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</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/

Original Cheerios go GMO-free
Jan 1, 2014

Yes on 37
Facebook Page
 WHICH ONE WOULD YOU CHOOSE?

Yes on 37 Facebook Page...and everywhere associated with Oregon’s Measure 92
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?
Age-adjusted Cancer Death Rates*, Males by Site, US, 1930-2010

*Per 100,000, age adjusted to the 2000 US standard population.
Note: Due to changes in ICD coding, numerator information has changed over time. Rates for cancer of the liver, lung and bronchus, and colon and rectum are affected by these coding changes.
©2014, American Cancer Society, Inc., Surveillance Research
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/
Adoption of genetically engineered crops in the United States, 1996-2013

Adoption of genetically engineered corn in the United States, by trait, 2000-13

Can you avoid eating GMO foods?

Yes (sort of).

USDA-certified organic food can not contain GMO ingredients (knowingly).
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
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
Is GM food safe?

If an overwhelming majority of experts say something is true, then any sensible non-expert should assume that they are probably right.

The American Association for the Advancement of Science (AAAS) is an international non-profit organization. AAAS serves some 261 affiliated societies and academies of science.

"The science is quite clear: crop improvement by the modern molecular techniques of biotechnology is safe."

The American Medical Association (AMA) is the premier body of physicians in the United States.

"There is no scientific justification for special labeling of genetically modified foods. Bioengineered foods have been consumed for close to 20 years, and during that time, no overt consequences on human health have been reported and/or substantiated in the peer-reviewed literature."

The World Health Organization (WHO) is the directing and coordinating authority for health within the United Nations system.

"No effects on human health have been shown as a result of the consumption of GM foods by the general population in the countries where they have been approved."

The National Academy of Sciences is a non-profit organization in the United States. It is the premier scientific body in the United States.

"To date more than 98 million acres of genetically modified crops have been grown worldwide. No evidence of human health problems associated with the ingestion of these crops or resulting food products have been identified."

England's top medical society, the Royal Society of Medicine is an independent educational organization for doctors, dentists, scientists and others involved in medicine and health care.

"Foods derived from GM crops have been consumed by hundreds of millions of people across the world for more than 15 years, with no reported ill effects (or legal cases related to human health), despite many of the consumers coming from that most litigious of countries, the USA."

The European Commission (EC) is the executive body of the European Union.

"The main conclusion to be drawn from the efforts of more than 130 research projects, covering a period of more than 25 years of research, and involving more than 500 independent research groups, is that biotechnology, and in particular GMOs, are no more risky than e.g. conventional plant breeding technologies."
The American Council on Science and Health is a non-profit group of scientists dedicated to ensuring that important public policies related to health and the environment have a sound scientific basis.

"with the continuing accumulation of evidence of safety and efficiency, and the complete absence of any evidence of harm to the public or the environment, more and more consumers are becoming as comfortable with agricultural biotechnology as they are with medical biotechnology."

The Academy of Nutrition and Dietetics is the world's largest organization of food and nutrition professionals.

We support biotechnology as a means for improving plant health, food safety, and sustainable growth in plant productivity.

The American Society for Cell Biology is an international community of biologists dedicated to advancing scientific discovery, advocating sound research policies and improving education.

"Far from presenting a threat to the public health, GM crops in many cases improve it. The ASCB vigorously supports research and development in the area of genetically engineered organisms, including the development of genetically modified (GM) crop plants."

The American Society for Microbiology represents over 42,000 microbiologists worldwide.

"The ASM is not aware of any acceptable evidence that food produced with biotechnology and subject to FDA oversight constitutes high risk or is unsafe. We are sufficiently convinced to assure the public that plant varieties and products created with biotechnology have the potential of improved nutrition, better taste and longer shelf-life."

American Society of Plant Sciences is a professional society devoted to the advancement of the plant sciences.

"The risks of unintended consequences of this type of gene transfer are comparable to the random mixing of genes that occurs during classical breeding. The ASPB believes strongly that, with continued responsible regulation and oversight, GE will bring many significant health and environmental benefits to the world and its people."

The International Seed Foundation facilitate the international movement of seed, related know-how and technology.

"The safety of genetically modified plant varieties is ensured through a most rigorous and comprehensive set of regulatory and quality assurance systems."

CAST is a nonprofit organization composed of scientific societies and many individual, student, company, and other groups.

"The Science Source for Food, Agricultural, and Environmental Issues."

The International Society of African Scientists (ISAS) is a non-profit international professional scientific organization with over 20,000 members from 51 countries. It has seven regional scientific associations, seven special interest divisions, and is headquartered in Nairobi, Kenya.
CAST
The Science Source for Food, Agricultural, and Environmental Issues

CAST is a nonprofit organization composed of scientific societies and many individual, student, company, nonprofit, and associate society members. Over the last decade, 6.5 million farmers have grown transgenic varieties of crops on more than 1 billion acres of farmland in 17 countries. These crops have been consumed by humans and animals in most countries. Transgenic crops on the market today are as safe to eat as their conventional counterparts, and likely more so given the greater regulatory scrutiny to which they are exposed.

Crop Science
SOCIETY OF AMERICA

The Crop Science Society of America (CSSA) is a prominent international scientific society dedicated to the conservation and wise use of natural resources to produce food, feed, and fiber crops while maintaining and improving the environment. The Crop Science Society of America supports education and research in all aspects of crop production, including the judicious application of biotechnology.

Federation of Animal Science Societies

Representing the American Dairy Science Association, the American Society of Animal Science, and the Poultry Science Association members. "Meat, milk and eggs from livestock and poultry consuming biotech feeds are safe for human consumption.

SOT
Society of Toxicology

Creating a Safer and Healthier World by Advancing the Science of Toxicology

The Society of Toxicology is a professional and scholarly organization of scientists from academic institutions, governmental agencies, and industries.

ISAS
The International Society of African Scientists (ISAS) is a non-profit organization with the aim of solving the technical problems facing countries primarily in Africa and the Caribbean. "Africa and the Caribbean cannot afford to be left further behind in acquiring the uses and benefits of this new agricultural revolution."

FIVB
SOCIETY FOR IN VITRO BIOLOGY

The FIVB has one of the largest groups of crop geneticists and biologists in the world among its membership. All crop and animal products that result from biotechnology are demonstrated to be safe as non-engineered versions of that plant or animal product, prior to their use by the public.

Consensus statement on GMO's, representing 14 Italian scientific societies

"GMOs on the market today, having successfully passed all the tests and procedures necessary to authorization, are to be considered, on the basis of current knowledge, it is safe for use human food and animal."
The scientific consensus around the safety of genetically modified foods is as strong as the scientific consensus around climate change. These foods are subjected to more testing than any other, and everything tells us that they’re safe.
Why? Because of Scientific Evidence


- **Assessment of GE food safety using '-omics' techniques and long-term animal feeding studies.**

- **Assessment of the health impact of GM plant diets in long-term and multigenerational animal feeding trials: a literature review.**

- [http://genera.biofortified.org/viewall.php](http://genera.biofortified.org/viewall.php)
Why? Because of Scientific Evidence

An overview of the last 10 years of genetically engineered crop safety research

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Abstract
The technology to produce genetically engineered (GE) plants is celebrating its 30th anniversary and one of the major achievements has been the development of GE crops. The safety of GE crops is crucial for their adoption and has been the object of intense research work often ignored in the public debate. We have reviewed the scientific literature on GE crop safety during the last 10 years, built a classified and manageable list of scientific papers, and analyzed the distribution and composition of the published literature. We selected original research papers, reviews, relevant opinions and reports addressing all the major issues that emerged in the debate on GE crops, trying to catch the scientific consensus that has matured since GE plants became widely cultivated worldwide. The scientific research conducted so far has not detected any significant hazards directly connected with the use of GE crops; however, the debate is still intense. An improvement in the efficacy of scientific communication could have a significant impact on the future of agricultural GE. Our collection of scientific records is available to researchers, communicators and teachers at all levels to help create an informed, balanced public perception on the important issue of GE use in agriculture.
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
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
T-DNA vector containing a “gene”

Plant-specific Promoter

Your favorite gene (e.g. CRY)

Plant-specific Terminator

Left border

Right border

Transfer DNA (T-DNA)
Gets inserted into plant chromosome
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.
Crown Gall Tissue: Wild Agrobacterium
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.
Getting genes into plants

**Agrobacterium method** of plant transformation

**Particle-gun method** of plant transformation

Diagram showing the process of gene transfer into plant cells.
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…….
Tissue culture and transgenic plants

- Fresh Callus
- Baby Tissue Culture Plants
- Callus Under Selection
- Adult Trans-genic Rice
Tobacco regenerated in tissue culture
Transgenic Tobacco Plants
Geneticist Sows Plot to Kill Lawn Mowers!

The papaya ringspot potyvirus (PRSV) story

One of the great successes of crop biotech and GMO
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.
Transgenic PRV-resistant papaya has been grown commercially in Hawaii since 1996. It was recently certified for import into Japan.

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.

Figure 1. Symptoms of PRSV. (a) affected papaya tree and (b) ringspot on papaya fruit. (Courtesy of S. Ferraira, copyright-free)
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?

http://www.civilbeat.com/articles/2013/08/05/19629-papaya-nightmares-a-farmer-struggles-amid-hawaiis-gmo-debate/

“That scene echoes a similar meeting a few weeks earlier on the Big Island where a crowd gathered to debate Bill 79. During the hearing, some anti-GMO advocates called for the genetically modified papaya trees to be cut down. Belmes attended that meeting with his wife and children, a family that he supports thanks to such trees. The thought of cutting them down brought tears to his eyes, he recounts.”
The Bt toxin (BT) story

Another great successes of crop biotech and GMO
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.

Bacterial spores or isolated toxins are already used as an organic insecticide.
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

Another great successes of crop biotech and GMO
Benefits of Roundup® Ready Crops

Fields need less tilling
Reduction in weed management costs of up to 37%
Decrease in herbicide use by >1lb/acre
Overall 74% increase in farmer profits¹

¹U.S. Corn Crop 2003
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.
Impact of Glyphosate-Tolerant Soybean and Glufosinate-Tolerant Corn Production on Herbicide Losses in Surface Runoff

Martin J. Shipitalo,* Robert W. Malone, and Lloyd B. Owens USDA-ARS

- 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.

Published on June 5, 2013

Palmer amaranth tough foe for cotton farmers

By Clint Thompson
University of Georgia, College of Agricultural and Environmental Sciences

The most destructive adversary to impact cotton production since the boll weevil is costing cotton farmers potential yields and profit.

Farmers have to work diligently to keep up with the herbicide-resistant weed, technically known as Palmer amaranth.

Stanley Culpepper, an agronomist with the University of Georgia Cooperative Extension, has researched Palmer amaranth for almost a decade. The veteran weed scientist hasn’t studied any pests that compare to “pigweed.”

“This is a significant adversary, or to be frank, it’s simply a stud,” Culpepper said. “It’s the first real weed pest that can come on your farm, you see it in year one and by year three, it dominates the entire landscape.”

Palmer amaranth can reach heights of up to 7-10 feet. Image credit: Clint Thompson. (view image)
Crop rotations can become a challenge if you rely on only one method of control.

Roundup resistant soybean and volunteer Roundup resistant corn

Roundup resistant corn and volunteer Roundup resistant corn
Herbicide resistant creeping bentgrass

A classic GMO mistake!
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. USDA comment period reopened 12/31/13.

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.
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

• 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