Global Market Trends for Plant Biotechnology

A presentation to the N.C. Ag & Biotech Summit, November 2014

Steve Savage, Ph.D.
A familiar chart: The unprecedented story of agricultural biotechnology adoption

GLOBAL AREA OF BIOTECH CROPS
Million Hectares (1996-2013)

- Total Hectares
- Industrial
- Developing

27 Biotech Crop Countries

A record 18 million farmers, in 27 countries, planted 175.2 million hectares (433 million acres) in 2013, a sustained increase of 3% or 5 million hectares (12 million acres) over 2012.

Source: Clive James, 2013.
Soybeans in the Americas

Soybean Biotech Adoption in the Americas

Data Source: CONTEXT
US Biotech corn adoption 98% and increasingly with stacked versions

U.S. Biotech Corn Acres

Data Source:
Biotech trait adoption in NA Canola has been >95% since 2007

Data Source:
Biotech Cotton adoption has transcended farm scale and geography

Biotech Acres (U.S., India & China)

Data Source: CONTEXT
This isn’t just about a few crops

Data Source:

- Sweet pepper: 1
- Poplar: 1
- Polish canola: 1
- Petunia: 1
- Melon: 1
- Eggplant: 1
- Creeping Bentgrass: 1
- Chicory: 1
- Bean: 1
- Sugar cane: 0
- Plum: 0

Biotech Crops With Planting Approvals

- Squash: 2
- Tobacco: 2
- Flax: 3
- Alfalfa: 4
- Papaya: 4
- Rose: 4
- Wheat: 4
- Tomato: 5
- Carnation: 6
- Potato: 10
- Argentine Canola: 13
- Rice: 13
- Sugarbeet: 13
- Cotton: 21
- Soybean: 21
- Maize: 27

Number of Countries
Two events each for Poplar, Rose, Squash, and Tobacco

One event each for Dry Beans, Bent grass, Eggplant, Flax, Melon, Petunia, Sweet Pepper and Wheat

<table>
<thead>
<tr>
<th>Crop</th>
<th>Events in ISAAA Database</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugarcane</td>
<td>3</td>
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<tr>
<td>Sugarbeet</td>
<td>3</td>
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<tr>
<td>Chicory</td>
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</tr>
<tr>
<td>Polish Canola</td>
<td>4</td>
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<tr>
<td>Papaya</td>
<td>4</td>
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<tr>
<td>Alfalfa</td>
<td>4</td>
</tr>
<tr>
<td>Rice</td>
<td>7</td>
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<tr>
<td>Tomato</td>
<td>11</td>
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<tr>
<td>Carnation</td>
<td>19</td>
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<tr>
<td>Soybean</td>
<td>30</td>
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<tr>
<td>Argentine Canola</td>
<td>30</td>
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<tr>
<td>Potato</td>
<td>31</td>
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<tr>
<td>Cotton</td>
<td>52</td>
</tr>
<tr>
<td>Maize</td>
<td>135</td>
</tr>
</tbody>
</table>

352 Events

Data Source:
Nor is it just about the Americas

Top 15 Countries for Biotech Cultivation Approvals

- Costa Rica: 15
- Argentina: 32
- Brazil: 33
- China, mainland: 48
- South Africa: 51
- Colombia: 51
- Philippines: 60
- Taiwan: 66
- New Zealand: 78
- Australia: 90
- Republic of Korea: 99
- Mexico: 131
- Canada: 146
- USA: 159
- Japan: 189

Data Source: ISAAA
Nor is it just about the Americas, continued

Second Tier Countries for Biotech Cultivation Approvals

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of Events</th>
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</thead>
<tbody>
<tr>
<td>Switzerland</td>
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<tr>
<td>Pakistan</td>
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<tr>
<td>Chile</td>
<td>2</td>
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<tr>
<td>Burkina Faso</td>
<td>2</td>
</tr>
<tr>
<td>Viet Nam</td>
<td>3</td>
</tr>
<tr>
<td>Indonesia</td>
<td>6</td>
</tr>
<tr>
<td>Honduras</td>
<td>6</td>
</tr>
<tr>
<td>Thailand</td>
<td>8</td>
</tr>
<tr>
<td>India</td>
<td>8</td>
</tr>
<tr>
<td>Uruguay</td>
<td>9</td>
</tr>
<tr>
<td>Paraguay</td>
<td>10</td>
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<tr>
<td>Norway</td>
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<tr>
<td>Singapore</td>
<td>13</td>
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<tr>
<td>Turkey</td>
<td>14</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>14</td>
</tr>
<tr>
<td>Malaysia</td>
<td>14</td>
</tr>
</tbody>
</table>

Single events also approved in: Bangladesh, Iran, Myanmar, Panama and Spain

Data Source:
There are 102 Different Genes In Use

Genes in the ISAAA Database of Biotech Crops

- Allergy Mitigation: 1
- Enzymes: 3
- Stress Tol.: 3
- Hybridization: 4
- Ripening: 6
- Pigment: 7
- Markers: 9
- Nutrition: Oils (8), Other (4)
- Herbicide Tol.: Glyphosate (7), Glufos, Dicamba, Other (10)
- Insect Res.: Leps (15), Coleops (8), Broad (4)

Data Source:
Some genes are widely used

- Herbicide tolerance
- Insect resistance
- Pigment modification
- Hybridization system

Data Source:
Plants and bacteria are the major sources of genes

**Sources of Genes for Biotech Crops**

- **Syn Plant**: 1 #Genes, 1 #Species/Subspecies
- **Syn Archae**: 1 #Genes, 1 #Species/Subspecies
- **Syn Actinomycete**: 1 #Genes, 1 #Species/Subspecies
- **Insect**: 1 #Genes, 1 #Species/Subspecies
- **Coralimorph**: 1 #Genes, 1 #Species/Subspecies
- **Actinomycete**: 2 #Genes, 2 #Species/Subspecies
- **Fungi**: 3 #Genes, 3 #Species/Subspecies
- **Virus**: 7 #Genes, 6 #Species/Subspecies
- **Syn Bacteria**: 9 #Genes, 9 #Species/Subspecies
- **Bt**: 16 #Genes, 10 #Species/Subspecies
- **Other Bacteria**: 14 #Genes, 14 #Species/Subspecies
- **Plant**: 31 #Genes, 25 #Species/Subspecies

Data Source: [ISAAA Logo]
For many biotech crops, the global area approved for cultivation is large.

Data Sources:
For many countries, a significant portion of cropland is approved

Percent of Major Crop Area With Biotech Approved Crops (Top 15)

- Panama: 8%
- Honduras: 16%
- Mexico: 17%
- Colombia: 18%
- Uruguay: 19%
- South Africa: 19%
- Philippines: 20%
- China, mainland: 20%
- Australia: 22%
- Argentina: 23%
- USA: 23%
- Canada: 24%
- Paraguay: 25%
- Brazil: 25%
- Japan: 27%
In other countries, approvals only effect a small proportion of cropland.
Estimated biotech planting rates are ~50% overall, but much higher in the certain countries.
However, the area of possible biotech crop planting is <10% of the total for major crops.
So, how should we view this situation?

**Optimist:** The glass is half full

**Pessimist:** The glass is half empty

**Engineer:** The glass is over-designed

**Connoisseur:** That’s great. Are there other glasses?

**Pessimist:** The glass is half empty

Let’s take a look back at how we got here
Initial Challenges/Barriers For Biotechnology Commercialization

- Technology
- Freedom to Operate
- R&D Cost
- Regulatory Pathway
- Germplasm Access
- Business Model
- Industry Buy-in
- Farmer Evaluation
- Food System Acceptance
Current Status of Challenges/Barriers for Biotechnology Commercialization

Technology

Regulatory Pathway

Industry Buy-in

Freedom to Operate

Germplasm Access

Farmer Evaluation

R&D Cost

Business Model

Food System Acceptance
Remaining Barriers (1)

- Jurisdictions where politics trumps science
- Asynchronous global process
- Regulation by method, not product
- Projection of “rich world precaution” on the developing world
- Green Imperialism?
Remaining Barriers (2)

- Biotech regulation as a non-tariff trade barrier
- Intensifying pressure on functional systems
- Uncertainty about how to deal with “synthetic biology” advances
Current Challenges/Barriers For Biotechnology Commercialization

- Technology
- Freedom To Operate
- R&D Cost
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- Farmer Evaluation
- Food System Acceptance
Remaining Barriers

- Brand protectionism
- Export customer leverage
- Marketing opportunism
- Industry intimidation
- Lack of rational thresholds for “adventitious presence”
- Manipulation of consumer perception
What sort of “other glasses” are out there?
<table>
<thead>
<tr>
<th>Trait Category</th>
<th>Articles</th>
<th>Field Trials</th>
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</thead>
<tbody>
<tr>
<td>Protein quality and amino acid content</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Oils, sugars and starches</td>
<td>21</td>
<td>14</td>
</tr>
<tr>
<td>Metabolites, nutritional quality</td>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td>Removing unwanted components</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>Fruit ripening and postharvest quality</td>
<td>16</td>
<td>40</td>
</tr>
<tr>
<td>Esthetics, flavor, convenience</td>
<td>14</td>
<td>25</td>
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<tr>
<td>Nutrient acquisition, remediation</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>Abiotic stress tolerance</td>
<td>43</td>
<td>34</td>
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<tr>
<td>Biotic stresses</td>
<td>83</td>
<td>137</td>
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<tr>
<td>Herbicide resistance</td>
<td>15</td>
<td>58</td>
</tr>
<tr>
<td>Pest resistance</td>
<td>45</td>
<td>34</td>
</tr>
<tr>
<td>Yield and fertility</td>
<td>10</td>
<td>17</td>
</tr>
</tbody>
</table>
Disease Resistant Strawberry

PD Resistant Grapes

Tomato with BS2 Pepper Gene for Bacterial Resistance

Virus Resistant Cassava
Non-browning, low acrylamide potato

Golden Bananas

High Anthocyanin Tomato

Arctic Apple (non-browning)
How could we open the paths to those other glasses?
Some of the voices for the future of crop biotech

Cornell
ALLIANCE FOR SCIENCE

I ♥ GM
GMOLOL

Skepti-Forum

BIOLOGY FORTIFIED

Truth about Trade & Technology

GENETIC LITERACY PROJECT
WHERE SCIENCE TRUMPS IDEOLOGY

North Carolina Biotechnology Center
World Food Center

Academics Review
Testing popular claims against peer-reviewed science
What do we need to avoid doing?

- Claiming that “biotech crops will feed the world” “only farmers will feed the world…with this and other tools”
- Going along with societal myths and misconceptions
  - “Industrial Agriculture”
  - “Corporate Farming”
  - “Evil Corporations”
  - “Monoculture”
- Enabling the synergistic use of the fear of pesticides and “GMOs”
Some ideas?

- More great science and general innovation
- Emphasize the vetting role of farmers
- Activism around a pioneer crop or crops?
- Challenge the paradigm of marketing food for what it is not
Some Ideas

• Encourage leadership from those who actually “control the food system”

• Encourage rich world consumer pushback against being manipulated?

• Encourage consumers in the developing world to pushback against “Green Imperialism”
Thanks!