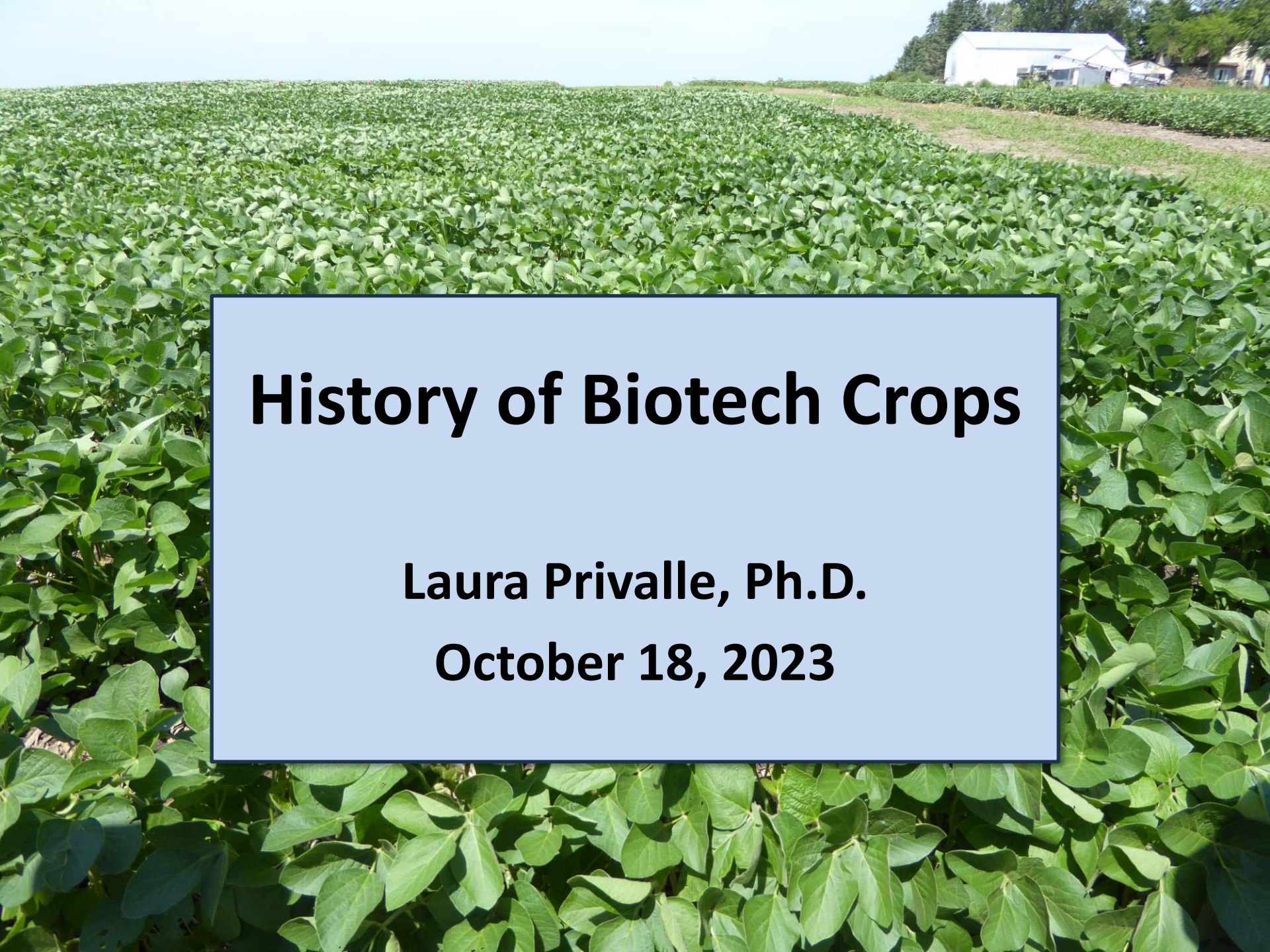
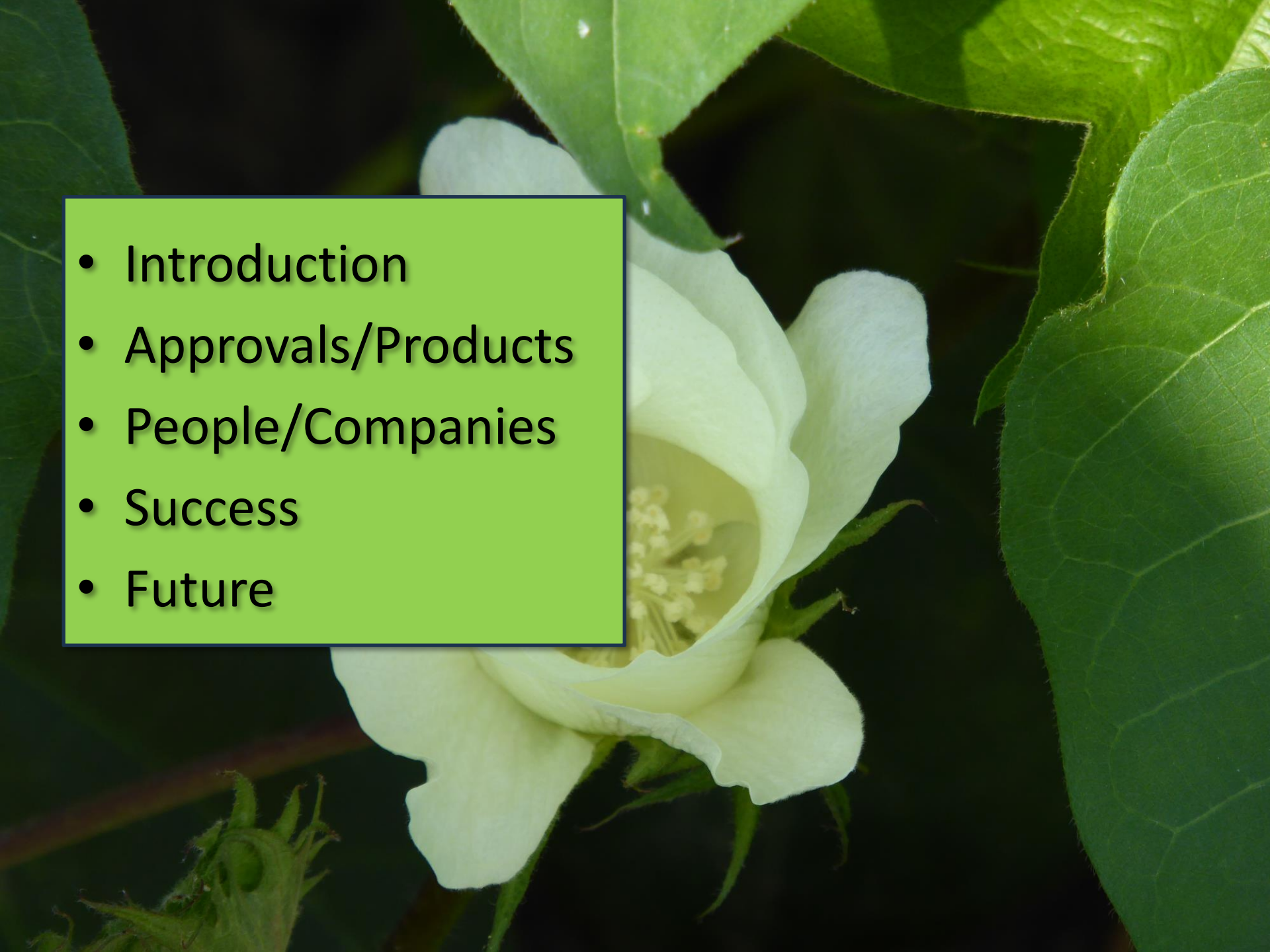


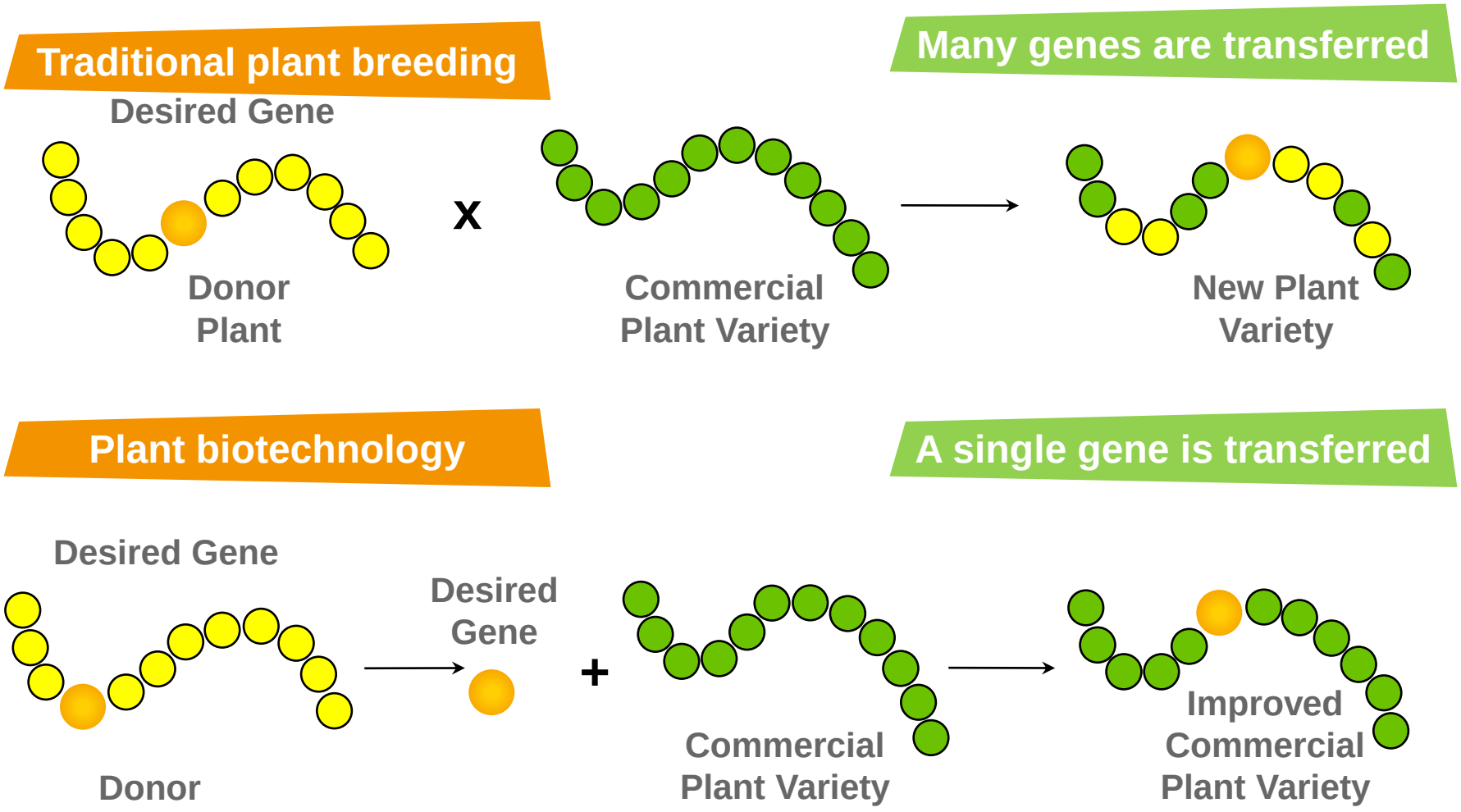
History of Biotech Crops

Laura Privalle, Ph.D.

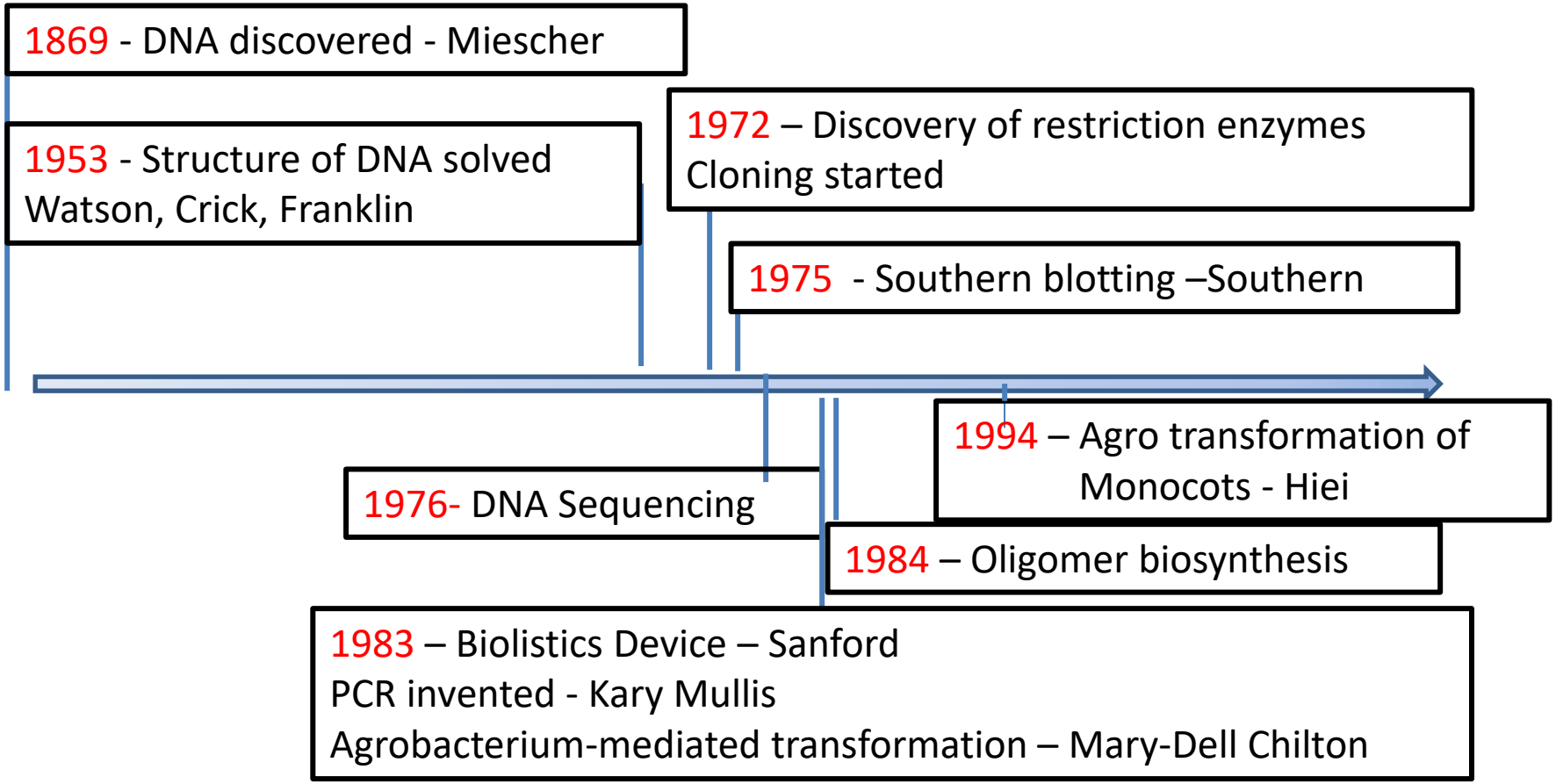
October 18, 2023


• Introduction
• Approvals/Products
• People/Companies
• Success
• Future

Biotechnology is an extension of traditional plant breeding



Critical Enabling Technologies



Product concept - scientifically what is possible

Single gene → Phenotype

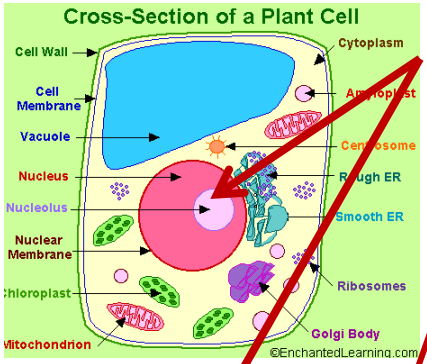
Herbicide tolerance

Insect Resistance

- **Multiple Genes → Phenotype**

Metabolic pathways
– i.e. modified oils

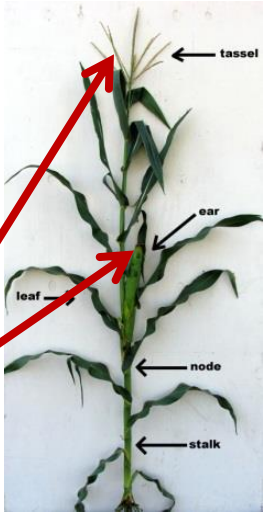
Many hurdles have to be overcome to generate transformed plants



gene into the plant genome

plant cell to turn into a plant…

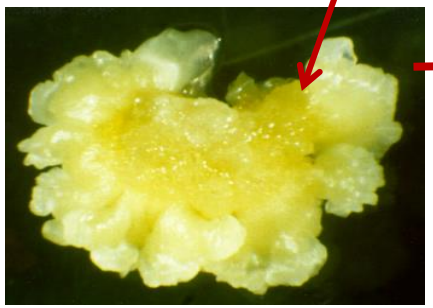
…that expresses the gene



Getting a transformed plant to be fertile

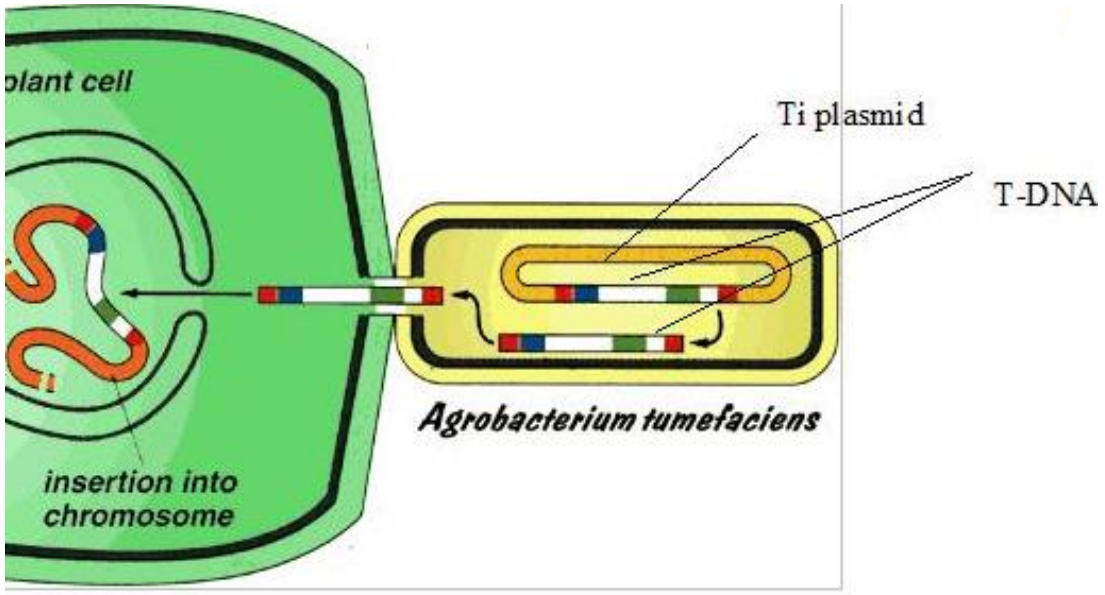
Getting the progeny to express the phenotype…

…without yield drag



Trait Introduction: Biolistics vs. Agro transformation

- Earliest events used biolistics (or similar brute force transformation)
- Protoplast transformation has also been used successfully
- Transformation using *Agrobacterium tumefaciens* is more precise



PSD-1000/He Particle Delivery System

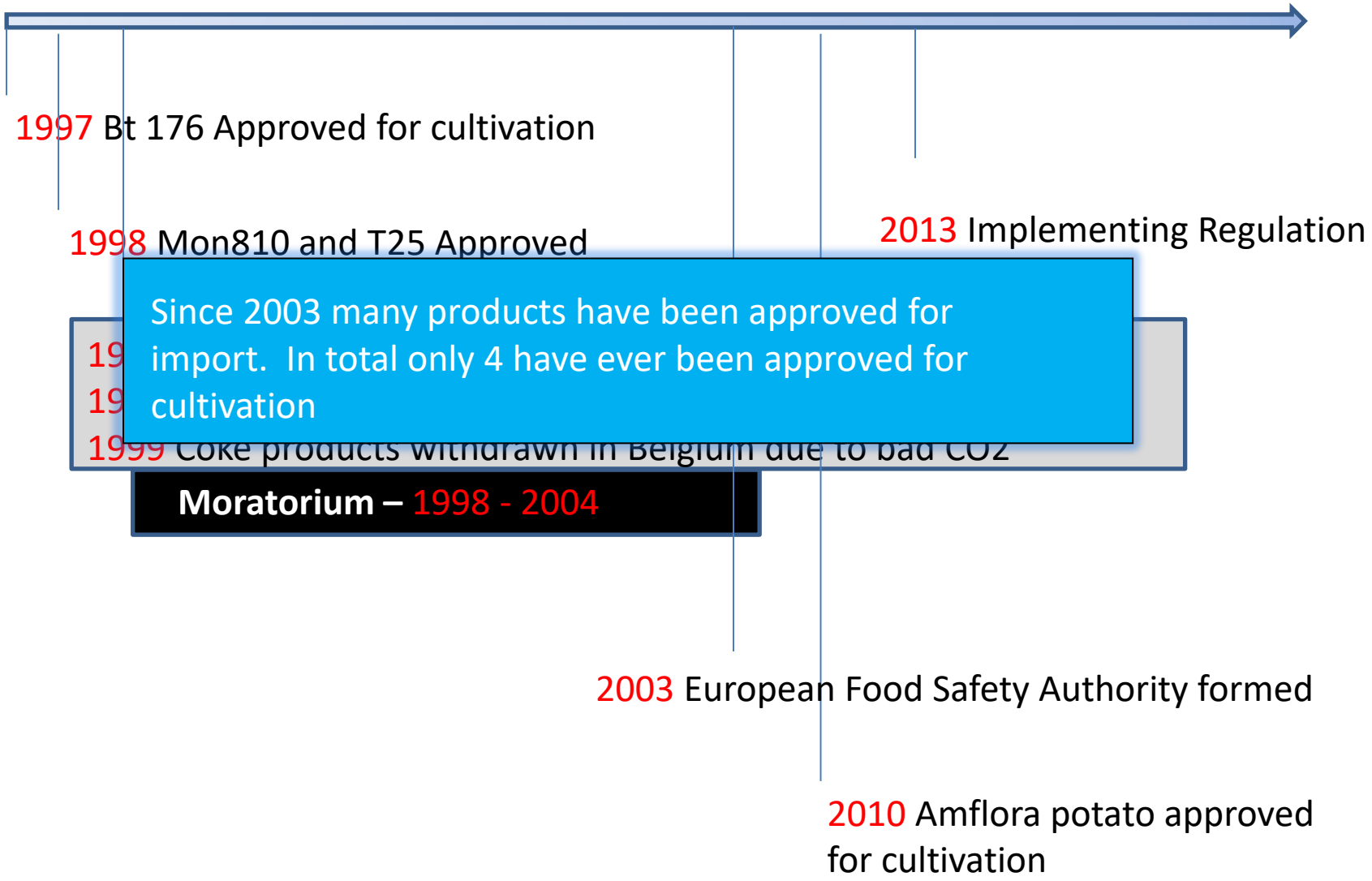
Key Early US Regulatory Approvals

Year	Product	Agency	Registrant
1992	FlavrSavr Tomato (delayed ripening)	FDA	Calgene (now Bayer)
1994	Bt176 Maize (insect resistance)	EPA (1995, USDA, FDA)	Ciba-GEIGY (now Syngenta)
	Bromoxynil Cotton (herbicide tolerant)	USDA, FDA	Calgene (now Bayer)
	RR Soybean (herbicide tolerant)	USDA (1995, FDA)	Monsanto (now Bayer)
1995	New Leaf Potato (insect resistant)	USDA, EPA, FDA	Monsanto (now Bayer)
	T25 Maize (herbicide tolerant)	USDA	Agrevo (now BASF)
	RR Canola (herbicide tolerant)	USDA, FDA	Monsanto (now Bayer)
	Mon810 (insect resistance)	EPA (1996, USDA, FDA)	Monsanto (now Bayer)
1996	Virus Resistant Papaya	USDA (1997, EPA, FDA)	Cornell University
	InVigor Canola (herbicide tolerant + hybrid technology)	FDA, USDA	Aventis (now BASF)
	Bt11 (insect resistant)	EPA, USDA, FDA	Northrup King (now Syngenta)
1998	RR Sugarbeet (herbicide tolerant)	FDA, USDA	Monsanto (now Bayer)/Novartis (now Syngenta)

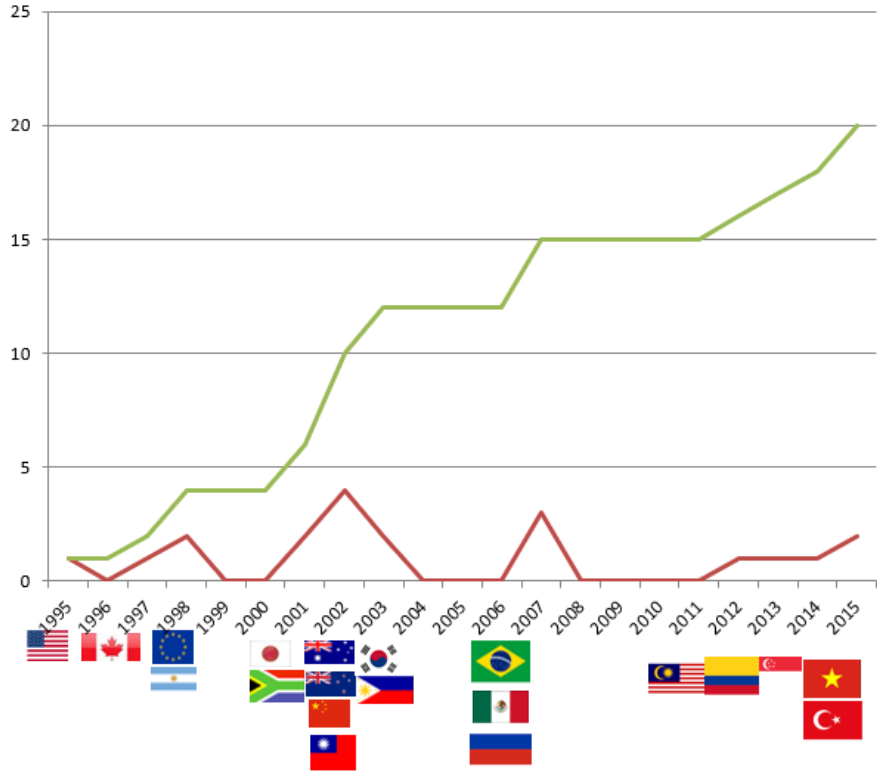
Critical Considerations

- Germplasm
- Value Capture
- Herbicide tolerance
- Patents
- Path to Market
- Antibiotic Resistance
- Refuge
- Extraneous DNA

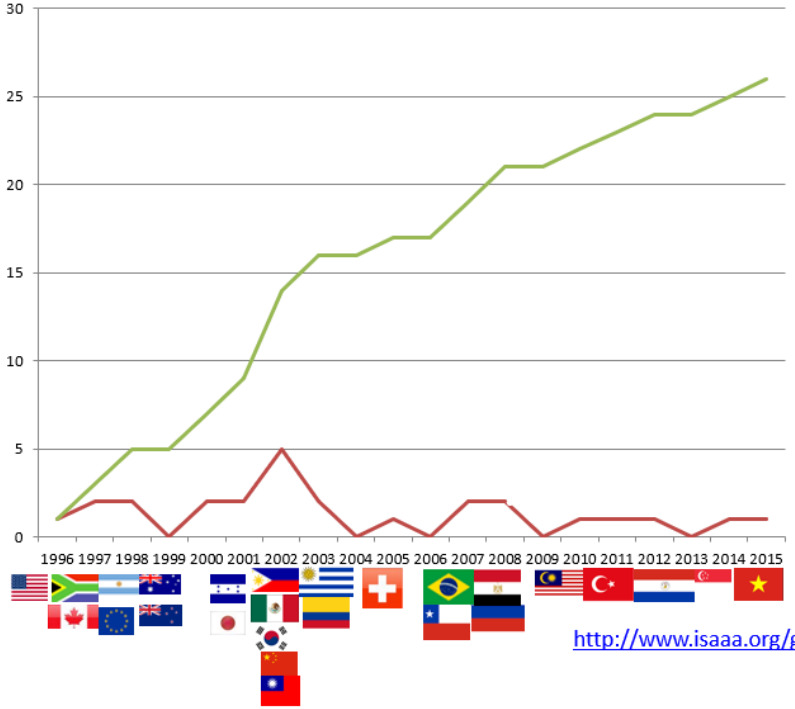
Biotech Products and Europe – Key Events



Approvals for T25 (LL corn) – 1st 21 Years



Approvals for Mon810 (Bt corn) – 1st 20 Years



http://www.isaaa.org/gmapprovaldataba

Top Ten Countries Which Granted Food, Feed and Cultivation/Environment 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	1315
	TOTAL	2115	1514	856	4485

*For Japan, data is collected from Japan Biosafety Clearing House (JBCH, English and Japanese) as well as the website of the Ministry of Health, Labor and Welfare (MHLW). However, intermediate events derived from an approved pyramided event recorded in JBCH are not included in our database if they do not appear in MHLW. Also, expired approvals are included in our database from 1992 while JBCH's records starts in 2004.

**USA only approves individual events.

***While cultivation approvals are granted in Japan, there are no current GM planting done.

Key Figures – Mary-Dell Chilton

Age

84 years

Awards

World Food Prize, Benjamin Franklin Medal in Life Science

Syngenta US

Mary-Dell Chilton, Distinguished Science Fellow - Syngenta US

Chilton has been recognized for her extensive contributions to science. Notable awards include the World Food Prize in...

About

Mary-Dell Chilton is one of the founders of modern plant biotechnology. Wikipedia

Born: 1939 (age 84 years), Indianapolis, IN

Awards: World Food Prize, Benjamin Franklin Medal in Life Science

Education: University of Illinois Urbana-Champaign

Known for: First genetically modified plants

Key Figures – Rob Fraley

Robert Fraley

Executive

Robert Thomas Fraley was Executive Vice President and Chief Technology Officer at Monsanto, where he helped to develop the first genetically modified seeds. He retired from Monsanto in June 2018. Wikipedia

Born: 1953 (age 70 years), Wellington, IL

Awards: World Food Prize, National Medal of Technology and Innovation

Education: University of Illinois Urbana-Champaign

Notable student: Elizabeth E. Hood

Key Figures – Marc van Montagu

YouTube • Annual Reviews

A Conversation with Marc Van Montagu

Marc Van Montagu, President of the European Federation of Biotechnology...

May 8, 2013

Place Of Birth

Ghent, Belgium

Awards

World Food Prize, Japan Prize

Google

Marc Van Montagu - Google Scholar

Marc Van Montagu. VIB-IPBO. Verified email at ugent.be - Homepage · Plant...

About

Marc, Baron Van Montagu is a Belgian molecular biologist. He was full professor and director of the Laboratory of Genetics at the faculty of Sciences at Ghent University and scientific director of the genetics department of the Flanders Interuniversity Institute for Biotechnology. Wikipedia

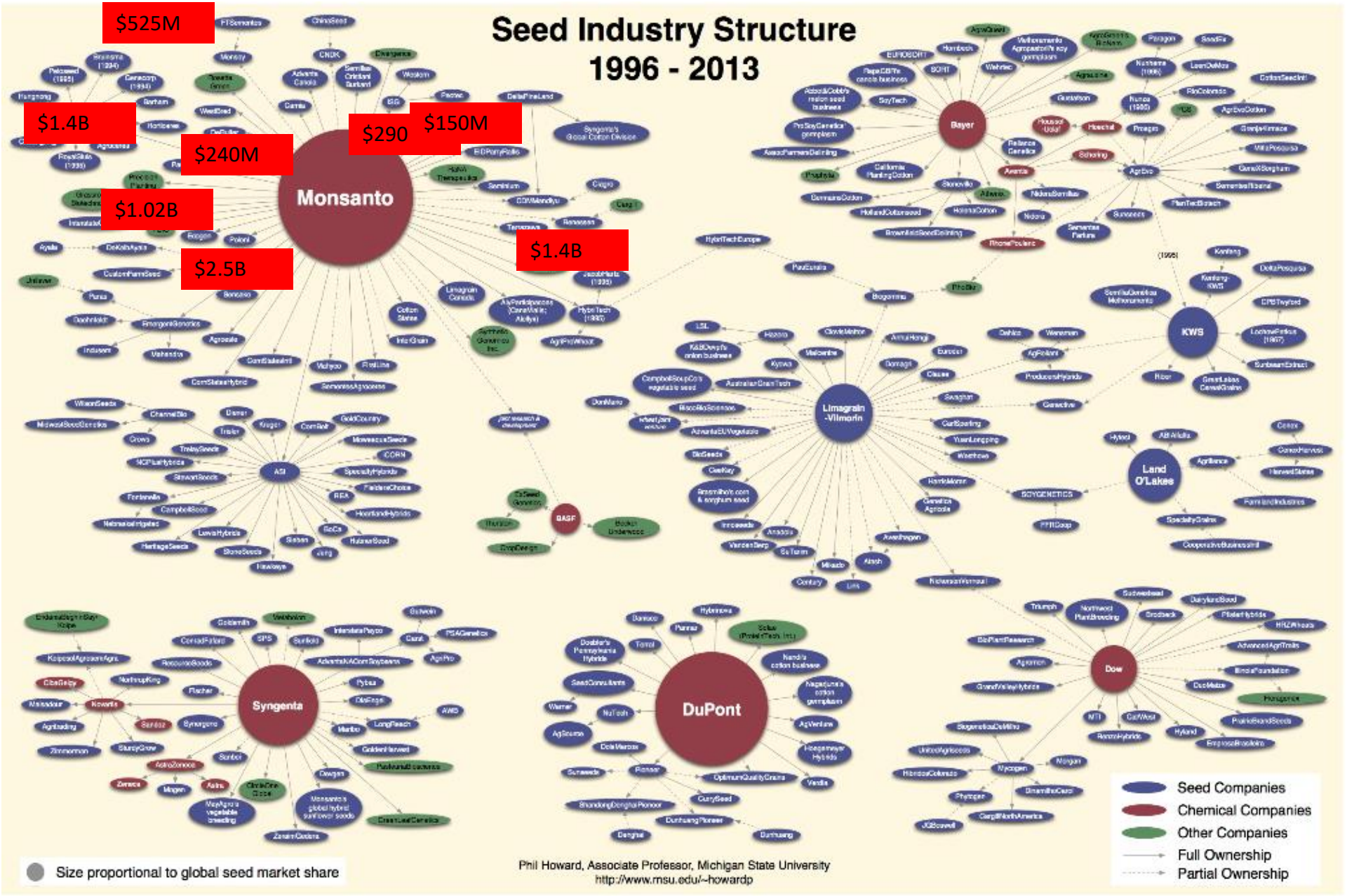
Place of birth: Ghent, Belgium

Awards: World Food Prize, Japan Prize

Education: Ghent University

Notable student: Kan Wang

Organizations founded: Plant Genetic Systems, CropDesign


Seed Industry Structure
1996 - 2013
$525M
$1.4B
$240M
$1.02B
$2.5B
$290
$150M
$1.4B
Monsanto
Bayer
Limagrain
-Vilmorin
KWS
Land
O'Lakes
ASI
Syngenta
DuPont
Dow
BASF
Seed Companies
Chemical Companies
Other Companies
Full Ownership
Partial Ownership
Size proportional to global seed market share
Phil Howard, Associate Professor, Michigan State University
http://www.msu.edu/~howardp

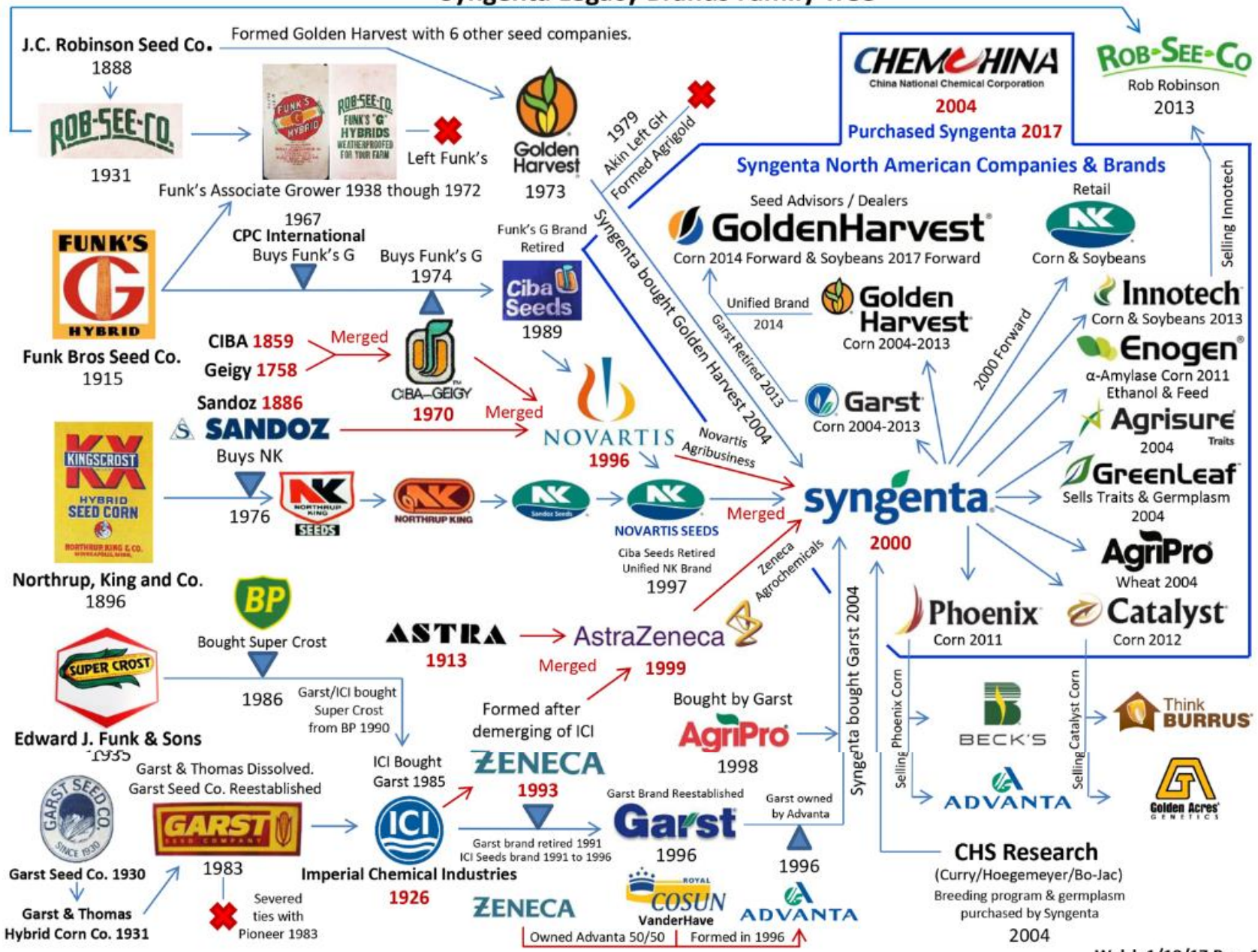
2017 Seed Company Family Tree

Sources: Walsh Timeline, Cornland Consulting, Farm Journal

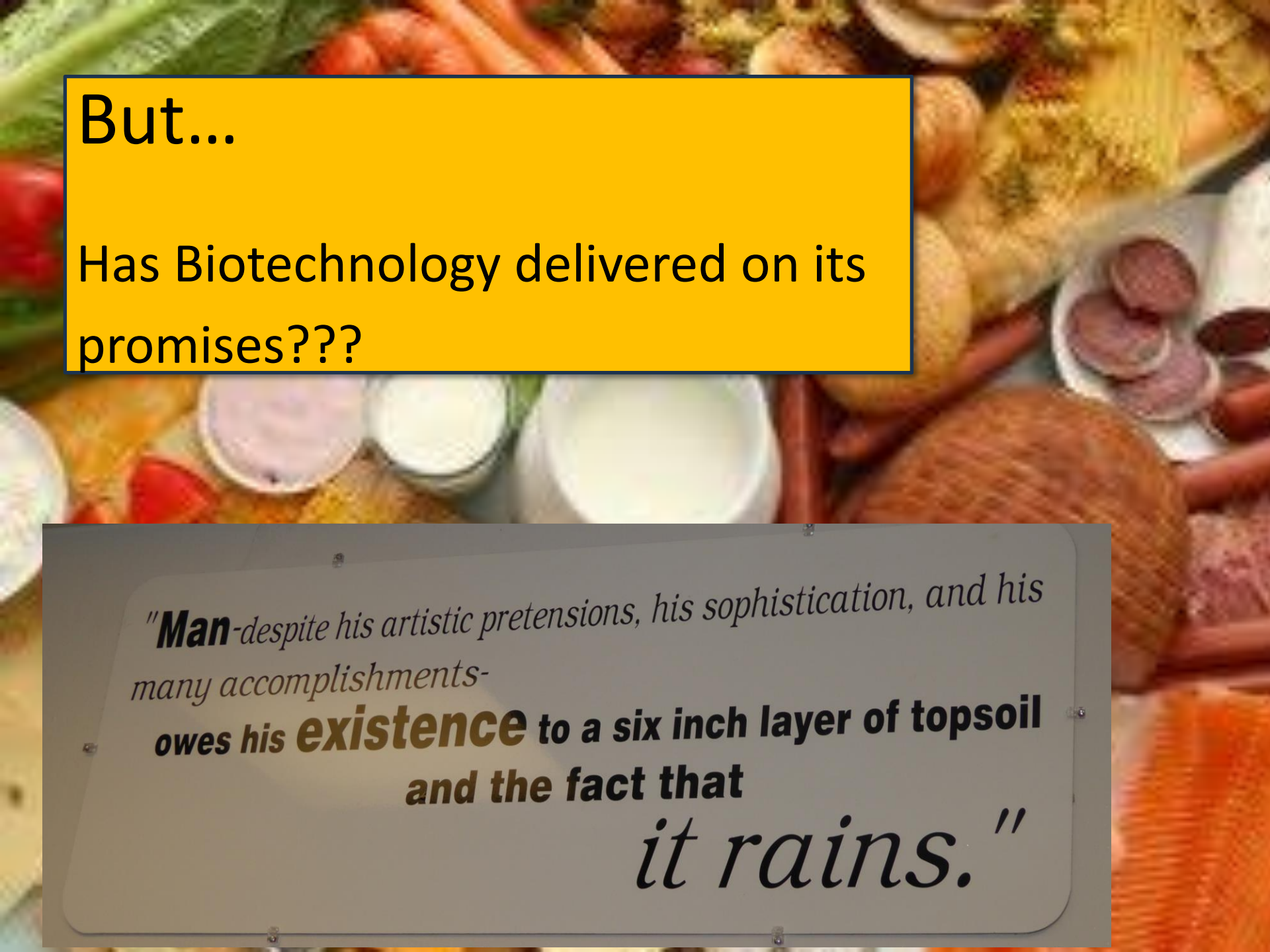
Details: Dates listed under seed brands indicate purchase or creation year by parent company

Rev 10, Walsh 9/10/17

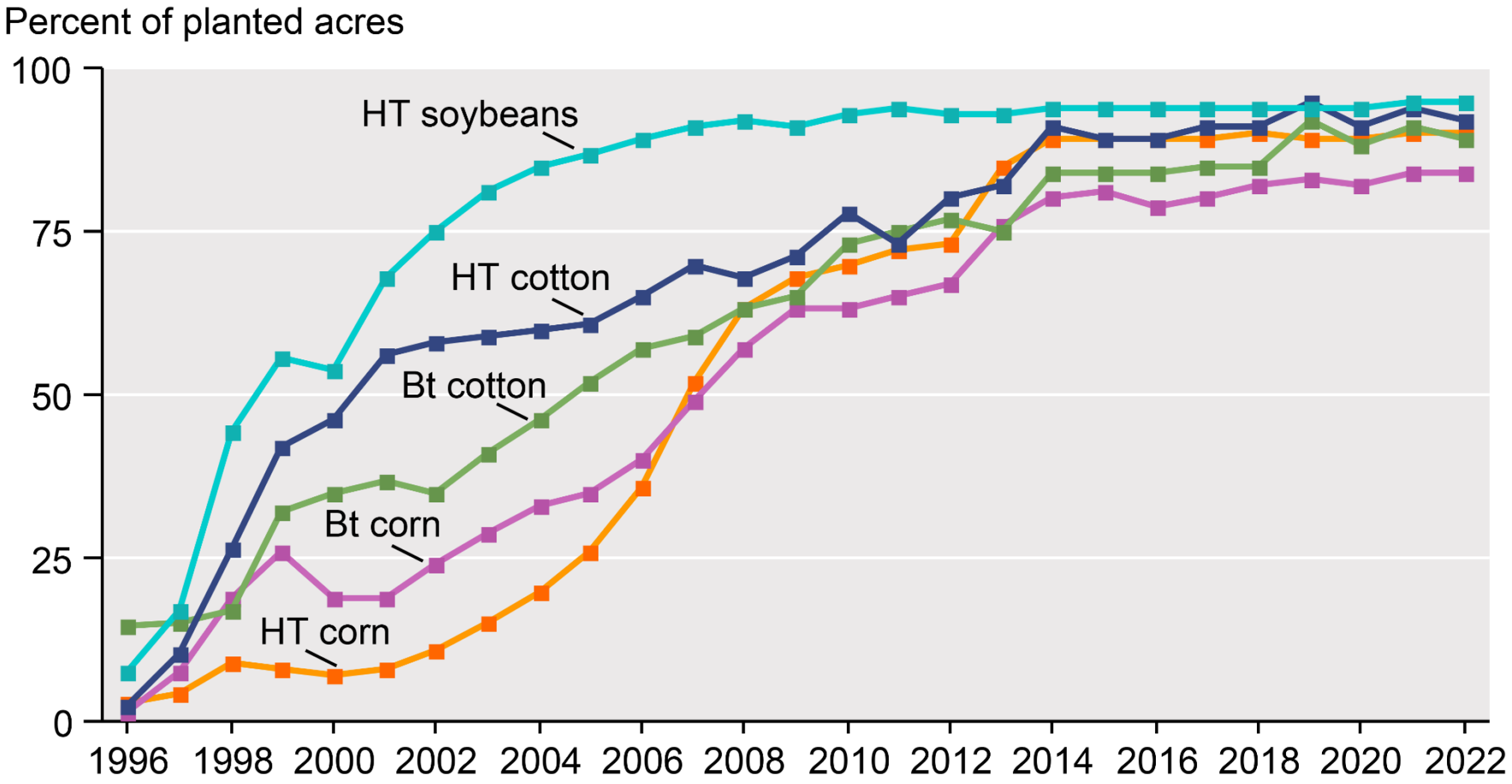
Syngenta Legacy Brands Family Tree



Walsh 1/18/17 Rev. 13


But…
Has Biotechnology delivered on its promises???
"Man-despite his artistic pretensions, his sophistication, and his many accomplishments-
owes his existence to a six inch layer of topsoil and the fact that it rains."

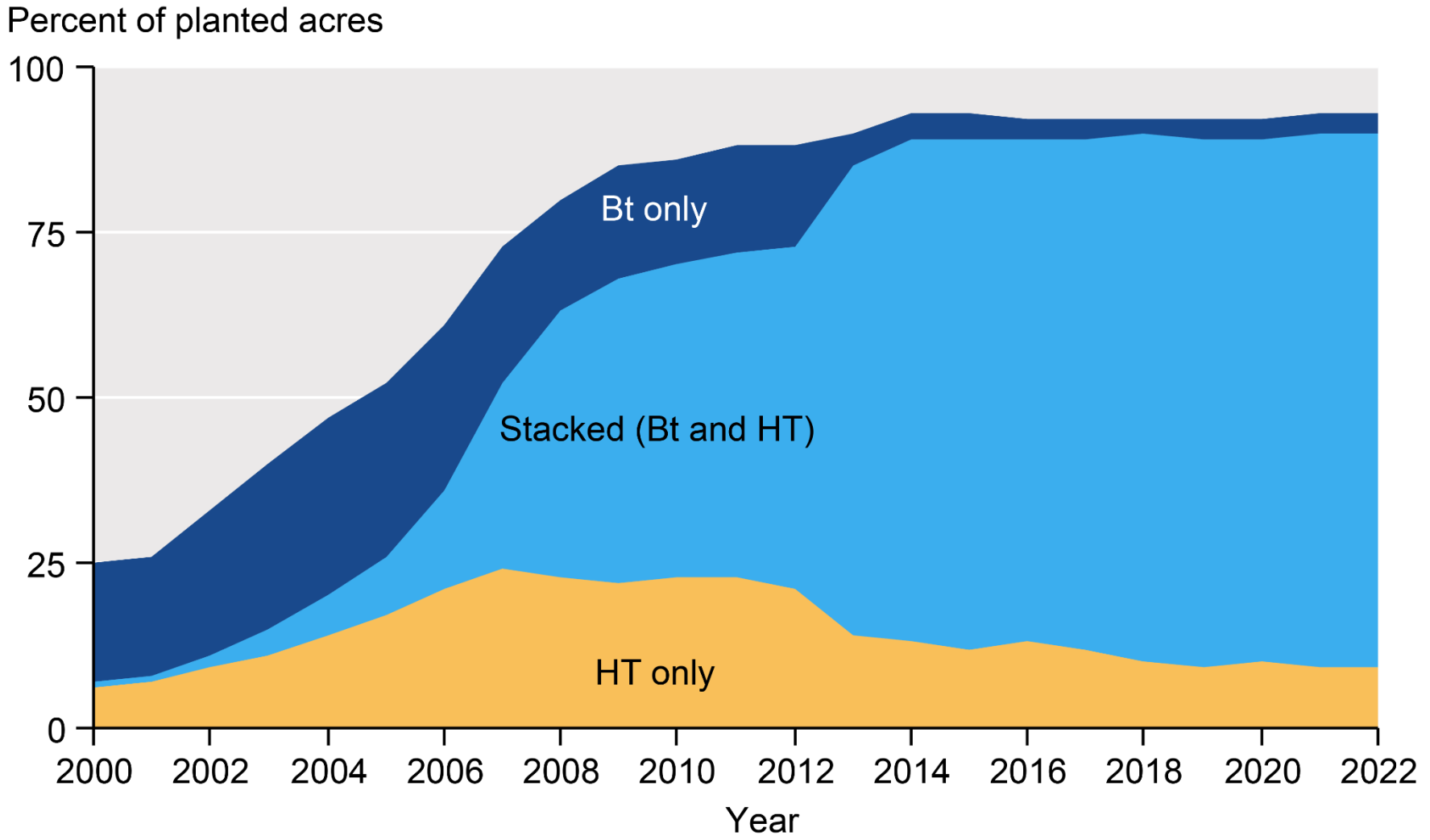
Adoption of genetically engineered crops in the United States, 1996–2022



Note: HT indicates herbicide-tolerant varieties; Bt (Bacillus thuringiensis) indicates insect-resistant varieties (containing genes from the soil bacterium Bt). Data for HT/Bt corn and cotton are not mututally exclusive, as HT and Bt categories include those varieties with overlapping (stacked) HT and Bt traits.

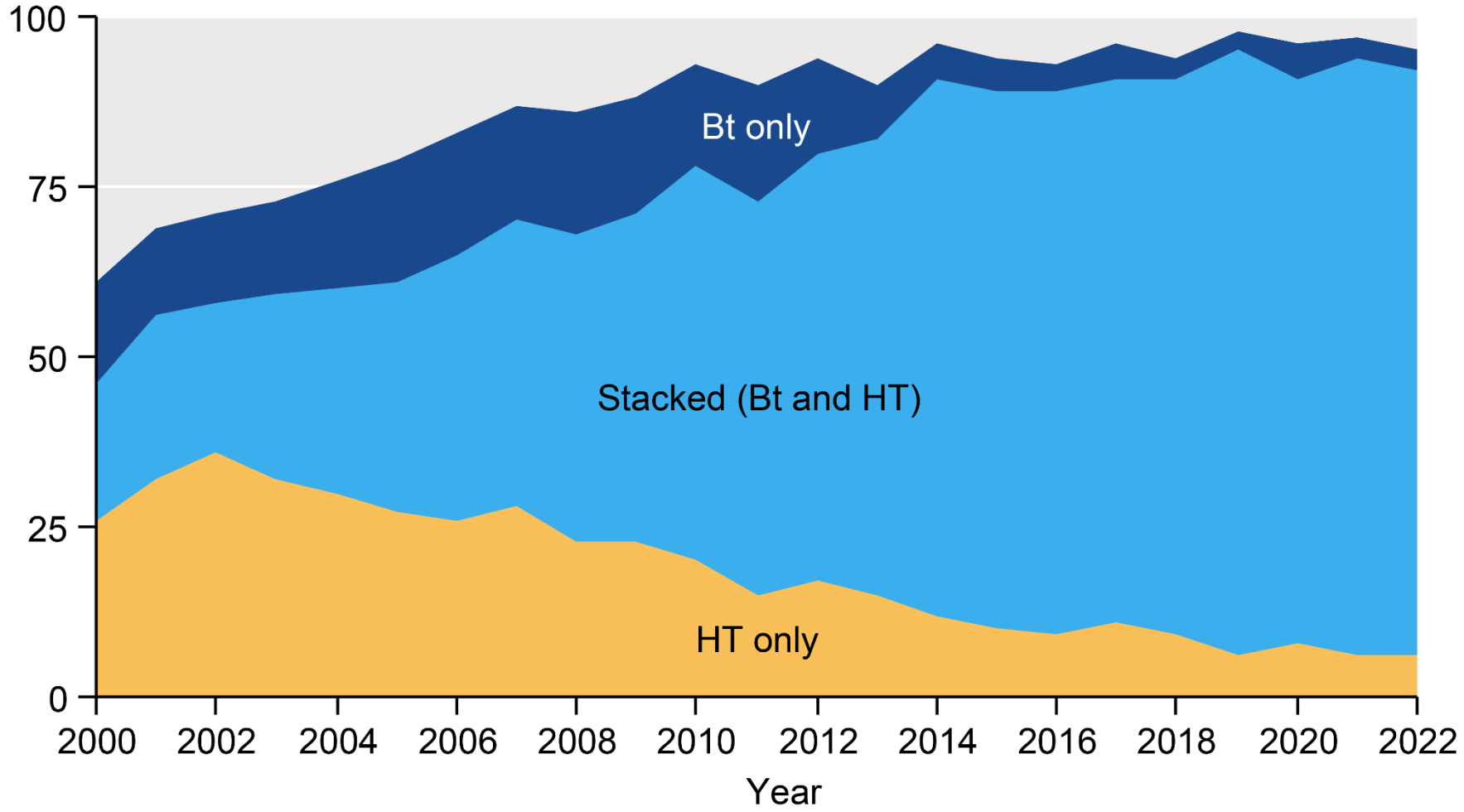
Source: USDA, Economic Research Service using data from the 2002 ERS report, Adoption of Bioengineered Crops (AER–810) for 1996–99 and National Agricultural Statistics Service, (annual) June Agricultural Survey for 2000–22.

Adoption of genetically engineered corn in the United States, by trait, 2000–22

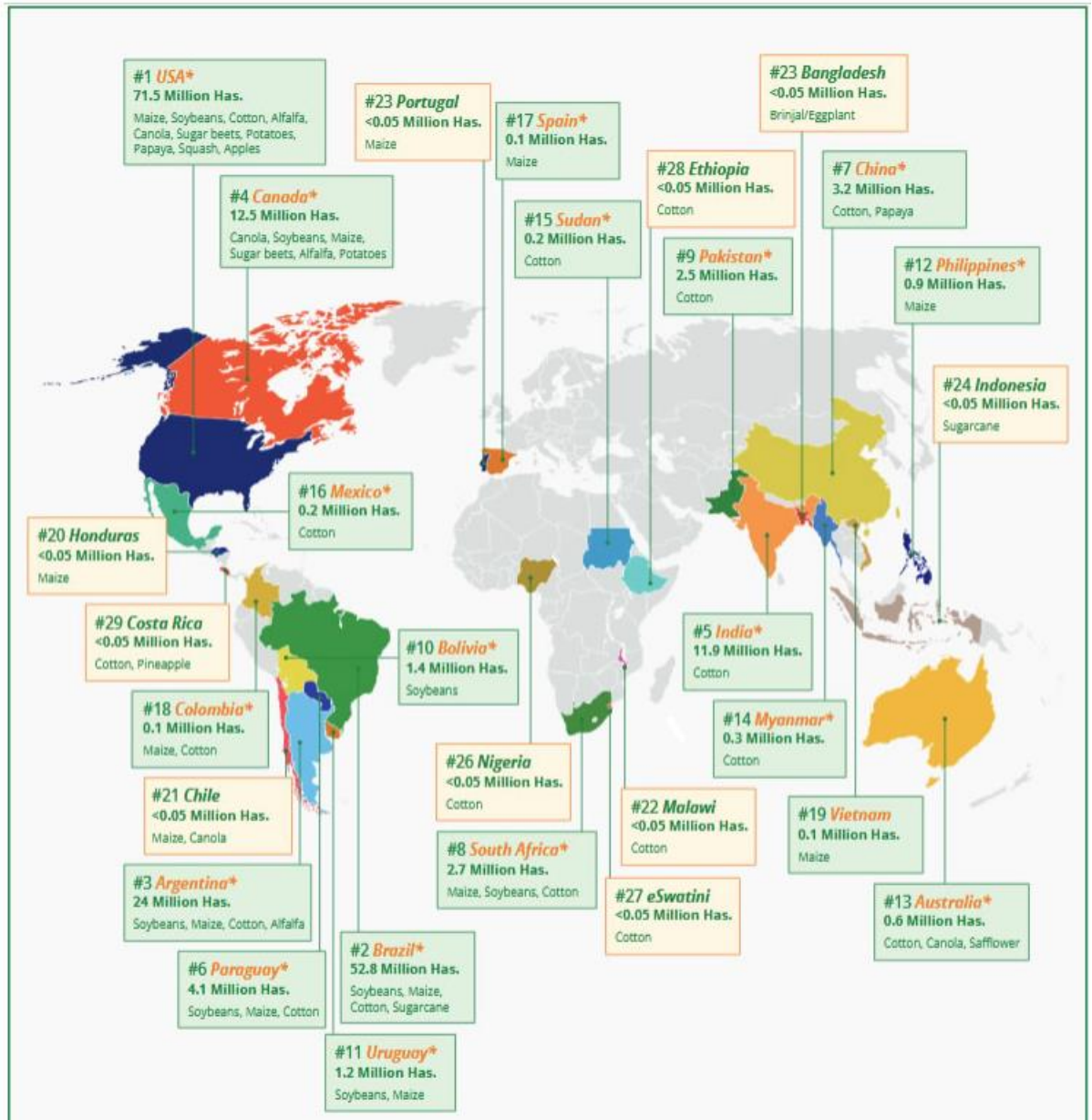


Note: HT indicates herbicide-tolerant varieties; Bt (Bacillus thuringiensis) indicates insect-resistant varieties (containing genes from the soil bacterium Bt).
Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, (annual) June Agricultural Survey.

Adoption of genetically engineered cotton in the United States, by trait, 2000–22



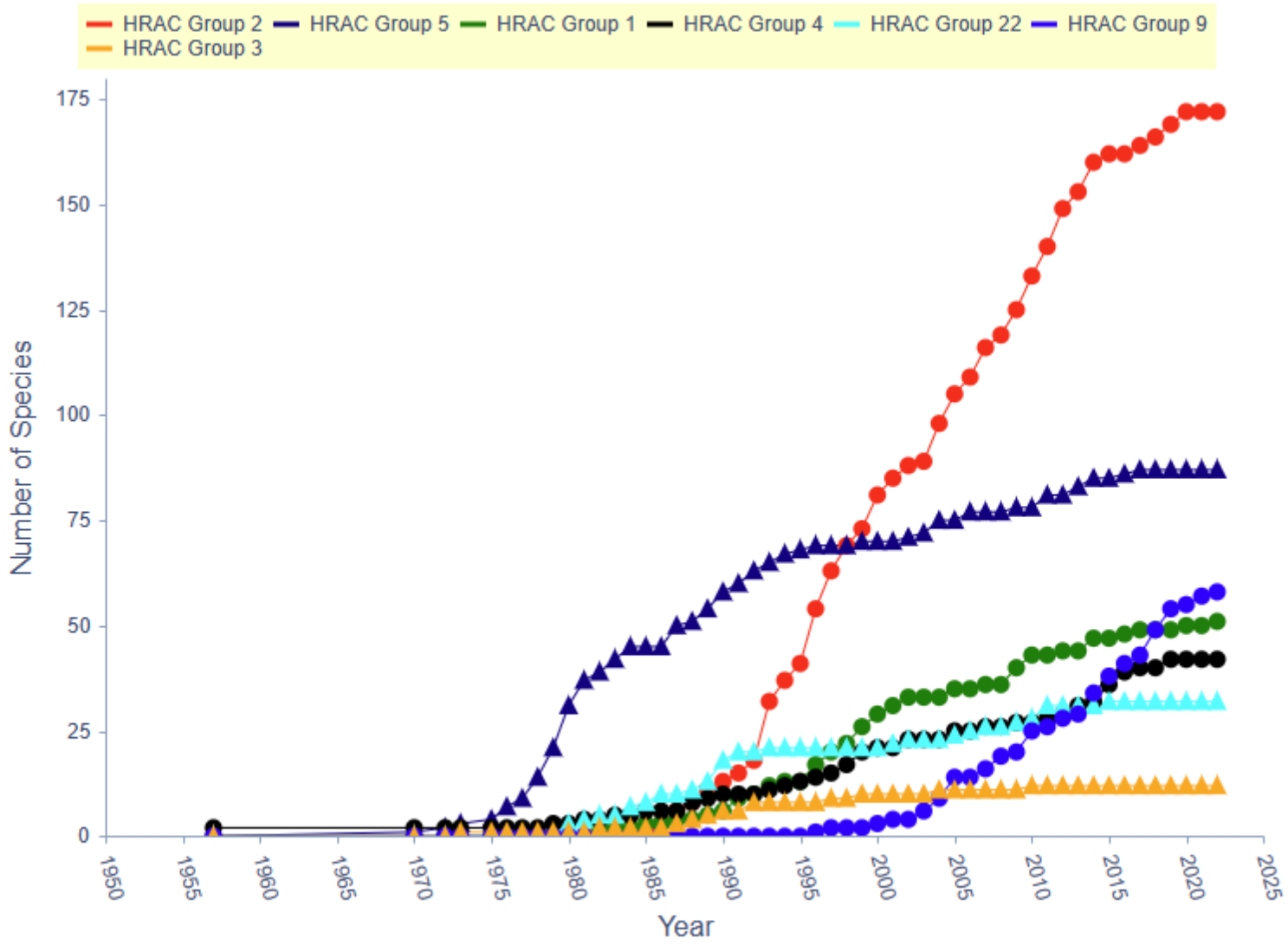
Note: HT indicates herbicide-tolerant varieties; Bt (Bacillus thuringiensis) indicates insect-resistant varieties (containing genes from the soil bacterium Bt).
Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, (annual) June Agricultural Survey.



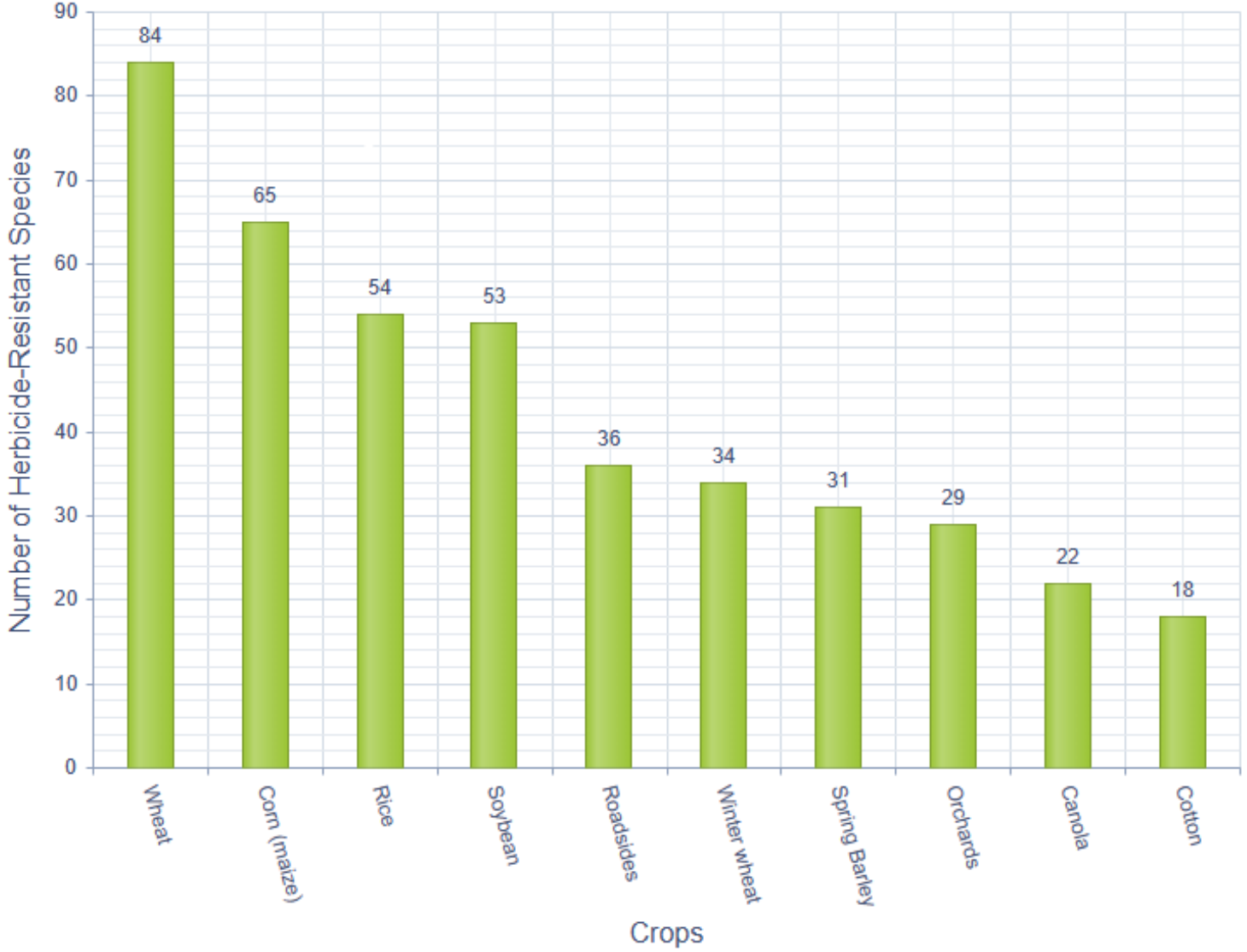
*19 biotech mega-countries growing 50,000 hectares, or more, of biotech crops.

Source: ISAAA, 2019

Chronological Increase to Resistant Weeds Globally



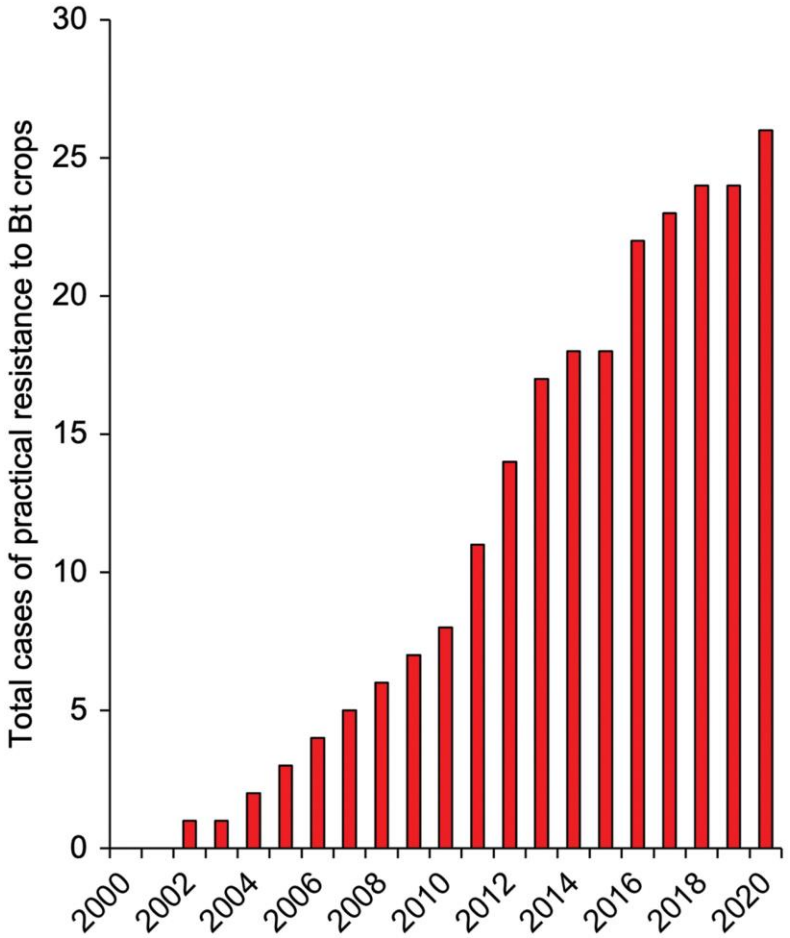
Number of Herbicide Resistant Species by crop (top 10)



Tabashnik, B. E., Fabrick, J. A., & Carrière, Y. (2023). *Journal of economic entomology*, *116*(2), 297-309. https://doi.org/10.1093/jee/toac183

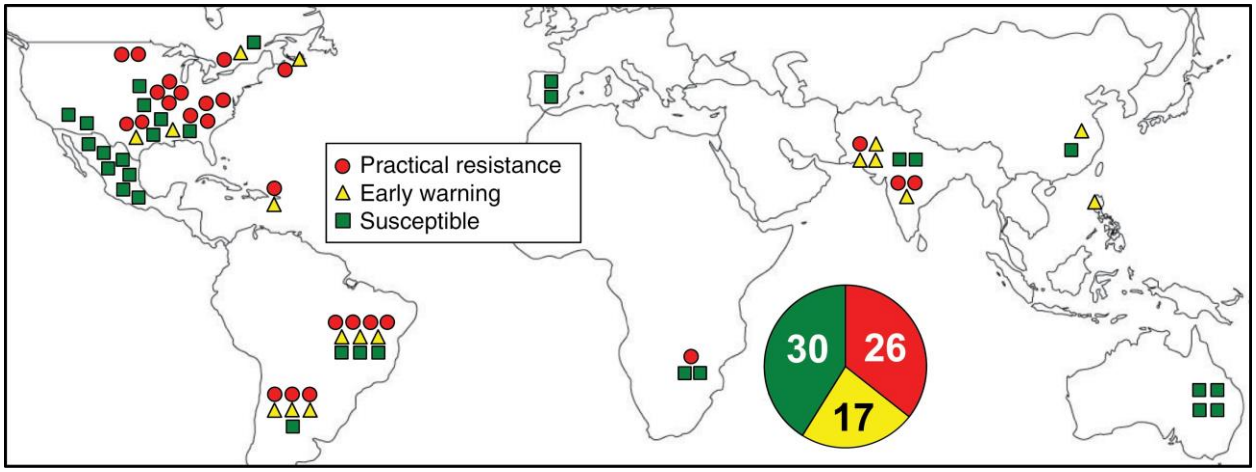
Global Patterns of Insect Resistance to Transgenic Bt Crops: The First 25 Years

Fig. 2. Cumulative reported cases of practical resistance to Bt crops.



J Econ Entomol, Volume 116, Issue 2, April 2023, Pages 297–309, https://doi.org/10.1093/jee/toac183

Fig. 3. Global status of field-evolved pest resistance to Bt crops. Each symbol represents 1 of 73 cases indicating ...



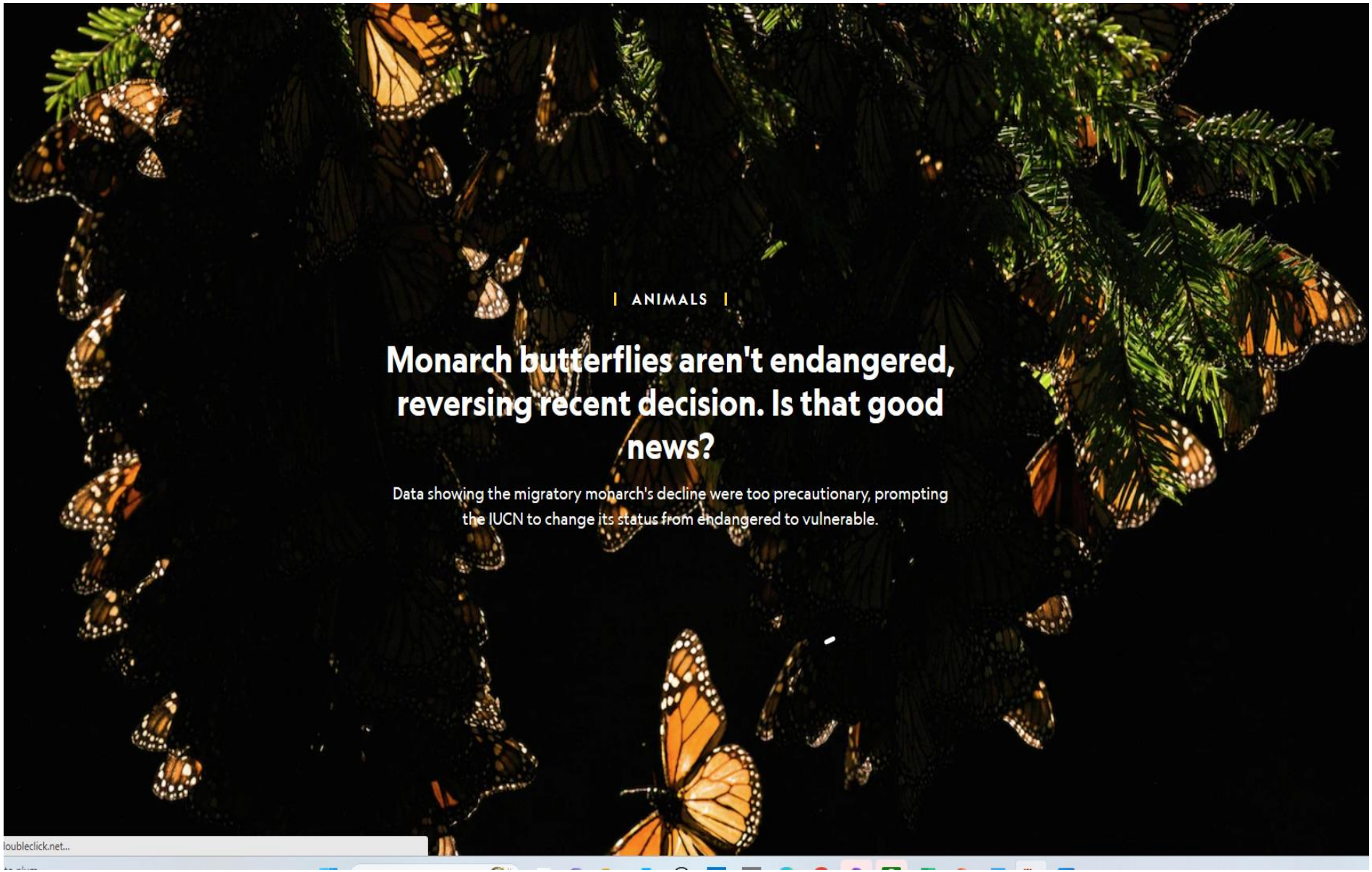
J Econ Entomol, Volume 116, Issue 2, April 2023, Pages 297–309, https://doi.org/10.1093/jee/toac183

Field Evolved Resistance to Bt Crops in 12 Countries (73 Cases)

Table 5.
Field-evolved resistance to Bt crops in 12 countries (73 cases, data from Tables 1–3)

Country	Practical resistance	Early warning	No decrease in susceptibility	Total cases	No decrease in susceptibility (%)[a]
Pakistan	1	3	0	4	0
Philippines	0	1	0	1	0
Argentina	3	3	1	7	14
Canada	2	2	1	5	20
Brazil	4	3	3	10	30
USA[b]	13	3	7	23	30
India	2	1	2	5	40
China	0	1	1	2	50
S. Africa	1	0	2	3	67
Australia	0	0	4	4	100
Mexico	0	0	7	7	100
Spain	0	0	2	2	100

[a]Percentage of cases showing no decrease in susceptibility.
[b]Includes Puerto Rico.


ANIMALS
Monarch butterflies aren't endangered, reversing recent decision. Is that good news?
Data showing the migratory monarch's decline were too precautionary, prompting the IUCN to change its status from endangered to vulnerable.

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: Graham Brookes, 2020

Thoughts to End On

- 2015 Japanese Changed their stack rules (familiarity)
- Genome Editing
- 2020/2021 USDA New Rules
- What have we missed – quality traits, small crops


Thank you!