“Mitigation of climate change in agriculture”

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Embrapa Soybean General Head

Brazilian Agricultural Research Corporation
Embrapa

Brazilian Agricultural Research Corporation
< 8% of The Brazilian Territory is used for crop production
## Harvest Season 2021/22
### Biggest Drought of the last 93 years

<table>
<thead>
<tr>
<th>State</th>
<th>Expected (Ton/ha)</th>
<th>Actual (Ton/ha)</th>
<th>Losses (Ton/ha)</th>
<th>Sowed Area (ha x million)</th>
<th>Losses (U$ billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS</td>
<td>3,300</td>
<td>1,620</td>
<td>-1,680</td>
<td>6.4</td>
<td>6.07</td>
</tr>
<tr>
<td>SC</td>
<td>3,480</td>
<td>2,880</td>
<td>-600</td>
<td>0.7</td>
<td>0.24</td>
</tr>
<tr>
<td>PR</td>
<td>3,660</td>
<td>2,040</td>
<td>-1,620</td>
<td>5.7</td>
<td>5.23</td>
</tr>
<tr>
<td>MS</td>
<td>3,600</td>
<td>2,520</td>
<td>-1,080</td>
<td>3.5</td>
<td>2.20</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>↓ 13,74</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Embrapa Soybean, 2022

### Drought
High unpredictability and high level of economical damage

~24 Million Ton not harvested
How to deal with this Challenge?
Strategies to Improve Drought Tolerance in Crop Production

Pre-Crop Management

- Long Term History: 3+ years
- Sequence: 1 year
- Fallow: 0.5 years

- Soil Structure
- Soil Fertility
- Seed Bank
- Diseases
- Nitrogen
- Water
- Weeds
- Weed Control
- Struggle
- Grazing
- Sowing Date
- Density
- No Tillage
- Disease/Insect Control
- Irrigation

Increase soil water capture and Storage

Crop Vigor/Reduce evaporative loss

Canopy Management/Harvest Index

In-Crop Management

- Management
- Genetics

- Classical Breeding
- GM Plants
- GE Plants
Complex Response Mechanisms
Agronomic and Physiological

- Gas Exchange
- Leaves Color
- Water Translocation
- Root Hairs
- Root system ramifications
- Nitrogen Fixation
- Leaves Movement
- Leaves Pubescence
- Flowers and Legume Abscission
- Nutrient Translocation
- Photosyntates Translocation
- Root system profundity
Plant Responses to Drought

• Drought resistance is a complex characteristic to express in plants.

• There are many genes and mechanisms involved.

Plant-Soil-Atmosphere Interactions

Whole Plant Level Defenses

Intensity
Duration
Developmental Phase
Other Stresses

Genetic Background
QTLs
Constitutive Genes
Inducible Genes

Stress Perception

Tissue Level Defenses

Cellular Level Defenses

Metabolites

mRNA
Strategies for the drought mitigation in soybean using Transgenesis and Genome Edition

Genome Edition
SDN1/SDN2 strategies

Transgenesis
Ox A.thaliana genes

Adapted: Umezawa et al 2006, 17:113-122
IRRIGATED STRESS PHENOTYPING IN THE FIELD 26 days of stress

Conventional genotypes x Transgenic genotypes

Porto Nacional, TO, BRAZIL
PRODUCTIVITY (kg.ha⁻¹): LOSSES UNDER WATER DEFICIT
FIELD TEST OF TRANSGENIC GENOTYPES FOR DROUGHT TOLERANCE

Porto Nacional, TO, BRAZIL – Oct/22
Overexpression of the ABA-Dependent AREB1 Transcription Factor from Arabidopsis thaliana Improves Soybean Tolerance to Water Deficit

Elton Gargioni Grisoste Barbosa • Juliana Paula Leite • Silvana Regina Rockenbach Marin • Juliane Prela Marinho • Josirley de Fátima Corrêa Carvalho • Renata Fuganti-Pagliarini • José Renato Bouças Farias • Norman Neumaier • Francismar Corrêa Marcelino-Guimarães • Maria Cristina Neves de Oliveira • Kazuko Yamaguchi-Shinozaki • Kazuo Nakashima • Kyonoshin Maruyama • Norihito Kanamori • Yasunari Fujita • Takuya Yoshida • Alexandre Lima Nepomuceno

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www.sbg.org.br
Research Article

Introduction of the rd29A:AtDREB2A CA gene into soybean (Glycine max L. Merril) and its molecular characterization in leaves and roots during dehydration

Cibelle Engels¹, Renata Fuganti-Pagliarini², Silvana Regina Rockenbach Marin², Francismar Corrêa Marcelino-Guimarães³, Maria Cristina Neves Oliveira², Norihito Kanamori³, Junya Mizoi⁴, Kazuo Nakashima³, Kazuko Yamaguchi-Shinozaki³,⁴ and Alexandre Lima Nepomuceno²

Molecular, anatomical and physiological properties of a genetically modified soybean line transformed with rd29A:AtDREB1A for the improvement of drought tolerance

A.M. Polizei², M.E. Medri¹, K. Nakashima³, N. Yamanaka³, N. Faria³, M.C.N. de Oliveira², S.R.R. Marin², R.V. Abdelenoor³, F.C. Marcelino-Guimarães³, R. Fuganti¹, F.A. Rodrigues¹, R. Stolf-Moreira¹, M.A. Beneventi¹, A.A.P. Rolla¹, N. Neumaier³, K. Yamaguchi-Shinozaki³, J.F.C. Carvalho¹ and A.L. Nepomuceno³

Characterization of Molecular and Physiological Responses Under Water Deficit of Genetically Modified Soybean Plants Overexpressing the AtAREB1 Transcription Factor

Juliane Prela Marinho¹,² • Norihito Kanamori³ • Leonardo Cesar Ferreira² • Renata Fuganti-Pagliarini¹ • Josirley de Fátima Corrêa Carvalho¹ • Rafaela Alves Freitas²,³ • Silvana Regina Rockenbach Marin¹,² • Fabiana Aparecida Rodrigues² • Lillian Mártha Mertz-Hennig² • José Renato Bouças Farias² • Norman Neumaier³ • Maria Cristina Neves de Oliveira² • Francismar Corrêa Marcelino-Guimarães³ • Takuya Yoshida⁴ • Yasunari Fujita⁴ • Kazuko Yamaguchi-Shinozaki³ • Kazuo Nakashima³ • Alexandre Lima Nepomuceno³
Drought Tolerant Variety

Breeding

Plant Physiology

Molecular Biology

Agronomical Drought Tolerant Crop
OGM: Each country created its own rule

Phases and Costs to Development of a GM Crop

<table>
<thead>
<tr>
<th>Phases</th>
<th>Gene Discovery</th>
<th>Prove of Concept</th>
<th>Development</th>
<th>Pre-Commercialization</th>
<th>Launch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Costs (US$ M)</td>
<td>31</td>
<td>28.3</td>
<td>13.6</td>
<td>45.9</td>
<td>17.2</td>
</tr>
<tr>
<td>Years</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Today, basically, only four companies can place GM Crop Varieties in the Market

- Bayer (+Monsanto)
- BASF
- Corteva (Dow+DuPont+Pioneer)
- Syngenta (+ChemChina)

Estimated Costs: ~US$136 million

Estimated Costs of Deregulation Phase: ~US$75 million

It can take ~12-20 years from discovering a gene(s) and placing a GM Commercial Variety in the Market.
... but evolution on genetics keeps moving fast...
... CRISPRs Technology brought a revolution in Genome Editing and is democratizing the use of biotechnology in agriculture
A more assertive global legislation is DEMOCRATIZING the use of biotechnology allowing more cultures, small and medium companies to also participate in the Market.
Site Directed Mutagenesis type:

SDN1
SDN2
SDN3

Cas9

DNA cutting is done in regions (sequences) chosen with precision

Gene Disruption

Gene Correction

Cas9

HDR (homology-Cotransfect cells)

Gene Inserion

Clustered
Regularly
Interspaced
Short
Palindromic
Repeats

Não OGM

Similar to mutations that occur in nature and are responsible for evolution on planet earth
Submission (Oct/22) at CTNBio to evaluate if a SDN1 mutation made in a Embrapa Soybean variety be considered a conventional genotype

EMBRAPA SOYBEAN - Genome Edited Soybean for Drought Tolerance

KNOCKOUT OF THE Gene A

13 Plants with edited cells/3 High percentage Analyzes using TIDE and ICE software

- Regeneration T0 lines
- T1 - Transgene-free with editing heritable
- T2 - Homozygous seeds

Molecular and phenotypic characterization in greenhouse

gRNA2 Glyma.XXXXXX

74% Edited

26% Wt
Leading project on Genome Edition at EMBRAPA

**CRISPRRevolution**

Four Crops and Two Strategies

**Knock-out (SDN1)**
- **Soybean**: Anti-nutritional Factors/Drought
- **Sugarcane**: Cell wall structure (2G Ethanol)
- **Corn**: Cell wall structure (2G Ethanol)
- **Common Bean**: Tegument Color

**HDR (SDN2)**
- **Soybean**: Drought
- **Sugarcane**: Drought
- **Corn**: Drought
- **Common Bean**: Drought
Lectin (soybean antinutritional factor) - knockout by SDN1 strategy

Considered NON GM in 01 September, 2022

Embrapa Soybean first genome edited evaluated by CTNBio

DNA Genómico
Editado

Soja com redução de fatores antinutricionais é aprovada pelo CTNBio

FOLHA DE S.PAULO

A agricultura brasileira entra na fase da edição gênica, de menor custo

Novo sistema já coloca no mercado pelo menos três dezenas de empresas pequenas, médias e startups focadas na tecnologia
Thank you!

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