GMO Crops
Science, Status, and Issues

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OSU
Oregon State
UNIVERSITY

Agenda

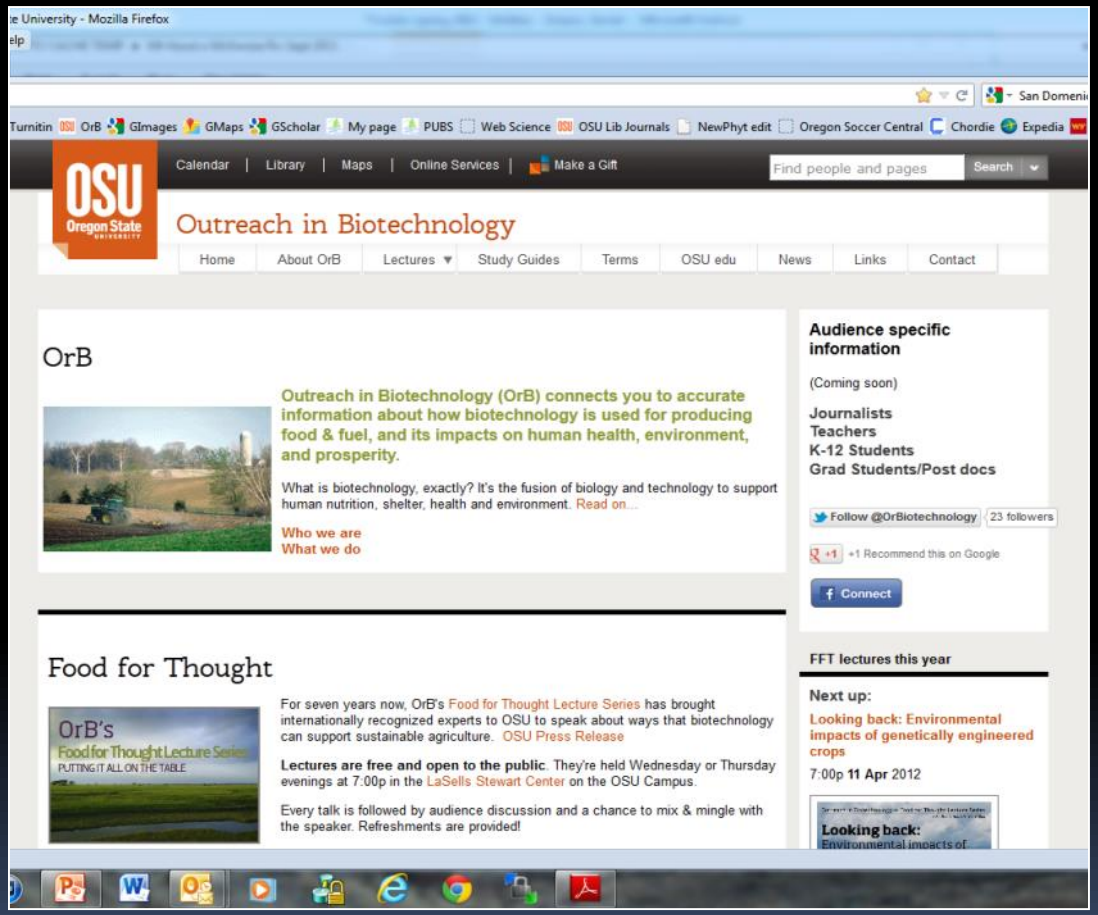
- A bit about me
- Broad perspective on GMO issues
- The science: What are and are not GMOs
- Extent of use in the world
- Examples of newer products, pipeline
- Issues in management, public reception

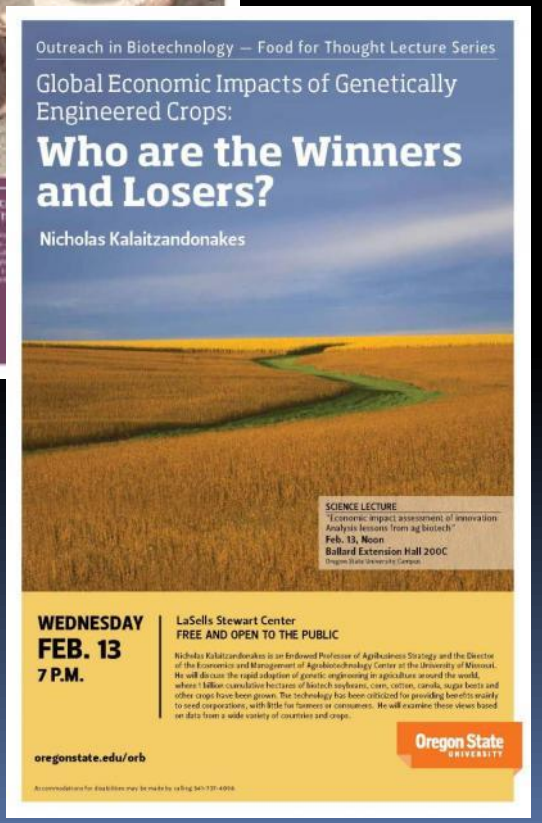
Strauss research

- Web site: http://people.forestry.oregonstate.edu/steve-strauss/
- Current research
  - Genetic engineering (GE) – poplars and eucalyptus
    - Emphasis on modifying flowering to avoid gene flow
  - Genomic basis of hybrid vigor in trees
    - Focus on poplar interspecies hybrids
    - Non-GMO genetics
  - Origin of Willamette Valley aspens
    - Genomic methods to trace evolution and migration

Short-rotation poplars an ag crop in Oregon

Former Director, OSU Outreach in Biotechnology Program





Available itunesU

Forty lectures, diverse aspects

Strauss funding and industry relations

- Research funds from many companies over many years
  - Mostly forestry-associated, also some from ag biotechnology companies
- Industry consortium at OSU
  - Tree Biosafety and Genomics Research Cooperative
  - 22 years and counting
- Total funds
  - Industry ~13%
  - Public sources ~87%
- ~No industry funds for OSU outreach programs
- No industry funds for this talk

Industry engagement the norm

- Extensive interactions with scientific network, including industry scientists and industry funded scientists
  - The **norm** for applied science and engineering
  - The **norm** at land grant universities – ENGAGE
  - Biotech companies largely create and market the technology
    - Essential to engage to be current, create opportunities for forest/bioenergy industries

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There are many pieces of the GMO controversy

- *"It is accurate to say that many of the real ethical issues [of GMOs in agriculture] have little to do with the use of transgenic technologies"* (Burkardt et al. 2005, Agricultural Ethics, CAST)

CAST

COUNCIL FOR AGRICULTURAL SCIENCE AND TECHNOLOGY

ISSUE PAPER

NUMBER 29 FEBRUARY 2005

AGRICULTURAL ETHICS

INTRODUCTION

It is widely known that agriculture has a long history. Starting approximately 12,000 years ago, the domestication of plants and animals began independently in several different places, including centers in West Asia, East Asia, Central America, and South America. Domestication also may have occurred in other locations, although convincing archeological evidence has not been found. In the

TASK FORCE MEMBERS: **Jeffrey Burkhardt, Chair**, Department of Food and Resource Economics, University of Florida, Gainesville; **Gary Comstock**, Department of Philosophy and Religion, North Carolina State University, Raleigh; **Peter G. Hartel**, Department of Crop and Soil Sciences, University of Georgia, Athens; **Paul B. Thompson**, Department of Philosophy, Michigan State University, East Lansing; REVIEWERS: **Maarten J. Chrispeels**, Center for Molecular Agriculture, University of California–San Diego; **Charles C. Muscoplat**, College of Agricultural, Food and Environmental Sciences, University of Minnesota, St. Paul; **Robert Streiffer**, Department

commented on the importance of agricultural knowledge in the quest for the "good life" by the individual and the polity. The fundamental value of agriculture was highlighted by Enlightenment thinkers from John Locke to Thomas Jefferson, who underscored the political, economic, and philosophical importance of "tillers of the soil" (Spiegel 1991). In the United States, problems faced by farmers became the focus of the nine-

…lots and lots of pieces….

- Large vs. small-scale agriculture
- Plant variety protection
- Ecological impacts
- Food safety
- Poverty and malnutrition
- Defining precaution
- Gene flow regulation
- Mandatory vs. voluntary labeling of ag and food production practices

Complex, emotive issue, cognitively difficult

- Life and death, health and safety, poor vs. food elite, innovation vs. precaution, right vs. wrong, etc etc etc
- Science: The GMO method is not inextricably linked to any of these larger issues – can be used and managed in many different ways
- Are we talking past each other?
- “GMO” as representing a type of food and social system, vs. “GMO” as a breeding method

Speaking as scientist, and seeking to reflect what mainstream science is thinking and saying

Mainstream science is supportive of responsible uses of GMOs

American Society of Plant Biologists

Cultivating a better future through plant biology research.

REVISED POSITION STATEMENT ON PLANT GENETIC ENGINEERING

Advances in agriculture are cumulative and build on the integration of new approaches with established breeding techniques and farming practices. The Food and Agricultural Organization anticipates the need for a 70% increase in agricultural productivity to meet the food, feed, fiber and fuel needs of an ever-growing world population, without further degrading the environment

The American Society of Plant Biologists (ASPB) supports the continued responsible use of genetic engineering (hereafter referred to as GE) as an effective tool for advancing food security and reducing the negative environmental impacts of agriculture. ASPB also supports the

and reducing the negative environmental impacts of agriculture. ASPB also supports the
continued use and further development of appropriate, science-based procedures and regulations

The use of GE to modify plants represents an important advance in plant science and agriculture that builds on centuries of human involvement in the genetic modification of crop species. GE

The use of GE to modify plants represents an important advance in plant science and agriculture that builds on centuries of human involvement in the genetic modification of crop species. GE
allows for the transfer into a plant of well-characterized genes. The precision of this technology, coupled with the knowledge of the specific nature of the manipulated genetic information, makes the risks of unintended consequences of this type of gene transfer comparable to or less than the random mixing of genes that occurs during classical breeding (National Research Council, 2004).

Revised 2014

AAAS: Position on GMO labeling

"Legally mandating such a label can only serve to mislead and falsely alarm consumers"

Statement by the AAAS Board of Directors On Labeling of Genetically Modified Foods

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

20 October 2012

There are several current efforts to require labeling of foods containing products derived from genetically modified crop plants, commonly known as GM crops or GMOs. These efforts are not driven by evidence that GM foods are actually dangerous. Indeed, the science is quite clear: crop improvement by the modern molecular techniques of biotechnology is safe. Rather, these initiatives are driven by a variety

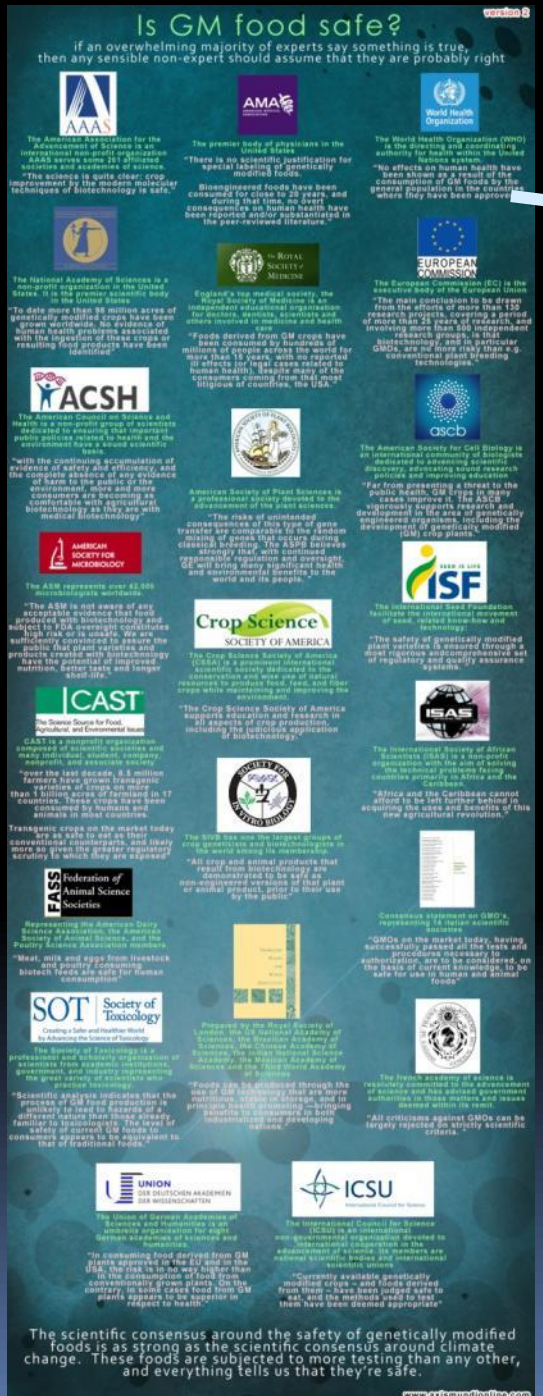
conclusion: consuming foods containing ingredients derived from GM crops is no riskier than consuming the same foods containing ingredients from crop plants modified by conventional plant improvement techniques.

Civilization rests on people's ability to modify plants to make them more suitable as food, feed and fiber plants and all of these modifica-

added, the protein must be shown to be neither toxic nor allergenic. As a result and contrary to popular misconceptions, GM crops are the most extensively tested crops ever added to our food supply. There are occasional claims that feeding GM foods to anima
ranging from di
to sterility, tum
death. Althoug
often sensationalized and receive a

Approved by the AAAS Board of Directors on 20 October 2012

AAAS
ADVANCING SCIENCE, SERVING SOCIETY



http://www.axismundionline.com/blog/the-new-is-gm-food-safe-meme/

Safety supported by many dozens of international science organizations

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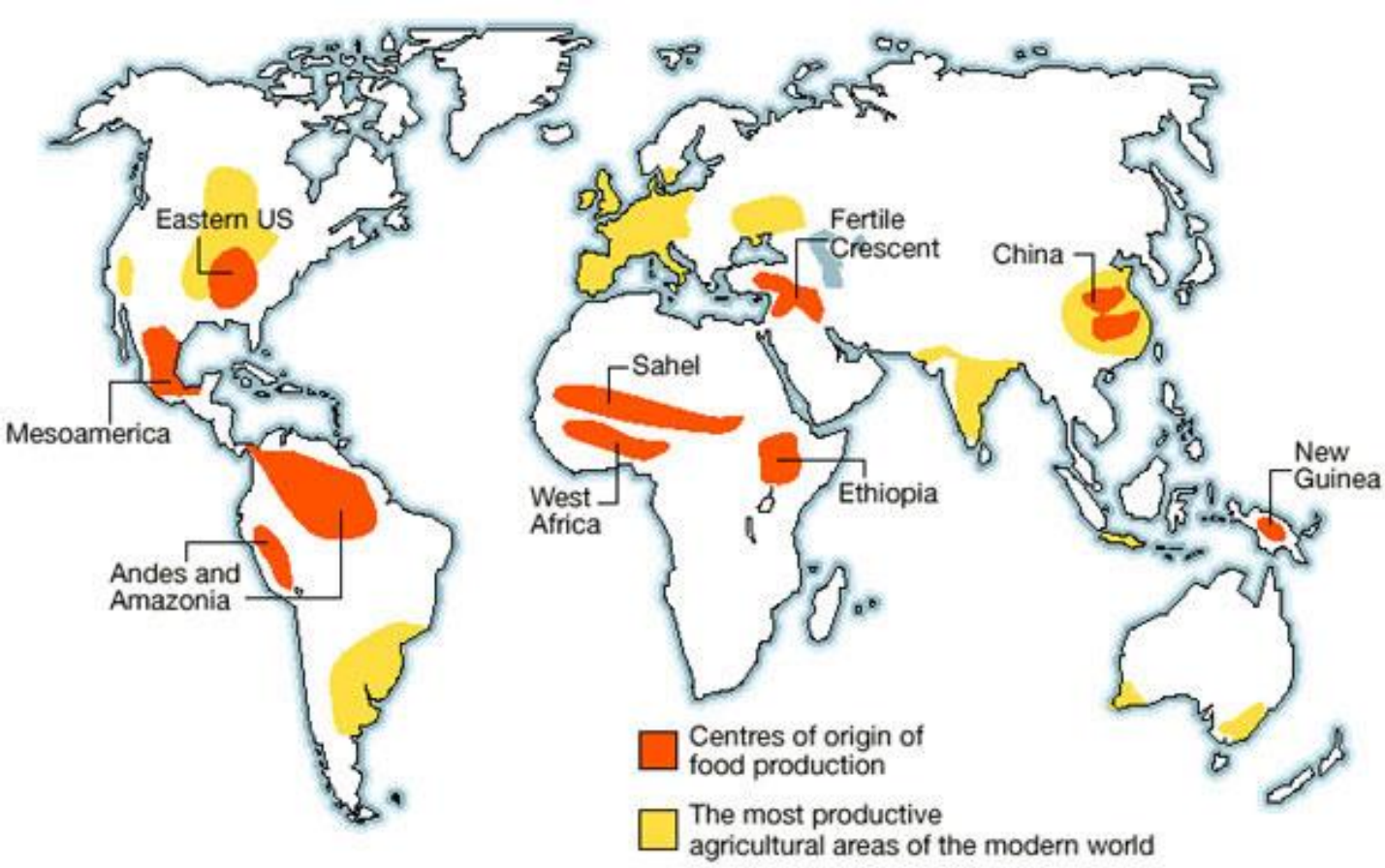
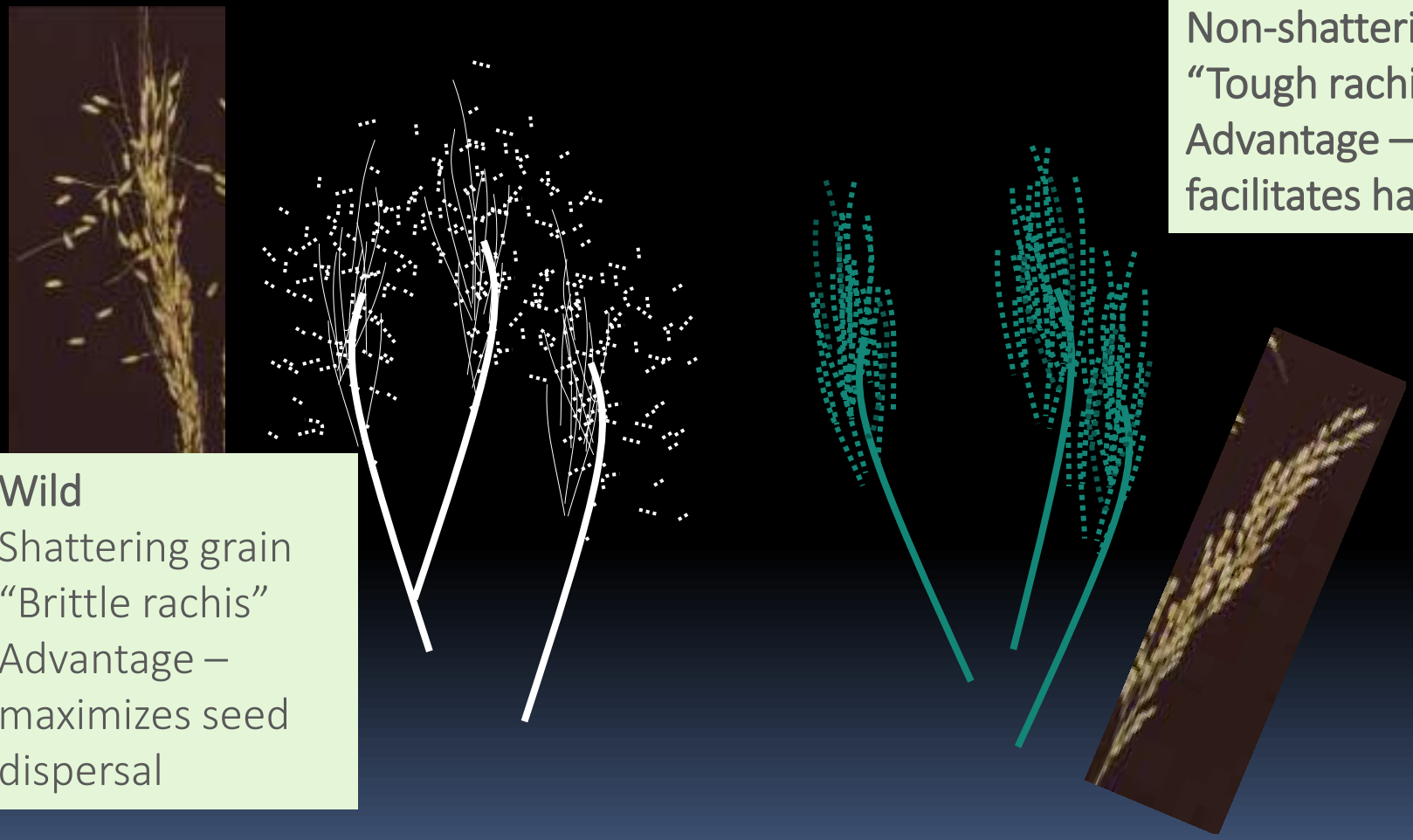
Plants were domesticated in parallel in several regions of the globe – then moved and further bred all over the world



Cereals: Seeds that don't break off were selected



Domesticated
Non-shattering grain
"Tough rachis"
Advantage –
facilitates harvesting

Wild
Shattering grain
"Brittle rachis"
Advantage –
maximizes seed
dispersal

From Konishi, S., Izawa, T., Lin, S.Y., Ebana, K., Fukuta, Y., Sasaki, T., and Yano, M. (2006). An SNP caused loss of seed shattering during rice domestication. Science 312: 1392-1396. Reprinted with permission from AAAS.

And many other types of modifications made

Radical changes in form: Diversity of crucifer crops derived from wild cabbage

Kohlrabi
Germany, 100 AD

Ornamental kale
Late 1900's

Brussel sprouts
Belgium, 1700's

Many plant varieties derived from induced mutations

Over 3,000 crop varieties derived from mutagenesis have been commercialized

Calrose 76 semi-dwarf rice

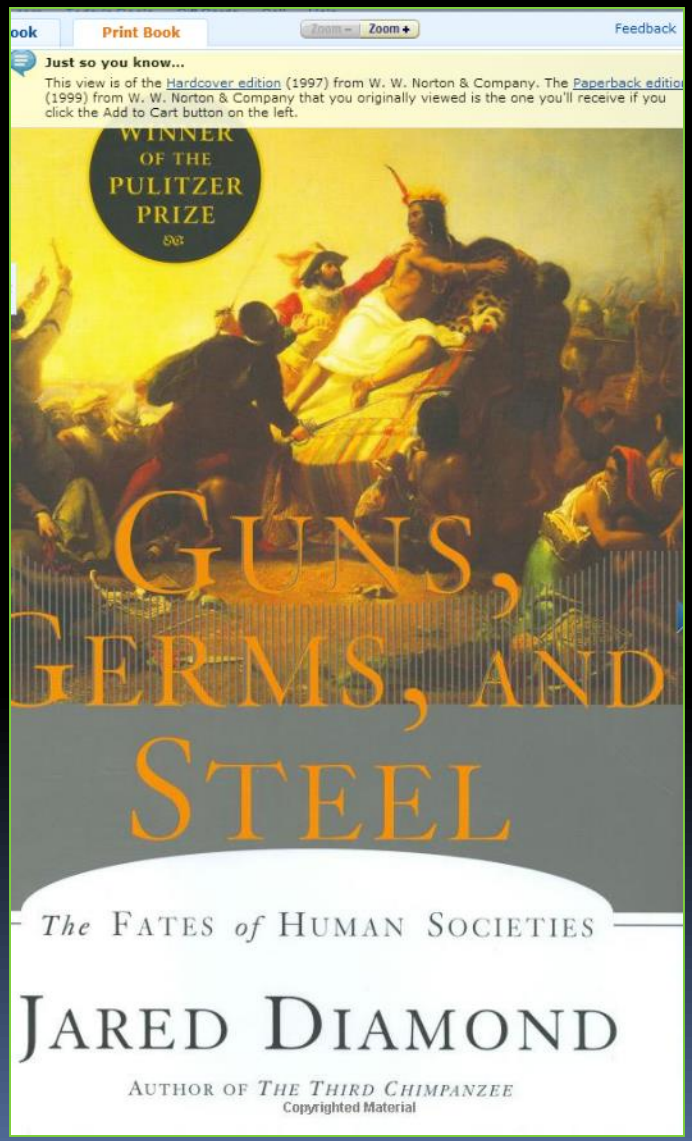
High oleic sunflower

Rio Red grapefruit

Radical changes in domesticated animals

All dogs derived from the wolf by breeding

Plant and animal domestication the basis of civilization



Pulitzer Prize winner

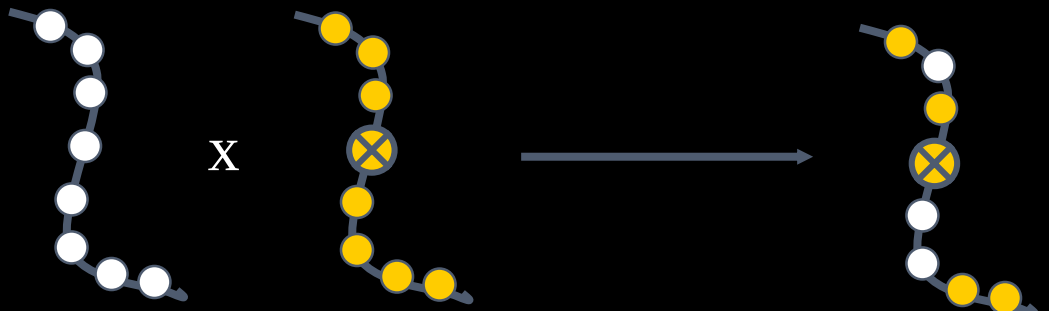
<u>Core story</u>:
Genetic change enabled agriculture

…which enabled cities, culture, and thus advanced technologies

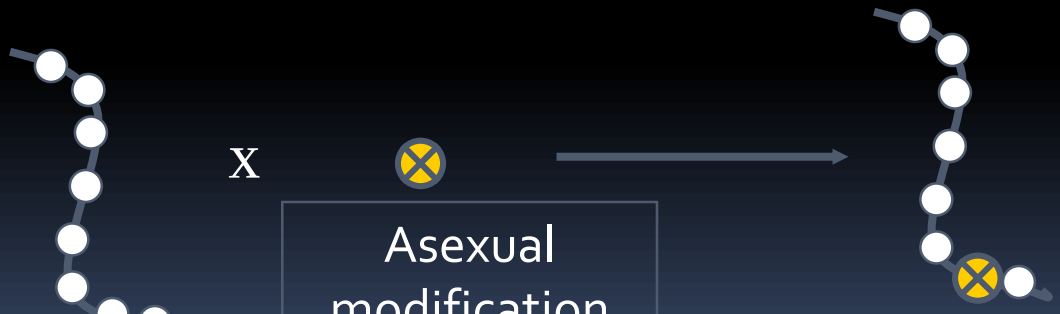
Breeding continues and is accelerating in age of massive DNA sequencing

GMO method (genetic engineering) defined

Traditional plant breeding



Genetic engineering



The acronyms, evolving in meaning

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

  GM, GMO = genetically modified organism

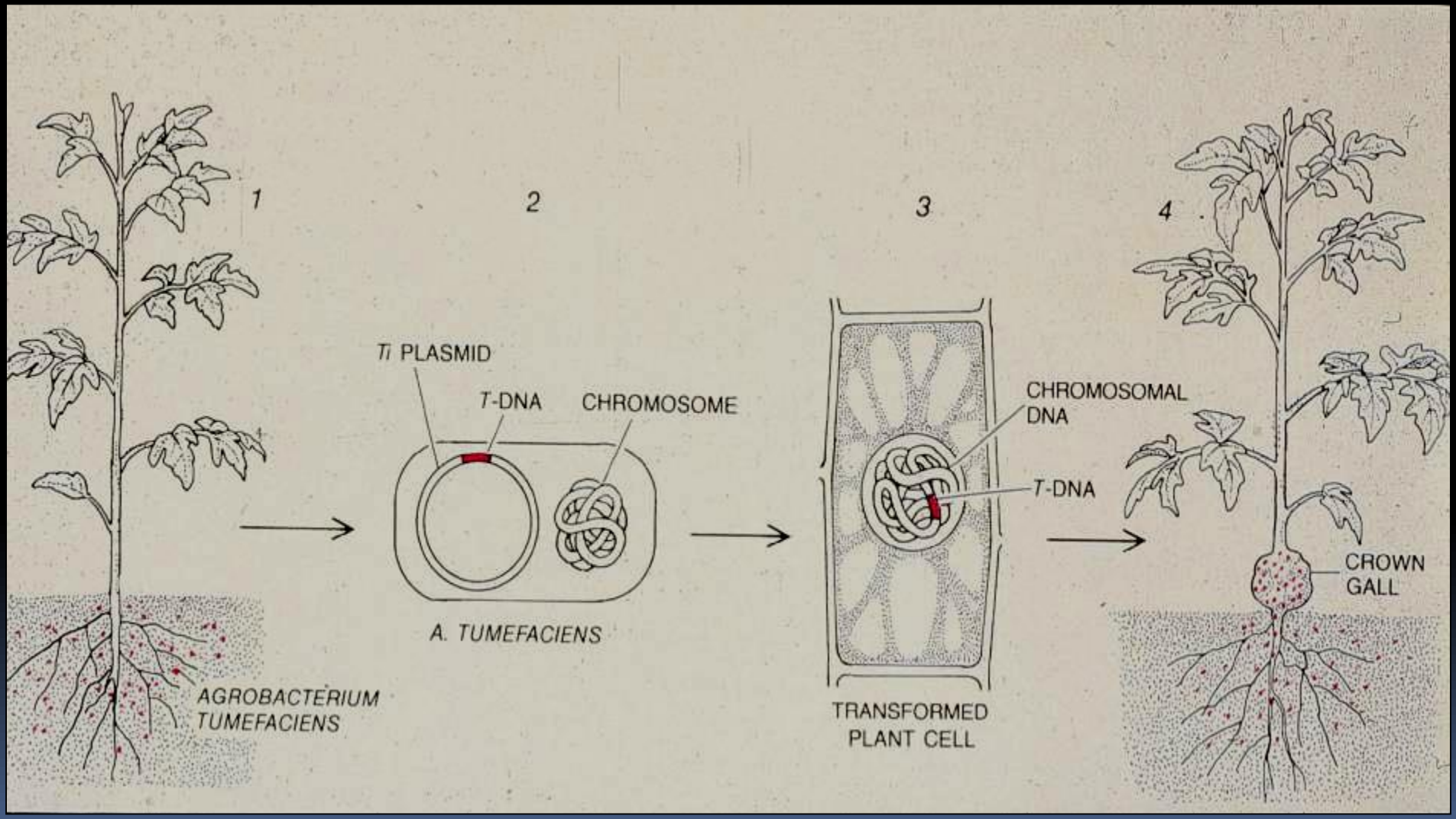
  GE, GEO = genetically engineered organism

  The terms "biotechnology" or "modern biotechnology" often equated with GE or GM methods

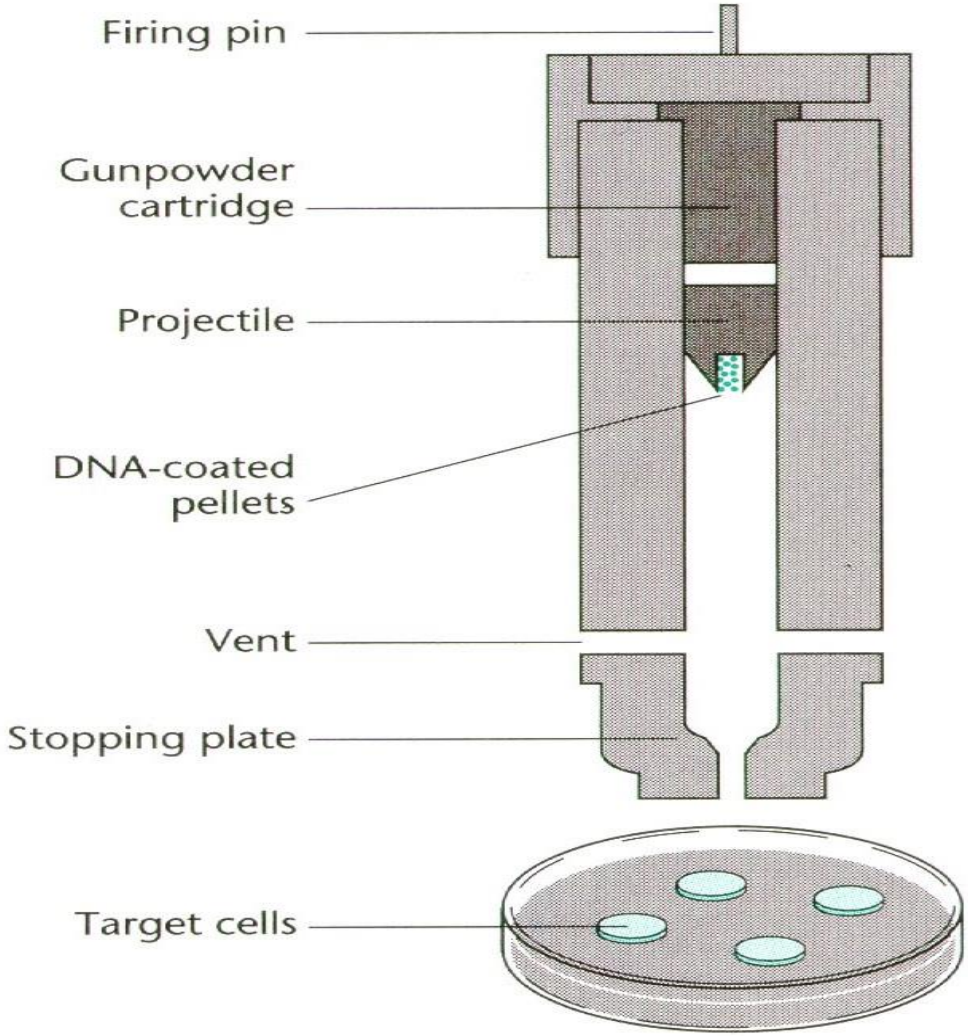
Transgenic = GE, or transfer of genes between distant species

Cisgenic, intragenic for transfer or modification of genes from closely related species

Agrobacterium is a natural, and commonly used, plant genetic engineer



The “gene gun” is also used to introduce DNA into cells



After cells are modified, they are induced to regenerate into whole plants

Then propagated normally (seeds, cuttings) and tested for health and new qualities, incorporated into breeding programs

Propagation in tissue culture

Growth in the field

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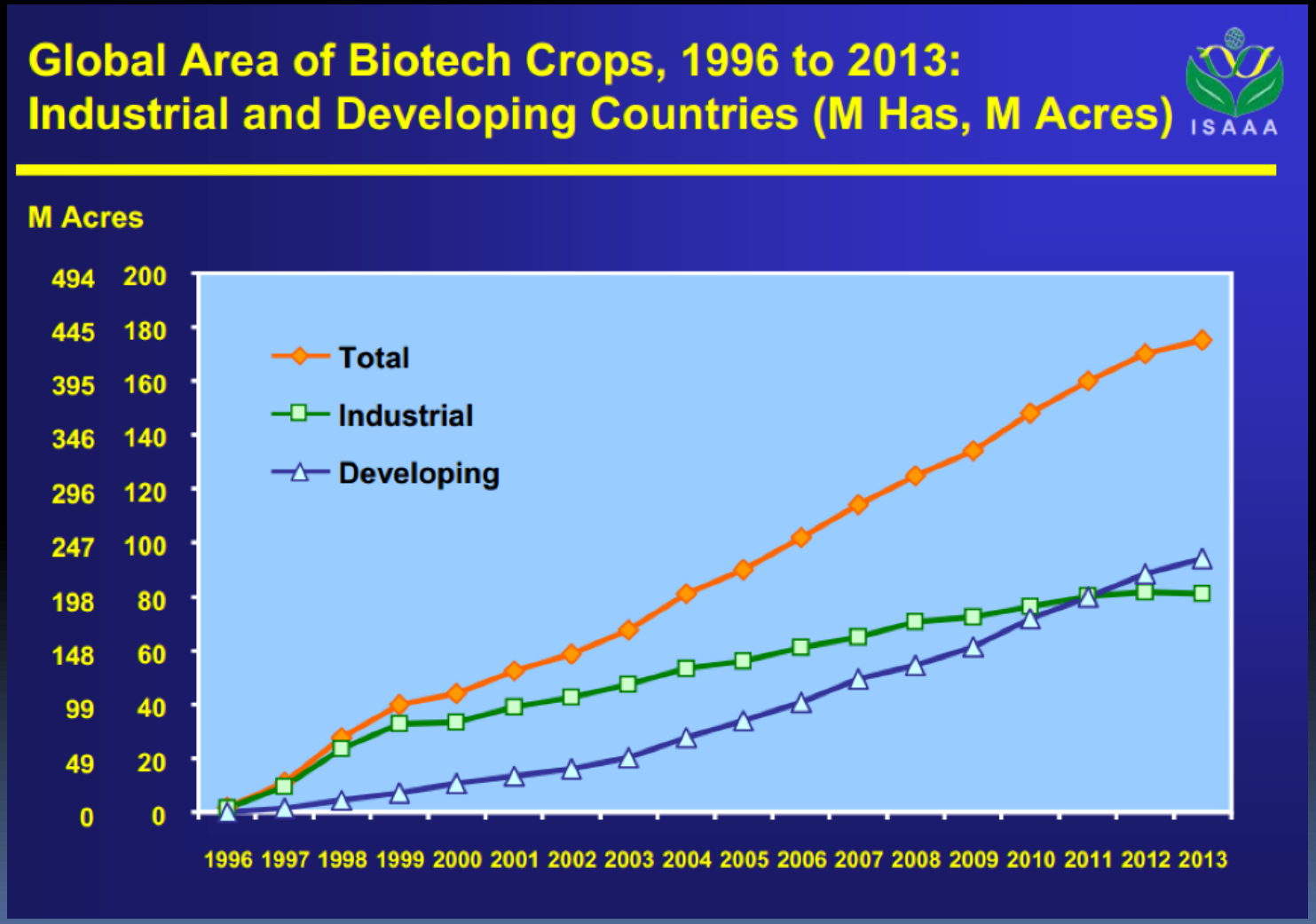
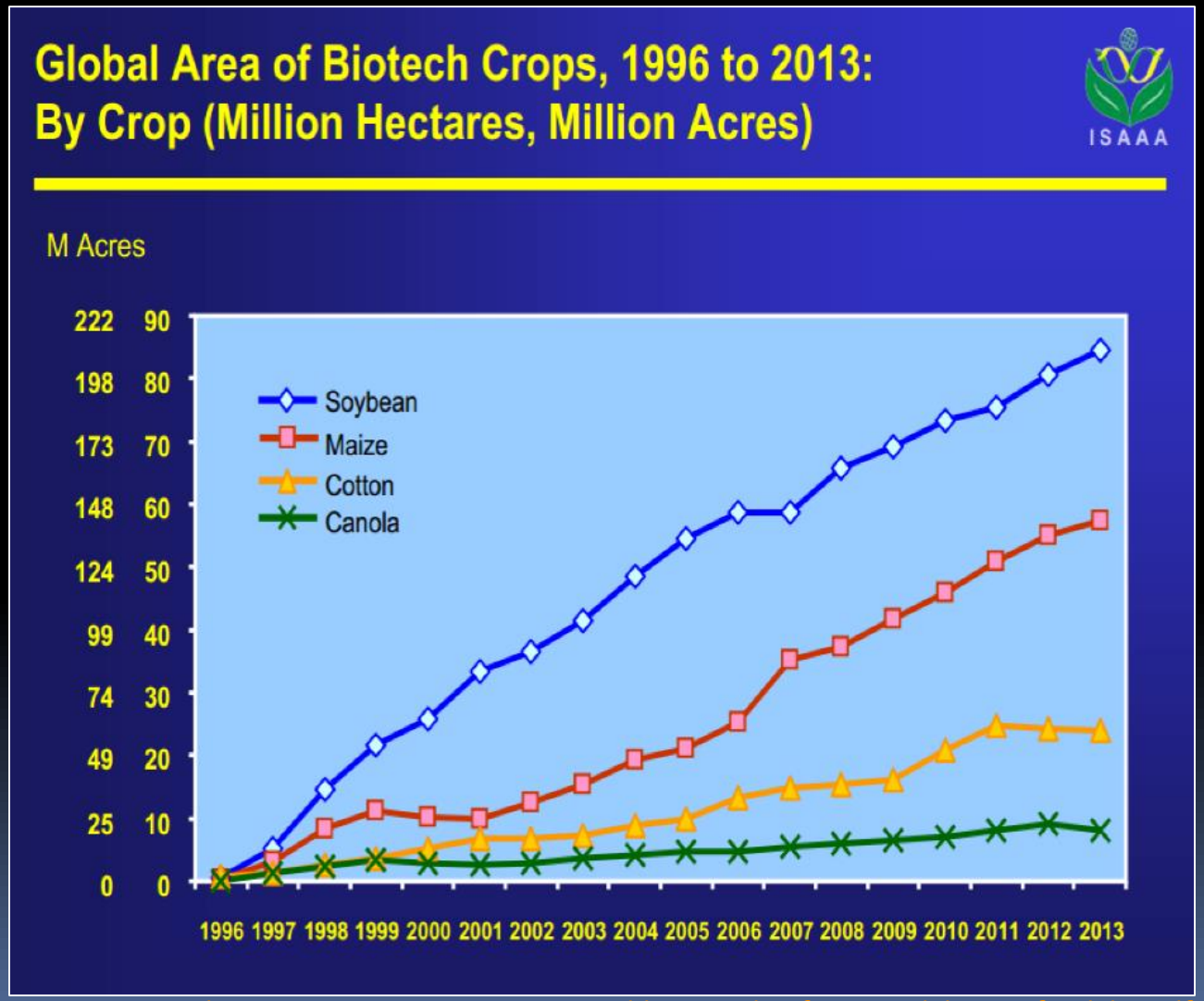
Biotech crops widespread, rapidly adopted: Grown on >10% arable land on planet, extensive uptake in developing world



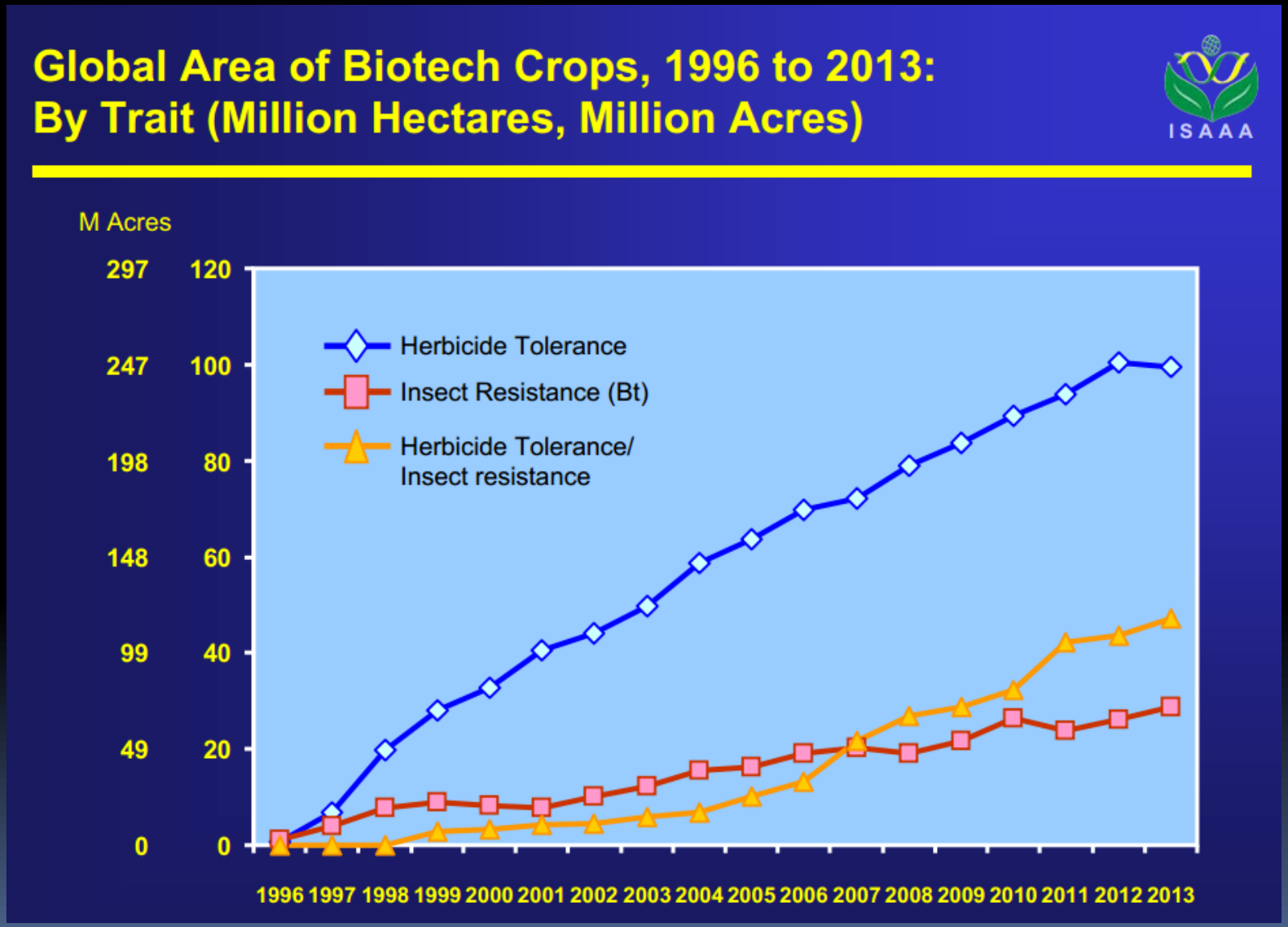
http://www.isaaa.org/resources/publications/briefs/46/pptslides/Brief46slides.pdf

Four crops dominate, 8+ crops in USA



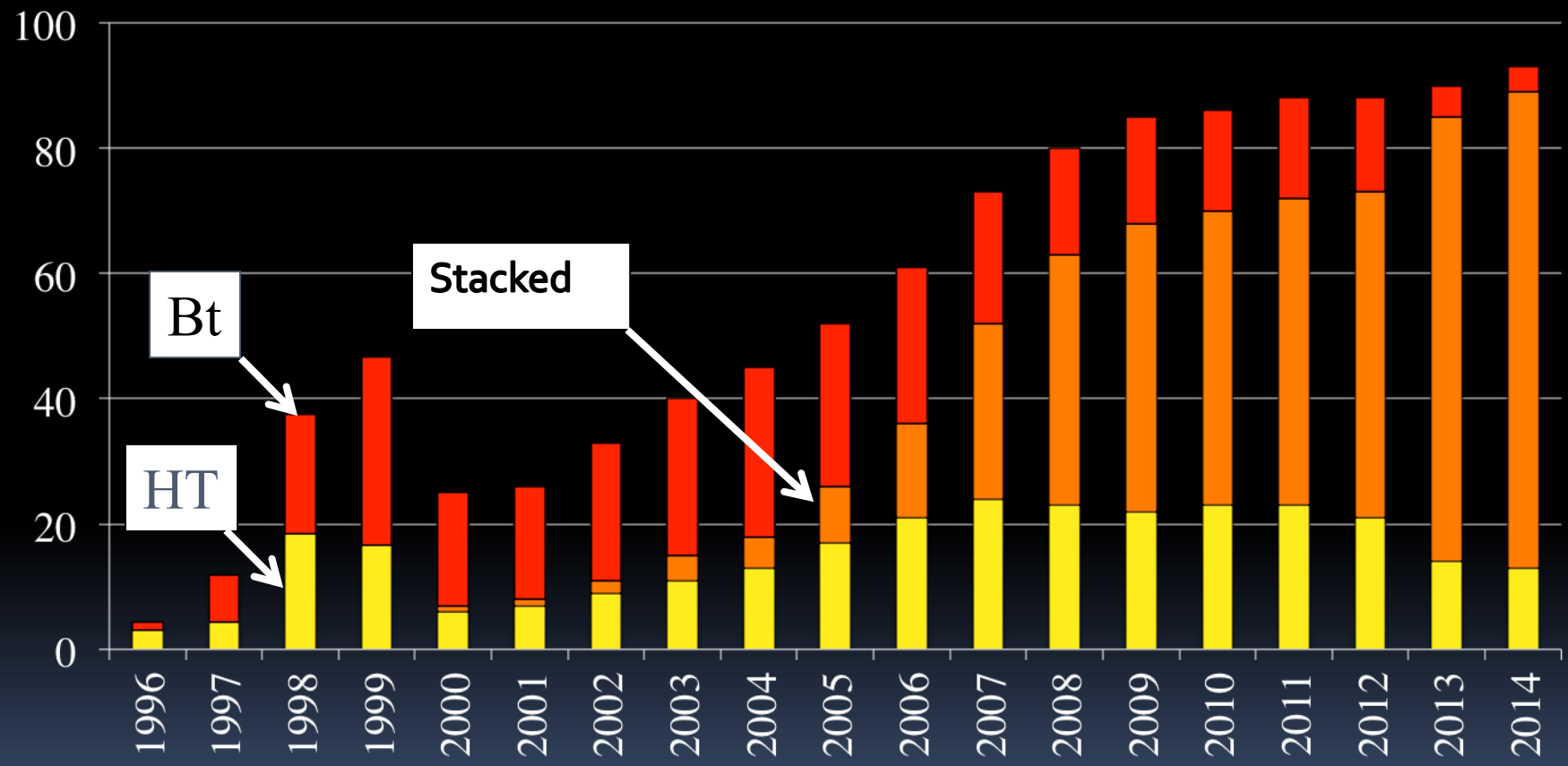
http://www.isaaa.org/resources/publications/briefs/46/pptslides/Brief46slides.pdf

Two traits dominate worldwide



http://www.isaaa.org/resources/publications/briefs/46/pptslides/Brief46slides.pdf

Growing use of stacked genes in maize, USA 1996 to 2014



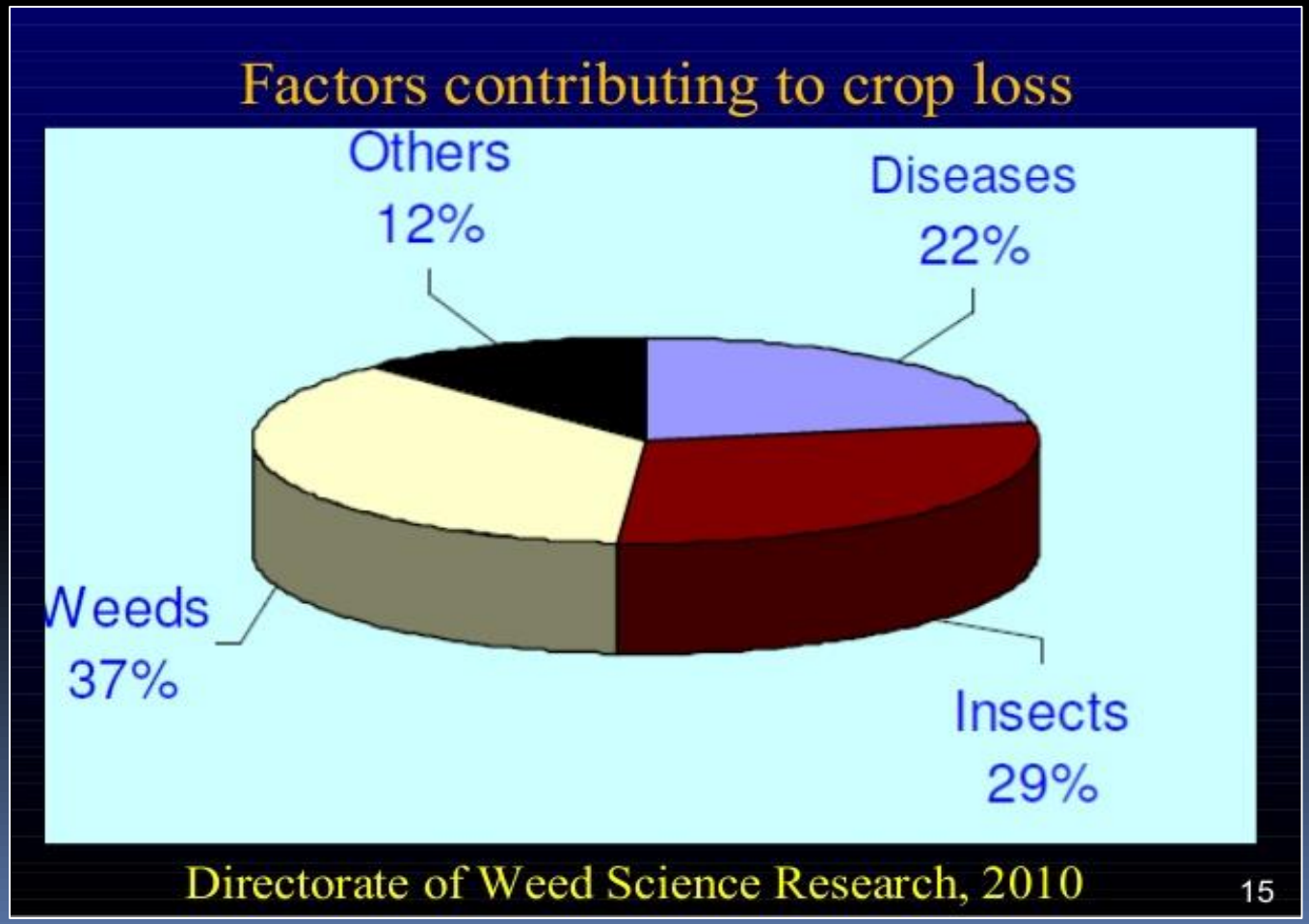
(data source: USDA ERS, 2014)

Three GE trait types widely grown in the USA

- **Bt insect resistant**
  (corn, cotton, sweet corn)
- **Herbicide resistant**
  (soybean, corn, cotton, canola, sugar beet, alfalfa)
- **Virus resistant**
  (papaya, squash)

Why these traits?

Of the total annual pest losses in crops, weeds account for 37%, insects 29%, diseases 22% and other pests 12%

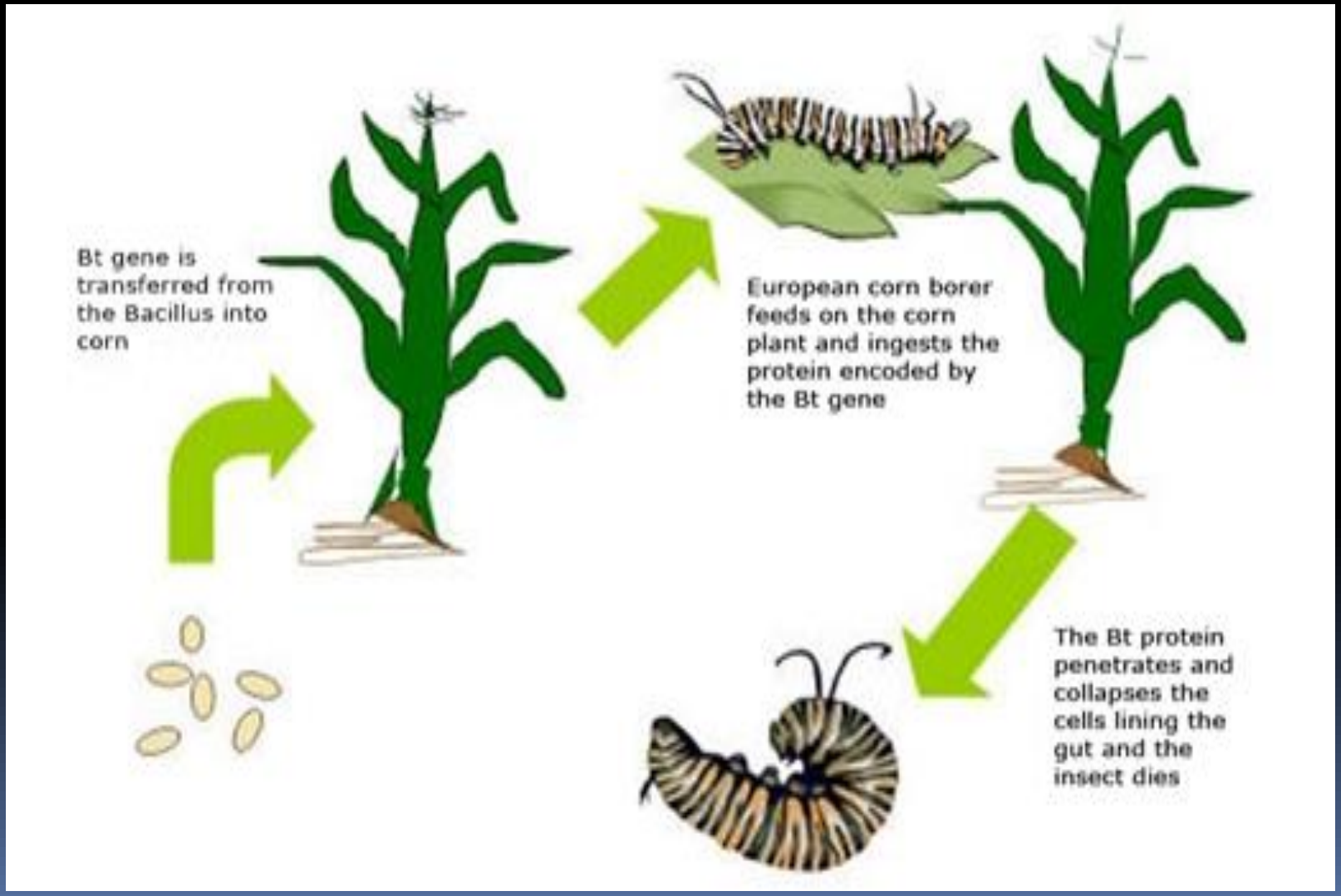


Herbicide resistant crops make weeds less costly and more efficient to control

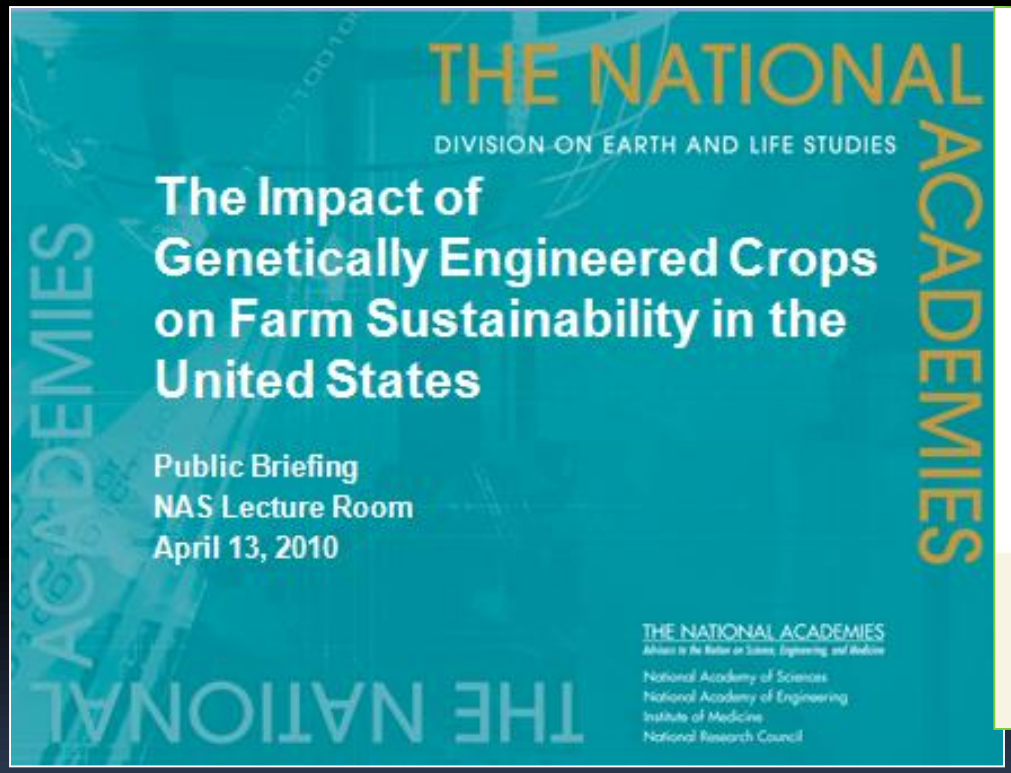
Weeds aggressively use water, light, and nutrients, and thus greatly decrease yield per acre

Insect-resistant Bt crops

More efficient and less harmful to non-targets than sprays -- Bt sprays widely used in organic agriculture



Major reports on biotech crops show very large and positive impacts on economics, sustainability, in USA



REVIEWS IN ADVANCE

Review in Advance first posted online on August 14, 2013. (Changes may still occur before final publication online and in print.)

Agricultural Biotechnology: Economics, Environment, Ethics, and the Future

Alan B. Bennett,[1,2] Cecilia Chi-Ham,[2] Geoffrey Barrows,[3] Steven Sexton,[4] and David Zilberman[3]

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[3]Department of Agricultural and Resource Economics, University of California, Berkeley, California 94720; email: gmb103@berkeley.edu, zilber11@berkeley.edu

[4]Department of Agricultural and Resource Economics, North Carolina State University, Raleigh, North Carolina 27607; email: steven.sexton@ncsu.edu

Annu. Rev. Environ. Resour. 2013. 38:19.1–19.31

The *Annual Review of Environment and Resources* is online at http://environ.annualreviews.org

This article's doi: 10.1146/annurev-environ-050912-124612

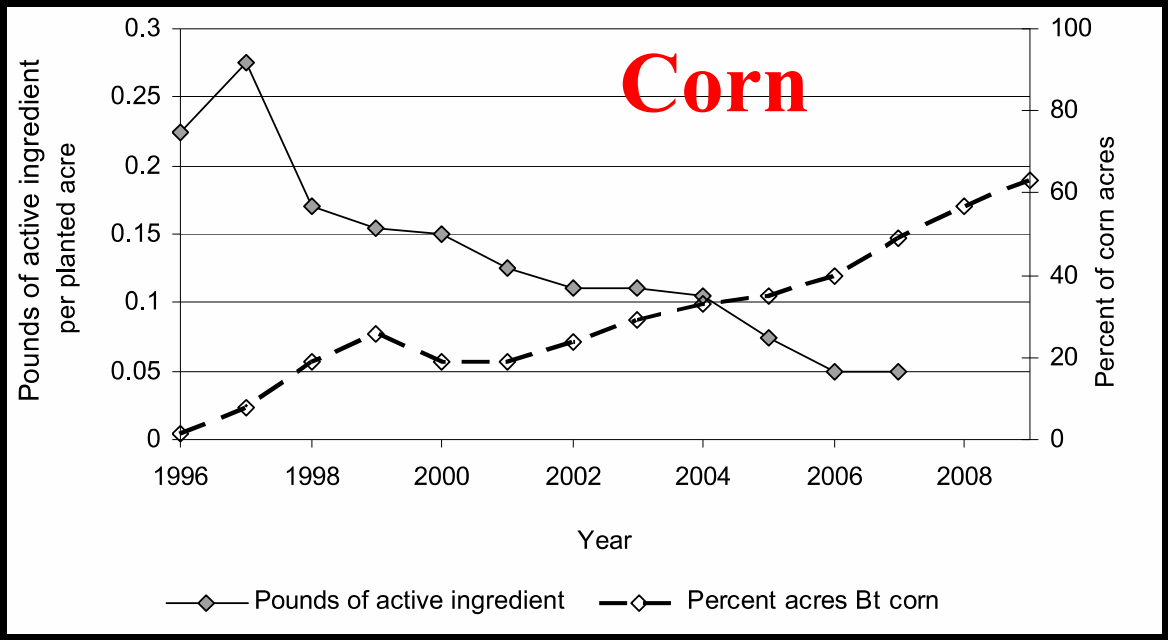
Keywords

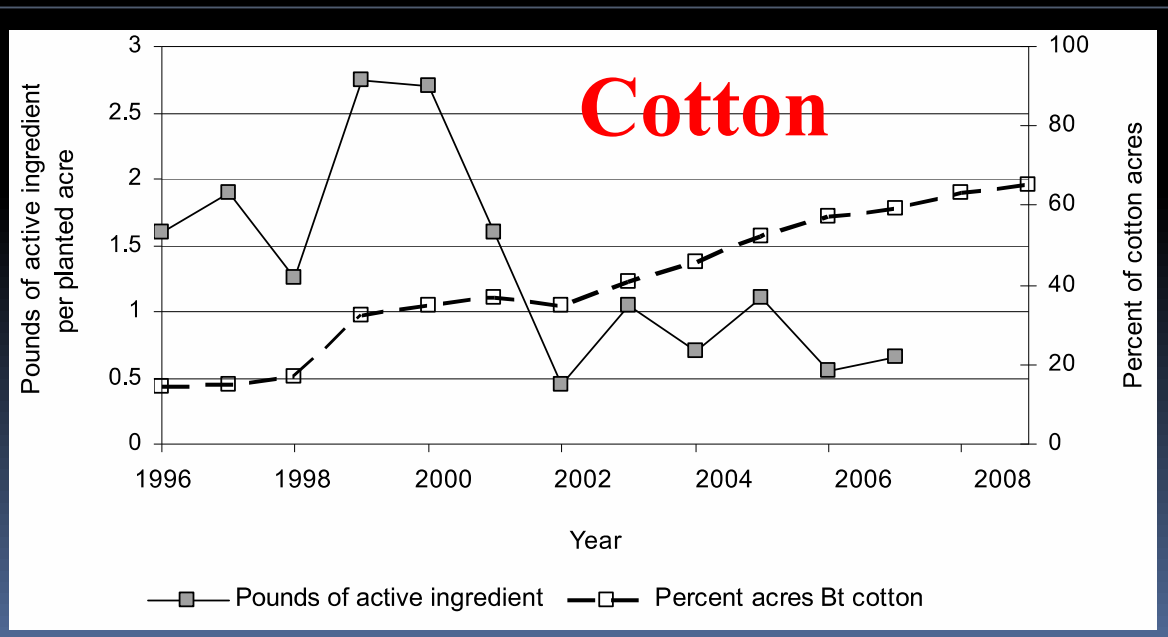
genetic modification, genetic engineering, GMO, GM crops, food security

Abstract

Agricultural biotechnology and, specifically, the development of genetically modified (GM) crops have been controversial for several reasons,

U.S. insecticide use per acre reduced due to Bt crops





National Research Council, National Academy of Sciences 2010

Global “meta-analysis” with similar results: 2014

“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

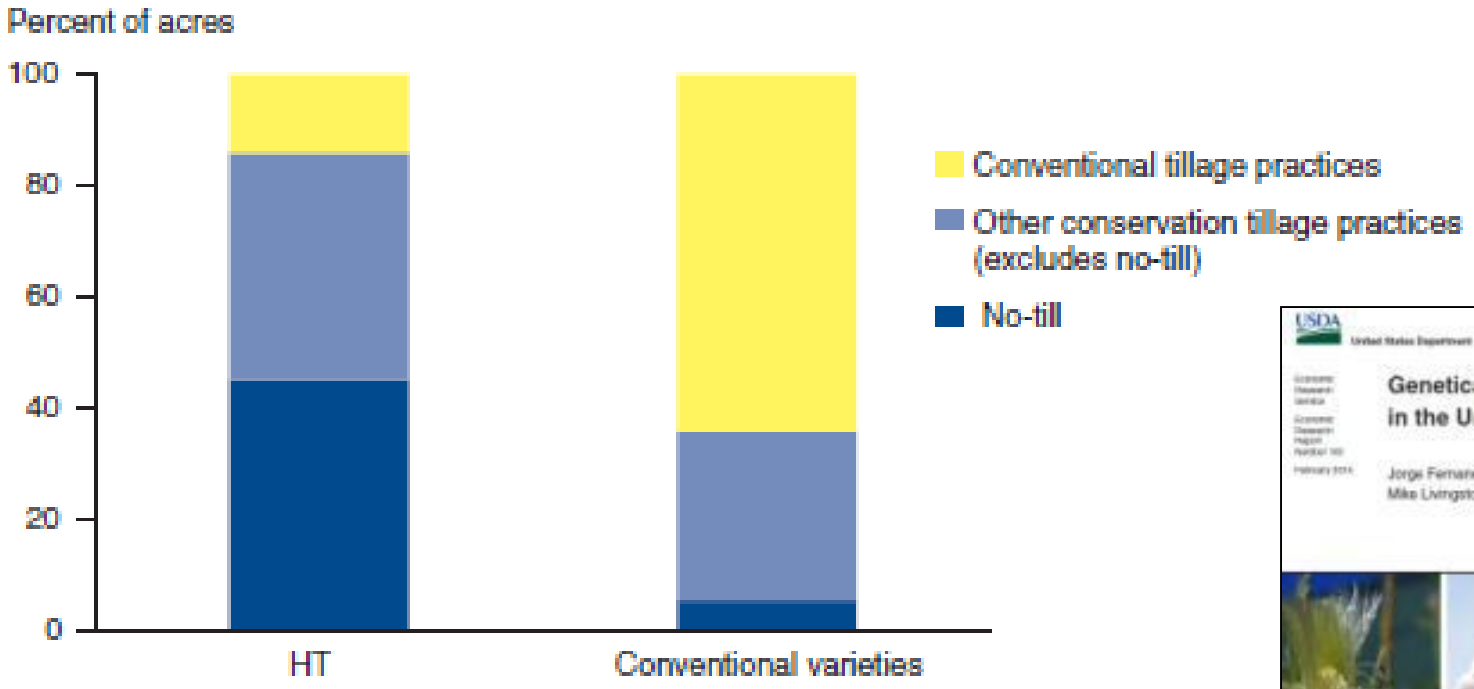
- Lowers greenhouse gas emissions
- Improves soil organic matter
- Reduces erosion and fertilizer runoff into water

Global: In 2012 reduced CO_2 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

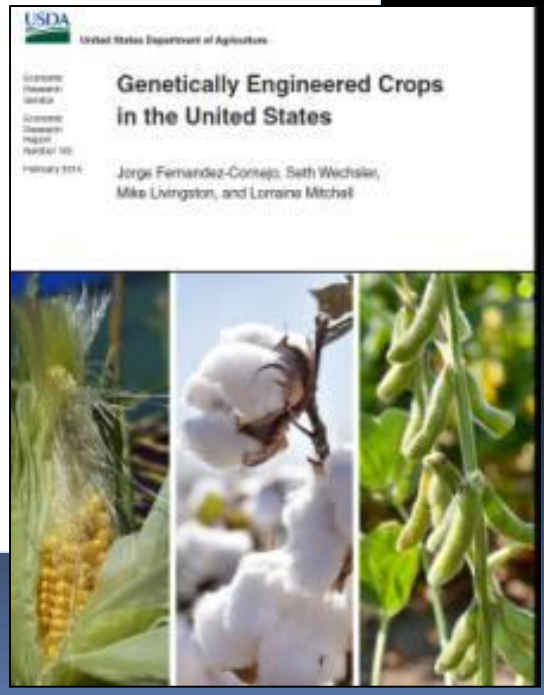
Figure 15

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



Conservation tillage includes no-till, ridge-till and mulch-till.

Source: USDA Economic Research Service using data from 2006 ARMS Phase II soybean survey.



Poor weed management has led to rapid development of herbicide-resistant weeds

And motivated development of new kinds of herbicide tolerant crops

nature biotechnology

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NATURE BIOTECHNOLOGY | NEWS

Glyphosate resistance threatens Roundup hegemony

Emily Waltz

Nature Biotechnology **28**, 537–538 (2010) | doi:10.1038/nbt0610-537
Corrected online **13 October 2010**
Corrigendum (October, 2010)

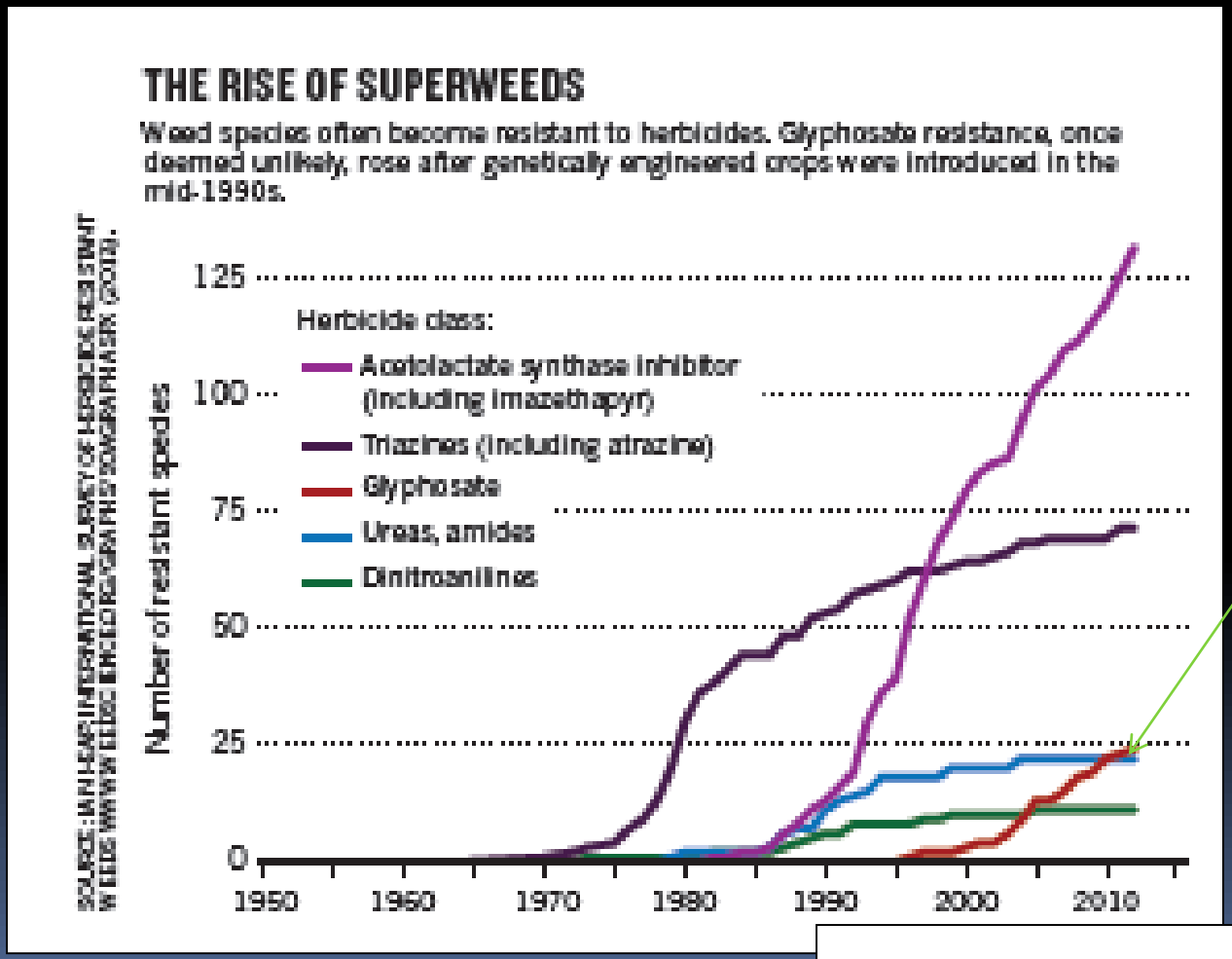
PDF | Citation | Reprints | Rights & permissions | Article metrics

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-tolerant predecessors, weeds will simply become resistant to the new technologies.

*The number of weed species evolving resistance to glyphosate

BILL BARKSDALE / AGSTOCKUSA /

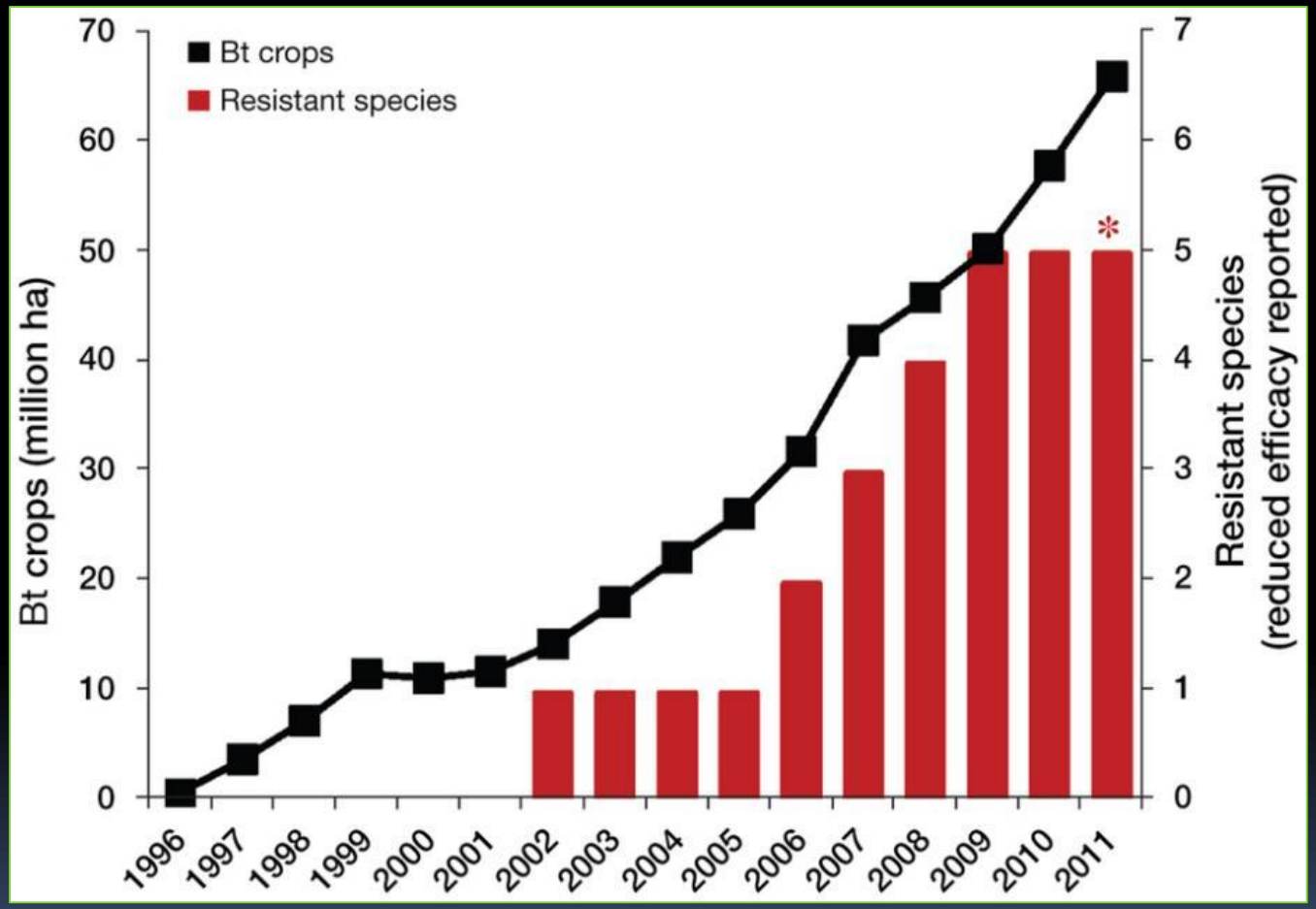
Herbicide-resistant weeds are an old problem in agriculture, but exacerbated by GE herbicide tolerant crops



Accelerated by GE Roundup-tolerant crops

24 | NATURE | VOL 497 | 2 MAY 2013

Insect resistance has developed too, but expected and much better managed



Insect resistance to Bt crops: lessons from the first billion acres

***Nature Biotechnology*, 31, 510–521 (2013)**

Analogous to antibiotics, continued benefits require integrated management, and inputs of new genes/traits

A difficult herbicide and GMO crop treadmill – can it be managed?

BUSINESS DAY

E.P.A. Revokes Approval of New Dow Herbicide for G.M.O. Crops

By ANDREW POLLACK NOV. 25, 2015

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The Environmental Protection Agency, in a surprising move, has decided to revoke the approval of a herbicide that was made to be used on a new generation of genetically modified crops.

The agency's decision could delay the introduction of corn, soybeans and cotton developed by Dow Chemical to be resistant to the herbicide 2,4-D. But Dow said it did not anticipate a significant delay.

In a court filing on Tuesday, the E.P.A. said it had discovered new information su
could be more

"E.P.A. can no
concern to nor

The New York Times

Overstated concerns over glyphosate exposure

Following a second mandate from the European Commission to consider the findings from the International Agency for Research on Cancer (IARC) … EFSA concluded that glyphosate is unlikely to pose a carcinogenic hazard to humans and the evidence does not support classification with regard to its carcinogenic potential

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Newly approved GE crop varieties in USA

- Soybean – insect resistant (Apr. 2014)
- Alfalfa – reduced lignin (Nov. 2014)
- Potato – reduced black spot bruise and low acrylamide production (Nov. 2014), reduced browning and disease resistant as well (August 2015)
- Soybean and cotton – new herbicide tolerances (Jul. 2014 – Jan. 2015)
- Apple – non-browning (Feb. 2015)
- Plum – virus resistant (2014)

RNA interference (RNAi) for gene suppression

Nobel Prize for it's impact and mechanism

The Nobel Prize in Physiology or Medicine 2006

Andrew Z. Fire, Craig C. Mello

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The Nobel Prize in Physiology or Medicine 2006

Photo: L. Cicero

Andrew Z. Fire

Prize share: 1/2

Photo: J. Mottern

Craig C. Mello

Prize share: 1/2

The Nobel Prize in Physiology or Medicine 2006 was awarded jointly to Andrew Z. Fire and Craig C. Mello *"for their discovery of RNA interference - gene silencing by double-stranded RNA"*

Virus-resistant GM papaya

Saved the Hawaiian industry in the mid-1990s, ~70% of crop today

Like a vaccine – "RNAi immunization" via implanting a viral gene in the papaya genome

GMO, virus-resistant trees

Courtesy of Denis Gonsalves, formerly of Cornell University

HoneySweet plum with RNAi resistance to plum pox virus

Ralph Scorza USDA-ARS

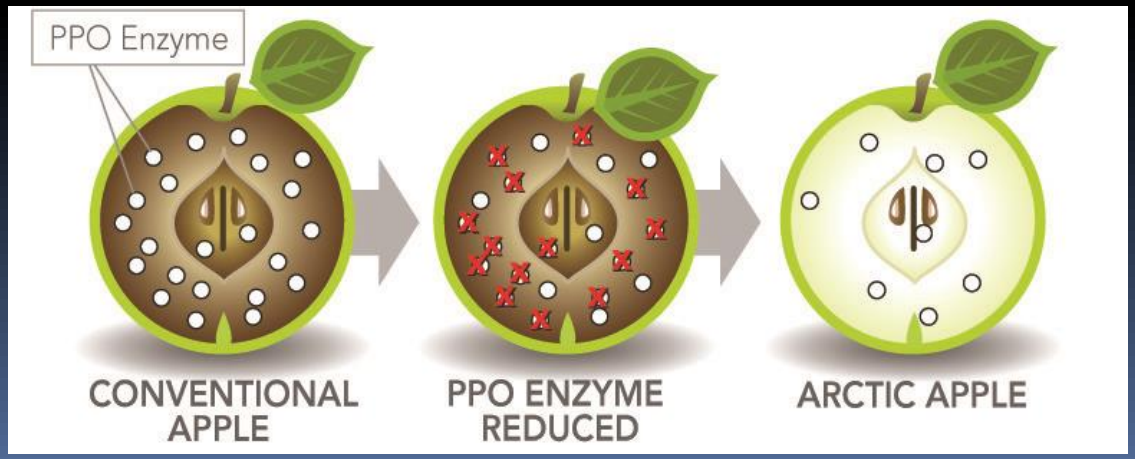
GE

Non-GE

Non-browning "Arctic Apple"

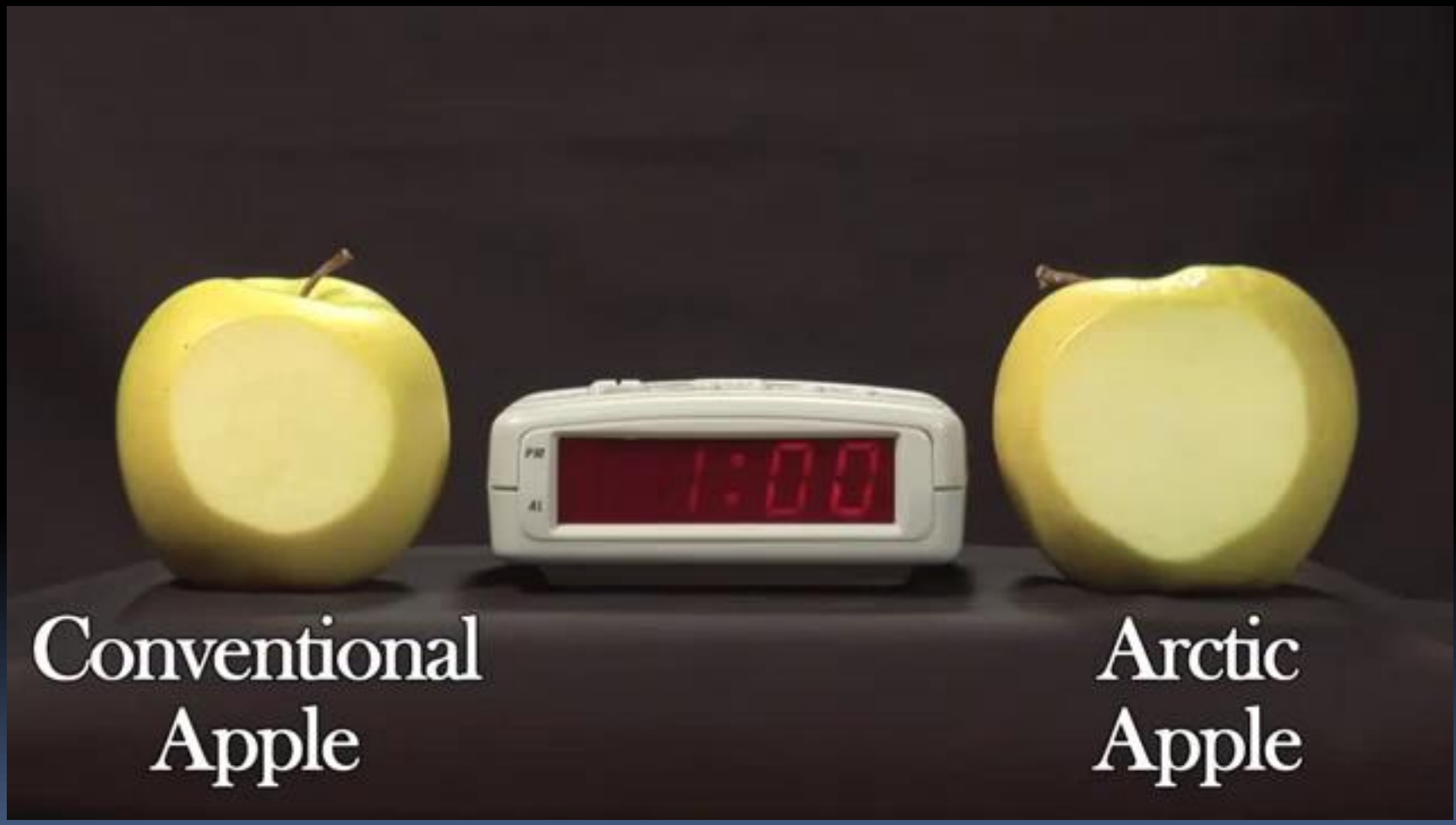
Reduced spoilage/waste, improved quality – USDA approved

Courtesy of Jennifer Armen, Okanagan Specialty Fruits, Canada



Non-browning “Arctic Apple”

Time lapse video



They are good!

“Innate” potato approved – reduced browning and acrylamide (↓waste, ↑safety)

Trait #1 - Silenced PPO (Enzyme)

- Non-browning when cut
- Reduced black spot bruise

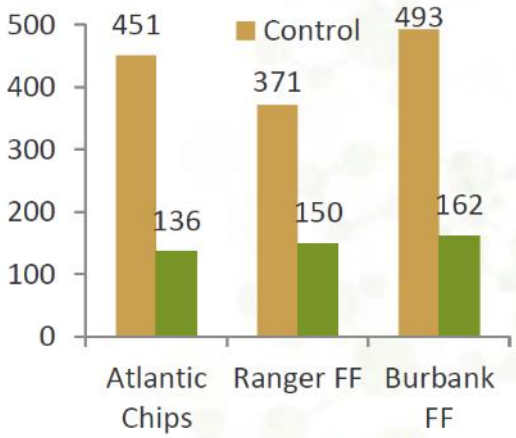
Trait #2 - Reduced Asparagine (Amino Acid)

- 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



Lower Acrylamide

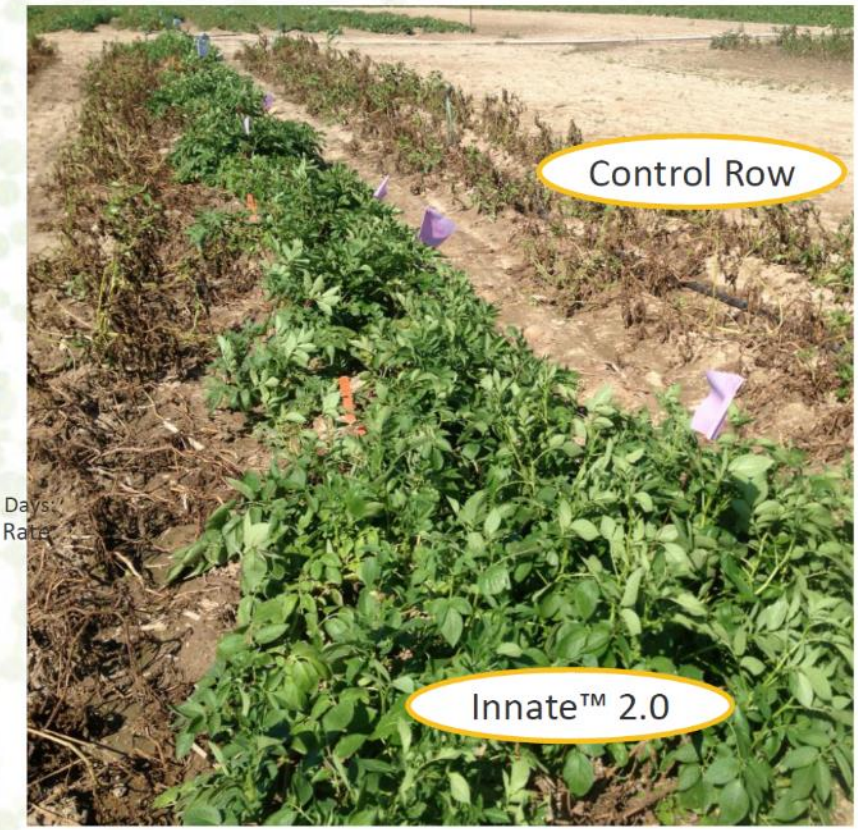
“Innate” potato in my hands for teaching

One hour after cutting – Control vs. Innate

Two days after cutting – Innate vs. Control

“Innate” potato 2.0 – late blight resistant, reduced acrylamide, reduced sprouting and browning (↓ waste, ↑ safety, ↓ pesticide, ↑ yield)

Midwest - Sept 4th 2013



Days
Rate

Dramatic change in color of chips, highly prized by consumers

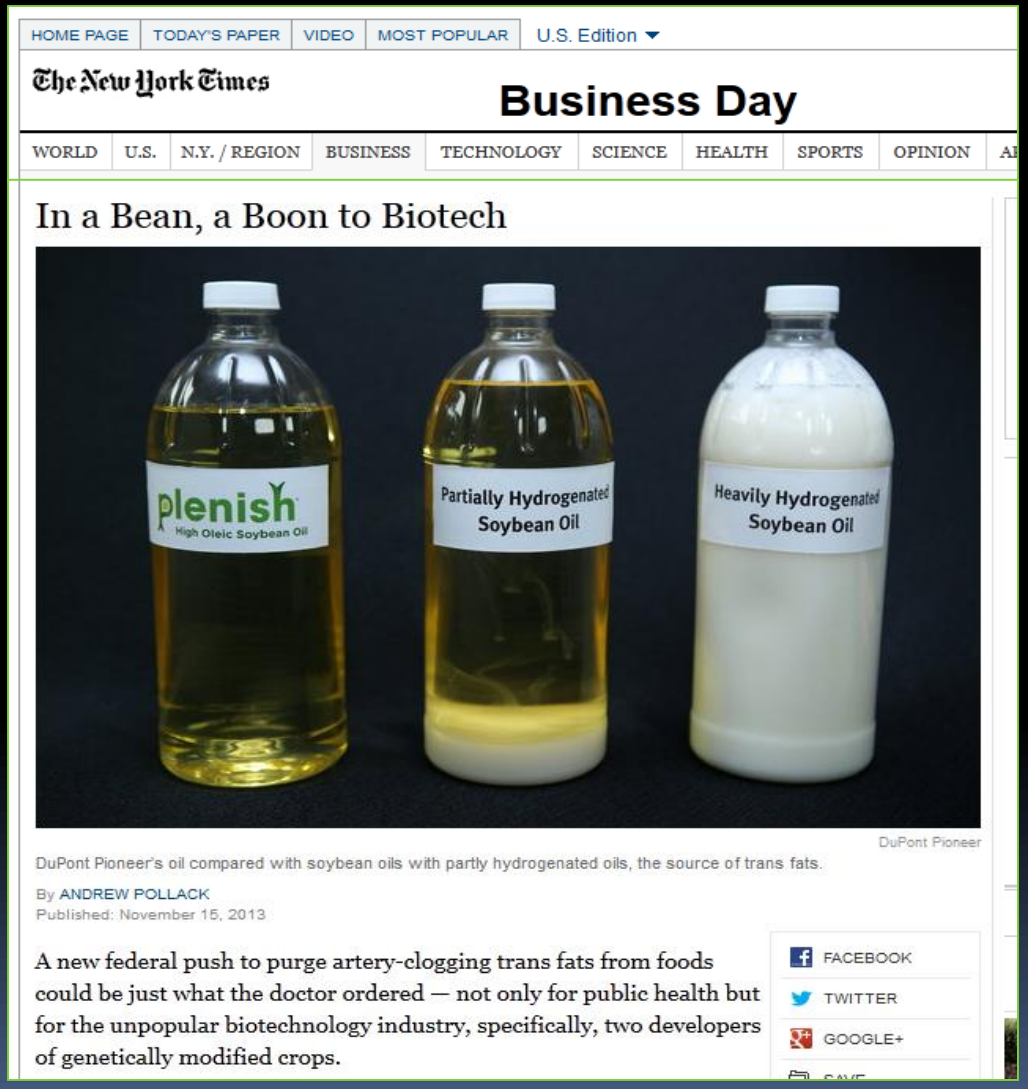
Provided by Walter De Jong, Cornell University

Innate benefits

- **If all USA potatoes had it's improved traits, each year….**
- Waste reduced by 5 billion pounds
- CO_2 emissions reduced by 734 million pounds
- Water use reduced by 84 billion gallons
- 2.5 million fewer pesticide acre-applications
- Marketable yields increase ~ 20%
- Growers save $240 million in production costs

Referenced analyses by Simplot Plant Sciences

Improved oil



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The New York Times

Business Day

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH | SPORTS | OPINION

In a Bean, a Boon to Biotech

DuPont Pioneer

DuPont Pioneer's oil compared with soybean oils with partly hydrogenated oils, the source of trans fats.

By ANDREW POLLACK
Published: November 15, 2013

A new federal push to purge artery-clogging trans fats from foods could be just what the doctor ordered — not only for public health but for the unpopular biotechnology industry, specifically, two developers of genetically modified crops.

FACEBOOK
TWITTER
GOOGLE+

"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."

Insect control via RNAi in corn:

Host induced gene silencing (HIGS)

LETTERS

nature biotechnology

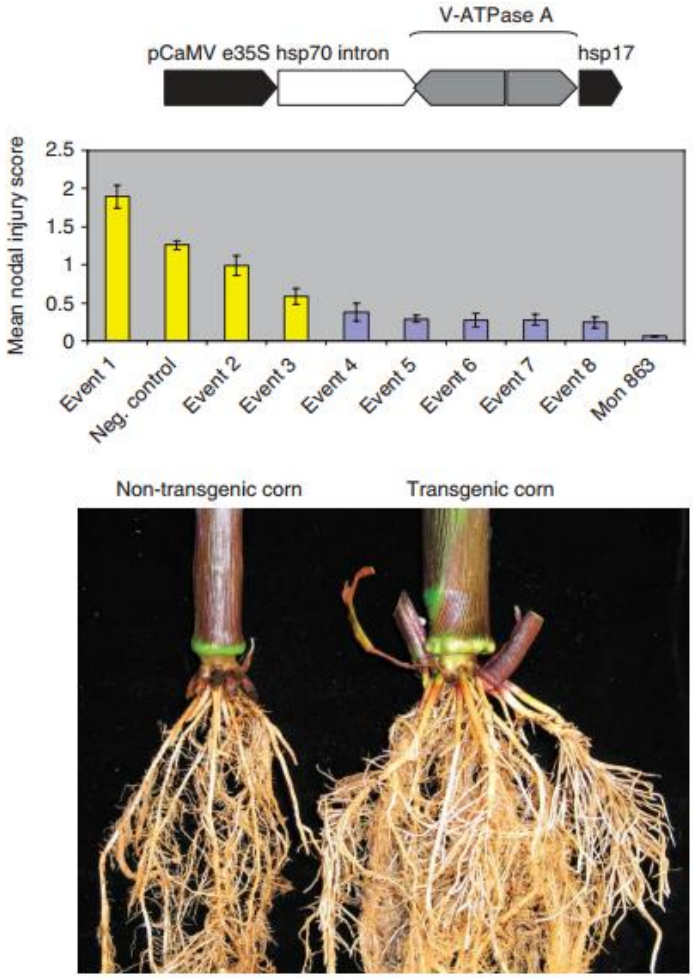
Control of coleopteran insect pests through RNA interference

James A Baum[1], Thierry Bogaert[2], William Clinton[1], Gregory R Heck[1], Pascale Feldmann[2], Oliver Ilagan[1], Scott Johnson[1], Geert Plaetinck[2], Tichafa Munyikwa[1], Michael Pleau[1], Ty Vaughn[1] & James Roberts[1,3]

Commercial biotechnology solutions for controlling lepidopteran and coleopteran insect pests on crops depend on the expression of *Bacillus thuringiensis* insecticidal proteins[1,2], most of which permeabilize the membranes of gut epithelial cells of susceptible insects[3]. 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.

initial bioassays, dsRNAs were applied to the surface of the WCR agar diet at concentrations from 520 ng/cm^2 to 780 ng/cm^2. As we anticipated a slower response to dsRNAs than to *B. thuringiensis* insecticidal proteins, the WCR bioassay incubation period was extended from 5 d to 12 d. Indeed, 7 d after infestation, little if any effect was observed. However, numerous dsRNAs exhibited significant activity 12 d after infestation, resulting in both larval stunting and mortality (**Supplementary Table 1** online).

Subsequent feeding assays demonstrated that certain dsRNA samples, including dsRNAs targeting putative genes encoding vacuolar ATPase (V-ATPase) subunit A, D and E, as well as α-tubulin, were active at applied concentrations well below 52 ng/cm^2. We identified additional WCR genes that caused mortality when targeted for suppression using dsRNAs in the WCR feeding assay. A two-tiered screen was implemented in which dsRNAs targeting different genes were tested at 52 and 5.2 ng/cm^2. Of the 290 dsRNAs tested, 125 showed significant ($P < 0.05$) larval mortality and/or stunting at 52 ng/cm^2. Of these, 67 showed significant mortality and/or stunting



ure 2 F1 plants expressing a V-ATPase A dsRNA are protected from WCR ding damage. (**a**) Map of the expression cassette. (**b**) Mean root damage ngs for eight F_1 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 left is a non-transgenic control with average root damage, whereas the plant on the right shows the average root protection seen when the transgene is expressed.

HIGS also effective for fungal resistance

Host-induced gene silencing of cytochrome P450 lanosterol C14α-demethylase–encoding genes confers strong resistance to *Fusarium* species

Aline Koch[a], Neelendra Kumar[a], Lennart Weber[b], Harald Keller[c], Jafargholi Imani[a], and Karl-Heinz Kogel[a,1]

[a]Institute for Phytopathology and Applied Zoology and [b]Institute for Microbiology and Molecular Biology, Centre for Bio Systems, Land Use, and Nutrition, Justus Liebig University, D-35392 Giessen, Germany; and [c]Institut Sophia Agrobiotech, Unité Mixte de Recherche 1355 Institut National de la Recherche Agronomique Centre National de la Recherche Scientifique, Université Nice-Sophia Antipolis, 06903 Sophia Antipolis, France

Edited* by Diter von Wettstein, Washington State University, Pullman, WA, and approved October 15, 2013 (received for review April 5, 2013)

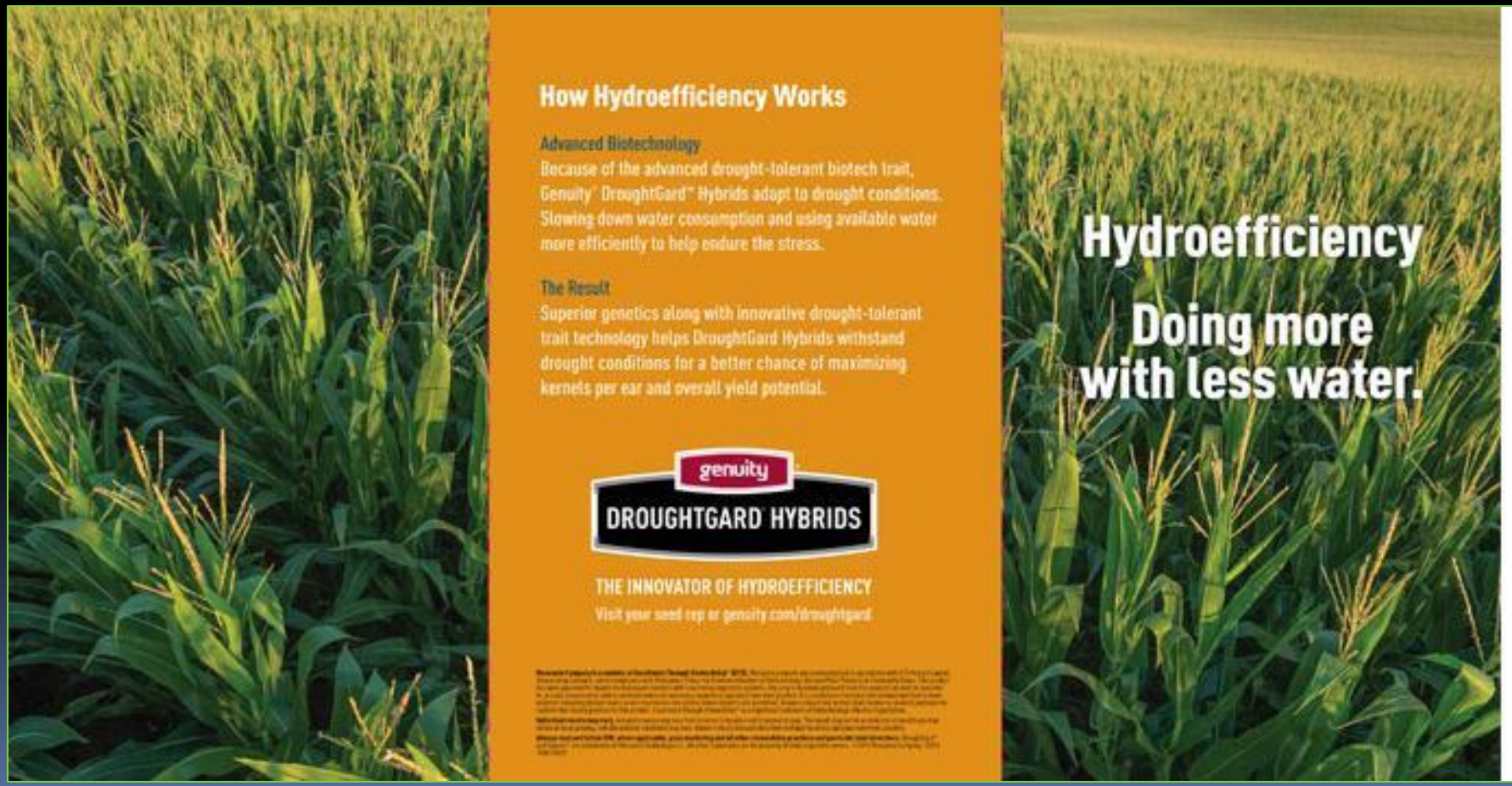
Head blight, which is caused by mycotoxin-producing fungi of the genus *Fusarium*, is an economically important crop disease. We assessed the po… the fungal cytoch… genes, which ar… fungal infection. … vitro feeding of … plementary to C… inhibition [half-… well as altered f… treatment with … CYP51 enzyme is a target. Expression of the same dsRNA in *Arabidopsis* and barley rendered susceptible plants highly resistant to fungal infection. Microscopic analysis revealed that mycelium formation on *CYP3RNA*-expressing leaves was restricted to the

their discovery in the 1970s. Therefore, it is hardly surprising that reduced sensitivity, or even resistance to DMI fungicides, has … mic fungi (8–14). The … the last few years (15) … control strategies. … as a powerful genetic … plant biotechnology … useful agronomical … gral part of the gene- … tes (16, 17); in plants, … silencing (18). Post-transcriptional gene silencing starts with the initial processing or cleavage of a precursor dsRNA into short 21–25 nucleotide small-interfering RNA (siRNA) or micro RNA (miRNA) duplexes

"…demonstrating that HIGS is a powerful tool, which could revolutionize crop plant protection."

Drought-tolerant maize – Planted on >150,000 acres – Also tested in Africa

Important tool given climate change, water shortages?



Many more stress tolerance innovations in the pipeline

NEWS FEATURE

Beating the heat

Despite the complexity of drought tolerance, researchers are making progress in the search for crops that can produce seed with limited water. Emily Waltz reports.

A revolution is quietly underway in the mid-West and Great Plains of the US. Following water shortages that have ravaged corn yields, the first of a new generation of drought-tolerant crops are being put to the test in the field. In March, Johnston, Iowa-based DuPont Pioneer announced that its newly developed transgenic corn, which downregulates production of the phytohormone ethylene, enhances grain yield after exposure to drought stress[1]. It could join DroughtGard maize, a variety expressing a *Bacillus subtilis* cold-shock protein made by Monsanto of St. Louis, that has already been planted on more than 200,000 ha by thousands of farmers.

With registrations elsewhere in the world—last year, Indonesia approved a sugarcane expressing choline dehydrogenase with enhanced resistance to water deprivation—and a half-dozen other transgenic approaches to drought tolerance and water use efficiency (WUE) in testing (**Table 1**), biotech is making strides in bolstering crop resistance to drought. But it may not be happening fast enough. Global population increases are put-

Interest in drought tolerance as a trait has been on the rise over the past decade, both in industry and academia. At least 117 field trials for drought tolerance were given the green light in 2013 by US regulatory authorities alone, up from just 29 in 2004, according to data from Information Systems for Biotechnology (ISB) in Blacksburg, Virginia, a group that tracks regulatory activity. And these numbers may not include trials of drought-tolerant plants that are categorized under a more general description or as an undisclosed phenotype.

Monsanto is currently conducting far more field trials of drought-tolerant crops than anyone else in the US, according to data from ISB

protein CspB, which binds and thereby stabilizes RNA, and unfolds RNA secondary structures, which often fold in response to environmental stress. This chaperoning of RNA is thought to minimize the effects of drought on photosynthesis, stomatal conductance and carbon fixation—cellular functions that affect grain yield. "The plant acclimates to the stress more quickly and utilizes water more efficiently, leaving it with more water to help it through critical periods of growth," says John Fietsam, a technology development manager at Monsanto. "It allows the plant to put more

Drought tolerant crops are making an appearanc in the US.

basis to farmers in states, where the cl Corn Belt states of t farmers participate planting no more

Table 1 Transgenic drought tolerant crops in commercial development and on the market

Developer	Crop	Mechanism	Implementation location and status	Field trial results
Monsanto	Corn	Expresses a cold-shock protein B from *B. subtilis*, which stabilizes RNA	Deregulated in US in December 2011; stewarded commercialization in US western Great Plains and Midwest	Average increase of five bushels of corn per acre during drought
PT Perkebunan Nusantara XI; University of Jember (East Java, Indonesia); Ajinomoto	Sugarcane	Expresses glycine betaine from *Rhizobium meliloti*	Approved in Indonesia by the National Genetically Modified Product Biosafety Commission in May 2013	20–30% higher sugar production than conventional counterparts during drought
Performance Plants (Kingston, Ontario)	Canola, corn, petunia and rice	Uses RNAi driven by conditional promoters to suppress farnesyltransferase; shuts down stomata	Licensed to Scotts (Marysville, Ohio), Syngenta (Basel), Bayer CropScience (Monheim, Germany), DuPont Pioneer, Mahyco (Jalna, India), RiceTec (Houston) and DBN (Beijing)	Canola, 26% higher yield; petunia, double the number of flowers
DuPont Pioneer	Corn	Expresses an ACS6 RNA construct to downregulate ACC synthase and decrease biosynthesis of ethylene	Field trials in the US and Chile	2.7–9.3 bushel per acre advantage over nontransgenic varieties in drought conditions
Arcadia Biosciences	Rice and canola	Expresses isopentenyltransferase from Agrobacterium, which catalyzes the rate-limiting step in cytokinin synthesis; accompanied by SARK promoter from bean	Two years of US field trials in rice with combined water use efficiency, nitrogen use efficiency and salt tolerance; technology licensed to developers who have put the gene into their own varieties of soybean, wheat, rice, cotton, sugar beets, sugarcane and tree crops	13–18% under various nitrogen application rates; 12–17% under water stress conditions; 15% under combined stress
Verdeca, a joint venture of Arcadia Biosciences and Bioceres	Soybean	Overexpresses Hahb-4, from sunflower thought to inhibit ethylene-induced senescence	Field trials in Argentina and the US	7–15% yield advantage over comparable varieties during drought and other stress
Japan International Research Center for Agricultural Sciences	Wheat, soybean and sugarcane	Expresses DREB1A transcription factor under the control of the rd29A promoter	Field trials via collaborations with International Maize and Wheat Improvement Center, International Rice Research Institute, International Center for Tropical Agriculture, Brazilian Enterprise for Agricultural Research	Varies
University of Tokyo and Japan International Research Center for Agricultural Sciences	Rice and peanut	Expresses DREB1A transcription factor under the control of the rd29A promoter	Field trials via collaborations with University of Calcutta (India, rice) and International Crops Research Institute for the Semi-Arid-Tropics (India, peanut)	Varies
Agricultural Genetic Engineering Research Institute (Giza, Egypt)	Wheat	Expresses HVA1 gene from barley, which confers osmotolerance	Conducting field trials and generating biosafety data required for approval by Egypt's regulatory authorities	Not disclosed
Indian Agricultural Research Institute (New Delhi)	Tomato	Overexpressing osmotin-encoding genes under the control of the 35S CMV promoter	Greenhouse studies in India	Better survival and growth; yield data not yet available

Increased gene expression:

Purple GE tomatoes with increased antioxidants and rot resistance

Current Biology 23, 1094–1100, June 17, 2013 ©2013 Elsevier Ltd All rights reserved http://dx.doi.org/10.1016/j.cu

Anthocyanins Double the Shelf Life of Tomatoes by Delaying Overripening and Reducing Susceptibility to Gray Mold

Yang Zhang,[1] Eugenio Butelli,[1] Rosalba De Stefano,[2] Henk-jan Schoonbeek,[1] Andreas Magusin,[1] Chiara Pagliarani,[3] Nikolaus Wellner,[4] Lionel Hill,[1] Diego Orzaez,[5] Antonio Granell,[5] Jonathan D.G. Jones,[6] and Cathie Martin[1,*]
[1]John Innes Centre, Norwich Research Park, Norwich, NR4 7UH, UK

They are produced by plants t
dispersers [9]. Anthocyanin p
induced under stress condition
gens [11]. Besides physiologica
cyanins are associated with pro
[12], cardiovascular diseases [
disorders [13].

Modified hormone expression

GE salmon approved for contained use last month

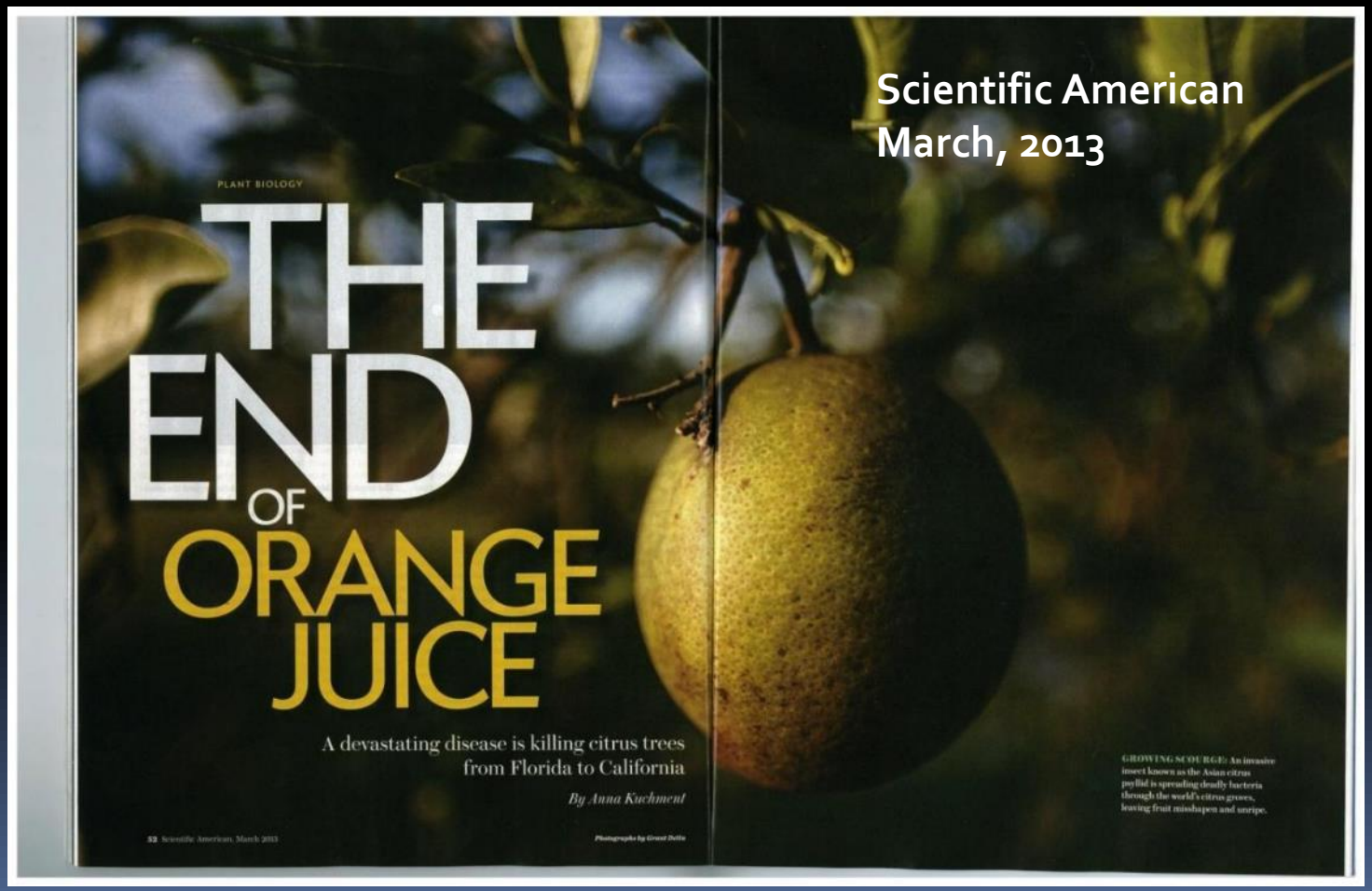
BUSINESS DAY

Genetically Engineered Salmon Approved for Consumption

By ANDREW POLLACK NOV. 19, 2015

The New York Times

Resistance transgenes promising solution/s to devastating ‘citrus greening’



The New York Times

July 27, 2013

A Race to Save the Orange by Altering Its DNA

By AMY HARMON

CLEWISTON, Fla. — The call Ricke Kress and every other citrus grower in Florida dreaded came while he was driving.

Face the "wall of opposition" ?

Defensin-like proteins from spinach for citrus greening disease resistance

Helping forests: American Chestnut restoration by genetic modification

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The American Chestnut's Genetic Rebirth

A foreign fungus nearly wiped out North America's once vast chestnut forests. Genetic engineering can revive them

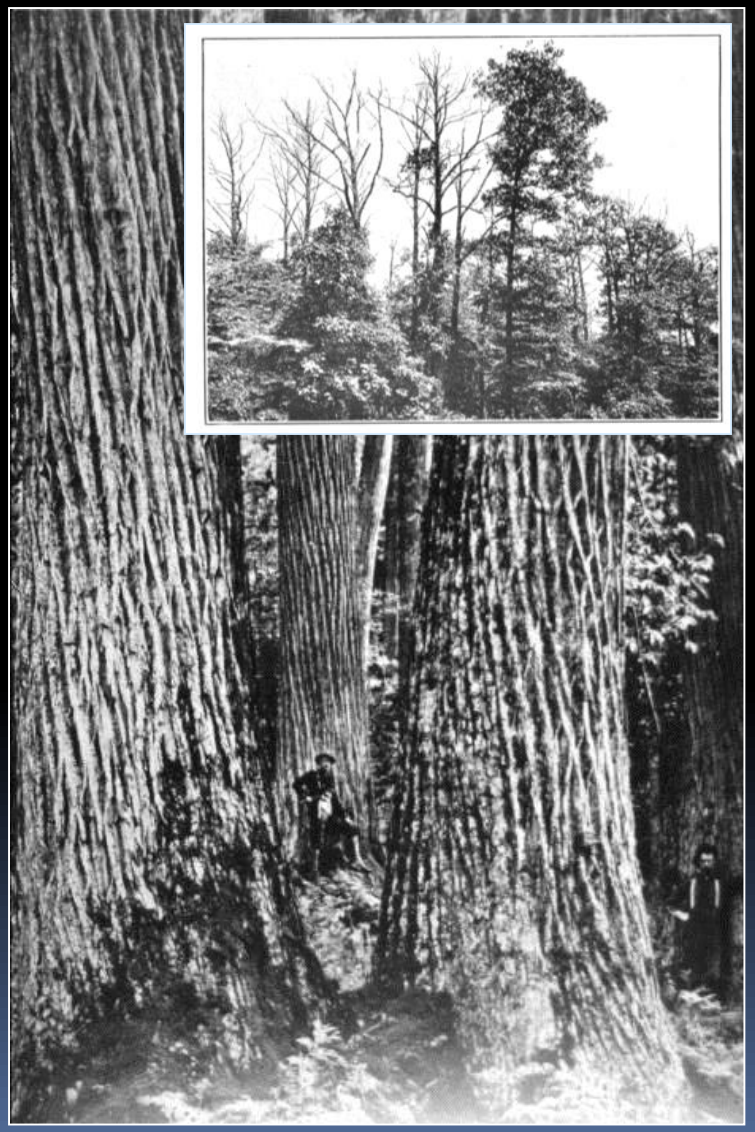
By William Powell

In 1876 Samuel B. Parsons received a shipment of chestnut seeds from Japan and decided to grow and sell the trees to orchards. Unbeknownst to him, his shipment likely harbored a stowaway that caused one of the greatest ecological disasters ever to befall eastern North America. The trees probably concealed spores of a pathogenic fungus, *Cryphonectria parasitica*, to which Asian chestnut trees—but not their American cousins—had evolved resistance. *C. parasitica* effectively strangles

More In This Article

A New Generation of American Chestnut Trees May Redefine America's Forests

March 2014 issue - Scientific American



Forest health a major and growing concern

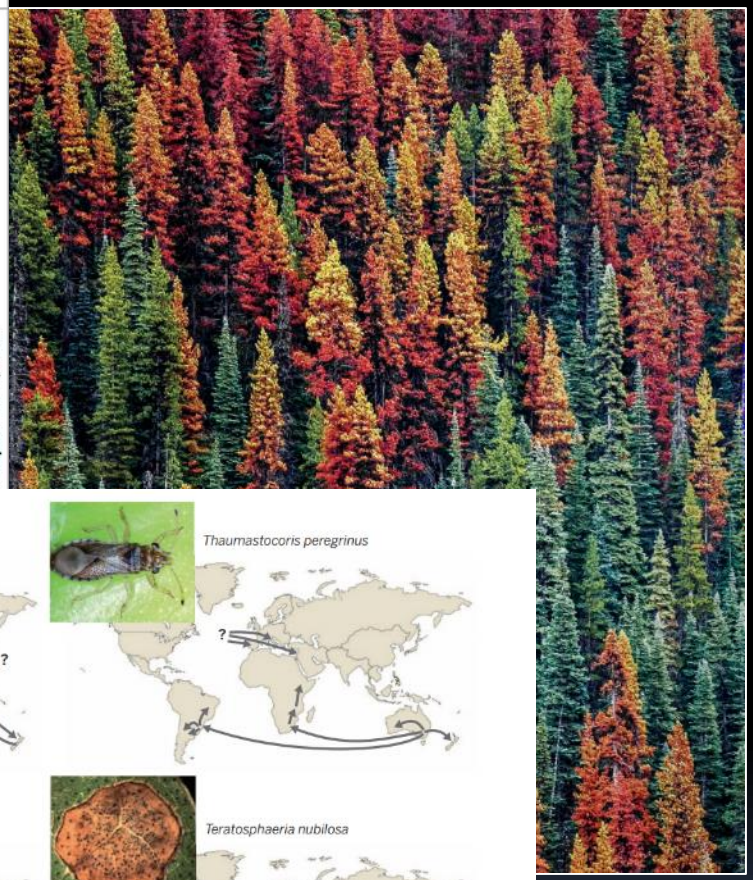
REVIEW

Planted forest health: The need for a global strategy

M. J. Wingfield,[1]* E. G. Brockerhoff,[2] B. D. Wingfield,[1] B. Slippers[1]

Several key tree genera are used in planted forests worldwide, and these represent valuable global resources. Planted forests are increasingly threatened by insects and microbial pathogens, which are introduced accidentally and/or have adapted to new host trees. Globalization has hastened tree pest emergence, despite a growing awareness of the ng of the costs, and an increased focus on the importance of and potential of planted forests, innovative solutions and a ach are needed. Mitigation strategies that are effective only in n invasions elsewhere in the world, ultimately leading to global st problems in the future should mainly focus on integrating lly, rather than single-country strategies. A global strategy to portant and urgently needed.

ems are a huge- ce, easily over- d (*1–3*). Globally, ted to rely on y more depend have been separated from their natural enemies. However, when plantation trees are reunited with their coevolved pests, which may be introduced accidentally, or when they encounter novel pests



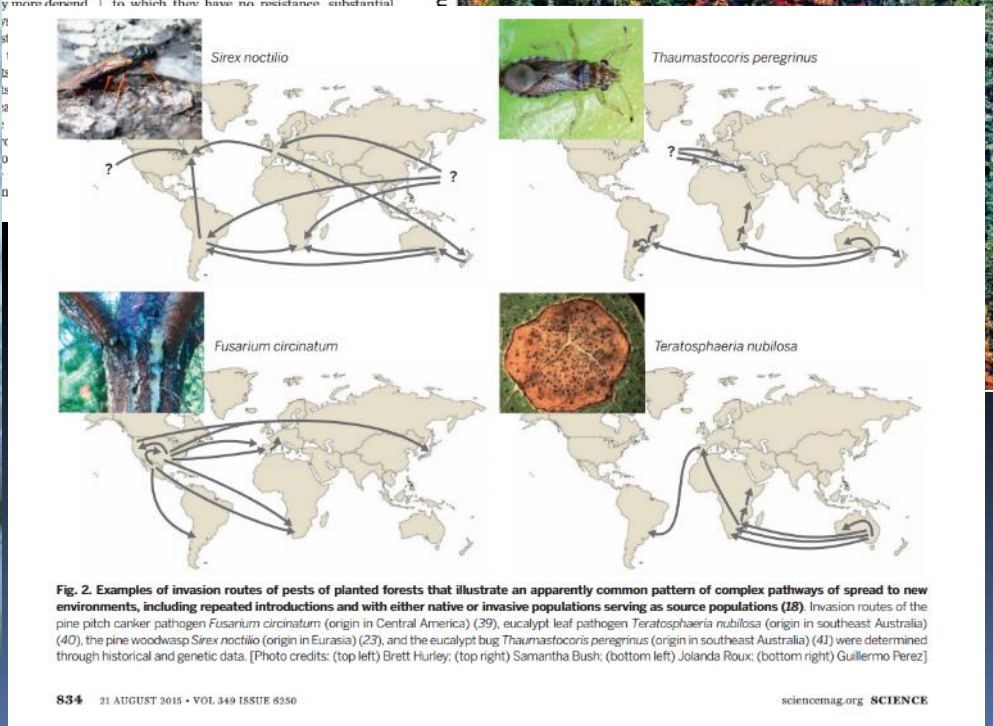
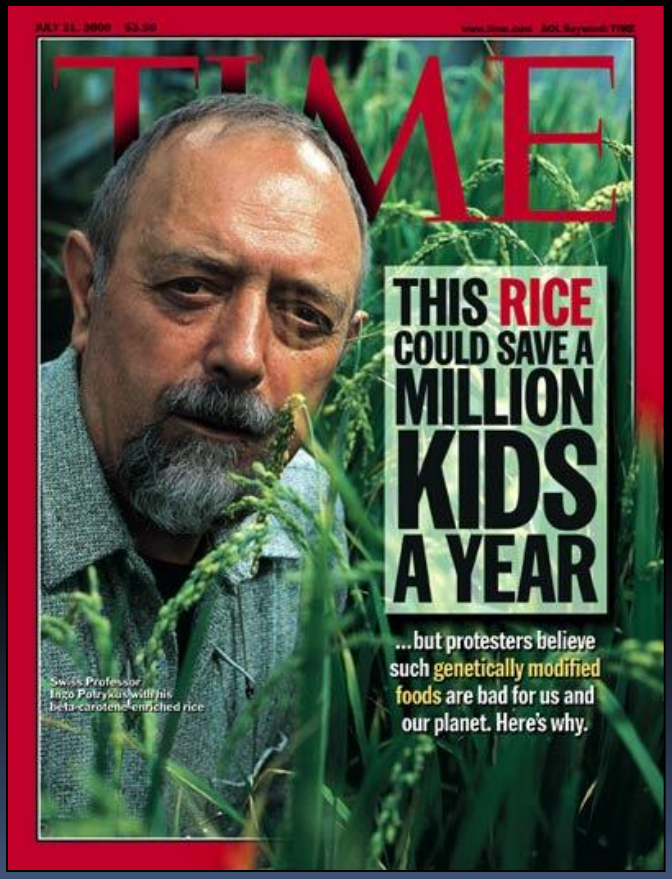
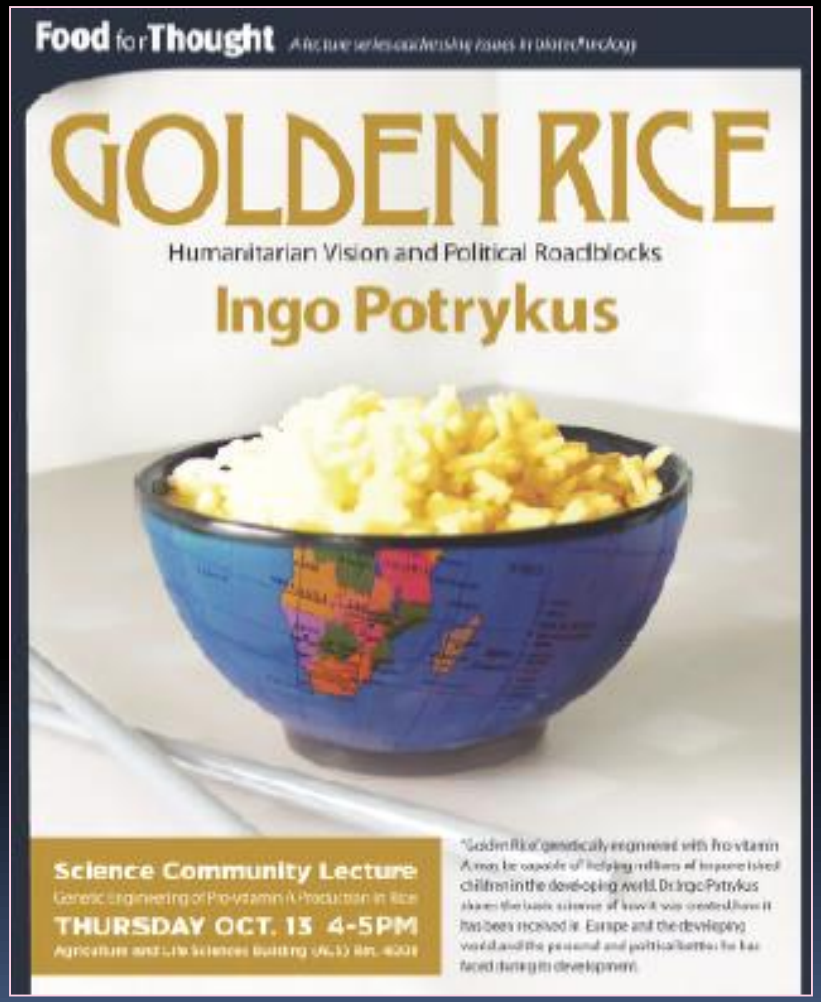


Fig. 2. Examples of invasion routes of pests of planted forests that illustrate an apparently common pattern of complex pathways of spread to new environments, including repeated introductions and with either native or invasive populations serving as source populations (*18*). Invasion routes of the pine pitch canker pathogen *Fusarium circinatum* (origin in Central America) (*39*), eucalypt leaf pathogen *Teratosphaeria nubilosa* (origin in southeast Australia) (*40*), the pine woodwasp *Sirex noctilio* (origin in Eurasia) (*23*), and the eucalypt bug *Thaumastocoris peregrinus* (origin in southeast Australia) (*41*) were determined through historical and genetic data. [Photo credits: (top left) Brett Hurley; (top right) Samantha Bush; (bottom left) Jolanda Roux; (bottom right) Guillermo Perez]

Diverse pipeline of biofortification products = enhancement of critical vitamins or nutrients





Many more examples funded by Gates Foundation / other sources

Biofortified plants are improving nutrition for many, and can do much more with aid of biotechnology

Sources: HarvestPlus; CIMMYT

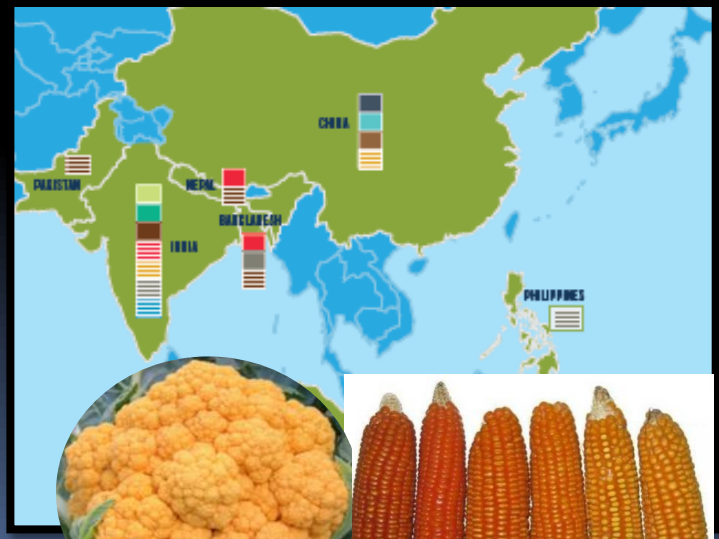
Biofortification breeding well underway, including a provitamin A enriched sweet potato that is **currently** being grown by > half a million families.

Other projects are underway to increase levels of protein, iron, zinc, antioxidants, and other beneficial components in food.

Gates Foundation a major supporter

The HarvestPlus program – worldwide impact by traditional breeding

- Nutrient targets start at:
  - 30% of the EAR of iron
  - 40% of the EAR of zinc
  - 50% of the EAR of provitamin A
- Reaches more than 40 countries



Biotech methods useful where breeding is ineffective or slow

- Rice
- Cassava
- Sorghum
- Banana

Rice

Cassava

DuPont reports breakthrough in introducing beta carotene in Sorghum

In Africa, up to half a million children become blind from Vitamin A Deficiency (VAD) with increased risk of cognitive impairment, disease and death from severe infections. Furthermore, nearly 600,000 women die from c..

20 Feb 2014

IOWA, USA: Dupont has achieved a breakthrough in introducing pro-vitamin (beta carotene) into sorghum, a stap food in Africa which is naturally deficient in key nutrients.

This is epxected to help improve nutrition for nearly 300 mn people in Africa dependent on Sorghum. DuPont said that the ability to achieve 100 % of the recommended daily allowance of vitamin A in children from Sorghum has never been achieved before.

In Africa, up to half a million children become blind from Vitamin A Deficiency (VAD) with increased risk of cognitive impairment, disease and death from severe infections. Furthermore, nearly 600,000 women die from childbirth-related causes, many from complications that could be reduced through more vitamin A in their diet.

http://www.commodityonline.com/news/dupont-reports-breakthrough-in-introducing-beta-carotene-in-sorghum-58036-3-58037.html

“Super banana”

Vitamin A Super Banana in human trials

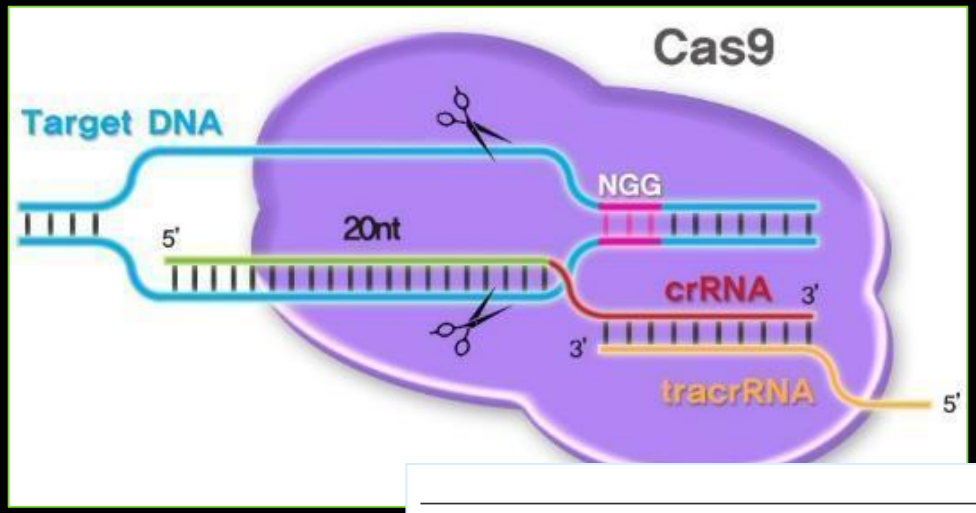
The first human trial to test the efficacy of a genetically modified (GM) nutritionally enhanced banana is starting in the US. Conceived by researchers at the Queensland University of Technology (QUT) in Brisbane, Australia, to provide a good source of beta carotene, the Super Banana has $10 million in backing from the Bill and Melinda Gates Foundation. The genetically enriched, golden-colored banana may help prevent blindness caused by vitamin A deficiency in Ugandan children whose diets are deficient in this nutrient (*Nat. Biotechnol.* **30**, 1017–1019, 2012). But leaders of the banana project are embarking on a historically precarious path. Golden Rice, the previous GM crop developed to alleviate vitamin A deficiency in the poor, met fierce hostility and regulatory hurdles that have plagued its development for 15 years. The rice still hasn't been commercialized in its target country, the Philippines. Whether the banana will meet a similar fate remains to be seen.

Opposition from anti-biotech activists in the media so far has been minimal, and radical activist presence in Uganda and other African countries is generally small. “I don't have the feel-

Erika Fish, QUT

But is it golden? Stephen Buah (left) and James Dale, from Queensland University of Technology, display the Super Banana.

Coming: Gene editing technology for diverse traits – is it biotech or breeding?



CRISPRs

PLANT BIOTECHNOLOGY

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.

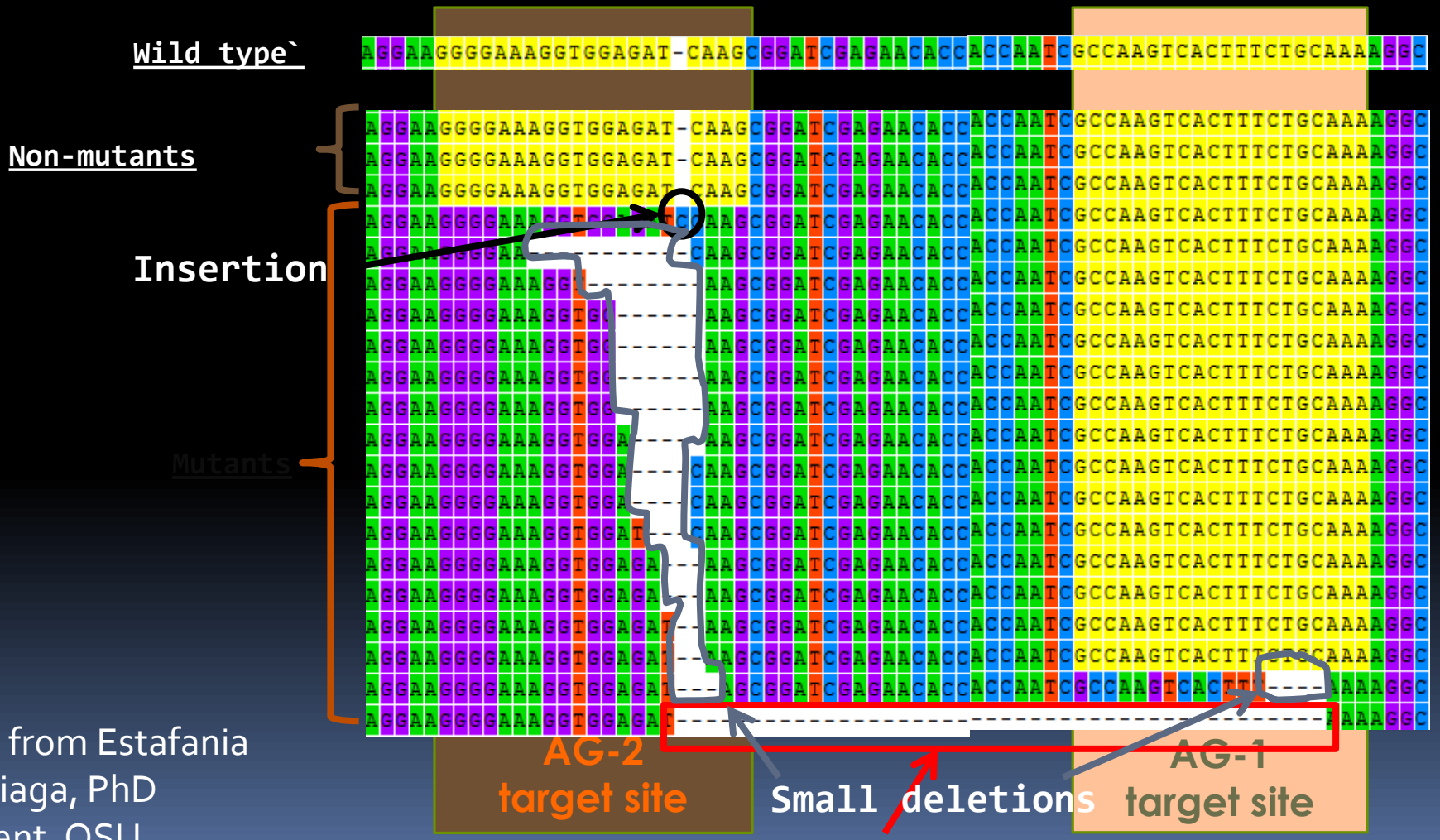
TALENs

NEWS & VIEWS

NATURE|Vol 459|21 May 2009

CRISPRs: Predictable, stable, certain change of DNA sequence

~50% biallelic mutation rate for genes in poplar



Data from Estafania Elorriaga, PhD student, OSU

Gene editing to produce hornless cattle

Open Season Is Seen in Gene Editing of Animals

By AMY HARMON NOV. 26, 2015

A calf, left, approximately the same age as the first two genetically modified c… they do not grow horns, right. Jenn Ackerman for The New York Times

The New York Times

Agenda

- A bit about me
- Broad perspective on GMO issues
- The science: What are and are not GMOs
- Extent of use in the world
- Examples of newer products, pipeline
- Issues in management, public reception

Why the disputes?

Diverse factors

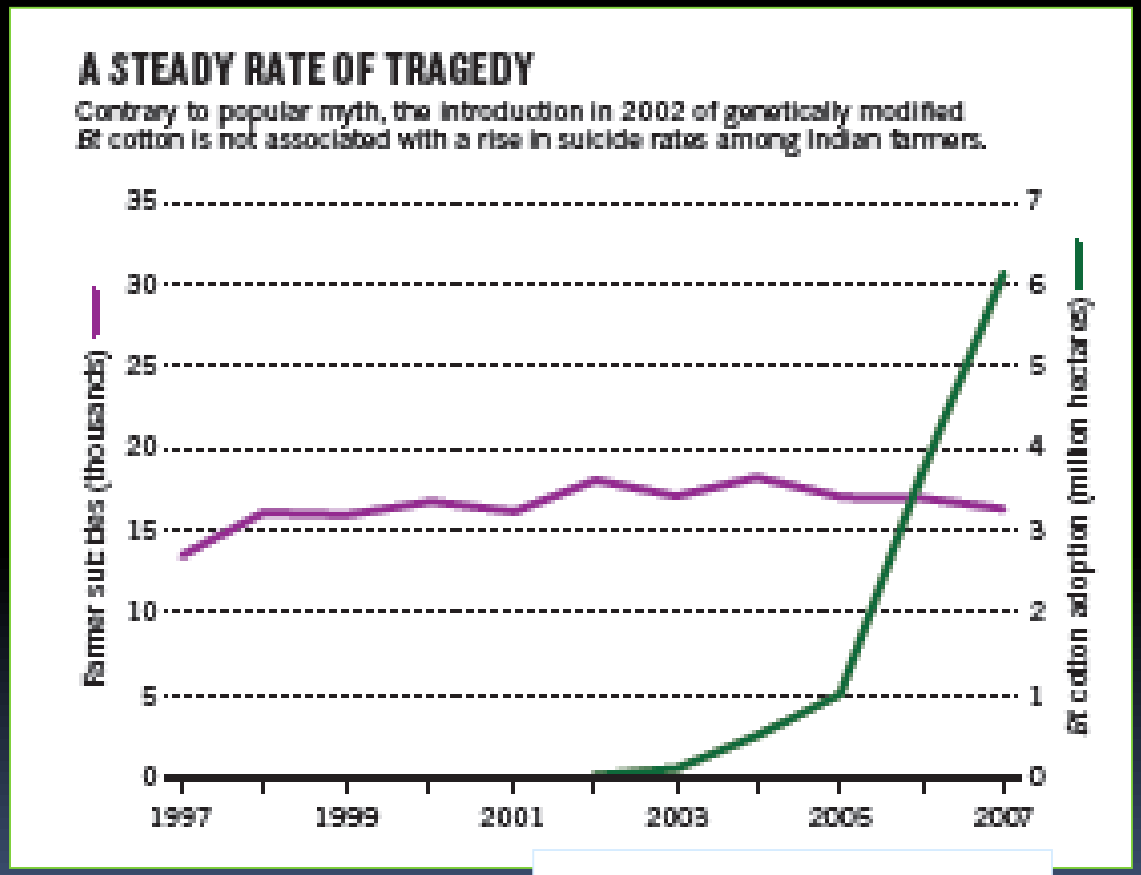
- Human need, new and rapid science
  - Population and consumption growth, food cost, widespread malnutrition, environmental damage
  - Gene science gives many options = technology push
- Ethics
  - Breaking of traditional boundaries in moving genes press concepts of rightness
- Risk perception adverse
  - Complex and invisible science and technology, often without direct consumer benefits = high perception of risk
  - Chemophobia: All pesticide bad, GMOs make worse
- Appropriate regulation unclear
  - Extent of precaution? Regulation stringency?
  - Labeling? Allowances for trade?

Why the dispute, continued

- Strong corporate role: Control of seeds, patents, industrial ag, the “Monsanto effect”
  - Communitarian vs. hierarchic ideologies (Kahan, Yale)
- Ideology, self-interest: Strong anti-GMO business and political forces
  - *Private sector*: Green and organic and “natural” vs. GMO
  - *Local*: Pressure on politicians to oppose, state/county measures
  - *Global*: Tool for state rivalries, non-tariff barriers (China, Russia, EU)
- Science uncertainties: Environment, food safety
- Gene flow: Ag is leaky, gene movement common
  - Coexistence challenges with low biotech tolerances

There are numerous myths that are rampant and recycled in media

Farmer suicides in India and GMO cotton among the most infamous myths promoted by Shiva and others



Monsanto and seed companies "control the food supply" another

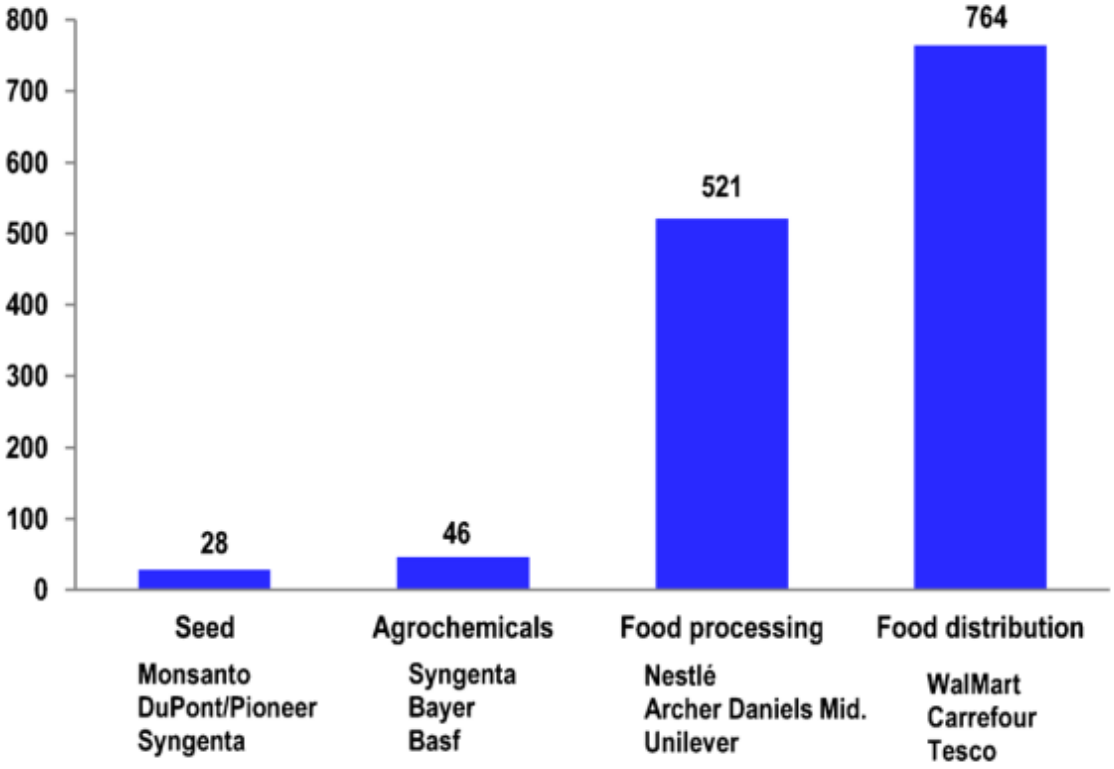


Fig. 1 Global sales of the top ten companies in four sectors: seed, agrochemicals, food processing, and food retailing (in 2012, billion USD). The names of the 3 major groups are indicated for each sector (from Forbes 2013; Supermarket News 2013)

Springer

Bonny, S. (2014), Taking stock of the genetically modified seed sector worldwide: market, stakeholders, and prices, Food Security, pp. 1-16, http://dx.doi.org/10.1007/s12571-014-0357-1 AND http://www.ask-force.org/web/Economics/Bonny-Taking-Stock-GM-Seed-Sector-2014.pdf

Myth: No food safety review of biotech crops

- Of 129 GE crops commercialized in the US 129 have had FDA consultation (2014)

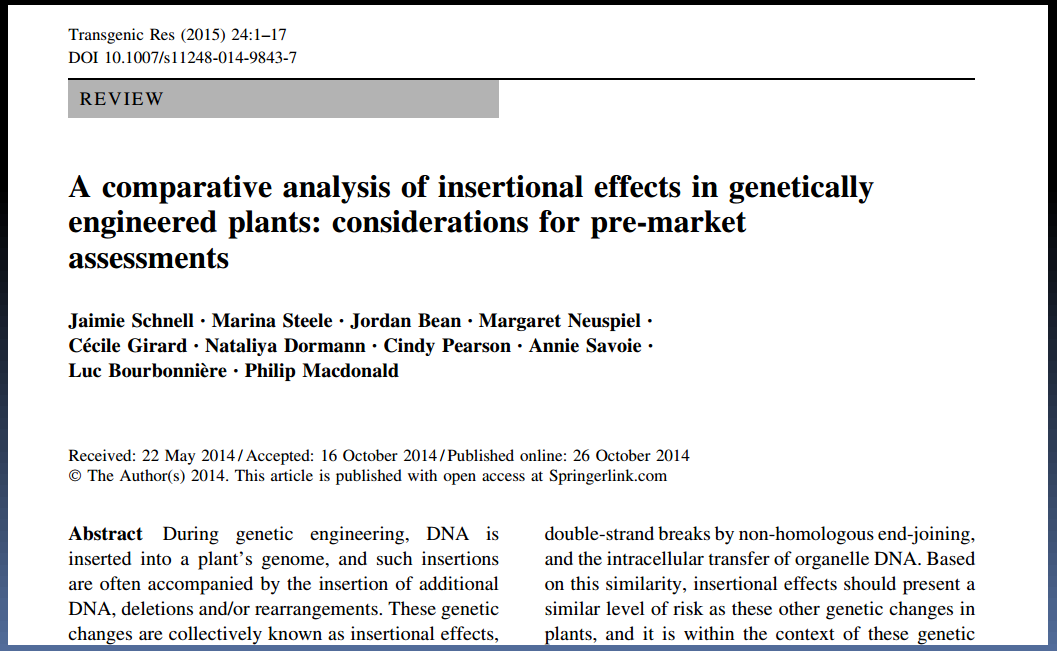
- Global evaluations include: FDA, USDA, EPA, Health Canada, FSANZ, EFSA, Korea FDA, EFSA, Chinese Ministry of Agriculture, Japan Food Safety Commission

Myth: GE method is inherently dangerous and disruptive

FDA, National Academy of Sciences says otherwise

"There is no evidence that unique hazards exist either in the use of rDNA techniques or in the movement of genes between unrelated organisms."

Recent genomic studies have confirmed



Transgenic Res (2015) 24:1–17
DOI 10.1007/s11248-014-9843-7

REVIEW

A comparative analysis of insertional effects in genetically engineered plants: considerations for pre-market assessments

Jaimie Schnell · Marina Steele · Jordan Bean · Margaret Neuspiel · Cécile Girard · Nataliya Dormann · Cindy Pearson · Annie Savoie · Luc Bourbonnière · Philip Macdonald

Received: 22 May 2014 / Accepted: 16 October 2014 / Published online: 26 October 2014

Abstract During genetic engineering, DNA is inserted into a plant's genome, and such insertions are often accompanied by the insertion of additional DNA, deletions and/or rearrangements. These genetic changes are collectively known as insertional effects, double-strand breaks by non-homologous end-joining, and the intracellular transfer of organelle DNA. Based on this similarity, insertional effects should present a similar level of risk as these other genetic changes in plants, and it is within the context of these genetic

Myth: Big Ag controls the media and public debate about GMOs

Not any more, big money also flows to demonize GMOs and associated ag/food

Agbiotech Info Net
Agribusiness Examiner
ACGA
American Pasturage
APHA
Animal Protection Institute
Consumers Union
Crop Choice
David Suzuki Foundation
Dawn Watch
Deep Ecology
Eco-Trust
Economic Democracy
Earth Spirit
Earth First
Environmental Defense
Environmental Media Services
FAIR
Family Farm Defenders
Farm Animal Reform Movement
Farm Aid
Farm Sanctuary
Friends of the Earth
GRACE
Government Accountability Project
Nishoren
No Spray coalition
NWARN
Organic Consumers Association
PANNA
PETA
PCRM
PIRG
Public Citizen
Purdey Fund
Sierra Club
SEAC
Water Keeper Alliance

More than 500 activist organizations in North America are spending in excess of $2 billion annually engaging in food-related campaigns targeting biotech and many other elements

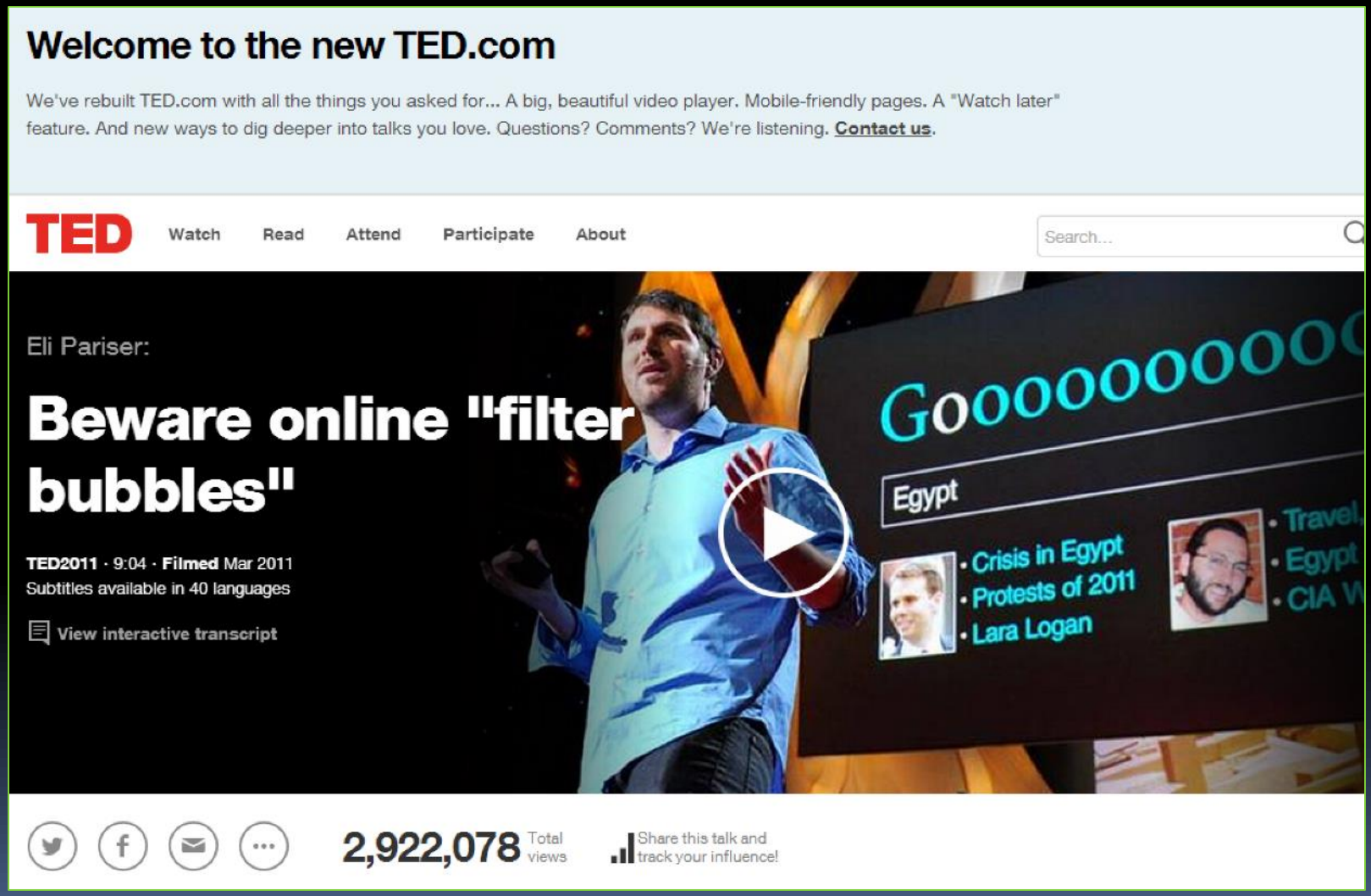
Jay Byrne, 2012, V-fluence

Internet, social media, a main focus of activism

Science selected, distorted, mass communicated, amplified

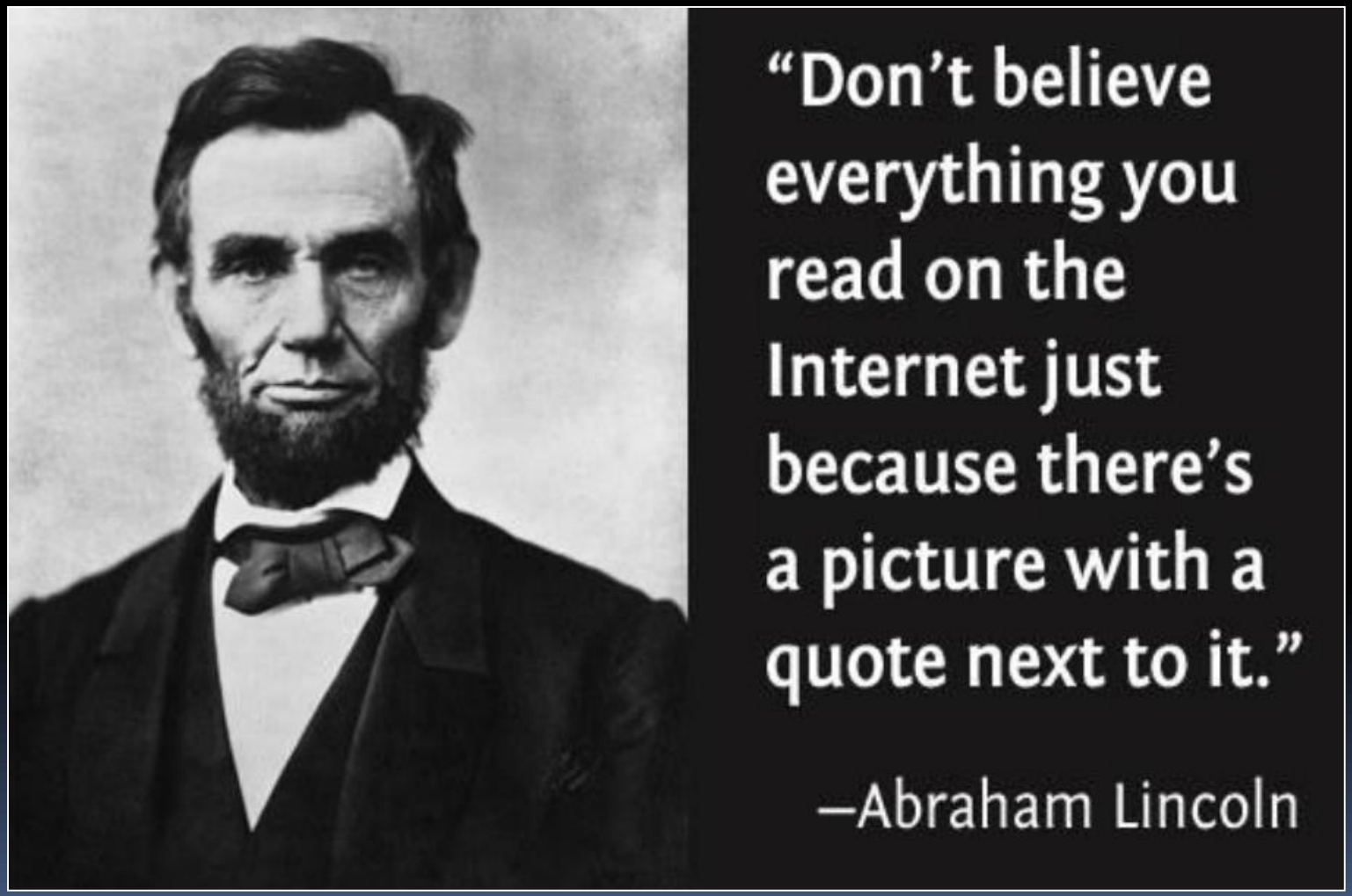
for ideology, and increasingly for financial gain

Pervasive online filters of information entrench



https://www.ted.com/talks/eli_pariser_beware_online_filter_bubbles

Abe Lincoln warned us, but….



http://weknowmemes.com/2012/07/dont-believe-everything-you-read-on-the-internet

Chipotle campaign a prominent example

careers gift cards

MENU NUTRITION FOOD WITH INTEGRITY WHAT'S HAPPENING CATERING TALK TO US LOCATIONS ORDER NOW

FOOD WITH INTEGRITY

G-M-OVER IT

WHEN IT CO

Chipotle is on a never-
years, as we have lear
with that vision. Chipot
our food, and now we

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the salt WHAT'S ON YOUR PLATE

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Chipotle's flashy ban on GMOs is totally backfiring

Ashley Lutz

May 6, 2015, 10:52 AM 40,777 78

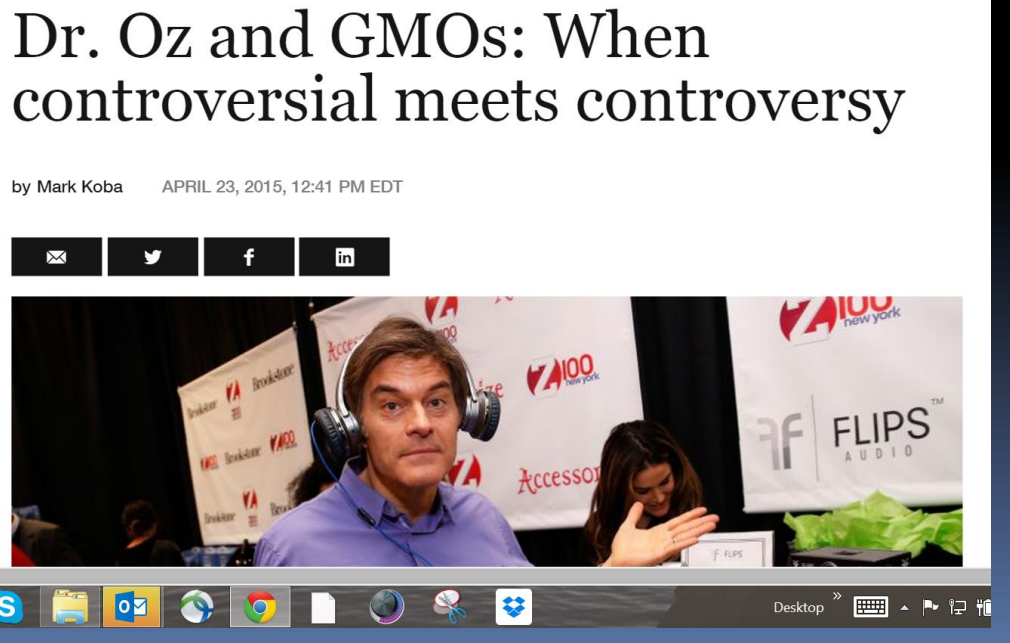
food for thought

Why We Can't Take Chipotle's GMO Announcement All That Seriously

APRIL 30, 2015 3:09 PM ET

DAN CHARLES

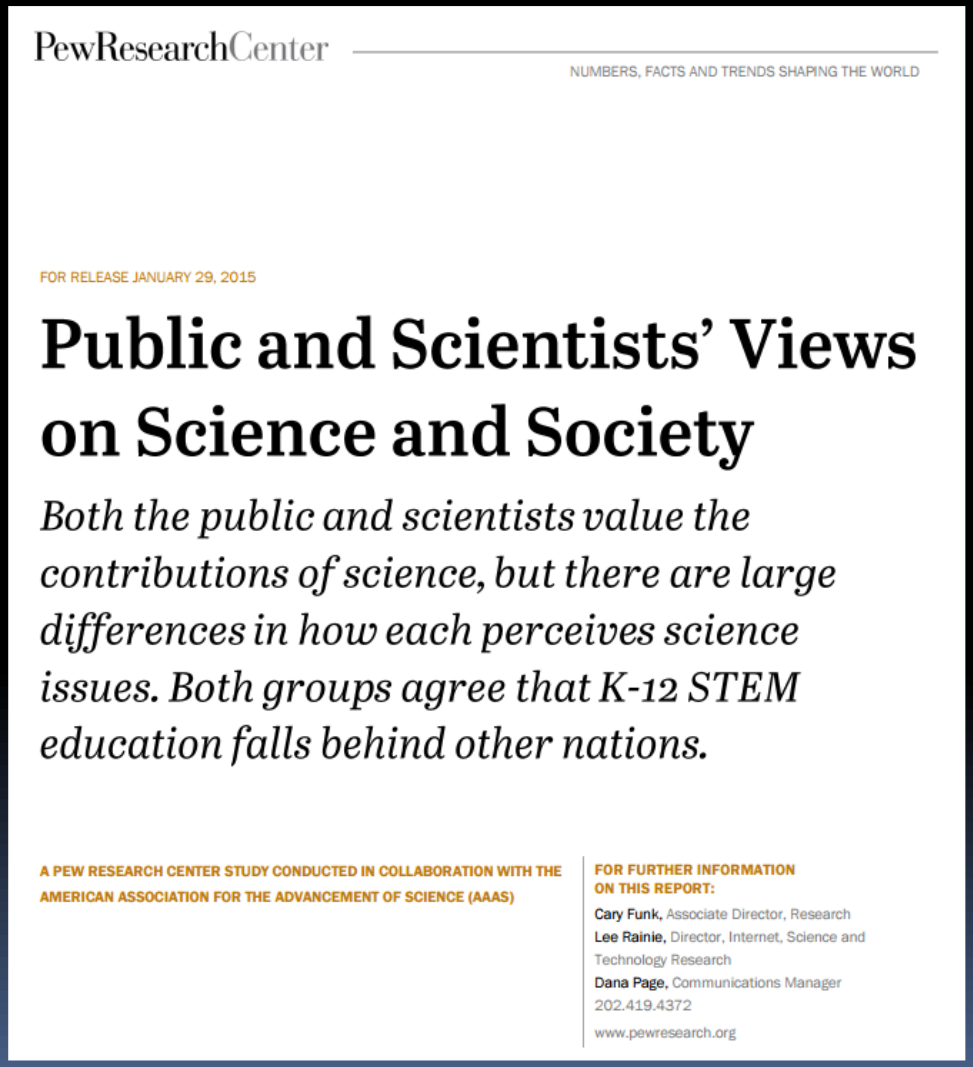
And many others



Corporate speech also through no-GMO labels

Ubiquitous labels reinforce notion that GMOs, as a class, are dangerous

It is not surprising how much scientists and the public differ in views of GMOs



PewResearchCenter

NUMBERS, FACTS AND TRENDS SHAPING THE WORLD

FOR RELEASE JANUARY 29, 2015

Public and Scientists' Views on Science and Society

Both the public and scientists value the contributions of science, but there are large differences in how each perceives science issues. Both groups agree that K-12 STEM education falls behind other nations.

A PEW RESEARCH CENTER STUDY CONDUCTED IN COLLABORATION WITH THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE (AAAS)

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202.419.4372
www.pewresearch.org

http://www.pewinternet.org/2015/01/29/public-and-scientists-views-on-science-and-society/

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PUBLICATIONS | TOPICS | PRESENTATIONS | INTERACTIVES | KEY INDICATORS

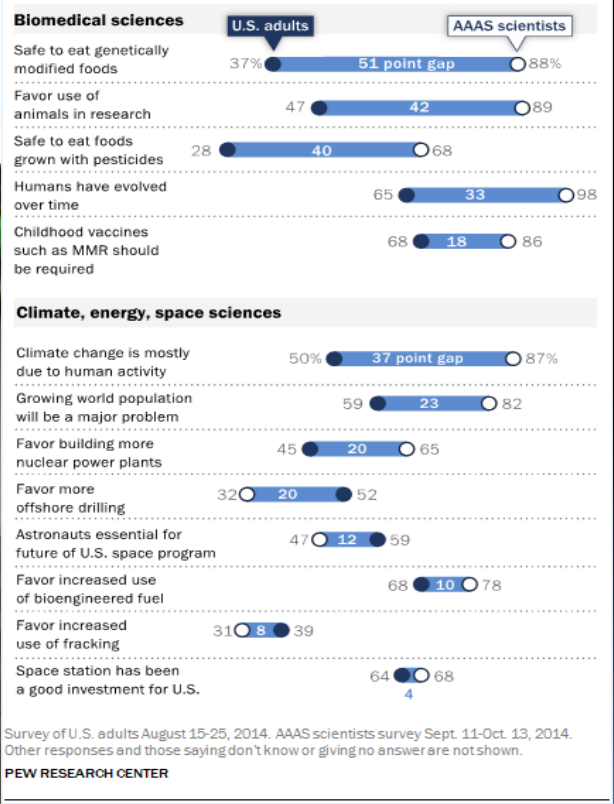
JANUARY 28, 2015

PUBLIC AND SCIENTISTS' VIEWS ON SCIENCE AND SOCIETY

88% of AAAS scientists say genetically modified foods are safe to eat; only 37% of the public agrees

Opinion Differences Between Public and Scientists

% of U.S. adults and AAAS scientists saying each of the following



Survey of U.S. adults August 15-25, 2014. AAAS scientists survey Sept. 11-Oct. 13, 2014. Other responses and those saying don't know or giving no answer are not shown.

PEW RESEARCH CENTER

http://www.pewinternet.org/2015/01/29/public-and-scientists-views-on-science-and-society/

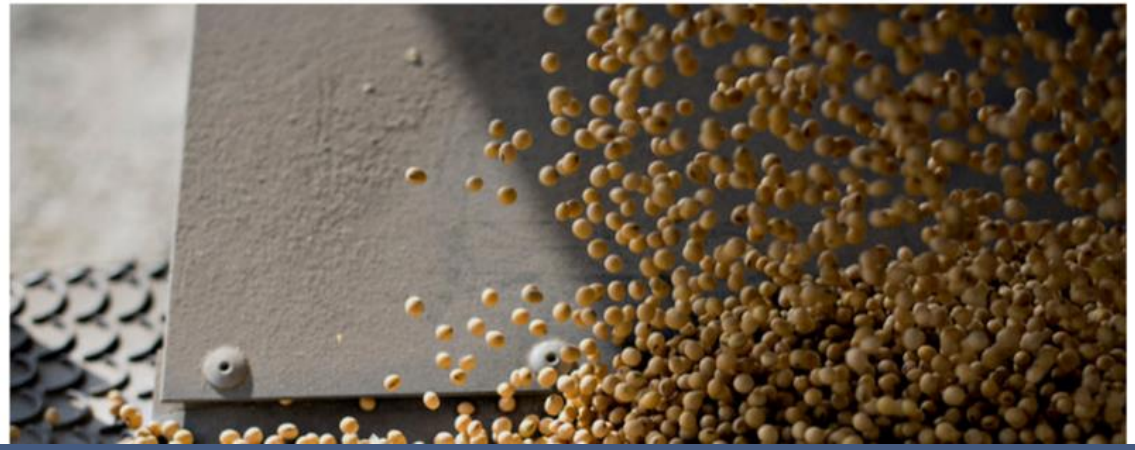
FOIAs a new tool in GMO related wars, changing the relationship of academics who engage in outreach and industry?

The New York Times

U.S.

Food Industry Enlisted Academics in G.M.O. Lobbying War, Emails Show

By ERIC LIPTON SEPT. 5, 2015



There are legitimate concerns that GMOs with pest management traits have not been managed well

THE TROUBLE WITH GMOs

AGAINST MY BETTER JUDGMENT, I'm dipping my toe into the genetically modified organism debate.

These are rough waters. GMOs seem to polarize people more than almost anything else — especially in terms of whether they are safe to eat or to grow. I try to stay open-minded on the topic, but it's obvious that the use of GMOs in agriculture has created some big problems.

The problem facing GMOs isn't with the technology per se; it's with how they have been deployed. Despite promises of improved food security, increased yields, decreased chemical use and more nutritious crops, GMOs end up causing many disappointing failures.

To begin, while GMO efforts may have started with good intentions to improve food security, they ended up focusing on crops that are better at improving profits, such as feed corn (mostly for animal feed and ethanol), soybeans (mostly for animal feed), cotton and canola. While the technology might have "worked," it wasn't applied to crops that actually feed the world's poor.

Furthermore, GMOs have had uneven success in boosting yields. Instead of improving plant growth, they have mainly replaced GMO crops, this was apparently more than offset by an increase in *herbicide* use on U.S. croplands, likely because weeds have become resistant to Roundup. Here there seems to have been a lack of systems thinking — which would have anticipated the "rebound" problems inherent in chemical weed control.

I also become skeptical when GMO approaches are pursued instead of simpler ways to address the same problem. For example, we hear a lot about biotech crops that are drought tolerant, fix their own nitrogen and so on, but they are a long way from being ready for the real world. Why not focus on agronomic approaches — such as using cover crops, mulching and organic-style techniques — instead, which could yield results *today*? Similarly, instead of engineering better nutrition into crops to make GMOs such as golden rice, why not grow conventional nutrient-rich crops such as fruits and vegetables? Why focus on more technical solutions, where a simple approach might be as (or more) effective?

Finally, many GMO advocates bristle at efforts to require labeling of GMO food because they see "no substantial biological difference" between GMO and traditional crops. Maybe, but that's not the point. It's

thinking, where the focus is on technology and business models, and less on the social and environmental impacts.

I urge GMO advocates to take a step back and think more *holistically* about GMO technologies in the context of the larger systems connecting agriculture, food, culture, people and the environment. I encourage them to build more *interdisciplinary* research teams — with social scientists, ecologists, organic farmers and GMO critics. I suggest supporting more of their work with public funding, to help ensure that social and environmental benefits are put ahead of profits. And I would strongly urge *both* sides of the GMO debate

GMOs have frequently failed to live up to their potential, not because they are inherently flawed, but because

ensia

SPRING 2014 | ENVIRONMENTAL SOLUTIONS IN ACTION

GMOs have frequently failed to live up to their potential, not because they are inherently flawed, but because **they have been poorly deployed into the complex social and environmental contexts of the real world.**

Landscape impacts of concern

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

Additional impacts on other pollinators?

YALE environment360
Opinion, Analysis, Reporting & Debate

01 APR 2013: INTERVIEW

Tracking the Causes of Sharp Decline of the Monarch Butterfly

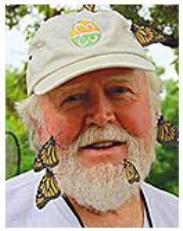
A new census found this winter's population of North American monarch butterflies in Mexico was at the lowest level ever measured. Insect ecologist Orley Taylor talks to Yale Environment 360 about how the planting of genetically modified crops and the resulting use of herbicides has contributed to the 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 59 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.



Monarch Watch/Catherine I Sherman

Orley Taylor

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, Fools, 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 as the

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.

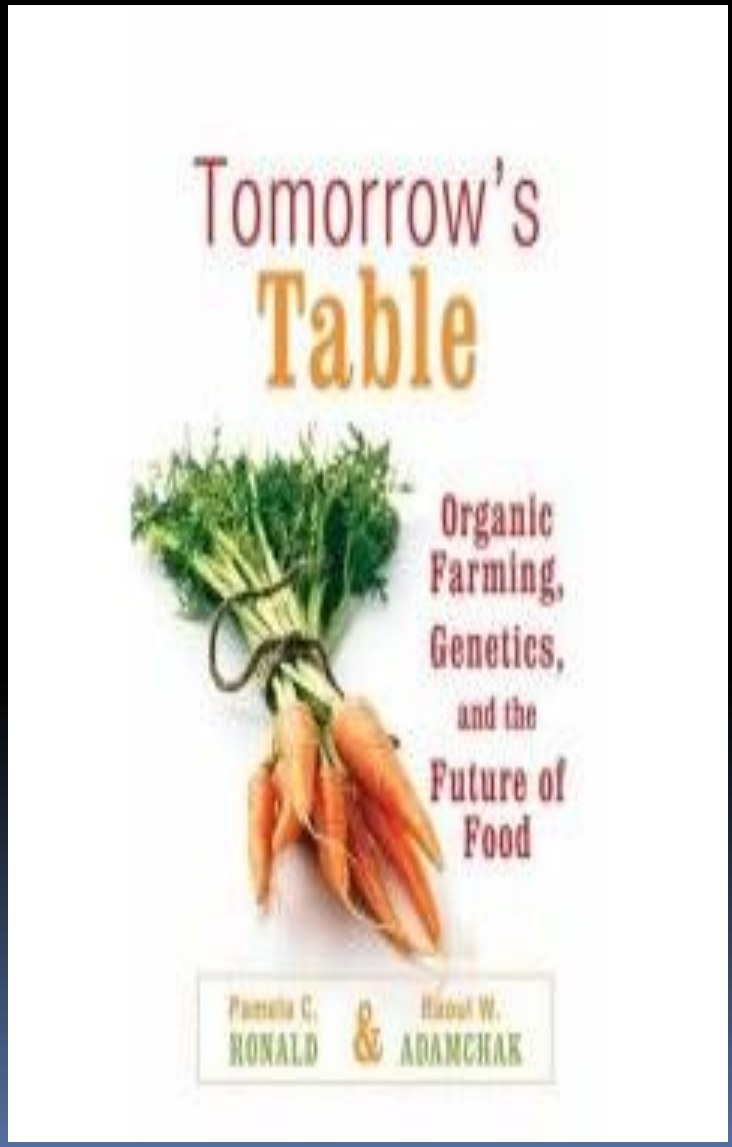
READ MORE

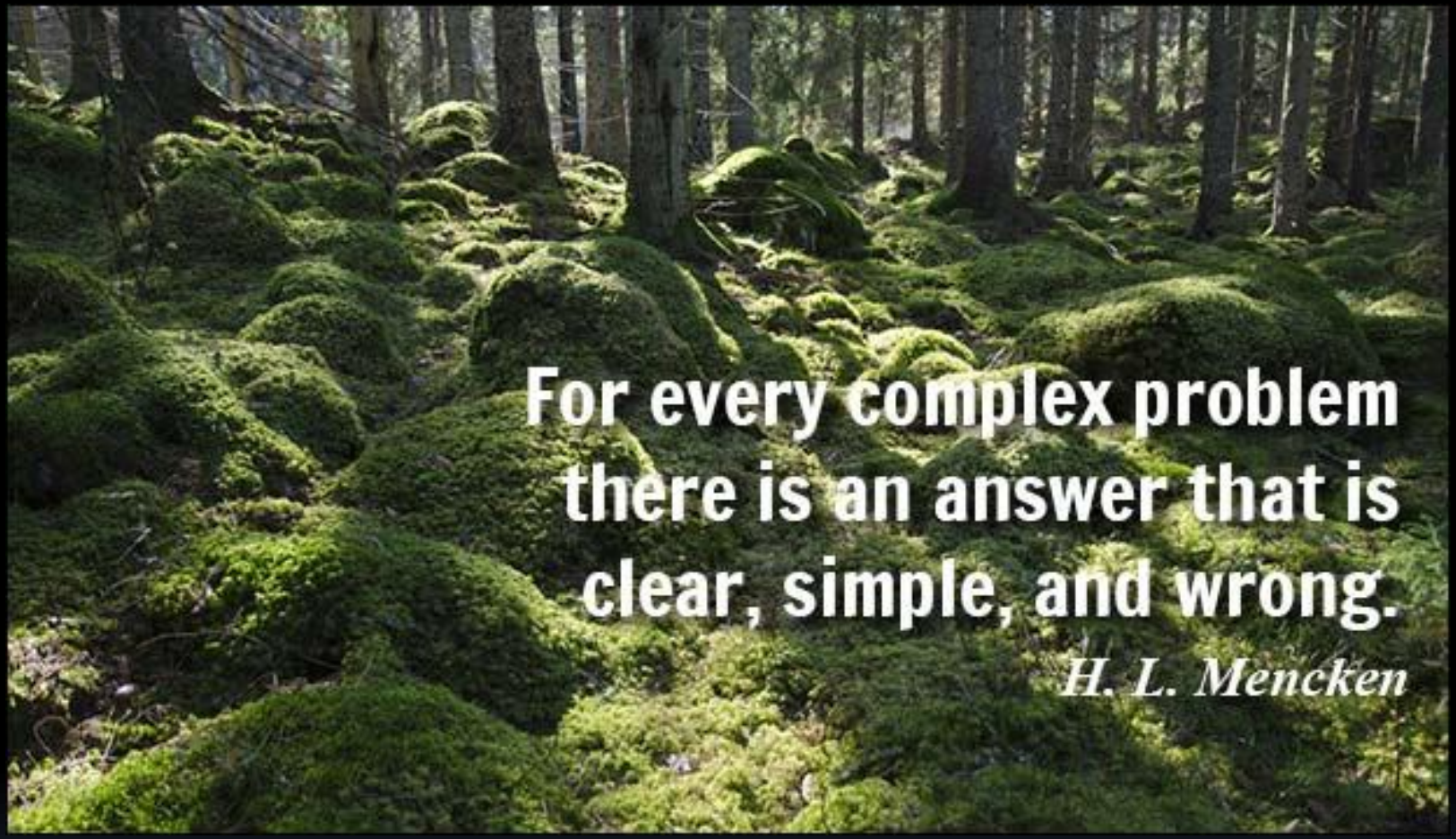
Part of larger discussion of intensification vs. extensification & ecological agriculture

Need to manage ag landscapes smarter

How?

Simple answers abound but seem wrong




For every complex problem
there is an answer that is
clear, simple, and wrong.
H. L. Mencken

In summary

- Majority of major food crops are highly genetically modified from natural forms, moved globally
- A small number of crop and trait types account for majority of GMO crops
  - Soy, corn, cotton, canola / Herbicide and insect resistant
- Wider variety of crop types slowly entering marketplace
  - Disease and pest resistance / Quality and nutrition traits
- More precise methods for modifying natural genes and gene expression, and creating pest tolerant crops - RNAi and CRISPR
- Difficult reception by public due to many factors
  - Perhaps most prominent are ideological, political, and profit motivated anti-GMO campaigns (online and labeling)