced by between the figures of US$26.47 and US$31.30 per hectare. The survey also revealed that for every extra US$1.00 spent by the farmers on the GM maize seed relative to conventional maize seed, the farmers gained an extra income amounting between US$6.84 to US$12.55.

As for environmental benefits, the results of the survey pointed to the reduced insecticide and herbicide use when planting biotech maize. The average amount of herbicide active ingredient applied to the biotech maize area went down by 26% than the average value used for the conventional maize area. Using the Environmental Impact Quotient (EIQ) indicator, it was recorded that the associated environmental impact of herbicide use in the biotech maize was lowered by 36% as compared to the value applicable to the conventional maize. Lastly, the average amount of insecticide used for the biotech maize was lowered by 78%, and its associated environmental impact use using the EIQ indicator was lowered by 77% (Brookes and Dinh, 2020; Crop Biotech Update, October 7, 2020).

BANGLADESH

Some 27,000 smallholder farmers (18% of the total eggplant farmers, average 0.072 h / farmer) planted biotech Bt eggplant on 1,931 hectares in 2019. This was 6,311 more farmers than the 2018 recorded farmers of 20,602, and an increase of 28% (427 hectares) compared to 2018 (Figure 12). The Bt eggplant farms were located across 64 districts of Bangladesh in the 7th season of its cultivation.

Bangladesh is the first developing country to release a commercial genetically engineered (GE) food crop. In Bangladesh, an estimated 150,000 farmers grow eggplant on approximately 50,000 ha of land (Mondal and Akter, 2018). Yield losses as high as 86% have been reported in Bangladesh due to infestation by the eggplant fruit and shoot borer (EFSB) pest, four Bt brinjal varieties expressing Cry12Ac (Bt brinjal) namely BARI Bt Begun 1 (Uttara), BARI Bt Begun-2 (Kazla), BARI Bt Begun-3 (Nayantara) and BARI Bt Begun-4 (ISD 006) were released in Bangladesh in 2013 (Shelton et al., 2019)

Bt eggplant provides complete control of EFSB, dramatically reduces insecticide sprays, provides a six-fold increase in grower profit and does not affect non-target arthropod biodiversity. It was first provided to 20 farmers in January 2014, since then, adoption has been rapid. The area under Bt eggplant has grown gradually over the last 7 seasons with the collaborative efforts of three key national partners namely Bangladesh Agricultural Research Institute (BARI), Bangladesh Agricultural Development Corporation (BADC) and Department of Agricultural Extension (DAE). Since 2014, more than 1,900 farmer field demonstration trials have been carried out by BARI across various districts of Bangladesh.

From 2016, DAE has provided extension activities including, demonstrating Bt eggplant in newer areas of Bangladesh. And since 2017, DAE has provided extension activities including demonstrating Bt eggplant in newer areas of Bangladesh while BADC has been producing the foundation seed and marketing it through their country-wide marketing and dealer network to cater to the increasing number of

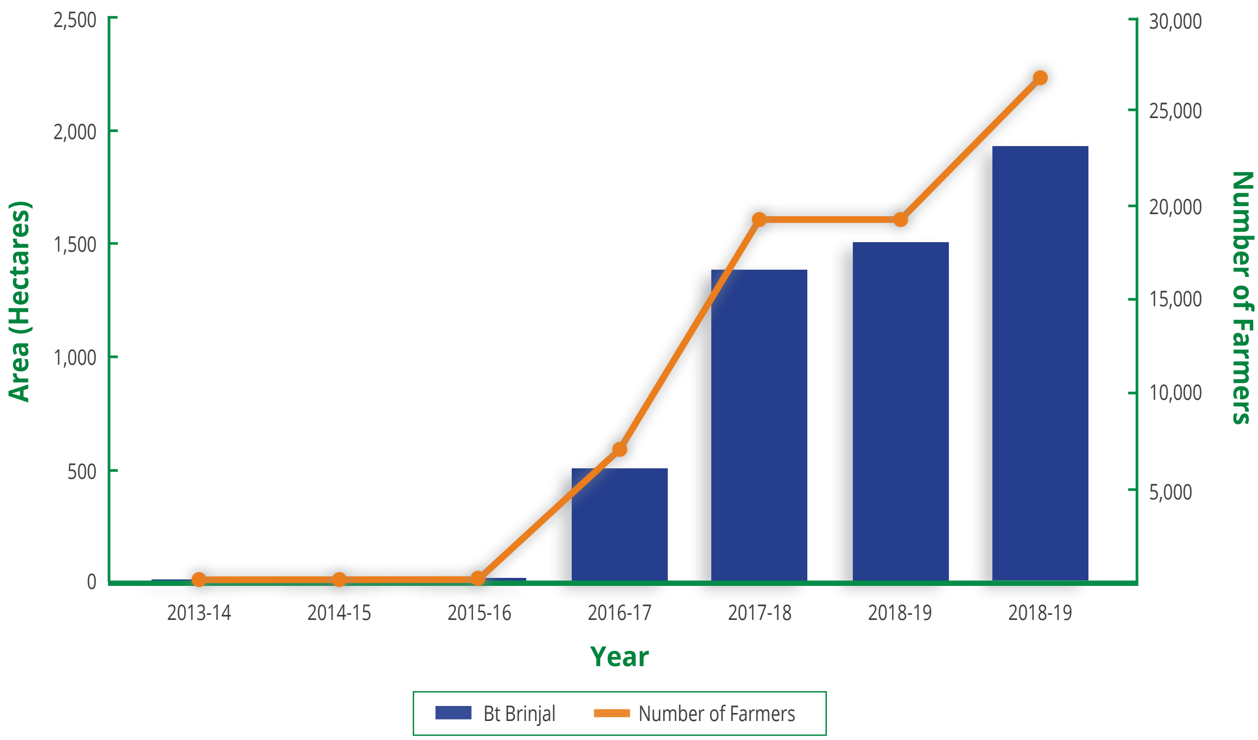


Figure 12. Adoption of Bt brinjal in Bangladesh, 2013-2019

Source: ISAAA, 2019

Table 19. Number of Farmers Conducting Field Trials in Bangladesh, 2013-2019

Year	BARI	DAE	BADC	Total
2013-14	20	0	0	
2014-15	108	0	0	108
2015-16	250	0	0	250
2016-17	512	6,000	0	6,512
2017-18	581	7,601	19,430	27,612
2018-19	125	7,077	13,400	20,602
2019-20	100	8,913	17,900	26,913
Total	**1,696**	**29,591**	**50,730**	**81,997**

Source: ISAAA, 2019

adopting farmers (Figure 12). In 2018-2019, an estimated total of 26,913 trials were conducted by BAR, DAE, and BADC (Table 19).

Multiple studies have demonstrated a dramatic reduction in insecticide use and a large increase in profit (Rashid et al., 2018; Ahmed et al., 2020). Farmers are realizing a six-fold increase in their returns of up to US$2,151/ha as compared to US$357/ha for non-Bt eggplant and saving almost 60% on pesticide cost compared to non-Bt eggplant farmers (Rashid et al., 2018). Bt eggplant has proven to be far superior to its non-Bt counterparts with negligible fruit infestations in Bt eggplant compared to 45% in the non-Bt eggplants (Prodhan et al., 2019). Furthermore, these same studies confirmed the increased environmental safety of Bt eggplant compared to the non-Bt eggplant.

Riding on this success, it is essential to adopt efficient lab and field stewardship practices to ensure sustainability of the technology in farmers' fields of Bangladesh. And to scale-up the adoption, the release of new and agronomically superior varieties and/or hybrids introgressed with Bt technology is important. Introduction of second-generation products would further build durability of the technology and delay the build-up of resistance in EFSB (Zulfikar et al., 2019).

Other economically important crops in Bangladesh are being improved for disease resistance, insect resistance and nutritional quality. This includes wheat (blast resistance and salt tolerance), tomato (leaf curl virus resistance), potato (late blight resistance), papaya (papaya ringspot virus resistance), rice (B-carotene enhanced, salt tolerance, late blight resistance) and cotton (bollworm and armyworm). It is noteworthy that strong public and private collaborations/partnerships exist in Bangladesh for research and development.

Benefits of IR (Bt) Eggplant in Bangladesh, 2014-2018

Brookes and Barfoot (2020) estimated that the farm income in Bangladesh was enhanced due to the large scale adoption of IR eggplant varieties estimated at US$4 million for the period 2006 to 2018 and the benefits for 2018 alone was at US$2.1 million, which will benefit the families and communities of the 17,900 IR cotton farmers.

INDONESIA

The planting of drought tolerant sugarcane event NX1-4T in Indonesia in 2018, marked the resumption of biotech crop planting in the country. Drought tolerant sugarcane was planted on 1,342.59 hectares in 2018 which increased to 2,000 hectares in 2019, an increase of 657 hectares (49% increase).

Indonesia is the number one sugar importing country around the world valuing at US$2 billion, which is 8% of total sugar imports. Sugarcane is sensitive to drought and high temperature, and these stresses can result in thin and short stem yield. The development of drought tolerant sugarcane was conducted to address the increasing domestic sugar demand in the face of climate change.

The drought tolerant biotech sugarcane variety named Cane PRT Drought Tolerant NX1-4T was developed by an Indonesian State-owned company, PT. Perkebunan Nusantara XI (PTPN-11) in collaboration with Jember University in East Java and PT. Ajinomoto Company International, Japan in 1999 (Rijzaani, 2013). The Indonesian state-run sugarcane producer 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 biotech sugarcane contains choline dehydrogenase gene (*betA*) obtained from a nitrogen-fixation bacteria *Rhizobium meliloti*. The biotechnology laboratory of PTPN-XI developed gene construct pM LH2113 (under the control of CaMV35S promoter followed by the successful genetic transformation of elite sugarcane variety TP2V through *Agrobacterium tumefaciens* strain LBA 4404. Several studies conducted to assess food safety and environment assessment in the period 1999 to 2013 (PTPN XI, 2014) revealed that the 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 the sugar production during drought stress in NX1-4T yielded 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 sugar cane content and yield (Sugiharto, 2017). The green house confined trial proved that the transgenic sugarcane survived for a longer period of time and developed a longer root profile during water stress. The transgenic sugarcane has been assayed for environmental, food and feed safety and was approved by the Indonesian Biosafety Commission for commercialization. The drought tolerant transgenic sugarcane has been released by the Indonesian Ministry of Agriculture. It was named NXI-4T cultivars and is used for sugar production in PT. Perkebunan Nusantara XI. During drought conditions, the transgenic sugarcane's production was found to be 20-30% higher than its conventional parental line. Future research plans include investigating traits that will enhance the crop's performance in dry conditions.

The drought tolerant sugarcane was issued the feed safety certificate by the Ministry of Agriculture on August 20, 2018, making it the first GE crop to be eligible for commercial cultivation. This particular drought tolerant sugarcane was previously granted a biosafety certificate, thus it did not require to wait for the establishment of the country's monitoring guidelines. The status of this crop's commercialization is unique because the PTPN XI's sugarcane is currently only grown on lands owned by PTPN XI and the company itself is restricted from selling or distributing the seeds due to lack of proper registration to do so. It is also unlikely that they will apply for such registration in the future, as the demand may be relatively limited to specific areas that frequently suffer from drought.

To summarize, there are 29 biotech/genetically engineered crops that have undergone risk assessment for either food, feed or environmental safety: 15 maize varieties, 9 soybeans, three sugarcane, one potato, and one canola have undergone risk assessment for either food, feed or environmental safety.

There are also various research and development activities being conducted to improve crops. These include stem borer resistant rice which has already completed confined field trials; tungro virus resistance, drought tolerance and salinity tolerance, and blast resistance in rice; and extended shelf life cassava from the Indonesian Institute of Science (LIPI). Some other researches include virus resistant tomato, late blight resistant potato, nitrogen use efficiency rice, IR rice, and genome editing for geminivirus resistant chili, greening disease resistant citrus, and low cadmium absorbent rice at the Indonesia Center for Agricultural Biotechnology and Genetic Resources (ICABIOGRAD).

The University of Jember, in collaboration with PT Perkebunan Nusantara XI, conducts research on high glucose content sugarcane, mosaic virus resistant sugarcane, and Golden Rice in IR36 and IR64 background. USAID is funding the development of a GE late blight resistant potato in partnership with Michigan State University, the University of Minnesota, University of Idaho, JR Simplot Company, and ICABIOGRAD, and organized under the Feed the Future Biotechnology Partnership Project. Arcadia Biosciences Inc. collaborated with MOA to complete their research on evaluating GE nitrogen use efficiency rice.

SUMMARY AND FUTURE PROSPECTS IN ASIA AND THE PACIFIC

Biotech countries in the Asia and Pacific region are led by India with the largest area of biotech crops at 11.9 million hectares cotton, followed by China (3.2 million hectares cotton and papaya), Pakistan (2.5 million hectares cotton), Philippines (875,000 hectares biotech maize), Australia (614,446 hectares cotton, canola and safflower), Myanmar (300,000 hectares cotton), Vietnam (92,000 hectares maize), Bangladesh (1,931 hectares eggplant), and Indonesia (2,000 hectares drought tolerant sugarcane). This region planted 19.5 million hectares in 2019, a 2% increase from 19.1 million hectares in 2018, 10.2% of the global biotech crop area of 190.4 million hectares.

Increases in biotech area were obtained in India (313,000 hectares, at 3%), China (245,000 hectares, 8%), Philippines (245,000 hectares, 38%), Vietnam (43,000 hectares, 46%), Bangladesh (427 hectares, 22%) and Indonesia (650 hectares, 32%). 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. The favorable climate during the maize planting period and the attractive global maize price motivated Filipino farmers to plant more biotech maize. In Vietnam, the high price of imported maize and increasing fall armyworm incidence increased biotech crop area. At the moment, the planting of drought tolerant sugarcane in Indonesia is only limited to government-owned farms, thus limiting its potential to contribute to the country's sugar industry.

However, these area expansions of biotech crops were made almost even by the decreases in biotech crop area in Pakistan (287,000, -11%) and Australia (186,000, -30%). In Pakistan, the slight reduction in area was again due to the uncertainty in approval of new generation biotech traits and high yielding cotton varieties IR/HT cotton, 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 2019 affected canola and cotton (biotech and total) area. Australia's canola planted area was the smallest on record, but the adoption rate of biotech canola went up due to better weed control and higher profit. There was a minimal decrease in Bt cotton area planted in Myanmar. New biotech cotton varieties and the approval of the new Biosafety Framework could increase the area planted in the future.

The expansion of biotech crops and traits in the Asia and the Pacific region is still a challenge. There are a number of 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 soybeans 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 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 is the delay in approving new biotech crops and traits, specifically in China. 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 protest of critics have become a strong barrier for trade and commercialization of biotech crops. Strengthening the already sensitized groups in these parts of the world such as the academics, researchers, and students and using them to expand knowledge on the technology and the benefits to reach the policy makers and regulators are vital in moving biotechnology forward in the region.

Finally, the estimated over 16 million biotech farmers in the developing countries of India, China, Pakistan, Philippines, Australia, Myanmar, and Bangladesh have been benefiting immensely in the last 23 years of commercialization. Economic benefits estimated by Brookes and Barfoot (2020) from the respective countries since the start year of planting until 2018 is over US$56.1 billion and for 2018 alone, was US$3.7 billion. Indonesia is not yet included in this estimate. 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

In 2019, Africa doubled the number of countries planting biotech crops from three in 2018 to six, positioning the continent for a major take-off towards agri-biotechnology adoption. The countries in descending order of biotech crop area are South Africa, Sudan, Malawi, Nigeria, Eswatini, and Ethiopia (Table 20). Kenya's cultivation approval came in late December

Table 20. African Countries Planting or with Commercial Approval of Biotech Crops by 2019

Country	Crop	Area (Hectares)
South Africa	Maize (Stack Bt and HT)	1,945,622
	Soybeans (HT)	693,975
	Cotton (Stack Bt and HT)	43,654
Sudan	Bt Cotton	236,200
Malawi	Bt Cotton	6,000
**Nigeria	Bt Cotton	700
Eswatini	Bt Cotton	401
Ethiopia	Bt Cotton	311
	Total	**2,926,863**
**Kenya*	*Bt Cotton*	*Commercial planting approved in December 2019*

Note: **Nigeria approved Bt cowpea varieties for cultivation. This raised the number of approved biotech crops in Africa to four, ref: cotton, cowpea, maize, and soybeans

2019, hence, there was no planting conducted yet. Each of the three new countries (Ethiopia, Malawi, and Nigeria) launched Bt cotton planting with a modest area. A lot of effort was put in training farmers on good agronomic practices and stewardship in readiness for full commercial cultivation in the year 2020. In total, seven African countries have the necessary biosafety approval to cultivate biotech crops, with three countries planting Bt cotton for the first time.

South Africa, Sudan, and Eswatini sustained previous growing of biotech crops with a combined estimated area of 2.93 million hectares, an increase of 0.6% from the 2.9 million hectares grown in 2018. The total biotech area from the six countries was 2,926,863 hectares (~2.93 million hectares).

SUDAN

Sudan approved its first biotech crop, IR cotton, for commercial planting in 2012. The year 2019 marked the eighth year of commercialization of biotech crops in Sudan. A total of 236,200 hectares of IR(Bt) cotton were planted, with a slight drop of 2.9% from the 243,000 hectares of IR(Bt) cotton planted in 2018 (Figure 13). The estimated number of farmers remained at 150,000 with average farm sizes of 2.1 hectares with a 98% adoption rate of biotech cotton. The drop in hectarage was attributed to the breakdown of some irrigation systems and extreme weather during the cropping season where there was severe flooding followed by a long dry spell. Two companies, the Chinese Centre and JK Agri-Genetics of India through a local company Elaeena, supplied the Bt cotton seed, most of which was IR hybrids. The public sector also contributed in production of open-pollinated varieties (OPVs) in the irrigated schemes. Both the public and private sector seed suppliers have a distribution arrangement in accordance with quotas as required by the different companies or farmers.

The IR cotton program in Sudan continue to spur positive change in the entire cotton sub-sector value chain from production through reduced number of chemical sprays, higher yields and labour-saving, intermediate services such as input supplies, transport to ginneries to textile mills and cottonseed oil extraction industries. Moreover, three new companies have indicated interest to introduce new cotton varieties. Sustaining this momentum will require strengthening of the cotton-breeding program to meet market needs and good stewardship to curb introduction of unapproved genes through smuggling.

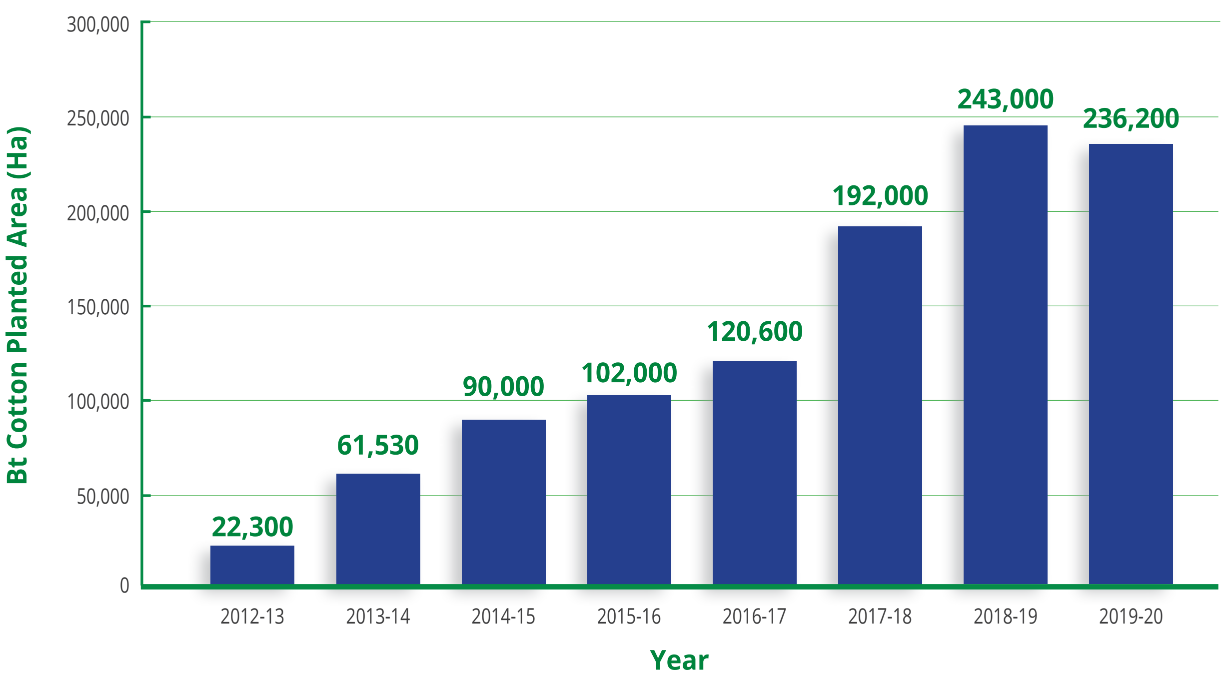


Figure 13. Bt Cotton Adoption in Sudan 2012-2019

Source: NBSC

Sensitization and increased awareness among farmers to avoid cultivating unapproved varieties will also be key.

MALAWI

The first IR (Bt) cotton commercial cultivation in Malawi was launched in 2019. A total of 6,000 hectares were grown with four hybrids by close to 2,000 farmers. The average farm size in Malawi is about 1.2 hectares and farmers practice mixed cropping. The Bt cotton hybrid seed was provided by Mahyco of India through their subsidiary company, Quton. The approval followed successful three-year trials on IR cotton hybrids in the country, which was approved for commercialization in December 2018. The release of Mahyco cotton IR hybrids coincided with the Government of Malawi's two-year pledge to support cotton production to the tune of MK 2 Billion (US$2.7 million) through the Cotton Council of Malawi (CCM). The revolving fund aimed to increase productivity and production through the procurement of quality seeds and other inputs for farmers. About 32 metric tons IR hybrid cotton seeds were sold to farmers across all six cotton growing Agricultural Development Divisions (ADDs), covering 52 Extension Planning Areas (EPAs). In addition to the seeds sold by CCM to farmers, Quton also gave out 2 metric tons of seeds to about 2,000 farmers as free samples across all the cotton-growing areas.

The farmers remained confident of getting at least 1.5 metric tons of extra yield of seed cotton per hectare over the traditional varieties, which only yield 500 kg per hectare on average. In this first year, yields of between 2-3mt/ha were evident and the projection was that many farmers were likely to get much higher yields than the average. It is encouraging to note of farmers adhering to the agronomic and stewardship recommendations made by extension officers. They were also eager to get sustainable seed supply for subsequent seasons. Smallholder farmers paid cash to purchase seeds from various Extension Planning Areas, instead of loaning the seeds. Historically, farmers have been receiving free or credited farm inputs for cotton cultivation. The willingness of farmers to pay cash for the seeds shows their confidence in the technology and cotton cultivation. They have the option to choose their preference, and are more open to learn the new techniques to improve productivity and farm income. Banks are also willing to provide crop loans as the credit score of the farmers improve. Importantly, Mahyco initiated training 450 Malawian farmers on Bt cotton hybrid seed production, which will be implemented in three locations: Machinga, Shire Valley, and Salima agricultural development districts (ADD). The objective of the training is to create competency and capacity for in-country production of commercial seeds.

NIGERIA

In 2019, the Federal Government of Nigeria made two landmark approvals: the commercial cultivation of Bt cotton and the regulatory approval for Bt cowpea. The Bt(IR) cotton was planted on 700 hectares, mainly through on-farm demonstration plots for two Bt cotton hybrids, provided by Mahyco of India. The planting coincided with the government's initiative to revive the cotton sector and followed two years of multi-locational trials conducted by the Institute for Agricultural Research, Zaria.

The primary objective of the demonstration plots was to promote the value of the hybrids and technology to Nigerian farmers in their own fields. The demonstrations also aimed to familiarize the public with the biotech crop and train farmers on appropriate product management using the correct agronomic practices to maximize the crop's benefits.

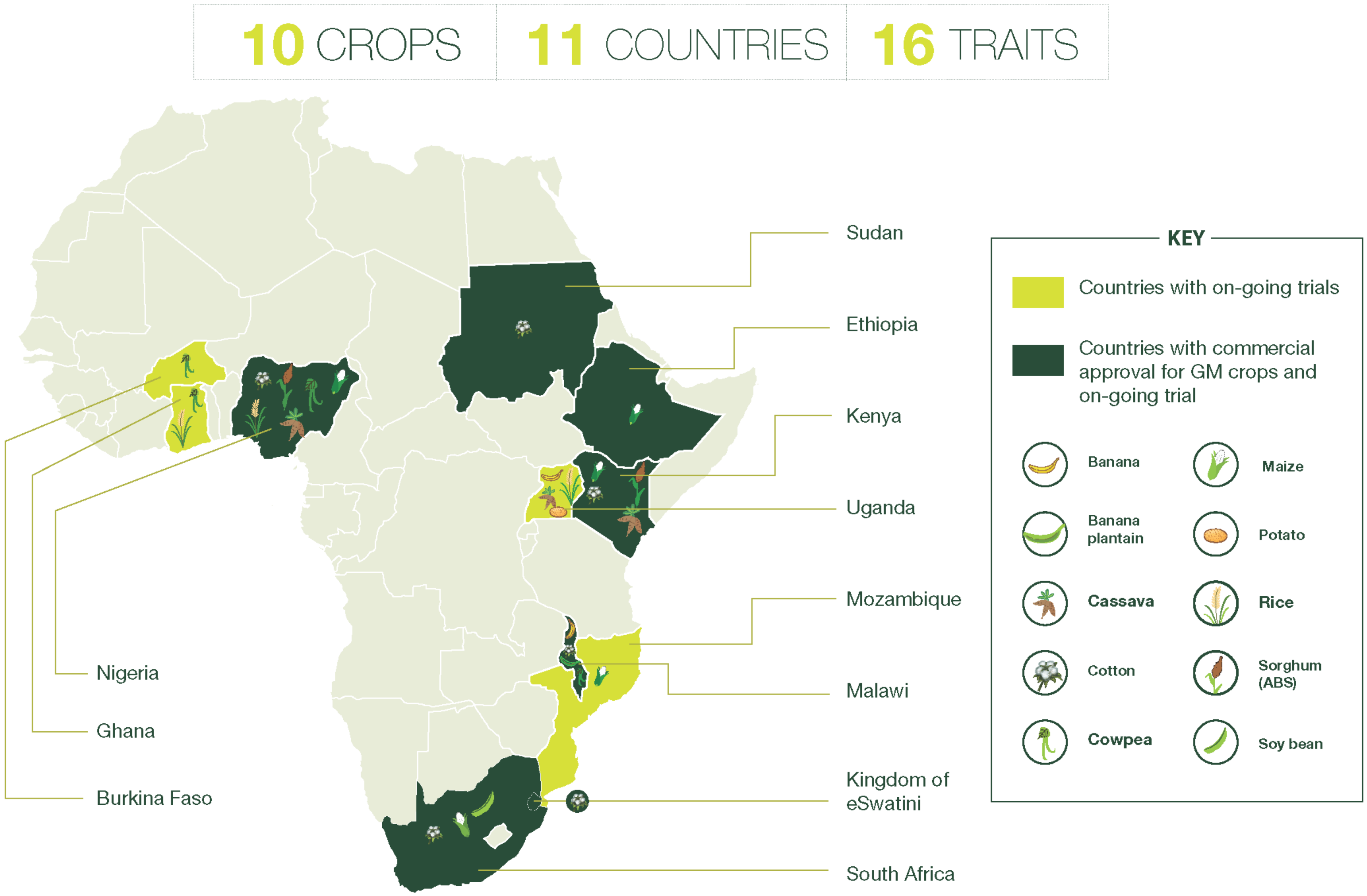


Figure 14. Africa Biotech/GM Research and Commercialization Status by 2019

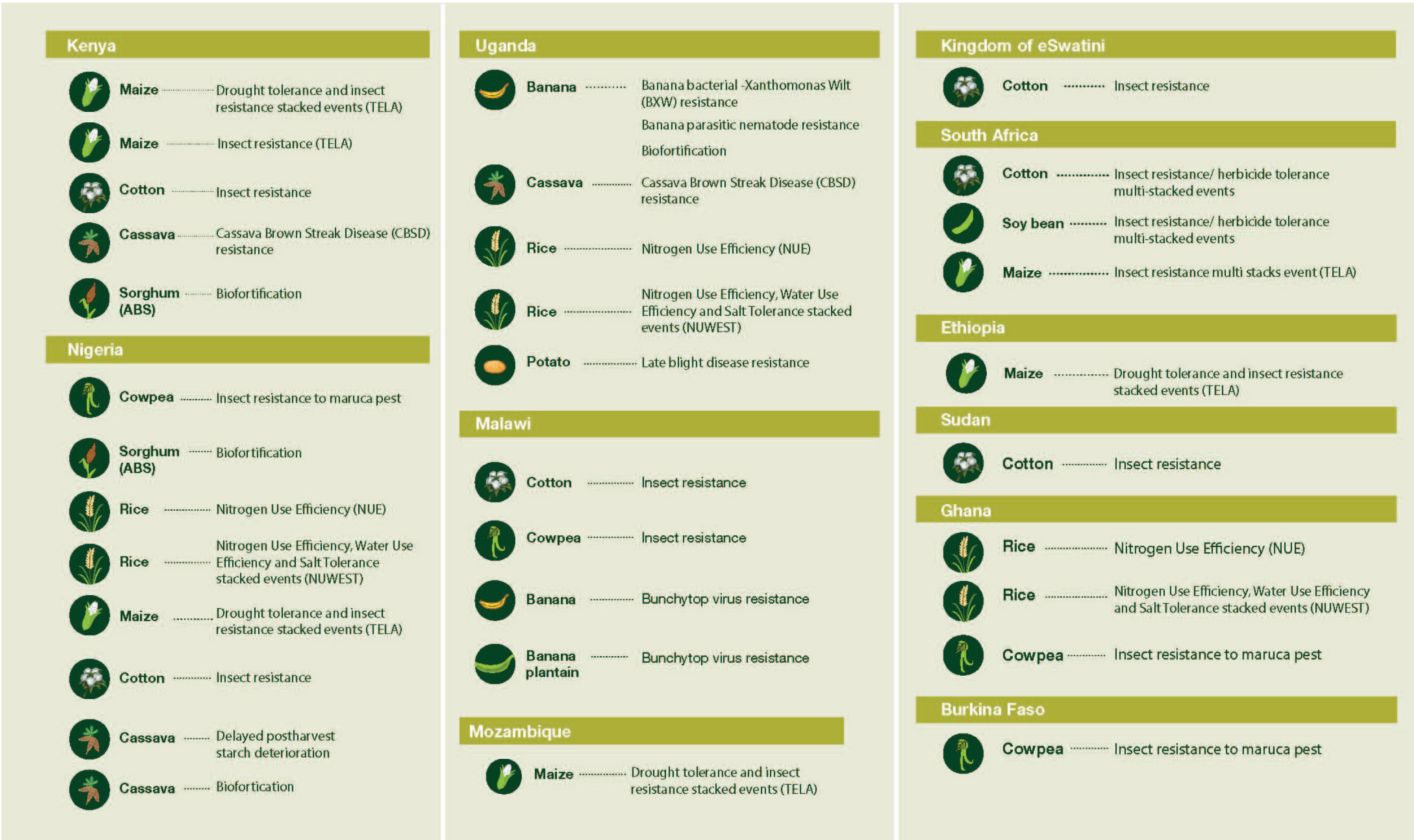


Figure 15. Crop Traits Under Various Stages of Research in Africa by 2019

More than 2,000 free samples were distributed to select farmers across key cotton-growing regions of the North-East and North-West zones. More than 10,000 farmers benefited in the demonstration programs in preparation for the crop's wide-scale planting in 2020.

IR cotton hybrids have demonstrated significantly higher yield levels compared to the conventional varieties, exhibiting superior cotton quality and decreased cost of pest control, thereby increasing the potential to improve farmers' incomes. The revival of cotton farming is estimated to strengthen the country's economy by generating over 450,000 cotton mills and revival of another 180 more. This will contribute close to 20 percent of the nation's gross domestic product (GDP) and employment opportunities through revitalization of cotton subsector value chain actors.

In the case of Bt cowpea, the Federal Government of Nigeria approved the commercialization of the biotech cowpea variety resistant to pod borers. This development placed Nigeria as the first country to commercialize genetically improved cowpea globally. The approval was a culmination of more than ten years of intensive trials of genetically modified (GM) cowpea and a breakthrough in the efforts to eradicate *Maruca vitrata* pod borer, an insect pest that can cause up to 80 percent yield loss. The new variety, named SAMPEA 20-T, was developed by scientists from the Institute of Agricultural Research, Ahmadu Bello University, Zaria in collaboration with several partners under the coordination of the African Agricultural Technology Foundation (AATF). By issuing the variety registration for commercialization, the National Committee on Naming, Registration and Release of Crop Varieties ruled that it met the set criteria: high yielding, early maturing and an observed added advantage of resistance to striga and Alectra, two notorious parasitic weeds that are also a major constraint to cowpea production in Nigeria and other dry savannah regions. The protein and nutrient content of variety SAMPEA 20-T was also comparable to that of other conventional varieties, meaning that the Bt gene that was introduced into the variety has no negative influence on the nutritional composition of both grain and fodder.

Cowpea is an important staple food crop in Nigeria and is used by millions of farmers for provision of a cost-effective, high protein diet, as opposed to animal protein (fish, poultry, and beef). The adoption of Bt cowpea will help improve the country's foreign exchange which is estimated at close to 500,000 tons worth of cowpea deficit that has to be imported due to low productivity caused by pests. Nigeria is the world's largest consumer of cowpea with an annual consumption of 3.6 million tons. The government is dedicated to ensuring local seed production, and 2019 was dedicated to foundation seed production for large-scale multiplication of certified seeds for planting in 2020. This will help smallholder farmers to purchase the improved seed through local companies' seed distribution system.

ESWATINI

In its 2nd year of commercialization, the area planted under Bt cotton in the Kingdom of Eswatini in 2019 was 403 hectares, an increase of 38% from the previous 250 hectares. Although the seeds arrived late, the farmers were still able to utilize the leftover seeds from 2018 cropping season. The target for the season was 800 hectares under irrigation but there were delays in issuance of the seed import permit to JK Agri-Genetics company of India that supplied the initial IR cotton seed. This resulted in the seeds arriving in late January 2019, which was already late for the cropping season. The leftover seeds were then supplied to large-scale cotton growers who planted the cotton under irrigation. Small scale growers continued to produce conventional cotton at 1,357 ha. One of the challenges that require urgent attention is the supposedly high seed price at US$30/kg, which is further complicated by the lengthy import permits' procedure. This issue could derail the adoption process, especially by small-scale growers.

ETHIOPIA

The year 2019 was the first commercial planting of a biotech crop in Ethiopia. Bt(IR) cotton was cultivated on 311 hectares in Gambella and Humera regions. This was after completion of the confined field trials conducted between 2017 and 2018 in six different locations under the auspices of Ethiopia Institute of Agricultural Research (EIAR), Ministry of Agriculture and Livestock. In issuing the commercialization approval, the Biosafety Affairs Directorate of the Ministry of Environment, Forest, and Climate Change (MOEFCC), the newly structured Environment Forest and Climate Change Commission, and the biosafety technical working team drawn from different institutions, expressed satisfaction with the final report submitted by EIAR. The approved Bt cotton hybrids, namely were obtained from the Indian company, JK Agri-Genetics. The country has a vibrant textile sector and the government has given its full support to the cotton subsector. The introduction of Bt cotton is therefore viewed as a strategy to increase domestic cotton production and supply the anticipated high demand for raw material. This is expected to generate thousands of jobs in the cotton sub-sector value chain in the country. However, ensuring sustainable access to Bt cotton hybrid seed by farmers remains to be a challenge due to the limited supply of FOREX to import the seed, thus making it expensive for farmers. This highlights the need to establish mechanisms for local Bt cotton seed production.

FUTURE PROSPECTS IN AFRICA

The major landmark commercial approval in 2019 was Nigeria's Bt cowpea, making it the first country globally to commercialize Bt cowpea. The biotech cowpea was also Nigeria's first GM food crop to get regulatory approval by the country's Biosafety Management Agency (NBMA). The more than ten years of intensive trials generated adequate data for assuring safety of the crop for food and feed, as well as to the environment. This biosafety decision has provided impetus for neighboring countries of Burkina Faso and Ghana that have also been conducting similar trials for the Bt cowpea trait and are gearing towards reaching a biosafety decision for the same in the near future.

Other African countries continued to transition from conducting confined field trials to the environmental release phase. In Mozambique, researchers from the Mozambique Institute of Agricultural Research (IIAM), sought approval for insect resistant and drought tolerant maize under the TELA project. An application submitted to the National Biosafety Authority (NBA) under the Ministry of Science and Technology was reviewed and is awaiting biosafety decision from the Science and Technology Minister. The TELA maize project is a public-private partnership coordinated by AATF, and aims towards the commercialization of transgenic drought tolerant and insect resistant maize varieties for enhanced food security in sub-Saharan Africa. The project transitioned out of the positive outcomes from its predecessor Water Efficient Maize for Africa (WEMA) project.

Cassava researchers from the Kenya Agricultural and Livestock Research Organization submitted an application to the country's National Biosafety Authority seeking approval for cassava brown streak disease (CBSD) resistant Cassava Line 4046 under the VIRCA Plus project. Resistance to CBSD is projected to protect cassava farmers from devastating losses estimated at 100% under severe infestation. The application is undergoing review by Kenyan regulatory agencies and independent experts, to ensure safety of the genetically modified CBSD resistant cassava line to human and animal health, and to the environment. The application was prepared by Kenyan scientists together with partners at Donald Danforth Plant Science Center and Uganda's National Crops Resources Research Institute. The biosafety decision expected will be the first global approval for a biotech cassava. Ugandan scientists were however unable to submit the same application as intended due to non-assent of the Genetic Engineering Regulatory Act (GERA) by their President citing some concerns with the Law. On the other hand, Rwanda, another East African country neighboring Uganda joined the VIRCA plus project and initiated preparatory activities in readiness to start conducting trials for the same CBSD trait in 2020. It is anticipated that Rwandan scientists will move fast in delivering genetically improved cassava varieties to farmers through this collaboration from the wealth of experiences and lessons learnt by their Kenyan and Ugandan counterparts over the years.

The continent continued to improve its biosafety regulatory environment in order to facilitate development and adoption of GM crops and products. The Republic of Niger passed its Biosafety Law in October 2019. The law will provide safety measures in research and development of living modified organisms (LMOs) and its products with respect to modern biotechnology and for transboundary movement. It also aims to help guarantee food security for the country's population of approximately 23.5 million people.

Meanwhile, Ghana's government considered new regulations that would facilitate the adoption of genetically modified (GM) food in the country. The Biosafety Management of Biotechnology Regulations 2019, a legislative instrument, was passed by the Ghanaian parliament.

Burkina Faso moved a step further towards strengthening its biosafety regulatory system following the inauguration of the National Biosafety Laboratory in September 2019 in Ouagadougou.

There was increased awareness of biotech/GM crops among African farmers in 2019. With increased knowledge, farmers have shown appreciation of the technology in addressing farming and food security challenges as well as their economic hardships. For instance, farmers in northern Ghana called on their government to speed up the commercialization of GM crops in the country. During a media briefing in Tamale in May 2019, representatives of farmer groups under the coalition of Concerned Farmers of the Northern Region expressed concern about the continuous decline of cotton and cowpea production in that part of the country.

The Kenyan farmers' appeal to their government paid off following the approval of Bt cotton for open cultivation in the country. In April 2019, during the country's first national dialogue on GM crops, farmers urged the government to approve the GM crop saying they have recorded big losses with conventional cotton due to its susceptibility to the African bollworm. The chairman of the Society for Biotech Farmers of Kenya (SOBIFAK) said farmers have been "waiting for GM cotton and maize far too long".

In February 2019, the International Institute of Tropical Agriculture (IITA) submitted an application to the National Biosafety Management Agency of Nigeria for the conduct of confined field trials of genetically engineered cassava with increased starch yield.

Furthermore, a number of African countries moved close to endorsing trade with biotech crops. Zambian government continued importing GM foods as the country's authorities expressed confidence that GM food is safe for consumption. Zambia Health Minister Dr. Chitalu Chilufya told the Parliament about results of studies conducted about GM food consumption, which indicated GM foods have no effect on the health of human organs. Zambian government's confidence in GM foods was further demonstrated when the country's National Biosafety Authority (NBA) released permits to four companies to import products that 'may' contain genetically modified components.

In Nigeria, the Open Forum on Agricultural Biotechnology (OFAB) stepped up its efforts to raise awareness and appreciation on agricultural biotechnology by rolling out a biotechnology awareness program in Nigerian schools in addition to increased grassroots outreach.

The increasing acceptance and adoption of biotech crops in the African continent observed in 2019 is a critical step in the quest for food sustainability (Figures 14 and 15). The success in this endeavor should be mirrored in other African countries. This will require sustained dissemination of factual information, education, and awareness activities on all attributes of crop biotechnology to curb gross misinformation that has led to policy impasse in some countries. Partnerships among the research and development institutions, the government, and the private sector should be forged to make this possible.

EUROPEAN UNION

Since 2016, only two countries cultivated biotech crops in the European Union: Spain and Portugal. In 2019, Spain cultivated 107,130 hectares and Portugal 4,753 hectares for a total of 111,883 hectares, 7.5% less than the biotech maize area of 120,980 hectares in 2018 (Figure 16).

The EU produces biotech maize but imports large amounts of biotech crops for feed. In 2019, the EU has imported more than 30 million metric tons (MT) of soybeans and soybean products (90-95% biotech), 10 to 20 million MT of maize products (20 to 25% biotech), and 2.5 to 5 million MT of rapeseed products (close to 25% biotech) per year, mainly for feed. The production of soybeans in the EU was low, estimated to be 2.6 million MT in 2019, compared to the more than 30 million MT of soybean products imported every year (USDA FAS, 2019). For maize, imports account for 10% of supply. The EU imports these products from Argentina, Brazil, and the United States, and may likely not to change in the medium-term.

SPAIN

Spain has been planting biotech maize for 20 years since 1998, and in 2019 has contributed ~96% of the 111,883 hectares in the total biotech maize area in the EU (Figure 16). Spain planted 107,130 hectares, a decline of 7% from 2018, which was 115,247 hectares. Biotech maize and conventional maize co-exist in the cornfields of Spain. 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 water availability, irrigation costs, prices paid to farmers, the season's incidence of European corn borer, and competition from alternative crops.

There were 12 regions in Spain that cultivated biotech maize in 2019. The autonomous regions of Aragon and Catalonia had the highest share of Spain's biotech maize area at 40% and 34%, respectively (Table 21), because the insect pest

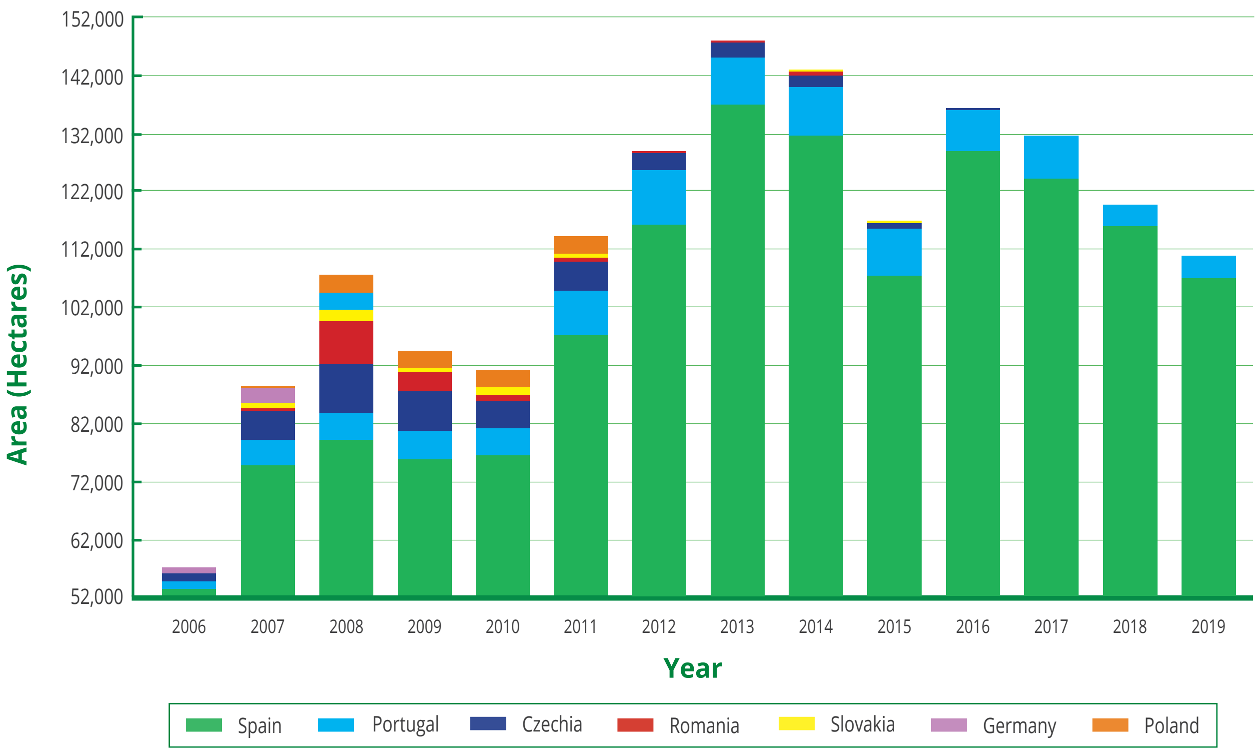


Figure 16. Biotech Maize Area in the European Union, 2006-2019 (Hectares)

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 since 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 soybeans in 2006 but had to cease growing it after becoming an EU member in January 2007.

Source: ISAAA, 2019

Table 21. Area of Biotech Maize by Region in Spain (Hectares)

Region	2013	2014	2015	2016	2017	2018	2019	% Biotech Area
Aragon	54,451	54,041	42,612	46,546	49,608	44,932	42,646	40%
Catalonia	33,996	36,381	30,790	41,567	39,092	38,752	36,430	34%
Extremadura	16,979	13,815	9,827	15,039	13,976	14,138	12,255	11%
Navarra	7,013	7,264	6,621	8,066	7,778	8,101	8,253	8%
Castile-La Mancha	8,766	7,973	5,734	5,932	5,069	3,805	3,101	3%
Andalucia	12,862	10,692	11,471	10,919	8,013	4,972	3,795	4%
Others*	2,895	1,371	695	1,011	691	547	650	1%
Total	**136,962**	**131,537**	**107,750**	**129,081**	**124,227**	**115,247**	**107,130**	

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

Source: Ministerio de Agricultural Y Pesca Alimentacion Y Medio Ambiente, 2019

European corn borer is endemic in these areas. The region of La Roja did not plant in 2018 and 2019.

The total area planted to maize increased by 11% from 322.4 million hectares in 2018 to 359 million hectares in 2019. With not much increase in biotech maize planting, adoption rate declined in 2019. Industry sources which provide the biotech planting area estimates through seed sales indicate similar seed sales as last year's planting season. The decline in the planting area is due to more average planting density of 95,000 seeds per hectare this year compared to the 85,000 seeds per hectare in 2018.

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.

Benefits from Biotech Maize

Some 5,500 farmers have benefited from growing biotech maize in the period 1998 to 2018, at an estimated US$324 million, and reached US$25.3 million in 2018 alone (Brookes and Barfoot, 2020). These are enormous benefits continuously being brought to farmers in Spain in the last 21 years of Bt maize adoption.

PORTUGAL

Portugal has been planting 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 2019, a further decline in maize area was observed: from 118,220 hectares in 2018 to 113,930 hectares, a 4% decline. Simultaneously, there was a decline in biotech maize area by 17% from 5,733 hectares to 4,753 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 have planted biotech maize. Alentejo and Lisboa were the regional leaders in the biotech maize area, at 58% and 27%, respectively (Table 22). Maize grown for grain were planted in these areas compared to the Norte region where maize was grown for silage, and 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 seasons 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, the USA, and Argentina.

Table 22. Area of Biotech Maize by Region in Portugal, 2012-2019 (Hectares)

Region	2012	2013	2014	2015	2016	2017	2018	2019	% of Total Biotech (2018)
Total Maize	143,000	147,000	137,000	126,000	118,000	115,667	118,220	113,930	
Norte	165	85	78	60	100	46	61	56	1%
Centro	774	853	933	1,013	1,485	1,609	1,311	1,262	27%
Lisboa	2,322	2,215	2,074	2,002	2,138	2,466	1,023	700	15%
Alentejo	5,796	5,041	5,457	4,942	3,346	3,187	3,338	2,735	58%
Algarve	13	8	0	0	0	0	0	0	0
Açores	208	0	0	0	0	0	0	0	0
Total Biotech	**9,278**	**8,202**	**8,542**	**8,017**	**7,069**	**7,308**	**5,733**	**4,753**	
Adoption Rate	**6.50%**	**5.60%**	**6.20%**	**6.40%**	**6.00%**	**6.30%**	**4.85%**	**4.0%**	

Source : Dados Nacionais, 2019. Republica Portuguesa.

BENEFITS FROM BIOTECH MAIZE IN THE EU

Brookes and Barfoot (2020) estimated an economic benefit for the EU of US$348 million for 1998 to 2018, and US$26.3 million for 2018 alone. In another earlier study, Brookes and Barfoot (2018), enumerated various benefits of biotech crops for EU farmers. Planting GM maize for food and feed would use fewer resources and decrease the use of insecticides and fossil fuels during crop spraying. In terms of farmers' income, planting GM maize has resulted in an increase in crop yield and the reduction of expenses for pesticide control, therefore providing farmers with higher income averaging €173 (US$210) per hectare and an average return on investment of +€4.95 for each extra €1 (US$1.21) spent on GM maize seed, as compared to using conventional maize seed. This was proven to have helped farm household incomes and, in the long run, boosted the rural and national economies of both countries. While the use of GM insect resistant maize was proven to have contributed to addressing crop production, environmental challenges, and has increased farmers' income, Brookes and Barfoot also pointed out that there are still members of the European Union that opted to ban the cultivation of GM maize despite being approved for planting in EU many years ago. These countries are missing out on the economic and environmental benefits of GM maize.

SUMMARY AND FUTURE PROSPECTS

The acceptance of biotech crops for cultivation has not improved in the last 24 years. Two countries planted biotech maize because of the infestation brought by the European corn borer. Since 2016, only Spain and Portugal planted biotech Bt maize at 107,130 hectares and 4,753 hectares, respectively, for a total of 111,883 hectares, 7.5% less than the biotech maize area of 120,980 hectares in 2018.

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 imports of more than 30 million metric tons (MT) of soybeans and soybean products (90-95% biotech), 10 to 20 million MT of maize products (20 to 25% biotech), and 2.5 to 5 million MT of rapeseed products (close to 25% biotech) per year, mainly for feed. This situation is expected to continue as there is no change in the EU regulation, there is no approval for cultivation in sight, and the movement against biotech crops remains present. 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 the renewal of three existing authorizations for maize and sugar beets were approved for food and feed uses.

In 2018, the European Court of Justice issued its decision that organisms created through innovative biotechnologies should be regulated as GE organisms in the EU. This is currently being appealed by biotech industries, associations, and scientist groups because of the negative impact that it will generate to agricultural research and could create trade disruptions.

DISTRIBUTION OF BIOTECH CROPS, BY CROP

Of the 32 crops approved for food, feed, and environmental release recorded at the ISAAA GM Approval Database, only 14 crops have been planted by 29 countries in 2019. There were four major biotech crops: soybeans at 91.9 million hectares, followed by maize (60.9 million hectares), cotton (25.7 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, potatoes, squash, brinjal, apples, pineapple, sugarcane, and safflower, the two latter crops planted in 2018 (Table 23). Cotton has been planted in the most number of countries (18) including the new African countries of Malawi, Nigeria, and Ethiopia, followed by maize (14), and soybeans (8).

The adoption trend provided in Figure 17 and Table 23 indicates the increase in area planted to biotech maize and cotton, a decrease in soybeans, with minimal changes in canola and alfalfa.

Biotech soybean area was 48% of the global biotech area

Biotech soybeans have been planted on 91.9 million hectares, which is 48% of the global area planted to biotech crops, and have been planted in eight countries led by Brazil (35.1 million hectares), USA (30.4 million hectares), Argentina (17.5 million hectares), Paraguay (3.6 million hectares), Canada (2.1 million hectares), Bolivia (1.4 million hectares), Uruguay (1.1 million hectares) and South Africa (694,000 hectares). For the first time, Brazil surpassed the biotech soybean area of the USA by 15.4% or 5.2 million hectares.

There were increases in biotech soybean areas in 2019 compared to 2018; in Brazil (257,000 hectares), Paraguay (205,000 hectares), Bolivia (96,000 hectares), and Chile (1,000 hectares). Biotech soybean area decreased in the USA by 3.6 million hectares, Argentina (477,000 hectares), Canada (343,000 hectares), Uruguay (171,000 hectares), and South Africa (21,000 hectares).

The total biotech soybeans area of 91.9 million hectares comprised 64.3 million hectares HT and 27.6 million hectares stacked IR/HT (Intacta™) – an increase of 4% or 1 million hectares in 2018. The stacked trait soybeans were deployed successfully in Brazil, Argentina, Paraguay and Uruguay. Planting of Intacta™ has provided economic benefits amounting to US$10.2 billion

Table 23. Global Area of Biotech Crops, 2018 and 2019: by Crop (Million Hectares)

Crops	2018	%	2018	%	+/–	%
Soybeans	95.9	50%	91.9	48.2%	–4.1	–4%
Maize	58.9	31%	60.9	32.0%	2.0	3%
Cotton	24.9	13%	25.7	13.5%	0.8	3%
Canola	10.1	5%	10.1	5.3%	0.0	0%
Alfalfa	1.3	1%	1.3	0.7%	0.0	0%
Sugar beets	0.5	<1	0.5	0.2%	0.0	<1
Papaya	<1	<1	<1	<1	<1	<1
Others*	<1	<1	<1	<1	<1	<1
Total	**191.7**	**100.0%**	**190.4**	**100.0%**	**–1.3**	**–0.7%**

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

Source: ISAAA, 2019

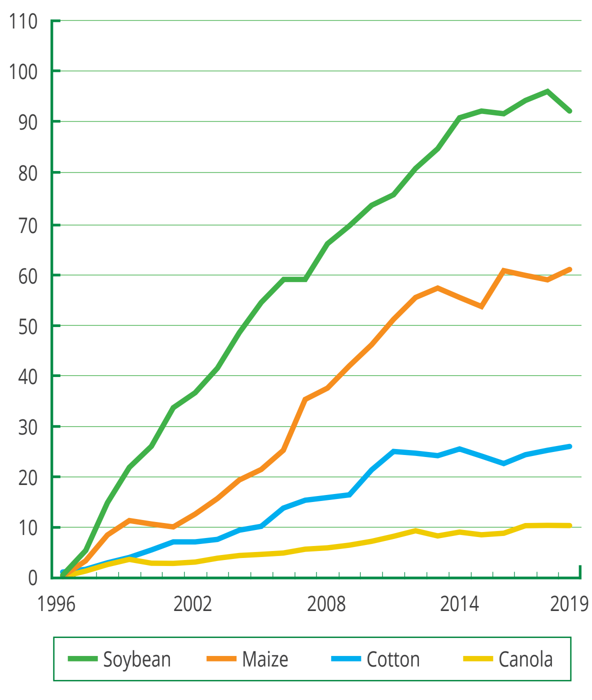


Figure 17. Global Area of Biotech Crops, 1996 to 2019: by Crop (Million Hectares)

Source: ISAAA, 2019

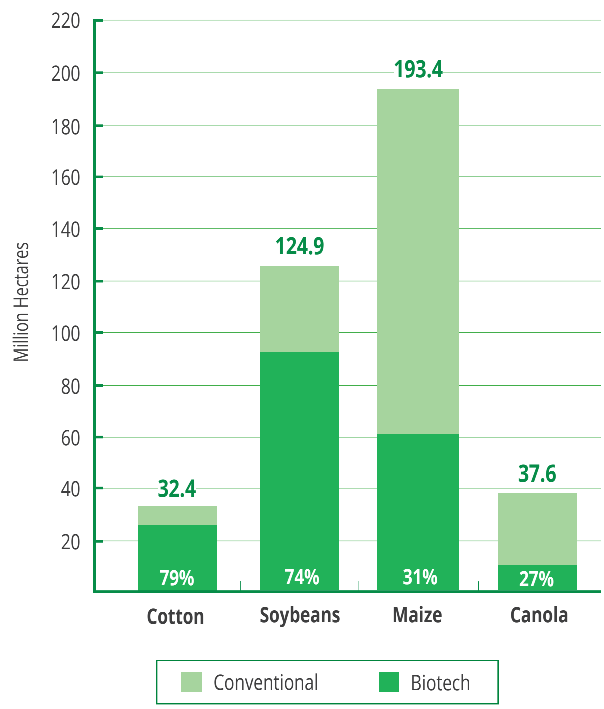


Figure 18. Global Adoption Rates (%) for Principal Biotech Crops, 2019 (Million Hectares)

Source: ISAAA, 2019

in these four countries from 2013 to 2018 and US$2.8 billion hectares in 2018 alone.

The global area planted to soybeans in 2018 was 124.9 million hectares (FAOSTAT, 2020), 74% (91.9 million hectares) was biotech soybeans (Figure 18).

The increase in income benefits for farmers growing biotech soybeans during the 23-year period 1996 to 2018 was US$74.5 billion and for 2018 alone, US$7.5 billion (Brookes and Barfoot, 2020).

Biotech maize area increased by 3%

Biotech maize occupied 60.9 million hectares in 2019, an increase of 3% from 2018 (Table 23). The 60.9 million hectares comprised of 5.1 million hectares IR, 4.9 million hectares HT, and 50.8 million hectares stacked IR/HT. Biotech maize was planted in 14 countries, including the USA (33.2 million hectares), Brazil (16.3 million hectares), Argentina (~6 million hectares), South Africa (~2 million hectares), Canada (1.6 million hectares), Philippines (0.87 million hectares), Paraguay (0.52 million hectares), Uruguay (0.12 million hectares), Spain (0.11 million hectares), and less than 0.1 million hectares in Vietnam, Colombia, Honduras, Chile, and Portugal.

Moreover, nine new stacked IR/HT events were approved for food, feed, processing (FFP), and cultivation in 2019 with various gene combinations for glufosinate, glyphosate, and dicamba herbicide tolerance; and coleopteran and lepidopteran insect resistance. These maize events will also address the problem of fall armyworm and rootworm.

Of the global 193.4 million maize area in 2018 (FAOSTAT, 2020), 31% or 60.9 million hectares were biotech maize in 2019 (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 demand for meat, and as people gain more income with a surplus to spend for meat. In addition, the continuing beneficial adoption of drought tolerant maize in the USA that increased to 3 million hectares in 2019, 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 23 years of biotech adoption (1996 to 2018) was US$65.8 billion and US$4.6 billion for 2018 alone (Brookes and Barfoot, 2020).

Biotech cotton area increased by 3%

The area planted to biotech upland cotton globally in 2019 was 25.7 million hectares, an increase of 3% from 24.9 million hectares in 2018 (Table 23). The 25.7 million hectares comprised of 18.4 million hectares IR, 578,000 hectares HT, and 6.7 million hectares IR/HT.

One new biotech stacked IR/HT cotton event GHB811 x T304-40 x GHB119 x COT102 was approved for the first time in 2019 for food, feed and processing in Brazil. This biotech cotton event is tolerant to glufosinate and isoxaflutole herbicides, and resistant to lepidopteran insect pests.

The 3% increase in the total biotech cotton area globally was due mainly to the improved global market value and the high adoption rate of IR/HT cotton in 2019.

Three African countries (Malawi, Nigeria, and Ethiopia) joined the 15 biotech cotton planting countries in 2019. The 18 biotech cotton planting countries are led by India (11.9 million hectares), USA (5.3 million hectares), China (3.2 million hectares), Pakistan (2.5 million hectares), Brazil (1.4 million hectares), Argentina (490,000 hectares), Myanmar (300,000 hectares), Sudan (236,000 hectares), Mexico (223,000 hectares), and less than 0.1 million hectares in Australia, South Africa, Paraguay, Colombia, Malawi, Eswatini, Nigeria, Ethiopia, and Costa Rica.

Large absolute increases in the area planted to biotech cotton were observed in Brazil (387,000, 38%), India (313,000 hectares, ~8%), USA (256,000 hectares, 5%), China (243,000 hectares, 8.3%), Argentina (115,000 hectares, 31%), and small increases in Mexico, Paraguay, South Africa, Colombia, Eswatini, and Costa Rica. Area 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 the two previous consecutive years.

The 80% reduction in biotech cotton planted in Australia was due to extreme drought conditions. The slight reduction in biotech cotton area in Pakistan 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. Once the regulatory environment and new cotton varieties become available, biotech cotton areas in Myanmar and Sudan are expected to increase.

Based on the 2018 FAOSTAT data (2020), cotton was planted on 32.4 million hectares globally, 79% (25.7 million hectares) of which was biotech (Figure 18).

The increase in income benefits for farmers growing biotech cotton during the 23-year period (1996 to 2018) was US$52 billion, wherein US$3.4 billion was for 2018 alone (Brookes and Barfoot, 2020).

Biotech canola area was maintained at 10.1 million hectares

The global area of biotech canola in 2019 is similar to 2018 at 10.1 million hectares. The decrease in biotech canola in the USA of 78,000 hectares was compensated by small area increases in Canada (29,000 hectares) and Australia (52,000 hectares). Chile grew biotech canola on 2,911 hectares in 2019, which is a 439 decrease from 2018 biotech area of 3,350 hectares in 2018, dedicated only for seed export.

In 2019, glyphosate herbicide tolerant canola was approved for food, feed, and processing for the first time in the Philippines.

Of the global hectarage of 37.6 million hectares of canola grown in 2018 (FAOSTAT, 2020), 29% or 10.1 million hectares were biotech canola grown in Canada, the USA, Australia, and Chile (Figure 2).

The increase in income benefits for farmers growing biotech canola during the 23-year period (1996 to 2018) was US$7.1 billion and US$0.62 billion for 2018 alone (Brookes and Barfoot, 2020).

Biotech alfalfa area planted for the first time in Argentina

Herbicide tolerant RR®alfalfa which was first approved for commercial planting in the USA in 2005 has been gaining acceptance for livestock fodder. This biotech crop has been planted in 2019 by the USA, Canada, and Argentina (for the first time), for a total of 1.28 million hectares, an increase of 1.5% compared to 2018. In 2019, the USA planted 1.12 million hectares RR®alfalfa and 158,000 hectares HarvXtra™, an increase of 32% from 2018. A total of 4,500 hectares of biotech alfalfa were planted in Canada in 2019, composed of 4,200 hectares HarvXtra™ alfalfa and 300 hectares HT alfalfa which was planted for the first time in Canada. In the Pampa region of Argentina, 1,000 hectares of alfalfa with stacked traits low lignin and herbicide tolerance were planted. The demand for more resilient HT alfalfa prompted some farmers to plant an unapproved HT alfalfa (with two HT genes pyramided wherein one HT event is unapproved) on 10,000 hectares (not included in the total biotech area for Argentina).

Other biotech crops

The total area of HT biotech sugar beets planted in the USA and Canada at 100% adoption decreased by 7% from 506,000 hectares in 2018 to 473,000 hectares in 2019.

A total of 20,000 hectares of sugarcane were planted in 2019. The insect resistant sugarcane area increased to 18,000 hectares in 2019 from its initial launch in 2018 at 400 hectares in Brazil. Drought tolerant sugarcane first planted in Indonesia in 2018 increased to 2,000 hectares in 2019, an increase of 657 hectares. Event NX1-4T is currently maintained inside a government-owned facility, the Perkebunan Nusantara XI.

China also grew a total of 12,000 hectares of PRSV-R papaya in 2019 compared to 9,600 hectares in 2018, an increase of 8%, at 85% adoption rate in five provinces of Guangdong, Hainan, Guangxi, Yunnan, and the new addition Fujian Province.

In Australia, biotech safflower with high oleic acid is planted on 3,500 hectares compared to 68 hectares in 2018. It is being maintained under a Closed Loop Identity Preservation Stewardship program.

A total of 2,265 hectares of Innate® biotech potatoes were grown in 2019 by the USA and Canada. In the USA, the area of Innate® potatoes increased from 1,700 hectares in 2018 to 1,780 hectares in 2019, representing 1% of the total US potato area. The 1,780 hectares were composed of 809.4 hectares Generation 2 Hibernate variety, 485.3 hectares Generation 1 (Gen 1) Innate® Cultivate, and 485.3 hectares of Innate® Acclimate. Some 40.5 hectares of Generation 2 Hibernate were planted in 2019 (compared to 65 hectares in 2018). These are processed in Canada but sold in the US in 2019 and 2020.

The area planted to Bt eggplant increased by 427 hectares in 2019 to 1,931 hectares and planted by 27,000 smallholder farmers in Bangladesh. This was largely due to huge government support and farmer acceptance.

Some 1,000 hectares of virus resistant squash is continuously being planted in the USA.

In 2019, non-browning Arctic®Golden and ®Granny apples were planted on 265 hectares, compared to 240 hectares planted in the USA in 2018. This is a 2.6-fold increase from 101 hectares planted during its launch in 2017.

The anthocyanin-rich biotech pink pineapple was grown in Costa Rica at 115 hectares, an increase of 91.3 hectares (385%) from 24 hectares in 2018, grown for seed export to the Northern hemisphere. The pink pineapple is now being sold online starting in October 2020 in the USA (FreshPlaza, 2020).

DISTRIBUTION OF BIOTECH CROPS, BY TRAIT

In the last 24 years, major biotech traits: insect resistance (IR), herbicide tolerance (HT), and stacked IR/HT have been deployed in the four major crops soybean, maize, cotton, and canola. Midway, the commercialization period of biotech crops (2003 onwards), a number of traits were introduced in successfully commercialized biotech crops to target biotic and abiotic stresses and improve nutritional quality.

As expected, the highest year-over-year

growth was obtained for the area planted to stacked traits IR/HT at 6% in 2019. Stacked IR/HT traits are deployed in soybean, maize, and cotton, and occupied 44.7%, surpassing the area planted to herbicide tolerant crops by 1.0% (Table 24, Figure 19). In 2019, there were percentage increases in area planted to stacked IR/HT cotton (11%), maize (6%), and soybeans (4%). 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 2019 for soybean, maize, and cotton.

The trend for increased use of stacks is expected to continue as country markets mature and more stacks are being 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.

Of the 85.1 million hectares of biotech crops with stacked traits, Brazil and the USA contributed 40.8% and 39.6%, respectively, with small contributions from other countries which planted IR/HT soybeans, maize, and cotton. In 2019, a total of 15 countries adopted biotech crops with stacked traits IR/HT: Brazil (34.7 million hectares), USA (33.7 million hectares), Argentina (9.9 million hectares), Paraguay (2.0 million hectares), South Africa (1.6 million hectares), Canada (1.4 million hectares), and smaller areas in the Philippines, Australia, Uruguay, Mexico, Vietnam, Colombia, Chile, Honduras, 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 was the second dominant trait deployed in soybeans, maize, canola, cotton, sugar beets, and alfalfa occupying 81.5 million hectares or 42% of the 190.4 million hectares of biotech crops planted by up to 17 million farmers globally (Table 24). This is a decrease of 7% or 6 million hectares compared to 87.5 million hectares in 2018. 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 herbicide tolerance in weeds that could impact growth. HT tolerant crops were commercialized in the USA (36.4 million hectares), Brazil (14.2 million hectares), Argentina (14.1 million hectares), Canada (11.0 million hectares), Paraguay (2.1 million hectares), Bolivia (1.4. million hectares), and less than 1 million hectares in South Africa (0.9 million hectares) and less than 1 million hectares in Uruguay, Mexico, Australia, Colombia, Philippines, Chile, and Honduras.

The area of biotech crops with insect resistance trait decreased slightly from 23.7 million hectares in 2018 to 23.6 million hectares in 2019. The global increase in cotton prices and the available new insect resistant traits in cotton slightly favored IR cotton adoption in India, Brazil, the USA, and China. Biotech crops with insect resistance traits were planted in India (11.9 million hectares, cotton only), Brazil (3.9 million hectares), China (3.1 million hectares, cotton only), Pakistan (2.5 million hectares, cotton only), USA (1.2 million hectares) and less than 1 million hectares grown in Myanmar, South Africa, Sudan, Malawi, Nigeria, Spain, Portugal, Bangladesh, Eswatini, and Ethiopia.

The distribution of economic benefits at the farm level by trait, for the 23 years of commercialization of biotech crops 1996 to 2018 was as follows: all herbicide tolerant crops at US$96.3 billion and all insect resistant crops

Table 24. Global Area of Biotech Crops, 2018-2019: by Trait (Million Hectares)

Traits	2018	%	2019	%	+/–	%
Herbicide Tolerance	87.5	45%	81.5	42.8%	–6.0	–7%
Stacked Traits	80.5	42%	85.1	44.7%	4.6	6%
Insect Resistance	23.7	12%	23.6	12.4%	0.4	2
Virus Resistance/ Other	<1	<1	<1	<1	<1	<1
Total	**191.7**	**100**	**190.4**	**100%**	**–1.3**	**–0.7%**

Source: ISAAA, 2019

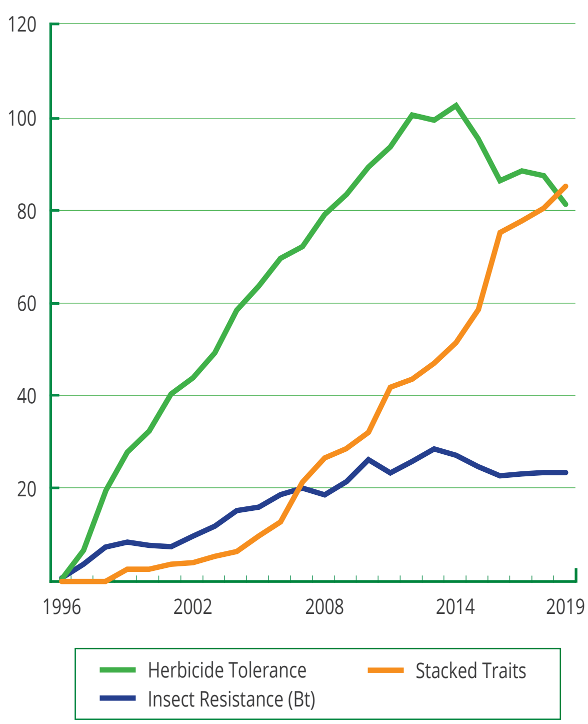


Figure 19. Global Area of Biotech Crops, 1996 to 2019: by Trait (Million Hectares)

Source: ISAAA, 2019

at US$128.1 billion, with the balance of US$0.46 billion for other minor biotech crops. For 2018 alone, the benefits were: all herbicide tolerant crops at US$8.7 billion, and all insect resistant crops at US$10.2 billion plus a balance of US$0.07 billion for the minor biotech crops, for a total of ~US$18.9 billion (Brookes and Barfoot, 2020).

New traits approved for 2019 for import and/or cultivation include: the stacked IR/HT/HT cotton with glyphosate and isofluxatole, IR/pyramided HT (glyphosate, glufosinate, dicamba, 2,4-D) and intermediates in maize, IR pyramided (for coleopteran, hemipteran, and lepidopteran)/ HT (glyphosate, glufosinate) and intermediates in maize, salt tolerant, and herbicide tolerant soybean, and insect resistant sugarcane, all in Brazil; Argentine canola with HT and modified oils and low gossypol cotton in the USA.

TRENDS IN GM CROP APPROVALS 1992-2019 (Based on ISAAA GM Approval Database available at https://www.isaaa.org/gmapprovaldatabase/updates/)

For the last 24 years, 2018 had the highest number of approvals for food, feed, and cultivation in 24 countries. This was the year when Ethiopia, Nigeria, and Eswatini approved biotech crops for the first time. In 2019, nine countries gave approval for biotech crops for food, feed, and processing, for a total accumulated number of 43 countries since 1992 (Figure 20).

The accumulated number of approvals (1992-2019) reached a total of 4,485 in 43 countries (including EU 28, counted as one) and given 2,115 food approvals, 1,514 feed approvals, and 856 cultivation approvals (not including approvals for ornamentals such as carnation, rose, and petunia), distributed among 403 events of 29 crops. On the other hand, if the data will include ornamentals, the counts will be 2,115 food, 1,514 feed, 918 cultivation, a total of 4,547 approvals distributed among 425 events in 32 crops.

The total number of approvals for 2019 was 134, wherein 57 were for food, 50 for feed, and 27 for cultivation. These approvals are divided among 50 events from 10 crops including a new GM crop, cowpea, and granted by Nigeria alone. Brazil issued the greatest number of approvals with 66 approvals followed by the Philippines with 25. USA approvals are single events and stacked traits are not counted.

In 2019, a total of 50 events were approved, with 14 single traits and 36 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 21).

Various combinations of stacked trait events are indicated in Figure 22, with stacked herbicide tolerance and insect resistance comprised of 31.5% of the events approved, while other stacked events (HT + PC, IR + DR, and HT + PQ and other stacked traits) made up 15.9% of the approved 403 events. This trend will likely

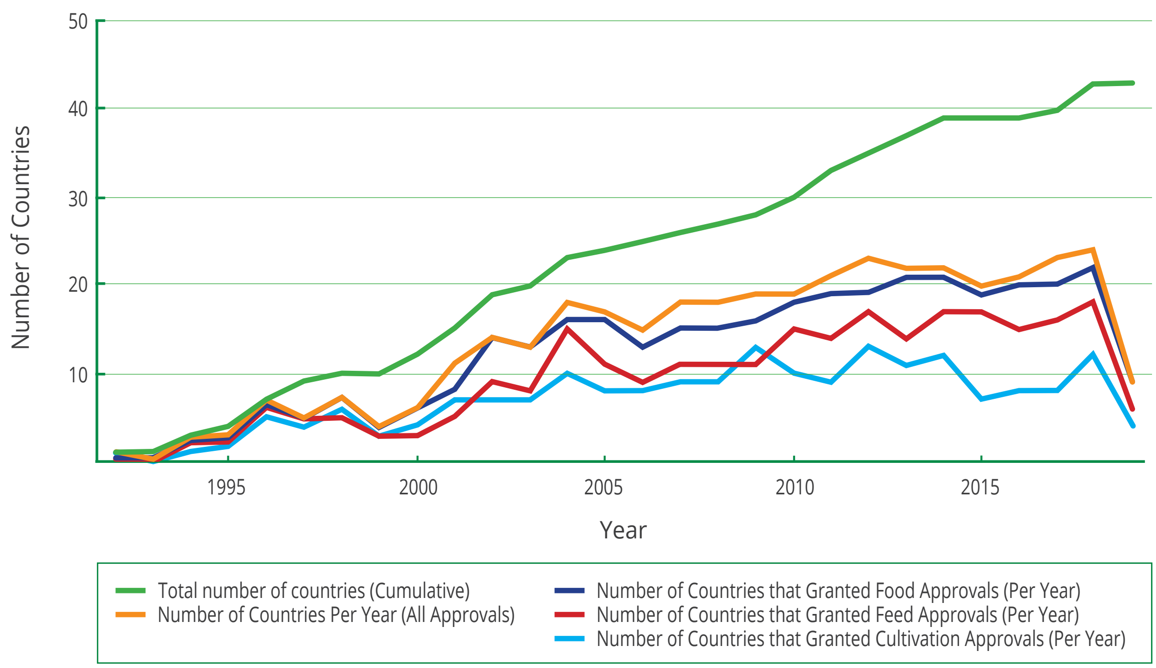


Figure 20. Number of Countries that Issued Food, Feed, and Cultivation Approvals, 1992-2019

Source: ISAAA, 2019

continue into the future since farmers demand more traits in an event, especially in maize.

Maize still has the greatest number of approved events at 36.2%. This may be due to the number of single maize events which can be combined with other events to form the desired event (Figure 23).

Biotech Crop Importing Countries

Globally, there are countries that adopt biotech crops through imports for food, feed, and cultivation. Since commercialization began in 1996, countries have set up biosafety regulations in order to facilitate the entry of biotech crops from outside sources. Laboratories were geared up to efficiently detect the entry of non-approved biotech products into the country. Biotech crop approval has never been synchronized globally, as each country approves new crop events based on its 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.

The US has the most number of approvals at 539, followed by Japan (493 approvals), and Canada (429 approvals) (Table 25).

Since 1996, a total of 42 non-planting countries (16 + 26 countries from the EU) have approved biotech crops for import (FFP) (Table 26).

Overall, a total of 71 countries (29 planting and 42 non-planting countries) adopted 29 biotech crops for food, feed, and cultivation in 2019. These biotech crops possess various traits with stacked HT/IR traits comprising 31.5%, (Figure 3) of the total 4,485 approvals from 1992 to 2019 composed of 2,115 food, 1,514 feed, and 856 cultivation approvals. Recorded

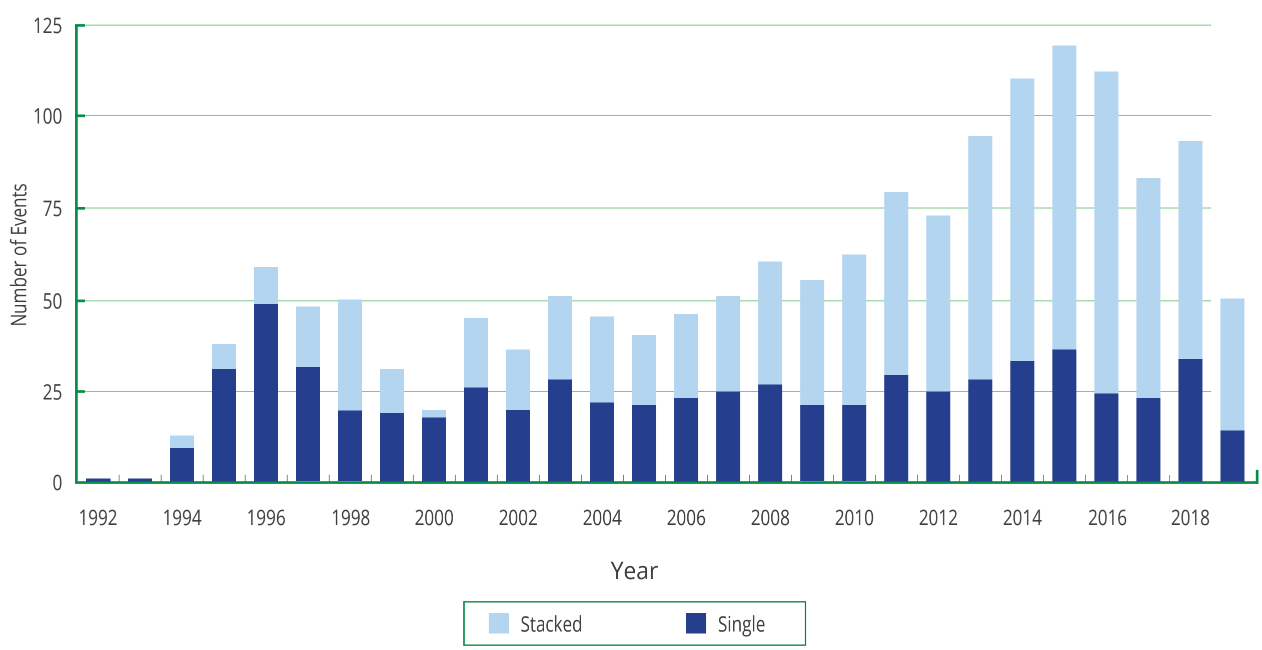
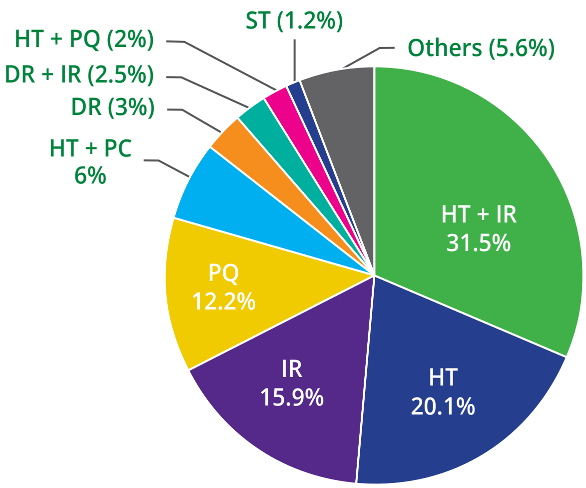


Figure 21. Number of Biotech Events Approved per Year (1992-2019)

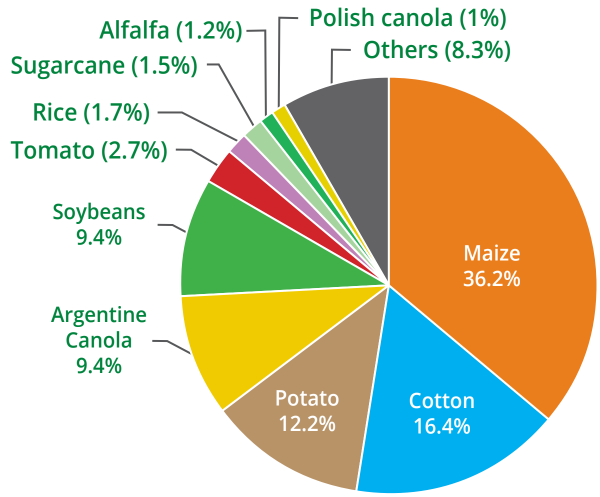
Source: ISAAA, 2019



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

Figure 22. Distribution of Traits of Approved GM Events (1992-2019)

Source: ISAAA, 2019



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 23. Number of GM Events Approved in 2019

Source: ISAAA, 2019

Table 25. Top Ten Countries with the Most Number of Approvals

Rank	Country	Food	Feed	Cultivation	Total
1	United States	183	178	178	539
2	Japan	186	177	130	493
3	Canada	147	138	144	429
4	Brazil	111	111	106	328
5	South Korea	157	148	0	305
6	Philippines	116	114	14	244
7	Mexico	188	29	14	231
8	Argentina	77	69	75	221
9	European Union	100	101	4	205
10	Australia	118	18	39	175
	Others	732	431	152	1,315
	Total	**2,115**	**1,514**	**856**	**4,485**

Source: ISAAA GM Approval Database

Table 26. Non-planting Countries which Granted Approvals for Import (Food, Feed, and Processing) from 1996 to 2019

	Countries	Crops Approved for Import	
		1996-2019	2019
1	Burkina Faso	Cotton	
2	Cuba	Maize	
3	Egypt	Maize	
4	Iran	Rice, soybeans, and rapeseed	
5	Japan	Alfalfa, canola, carnation, cotton, maize, papaya, potato, rice, rose, soybeans, and sugar beets	IR (to control aphids, leafhoppers, delphacids) maize
6	Malaysia	Canola, carnation, cotton, maize, potato, and soybeans	
7	New Zealand	Alfalfa, canola, cotton, maize, potato, rice, sugar beets, and wheat	
8	Norway	Carnation	
9	Panama	Maize	
10	Russian Federation	Maize, potato, rice, soybeans, and sugar beets	HT (2,4-D) maize, HT (glyphosate/dicamba) soybean
11	Singapore	Alfalfa, canola, cotton, maize, soybeans, and sugar beets	
12	South Korea	Alfalfa, canola, cotton, maize, and soybeans	MS11 (ster/fert) canola
13	Switzerland	Maize and soybeans	
14	Taiwan	Canola, cotton, maize, soybeans, and sugar beets	HT(glyphosate/isoxaflutole) cotton, IR (hemipteran) cotton, IR/HT cotton, HT/PQ soybean
15	Thailand	Maize and soybeans	
16	Turkey	Maize and soybeans	
17	26 EU countries	Canola, carnation, cotton, maize, potato, soybeans, and sugar beets	

Source: ISAAA GM Approval Database

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.

New Approvals, Events, and Countries

The most number of import approvals was granted to biotech maize by 26 countries, followed by soybean (24), cotton (16), and canola (13).

In 2019, 9 countries approved a total of 50 events: maize (24, IR, HT, IR/HT ,pyramided HT (glyphosate, glufosinate, dicamba, 2,4-D), pyramided IR (for coleopteran, hemipteran, and lepidopteran); soybeans (12, DT, DT/HT, HT/HT[gly/iso], HT/PQ [modified fatty acids]); cotton (5, IR [hemipteran], IR/HT, low gossypol); canola (3, HT, fert/rest, HT/PQ [improved oils]) and one each for alfalfa (low lignin), potato (non-browning), rice (B-carotene enriched), sugarcane (IR), apple (non-browning), and the new biotech crop commercialized for the first time, IR cowpea.

The new countries which approved and planted IR cotton in 2019 were Malawi, Nigeria, Eswatini, and Ethiopia.

New traits approved in 2019 for import and/or cultivation include: the stacked IR/HT/H cotton with glyphosate and isofluxatole, IR/pyramided HT (glyphosate, glufosinate, dicamba, 2,4-D) and intermediates in maize, IR pyramided (for coleopteran, hemipteran, and lepidopteran)/ HT (glyphosate, glufosinate) and intermediates in maize, salt tolerant and herbicide tolerant soybean, and insect resistant sugarcane, all in Brazil; Argentine canola with HT and modified oils and low gossypol cotton in the USA; and insect resistant cowpea in Nigeria.

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 23 years (1996-2018) have amounted to US$224.9 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 822 million tons valued at US$224.9 billion in 1996-2018; and 86.9 million tons valued at US$18.9 billion in 2018 alone;
- **conserving biodiversity** in 1996 to 2018 by saving 231 million hectares of land and 24.3 million hectares of land in 2018 alone;
- **providing a better environment**
  - by saving on 776 million kg. a.i. of pesticides in 1996-2018 and by 51.7 million kg in 2018 alone from being released into the environment;
  - by saving on pesticide use by 8.3% in 1996-2018, and by 8.6% in 2018 alone;
  - by reducing EIQ (Environmental Impact Quotient) by 18.3 % in 1996-2018, and by 19% in 2018 alone.
- **reducing CO2 emissions** in 2018 by 23 billion kg, equivalent to taking 15.3 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, 2020).

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.

SUMMARY AND CONCLUSION

On the 24th year of biotech crop commercialization, 29 countries grew 190.4

million hectares of biotech crops with economically important traits such as insect resistance, herbicide tolerance, disease (virus) resistance, drought tolerance, product quality traits such as anti-allergy, delayed fruit softening, modified oil/fatty acid content, non-browning, as well as pollination control traits. Three new countries in Africa: Malawi, Nigeria, and Ethiopia commenced planting Bt cotton in 2019, doubling the number of biotech crop planting countries in Africa from three to six.

The USA was still at the forefront of new biotech crop development and commercialization (import and cultivation) approvals. The new approvals for biotech crops and traits in the US include USDA cultivation approval for Argentina's HB4 drought tolerant soybeans. Biotech cotton with low gossypol content (event TAM66274) received a non-regulated status from USDA APHIS and FDA approval in 2019, for commercialization and use for human food and animal feed within the USA. Another variety of apple, Arctic®Gala with non-browning trait was approved for commercialization. The non-browning trait has also been successfully introduced to GreenVenus™ Romaine lettuce by Intrexon and is currently in the US pipeline. Brazil also approved HB4 drought tolerant soybean while Paraguay approved the stacked herbicide tolerant and drought tolerant (HB4) soybeans. Bolivia on the other hand approved Intacta™ and HB4 soybeans to boost biofuel production in the country.

Other new traits approved for 2019 for import and/or cultivation include: the stacked IR/HT/HT cotton with glyphosate and isofluxatole, IR/pyramided HT (glyphosate, glufosinate, dicamba, 2,4-D) and intermediates in maize, IR pyramided (for coleopteran, hemipteran, and lepidopteran)/HT (glyphosate, glufosinate) and intermediates in maize, salt tolerant, and herbicide tolerant soybean, and insect resistant sugarcane, all in Brazil; Argentine canola with HT and modified oils and low gossypol cotton in the USA.

The accumulated biotech crop area (planted since 1996) surged to a record 2.7 billion hectares or 6.7 billion acres. Of the total 29 countries planting biotech crops, 24 were developing countries and 5 were industrial countries. The slight decrease of 0.7% is equivalent to 1.3 million hectares or 3.2 million acres. Developing countries grew 56% of the global biotech area compared to 44% for industrial countries. Soybeans occupied 48% (91.9 million hectares) of the global biotech crop area, a 4% decrease (4.1 million hectares) compared to 2018. Stacked traits with insect resistance and herbicide tolerance increased by 6% equivalent to 85.1 million hectares and covered 45% of the global area. The area planted to herbicide tolerant crops was reduced to 81.5 million hectares or 43%. Herbicide tolerance in soybeans, canola, maize, alfalfa, and cotton, has consistently been the dominant trait till 2018. Some 12% of the global area was planted to insect tolerant traits. Based on the global crop area for individual crops, 79% of cotton, 74% of soybeans, 31% of maize, and 27% of canola were biotech crops in 2019. In addition to the 29 planting countries, 42 non-planting countries (16 + 26 EU countries) have approved the import of biotech crops for food, feed, and processing, for a total of 71 countries adopting biotech crops globally. The total biotech crop approvals from 1992 to 2019 were 4,485, comprising 2,115 food, 1,514 feed, and 856 cultivation approvals.

A total of US$224.9 billion economic benefits was gained by countries planting biotech crops from 1996 to 2018. The highest gain was obtained by the USA (US$95.9 billion), Argentina (US$28.1 billion), Brazil (US$26.6 billion), India (US$24.3 billion), China (US$23.2 billion), Canada (US$9.7 billion), and others (US$23.2 billion) for a total of US$224.9 billion. For 2018 alone, six countries gained the most economically from biotech crops, they were the USA (US$7.8 billion), Brazil, (US$3.8 billion), Argentina (US$2.4 billion), India (US$1.5 billion), China (US$1.5 billion), Canada (US 0.9 billion), and others (US$1 billion) for a total of US$18.9 billion (Brookes and Barfoot, 2020).

Remarkably, the average biotech crop adoption rate in the top five biotech crop-growing countries increased anew in 2019 to reach close to saturation, with the USA at 95% (average for soybeans, maize, and canola adoption), Brazil (94%), Argentina (~100%), Canada (90%), and India (94%).

Adoption of biotech crops in 2019, was a result of an interplay of various factors including, but not limited to: 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. To sum it all up:

- Consumer demand for the commodity and global prices incentives increased biotech cotton and/or maize adoption in the USA, Latin American countries, India, China, Paraguay, Philippines, Mexico, Bangladesh, and Vietnam;
- Industry demand for biofuels increased adoption in the USA, Brazil, Bolivia, and Indonesia;
- The global need for livestock and poultry feeds influenced biotech crop adoption in exporting countries in Latin America;
- Conducive weather conditions and favorable global and domestic prices in Brazil, Argentina, Paraguay, Uruguay, and Honduras; and
- Government financing support to farmers in Paraguay.

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

- Reduced market opportunities for US soybean in main importer China that reduced the export volume and the prices of soybeans;
- The onset of environmental stresses, such as drought and high temperatures in Canada and Australia; and
- Confusing regional policies related to biosafety and marketability in Pakistan, Spain, and Portugal.

Once again, in its 24th year of commercialization, more than 17 million farmers adopted biotech crops, 95% of whom are small, resource-poor farmers. The wide adoption also implies favorable consumer acceptance, which is attributed to the agricultural, socio-economic, and environmental benefits, as well as food safety and nutritional improvement. More importantly, a regional regulatory harmonization that facilitates data transportability would expedite biosafety decision-making. 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 who are in need of resources.

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