Plant Biotechnology

Bayer Russia Plant Biotechnology Conference

July 2023 – week 1

Bayer Russia Plant Biotechnology Conference:

Day 1	Plant Biotechnology Overview and Evolution
Day 2	Introduction to Plant Vectors & Agrobacterium
Day 3	Introduction to Plant Transformation - Corn
Day 4	Soy Plant Transformation & Gene Expression
Day 5	Introduction to Plant Health & Controlled Environment (CE)

Plant Biotechnology Overview & Evolution

Bayer Russia Biotechnology Conference

July 2023

Personal Introduction—Jeff Ahrens

- Member of the Biotechnology sector of Bayer Crop Sciences for 25 years
- Experience working on products for Corn, Soybeans, and Cotton
- Past projects have included Weed & Pest Resistance, Yield, Quality, and Disease
- Formerly the Indication lead for Cotton Insect Control projects
- Currently leading a platform of 30+ scientists working across traits in the early pipeline for transgenic and gene edited products

How Crops are Genetically Modified

Traditional Breeding	Mutagenesis	RNA Interference	Transgenics	Gene Editing
Crossing plants and selecting offspring	Exposing seeds to chemicals or radiation	Switching off selected genes with RNA	Inserting selected genes using recombinant DNA methods	When used to delete genes using engineered nucleases (CRISPR, TALENs, ZFNs, etc.)
Desired gene(s) inserted with other genetic material	Random changes in genome, usually unpredictable	Targeted gene(s) switched off or 'silenced'	Only gene(s) inserted at desired locations selected	Desired gene(s) deleted only at known locations
Almost all crops				
Number of genes affected: few genes to whole genomes	100s - 1,000s	1 – dozens	1 – 8	1 or more
No safety testing required; **Unregulated**	No safety testing required; **Unregulated**	Safety testing required; **Highly regulated**	Safety testing required; **Highly regulated**	Safety testing required depending on jurisdiction; **Mixed regulations**

Undesirable, unintended effects rarely occur in the final product of any crop, regardless which process is used.

Genetic Literacy Project
SCIENCE NOT IDEOLOGY

Sources: Biotechnology Provides New Tools for Plant Breeding, University of California Davis Publication 8043; Plant Breeding: Induced Mutation Technology for Crop Improvement, F.J. Novak, H. Brunner, International Atomic Energy Agency, 1992; Atomic Gardens: Public Perceptions and Public Policy, B. Dick, M. Jones, Life Sciences Foundation Magazine: RNAi for Crop Improvement, International Service for the Acquisition of Agri-Biotech Applications Pocket K No. 34. **Infographic by Kayleen Schreiber, PhD; advisor: Wayne Parrott, PhD.**

Give It a Minute: Introduction to GMOs

https://youtu.be/QXHWQTLJpBY

Biotechnology Is Used in Many Common Products

Enzymes

Nearly all cheese is made using rennet produced through biotechnology

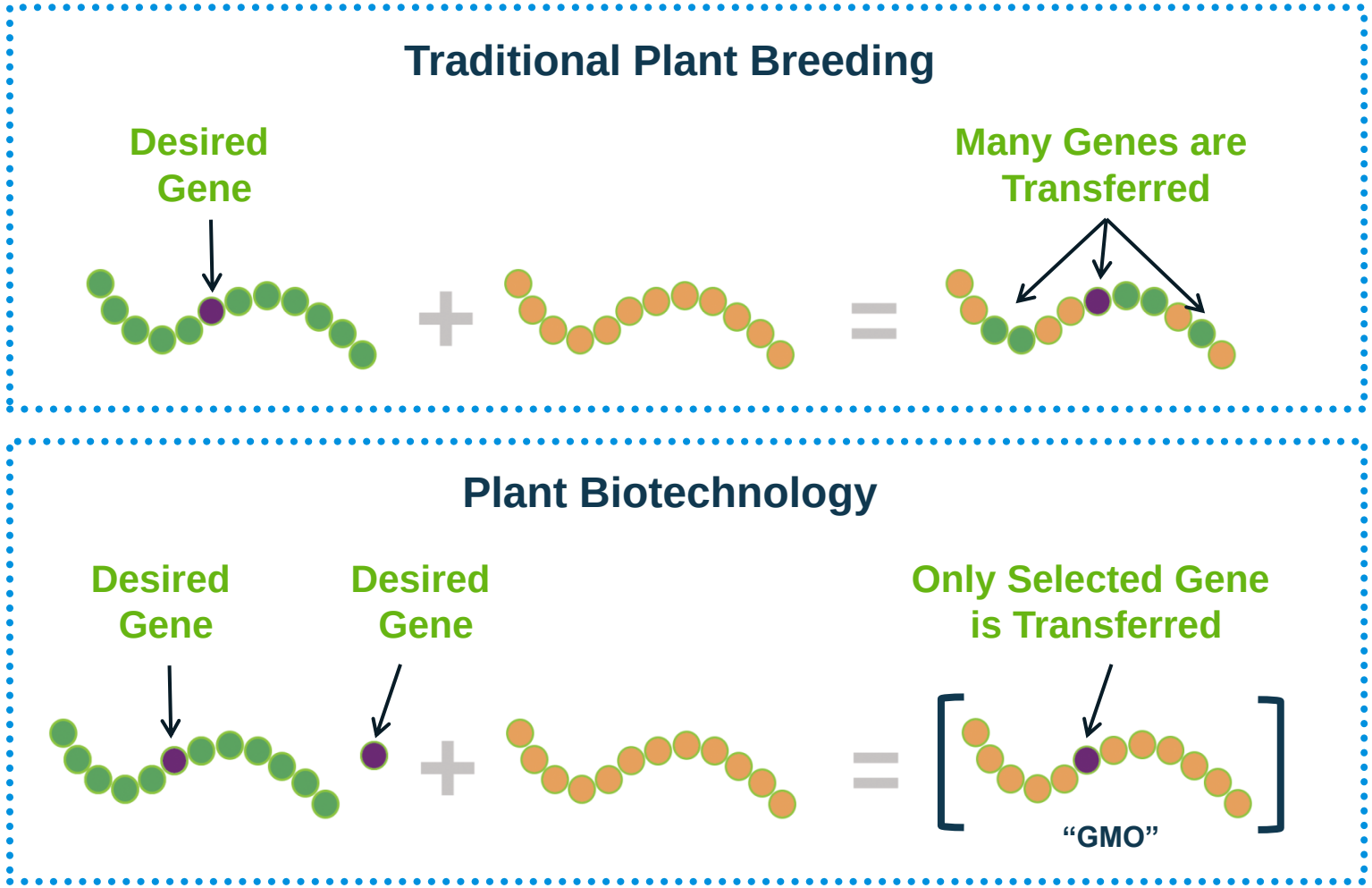
Yeast

Scientists use biotechnology to create unique yeast strains for use in brewing beer and making bread

Medicine

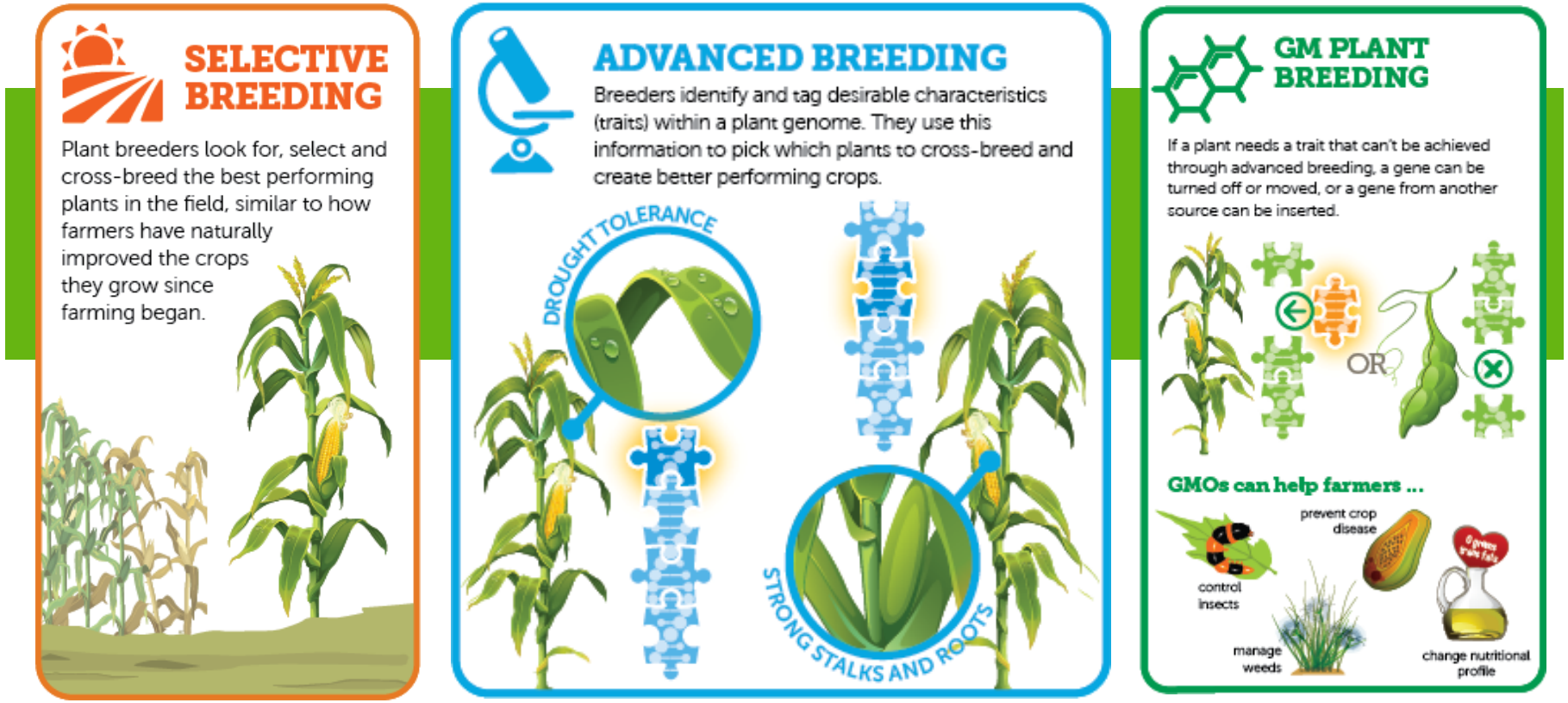
Most insulin used by diabetics is produced through biotechnology

Plant Biotechnology Is an Extension of Traditional Plant Breeding



Ways to Have Better Harvests

GMOs are the product of a specific type of plant breeding where precise changes are made to a plant's DNA to give it characteristics that cannot be achieved through traditional plant breeding methods.



Source: GMOAnswers.com https://gmoanswers.com/sites/default/files/WhatIsGMO_Infographic_1224x792px-Jan2018_0.jpg

Development of a GM Seed Trait is Rigorous and Complex

Trait Development Process (12-16 Years)

Phase 0

Phase 01

Phase 02

Phase 03

Phase 04

Thousands of genes are often tested | **A few genes are advanced for optimization** | **Products combine desired traits**

Gene/Trait Identification

Scientists identify the genes that enable desired characteristics in the plant

Proof of Concept

The genes with desired characteristics are introduced to crops to develop product concepts

Early Development

Product candidates are tested to make sure they are safe for people and the environment, and they perform as expected

Advanced Development

Products are tested in specific countries to make sure they perform well in those conditions

Pre-Launch

Data from all tests is submitted to regulators who review it for several years

Seed is produced in large quantities

Preparation for commercialization

Takes place at R&D facilities in the US | Takes place at regional level

The GMO Process

Step 1: Trait Identification

Fun fact:

For every one trait that is brought to market, more than **6,000** others are screened and tested.

Scientists conduct research to identify the specific genes responsible for beneficial traits that make crops resistant to disease, pests or drought.

Source: GMOAnswers.com https://gmoanswers.com/sites/default/files/GMOA%2011x17%20Handout_0.pdf

The GMO Process

Step 2: Transformation

Fun fact:

There are many ways to transform a cell. One common method uses **agrobacterium** - a natural bacterium that passes genes to plants.

. . TRANSFORMATION

Once the desired gene has been identified, scientists transfer the gene into a plant seed. The result is a genetically modified organism or GMO. Researchers can also turn off or move a gene within a plant to create a GMO.

Source: GMOAnswers.com https://gmoanswers.com/sites/default/files/GMOA%2011x17%20Handout_0.pdf

The GMO Process

Step 3: Regulatory Science

Although the regulatory review process *begins* here, it will continue throughout the GMO process and carry on **through the life cycle of the product**.

Safe to grow
Crop exhibits expected characteristics (e.g. insect resistance)

Safe for the environment and beneficial insects

Safe to eat
Same nutrients as non-GM crops & No new dietary allergens

Fun fact:

A new biotech seed product takes an average of **13 years and $136 million** in R&D before coming to market.[2]

More than 75 different studies are performed on each new biotech product before commercialization to ensure that they are safe for people, animals and the environment.[1]

Sources: Phillips McDougall 2011; GMOAnswers.com https://gmoanswers.com/sites/default/files/2018-11/How%20Does%20a%20GMo%20Get%20to%20Market_0.JPG

The GMO Process

Step 4: Greenhouse Testing

Fun fact:

Only after several years of **rigorous testing** are the top performing plants and traits selected to advance to field testing and further regulatory review.

After a GMO is developed in the lab, the seedlings are moved to greenhouses where further tests are performed.

Source: GMOAnswers.com https://gmoanswers.com/sites/default/files/GMOA%2011x17%20Handout_0.pdf

The GMO Process

Step 5: Field Testing

Fun fact:

More than **90 government bodies in more than 60 countries** globally review and approve GMOs. In many countries, multiple agencies are involved in the regulation of GMOs.

Field trials are an important part of developing new products. They provide critical scientific and performance data.

Source: GMOAnswers.com https://gmoanswers.com/sites/default/files/GMOA%2011x17%20Handout_0.pdf

The GMO Process

Step 6: Getting Seeds to Farmers

Fun fact:

In 2018, **17 million farmers** globally chose to plant GMO seeds for better harvests, improved crop quality and the ability to use sustainable farming practices, such as no-till.

Farmers choose seeds that are best for their farms and businesses. Both GM and non-GM seeds are available options for farmers.

Source: ISAAA.org https://www.isaaa.org/resources/publications/briefs/55/executivesummary/default.asp

Genetic Traits Expressed in GMOs in the U.S.

APPLE

Genetic Traits
Non-browning
Uses: Food

POTATO

Genetic Traits
Reduced Bruising and Black Spot
Non-browning
Low Acrylamide
Blight Resistance
Uses: Food

CANOLA

Genetic Traits
Herbicide Tolerance
Uses: Cooking oil, Animal feed

ALFALFA

Genetic Traits
Herbicide Tolerance
Uses: Animal feed

FIELD CORN

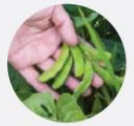
Genetic Traits
Insect Resistance
Herbicide Tolerance
Drought Tolerance
Uses:
- Livestock and poultry feed
- Fuel ethanol
- High-fructose corn syrup and other sweeteners
- Corn oil
- Starch
- Cereal and other food ingredients
- Alcohol
- Industrial uses

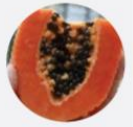
CANOLA

Genetic Traits
Herbicide Tolerance
Uses: Cooking oil, Animal feed

ALFALFA

Genetic Traits
Herbicide Tolerance
Uses: Animal feed

SOYBEAN

Genetic Traits
Insect Resistance
Herbicide Tolerance
Uses:
- Livestock and poultry feed
- Aquaculture
- Soybean oil (vegetable oil)
- High oleic acid (monounsaturated fatty acid)
- Biodiesel fuel
- Soymilk, soy sauce, tofu, other food uses
- Lecithin
- Pet food
- Adhesives and building materials
- Printing ink
- Other industrial uses

RAINBOW PAPAYA

Genetic Traits
Disease Resistance
Uses: Table fruit

COTTON

Genetic Traits
Insect Resistance
Herbicide Tolerance
Uses: Fiber, Animal feed, Cottonseed oil

SUGAR BEET

Genetic Traits
Herbicide Tolerance
Uses: Sugar, Animal feed

SWEET CORN

Genetic Traits
Insect Resistance
Herbicide Tolerarnce
Uses: Food

SUMMER SQUASH

Genetic Traits
Disease Resistance
Uses: Food

Source: GMOAnswers.com :https://gmoanswers.com/sites/default/files/GMOA-GeneticTraits10crops-4x6_Postcard-Jan2018.pdf

The Benefits of GM Crops

The Benefits of GMOs

Some Examples of the Benefits of GMOs

CORN that is tolerant to drought, insects and disease

SOY that can be planted without tilling, preserving precious topsoil

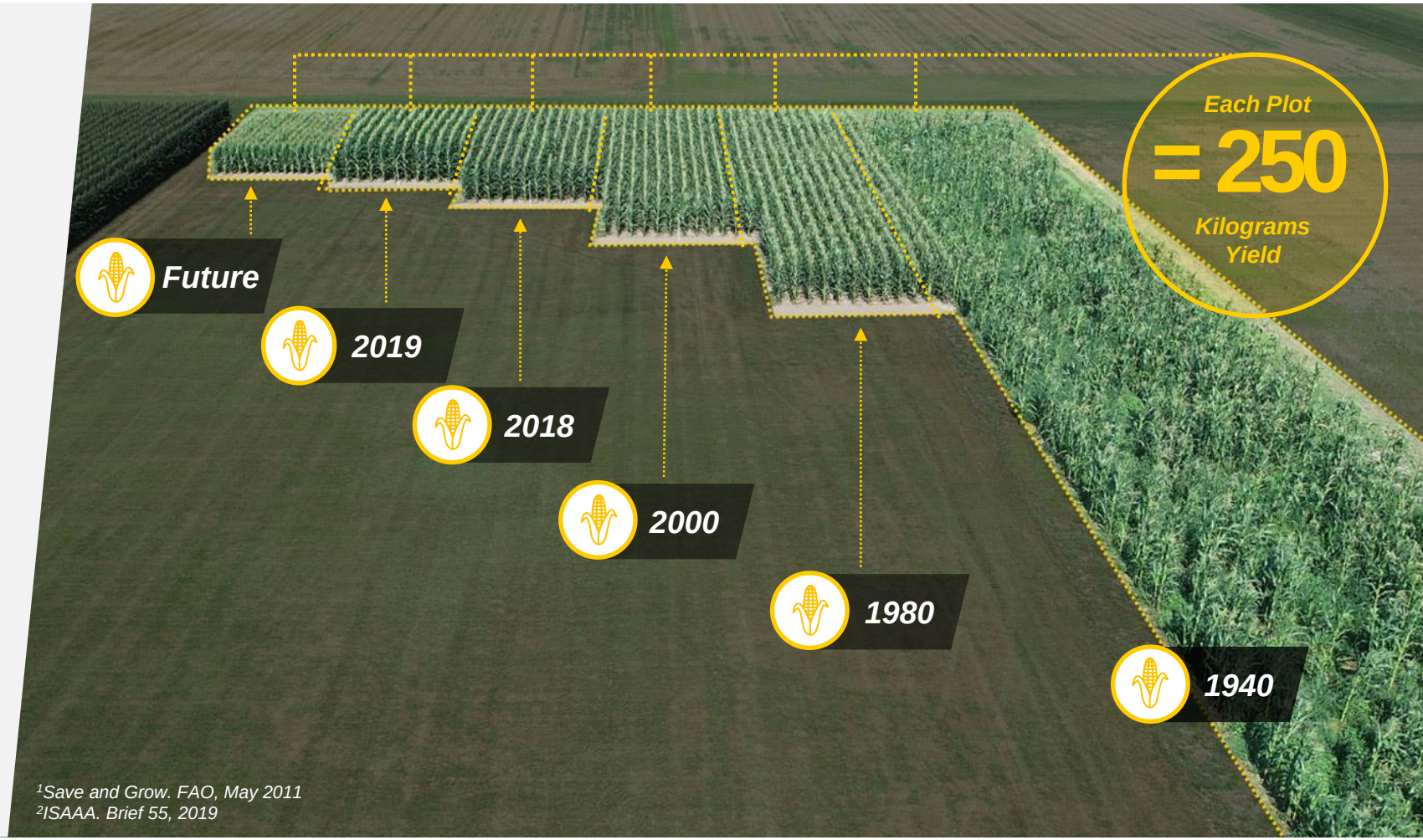
COTTON that is protected from harmful insects

PAPAYA that resists a disease that threatened to wipe out the crop

Source: ISAAA.org https://www.isaaa.org/resources/publications/briefs/55/executivesummary/default.asp

Modern agriculture technologies make it possible to grow more with less

GM crops improve productivity on the farm, allowing farmers to grow more on available land



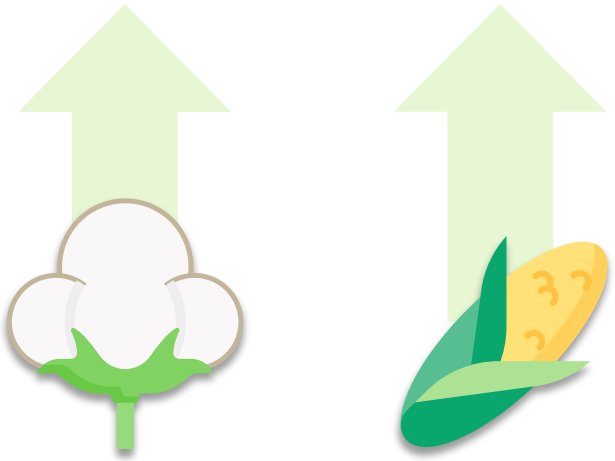
[1]Save and Grow. FAO, May 2011
[2]ISAAA. Brief 55, 2019

The introduction of GM traits has helped to protect plants and improve yields

Between 1996 and 2020, **global** adopters of insect-resistant GM crops experienced yield increases in cotton and corn averaging:

14.5%
increase

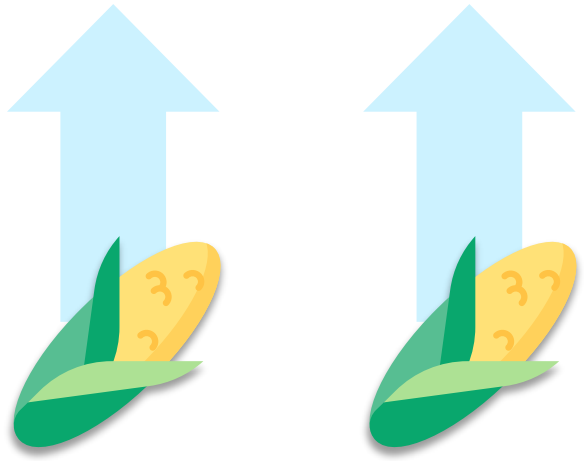
17.7%
increase



Between 1996 and 2018, farmers in the **Philippines** and **Vietnam** saw yield increases in corn after adopting GM corn:

23.5%
increase

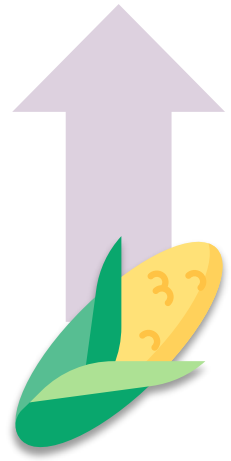
30.4%
increase



PHILIPPINES VIETNAM

Adoption of glyphosate and insect-resistant corn in **Indonesia** is expected to deliver a yield gain over conventional corn of:

+15.2%
increase



Sources: pgeconomics.co.uk, 2022; 2020

Grow more while using less land

In 2020, had biotechnology not been used, additional land would have been needed to produce the same amount of commodities

2.8 M
Hectares for Cotton

11.6 M
Hectares for Soybeans

8.5 M
Hectares for Corn

This is the amount of land equivalent to the combined agricultural area of the **Philippines** and **Vietnam**

Sources: pgeconomics.co.uk, 2022

Biotech traits have led to a reduction in the amounts of pesticides used in fields

1996 – 2020

Reduced the application of crop protection products **by 748.6 million kilograms**, a global reduction of **7.2 percent** on the area planted to GM crops.

- *This is equal to 1.5 times China's total annual crop protection product use.*

Farmers who grow GM crops have reduced the environmental impact associated with their crop protection practices by **17.3 percent**.

Sources: pgeconomics.co.uk, 2022

Improved Ecology Through GMOs

decreases insecticide use

Bt crops are designed to allow important, beneficial bugs to thrive, including:

BEES

EARTHWORMS

BUTTERFLIES

LADYBUGS

Brookes, G., (2022). GM crops: global socio-economic and environmental impacts 1996-2020. Retrieved from https://pgeconomics.- co.uk/pdf/Globalimpactbiotechcropsnalreportoctober2022.pdf

Improved soil health is possible due to reduced need for soil tillage

Creates multiple benefits

Herbicide tolerant GM crops enable farmers to till – or turn over and break up the soil – less often. This has **increased nutrient-rich organic matter up to 1,800 pounds per acre per year.**

LESS TILLING=

- **Soil Moisture**
- **Greenhouse Gas Emissions**
- **Soil Erosion**

Economic gains on farms due to the adoption of biotech crops

Economic gains of ~$261B (US) were generated globally by biotech crops between 1996 to 2020.

30%
Due to reduced production costs

70%
Due to substantial yield gains

In 2020, farmers in developing countries received **$5.22** as extra income for each extra dollar invested in GM crop seeds

Sources: pgeconomics.co.uk, 2022

Impact of adoption of GM crops in the Philippines

Philippines Gain First-Adopted Advantage

The Philippines was the first country in Southeast Asia to plant biotech corn in 2003 after its approval for commercial planting in 2002.

630,000 hectares biotech corn planted in the Philippines in 2018

470,500 Filipino farmers & their families benefited from biotech corn in 2018

Average landholding of Filipino biotech corn farmers is **2 hectares**

13th Biggest Producer of Biotech/ GM crops in the world in 2018

BIOTECH CROP APPROVALS

13 biotech corn events approved for commercial planting since 2002

218 approvals for food, feed & cultivation for 105 events

From 2003-2016, Filipino farmers & their families benefited US $724 Million from planting biotech corn

23.5%

Yield gains from biotech corn by 2018

Additional income associated with higher yields enabled farming families to:

- Better feed and clothe their families
- Undertake property repairs and improvements
- Invest in better education for children

Sources: https://www.isaaa.org/resources/infographics/biotech-facts-and-trends/philippines/default.asp
Torres C et al (2013)
"The potential socio-economic and environmental impacts from adoption of corn hybrids with biotech trait/technologies in Indonesia," Graham Brookes, 2020

3 Big Ways GMOs SUPPORT THE ENVIRONMENT

In the past 20+ years, the positive effect on the environment from GMO crops and the traits they express has been nothing short of extraordinary.

GMOs foster sustainable farming practices

Conservation tillage reduced CO_2 emissions by **52.0 billion pounds** in 2020

That's like taking **15.6 million cars off the road for a year.**[1]

GMOs let us grow more food on less land

93.4 million tons additional crop yield in 2020

conserving **57.8 million acres of land.**[1]

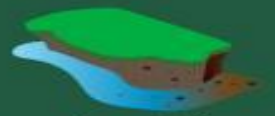
GMOs build healthy soil

LESS TILLING =

More Beneficial Insects

Increased Organic Material

Better Moisture Retention



Less Soil Erosion

[1] Brookes, G., (2022). GM crops: global socio-economic and environmental impacts 1996-2020. Retrieved from https://pgeconomics.co.uk/pdf/Globalimpactbiotechcropsfinalreportoctober2022.pdf

gmo answers

GM Crop Safety

GM crops are reviewed by hundreds of independent risk assessors and scientists.

Every credible U.S. and international food safety authority that has studied GM crops has found that they are safe & no health effects attributable to their use.

Since 1992, **71 different** countries have granted more than **4,485 commercial use approvals for 403 different biotech events in 29 biotech crops**.

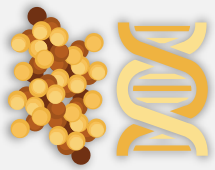
In many countries there are multiple regulatory authorities (up to seven in one country) with the responsibility of assessing a particular aspect of safety.

Source: ISAAA.org https://www.isaaa.org/resources/publications/briefs/55/executivesummary/default.asp

Development Process for GM Crops Is Long and Rigorous

Time to Market Product Comparison

Compared to most products, a new GM seed variety takes much longer to bring to market. It requires at least 12-16 years of research and development, as well as regulatory approvals for new GM seeds to be introduced.



GM Crop

Average number of years to get a new GM variety from discovery to a grower's field

13 YEARS

Automobile

Number of years from conceptualization to market release

3 YEARS

Pharma Drug Product

Average number of years to get a new medicine from the laboratory to the pharmacy shelf

12 YEARS

New Food Packaging

Number of years to develop and come to market

3 YEARS

Jet Aircraft

Number of years from conceptualization to market release

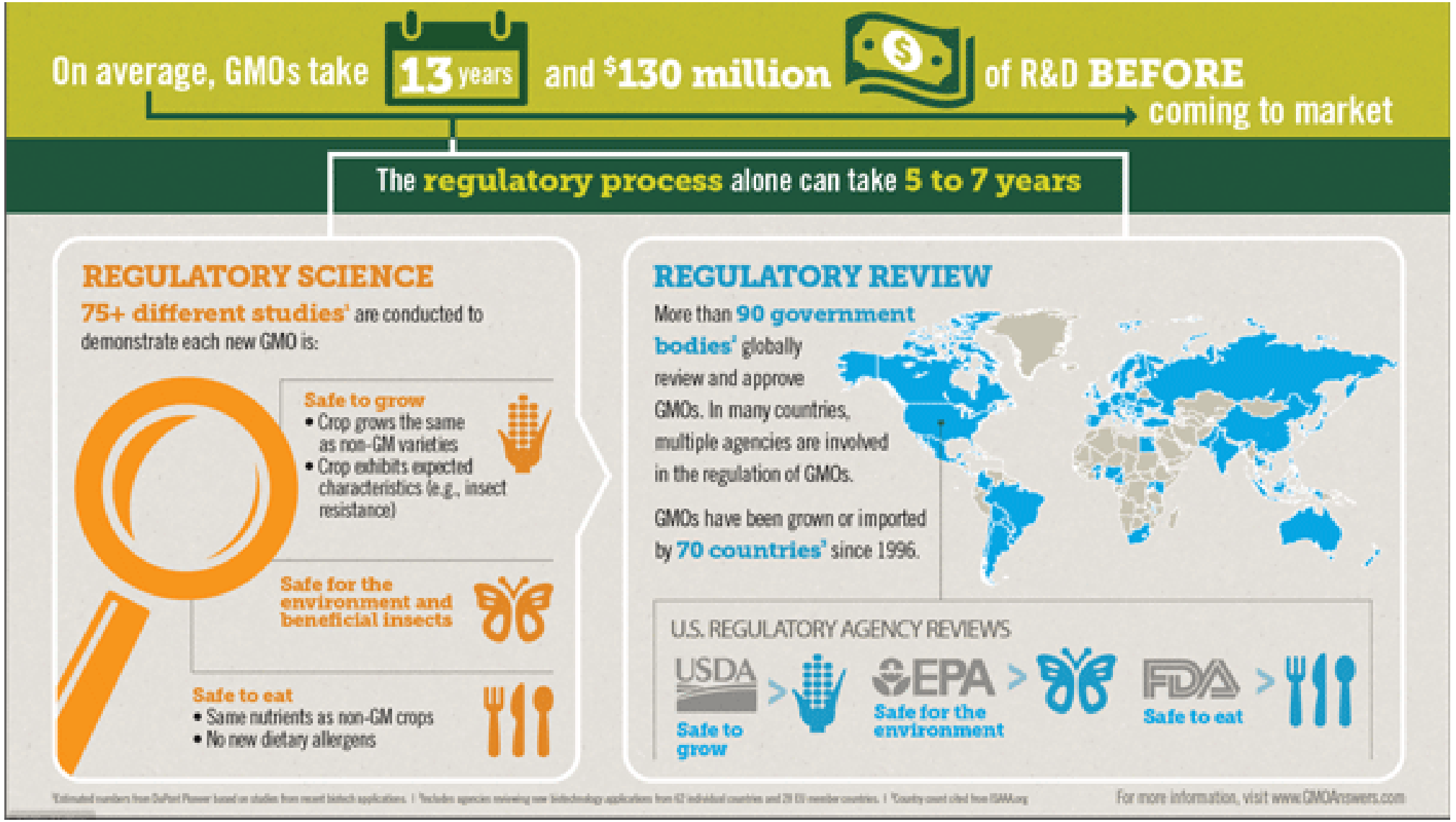
8.5 YEARS

Gaming System

Number of years from conceptualization to market release

2.9 YEARS

GMO Research, Review and Regulation

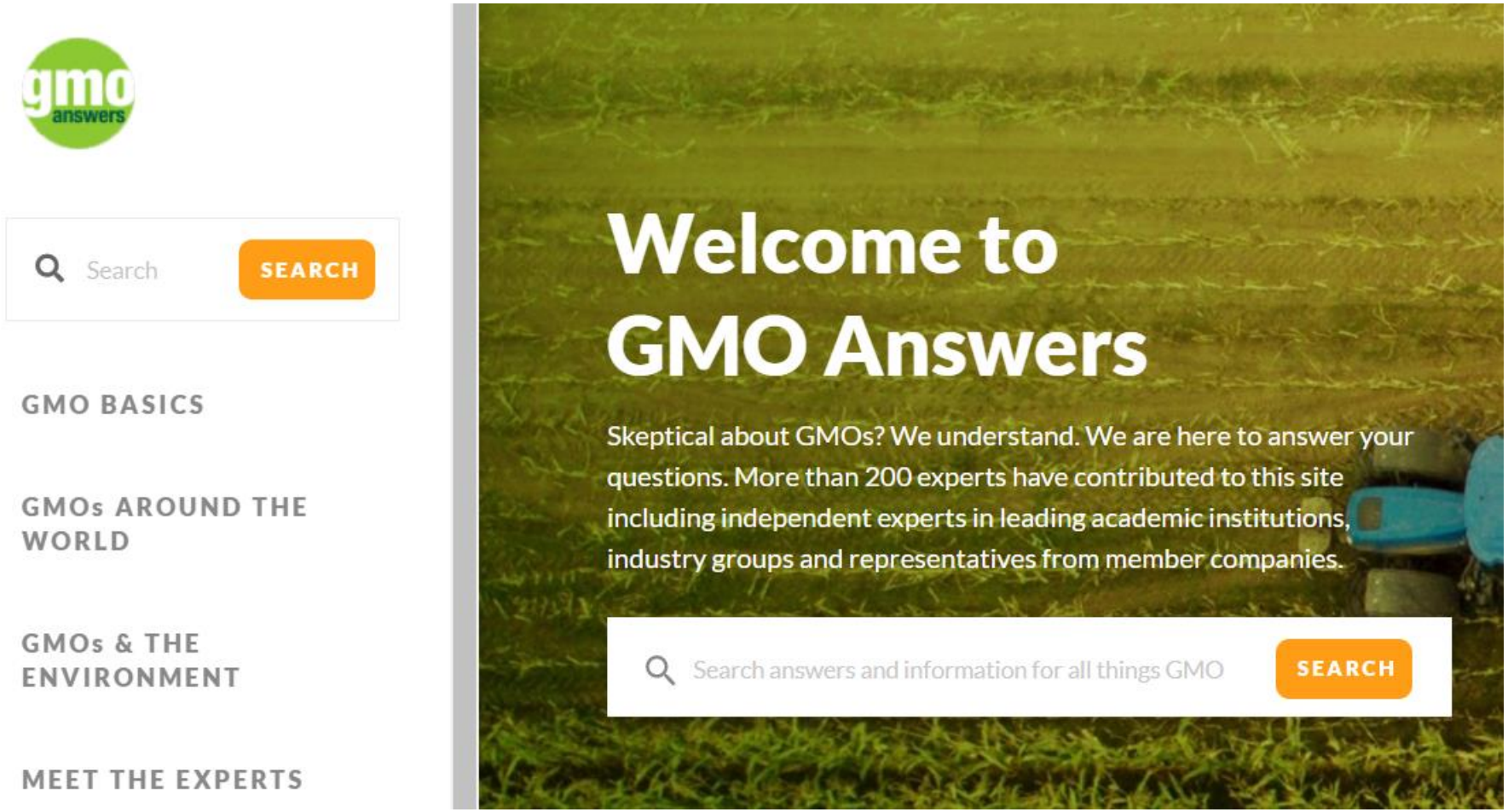


Source: GMOAnswers.com https://gmoanswers.com/sites/default/files/2018-11/How%20Does%20a%20GMo%20Get%20to%20Market_0.JPG

Give It a Minute: Bringing a GM Crop to Market

https://youtu.be/sP58TKFM2ag

More Information Is Available at GMOAnswers.com



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Thank you!

Any questions?