Genome Editing's Potentially Fundamental Role in Food Security

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Genome Editing: Potential Benefits are Real

- Disease resistances
- Drought tolerance
- Enhanced nutritional quality
- Food innocuity
- Salinity tolerance
- Increased yield
- Affordable seed
- Parasitic weed control

Who might want/need them?

Target trait	Plant species	Targeted sequence(s)	Results	Method	Reference
Yield	*Oryza sativa*	*GS3, Gn1a*	Grain size and number increase	CRISPR/Cas9	Shen et al., 2018a
	Oryza sativa	*GW2, GW5, TGW6*	Grain weight increase	CRISPR/Cas9	Xu et al., 2016
	Oryza sativa	*Gn1a, DEP1, GS3*	Grain size and number increase and dense, erect panicles	CRISPR/Cas9	Li M. et al., 2016
Drought tolerance	*Arabidopsis*	*mir169a*	Improved drought tolerance	CRISPR/Cas9	Zhao et al., 2016
	Zea mays	*ARGOS8*	Improved grain yield under field drought stress conditions	CRISPR/Cas9	Shi et al., 2017
Salt tolerance	*Oryza sativa*	*OsRAV2*	Salt stress tolerance	CRISPR/Cas9	Duan et al., 2016
Nutritional improvement	*Camelina sativa*	*FAD2*	Enhancement of seed oil		
	Oryza sativa	*SBEI, SBEIIb*	High amylose content		
	Oryza sativa	*OsBADH2*[2]	Increased fragrance content		
	Solanum tuberosum	*GBSS*	High-amylopectin starch		
	Zea mays	*ZmIPK*	Reduced phytic acid content		

Sedeek et al. Front. Plant Sci., 12 February 2019

CRISPR-Cas9 scientists awarded Nobel in chemistry

Charpentier and Doudna (Henrik Montgomery/Getty Images)

Emmanuelle Charpentier of France and Jennifer Doudna of the US have been awarded the Nobel Prize in chemistry for their work with the genome-editing tool CRISPR-Cas9. Their work "has not only revolutionized basic science, but also resulted in innovative crops and will lead to groundbreaking new medical treatments," says Claes Gustafsson, chair of the Nobel Committee for Chemistry.

Full Story: The Associated Press (10/7), The Guardian (London) (10/7) 2020

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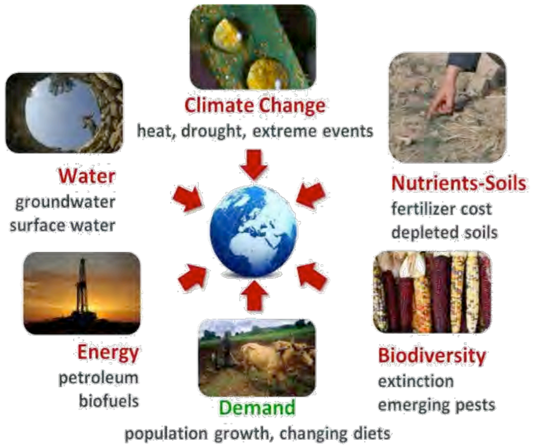
The CGIAR Genome Editing Challenge

Three converging challenges:

climate change

population growth

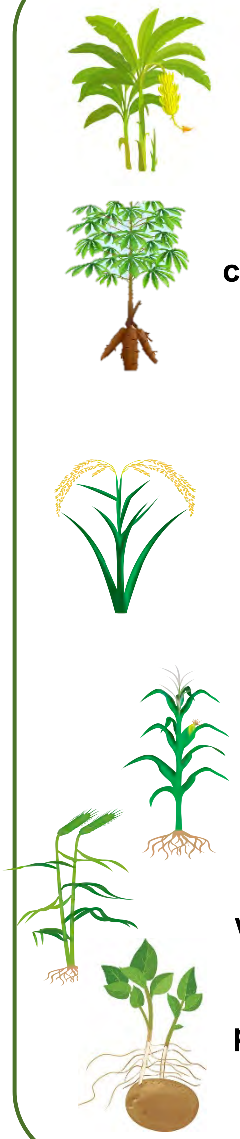
limited natural resources



- Reduce crop losses by ~ 20%
- Reduce pesticide use by ~ 50%
- Improve micronutrient content to reach 30-50% estimated-average-requirement (EAR)
- With a reduced environmental footprint

CGIAR Genome Editing Projects

CGIAR product: First gene-edited variety in the Global South – Xoo, bacterial blight of rice - approved by the Colombian authorities.



Crop	Trait	Stage
banana	Disease resistance (BXY, Fusarium, BBTV)	3 &1
cassava	Quality trait (specialty starch)	3
	Safety trait (reduce cyanide)	3
	Herbicide tolerance	2
rice	Disease resistance (BLB, RHB)	4, 3
	Enhanced yield	3
	Nitrogen use efficiency, drought and methane reduction	2
	Nutrition (↑ micronutrient and ↓ glycemic index)	2
maize	Disease resistance (MLN, Striga)	4, 1
wheat	Disease resistance (rust, mildew)	3
potato	Disease resistance	2

1. Discovery
2. Proof of concept
3. Early development
4. Advanced development
5. Commercialization

Potentially Coming Soon

Cassava: Cyanide-free, Bacterial blight, Brown Streak virus, Waxy starch, Haploid inducers

Bean: Nutritional quality, digestibility

Maize: Nutrition (low phytic acid, provitamin A)

Wheat: Bread quality (low polyphenol oxidase), Nutrition (low phytate), less acrylamide (ASN2)

Rice: Low Arsenic & Cadmium, amylose, *Hoja Blanca* virus, hybrid-facilitating traits, yield (grain number).

Potato and rice: Apomixis (3 knock-outs for potato/SDN-1; 3 KO + cisgenic SDN3 for rice)

…and many more!

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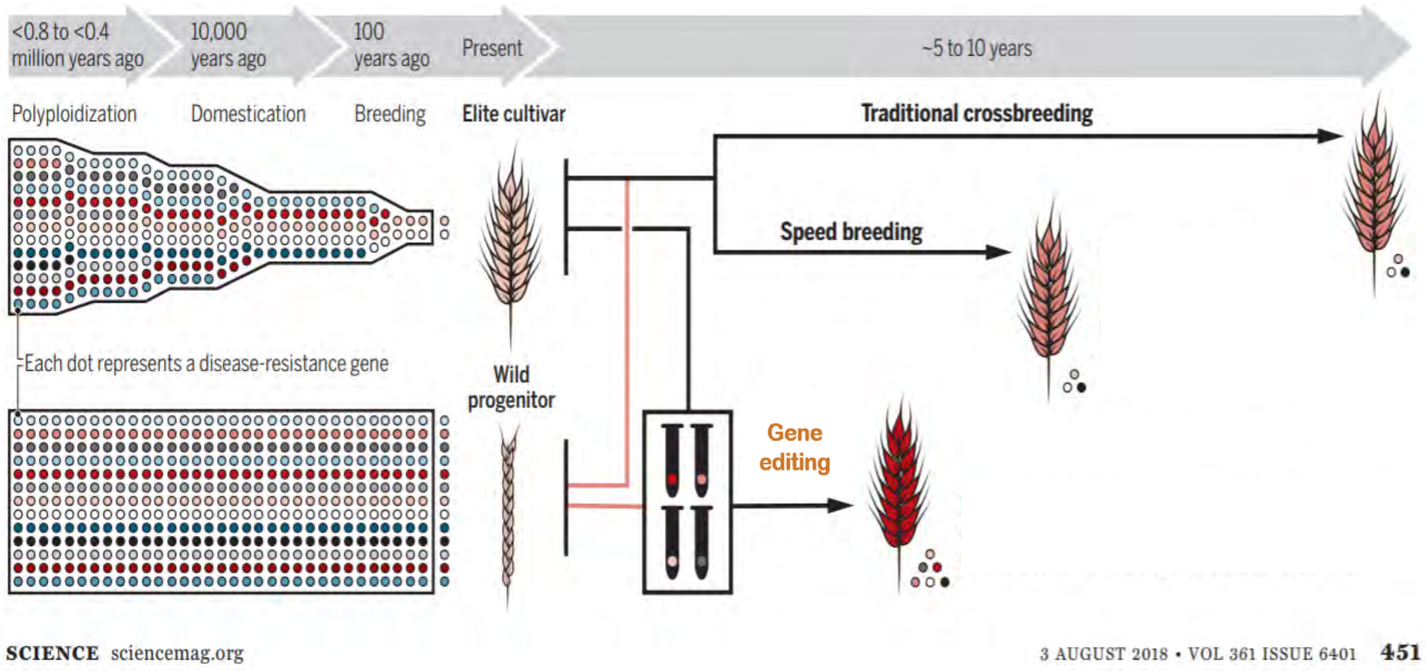
Understanding and Leveraging Diversity



- Genebanks are great source of diversity for cultivated species
- Advances in genotyping, phenotyping, and bioinformatics, enable rapid identification of alleles of value in germplasm collections
- Genome editing can accelerate transfer of alleles discovered in genebanks and germplasm collections to elite cultivars, without linkage drag

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Genome Editing for Sustainable Agriculture

Innovative Genomics Institute

Agriculture is responsible for nearly 25% of greenhouse gas emissions.

Plants and microbes can be the solution, not part of the problem.

Accelerating biological carbon capture & Sequestration

- Genome editing and soil microbial farming to enhance carbon uptake by plants and soil microbes

Climate Resilience

- Drought tolerant rice
- Cyanide-free cassava

Improved Water Use Efficiency

- Optimizing stomatal density

Reduced Pesticide Application

- Disease resistance

Reduced Fertilizer Dependency

- Nitrogen use efficiency

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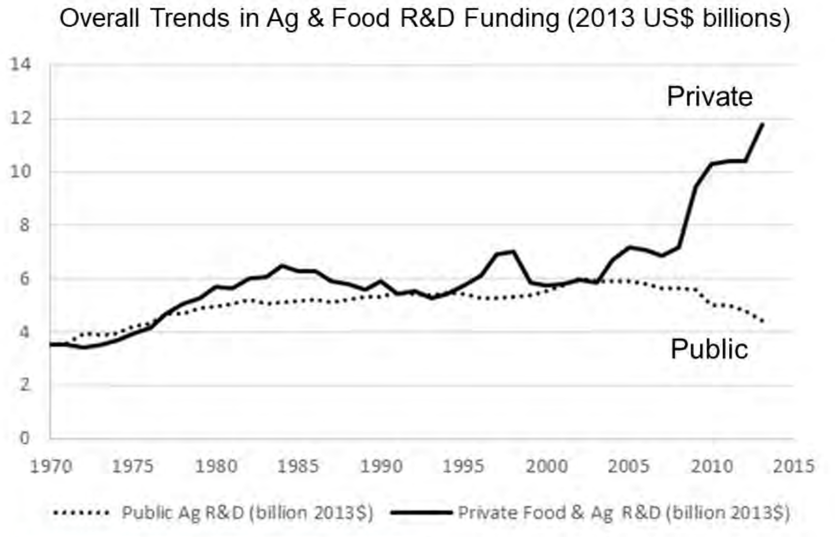
Who Invests Determines Which Crops, Traits, Farmers and Consumers Benefit



Clancy, Fuglie, and Heisey, 2016

"…[in Africa] each year the agricultural research funds keep reducing in comparison to other government priorities (like security and developing infrastructure) even with clear policies that urge on the need for funding agriculture."

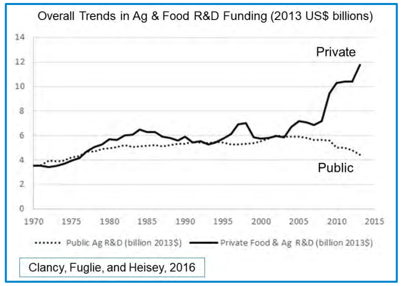
Private Sector:

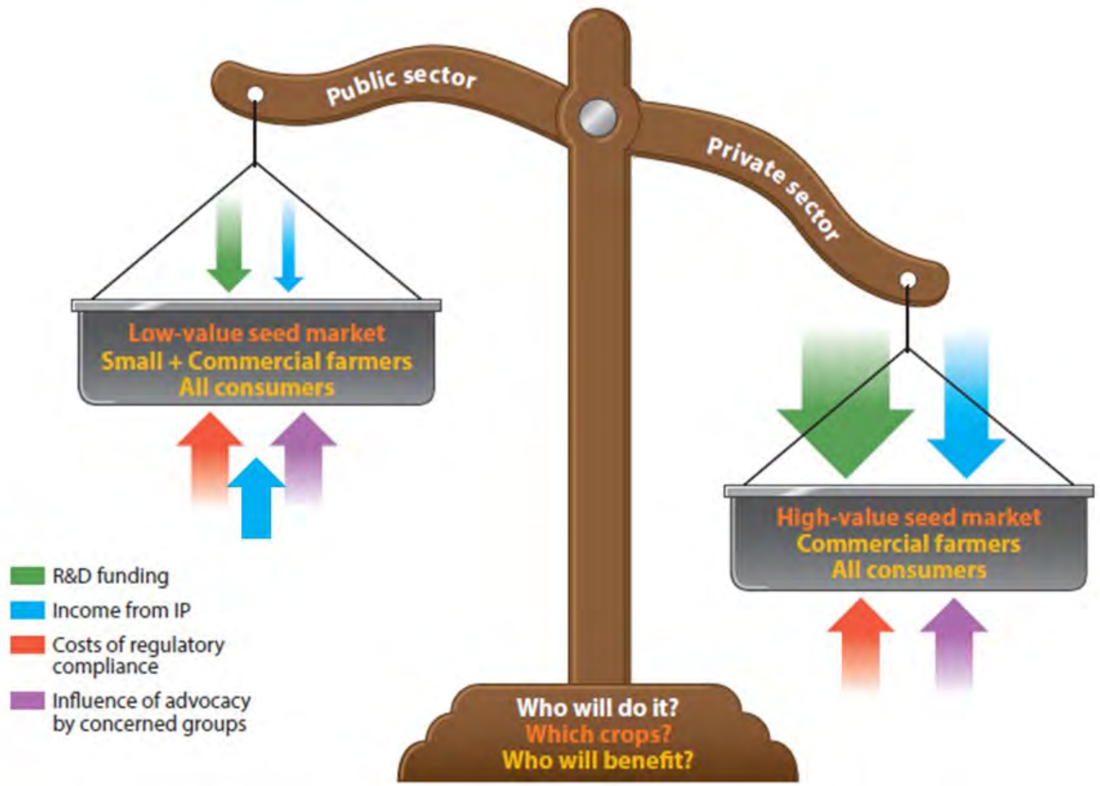
- Increasing investment in research
- Pressure to achieve return on investments
- Traits and crops grown on large areas

Public Sector:

- Decreasing investment in research
- Pressure to increase returns from R&D
- Shifting away from minor, toward major crops

Who Might Benefit from Genome Edited Crops?





Pixley et al., Ann. Rev. Phytopath., 2019

Number of GM events in extensive crops

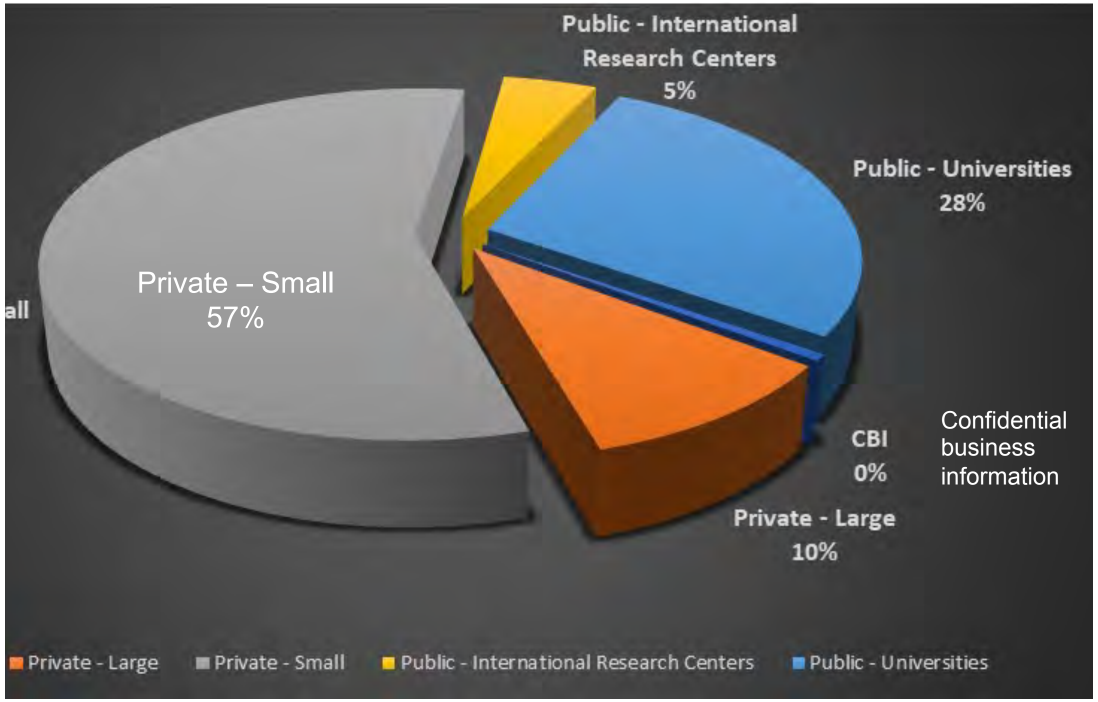
Canola	41
Cotton	59
Maize	229
Rice	8
Sunflower	2
Soybean	49
Total	388

From GM Crops Database, ISAAA, 2018

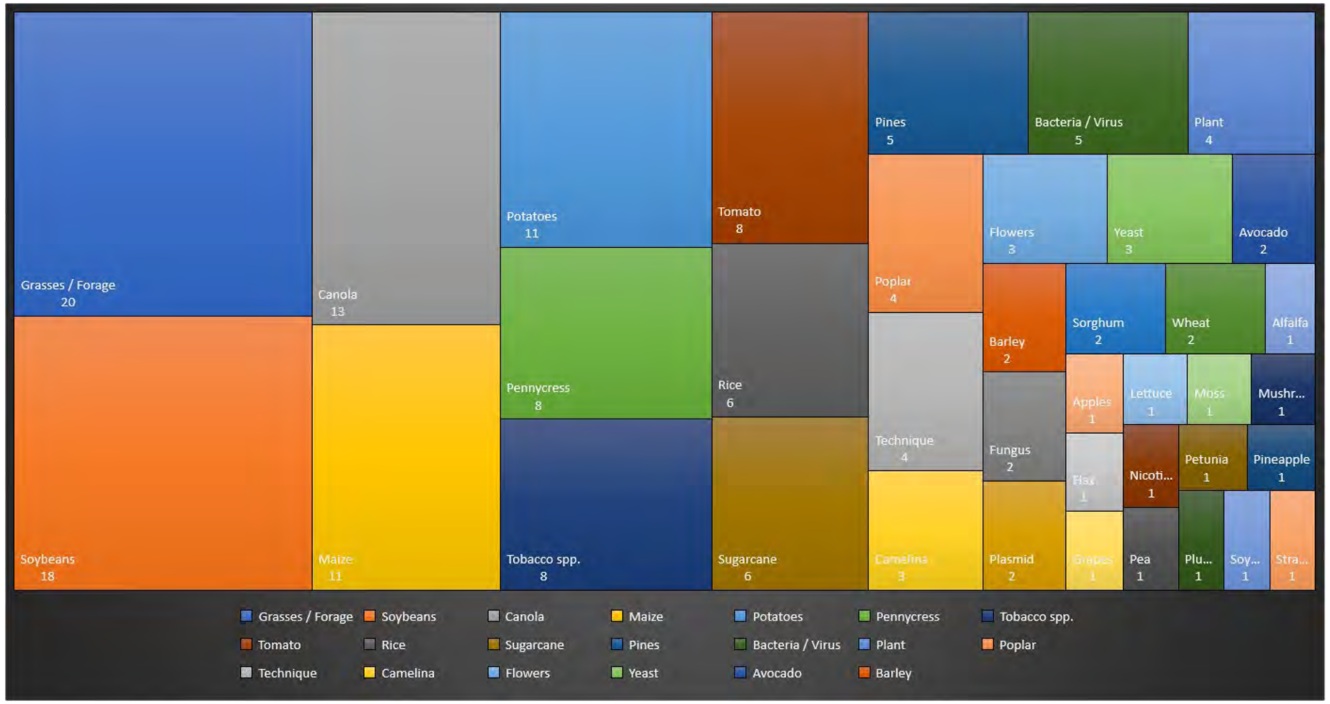
Will genome editing follow a similar path as transgenic technology?

Genome Editing in Crops

A changing institutional landscape?



A changing crop landscape?



Factors Determining Who Might Benefit

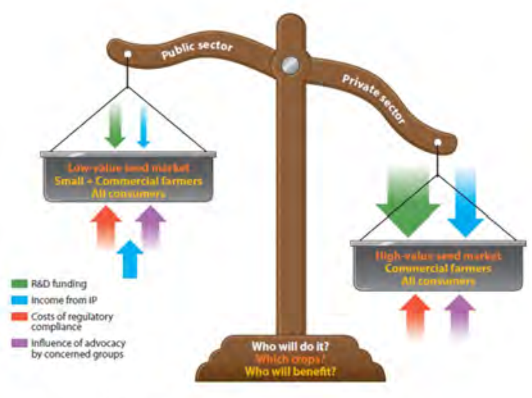


Figure created by Nancy Valtierra, CIMMYT

- ✓ Where we put R&D investment
- ✓ The incentives created for others to invest in R&D*
- ✓ The regulatory frameworks demanded
- ✓ Our willingness and vision to seek win-win compromises

* The Broad Institute and Corteva Agriscience in 2017 agreed to mutually license interested parties with foundation Intellectual Property for the use of CRISPR-Cas9 in agriculture. They are licensing technology for those developing smallholder farmer uses in developing countries at essentially no cost.

https://openinnovation.corteva.com/crispr-cas/
https://www.broadinstitute.org/news/dupont-pioneer-and-broad-institute-join-forcesenable-democratic-crispr-licensing-agriculture.

Genome Editing in Africa's Agriculture 2021

Genome editing projects and experts in Africa

Striga resistance in low germination stimulant (LGS1) knock-out sorghum

Prof. Steven Runo
Kenyatta University

Knock-out PARP genes in maize for tolerance to drought, genotoxic and oxidative stresses

Dr. Elizabeth Njuguna
VIB-UGENT Ghent University Kenyatta University, Kenya)

Gene editing to control maize lethal necrosis in Africa

James Kamau Karanja
Kenya Agriculture and Livestock Research Organization (KALRO)

Genome editing disease susceptibility loci of popular Roots, Tubers and Banana varieties

Dr. Leena Tripathi
International Institute of Tropical Agriculture (IITA)

Karembu M. 2021. Genome Editing in Africa's Agriculture 2021: An Early Take-off. (ISAAA AfriCenter), Nairobi Kenya.

Genome Editing in Africa's Agriculture 2021

Genome editing projects and experts in Africa

Screening of wild and edited genes associated with response of cassava to South African cassava mosaic virus (SACMV)

Chrissie Rey Chatukuta

University of the Witwatersrand

Patience

Developing sal1 mutant drought tolerant wheat using CRISPR/Cas genome editing

Prof. Naglaa Abdallah

Cairo University Egypt

Improving oil qualities of Ethiopian mustard through CRISPR/CAS 9-based genome editing

Prof. Teklehaimanot Haileselassie Teklu

Addis Ababa University

Gene editing for high yielding, stress resistant and nutritious cassava, rice, maize

Dr. John Odipio

Nat. Agric. Res. Org. (NARO, Uganda)

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Karembu M. 2021. Genome Editing in Africa's Agriculture 2021: An Early Take-off. (ISAAA AfriCenter), Nairobi Kenya.

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Genome Editing: Potentially Valuable Technology

- ✓ Relatively accessible, affordable; public and small private sector can avail
- ✓ Can be used by and for the priorities of resource-poor countries; for their crops, traits, farmers, and consumers
- ✓ Can address important goals of the G-20 countries
  - Enhancing global food & nutrition security and livelihoods
  - Mitigating climate change
  - Supporting more sustainable agricultural systems
  - Addressing environmental improvement

CIMMYT recognizes and respects the sovereignty of individual nations to determine if, when, and how biotechnologies, including genome editing, are used in their territory, and provides technical support as requested in this process.

https://www.cimmyt.org/content/uploads/2019/04/CIMMYT-Position-Statement-on-Novel-Genome-Editing-Technologies-2017-12-17.pdf

Many Thanks!

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G20 – Italia

Grazie Mille!

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