GMO’s and the Environment

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Introduction

- What is a GMO, i.e. GEO (Genetically Engineered Organism)?
  - Transfer of genes via non-sexual means:
    - Agrobacterium
    - Biolistics
  - Advantages and disadvantages:
    - Any gene from any source
    - Single-gene traits; lack of control over insertion location “events”
Gene transfer methods in genetic engineering

http://www.colostate.edu/programs/lifesciences/TransgenicCrops/

From http://escience.ws/b572/L20/L20.htm
Crop Gene Pools

Gepts 2000, modified from Harlan and de Wet 1971
GE crops in CA

Currently:
- Cotton: Upland
  - Herbicide, Bt
- Corn: small

Short-term:
- Alfalfa
  - Herbicide

Potential
- Rice
  - Herbicide
Other potential GE crops?

- Top CA commodities: milk and cream, nursery, grapes, lettuce, almonds, cattle and calves, strawberries, flowers, tomatoes, hay (alfalfa), cotton, broccoli, chickens, oranges, carrots, rice, avocados, walnuts, eggs, and lemons.
The golden rule of GEO evaluation:

Case by case

Environment

Organism

Trait
Potential Environmental Concerns

- Escape of transgenes from cultivated to wild or from cultivated to cultivated
- Effect on target organisms
- Effect on non-target organisms
Crops with wild relatives in California

- Same or different species
- Asparagus, broccoli*, canola, carrot, cauliflower*, celery, lettuce, onion, potato, strawberry, sugarbeet, sunflower, tomato*

* Short-lived escape from cultivation
Escape of (Trans)genes from Domesticated to Wild

**Domesticated with transgene**

- Wild Relative: Yes → Crossable & fertile progeny: Yes
- Wild Relative: No → No gene flow

**Wild with transgene**

- Genetic: Yes → Gene flow (pollen, seed): Yes
- Genetic: No → Migration-Selection Balance: Yes

- Migration-Selection Balance: No → No gene flow

- Environmental: No → No establishment of transgenes

**Summary:**
- Gene flow (pollen, seed): Yes → Same phenotype: Yes
- Gene flow (pollen, seed): No → No gene flow

**No gene flow**
## California’s Ten Most Important Vegetable Crops and their Relatives in California
*(from Ellstrand 1992 based on Muntz 1959)*

<table>
<thead>
<tr>
<th>Crop</th>
<th>Same species in California flora?</th>
<th>Other congeners in California flora?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asparagus</td>
<td>Yes</td>
<td>0</td>
</tr>
<tr>
<td>Broccoli</td>
<td>Yes*</td>
<td>8</td>
</tr>
<tr>
<td>Carrot</td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>Yes*</td>
<td>8</td>
</tr>
<tr>
<td>Celery</td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>Corn, sweet</td>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td>Lettuce</td>
<td>No</td>
<td>6</td>
</tr>
<tr>
<td>Onion</td>
<td>No</td>
<td>37</td>
</tr>
<tr>
<td>Potato</td>
<td>No</td>
<td>21</td>
</tr>
<tr>
<td>Tomato</td>
<td>Yes*</td>
<td>0</td>
</tr>
</tbody>
</table>

* Only as a short-term non-persistent escape from cultivation
Corn pollen dispersal curves

- Rapid decline within 20 m; slower after that
- Detectable gene flow beyond isolation distance of 200 m

Sources of Escape

Transformation → S

Plant Breeding: Breeders’ Seed

Seed Certification: Commercial Seed

Production Agriculture: In planta Production

Extraction and Processing

P: Pollen
- Other fields
- Wild relatives
S: Seeds
- Volunteers
- Spillage
- Mixture

Vegetative
- Dispersal
- Incorporation
Bottom line: Escape of transgenes

- Gene flow will take place: pollen, seed
- Given the current GE crops (cotton, corn, alfalfa):
  - From crop to crop
  - Short distances: corn, cotton (< 100 m)
  - Long distances:
    - alfalfa (> 1.5 km) + volunteers, spillage
- Within these distances, gene flow will be of consequence, only if repeated and abundant opportunities
Effect on Target Organisms?
Development of Resistance

- General strategy to limit development of resistance: *change the environment*:
  - *Bacillus thuringiensis* toxin:
    - Avoid unnecessary exposure + IPM
    - Refugia (high dose/refuge strategy)
    - Pyramided toxins: *cry2Ab* + *cry1Ac*
      - Broader spectrum, smaller refuge
      - Except if used with single toxin cultivars
    - Different insecticides
  - Herbicide resistance:
    - Avoid unnecessary exposure + IPM
    - Alternate herbicides
    - Appropriate rotations and cropping practices
Insecticide Mode of Action Classification:
Diversity is a key to successful resistance management
IRAC website: www.plantprotection.org/irac

**Moulting & Metamorphosis**
- Group 18 Ecdysone agonist / disruptor
  - Tebufenozide
- Group 7 Juvenile hormone mimics
  - Fenoxycarb, Methoprene, etc

**Midgut**
- Group 11 Microbial disruptors of insect midgut membranes
- Toxins produced by the bacterium *Bacillus thuringiensis* (Bt): Bt sprays and Cry proteins expressed in transgenic Bt crop varieties (specific cross-resistance subgroups)

**Nervous System**
- Group 1 Acetylcholinesterase (AChE) inhibitors
- Carbamates and Organophosphates
- Group 2 GABA-gated chloride channel agonists
- Cyclodiene and Fiproles
- Group 3 Sodium channel modulators
  - DDT, pyrethrins, pyrethroids
  - Group 4 Acetylcholine receptor agonists
  - Neonicotinoids
  - Group 5 Acetylcholine receptor modulators
  - Spinosyns
- Group 6 Chloride channel activators
  - Avermectin, Emamectin Benzoate and Milbemycin
- Group 22 Voltage dependent sodium channel blocker
  - Indoxacarb

**Cuticle Synthesis**
- Groups 15, 16 and 17 Inhibitors of chitin biosynthesis
- Benzoylureas (Lepidoptera and others), Buprofezin (Hemiptera) and Cyromazine (Diptera)

**Metabolic Processes**
- Acting on a wide range of metabolic processes including:
  - Group 12 Inhibitors of oxidative phosphorylation, disruptors of ATP
  - Diflubenzuron & Organotin miticides
  - Group 12 Uncoupler of oxidative phosphorylation via disruption of H proton gradient—Chlorfenapyr

**Non-specific MoA**
- Group 10 Compounds of non-specific mode of action (mite growth inhibitors)
  - Clofentezine, Hexythiazox, Etoxazole

**Metabolic processes**
- Group 20 Site II electron transport inhibitors
  - Hydramethion and Dicofol
- Group 21 Site I electron transport inhibitors
  - Rotenone, METI acaricides

**Non-specific MoA**
- Group 9 Compounds of non-specific mode of action (selective feeding blockers)
  - Cryolite, Pymetrozine
Effect on Non-Target Organisms?

- **Positive effects:**
  - Reduction in pesticide use
  - Reduction of secondary infections:
    - *Fusarium* infections: fumonisin (horse, swine; humans)

- **Negative effects:**
  - Effect on beneficial insects?
  - Effect on bystanders?
Effect of pesticides

(Pimentel and Raven 2000)

- 115 x 10^6 kg/yr of pesticides on corn:
  - corn rootworm: 45% yield reduction; other control: rotation
  - European corn borer: 20% yield reduction; difficult to control when inside the plant --> Bt

- Effect of pesticides:
  - pesticide poisonings, cancer
  - 35% of food samples have pesticide residues
  - 70 x 10^6 birds/yr killed
  - 10^9s of insects, including beneficials: pollination, biological control

- Reasons for decline of monarch: insecticide use, loss of habitat
Is everything fine and dandy?

- Chronology of Bt maize:
  - 1996: First available
  - 1999:
    - Losey et al. Nature
    - BIO e-mail
  - 2001:
    - Publication of detailed studies in PNAS

Why posterior analyses?

Adoption of Bt maize in the U.S.

E-mail: “BIO TALKING POINTS RE MONARCH BUTTERFLY BT CORN POLLEN”
Issues associated with the use of transgenics

Genetic Engineering
- Escape of transgenes:
  - from domesticated (transgenic) to wild
  - from domesticated (transgenic) to domesticated (non-transgenic)
- Effect on target organisms
- Effect on non-target organisms

Environmental aspects
- Human and animal health
  - New compounds
  - Allergenic
- Socio-economic & political
  - Economic losses for farmer households and communities
  - Effects on consumer confidence
  - Large-scale cultural changes in rural communities
  - Ownership of the food system
  - Differences among countries

Plant Breeding & Agronomy
- Alternatives: PB v. GE
- Integration of GE into PB
- Alternative cropping systems
- Coexistence among cropping systems

Philosophical & ethical aspects
- Attitudes & Approaches to:
  1) Risk: risk minimization, informed consent, precautionary approach
  2) Genetic modification
  3) Ownership of biodiversity

Legal
- Intellectual property rights
- International treaties
- Regulatory frameworks
- Labelling

Economic losses for farmer households and communities
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Attitudes & Approaches to:
1) Risk: risk minimization, informed consent, precautionary approach
2) Genetic modification
3) Ownership of biodiversity
Conclusions

- Case-by-case approach
- Fast moving technology
- Currently, probably limited environmental effects in the short term
- Role of UC:
  - Impartial information to the public
Sources

- Transgenic plants: [http://escience.ws/b572/L20/L20.htm](http://escience.ws/b572/L20/L20.htm)
  [http://www.colostate.edu/programs/lifesciences/TransgenicCrops/](http://www.colostate.edu/programs/lifesciences/TransgenicCrops/)
  [http://geo-pie.cornell.edu/gmo.html](http://geo-pie.cornell.edu/gmo.html)
- Bacterial crown gall: [http://ohioline.osu.edu/hyg-fact/3000/3301.html](http://ohioline.osu.edu/hyg-fact/3000/3301.html)
- Herbicide resistance management: [http://cottoninfo.ucdavis.edu/IMAGES/Field%20Check_June20_04.pdf](http://cottoninfo.ucdavis.edu/IMAGES/Field%20Check_June20_04.pdf)