Genetically Modified Foods

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Outline

• What is a GMO?
• Traditional Plant Breeding
• How do you make a GMO?
• GMOs in our Food System
• Potential Benefits/Concerns with GMOs
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What is a GMO?

• GMO = Genetically Modified Organism
  – GMC = Genetically Modified Crop
  – GM = Genetically modified

• Also know as transgenics

• Organism where genetic material altered by genetic transfer techniques

• Gene transfer techniques are referred to as biotechnologies or biotechnology.
What is a GMO?

Image Source: http://www.shigen.nig.ac.jp/medaka/images/strainImages/TG849.gif

Diagram showing overlapping circles labeled Economic, Social, Ecological, Legal, and Political, with GMOs at the center.
Oregon's organic farmers fight genetically modified seeds
by Scott Lear, The Oregonian
Friday October 31, 2008, 10:06 PM

PHILOMATH -- Critics of genetically modified crops have warned about "Frankenfood" and "superweeds" for years. But today, more than four-fifths of the nation's corn, cotton and soybean crops are altered to resist pesticides and insects.

Now Frank Morton, a 59-year-old organic seed farmer in Philomath, and other activists are gaining new legal ground in the battle, charging that genetically modified crops will spread and contaminate organic crops.

GMOs
Disclosure of Intent

• Pro or Con GMO?: I’m GMO neutral, but pro-science.

• Intent: You will be informed, and thus in a better position to make up your mind regarding the benefits and risks of GMO crops

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Biotechnology vs Plant Breeding

Traditional 'Miracle' Crosses

<table>
<thead>
<tr>
<th>Generation 1</th>
<th>Seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000</td>
<td>0%</td>
</tr>
<tr>
<td>130</td>
<td>100%</td>
</tr>
</tbody>
</table>

Plant Breeding: Miracle Rice

38 Crosses

130 Seeds Cross 8

10,000 Seeds

This picture shows a dwarf rice plant on the left and a traditional rice plant on the right.
Source: www.abcdef.co.jp
**Plant Breeding: Miracle Rice**

**Generation 2**
- 75% Seeds from Short Plants
- 25% Seeds from Short Plants

**Generation 3**
- 298 Chosen Seeds from 'Chosen' Plants Planted

**Generation 4**
- Row 288 Plant 3

**Generation 5**
- Source of IR 8

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This picture shows a dwarf rice plant on the left and a traditional rice plant on the right. Source: www.sheffield.gov.uk
Biotechnology vs Plant Breeding

Traditional 'Miracle' 'Super'

440 million base pairs

http://www.shigen.nig.ac.jp/pln/rgn/vol9/v9p111.html

http://www.nature.com/nrg/journal/v2/n10/images/nrg1001-815a-f1.gif
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How to Make a GMO:

• Find gene with a desirable trait
• Place gene into a vector
• Place gene-carrying vector into a plant
• Select plant cuttings where vector was successfully placed
• Grow cuttings and select for plants expressing desirable trait
microprojectile bombardment
“biolistics” or “gene gun”

tiny DNA-coated particles are shot into plant cells
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GMOs are Developed for:

• Pest Resistance: Bt crops
• Herbicide Tolerance: Roundup Ready crops

• Disease Resistance
• Cold Tolerance: anti-freeze gene from coldwater fish in potatoes/tobacco
  – Type II fish antifreeze protein accumulation in transgenic tobacco does not confer frost resistance [Transgenic Research, Vol 8, No 2, pp 105-117, Apr 1999]
• Drought Tolerance/Salinity Tolerance: C4 Rice
• Nutrition: Golden Rice
• Pharmaceuticals/Medicines: vaccines in tomatoes and potatoes
• Phytoremediation: heavy metal accumulating poplars
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Rapid growth in adoption of genetically engineered crops continues in the U.S.

Percent of acres

Data for each crop category include varieties with both HT and Bt (stacked) traits.
Deciphering Labels

- At least 95% organic
- GMOs disallowed in organic production

- Best practices for GMO avoidance
- Testing of risk ingredients
- <0.9% GMO
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Potential Benefits

• Reduced Pesticide Use
• Increased Yield and/or Nutrition
### Potential Benefits

<table>
<thead>
<tr>
<th>Parameter</th>
<th>GM Rice</th>
<th>Non-GM Rice</th>
</tr>
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<tbody>
<tr>
<td><strong>Number of Pesticide Sprays</strong></td>
<td>0.50</td>
<td>3.70</td>
</tr>
<tr>
<td><strong>Cost of Pesticide (yuan/ha)</strong></td>
<td>31.0</td>
<td>243</td>
</tr>
<tr>
<td><strong>Pesticide Use (kg/ha)</strong></td>
<td>2.00</td>
<td>21.2</td>
</tr>
<tr>
<td><strong>Pesticide Spray Labor (days/ha)</strong></td>
<td>0.73</td>
<td>9.10</td>
</tr>
<tr>
<td><strong>Yield (kg/ha)</strong></td>
<td>6,364</td>
<td>6,151</td>
</tr>
</tbody>
</table>

### GMOs in Developing Nations

<table>
<thead>
<tr>
<th></th>
<th>Argentina</th>
<th>China</th>
<th>India</th>
<th>Mexico</th>
<th>South Africa</th>
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<tbody>
<tr>
<td>Yield</td>
<td>33</td>
<td>19</td>
<td>34</td>
<td>11</td>
<td>65</td>
</tr>
<tr>
<td>Revenue</td>
<td>34</td>
<td>23</td>
<td>33</td>
<td>9</td>
<td>65</td>
</tr>
<tr>
<td>Pesticide Costs</td>
<td>-47</td>
<td>-67</td>
<td>-41</td>
<td>-77</td>
<td>-58</td>
</tr>
<tr>
<td>Seed Costs</td>
<td>530</td>
<td>-12</td>
<td>17</td>
<td>165</td>
<td>89</td>
</tr>
<tr>
<td>Profit</td>
<td>31</td>
<td>340</td>
<td>69</td>
<td>12</td>
<td>299</td>
</tr>
</tbody>
</table>


### GMOs in the USA - First 8 Years

- 2 of 5 GMOs sustained their positive impacts on the pounds of pesticides applied per acre – Bt corn and Bt cotton.

- Bt corn and Bt cotton reduced the pounds of insecticide applied by ≈ 2.3 million pounds
  - 7 percent of total insecticide use on these two crops.

What about the USA?

- Bt corn and cotton have reduced insecticide use by 64.2 million pounds
- Herbicide tolerant crops increased herbicide use by 382.6 million pounds
- GMOs increased pesticide use by 318.4 million pounds (estimate)

Potential Concerns

• Harm to other organisms
• Pest resistance
• Human Health
• Transgene ‘Escape”


Touching ‘zero’ = No Difference Between GMO and Conventional Cotton

GMO vs No-Pesticide Cotton

Below ‘zero’ = Fewer Insects in GMO Cotton

GMO vs Regular Cotton, both with Pesticides
Above ‘zero’ = More Insects in GMO Cotton


GMO, no pesticides vs Regular Cotton, with Pesticides

Below the ‘zero’ line: fewer arthropods in GMO Cotton

GMO cotton vs No Pesticide Cotton
Honey Bees

Harm to other organisms

Pest resistance

Human Health

Transgene ‘Escape

Potential Concerns

A Meta-Analysis of Effects of Bt Crops on Honey Bees (Hymenoptera: Apidae).
In the possible event a resistant mutant occurs:

- **Refuge Area**
  - Wildtype
  - Non-resistant progeny

- **Transgenic crop**
  - Bt resistant mutant

Legend:
- S
  - Susceptible
<table>
<thead>
<tr>
<th>Weed</th>
<th>Situation</th>
<th>Year</th>
</tr>
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<tbody>
<tr>
<td>Italian Ryegrass</td>
<td>Wheat</td>
<td>1987</td>
</tr>
<tr>
<td>Wild Oat</td>
<td>Wheat</td>
<td>1990</td>
</tr>
<tr>
<td>Wild Oat</td>
<td>Cropland</td>
<td>1990</td>
</tr>
<tr>
<td>Kochia</td>
<td>What</td>
<td>1993</td>
</tr>
<tr>
<td>Prickly Lettuce</td>
<td>Wheat</td>
<td>1993</td>
</tr>
<tr>
<td>Russian Thistle</td>
<td>Wheat</td>
<td>1993</td>
</tr>
<tr>
<td>Redroot Pigweed</td>
<td>Mint</td>
<td>1994</td>
</tr>
<tr>
<td>Annual Bluegrass</td>
<td>Grass Seed</td>
<td>1994</td>
</tr>
<tr>
<td>Common Groundsel</td>
<td>Mint</td>
<td>1995</td>
</tr>
<tr>
<td>Downy Brome</td>
<td>Kentucky Bluegrass</td>
<td>1997</td>
</tr>
<tr>
<td>Smallseed Falseflax</td>
<td>Wheat</td>
<td>1999</td>
</tr>
<tr>
<td>Italian Ryegrass</td>
<td>Orchards</td>
<td>2004</td>
</tr>
<tr>
<td>Downy Brome</td>
<td>Grass Seed</td>
<td>2005</td>
</tr>
<tr>
<td>Shepherd’s Purse</td>
<td>Alfalfa</td>
<td>2007</td>
</tr>
</tbody>
</table>

Herbicide Resistant Weeds in Oregon
www.weedscience.org

Potential Concerns

• Harm to other organisms
• Pest resistance
• Human Health
• Transgene ‘Escape
**Human Health Concerns**

- Allergenicity: Not much research done, at this time.
  - Nut allergies: proposal to incorporate gene from Brazil nuts into soybeans abandoned

- Unknown Effects on Human Health: Not much good research done, at this time.

**Potential Concerns**

- Harm to other organisms
- Pest resistance
- Human Health
- Transgene ‘Escape”
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Potential for Transgene Escape
Wild Oryza rufipogon field at Tram Chim National Park, Vietnam

Cultivated Oryza sativa & Wild Oryza rufipogon

O. sativa & O. rufipogon known to hybridize under field conditions (Lu et al. 2003)

O. rufipogon found in margins of rice fields, marshes, and canals in the Mekong delta & Central Plains of Vietnam (Lu and Snow 2005)

Outcrossing of Bt genes to wild and weedy rice will almost certainly occur. (Cohen et al. 2008)

“Top Rice Producer China Approves GMO Rice Strain” (Reuters, Nov 27, 2009)

http://www.reuters.com/article/idUSTP364484

- Large scale production of Bt rice could start as early as 2011
- Increased yield of staple amid decreasing land and water resources
- “We expect that with the Chinese approval of Bt rice it will be much easier for other countries to do this, . . . “ (Robert Ziegler, Director General, IRRI)
Cultivated Rice Communities

- Philippines: 645 taxa, >9,000 trophic links across 23 sites and 9 years (Cohen et al. 1994)
- Java: ≈765 species of arthropods across 6 sites and 4 years (Settle et al. 1996)
- Sri Lanka: 494 species of invertebrates across 1 site and ≈2.5 years (Bambaradeniya et al. 2004)
### Wild Rice Species

<table>
<thead>
<tr>
<th>Order</th>
<th>Wild Rice Species</th>
<th>Farmed Rice Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bugs</td>
<td>4270</td>
<td>3418</td>
</tr>
<tr>
<td>Spiders</td>
<td>4181</td>
<td>274</td>
</tr>
<tr>
<td>Springtails</td>
<td>3867</td>
<td>38</td>
</tr>
<tr>
<td>Beetles</td>
<td>2506</td>
<td>37</td>
</tr>
<tr>
<td>Flies</td>
<td>2172</td>
<td>433</td>
</tr>
<tr>
<td>Bees/Wasps/Ants</td>
<td>1930</td>
<td>52</td>
</tr>
<tr>
<td>Crickets/Grasshoppers</td>
<td>1507</td>
<td>14</td>
</tr>
<tr>
<td>Mites</td>
<td>596</td>
<td>2</td>
</tr>
<tr>
<td>Roaches</td>
<td>558</td>
<td>2</td>
</tr>
<tr>
<td>Moths/Butterflies</td>
<td>314</td>
<td>135</td>
</tr>
<tr>
<td>Earwigs</td>
<td>37</td>
<td>2</td>
</tr>
<tr>
<td>Thrips</td>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td>Dragonflies/Damselflies</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>Caddisflies</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Mayflies</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>22,480</strong></td>
<td><strong>4,408</strong></td>
</tr>
</tbody>
</table>

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### Experimental Food Web

**What if Bt gene ‘escapes’ into wild rice?**

*Image Credit: Oregon State University Extension Service*

**Experimental Food Web**

- *Pardosa pseudoannulata* (90/m²)
- *Metioche vittaticollis* (18/m²)
- *Clubiona japonicota* (8/m²)
- *Nilaparvata lugens* (360/m²)
- *Cytonhinus lividipennis* (11/m²)
- *Cnaphalocros medinalis* (60/m²)
- *Rice*
• Arthropods placed onto Bt hybrid rice or wild rice hybrid
• Five experimental replicates run for 1 month
• Abundance and biomass of all arthropods assessed at $t = 0, 1, 2, 3,$ and $4$ weeks
Protein Dies Right Away!

- **Week 0, 1, 2, 3, 4**
- **Mean Abundance**
- **Bt Hybrid Adult**
- **O. rufipogon Adult**
- **Bt Hybrid Larvae**
- **O. rufipogon Larvae**

Spiders get Bigger?

- **Week 0, 1, 2, 3, 4**
- **Mean Biomass (g)**
- **Bt Hybrid - Adults**
- **O. rufipogon - Adults**
- **Bt Hybrid - Spiderlings**
- **O. rufipogon - Spiderlings**
Experimental Food Web

Pardosa pseudoannulata (90/m²)
Nilaparvata lugens (360/m²)
Cytorrhinus lividipennis (11/m²)
Cnaphalocrocis medinalis (60/m²)
Rice

What if Bt gene ‘escapes’ into wild rice?

Summary
GMO Crops are the product of biotechnologies and molecular biology techniques.

Different from traditional plant breeding.
Summary

- GMO Crops are prevalent in the US (soy, corn, cotton)
- GMO Crops may hold benefits for developing nations

Benefits/Concerns about GMO Crops
- Increased Yield/Decreased Pesticides
- Non-target effects
- ‘Superweeds’
- Transgene Escape
- No strong data exists on impacts (good, neutral, negative) on human health