GMOs
What are they & why so controversial?

Steve Strauss
Distinguished Professor
Oregon State University
Steve.Strauss@OregonState.Edu
Agenda

• What are and are not GMOs?
• What are the major GMO crops out there?
  • What is coming?
• Sources of controversy
These are highly genetically modified but not GMO
Many crucifer crops derived from wild cabbage – not GMO

Wild cabbage

Kohlrabi
Germany, 100 AD

Ornamental kale
Late 1900's

Kale, 500 BC

Cauliflower
1400's

Brussel sprouts
Belgium, 1700's

Cabbage, 100 AD

Broccoli
Italy, 1500's
Many plant varieties derived from induced mutations – not GMO

Over 2,000 crop varieties derived from mutagenesis have been commercialized

Calrose 76 semi-dwarf rice

High oleic sunflower

Rio Red grapefruit
Radical changes in domesticated animals

All dogs derived from the wolf by breeding
Breeding continues and is accelerating in age of massive DNA sequencing
GMO method (genetic engineering) defined

Traditional plant breeding

Genetic engineering

X

Variety A

Variety B

Asexual modification or insertion from any gene source
The acronyms

- GE (genetic engineering) = GM (genetic modification) = transgenic = asexual modification and/or insertion of DNA

GM, GMO = genetically modified organism
GE, GEO = genetically engineered organism

The terms “biotechnology” or “modern biotechnology” often equated with GE or GM methods
Regeneration of GE plants
Then propagated normally (seeds, cuttings) and tested for health and new qualities, incorporated into breeding programs.
GMO crops widespread, rapidly adopted
Grown on >10% arable land on planet, extensive uptake in developing world
Four crops dominate, 8 crops grown in USA

Global Area of Biotech Crops, 1996 to 2013: By Crop (Million Hectares, Million Acres)

Two traits dominate

Global Area of Biotech Crops, 1996 to 2013: By Trait (Million Hectares, Million Acres)

Major reports on GMO crops show very large positive impacts on economics, sustainability, in USA
2014 global “meta-analysis”

“147 original studies were included.”

“On average, GM technology adoption has reduced chemical pesticide use by 37%, increased crop yields by 22%, and increased farmer profits by 68%.”
Herbicide tolerant plants promote conservation tillage – With many environmental benefits thereof

Conservation Technology Information Center

- Lowers greenhouse gas emissions
- Improves soil organic matter
- Reduces erosion and fertilizer runoff into water

Global: In 2012 reduced CO2 emissions by ~27 billion kg, equivalent to ~13 million cars off the road

http://www.isaaa.org/resources/publications/briefs/46/topfacts/default.asp
Increased conservation tillage due to GE crops in USA: Soy 2006

Figure 15: Adopters of herbicide-tolerant crops used conservation tillage more than did growers of conventional varieties: soybeans, 2006

- Conventional tillage practices
- Other conservation tillage practices (excludes no-till)
- No-till

Conservation tillage includes no-till, ridge-till and mulch-till.
Virus-resistant GM papaya
Saved the Hawaiian industry in the mid-1990s, ~70% of crop today

“RNAi immunization” via by implanting a viral gene in the papaya genome

GMO, virus-resistant trees

Courtesy of Denis Gonsalves, formerly of Cornell University
Drought-tolerant maize – Planted on >150,000 acres – Also tested in Africa

*Important tool given climate change, water shortages?*
Diverse pipeline of biofortification products = enhancement of critical vitamins or nutrients

Many more examples funded by Gates Foundation / other sources
“The developers, Monsanto and DuPont Pioneer, have manipulated the genes of the soybean to radically alter the composition of its oil to make it longer-lasting, potentially healthier and free of trans fats.”

“It almost mirrors olive oil in terms of the composition of fatty acids.”
“Innate” Potato approved – reduced browning and acrylamide (↓waste, ↑safety)

Trait #1 - Silenced PPO (Enzyme)
- Non-browning when cut
- Reduced black spot bruise

Trait #2 - Reduced Asparagine (Amino Acid)
- Yields a 50-80% reduction in acrylamide when baked or fried
- Meets Prop 65 in California

Four Improved Varieties
- Russet Burbank, Ranger Russet, Atlantic, Snowden
- No effect on taste, texture, or performance
- USDA approval expected in 2014
Non-browning “Arctic Apple”
Reduced spoilage/waste, improved quality – USDA approved

Courtesy of Jennifer Armen, Okanagan Specialty Fruits, Canada
Control of coleopteran insect pests through RNA interference

James A Baum, Thierry Bogaert, William Clinton, Gregory R Heck, Pascale Feldmann, Oliver Ilagan, Scott Johnson, Geert Plautinck, Tichafa Munyikwa, Michael Pleau, Ty Vaughn & James Roberts

Commercial biotechnology solutions for controlling lepidopteran and coleopteran insect pests on crops depend on the expression of Bacillus thuringiensis insecticidal proteins, most of which permeabilize the membranes of gut epithelial cells of susceptible insects. However, insect control strategies involving a different mode of action would be valuable for managing the emergence of insect resistance. Toward this end, we demonstrate that ingestion of double-stranded (ds)RNAs supplied in an artificial diet triggers RNA interference in several coleopteran species, most notably the western corn rootworm (WCR) Diabrotica virgifera virgifera LeConte. This may result in larval stunting and mortality. Transgenic corn plants engineered to express WCR dsRNAs show a significant reduction in WCR feeding damage in a growth chamber assay, suggesting that the RNAi pathway can be exploited to control insect pests via in planta expression of a dsRNA.

Figure 2  F1 plants expressing a V-ATPase A dsRNA are protected from WCR feeding damage. (a) Map of the expression cassette. (b) Mean root damage ratings for eight F1 populations, the parental inbred line (negative control) and the corn rootworm-protected Cry3Bb event MON863; NiS, nodal injury score (Iowa State ranking system). (c) The plant on the left is a non-transgenic corn, whereas the plant on the right shows the average root protection seen when the transgene is expressed.
Resistance transgenes promising solution/s to devastating ‘citrus greening’
Defensin-like proteins from spinach promising

Courtesy of Eric Mirkov, Texas A & M
Gene editing technology recently developed – GMO?

**Zinc fingers on target**

Matthew H. Porteus

The existing methods of creating genetically modified plants are inefficient and imprecise. Zinc-finger technology offers the prospect of opening up a swifter and more exact route for crop improvement.
Why is biotech controversial?

Diverse factors

- **Human need**: Population and consumption growth, food cost, widespread malnutrition, environmental damage from agriculture
- **New and rapid science** (genes and gene transfer) give many options = technology push
- **Ethics**: Breaking of traditional boundaries in moving genes press concepts of rightness
- **Risk perception high**
  - Complex and invisible science and technology, often without direct consumer benefits = high perception of risk
  - Context of breeding and extensive modification of food crops and products unknown to most
Why controversial, continued

• **Ideology**: Strong anti-GMO business and political forces
  • Green and organic and “natural” vs. GMO

• **Strong corporate role**: Control of seeds and agriculture, industrial ag, the “Monsanto effect”
  • Patents on life, furthering private control

• **Role of governments**
  • Extent of precaution? Regulation stringency?
  • Labeling? Allowances for trade?

• **Science uncertainties**
  • Environment, food safety, allergenicity

• **Chemophobia**
  • All pesticides are bad, GMOs make worse

• **Gene flow**: Ag is leaky, “contamination” common
Rutgers survey data - USA (2005) – Prof Bill Hallman, Rutgers University

http://www.foodpolicyinstitute.org/resultpub.php

• Seven in ten (70%) don't believe it is possible to transfer animal genes into plants
• Six in ten (60%) don't realize that ordinary tomatoes contain genes
• Fewer than half (45%) understand that eating a genetically modified fruit would not cause their own genes to become modified
“Entertaining” and strikingly misleading books and “documentaries” are common.
The real stuff underneath the noise

**Ecological impacts**

Are declines in monarch butterflies--associated with reduced milkweed populations--due to improved weed control from herbicide-tolerant crops?

---

Tracking the Causes of Sharp Decline of the Monarch Butterfly

A new census found this winter’s population of North American monarch butterflies in Mexico was at the lowest level ever measured. Insect ecologist Orley Taylor talks to Yale Environment 360 about how the planting of genetically modified crops and the resulting use of herbicides has contributed to the monarchs’ decline.

**By Richard Conniff**

University of Kansas insect ecologist Orley R. “Chip” Taylor has been observing the fragile populations of monarch butterflies for decades, but he says he has never been more concerned about their future.

Monarchs are beloved for their spectacular migration across Canada and the United States to overwintering sites in central Mexico — and back again. But a new census taken at the monarchs’ wintering grounds found their population had declined 99 percent over the previous year and was at the lowest level ever measured.

In an interview with Yale Environment 360 contributor Richard Conniff, Taylor — founder and director of Monarch Watch, a conservation and outreach program — talked about the factors that have led to the sharp drop in the monarch population. Among them, Taylor said, is the increased planting of genetically modified corn in the U.S. Midwest, which has led to greater use of herbicides, which in turn kills the milkweed that is a prime food source for the butterflies.

---

**Related Articles**

*Into the Heart of Ecuador’s Yasuni*

Few places on earth harbor as much biodiversity as Ecuador’s Yasuni Biosphere Reserve, which sits atop vast deposits of oil and now faces intense development pressure. In a Yale Environment 360 video, filmmaker Ryan Killackey travels to the heart of Yasuni with scientists inventorying its stunning wildlife and plants. The researchers hope their work will bolster initiatives to preserve this threatened land.

---

**About the Author**

Richard Conniff, who conducted this interview for Yale Environment 360, is a National Magazine Award-winning writer whose articles have appeared in Time, Smithsonian, The Atlantic, National Geographic, and other publications. He is the author of several books, including The Species Seekers: Heroes, Icons, and the Mad Pursuit of Life on Earth. In previous articles for Yale Environment 360, he has written about the pricing of ecosystem services and about new advances that could help produce food crops that can thrive at the...
Despite an extraordinary record of safety, are some further restrictions on use of glyphosate called for?
Poor weed management has led to rapid development of herbicide-resistant weeds. And development of new kinds of herbicide tolerant crops.

Weeds are becoming increasingly resistant to glyphosate, a report from the US National Academy of Sciences (NAS) released in April has found. The driving force, according to the report, is farmers' dependence on the weed killer accompanied by the widespread adoption of genetically modified (GM) herbicide-tolerant crops. Seed makers are hoping to forestall the problem by developing GM crops with 'stacked' traits that tolerate multiple herbicides. But weed scientists warn that if farmers manage these new crops in the same way as they managed their glyphosate-resistant predecessors, weeds will simply become resistant to the new technologies.

*The number of weed species evolving resistance to glyphosate
Oregon with major coexistence struggles due to seed industry, much non-GMO production, & many exports 2014 Task Force
The way forward a bit difficult
In summary

• Remarkable progress and benefits from GMO crops, with much more coming, but also problems
  • Significant mismanagement of herbicide tolerant crops hurts value, credibility

• Extraordinary GMO-method focused regulatory and social barriers
  • USA National Academy of Sciences 1987
    “There is no evidence that unique hazards exist either in the use of rDNA techniques or in the movement of genes between unrelated organisms”

• Way forward unclear, difficult
  • Need for state, national and global regulatory / market changes to enable progress and also coexistence