Modern Plant Breeders Toolbox - Current Technologies

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The Toolbox

- **Mutation** creation – produce large numbers of mutants, sort between preferred and deleterious
- **Wild Crosses** – cross two species, use tissue culture to identify hybrid
- **Gene stacking** – different traits in different growing environments
- **Transgenic plants** – recombinant DNA (rDNA from selected sources)
- **Back-crossing** into varieties for different geographies

Transgenic DNA Sequences
Soy Genome
$10^8 - 10^{10}$ base pairs

GMO Event Traits

- **Yield/Quality Attributes**
- **Herbicide Resistance**
- **Insect Resistance**
- **Toolbox**
- **Other Agronomic Traits**

Important to:
- Grower/Consumer
- Developer

- Drought
- Yield
- Nitrogen Use
- Multiple pests
- Multiple modes of action

History of GMOs - commercial releases built on early successes

- Roundup Ready® canola – Canada, U.S.A. 1995
- Roundup Ready® soybeans – U.S.A. 2000
- Bollgard® cotton – U.S.A.
- Liberty Link® soybean – U.S.A.
- Roundup Ready® sugar beets – U.S.A. 2006
- Roundup Ready® canola – U.S.A. 2007
- Roundup RReady2Yield™ soybean – Canada, U.S.A. 2009

2nd Generation

Adoption of genetically engineered crops in the United States, 1996-2016

Data for each crop category include varieties with both HT and Bt (stacked) traits. Sources: USDA, Economic Research Service using data from Fernandez-Cornejo and McBride (2002) for the years 1996-99 and USDA, National Agricultural Statistics Service, June Agricultural Survey for the years 2000-16.
Gene Stacking - a Stacked Event

• The use of plant breeding to combine two or more genetically engineered Traits into a single plant variety (plant or seed)

  – Source APHIS USDA

Seed and Field Stacks?

A Seed Stack
  – Stack in which the Events have been deliberately combined during the breeding process to be present in every seed in the lot

A Field Stack
  – is an adventitious combination of Events arising from pollination in the farmers' field

Commodity grain may contain Mixtures and Field Stacks of a variety of commercial events

Stacked Event Traits

Important to -
• Grower/Consumer
• Developer

Grain Quality
• Glufosinate
• Glyphosate
• Sulfonyleurea

Other Agronomic Traits
• Drought
• Yield
• Nitrogen Use

Traits assembled in various combinations

Herbicide Resistance
• Multiple pests
• Multiple modes of action

Insect Resistance

History of GMOs - commercial releases built on early successes

Improvements in genetic engineering capabilities allowed breeders to combine traits in elite crop varieties

2004
YieldGard™ Plus with RR - Three-way stack in corn combines gene for a Bt protein (European corn borer), a gene for another Bt protein (protection corn rootworm) and herbicide tolerance in the same hybrids

2009

2016
Genuity® SmartStax™ - Eight-way stack that delivers multiple modes of action against several insect pests as well as the opportunity for growers to choose among key herbicides for efficient weed control

3rd and 4th Generation

www.cera-ynr.org/GMCropDatabase
www.isaaa.org/gmapprovaldatabase
Number of releases approved by APHIS by GE trait (includes permits and notifications)*

<table>
<thead>
<tr>
<th>Trait</th>
<th>Release Count</th>
</tr>
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<tbody>
<tr>
<td>Herbicide Tolerance</td>
<td>7834</td>
</tr>
<tr>
<td>Bt only</td>
<td></td>
</tr>
<tr>
<td>Stacked (Bt and HT)</td>
<td></td>
</tr>
<tr>
<td>Source Clive James, 2015</td>
<td></td>
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</tbody>
</table>

Source: USDA (APHIS) authorizes releases to allow field testing


International Planting

<table>
<thead>
<tr>
<th>Country</th>
<th>Area (million hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA*</td>
<td>70.9</td>
</tr>
<tr>
<td>Brazil*</td>
<td>44.2</td>
</tr>
<tr>
<td>Argentina*</td>
<td>24.0</td>
</tr>
<tr>
<td>India*</td>
<td>11.6</td>
</tr>
<tr>
<td>China*</td>
<td>3.7</td>
</tr>
<tr>
<td>Peru</td>
<td>3.6</td>
</tr>
<tr>
<td>Pakistan</td>
<td>2.9</td>
</tr>
<tr>
<td>South Africa*</td>
<td>2.3</td>
</tr>
<tr>
<td>Uruguay*</td>
<td>1.4</td>
</tr>
<tr>
<td>Bolivia*</td>
<td>1.1</td>
</tr>
<tr>
<td>Philippines*</td>
<td>0.7</td>
</tr>
<tr>
<td>Australia</td>
<td>0.7</td>
</tr>
<tr>
<td>Burkina Faso*</td>
<td>0.4</td>
</tr>
<tr>
<td>Myanmar*</td>
<td>0.3</td>
</tr>
</tbody>
</table>

* Planted 50,000 hectares or more

Source: Clive James, 2015

179.7 Million Hectares
Global Spread

Uptake Bt Cotton in China

Uptake of GM technology

- Similar studies – India cotton and Philippines corn
- Farmers keen to take advantage of new technologies
- Gaps exist in regulation of seed quality, technical advice
- Generally farmers are dependent on information from other farmers and the seed suppliers
- In Philippines farmers who grow Bt corn - open to other GM crops

In general, gaps in information regarding global crops

GM Regulations

- Approval process
- Risk assessment
- Labeling policies
- Traceability system
- Co-existence management
- Membership in International agreements GMO related – Codex Alimentarius (consumer health and fair trade), Cartegena Protocol on Biosafety (shared procedure for risk assessment, risk management and trans-boundary movements of Living modified Organisms, LMOs)
GM and Trade

List of supplying markets for a product imported by Malaysia
Product: 1201 Soyabean, whether or not broken

- U.S.A. Soya
- Canada
- Argentina
- Brazil
- Paraguay

Soya Imported to Malaysia 2015

List of supplying markets for a product imported by Malaysia in 2015
Product: 1201 Soyabean, whether or not broken

Cereals Imported to Malaysia 2015

List of supplying markets for a product imported by Malaysia in 2015
Product: 10 Cereals

- Maize (Argentina, Brazil, India, Paraguay, USA)
- Rice (Thailand, Viet Nam, Pakistan)
- Wheat (Australia, Canada)

Questions?

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