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

Who might want/need them?

- Salinity tolerance
- Increased yield
- Affordable seed
- Parasitic weed control


CRISPR-Cas9 scientists awarded Nobel in chemistry

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
Three converging challenges:
- climate change
- population growth
- limited natural resources

The CGIAR Genome Editing Challenge

- 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
<table>
<thead>
<tr>
<th>Crop</th>
<th>Trait</th>
<th>Stage</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>banana</td>
<td>Disease resistance (BXY, Fusarium, BBTV)</td>
<td>3 &amp; 1</td>
<td></td>
</tr>
<tr>
<td>cassava</td>
<td>Quality trait (specialty starch)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>cassava</td>
<td>Safety trait (reduce cyanide)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>cassava</td>
<td>Herbicide tolerance</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>cassava</td>
<td>Disease resistance (BLB, RHB)</td>
<td>4, 3</td>
<td></td>
</tr>
<tr>
<td>rice</td>
<td>Nitrogen use efficiency, drought and methane reduction</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>rice</td>
<td>Enhanced yield</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>rice</td>
<td>Nutrition (↑ micronutrient and ↓ glycemic index)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>maize</td>
<td>Disease resistance (MLN, Striga)</td>
<td>4, 1</td>
<td></td>
</tr>
<tr>
<td>wheat</td>
<td>Disease resistance (rust, mildew)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>potato</td>
<td>Disease resistance</td>
<td>2</td>
<td></td>
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**CGIAR product:** First gene-edited variety in the Global South – Xoo, bacterial blight of rice - approved by the Colombian authorities.

**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!
• 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
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
Who Invests Determines Which Crops, Traits, Farmers and Consumers Benefit

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

“…[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.”

Clancy, Fuglie, and Heisey, 2016
Who Might Benefit from Genome Edited Crops?

Will genome editing follow a similar path as transgenic technology?

Number of GM events in extensive crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Number</th>
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<tbody>
<tr>
<td>Canola</td>
<td>41</td>
</tr>
<tr>
<td>Cotton</td>
<td>59</td>
</tr>
<tr>
<td>Maize</td>
<td>229</td>
</tr>
<tr>
<td>Rice</td>
<td>8</td>
</tr>
<tr>
<td>Sunflower</td>
<td>2</td>
</tr>
<tr>
<td>Soybean</td>
<td>49</td>
</tr>
<tr>
<td>Total</td>
<td>388</td>
</tr>
</tbody>
</table>

From GM Crops Database, ISAAA, 2018

Pixley et al., Ann. Rev. Phytopath., 2019
Genome Editing in Crops

A changing institutional landscape?

A changing crop landscape?
Factors Determining Who Might Benefit

✓ 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/
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

- **Gene editing to control maize lethal necrosis in Africa**
  - **James Kamau Karanja**
  - Kenya Agriculture and Livestock Research Organization (KALRO)

- **Knock-out PARP genes in maize for tolerance to drought, genotoxic and oxidative stresses**
  - **Dr. Elizabeth Njuguna**
  - VIB-UGENT Ghent University Kenyatta University, Kenya

- **Genome editing disease susceptibility loci of popular Roots, Tubers and Banana varieties**
  - **Dr. Leena Tripathi**
  - International Institute of Tropical Agriculture (IITA)
Gene editing for high yielding, stress resistant and nutritious cassava, rice, maize

Dr. John Odipio
Nat. Agric. Res. Org. (NARO, Uganda)

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

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 Haileelassie Teklu
Addis Ababa University

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

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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.

Many Thanks!

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G20 – Italia

**Grazie Mille!**