Transgenic Crops- the methods, pros and cons of GMOs and biotechnology

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What is a GMO?

- A genetically modified organism (GMO) is one whose genetic material (DNA) has been changed using the techniques of DNA or RNA based genetic engineering.
- Includes: bacteria, yeast, mammals, insects, fish and plants.
- GM foods are GMO.
- GMO is not defined by cloning although that may be involved.
- GMO is not defined by breeding although that may be involved.
- GMO is not specific to any genetic changes done through sexual (breeding) or asexual (cloning) reproduction.

Examples of GM Bacteria (E. coli)

<table>
<thead>
<tr>
<th>GMO Trait</th>
<th>Uses</th>
<th>Original source</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Insulin</td>
<td>Insulin dependent diabetes</td>
<td>Harvested from dogs and pigs.</td>
<td>Chemically indistinguishable from human insulin. Much safer- no allergic reaction. No vegetarian issue.</td>
</tr>
<tr>
<td>Taxol</td>
<td>Cancer treatments</td>
<td>Pacific yew tree</td>
<td>Preserves yew trees. Excellent platform for drug discovery for chemotherapy.</td>
</tr>
<tr>
<td>Vitamins</td>
<td>Diet supplement Fortifying cereal</td>
<td>Many</td>
<td>Cheaper, Easier purification.</td>
</tr>
<tr>
<td>Chymosin (a protease from rennet)</td>
<td>Making Cheese (needed to separate the curd from whey) In 80-90% of hard cheeses made in USA</td>
<td>Lining of calf stomachs</td>
<td>More controlled and predictable cheese. No need to harvest from calves. No vegetarian issue.</td>
</tr>
</tbody>
</table>

GMO does not include Photoshop


Are you still feeding your baby with GMOs?

http://seattleorganicrestaurants.com/vegan-whole-foods/top-20-genetically-modified-foods/

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Original Cheerios go GMO-free
Jan 1, 2014

Yes on 37 Facebook Page
Stop crop mutation
To further their high-dollar corporate power grip on the seed, Monsanto Corp. now brags that to make herbicides more effective in weed control they are injecting the seed with more potent chemical poisons to genetically make the seed immune to the effects of herbicides sprayed on crops.

Why not just put the poison right into the butter we like to spread on the corn before eating it? Forget groundwater contamination; why don’t we just drink herbicides right from the container – or inject the livestock directly to produce fewer weeds upon defecation?

Consumers should wake up and realize that not all science is beneficial to us! More autism and brain disorders are diagnosed yearly in our children – why? Cancer finds its stronghold in all ages with no cure or prevention yet – who profits from this?

Genetically altered seed produces beautiful specimens, except for the mutations you’ll never see at your grocer’s counter. What you don’t see can still hurt you. Picture grotesque mutant humans born – we are what we eat.

In caring about your family, you should think: how much does corporate greed (a collective conscience) care about the welfare of you and your family, including your pets?

http://tylervigen.com/

http://boingboing.net/2013/01/01/correlation-between-autism-dia.html

OMG
GMO!
Are you eating GMO food?
In 2012, about 420 million acres were used to grow GMO crops worldwide. (14%)

1 hectare = 2.47 acres

http://www.isaaa.org/resources/publications/pocketk/16/

Major (and some minor) crops that are likely to be GMO

- Alfalfa (first planting 2011)
- Canola (approx. 90% of U.S. crop)
- Corn (approx. 88% of U.S. crop in 2011)
- Cotton (approx. 90% of U.S. crop in 2011)
- Soy (approx. 94% of U.S. crop in 2011)
- Sugar Beets (approx. 95% of U.S. crop in 2010)
- Zucchini and Yellow Summer Squash (approx. 25,000 acres)
- Papaya (most of Hawaiian crop; approximately 988 acres)

Why?

Weed and insect control and virus resistance.

www.nongmoproject.org/learn-more/what-is-gmo/

Can you avoid eating GMO foods?

Yes.

USDA-certified organic food can not contain GMO ingredients.

Advances

- 50 years: major increases in food production
- Based on agricultural research in the 19th and 20th centuries
- Heavy public funding/input
- “Green Revolution”
  - Changes in plant genetic material
  - Changes in farming equipment and practices
- Challenges lie ahead
Private sector research

- Private sector has provided major contributions to agricultural research
  - Developing countries: ~5%
  - Developed countries: ~50%
  - Overall: ~30%
- Private investment focuses on commercially viable approaches
- Research costs are expensive
- Monetary returns justify research even with 15 to 30 year lag
- Intellectual property (IP) rights key to private investment
- IP issues can also slow/stop some agricultural research

http://www.biofortified.org/2013/10/right-to-save-seeds/

Major plant biotech IP-claim areas

- Plant germplasm (background genetic material)
- Trait-specific genes “input”
  - “Roundup Ready” herbicide tolerance
  - Bt-mediated insect resistance
  - Increased yield: larger as well as semi-dwarf
  - Abiotic stress tolerance, disease resistance, cold tolerance, ripening...
- Trait-specific genes “output”
  - Altered content of starch, oil, amino acids, protein, vitamins, minerals, allergens, flavor, processing, shelf life
  - Bioremediation
  - Biomass and biofuels
- Enabling technologies

Why GM crops?

Pro:
GM crops may be able to contribute to increasing yield, food quality and agricultural sustainability

Con:
GM crops may contribute to hurting us or the environment
Why? Because of Scientific Evidence

The Genetic Engineering Tool Box

- Genes:
  - Genes encoding proteins (traits) of interest
  - can come from essentially any source

- Promoters:
  - Control when and where genes are expressed
  - constitutive expression (CaMV 35S)
  - for more specific control
    - when, where
    - inducible expression

- Terminators:
  - The end of the gene.
  - Where the “transcript” stops

Pro GM crops?

- Cannot make a blanket statement for or against
- Must examine each on a case by case basis
- Must have the scientific knowledge to develop an opinion
- Must be able to inform and educate the public based on each analysis
- Must be able to keep an open mind to all sides of the argument
Getting genes into plants

• Biologically- *Agrobacterium tumefaciens*
  • Uses an organism that normal inserts DNA into plant genomes as part of infection.
  • Region that is inserted is clearly defined. Called T-DNA- inserts genes to cause plant to feed bacteria.
  • We have removed the “bad” genes and put our genes into the T-DNA.
  • *Agrobacterium tumefaciens* inserts our genes.

Getting genes into plants

• Physically- Particle bombardment or “Gene Gun”.
  • Gold beads coated with DNA are shot into plant cells.
  • Selectable marker allows regeneration of transgenic plants.

• **Both techniques usually require a tissue culture phase to select for transformed plants.**

Plant cell tissue culture

• “Tissue culture” is the process of taking a plant cell, differentiating into callus and then turning it back into another plant.
  • Used to propagate orchids that are difficult to multiply via sexual reproduction.
  • To bring in a new, foreign, piece of DNA, some sort of *selectable marker* is usually used.
  • “*Selectable markers*” are often genes that encode a protein allowing herbicide or antibiotic resistance…….
Tobacco regenerated in tissue culture

Transgenic Tobacco Plants

Geneticist Sows Plot to Kill Lawn Mowers!


The papaya ringspot potyvirus (PRSV) story

Increased virus resistance: Papaya ringspot virus (PRV)

Virus has had huge impact on papaya industry in Hawaii - reduction of fresh fruit production directly related to spread of PRV

No naturally occurring resistance genes - without GM, papaya industry in Hawaii would be destroyed

Transgenic PRV-resistant papaya has been grown commercially in Hawaii since 1996. It was recently certified for import into Japan.

Virus-resistant Papaya

Papaya, a tropical fruit high in vitamins C & A, is an important food crop worldwide and the 2nd largest export crop in Hawaii.

Papaya ringspot virus (PRSV), which is spread by aphids, was found in Hawaii in the 1940’s and had wiped out papaya production on Oahu by the 1950’s.

The papaya industry moved to the Puna district on the Big Island of Hawaii.

PRSV was discovered in Puna in 1992, by late 1994, PRSV had spread throughout Puna and many farmers were going out of business.

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Virus-resistant Papaya
In anticipation of a new virus outbreak, scientists at Cornell, began a project to develop transgenic virus-resistant papaya in 1986.

Papaya transformation was greatly facilitated by the recent invention of the "gene gun" at Cornell.
The coat protein of the virus was engineered into papaya to confer resistance, similar to a vaccine.

Funding: USDA

Organic Papaya?

• Most organic papaya is currently grown in Mexico.
• Will virus eventually make it to Mexico?
• Some organic papaya is grown in Hawaii.
  • Definition of organic includes “no GMO”
  • How can organic papaya be grown in Hawaii?

The Bt toxin (BT) story

Microbes that are pathogenic to insects are alternatives to chemical pesticides to prevent insect damage to agricultural crops and disease transmission. Bacillus thuringiensis infections are fatal in many insects but harmless to other animals including humans and to plants.

Advantages and disadvantages to BT in insect control

A: BT is highly specific, not harmful to other insects, mammals, fish etc.
A: Natural product, used as an applied microbial insecticide since the 1960s, used in ORGANIC farming
A: Application reduces the use of chemical pesticides
A: Breaks down quickly, after a few days (light sensitive)
  - This can also be a disadvantage
D: Must be ingested by insect- when applied to surface does not work on boring insects
D: Must target specific larval stages- timing of application is critical
D: Can lead to resistant insects

Engineering resistance to insects
The herbicide resistance story

Roundup Resistant Sugar Beets

With Roundup  No Roundup

Roundup resistant crops do not yield more than unmodified crops if weeds are controlled but they allow less expensive weed control and lower operating costs.

Concentrations of atrazine in runoff: up to 240X higher than drinking water standard
Concentrations of alachlor: up to 700X higher
Max glyphosate concentration 4X lower than standard
Glufosinate: (no established standard) but low concentrations and undetectable after 80 days

Resistant weeds can become a problem if you rely on only one method of control

http://www.caes.uga.edu/applications/gafaces/?public=ViewStory&pk_id=4771

Crop rotations can become a challenge if you rely on only one method of control

Roundup resistant soybean and volunteer
Roundup resistant corn

Herbicide resistant creeping bentgrass
Creeping Bentgrass

- Used on Golf Courses
- Scotts Turf generated Roundup Ready bentgrass
- Tested plots in Oregon
- Open pollinated (via wind)
- Weed populations throughout US
- Transgene escaped into neighboring weeds
- Also escaped into seed plot fields
- 2007: Scotts fined $500,000 by USDA-APHIS
- Scotts had to buy up neighboring fields: millions of dollars paid. Can only sell back when transgene free!

Crops and issues to watch

Seeds: Hawaii bill 79. Prohibits GMO seed production and breeding in Maui (w/ exception to GM papaya).

Oranges: Citrus greening is a bacterial disease of citrus. There is no natural resistance. Serious threat to oranges in Florida and insect vector recently found in California. Candidate transgenic resistance (Texas A&M).

Apples: Arctic apple, non-browning technology developed by Okanagan Specialty Fruits.

Gluten free wheat: Would help deal with Celiac Disease and other gluten allergies.

Golden Rice: Incorporates Vitamin A into rice. VAD: 1 million dead/yr, 200 million deficient.

CRISPR/Cas9-mediated genome editing

- Easy design, preparation and cost-effective

The anti-GMO quandary

- GMOs can be safe and effective
- But many people just don’t like Monsanto
- They don’t want Monsanto to be successful
- The current anti-GMO approach is actually helping Monsanto succeed:
  - Free advertisement for Monsanto
  - Prevents other smaller companies from competing with Monsanto
  - Prevents Universities from deploying products that could help society and/or compete with Monsanto

Looking to the Future:

- Organic definition includes GMO-free
- Can GMO approaches help organic farmers?
- Can GMO approaches facilitate sustainable farming and sustainable living?
- Can GMO approaches help remove dependence on fossil fuels?
- Can an “open source” approach be used with GMOs?
- All of this should be open to discussion.
Some final talking points
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• Empower through education but don’t expect attitude changes
  • Be passionate and stay committed
    • Be credible and listen
    • Adapt to your audience
    • Be aware of your effects
      • Use all channels
      • Collaborate