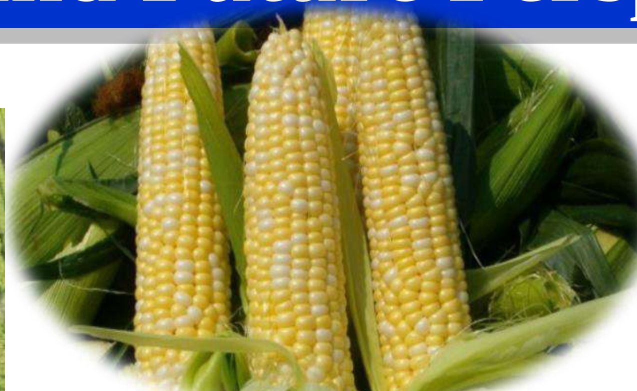
GMOs:
Current Status and Future Perspectives



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GMOs:
Current Status and Future Perspectives

Babak Nakhoda

Agricultural Biotechnology Research Institute of Iran

Department of Plant Molecular Physiology

Email: B.Nakhoda@Gmail.com

ISAAA
INTERNATIONAL SERVICE FOR THE ACQUISITION OF AGRI-BIOTECH APPLICATIONS

ISAAA Briefs

BRIEF 55
EXECUTIVE SUMMARY

GLOBAL STATUS OF COMMERCIALIZED BIOTECH/GM CROPS IN 2019:

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

APAARI APCoAB CropLife ASIA FSII

Virtual Regional Workshop on

INVESTMENT IN MODERN AGRICULTURAL BIOTECHNOLOGY AND ITS SOCIO-ECONOMIC IMPACT ON LIVELIHOODS OF FARMERS IN ASIA-PACIFIC

August 2-3, 2021 *via* zoom

PROCEEDINGS AND RECOMMENDATIONS

ASIA-PACIFIC ASSOCIATION OF AGRICULTURAL RESEARCH INSTITUTIONS

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Challenges in Agriculture

- Climate change challenges
- Water shortage and salinity
- Restricted arable land
- Grow more food with less resources, including energy
- New biotic stresses

Biotechnology and its Application to Overcome above Bottlenecks

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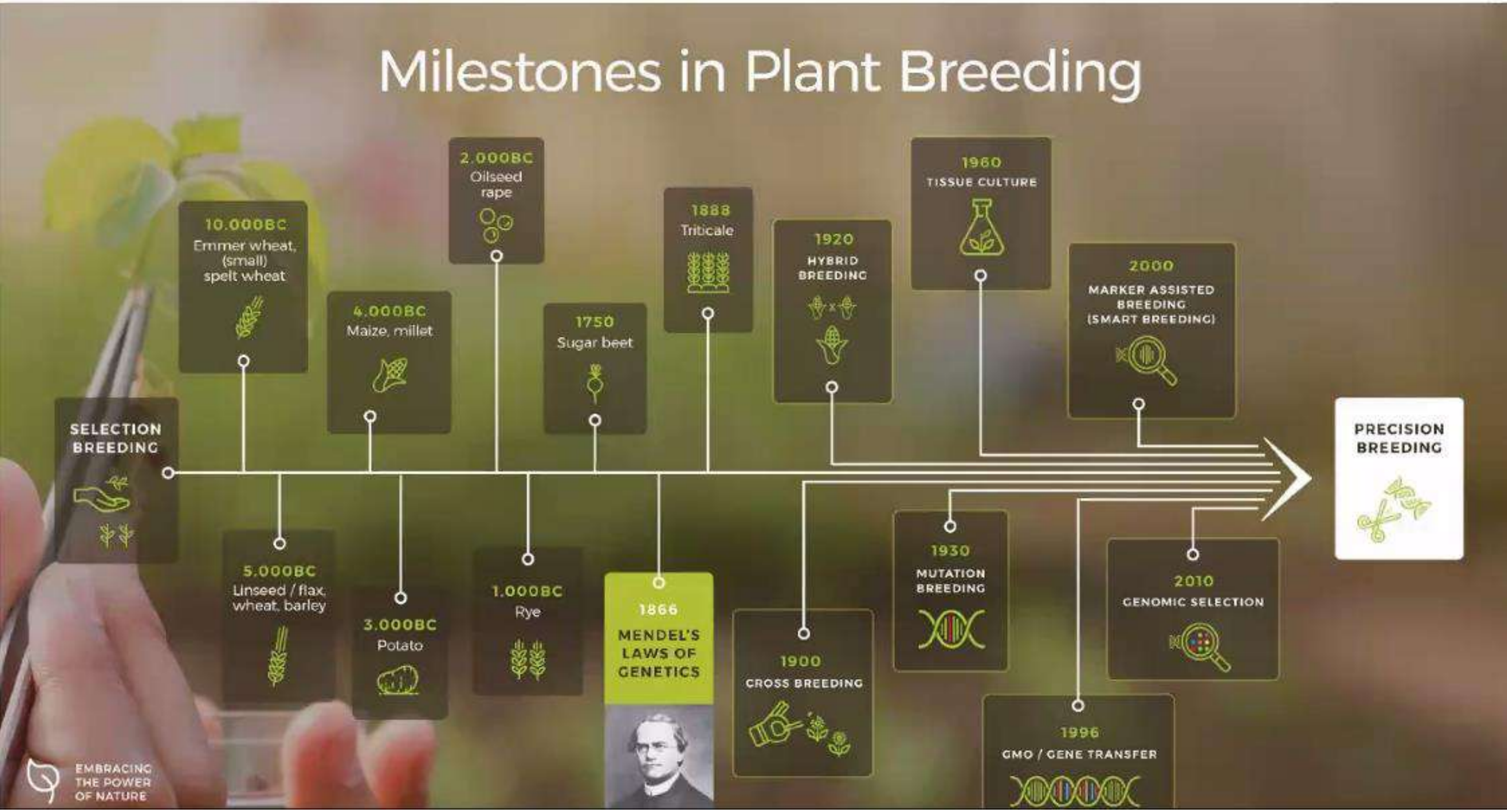
Evolution of Plant Breeding
(Selection to Gene Editing)



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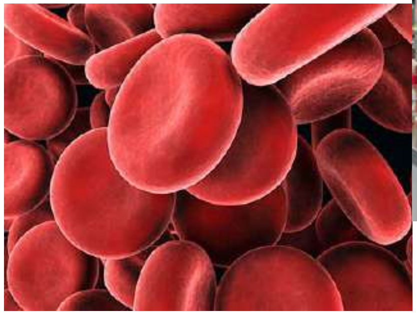
Biotechnology

- Green Biotechnology
  - Agricultural biotechnology

- White Biotechnology
  - Industrial Biotechnology

- Blue Biotechnology
  - Marine Biotechnology

- Red Biotechnology
  - Medicinal Biotechnology,
  - Drug discovery



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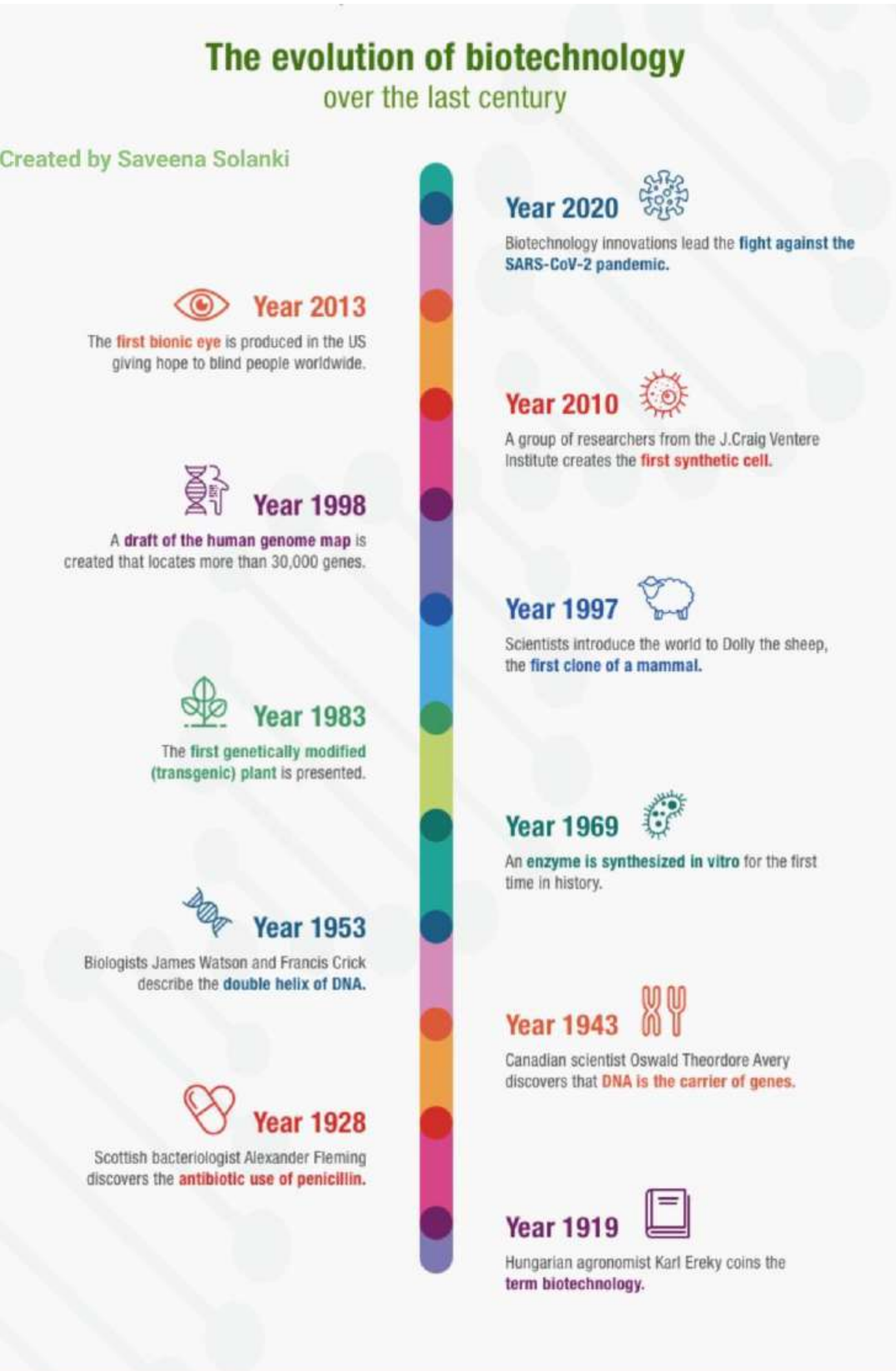
Red	Health, Medical, Diagnostics
Yellow	Food Biotechnology, Nutrition Science
Blue	Aquaculture, Coastal and Marine Biotech
Green	Agricultural, Environmental Biotechnology – Biofuels, Biofertilizers, Bioremediation, Geomicrobiology
Brown	Arid Zone and Desert Biotechnology
Dark	Bioterrorism, Biowarfare, Biocrimes, Anticrop warfare
Purple	Patents, Publications, Inventions, IPRs
White	Gene-based Bioindustries
Gold	Bioinformatics, Nanobiotechnology
Grey	Classical Fermentation and Bioprocess Technology



The first GM plant was introduced in 1983.

GM crops are being commercialized since 1996.

Over the past two decades, as many as 10 genetically modified (GM) crops (soybeans, maize, cotton, alfalfa, canola, sugar beets, potatoes, papaya, squash, and apples), are being grown in 29 countries globally.

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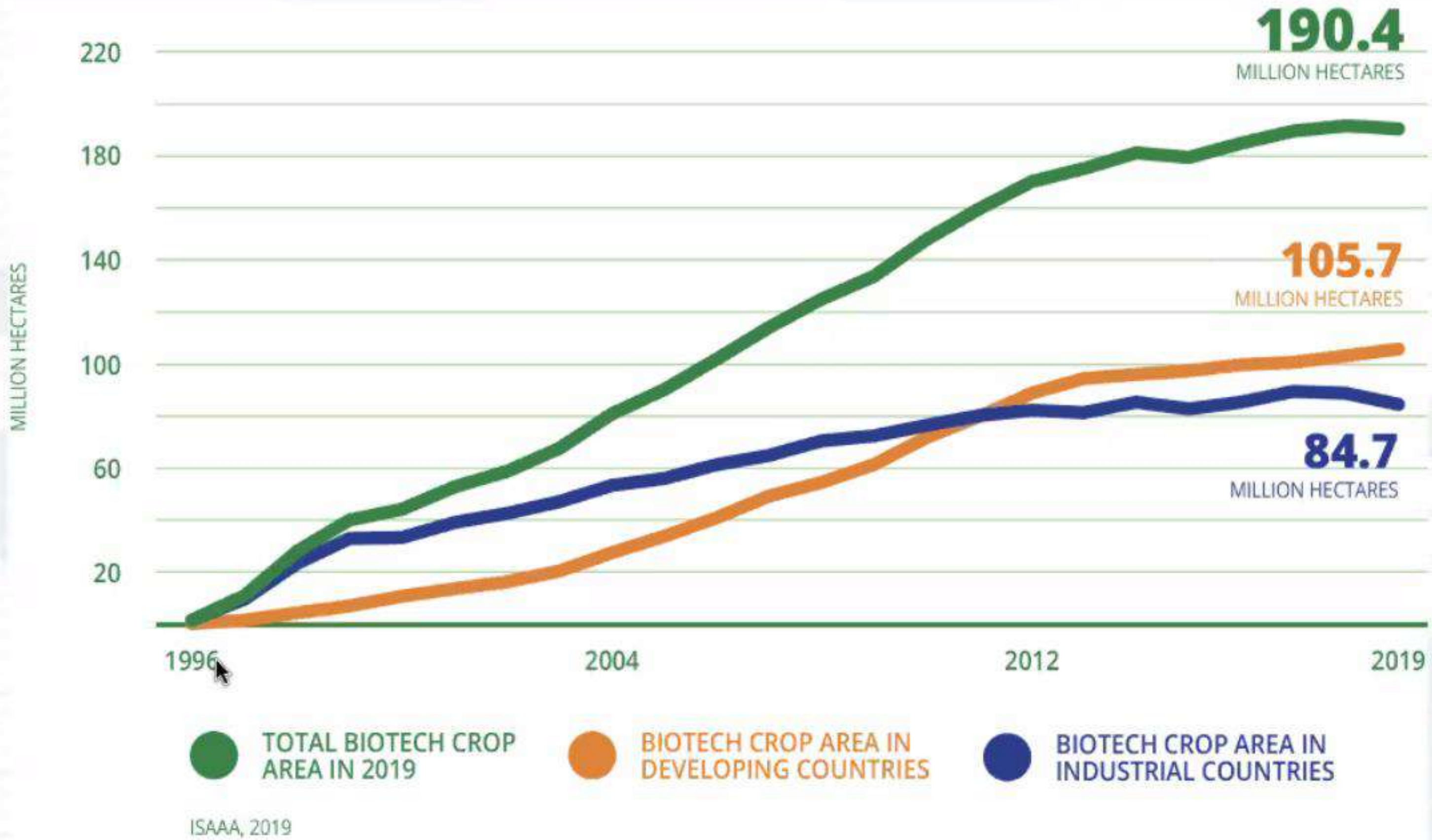
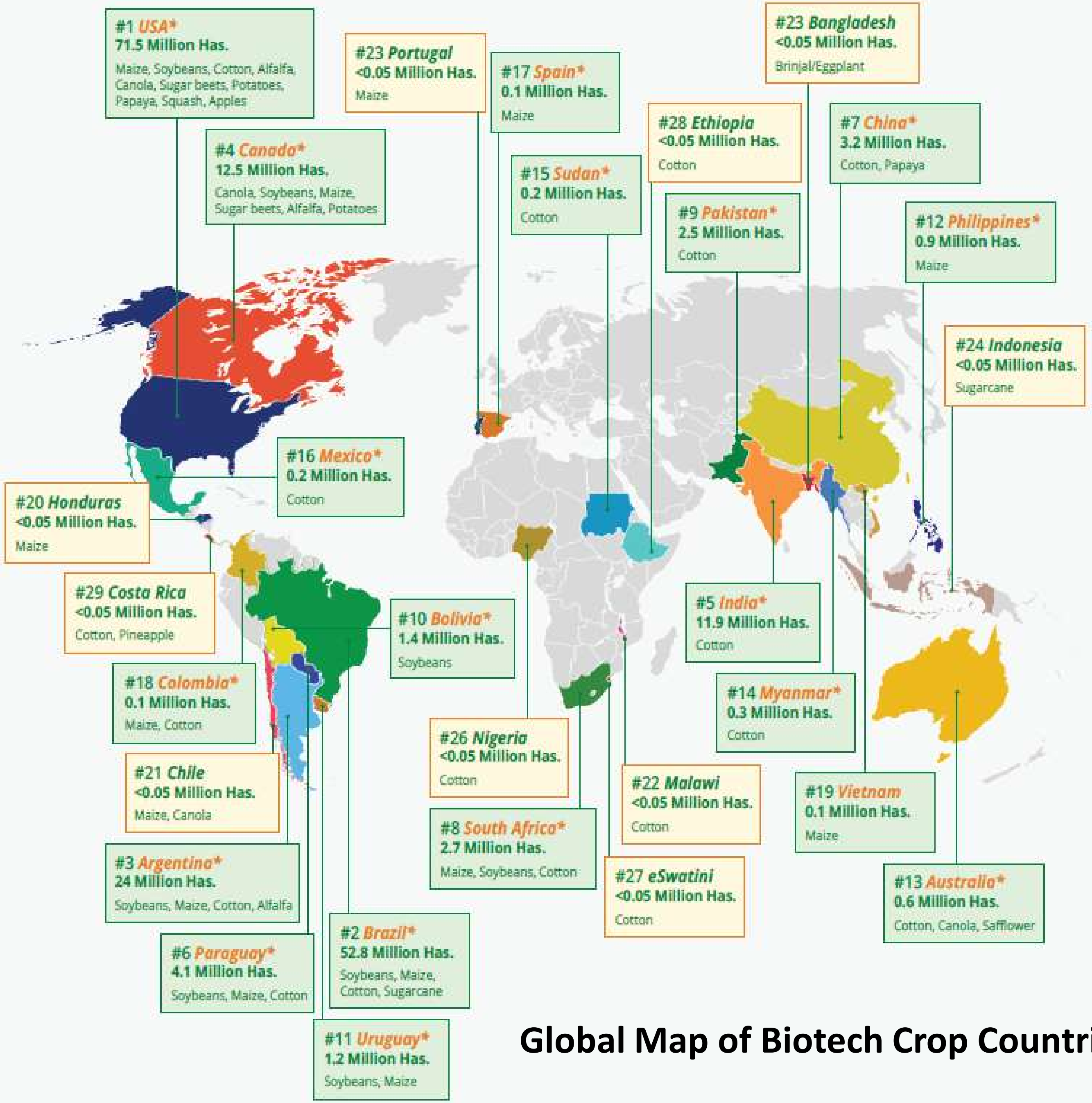
Global Area of Biotech Crops, 1996 to 2019: Industrial and Developing Countries



55.5% DEVELOPING COUNTRIES AND 44.5% INDUSTRIAL COUNTRIES



Global Map of Biotech Crop Countries and Mega-Countries

*19 biotech mega-countries growing 50,000 hectares, or more, of biotech crops.

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Global Area of Biotech Crops in 2019: by Country (Million Hectares)**

Rank	Country	Area (Million Hectares)	Biotech Crops
1	USA*	71.5	Maize, soybeans, cotton, alfalfa, canola, sugar beets, potatoes, papaya, squash, apples
2	Brazil*	52.8	Soybeans, maize, cotton, sugarcane
3	Argentina*	24.0	Soybeans, maize, cotton, alfalfa
4	Canada*	12.5	Canola, soybeans, maize, sugar beets, alfalfa, potatoes
5	India*	11.9	Cotton
6	Paraguay*	4.1	Soybeans, maize, cotton
7	China*	3.2	Cotton, papaya
8	South Africa*	2.7	Maize, soybeans, cotton
9	Pakistan*	2.5	Cotton
10	Bolivia*	1.4	Soybeans
11	Uruguay*	1.2	Soybeans, maize
12	Philippines*	0.9	Maize
13	Australia*	0.6	Coton, canola, safflower
14	Myanmar*	0.3	Cotton
15	Sudan*	0.2	Cotton
16	Mexico*	0.2	Cotton
17	Spain*	0.1	Maize
18	Colombia*	0.1	Maize, cotton
19	Vietnam*	0.1	Maize
20	Honduras*	<0.1	Maize
21	Chile	<0.1	Maize, canola
22	Malawi	<0.1	Cotton
23	Portugal	<0.1	Maize
24	Indonesia	<0.1	Sugarcane
25	Bangladesh	<0.1	Brinjal/Eggplant
26	Nigeria	<0.1	Cotton
27	Eswatini	<0.1	Cotton
28	Ethiopia	<0.1	Cotton
29	Costa Rica	<0.1	Cotton, pineapple
	Total	**190.4**	

*19 biotech mega-countries growing 50,000 hectares, or more, of biotech crops
**Rounded-off to the nearest hundred thousand.

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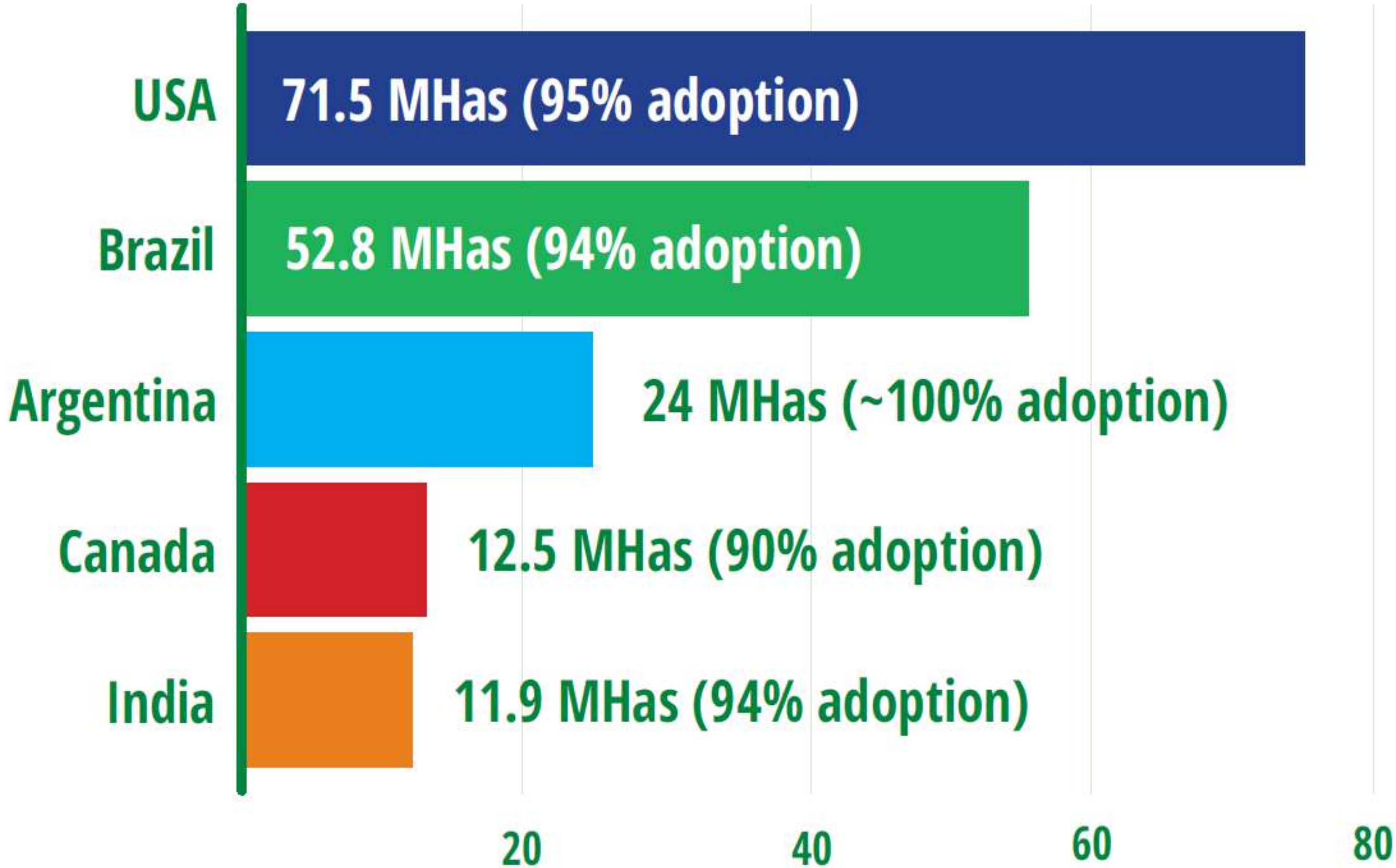

TOP 5 COUNTRIES THAT PLANTED BIOTECH CROPS IN 2019 (AREA AND ADOPTION RATE)

Source: ISAAA, 2019

The top five countries (USA, Brazil, Argentina, Canada, and India) planted 91% of the global biotech crop area of 190.4 million hectares.

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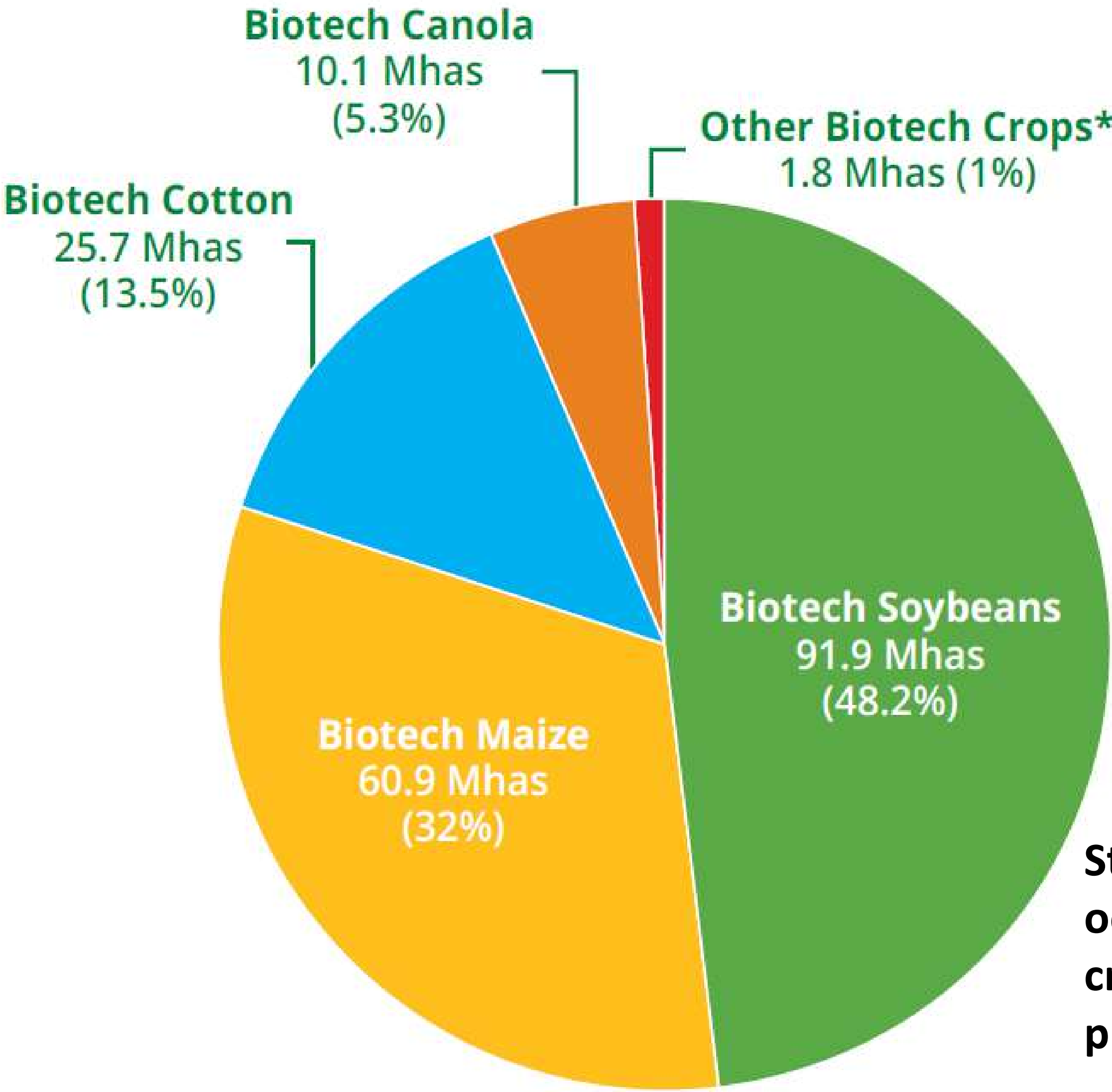

Stacked IR/HT traits increased by 6%, occupied 45% of the global biotech crop area, and surpassed the area planted to herbicide tolerant traits.

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

BIOTECH CROPS IN 2019 (AREA AND ADOPTION RATE)

Source: ISAAA, 2019

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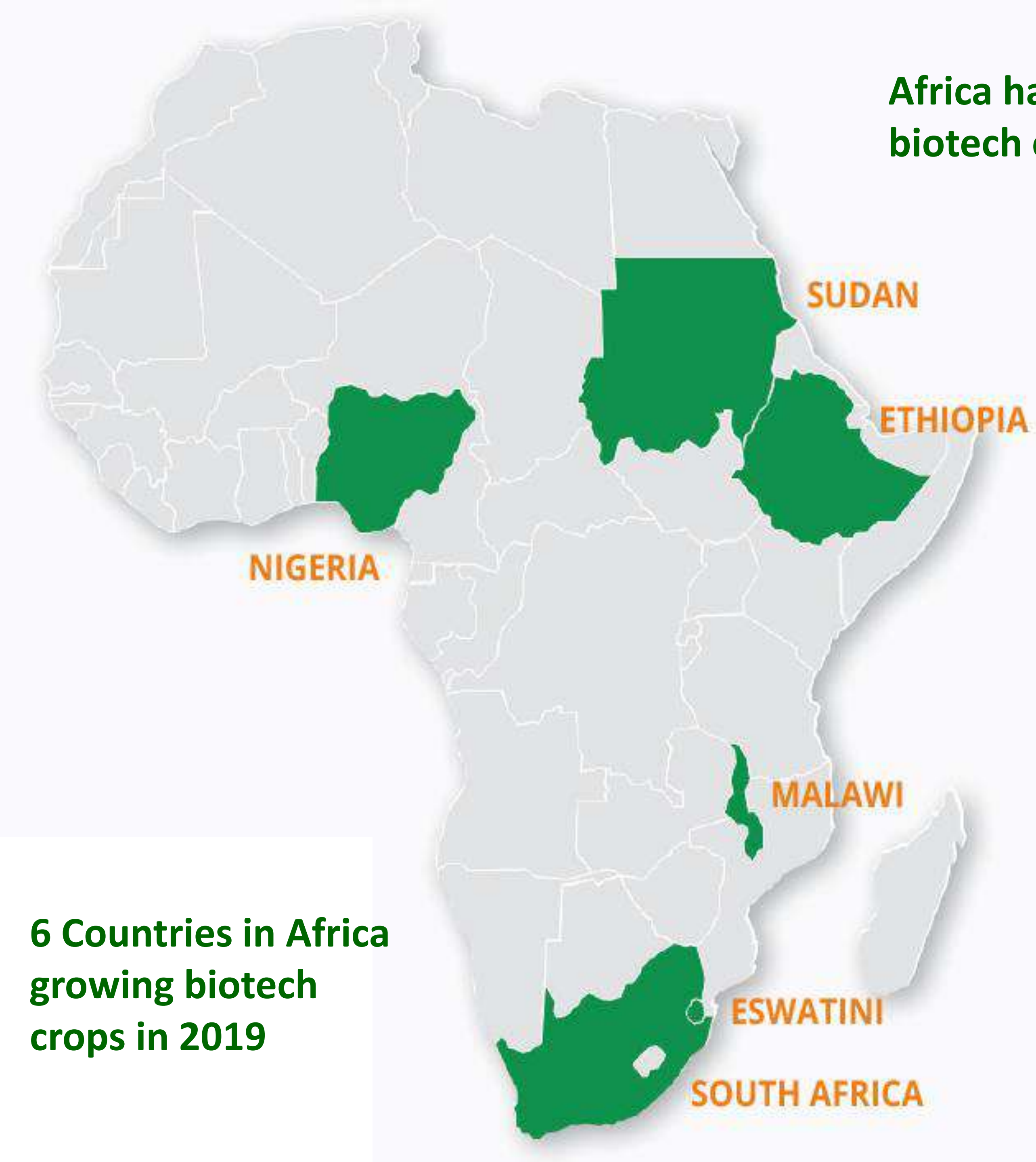
Common gene stacking methods used in the production of biotech stacks

Gene stacking method	Description	Examples of commercial stacks*
Hybrid stacking	A plant harboring one or more transgenes is cross-hybridized with another plant containing other transgenes. Development of a multi-stack hybrid occurs via iterative hybridization.	Maize: Agrisure™ Viptera™ 3220 (Bt11 x MIR162 x TC1507 x GA21) Cotton: Roundup Ready™ Flex Bollgard™ II (MON88913 x MON15985)
Co-transformation	A plant is transformed with two or more independent transgenes. The transgenes of interest are in separate gene constructs and delivered to the plant simultaneously.	Maize: NaturGard™ Knockout™ (Bt176), Bt Xtra™ (DBT418), YieldGard™ (MON810, MON809, MON802)
Linked genes or multigene cassette transformation	A plant is transformed with a single gene construct that harbors two or more linked transgenes.	Maize: Herculex™ I (TC1507), Herculex™ RW (59122), Agrisure™ CB/LL (Bt11) Soybean: Vistive™ Gold (MON87705)
Re-transformation	A plant harboring a transgene is transformed with other transgenes.	Cotton: Bollgard™ II (MON15985)

In 2019, Argentina planted biotech alfalfa for the first time. The US planted 33.17 million hectares biotech maize. 18 countries planted biotech cotton including USA, Brazil, Argentina, India, Paraguay, China, South Africa, Pakistan, Australia, Myanmar, Sudan, Mexico, Colombia, Malawi, Nigeria, Eswatini, Ethiopia, and Costa Rica.

Africa had a 100% increase in biotech crop planting-countries.



6 Countries in Africa growing biotech crops in 2019

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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 by saving 231 million hectares of land and 24.3 million hectares of land in 2018 alone; 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, 2020).

- **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 CO_2 emissions** in 2018 by 23 billion kg, equivalent to taking 15.3 million cars off the road for one year; and

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

INCREASE CROP PRODUCTIVITY

US$225 BILLION

FARM INCOME GAINS IN 1996-2018 GENERATED GLOBALLY BY

BIOTECH CROPS

CONSERVE BIODIVERSITY

IN 1996-2018, PRODUCTIVITY GAINED THROUGH BIOTECHNOLOGY SAVED

231 MILLION HECTARES

OF LAND FROM PLOWING AND CULTIVATION

PROVIDE A BETTER ENVIRONMENT

DECREASED USE OF CROP PROTECTION PRODUCTS BY

776 MILLION KGS

A GLOBAL REDUCTION OF 8.6% IN 1996-2018

REDUCE CO2 EMISSIONS

SAVED **23 BILLION KGS CO2** EQUIVALENT TO REMOVING

15.3 MILLION CARS

OFF THE ROAD FOR 1 YEAR

HELP ALLEVIATE POVERTY AND HUNGER

BIOTECH CROPS UPLIFTED THE LIVES OF

17 MILLION FARMERS

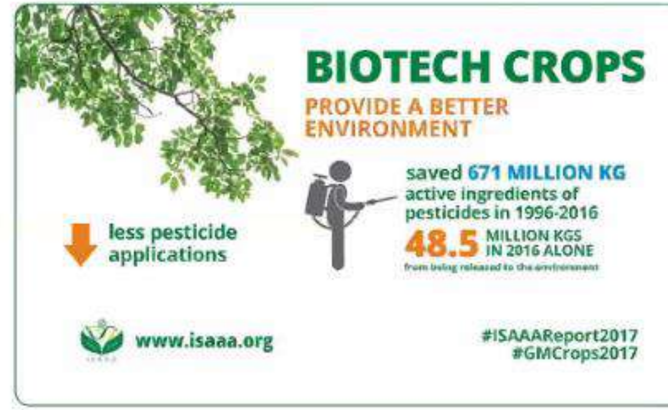
AND THEIR FAMILIES TOTALING

>65 MILLION PEOPLE

Source: Brookes and Barfoot, 2020

Biotech Crops *vis-a-vis* SDGs

Alleviating Poverty and Hunger **SDG # 1, 2, 5**

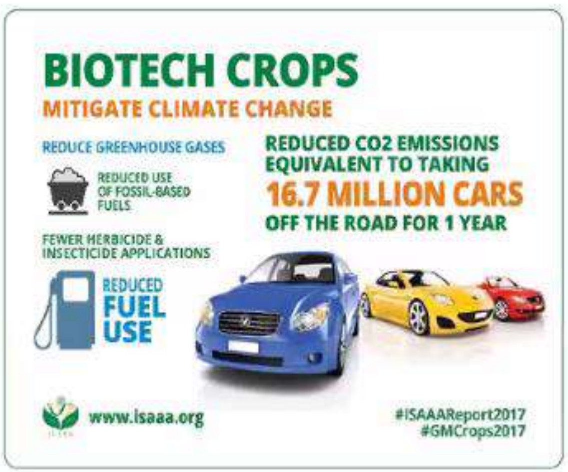


Environment Protection

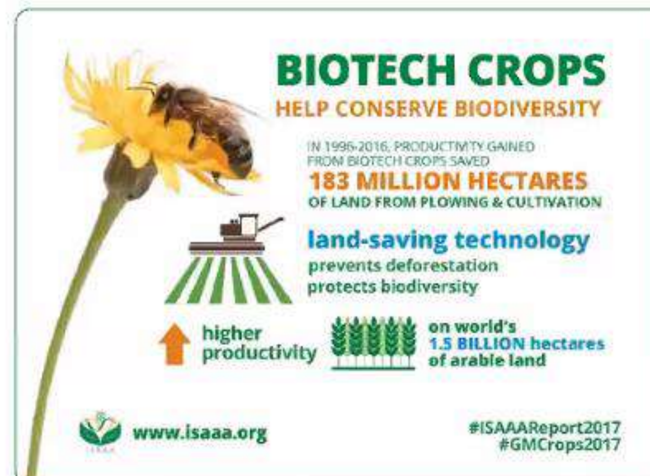
SDG # 3,6,11

Food, Feed and Fibre Security

SDG # 1,2,3,12



Mitigate Climate



Conservation of

Infographics Credit: ISAAA

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The perspective of the commercialization of transgenic crops for the next decade, shows the continued development of transgenic crop cultivation up to the level of more than 200 million hectares by 20 million farmers in about 30 countries of the world or more in 2025.

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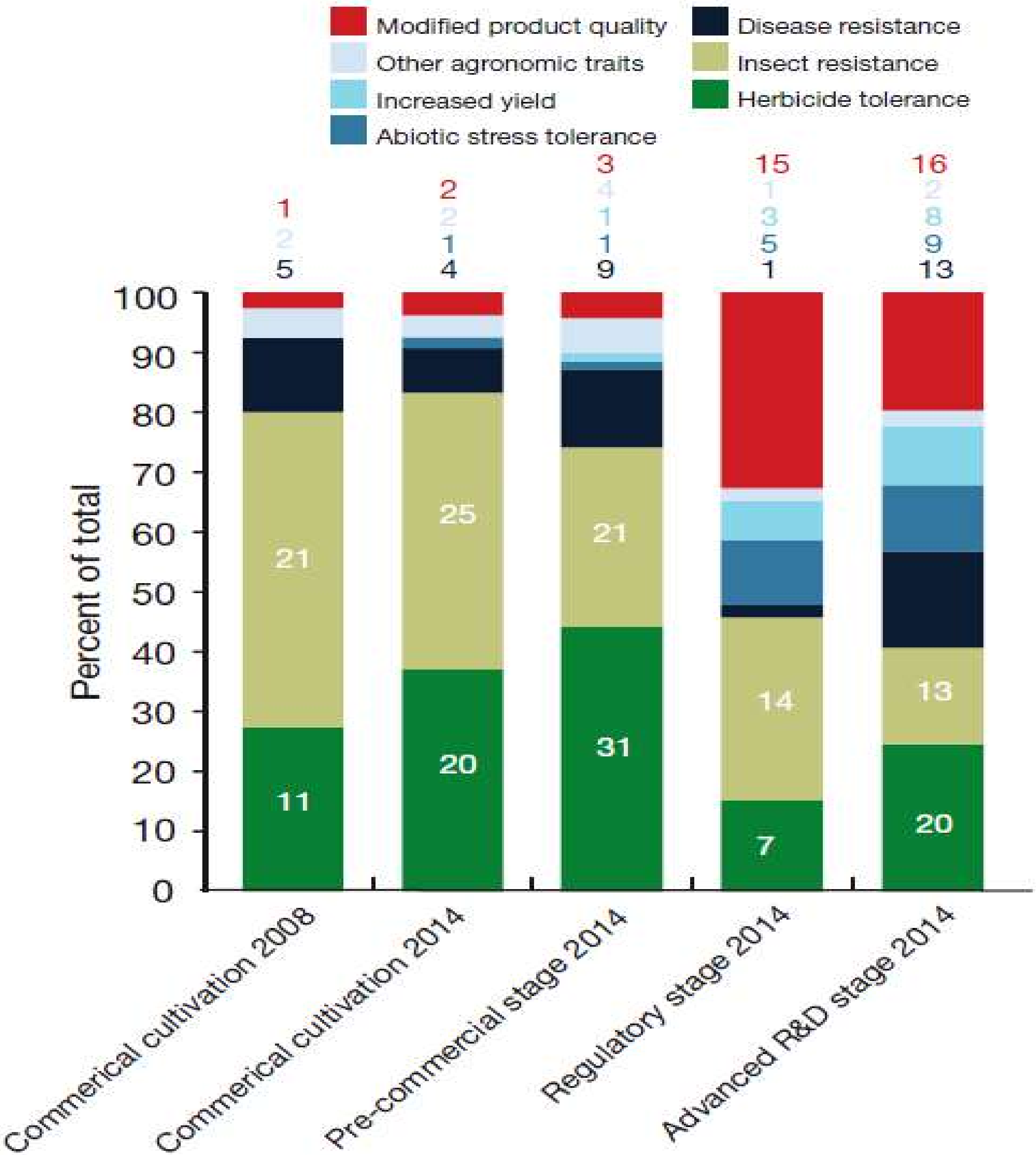

Modified product quality
Disease resistance
Other agronomic traits
Insect resistance
Increased yield
Herbicide tolerance
Abiotic stress tolerance
Percent of total
0
10
20
30
40
50
60
70
80
90
100
1
2
5
21
11
2
2
1
4
25
20
3
4
1
1
9
21
31
15
1
3
5
1
14
7
16
2
8
9
13
13
20
Commerical cultivation 2008
Commerical cultivation 2014
Pre-commercial stage 2014
Regulatory stage 2014
Advanced R&D stage 2014

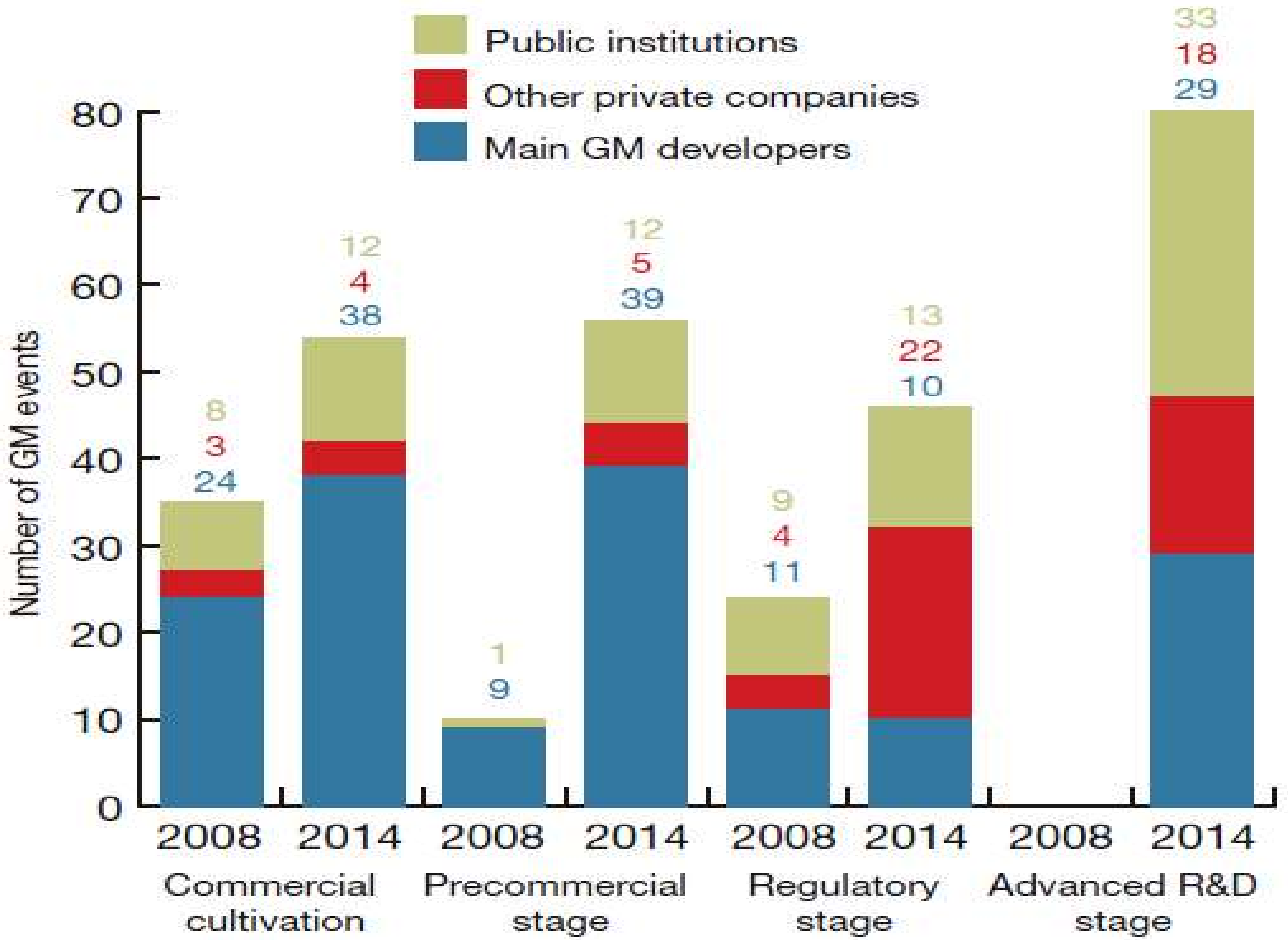

Figure 3 Distribution of GM crop events per developer type and development phase. 'Main GM developers' include BASF, Bayer CropScience, Cargill, Dow AgroSciences, DuPont Pioneer, Monsanto and Syngenta. Data for the advanced R&D stage in 2008 were not included in the former review of the pipeline[5].

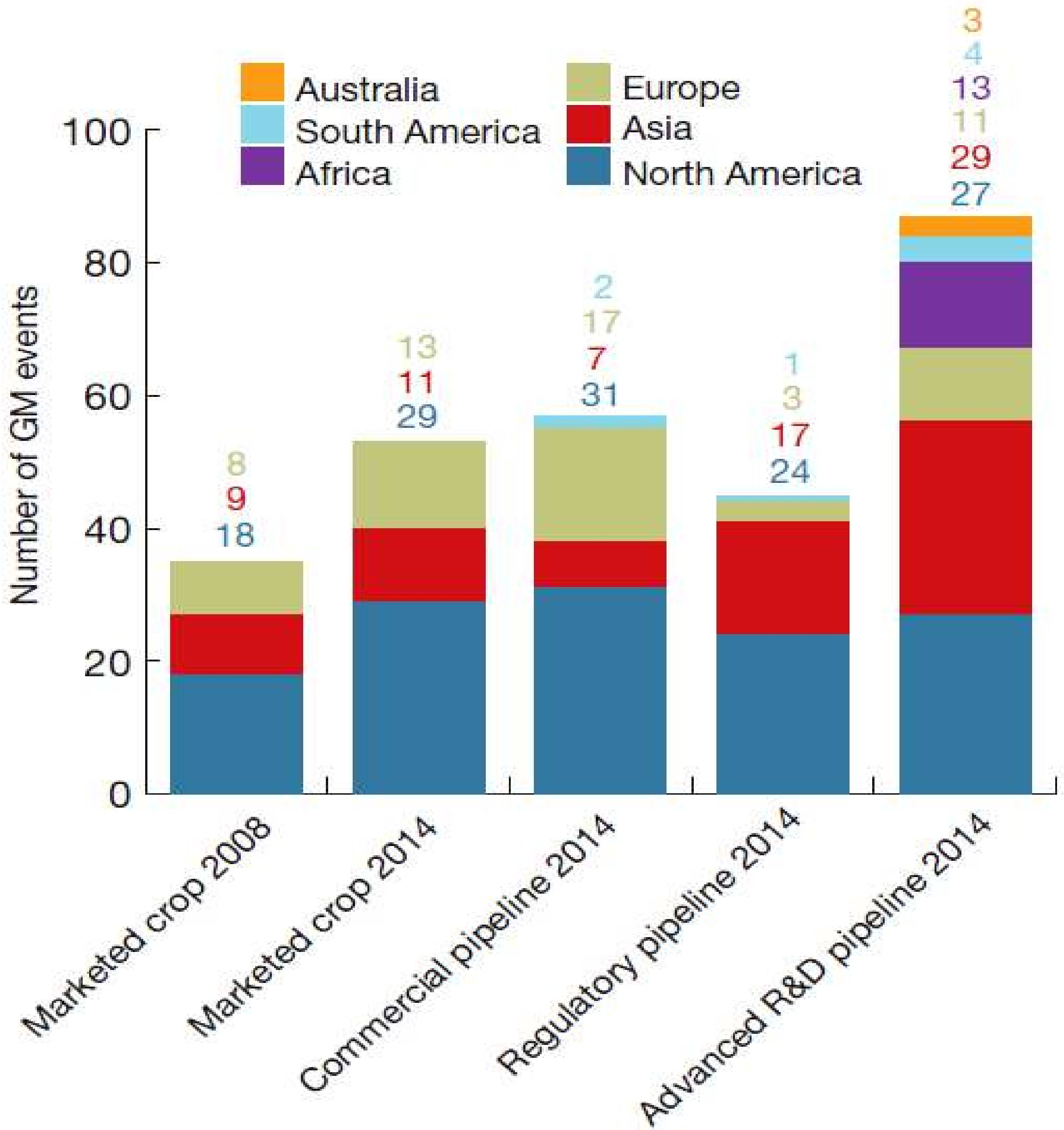

Figure 4 Distribution of GM crop developers per development phase and geographic origin.

AgbioInvestor

gm monitor

Global GM Crop Area Review

May 2023

https://gm.agbioinvestor.com

Key Data

Global GM Crop Area Historical

Year	GM Area (Ha m.)	% Change
2012	163.5	3.5
2013	170.0	4.0
2014	178.6	5.0
2015	176.5	-1.2
2016	179.6	1.7
2017	186.6	3.9
2018	185.9	-0.3
2019	185.7	-0.1
2020	188.8	1.7
2021	195.7	3.6
2022	202.2	3.3

Global GM Crop Area by Crop

Crop	GM Area (Ha m.)	% Change	% Share
Alfalfa	1.1	-2.1	0.5
Brinjal	0.03	80.9	0.0
Canola	9.9	-0.7	4.9
Cotton	25.4	7.9	12.6
Maize	66.2	3.3	32.7
Rice	0.02	Na	0.0
Soybean	98.9	2.6	48.9
Sugar beet	0.5	0	0.3
Sugarcane	0.1	-16.6	0.1
Wheat	0.1	Na	0.1
Total	**202.2**	**3.3**	**100.0**

GM Crop Area by Leading Country

Rank	Country	GM Area (Ha m.)	% Change	% Share
1	USA	74.7	-1.0	36.9
2	Brazil	63.2	10.4	31.3
3	Argentina	23.5	0.4	11.6
4	India	12.4	4.8	6.1
5	Canada	11.3	-3.0	5.6
6	Paraguay	3.7	8.4	1.9
7	South Africa	3.2	8.8	1.6
8	China	2.9	-3.2	1.4
9	Pakistan	1.7	-10.0	0.8
10	Australia	1.5	74.6	0.7
Na	Others	4.2	2.6	2.1
	Total	**202.2**	**3.3**	**100.0**

Transgenic ornamental plants

Transgenic rose and carnation

Transgenic blue rose named APPLAUSE^{TM} by the Japanese company Suntory

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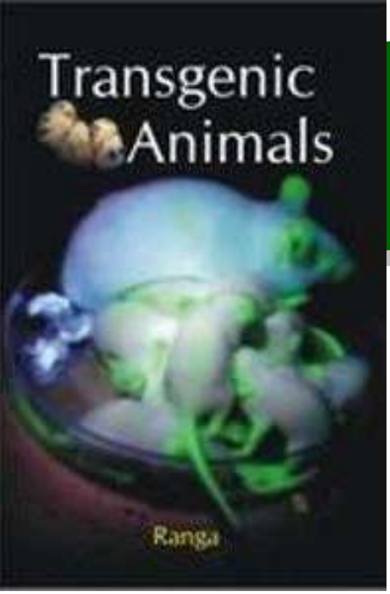
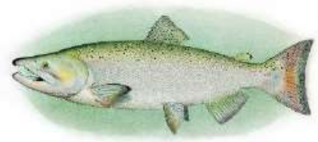


Transgenic animals

- **Transgenic Carp in China**
- **Transgenic Tilapia in Cuba**
- **Transgenic salmon in the US**

Source: Nature Biotechnology (2016)



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Transgenic Goats!

- Transgenic goats with human lysozyme gene for milk production with higher shelf life and anti bacterial properties for kids
- Transgenic goats with human recombinant protein gene for treatment of haemophilia (**Factor IX** or **Christmas factor**)

Dr. James Murray scritches a happy goat - one of the goats that could hold the secrets to treating gut disease in humans. Photo credit: Pat Bailey, photo © Regents of the University of California, Davis

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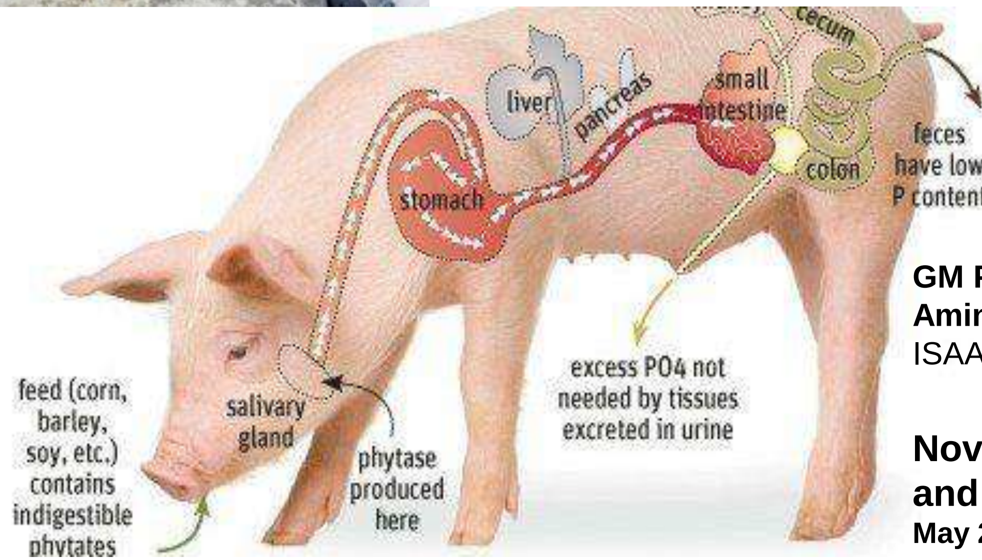
Transgenic Pigs!



GM Phytase Corn Found to Promote Digestion of Amino Acids in Pigs
ISAAA, February 9, 2022

Novel transgenic pigs with enhanced growth and reduced environmental impact (Elife. 2018 May 22;7:e34286. doi: 10.7554/eLife.34286.)

a diagram of another transgenic animal, the ***Enviropig****, a pig designed to* ***produce phytase in its saliva****. This enzyme helps free up bound phosphorous in certain feeds, improving animal use of the mineral and reducing manure phosphorus content. Image credit: University of Guelph via* *http://www.producer.com/2010/05/industry-wary-about-enviropig/*

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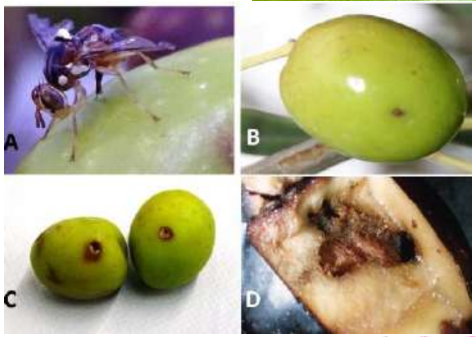
Transgenic insects

- Producing transgenic insects for controlling different agricultural pests such as cotton red boll worm, Mexican fruit fly, olive fly as well as human diseases such as dengue fever, Malaria and Zika…
- Transgenic male sterile insects

- More than 5 million ha of olive orchards in Europe Union
- 35 million Euros for insecticides only in Greece



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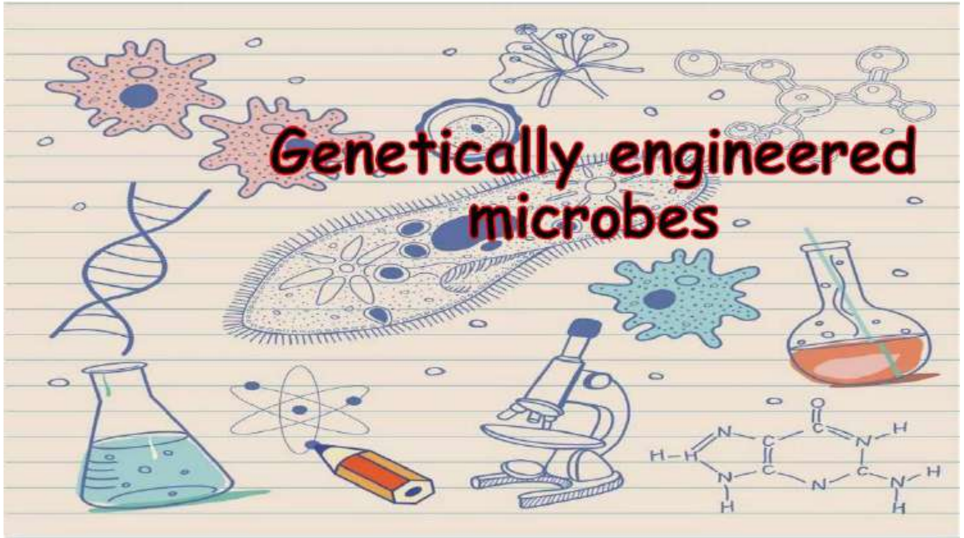
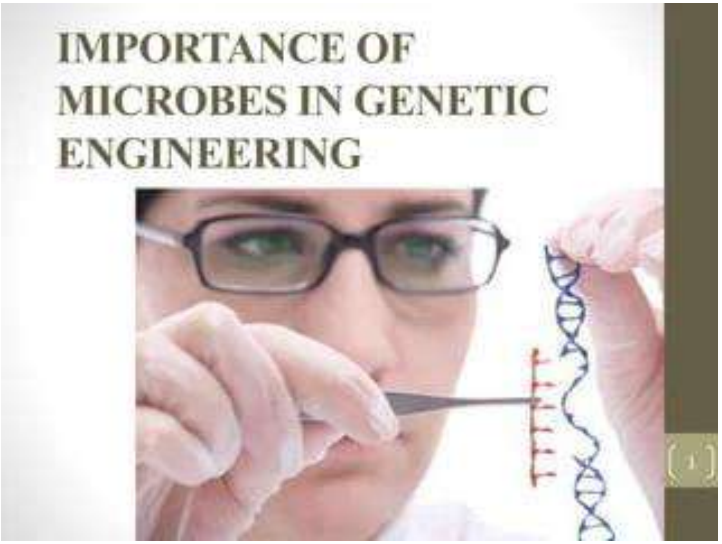
Transgenic micro-organisms

- Producing different transgenic micro-organisms for producing different metabolites including enzymes, amino acids, vitamins, dyes, etc., for different purposes e.g. lysine, methionine, tryptophan, and phytase for poultry and pig industry.





Examples of Specific Gene-edited Products in Agriculture

筑波大学
University of Tsukuba

sanatechseed

Released by a university-launched venture company in April 2021.

Gene-edited tomato with increased GABA

Examples of Specific Gene-edited Products in Agriculture

Plant Biotechnology 36, 167–173 (2019)
DOI: 10.5511/plantbiotechnology.19.0805a

Source:
https://www.jstage.jst.go.jp/article/plantbiotechnology/36/3/36_19.0805a/_pdf/-char/ja

Original Paper

Efficient genome engineering using Platinum TALEN in potato

Shuhei Yasumoto[1], Naoyuki Umemoto[2,*], Hyoung Jae Lee[3], Masaru Nakayasu[3], Satoru Sawai[1], Tetsushi Sakuma[4], Takashi Yamamoto[4], Masaharu Mizutani[3], Kazuki Saito[2], Toshiya Muranaka[1,**]

[1] Department of Biotechnology, Graduate School of Engineering, Osaka University, Suita, Osaka 565-0871, Japan; [2] RIKEN Center for Sustainable Resource Science, Tsurumi-ku, Yokohama, Kanagawa 230-0045, Japan; [3] Graduate School of Agricultural Science, Kobe University, Nada-ku, Kobe, Hyogo 657-8501, Japan; [4] Department of Mathematical and Life Sciences, Graduate School of Science, Hiroshima University, Higashi-Hiroshima, Hiroshima 739-8526, Japan
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** E-mail: muranaka@bio.eng.osaka-u.ac.jp Tel: +81-6-6879-7423 Fax: +81-6-6879-7426

Received June 4, 2019; accepted August 5, 2019 (Edited by S. Nonaka)

Gene-edited potato with reduced toxic and bitter contents.

Evaluation of trait stability in field cultivation began in April 2021.

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Examples of Specific Gene-edited Products in Agriculture

ELSEVIER

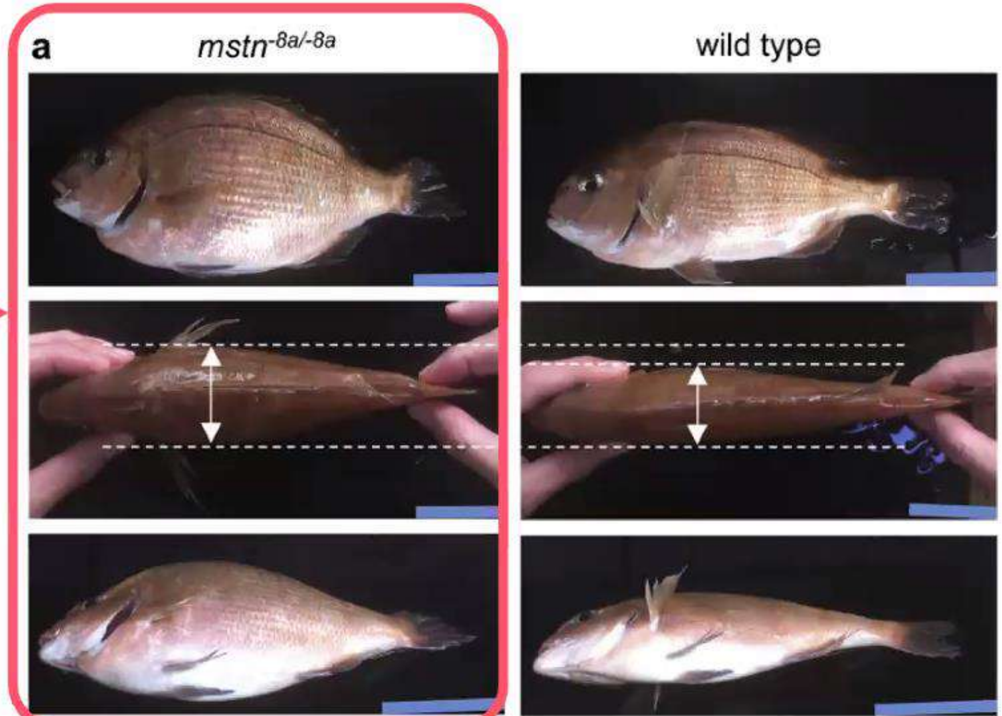
Aquaculture
Volume 495, 1 October 2018, Pages 415-427

Source:
https://www.sciencedirect.com/science/article/pii/S0044848617324705

Production of a breed of red sea bream *Pagrus major* with an increase of skeletal muscle mass and reduced body length by genome editing with CRISPR/Cas9

Kenta Kishimoto [a], Youhei Washio [b], Yasutoshi Yoshiura [c], Atsushi Toyoda [d], Tomohiro Ueno [e], Hidenao Fukuyama [f], Keitaro Kato [b], Masato Kinoshita [a]

Gene-edited red sea bream with an increase of skeletal muscle mass



https://regional.fish/

Regional Fish

Set up a university-launched venture company.

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Scientific Consortiums for Gene-Edited Crops/Animals in Japan

OPERA Program funded by Japan Science and Technology Agency
"Discovering innovative advanced agricultural technology for creating the future of food"

OPERA

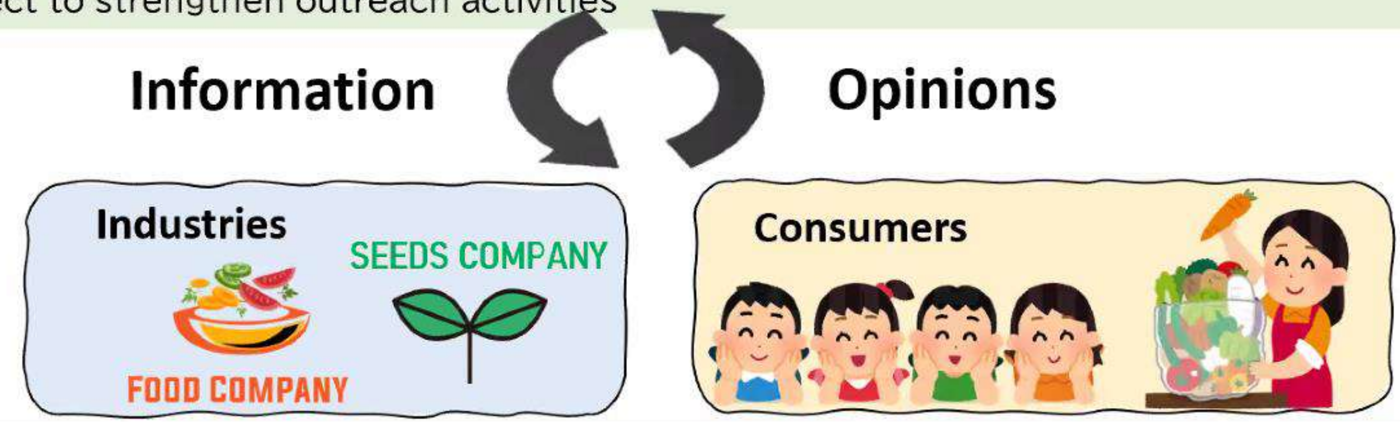
SIP funded by Cabinet Office
"Promoting the public understanding of biotechnology"

SIP

Ministry of Agriculture, Forestry and Fisheries commissioned projects

MAFF

"Accumulation of scientific knowledge for promoting public understanding of genome editing technologies"
"Project to strengthen outreach activities"



A Wide Variety of Activities 'with' and 'for' Society

- Development of textbooks for school children
- Developing websites
- Developing of a glossary of gene editing technologies
- Development of Message Map
- Study of consumer perceptions
- Study the contents of news reports
- Dialogue programs between stakeholders

Website: *Biostation* - SIP

Source: https://bio-sta.jp/

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Website: *What is Gene Editing Technologies?* - Network for Breeding by Genome Editing

Use of Social Scientific Approach

Message Map (MMP)

↓

Focus group discussion to test MMP with nutritionists, journalists and science communicators

↓

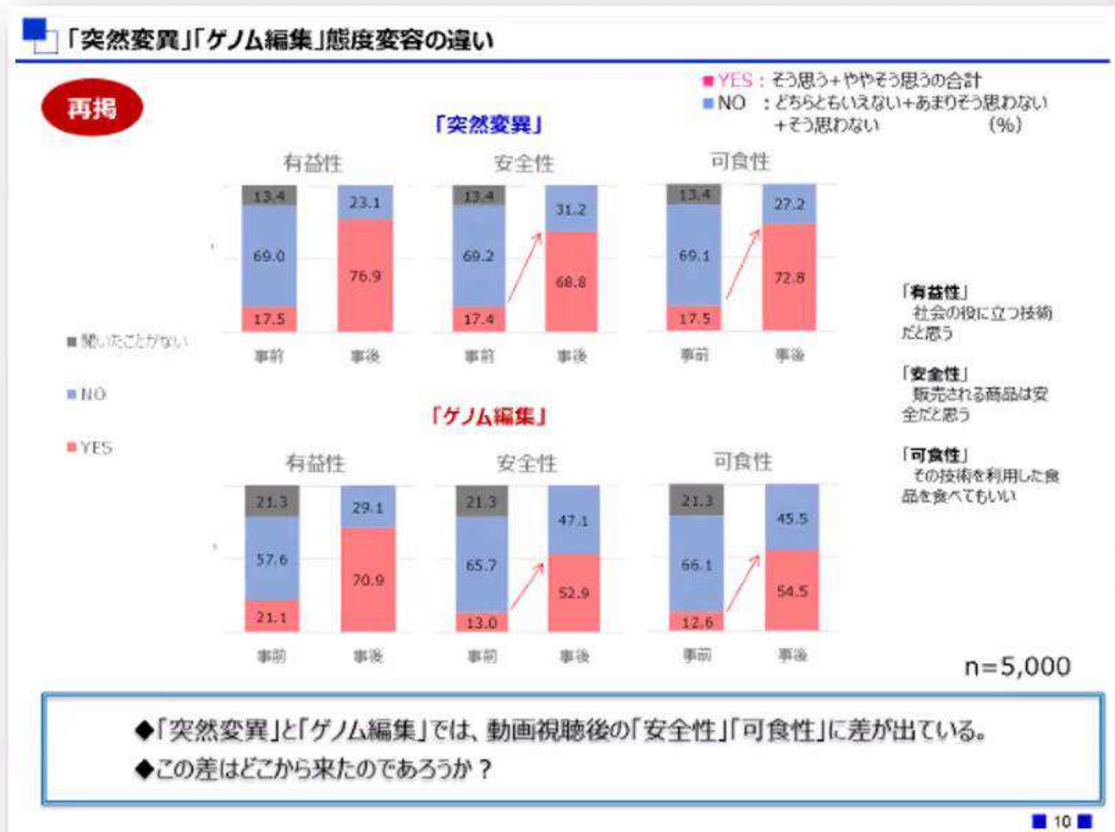
Edit texts of MMP

↓

Developing Website with YouTube Clips

Source: PPT Slides for Communicating Plant Gene Editing
https://genome.t-pirc.tsukuba.ac.jp/communication

Study of Public Perception



OPERA

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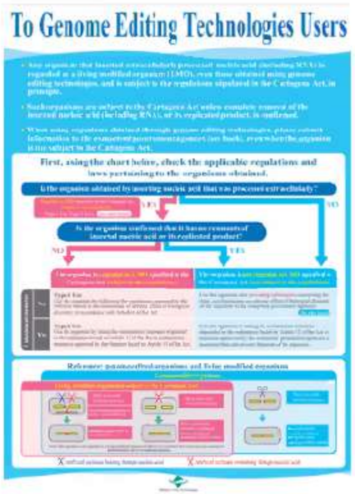
Handling of Gene Editing in Japan (in terms of SDN class)

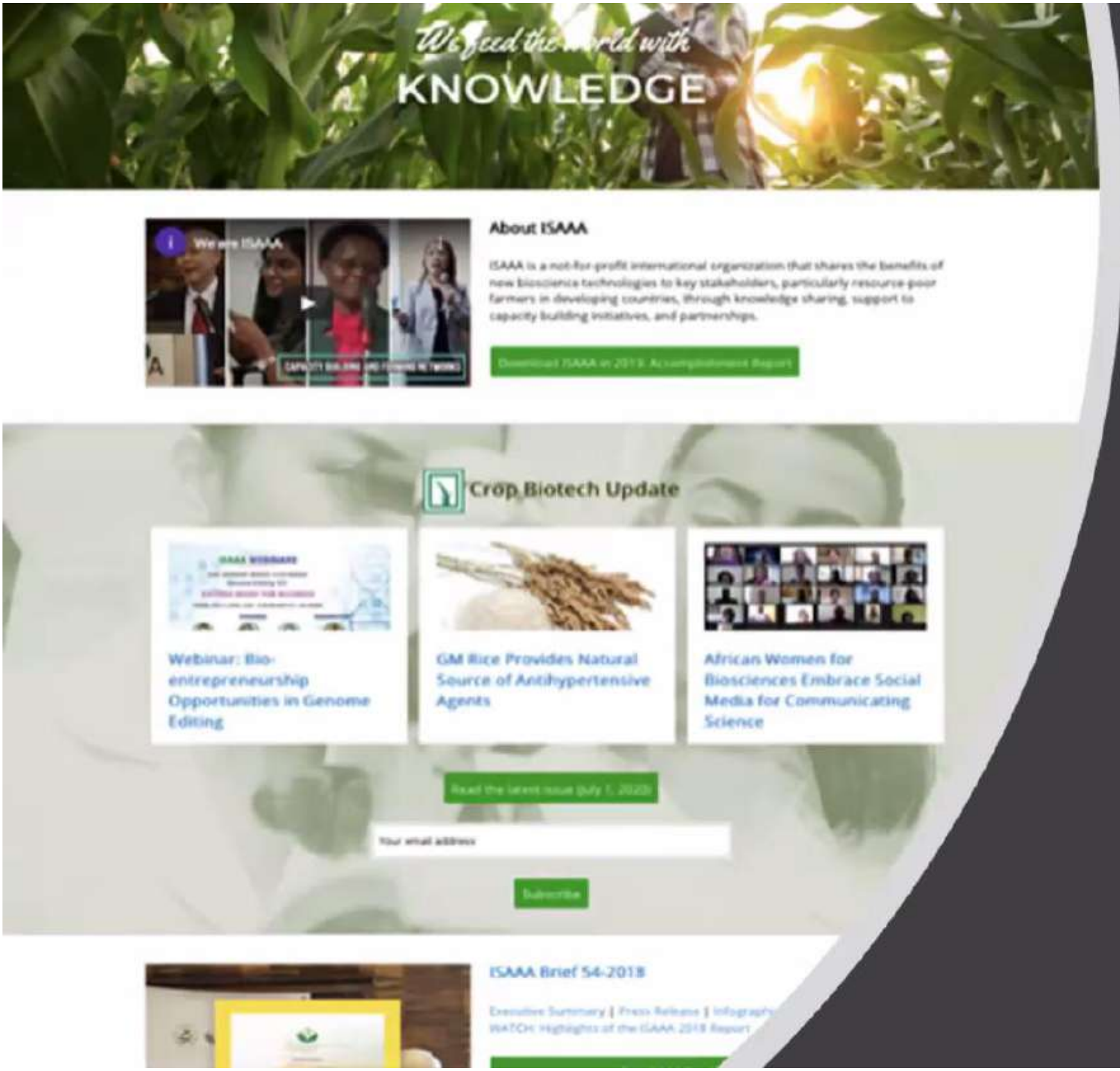
On February 8, 2019, the final decision was reported by the MOE ⇒

Class	MOE [Environment]	MHLW [Food]
SDN1 Editing by the natural repairing of DNA strands	Non-GMO	Non-GMO
SDN2 Editing using template DNA	GMO*	GMO/ Non-GMO
SDN3 Gene Insertion	GMO*	GMO

Leaflet "To Genome Editing Technologies Users"



*In case nucleotides are from same species (self cloning) or cross compatible species (natural occurrence), the product is considered as non-GMO



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