Overview on Crop Protection & Plant Biotechnology

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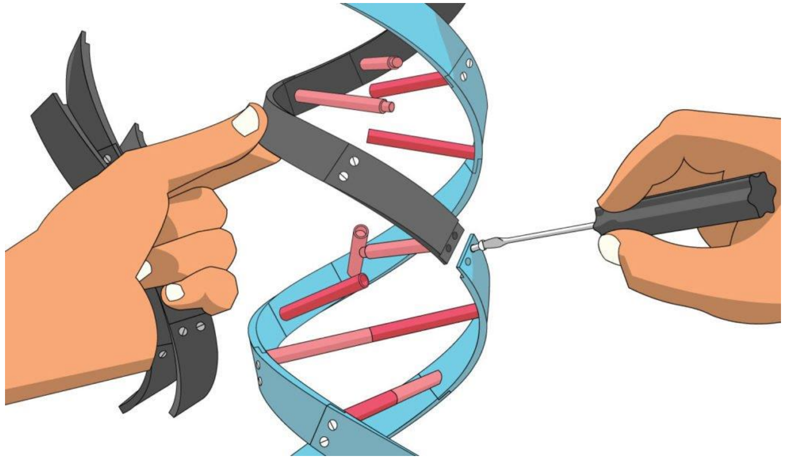
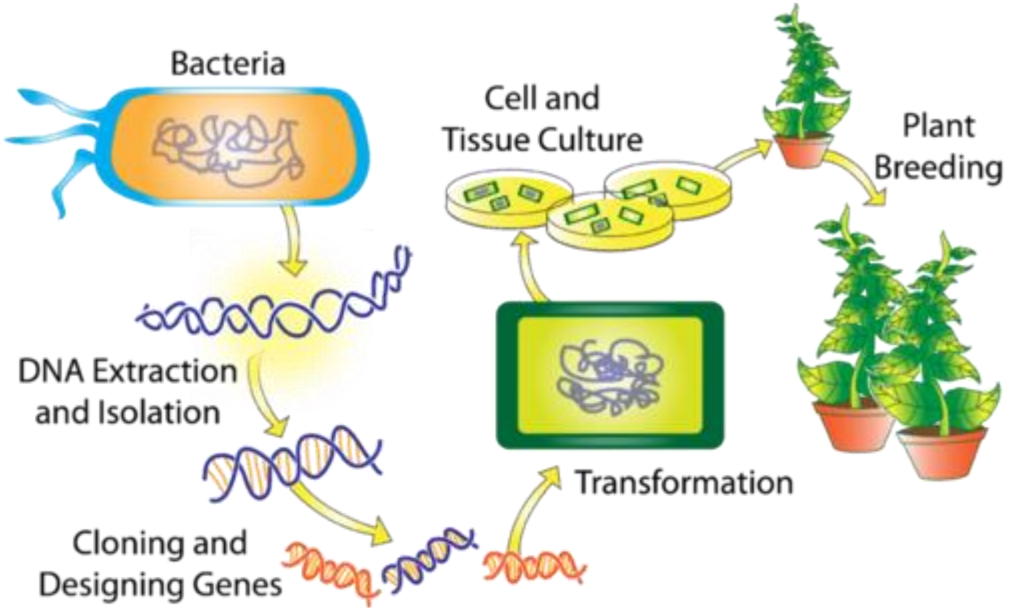
Self Intro

- Director at Hanson AgroSciences Co. Ltd. (www.hansonagrochemical.com), Stittsville, Ontario 2014 to present
- Correspondent at Agrow Journal (www.agrow.com), London UK, 2012 to present
- Postdoc in plant biotechnology, Agriculture and Agri-Food Canada, 2009 – 2011
- PhD in plant biotechnology, University of Ottawa, 2004 – 2009
- Master in plant biotechnology, Carleton University, 2002 – 2004
- Worked in multinational companies, such as Syngenta, Arysta, playing different roles, from sales reps, sales manager, technical support manager, marketing manager, to a consultant
- Master in entomology, Fujian Agricultural U, 1987 – 1990
- Bachelor in crop protection, Huazhong Agricultural U, 1983 - 1987

Content

- Plant Biotechnology
    - Definition of Plant Biotech
    - Research on Plant Biotech
    - How does It Work?
    - ***Input Traits vs Output Traits***
    - Insect Resistant Crops - Bt Crops
    - Herbicide Tolerant Crops – ***Roundup Ready, LibertyLink***
    - Contributions of Biotech Crops
    - Biotech Crop Patent Watch (2018)
    - Global Area of Biotech Crops
    - **Biotech Crops in Canada**
- Market Values of Biotech Crop
    - Market Values
    - Single Trait vs Stacked Traits
    - Roundup Ready Crops
        - ✓ Situation, Regulation, Issues
    - LibertyLink Crops
        - ✓ Invigor Canola
    - ***Crop Protection & Plant Biotech Market in Canada***
- R&D
    - Agrochemicals vs Seed Traits
    - ***Transgenic Crops vs Gene-edited Crops***
    - Outlook





What is Biotechnology?

- In 1919, the agriculturalist **Karl Ereky** described ‘biotechnology’ as ***“all lines of work by which products are produced from raw materials with the aid of living things.”*** In modern biotechnology, researchers modify DNA and proteins to shape the capabilities of living cells, plants, and animals into something useful for humans. Biotechnologists do this by sequencing, or reading, the DNA found in nature, and then manipulating it in a test tube – or, more recently, inside of living cells.

- **Biotechnology Definition (1992)** : Any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use.

- **Agricultural biotechnology** is a collection of scientific techniques used to improve **plants**, animals and microorganisms. ***Based on an understanding of DNA, scientists have developed solutions to increase agricultural productivity***. Starting from the ability to identify genes that may confer advantages on certain crops, and the ability to work with such characteristics very precisely.

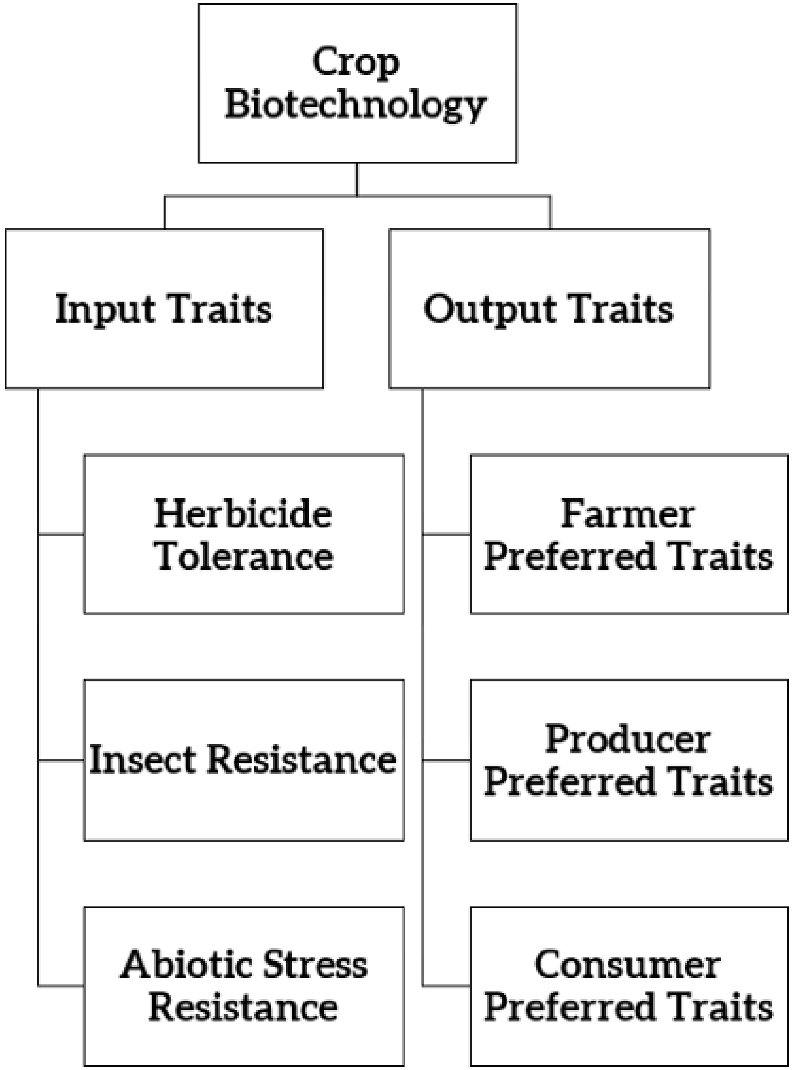
- Biotechnology enhances breeders’ ability to make improvements in crops and livestock**. *Biotechnology enables improvements that are not possible with traditional crossing of related species alone***.

Input Traits vs Output Traits

- **Input traits** are those that potentially alter inputs, especially crop protection products, needed in production.
  - An example would be Bt corn where the need to apply a pesticide to control European corn borer is eliminated.
  - Another example would be Roundup resistant crops that allow producers to spray Roundup for weed control without damaging crop plants.

- **Input traits** generally benefit producers by means of reducing the production cost through a better resistance to biotic and abiotic stress, which in turn contributes to a higher yield.
  - Confer resistance to pests or disease pathogens
  - Confer tolerance to heat, cold and drought

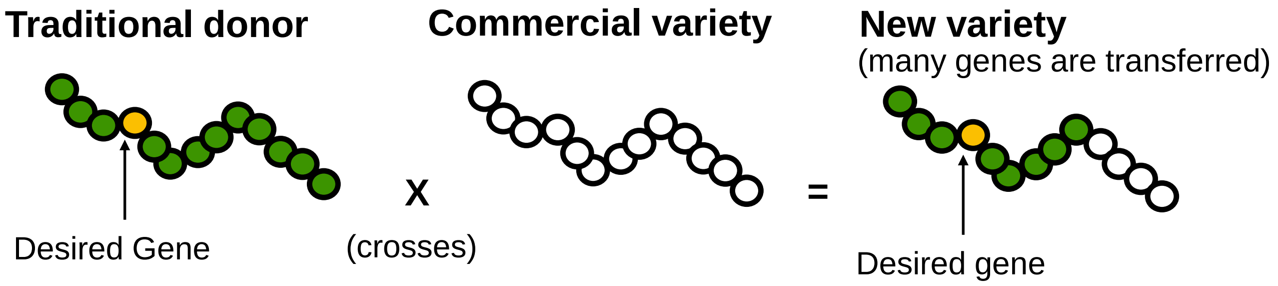
- **Output traits** are those that ***alter the harvested product***. An example would be high-oleic acid soybeans, which have improved the product for food and industrial uses.
  - Result in higher yield.
  - Result in improved quality



How does Plant Biotechnology Work?

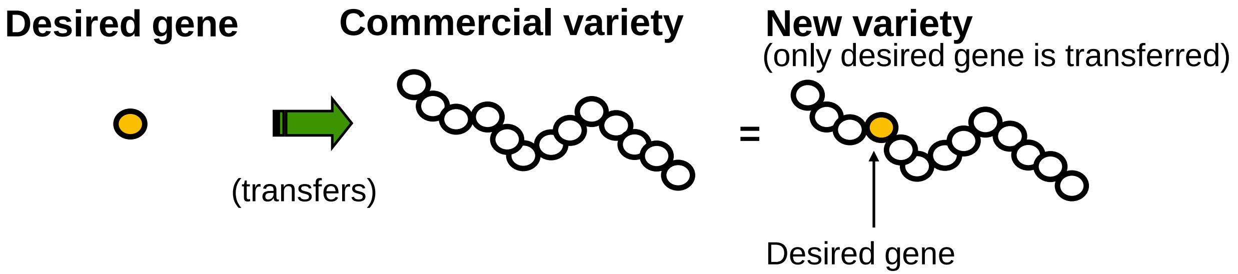
Traditional plant breeding

DNA is a strand of genes, much like a strand of pearls. Traditional plant breeding combines many genes at once.



Plant biotechnology

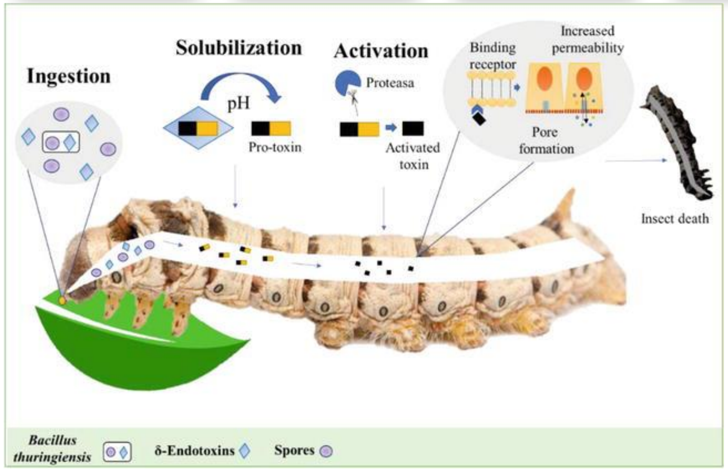
Using plant biotechnology, a single gene may be added to the strand.



Three Types of Resistance

- Herbicide Resistance (HR)
  - crops engineered with resistance to glyphosate

- Insect Resistance (IR)
  - Types of soil bacterium (*Bacillus thuringiensis*) introduced into plant to target susceptible insects



- Virus Resistance
  - Papaya

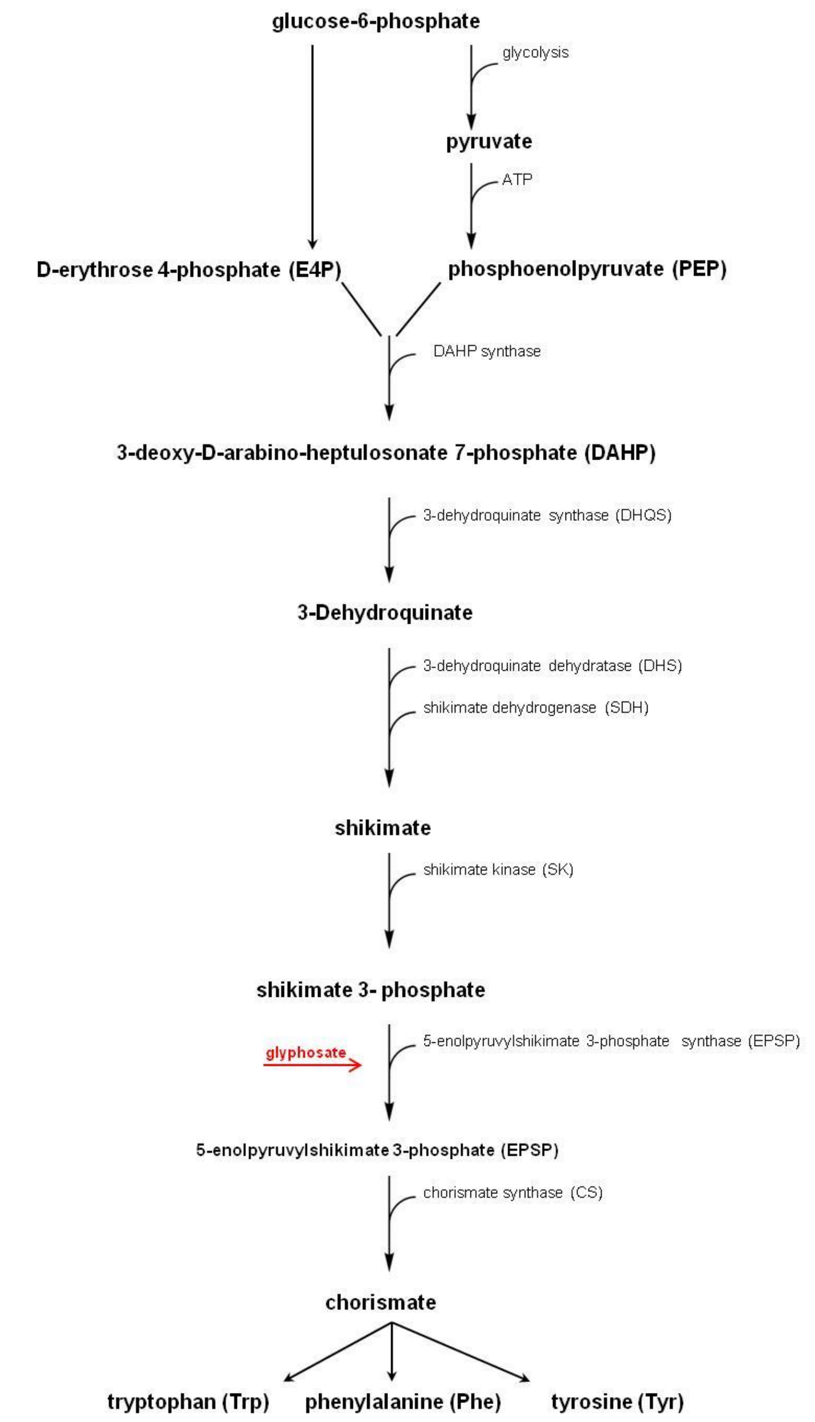
What is Bt ? How does It Work?

- Bacterium *Bacillus thuringiensis* produces protein, ***delta-endotoxin***, that is toxic to insects in orders Lepidoptera (corn worms), Coleoptera (beetles);
- Bt toxin in form of powder used as insecticide spray , being applied to leaves where larvae feed on;

- Mode of Action:
  - Insect eats Bt crystals and bacterial spores. Bt crystals dissolve at high pH (alkaline) in insect gut.
    - *Note: human gut is acidic*
  - Toxin binds to specific receptors in gut and insects stops eating.
  - Toxin causes the gut wall to break down, allowing spores and normal gut bacteria to enter the body.
  - Insect dies

How do Glyphosate Tolerant Crops Work?

- Glyphosate herbicide kills plants by blocking the EPSPS enzyme, an enzyme involved in the biosynthesis of ***aromatic amino acids***, vitamins and many secondary plant metabolites. There are several ways by which crops can be modified to be glyphosate-tolerant. One strategy is to incorporate a soil bacterium gene that produces ***a glyphosate tolerant form of EPSPS***. Another way is to incorporate a different soil bacterium gene that produces a glyphosate ***degrading*** enzyme.



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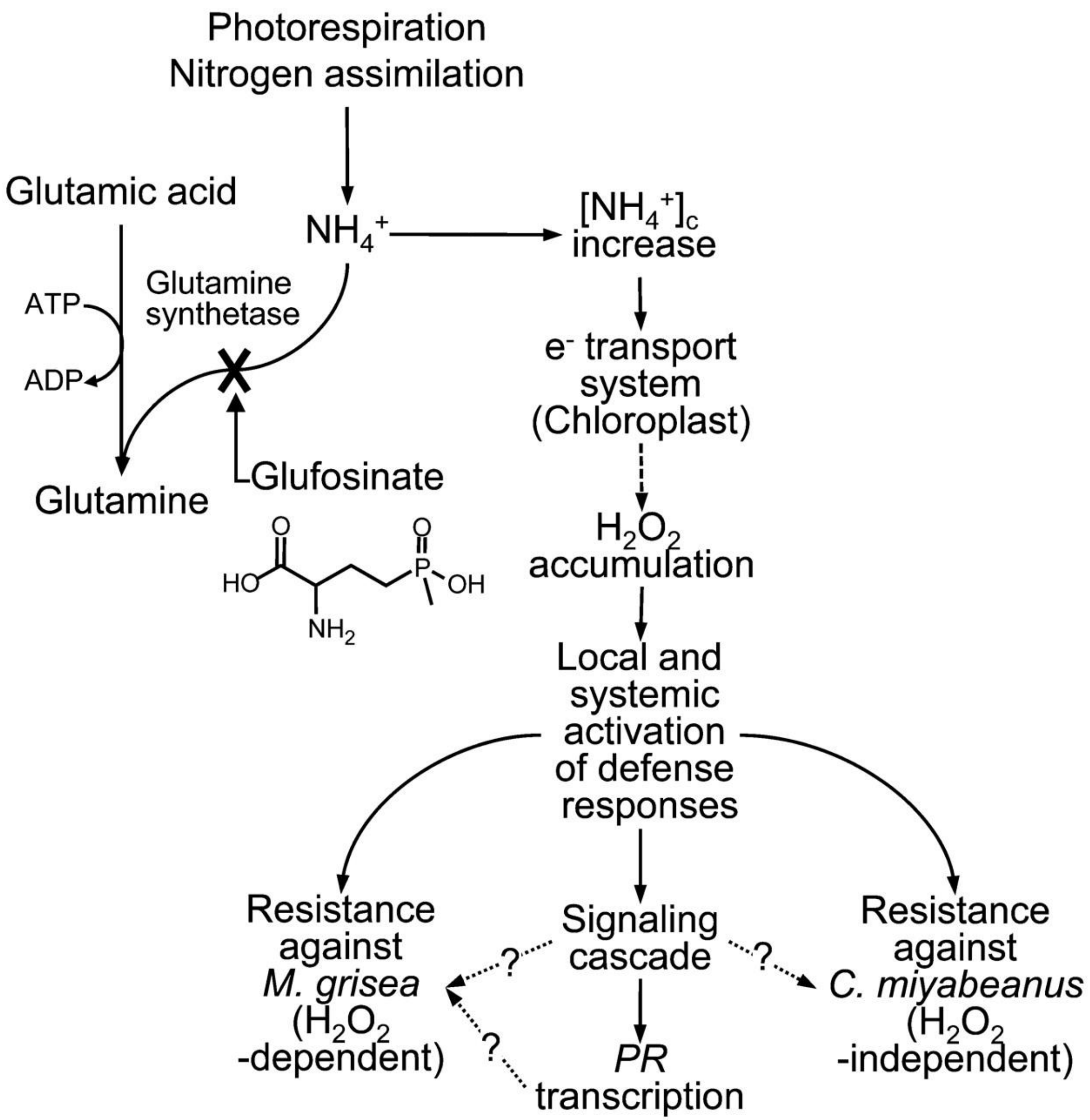
How do Glufosinate Herbicide Tolerant Crops Work?

- Glufosinate herbicides contain the active ingredient ***phosphinothricin***, which kills plants by blocking the enzyme responsible for nitrogen metabolism and for detoxifying ammonia, a by-product of plant metabolism. Crops modified to tolerate glufosinate contain a bacterial gene that produces an enzyme that detoxifies phosphinothricin and prevents it from doing damage.



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Commercialised Herbicide Tolerant Crops

Herbicide Tolerance	Brand Name(s)	Plant Species
Glyphosate	Roundup Ready	Soybean, maize, canola, cotton, sugarbeet, alfalfa
Glyphosate	Roundup Ready 2	Soybean, maize, canola, cotton, sugarbeet, alfalfa
Glyphosate	Agrisure GT	Maize
Glyphosate	Optimum GLY	Canola, soybean
Glyphosate	GlyTol	Cotton
Glufosinate	LibertyLink	Canola, maize, cotton
Imidazolinones	Cultivance	Soybean
Sulfonylureas	STS	Soybean
Dicamba	Roundup Ready Xtend	Soybean, maize, canola, cotton
2,4-D	Enlist	Soybean, Maize, cotton

Advantages of Herbicide Tolerant Crops

- Excellent weed control and hence higher crop yields;
- Flexibility – possible to control weeds later in the plant’s growth;
- Reduced numbers of sprays in a season;
- Reduced fuel use (because of less spraying);
- Reduced soil compaction (because of less need to go on the land to spray);
- Use of low toxicity compounds which do not remain active in the soil;
- The ability to use no-till or conservation-till systems, with consequent benefits to soil structure and organisms (Felsot, 2000).

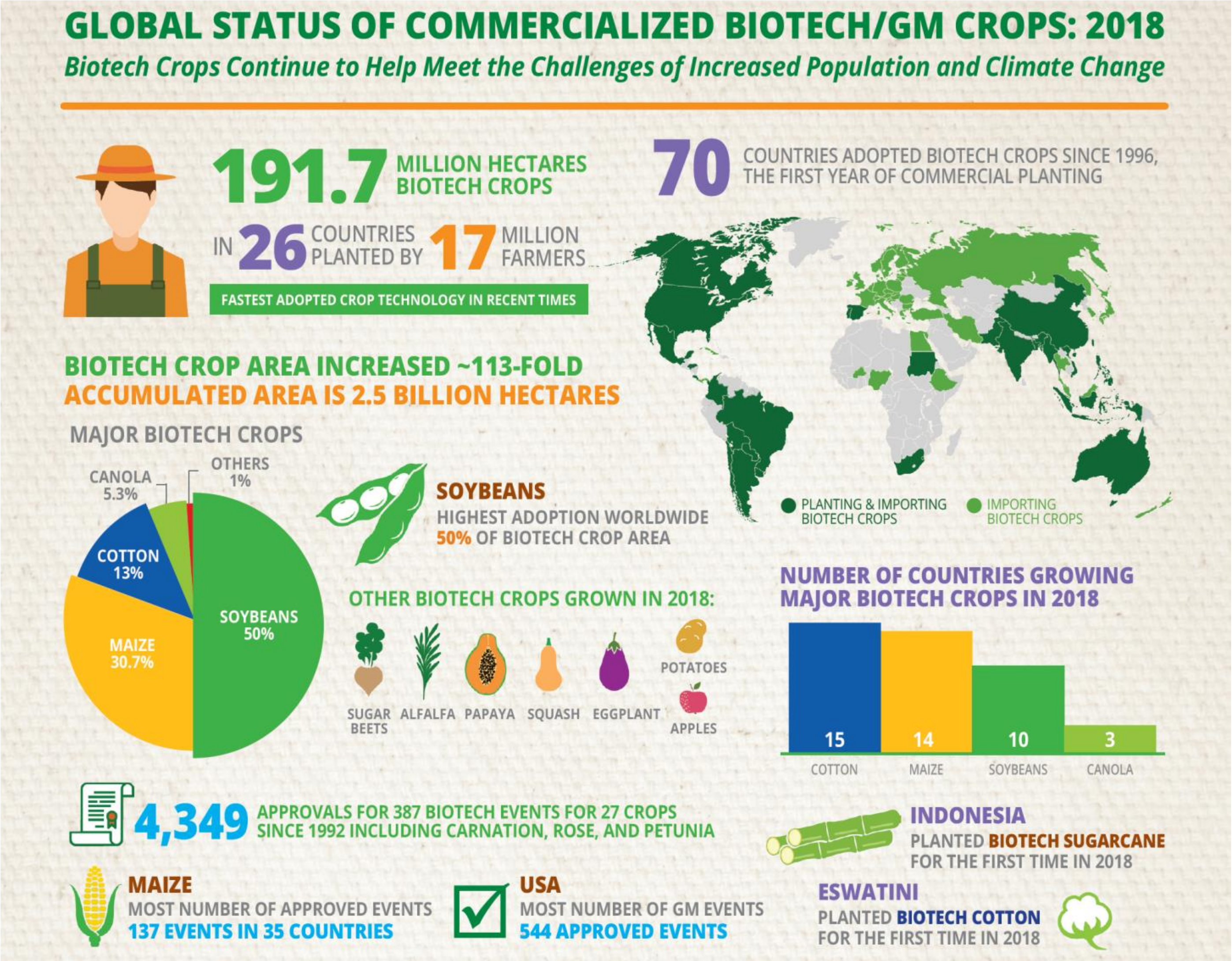
https://isaaa.org/resources/publications/pocketk/10/default.asp

Global Status of Commercialized Biotech Crops

- GMO crops are grown around the world by approximately 17 million farmers, most of them in developing countries.

- In total, more than 75 countries import, grow and/or research GMOs, and in 2018, ***26 countries (seven industrial and 19 developing) planted biotech crops***.

- As of 2018, the top five countries growing GMOs in terms of crop area are the United States, Brazil, Argentina, Canada and India.



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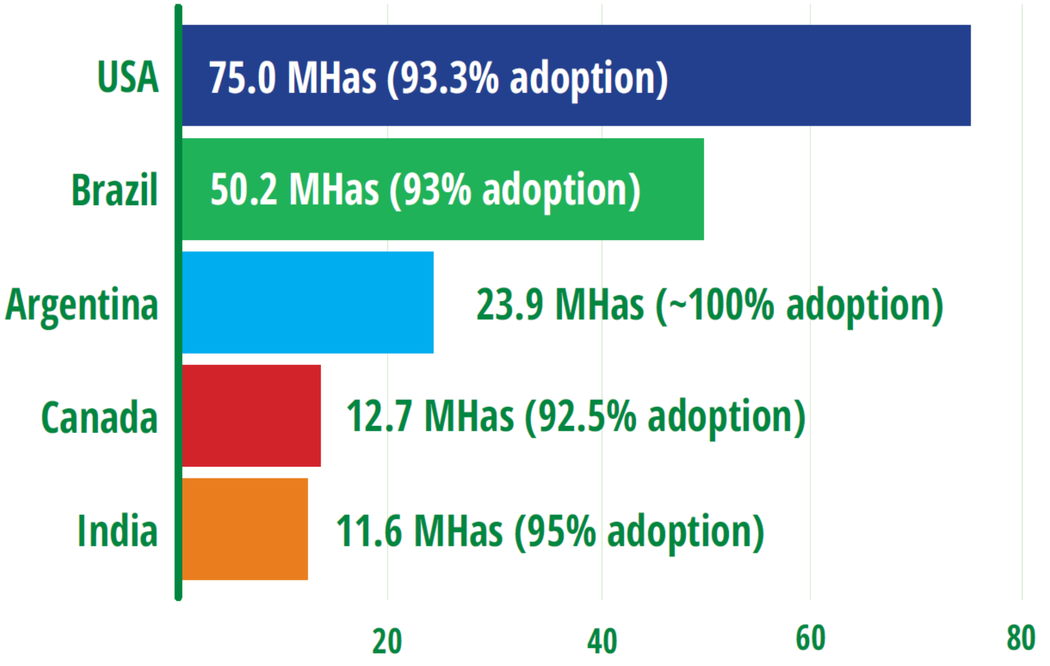
Global Area of Biotech Crops in 2018: by Country (mHa)

Rank	Country	Area (Million Hectares)	Biotech Crops
1	USA*	75.0	Maize, soybeans, cotton, canola, sugar beets, alfalfa, papaya, squash, potatoes, apples
2	Brazil*	51.3	Soybeans, maize, cotton, sugarcane
3	Argentina*	23.9	Soybeans, maize, cotton
4	Canada*	12.7	Canola, maize, soybeans, sugar beets, alfalfa, potatoes
5	India*	11.6	Cotton
6	Paraguay*	3.8	Soybeans, maize, cotton
7	China*	2.9	Cotton, papaya
8	Pakistan*	2.8	Cotton
9	South Africa*	2.7	Maize, soybeans, cotton
10	Uruguay*	1.3	Soybeans, maize
11	Bolivia*	1.3	Soybeans
12	Australia*	0.8	Cotton, canola
13	Philippines*	0.6	Maize
14	Myanmar*	0.3	Cotton
15	Sudan*	0.2	Cotton
16	Mexico*	0.2	Cotton
17	Spain*	0.1	Maize
18	Colombia*	0.1	Cotton, maize
19	Vietnam	<0.1	Maize
20	Honduras	<0.1	Maize
21	Chile	<0.1	Maize, soybeans, canola
22	Portugal	<0.1	Maize
23	Bangladesh	<0.1	Brinjal/Eggplant
24	Costa Rica	<0.1	Cotton, soybeans
25	Indonesia	<0.1	Sugarcane
26	eSwatini	<0.1	Cotton
	Total	**191.7**	

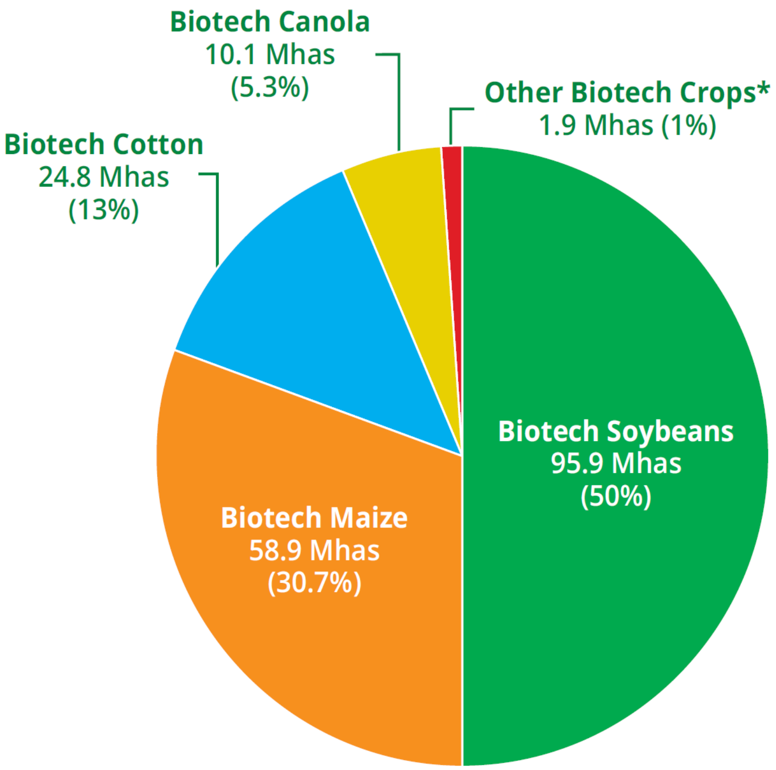
Source： ISAAA, 2018

Top Countries and Top GM Crops



TOP 5 COUNTRIES THAT PLANTED BIOTECH CROPS IN 2018 (AREA AND ADOPTION RATE)

Source: ISAAA, 2018



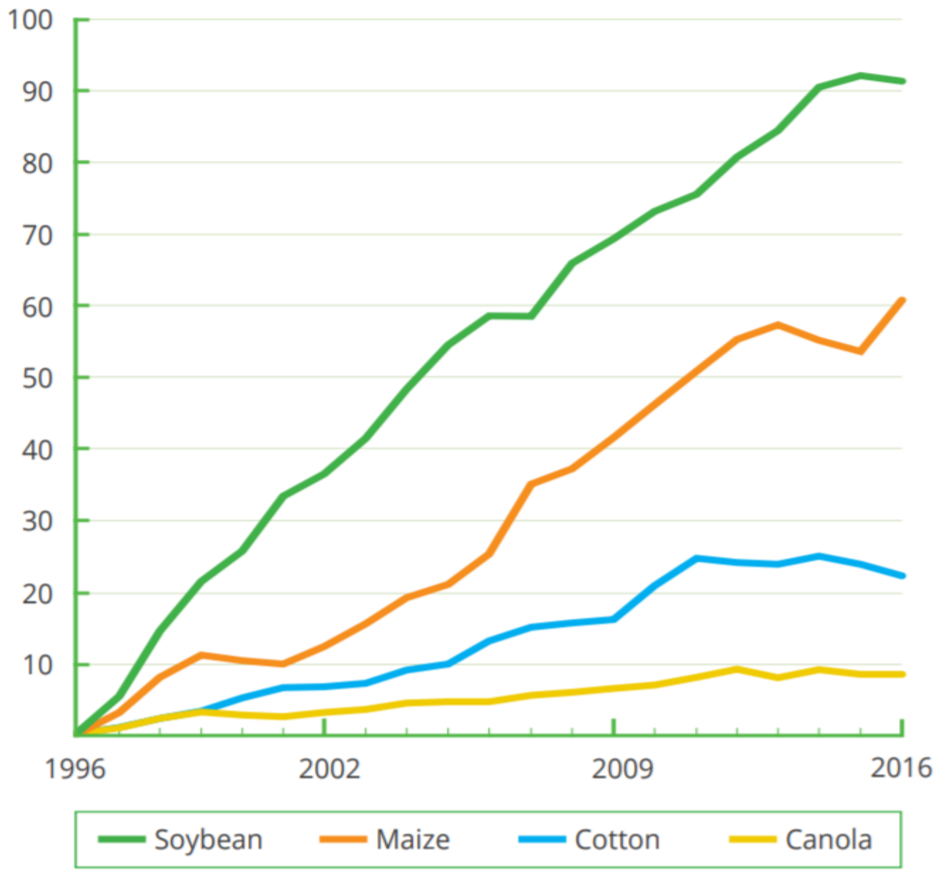
** Biotech sugar beets, potatoes, apples, squash, papaya, and brinjal/eggplant.*

BIOTECH CROPS IN 2018 (AREA AND ADOPTION RATE)

Source: ISAAA, 2018

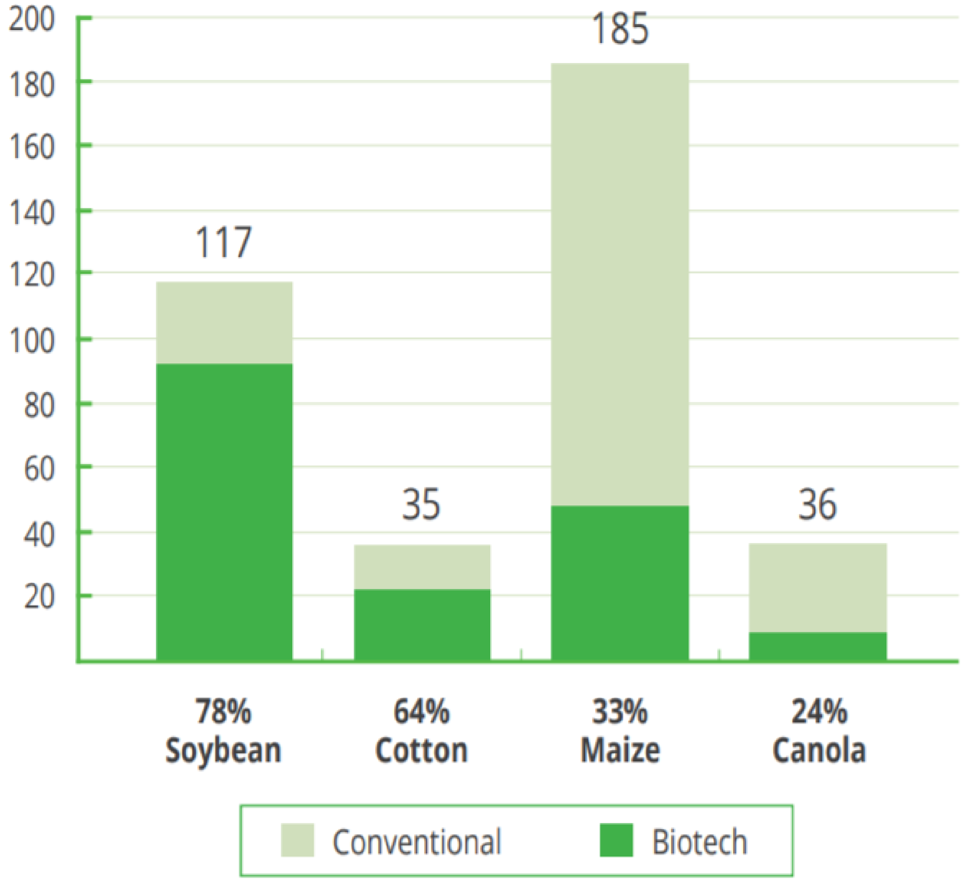
Source： ISAAA, 2018

Global Area of Biotech Crops, 1996 to 2016: by Crop (Million Hectares)



Source: ISAAA, 2016

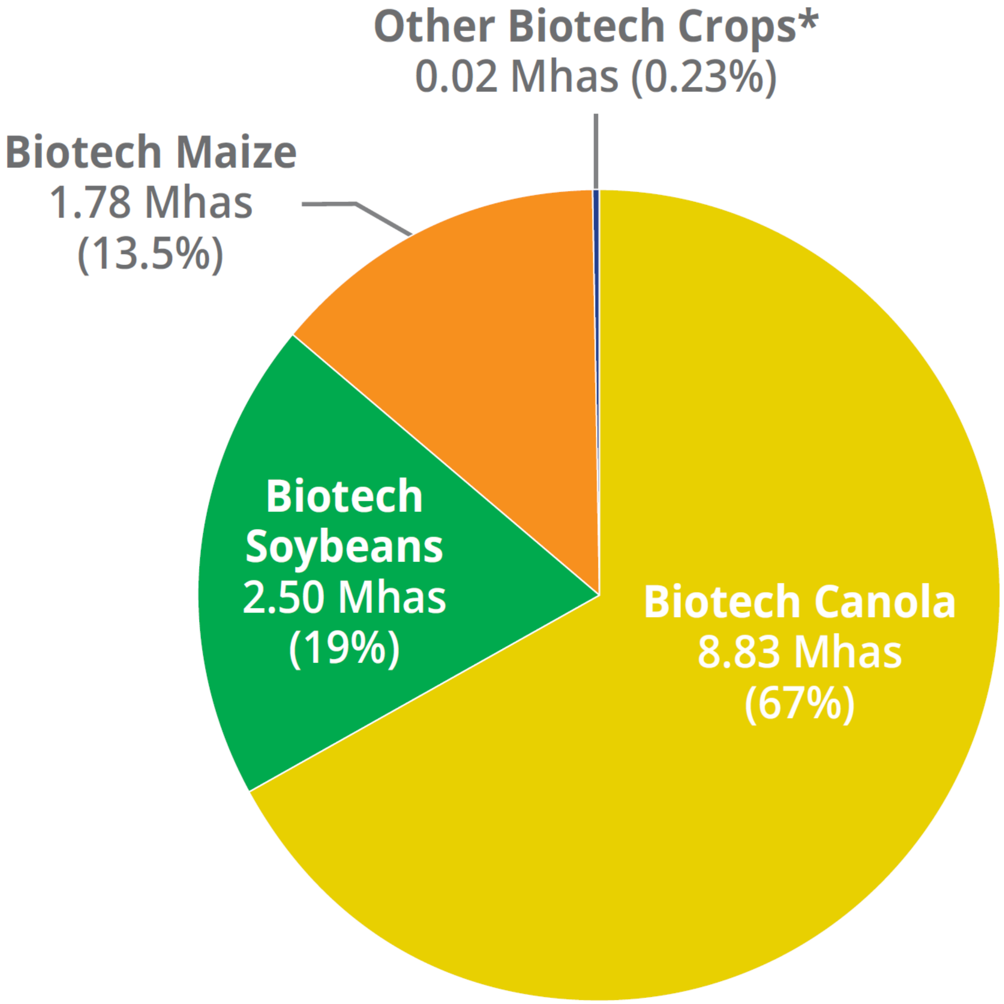
Global Adoption Rates (%) for Principal Biotech Crops, 2016 (Million Hectares)



Source: ISAAA, 2016

GM Crops in Canada (2017)

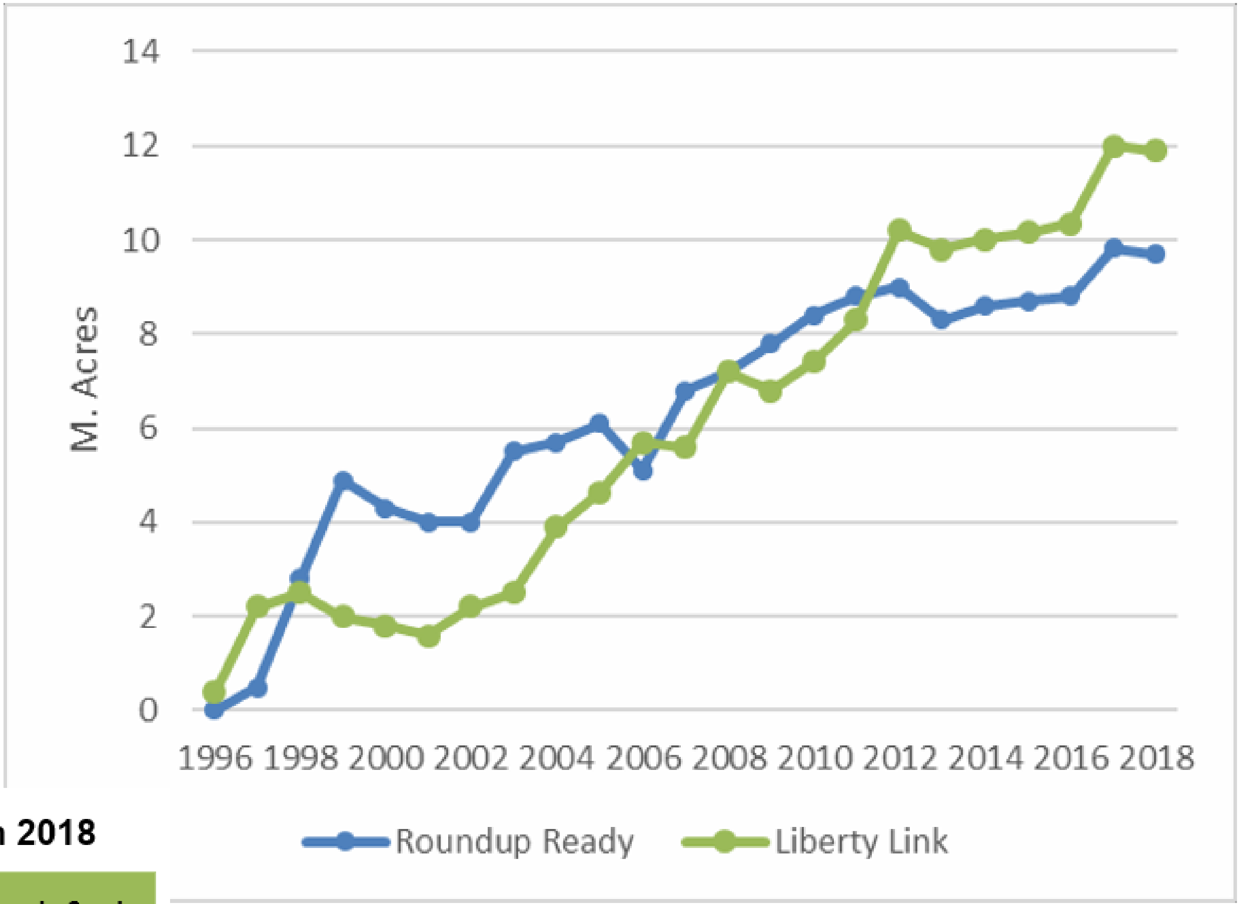
- Canada is a member of the group of ***six "founder biotech crop countries***," having commercialized biotech tolerant canola in 1996, the first year of commercialization of biotech crops.
- Canada planted ***six biotech crops*** in 2017 at 13.12 million hectares, an unprecedented 18% increase from 11.1 million hectares in 2016.
- The biotech crops were comprised of 2.50 million hectares soybeans, 1.78 million hectares maize, 8.83 million hectares canola, 15,000 hectares sugar beets, 3,000 hectares alfalfa, and 40 hectares potato, for a total of 13.12 million hectares.
- The average adoption rate for the four major crops of soybeans, maize, canola and sugar beets was at 95%.



* Biotech sugar beets, biotech alfalfa, and biotech potato
Source: ISAAA, 2017

Globally, 25% Canola is Grown in Canada, and 95% is Herbicide Tolerant

Canadian Area Planted with Herbicide Tolerant Canola



2018 Total = 21.6 million acres

GM Canola Utilisation Rates and Seed Sales in Key Countries in 2018

Country	GM Area (Million acres)	Total Area (Million acres)	Utilisation (%)	GM Canola Seed Sales ($m)
Canada	21.6	22.7	95.2	801.0
USA	2.0	2.0	99.0	74.7
Australia	1.2	5.1	23.5	43.1

Phillips McDougall, 2019

A Year in Plant Biotechnology Patents

58 crop protection biotechnology patents in 2017

During 2017 there were 58 crop protection-related plant biotechnology patents released by the US Patent and Trademark Office. Explore how these are broken down by organisation, main targeted crops and main trait categories. Examine in more detail by downloading the **Agrow Annual Review 2017** report now.

Organisations

Dow AgroSciences	DuPont	Monsanto	syngenta	BASF The Chemical Company
15 filings	14 filings	10 filings	1 filing	1 filing

71% The big six crop protection companies claimed 41 filings, accounting for **71%** of those filed patents, continuing their dominance of plant biotechnology innovations.

16% Universities and research centres have also been the driving forces in 2017, filing 9 claims among them, making up **16%** of the total.

Targeted Crops

- 50% **Maize** with 29 filings
- 14% **Soybeans** with 8 filings
- 5% **Cotton** with 3 filings
- 3% **Tomatoes** with 2 filings

Main Trait Categories

- 55% Insect resistance traits with 32 filings
- 34% pathogen resistance traits with 20
- 5% herbicide tolerance traits with 3

There were two filings with stacked traits (3%)

Research

91% In terms of the molecular means used for research, most of the claims were achieved by transgene expression with **53 filings (91%)**. The rest were obtained by marker assisted breeding and other means.

Overall Cost & Overall Time to Commercialization – Plant Biotech

- The cost of discovery, development and authorization of a new plant biotechnology trait introduced between 2008 and 2012 is ***US $136 million***,

- The time from the initiation of a discovery project to commercial launch is ***13.1 years*** on average. This does not include the time required to develop and obtain regulatory approval for stacked trait varieties which are the final product in most crops today.

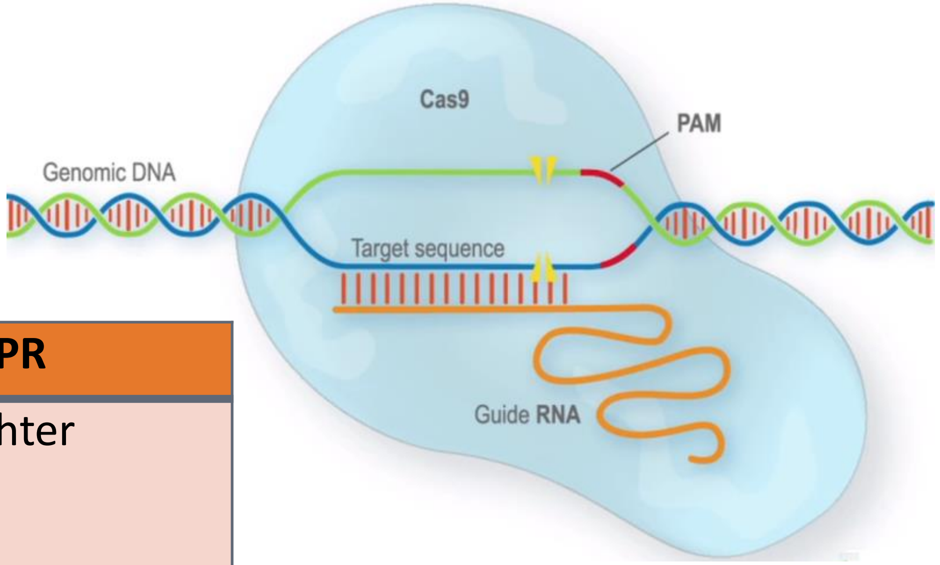
- The time associated with registration and regulatory affairs is increasing from a mean of 3.7 years for an event introduced before 2002, to the current (2011) estimated 5.5 years.

Number of Years Required to Discover, Develop and Authorize a new Plant Biotech Trait (Mean Values)

	Canola	Corn	Cotton	Soybean	All crops
Number of years from discovery of trait to first commercial sale	11.7	12.0	12.7	16.3	13.1

https://croplife.org/plant-biotechnology/regulatory-2/cost-of-bringing-a-biotech-crop-to-market/

CRISPR vs GM Trait Development



Criterion	GM	CRISPR
Regulation	Heavy – currently only permitted in ~30 countries	Potentially lighter regulations
Cost of developing a new trait	~ $136 million *	~ $10 million *
Time to develop a new trait**	~ 13 years	< 5 years
Focus of innovation	Input traits	Input traits; agronomic traits; processor traits; consumer traits

Phillips McDougall, 2019