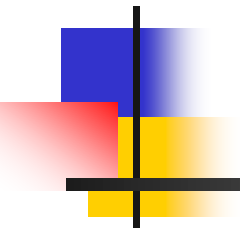
GMO Crops: Scourge or Salvation?

Paul Vincelli
Extension Professor and
Provost's Distinguished Service Professor
University of Kentucky

Thanks to all farmers

Outline

- Introduction
- Herbicide-tolerant crops
- Bt crops
- Other traits
- Issues and concerns
- Use your voice
- Some resources



Introduction

List of all industry funding received for GE work (=GMOs)

Science Literacy Project
c/o Ludwig Business Consultants
100 West Main Street, Suite 420
Lansdale, PA 19446

No. 1061

63-9211/630

DATE 9/7/16

Pay to the order of Paul Vincelli

One Thousand no/100

$ 1000.00

DOLLARS

EverBank

FOR Writer

Rhyllis A Judaj

⑈001061⑈ ⑆063092110⑆ 0760101280⑈

All crops are “genetically modified”

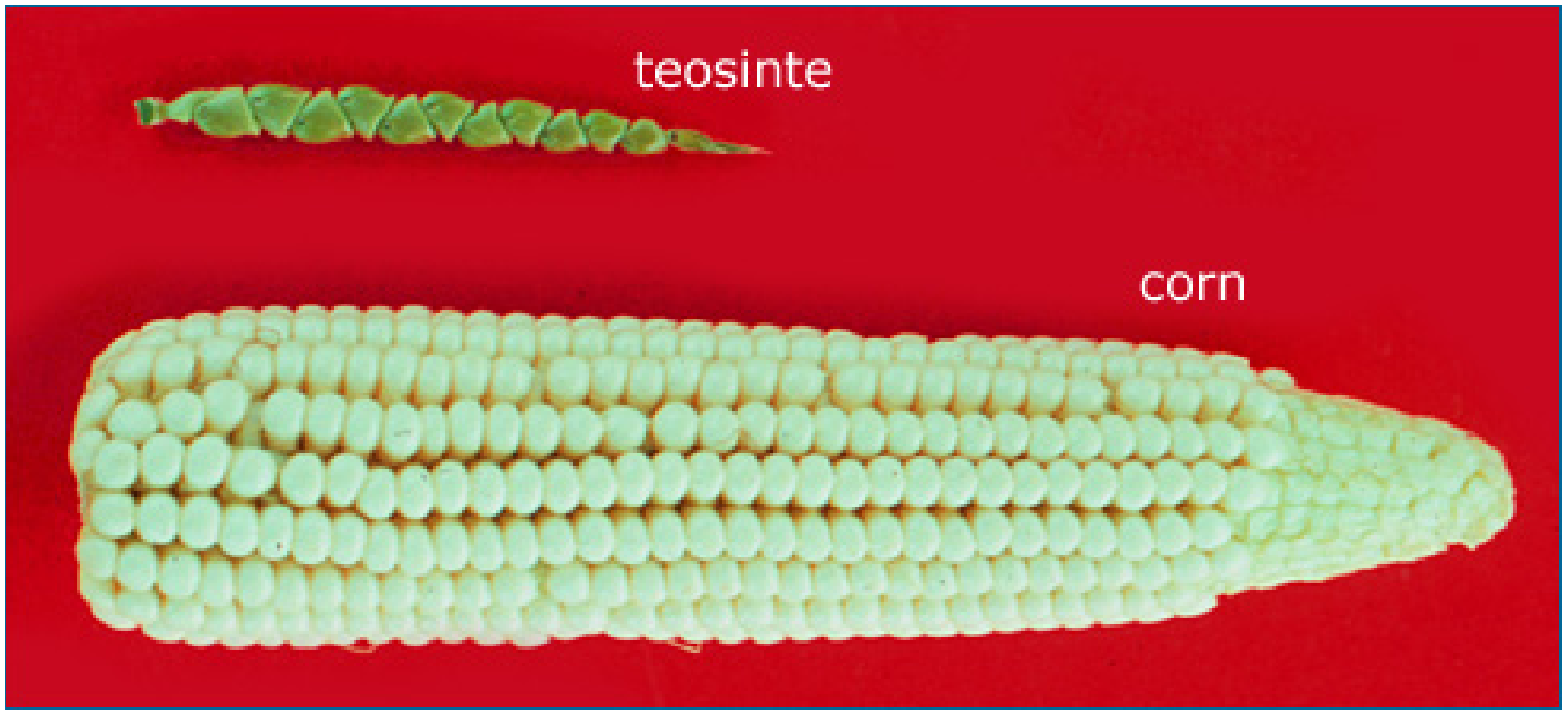
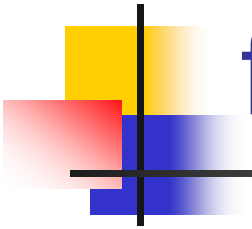


Image from http://evolution.berkeley.edu/evolibrary/news/070201_corn

A gene sequence

http://www.bioinfo-cbs.org/igd/help.php

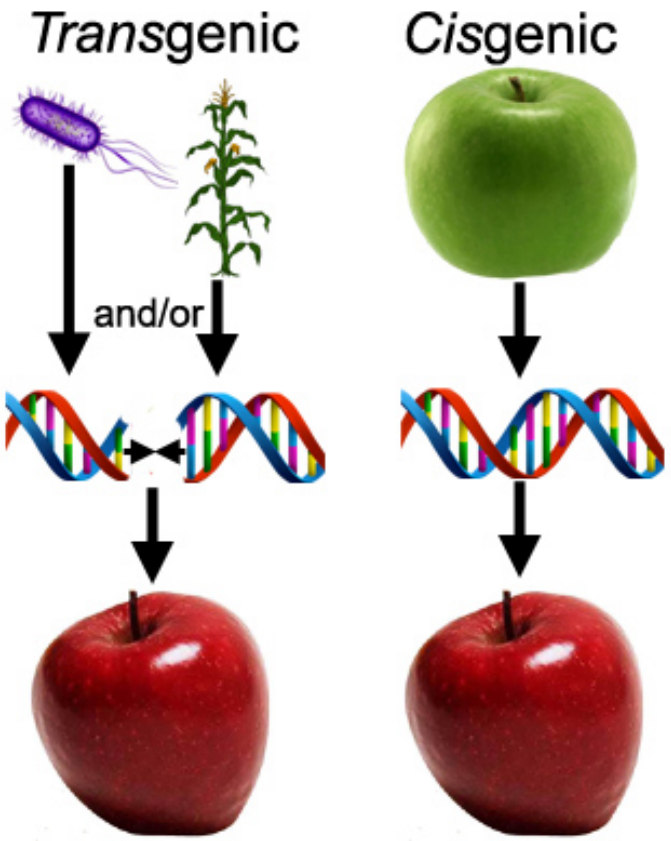
Word processing: a metaphor for genetic engineering



- Genes are sentences composed of letters
- Words don’t hurt us, only the way they are used
- Older techniques: Copy and paste

Genetic engineering is more precise than conventional breeding

Transgenes and cisgenes



http://www.biofortified.org/2013/08/cisgenesis-new-dawn-on-food-production/

Sweet potato, a naturally transgenic crop

At least four bacterial genes

Kyndt et al, 2015. PNAS 5844–5849

Biology Direct

BioMed Central

Research

Open Access

A horizontal gene transfer at the origin of phenylpropanoid metabolism: a key adaptation of plants to land

Giovanni Emiliani[1], Marco Fondi[2], Renato Fani[2] and Simonetta Gribaldo*[3]

Address: [1]Department of Environmental and Forestry Sciences and Technologies, University of Florence, via S. Bonaventura, 13, 50145, Florence, Italy, [2]Department of Evolutionary Biology, University of Florence, via Romana 19, 50125, Florence, Italy and [3]Institut Pasteur, Unité de Biologie Moléculaire du gène chez les Extrêmophiles, 25 rue du Docteur Roux, 75724, Paris Cedex 15, France

Email: Giovanni Emiliani - giovanni.emiliani@unifi.it; Marco Fondi - marco.fondi@unifi.it; Renato Fani - renato.fani@unifi.it; Simonetta Gribaldo* - simonetta.gribaldo@pasteur.fr

* Corresponding author

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Biology Direct 2009, **4**:7 doi:10.1186/1745-6150-4-7

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This article is available from: http://www.biology-direct.com/content/4/1/7

All land plants are naturally transgenic.

We are all naturally transgenic

Crisp *et al. Genome Biology* (2015) 16:50
DOI 10.1186/s13059-015-0607-3

Genome Biology

RESEARCH Open Access

Expression of multiple horizontally acquired genes is a hallmark of both vertebrate and invertebrate genomes

Alastair Crisp[1†], Chiara Boschetti[1†], Malcolm Perry[1,2,3], Alan Tunnacliffe[1*] and Gos Micklem[2,3*]

“Between tens and hundreds of foreign genes are expressed in all the animals we surveyed, including humans.”

established, and is controversial in humans.

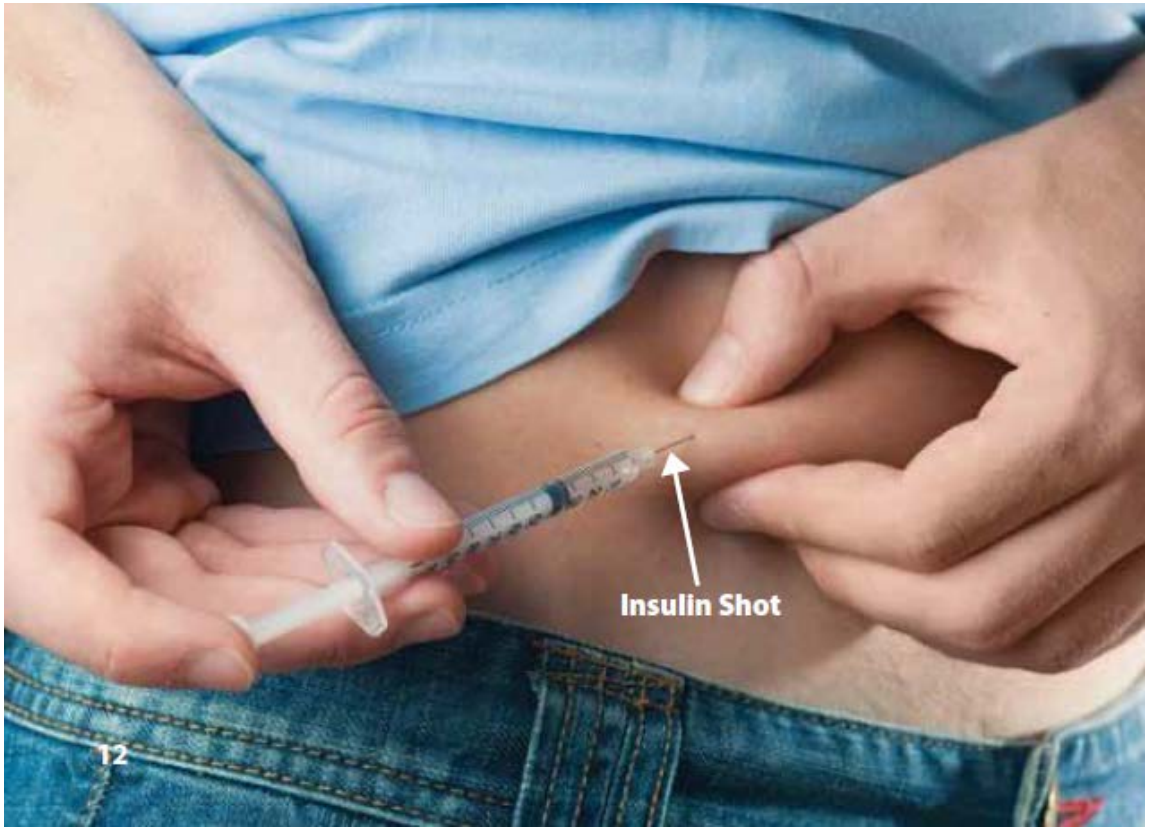
Word processing: a metaphor for genetic engineering

- Genes are sentences composed of letters
- Words don’t hurt us, only the way they are used
- Older techniques: Copy and paste
  - Transgenes and cisgenes
- Latest techniques: modest edits
  - Can emulate Nature

Genome editing (CRISPR)

Wine is made from grape juice.

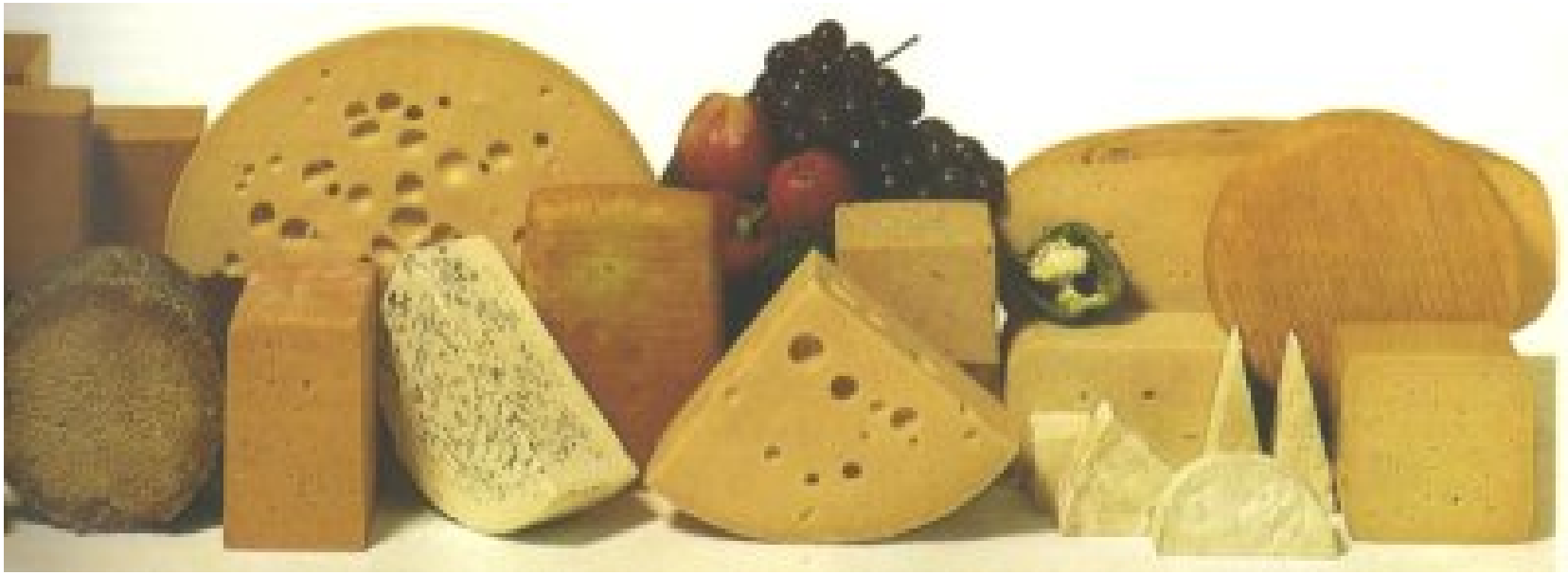
Insulin from GE bacteria



GE vaccine

https://www.linkedin.com/pulse/8836206132291137010, via USA Today, July 2015

Enzymes for cheese from GE yeast



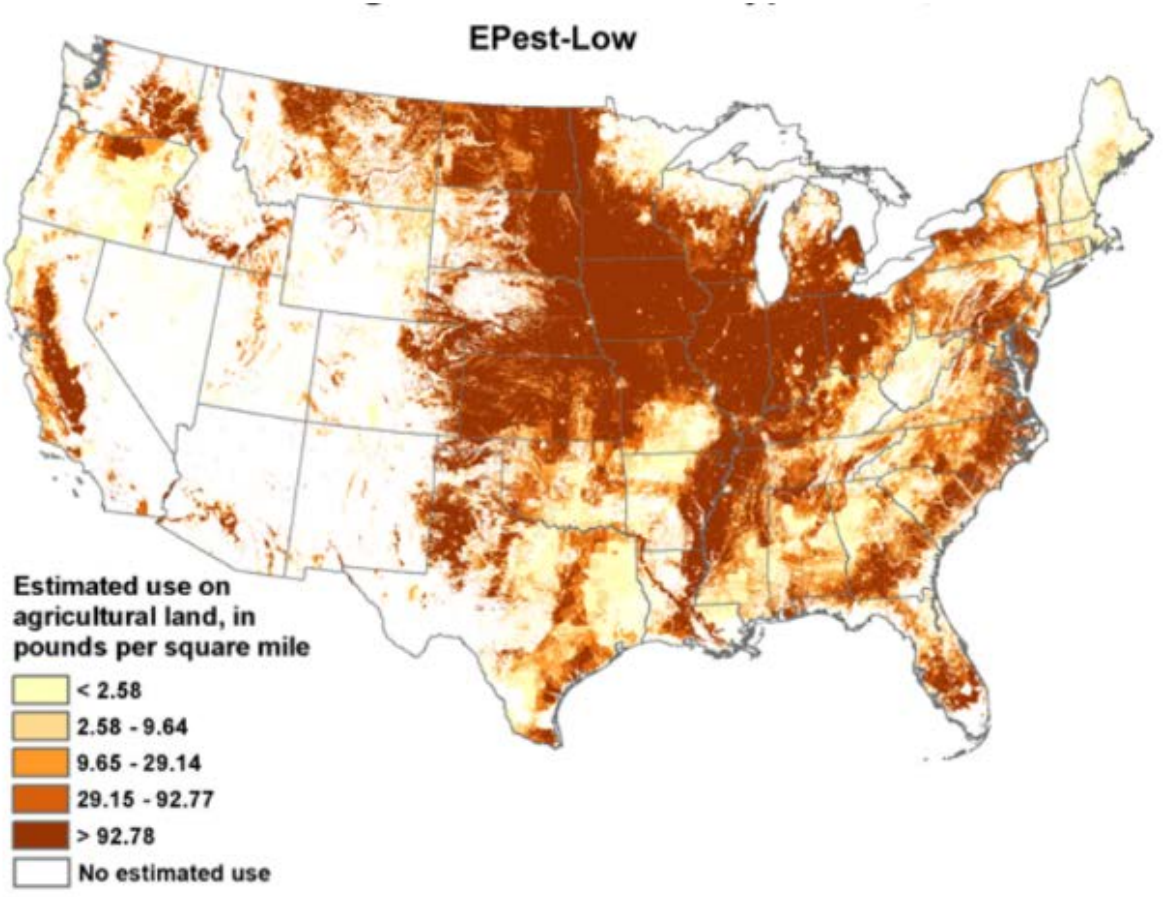
http://arbl.cvmbs.colostate.edu/hbooks/pathphys/digestion/stomach/rennin.html

Herbicide-tolerant crops

Glyphosate-tolerant corn

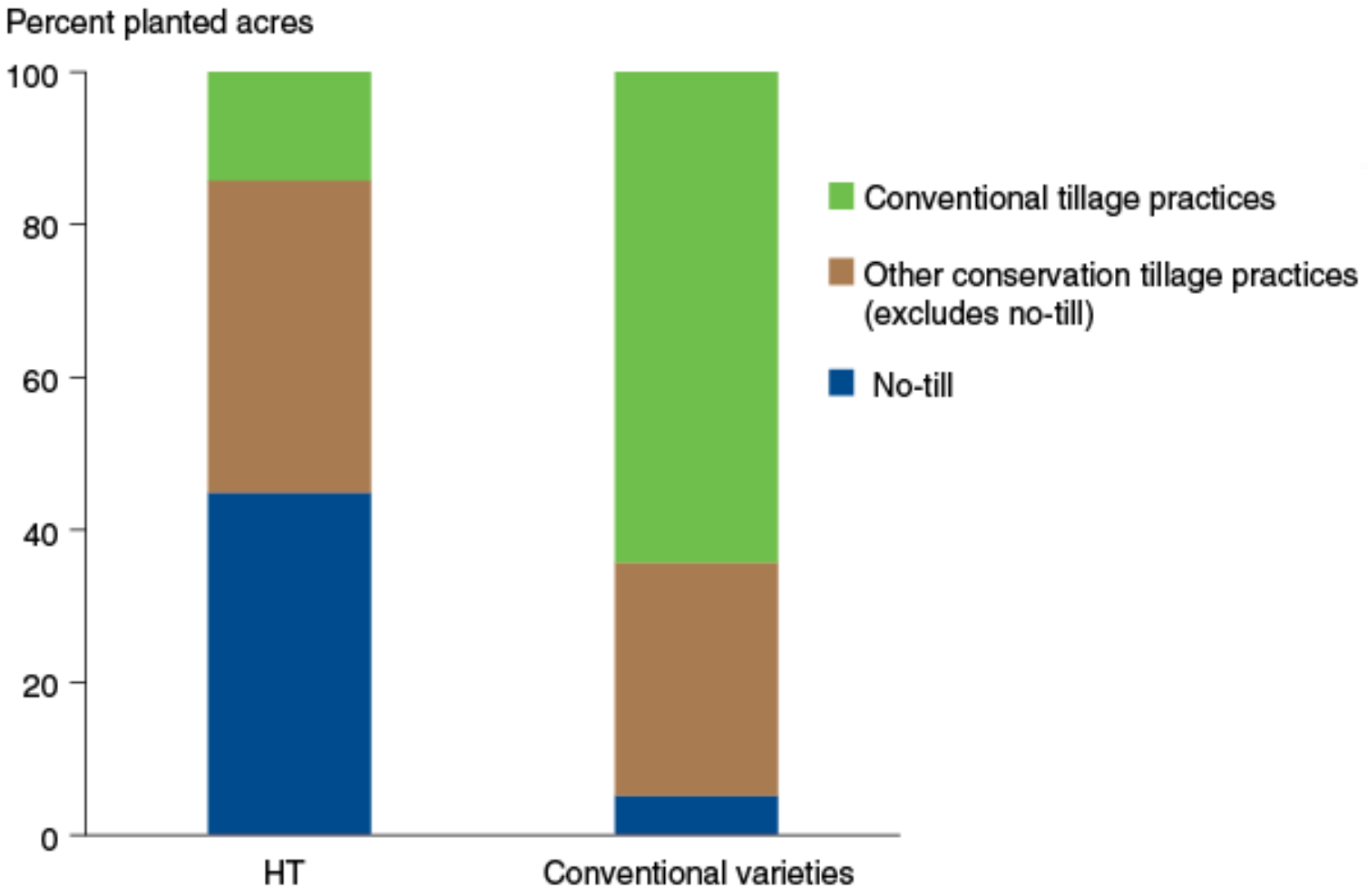
Simple, cheap, and effective

Glyphosate usage, 2011



http://water.usgs.gov/nawqa/pnsp/usage/maps/compound_listing.php

Adopters of HT soybeans had higher rates of adoption of conservation tillage relative to users of conventional varieties, 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.

Imidazolinone-resistant rice (nontransgenic)

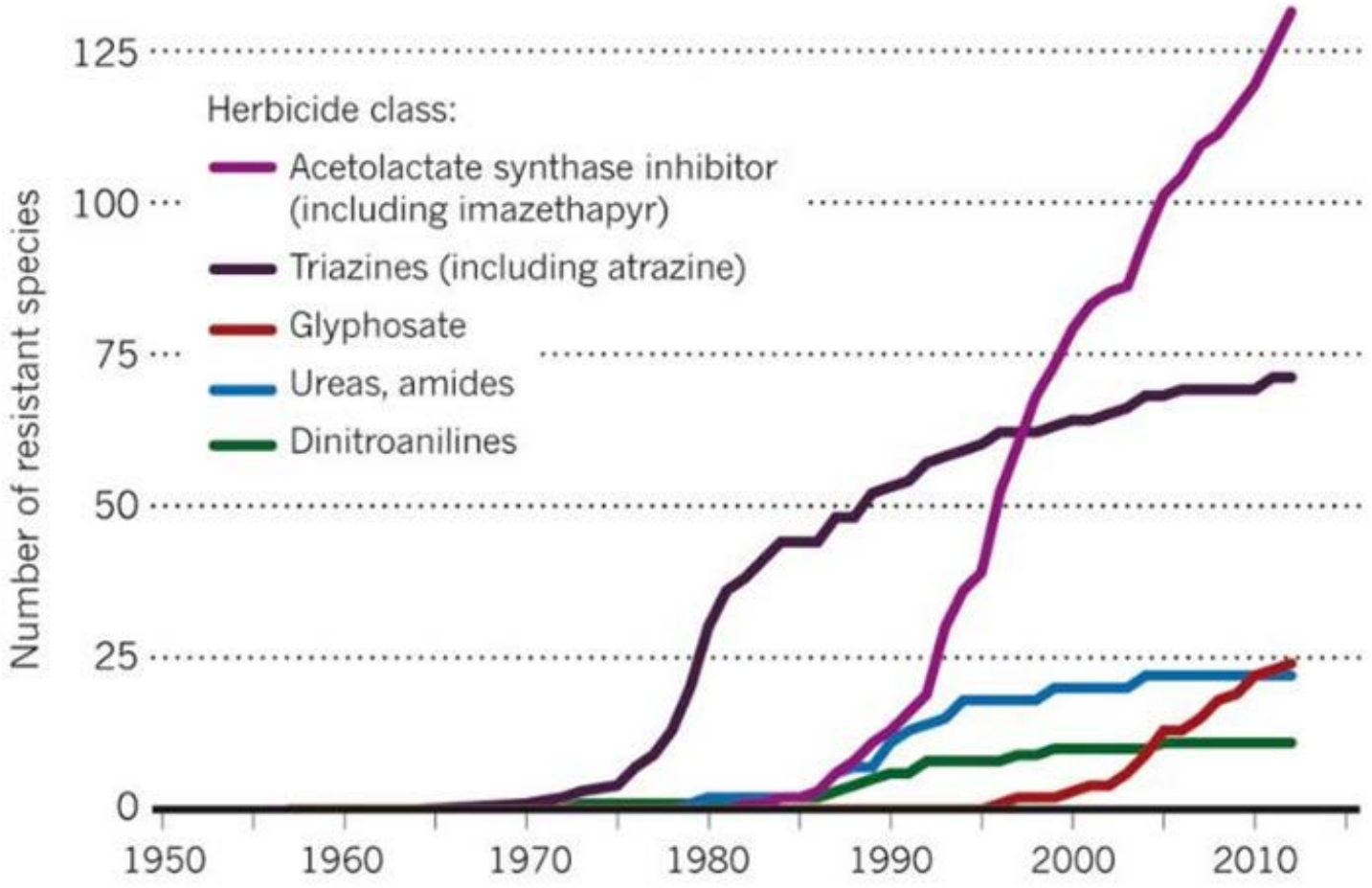
Image from http://edu.basf.us/clearfield/

“Pesticide treadmill”

Alternative herbicide program

Glyphosate-tolerant marestail

Herbicide-resistant weeds



http://www.nature.com/news/case-studies-a-hard-look-at-gm-crops-1.12907

nature International weekly journal of science

NATURE | NEWS: EXPLAINER

Widely used herbicide linked to cancer

As the World Health Organization's research arm declares glyphosate a probable carcinogen, *Nature* looks at the evidence.

Daniel Cressey

24 March 2015

Food and Agriculture Organization of the United Nations

World Health Organization

JOINT FAO/WHO MEETING ON PESTICIDE RESIDUES

Geneva, 9–13 May 2016

SUMMARY REPORT

Issued 16 May 2016

Edited versions of these evaluations and general considerations will be published in the report of the May 2016 JMPR. They are reproduced here so that the information can be disseminated quickly. These drafts are subject to technical editing.

A Joint Meeting of the Food and Agriculture Organization of the United Nations (FAO) Panel of Experts on Pesticide Residues in Food and the Environment and the World Health Organization (WHO) Core Assessment Group on Pesticide Residues (JMPR) was held at WHO Headquarters, Geneva (Switzerland), from 9 to 13 May 2016. Diazinon, glyphosate and malathion were placed on

Glyphosate Issue Paper: Evaluation of Carcinogenic Potential

EPA's Office of Pesticide Programs September 12, 2016

efsa

Published on *European Food Safety Authority* (http://www.efsa.europa.eu)

Home > Glyphosate: EFSA updates toxicological profile

Glyphosate: EFSA updates toxicological profile [1]

News
12 November 2015

EFSA and the EU Member States have finalised the re-assessment of glyphosate, a chemical that is used widely in pesticides. The report concludes that glyphosate is unlikely to pose a carcinogenic hazard to humans and proposes a new safety measure that will tighten the control of glyphosate residues in food. The conclusion will be used by the European Commission in deciding whether or not to keep glyphosate on the EU list of approved active substances, and by EU Member States to re-assess the safety of pesticide products containing glyphosate that are used in their territories.

A peer review expert group made up of EFSA scientists and representatives from risk assessment bodies in EU Member States has set an acute reference dose (ARfD) for glyphosate of 0.5 mg per kg of body weight, the first time such an exposure threshold has been applied to the substance.

Jose Tarazona, head of EFSA's Pesticides Unit, said: "This has been an exhaustive process – a full assessment that has taken into account a wealth of new studies and data. By introducing an acute reference dose we are further tightening the way potential risks from glyphosate will be assessed in the future. Regarding carcinogenicity, it is unlikely that this substance is carcinogenic."

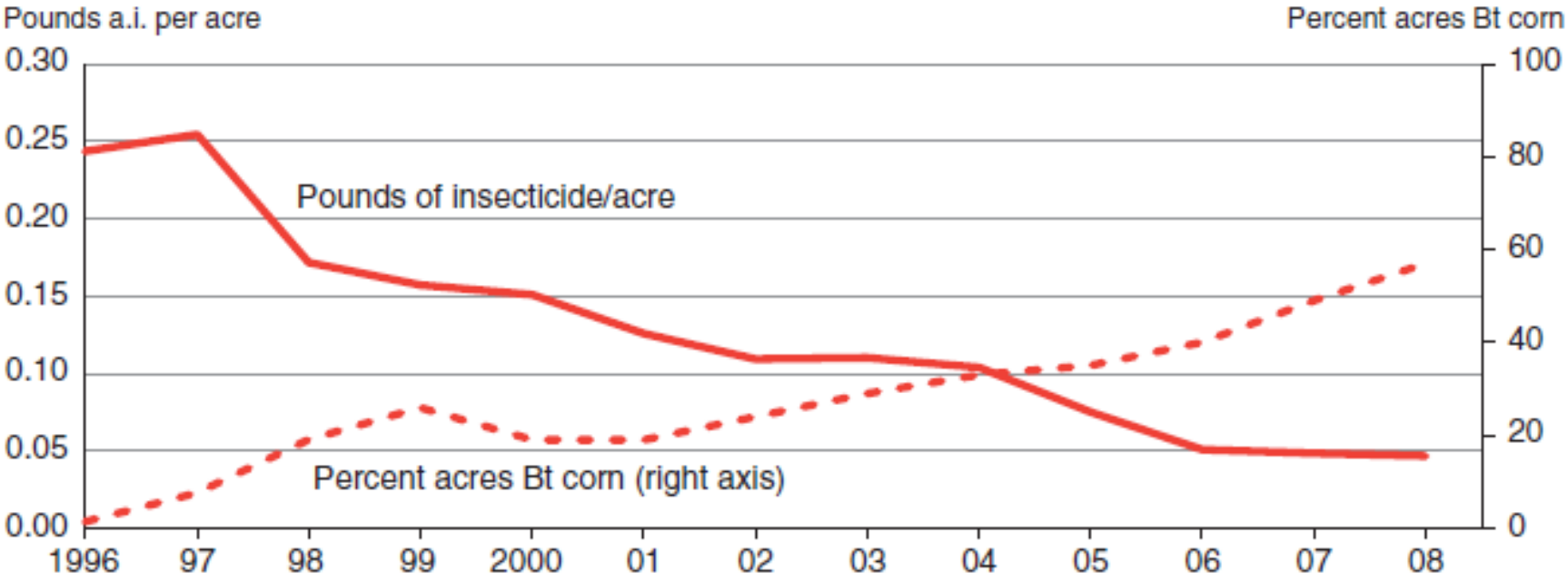
Bt crops


© Society for In Vitro Biology. Photo
by Parrott Lab, UGA

Insecticide use in U.S. corn

Figure 18

Pounds of insecticide active ingredient (a.i.) per planted acre and percent acres of Bt corn, 1996-2008



Fernandez-Cornejo, et al, *Pesticide Use in U.S. Agriculture: 21 Selected Crops, 1960-2008*, EIB-124, U.S. Department of Agriculture, Economic Research Service, May 2014

Poor analysis by the *NY Times*

Doubts About the Promised Bounty of Genetically Modified Crops

By DANNY HAKIM OCT. 29, 2016

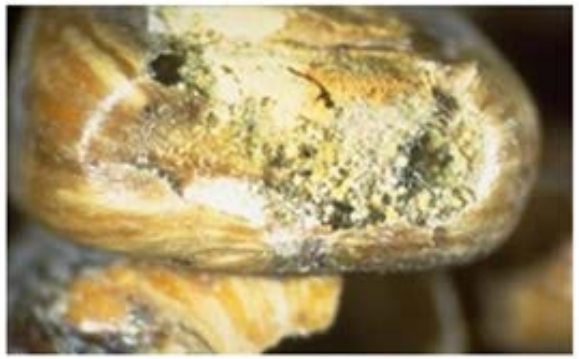
https://www.youtube.com/watch?v=_LoKPldPopU
http://biotecnologiasi.tumblr.com/post/134464391394/

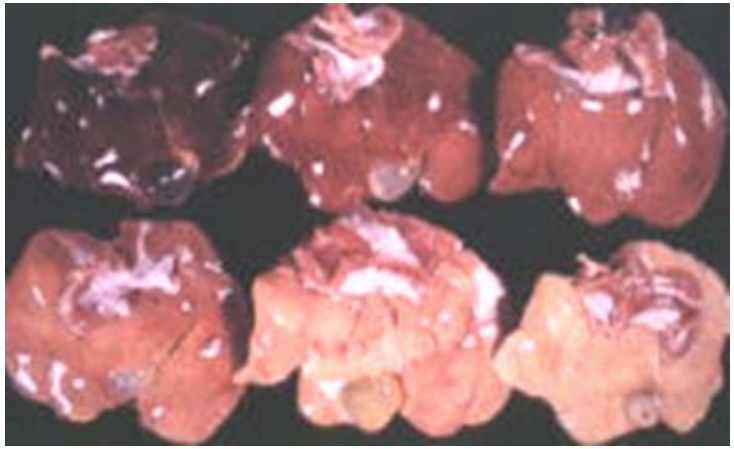
Bt corn

http://www.apsnet.org/publications/apsnetfeatures/Pages/InsectResistantCorn.aspx

Fusarium Fumonisins

Aspergillus, Aflatoxins





Rat livers injected with increasing doses of aflatoxin B1. Upper left = aflatoxin-free control.

http://poisonousplants.ansci.cornell.edu/toxicagents/aflatoxin/aflatoxin.html

Fumonisins: a risk factor for certain birth defects

Parrott, 2010. Genetically Modified Myths and Realities, *New Biotechnology*, p. 545+

Field-evolved resistance by western corn rootworm to multiple *Bacillus thuringiensis* toxins in transgenic maize

Aaron J. Gassmann[1], Jennifer L. Petzold-Maxwell, Eric H. Clifton, Mike W. Dunbar, Amanda M. Hoffmann, David A. Ingber, and Ryan S. Keweshan

Department of Entomology, Iowa State University, Ames, IA 50011

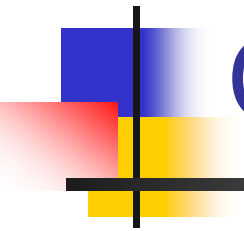
Edited by Charles J. Arntzen, Arizona State University, Tempe, AZ, and approved January 27, 2014 (received for review September 12, 2013)

The widespread planting of crops genetically engineered to produce insecticidal toxins derived from the bacterium *Bacillus thuringiensis* (Bt) places intense selective pressure on pest populations to evolve resistance. Western corn rootworm is a key pest of maize, and in continuous maize fields it is often managed through planting of Bt maize. During 2009 and 2010, fields were identified in Iowa in which western corn rootworm imposed severe injury to maize producing Bt toxin Cry3Bb1. Subsequent bioassays revealed Cry3Bb1 resistance in these populations. Here, we report that, during 2011, injury to Bt maize in the field expanded to include mCry3A maize in addition to Cry3Bb1 maize and that laboratory analysis of western corn rootworm from these fields found resistance to Cry3Bb1 and mCry3A and cross-resistance between these toxins. Resistance to Bt maize

susceptible insects and render resistance a functionally recessive trait (9, 10). None of the currently commercialized Bt maize targeting the western corn rootworm is high dose, so the risk of resistance is increased (11, 12).

In 2003, Cry3Bb1 maize was registered by the United States Environmental Protection Agency (US EPA) for management of western corn rootworm larvae (7). In 2009, farmers in Iowa observed severe injury to Cry3Bb1 maize by larval western corn rootworm in the field, and subsequent laboratory assays revealed that this injury was associated with Cry3Bb1 resistance (13). More fields with Cry3Bb1 resistance were identified in 2010 (14), and research in fields identified in 2009 as harboring Cry3Bb1-resistant western corn rootworm found no difference in survival for this pest between non-Bt maize and Cry3Bb1 maize (11)

www.pnas.org/cgi/doi/10.1073/pnas.1317179111www.pnas.org/cgi/doi/10.1073/pnas.1317179111



Other traits

Papaya ring spot virus damage in Hawaii in 1994

http://www.agbioforum.org/v7n12/v7n12a07-gonsalves.htm

Transgenic papaya resistant to papaya ringspot virus

https://twitter.com/Hec_Martinez/status/462766242693394432/photo/1

Fig. 2. Hawaiian papaya plot in 2011. Hawaiian papaya plot showing diseased, devastated, non-transformed trees in the foreground and healthy transgenic trees behind. [Photo courtesy of Dennis Gonsalves, Agricultural Research Service, U.S. Department of Agriculture, Hawaii]

Dangl et al, 2013. Pivoting the plant immune system from dissection to deployment. Science 341:746

‘Rainbow’ papaya (transgenic) surrounded by ‘Sunrise’ papaya

http://www.agbioforum.org/v7n12/v7n12a07-gonsalves.htm

R gene from pepper triggers disease resistance in tomato

Example of a boom sprayer. (Photo credit: University of Georgia)

Figure 3. Photographs of non-transgenic and Bs2-transgenic VF36 lines in field trials. Top. Plants of the non-transformed VF36 line. Bottom. Plants of the transgenic VF36 line containing the 35S:Bs2 gene. Balm, FL, Spring 2008 Trial.
doi:10.1371/journal.pone.0042036.g003

Transgenic Resistance Confers Effective Field Level Control of Bacterial Spot Disease in Tomato, 2012, PlosOne

Potato late blight control with cisgene

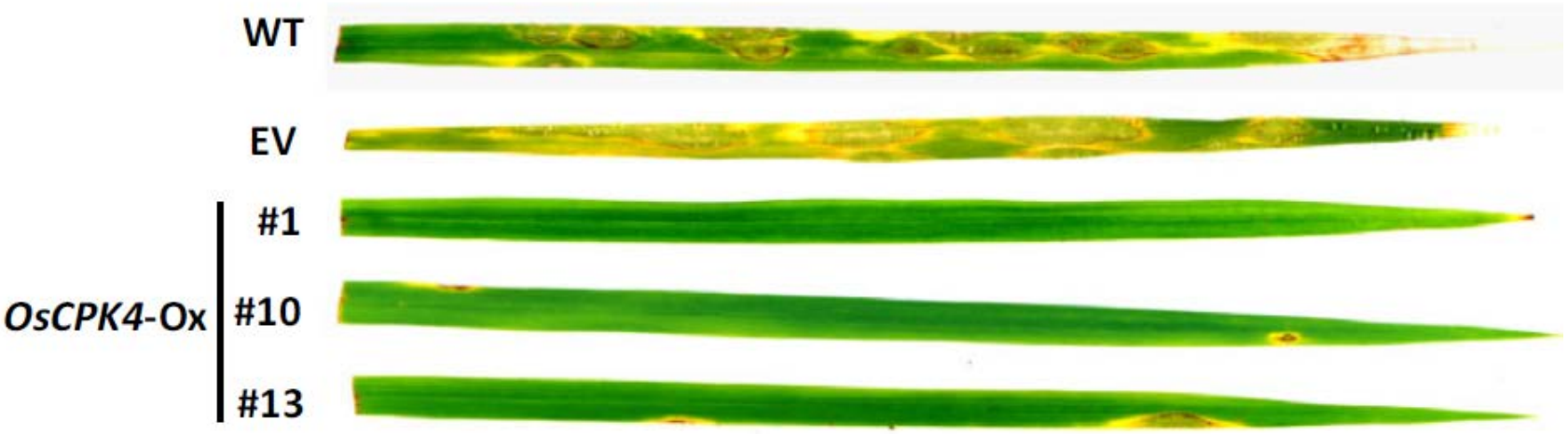
Halterman et al, 2015. Biotech Potatoes in the 21st Century: 20 Years Since the First Biotech Potato. Am. J. Potato Res. DOI 10.1007/s12230-015-9485-1

Rice blast

O.P. Sharma, Bugwood.org

William M. Brown Jr., Bugwood.org

Rice blast: native rice gene coupled with maize promotor



Transformants under the control of ubiquitin-1, a constitutive promotor from maize. Mireia Bundo and Maria Coca. Enhancing blast disease resistance by overexpression of the calcium-dependent protein kinase OsCPK4 in rice. Plant Biotechnology Journal (2015), pp. 1–11

Impact of viruses in African cassava

Left: https://twitter.com/Pvincell/status/363999930349654016
Right: Tuber symptoms consist of dark brown necrotic areas within the tuber. (Leaf symptoms do not necessarily imply the presence of tuber symptoms.) Image copyright J. Legg

Africa: Resistance to cassava viruses

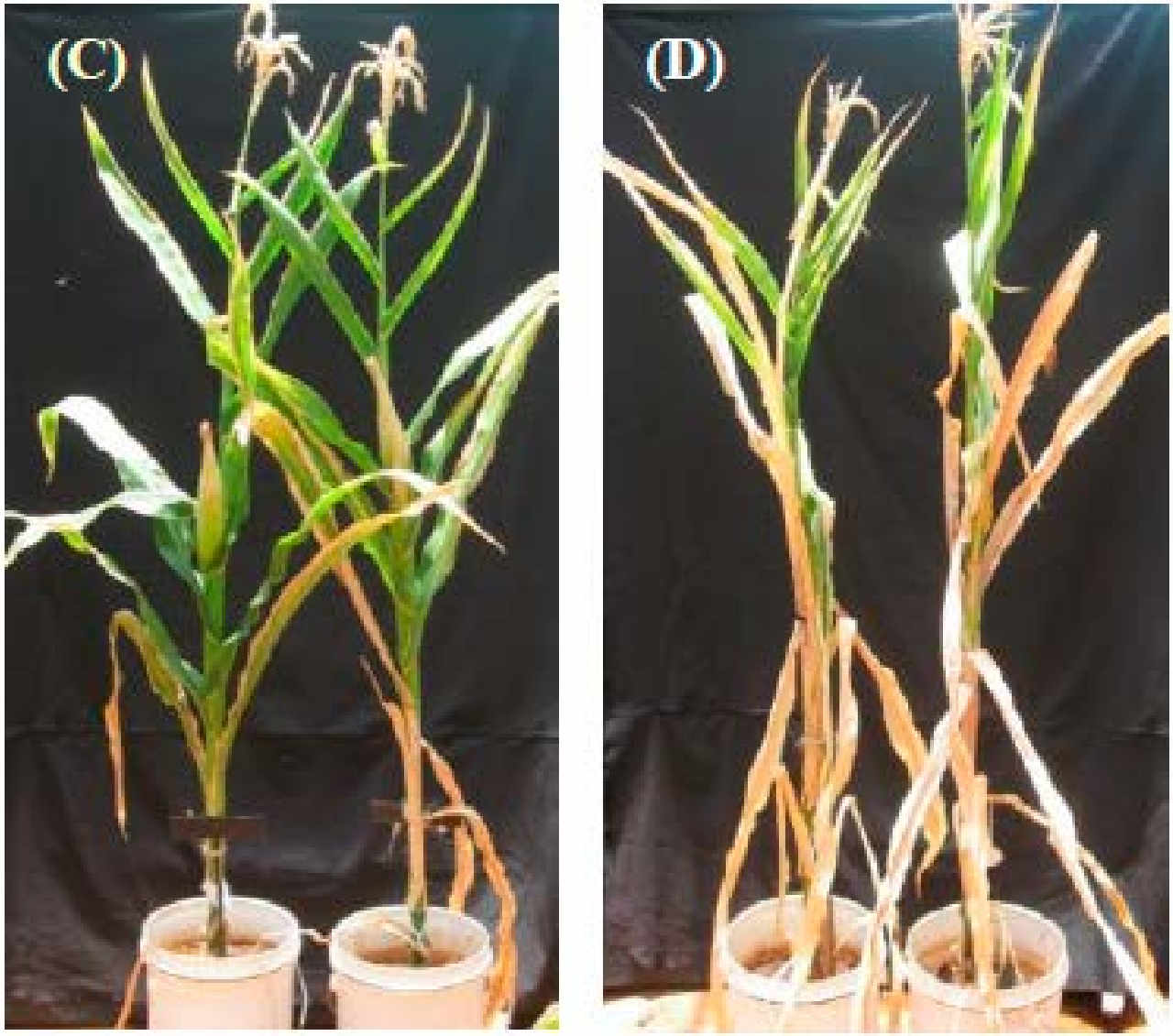
https://twitter.com/mark_lynas/status/362877275470962688/photo/1

US-AID and the Bill and Melinda Gates Foundation are funding cassava virus work

P_{SARK}::*IPTCML21*

Wild

Two months after drought



Bedada et al, 2016. Drought tolerant tropical maize (*Zea mays* L.) developed through genetic transformation with isopentenyltransferase gene. DOI: 10.5897/AJB2016.15228

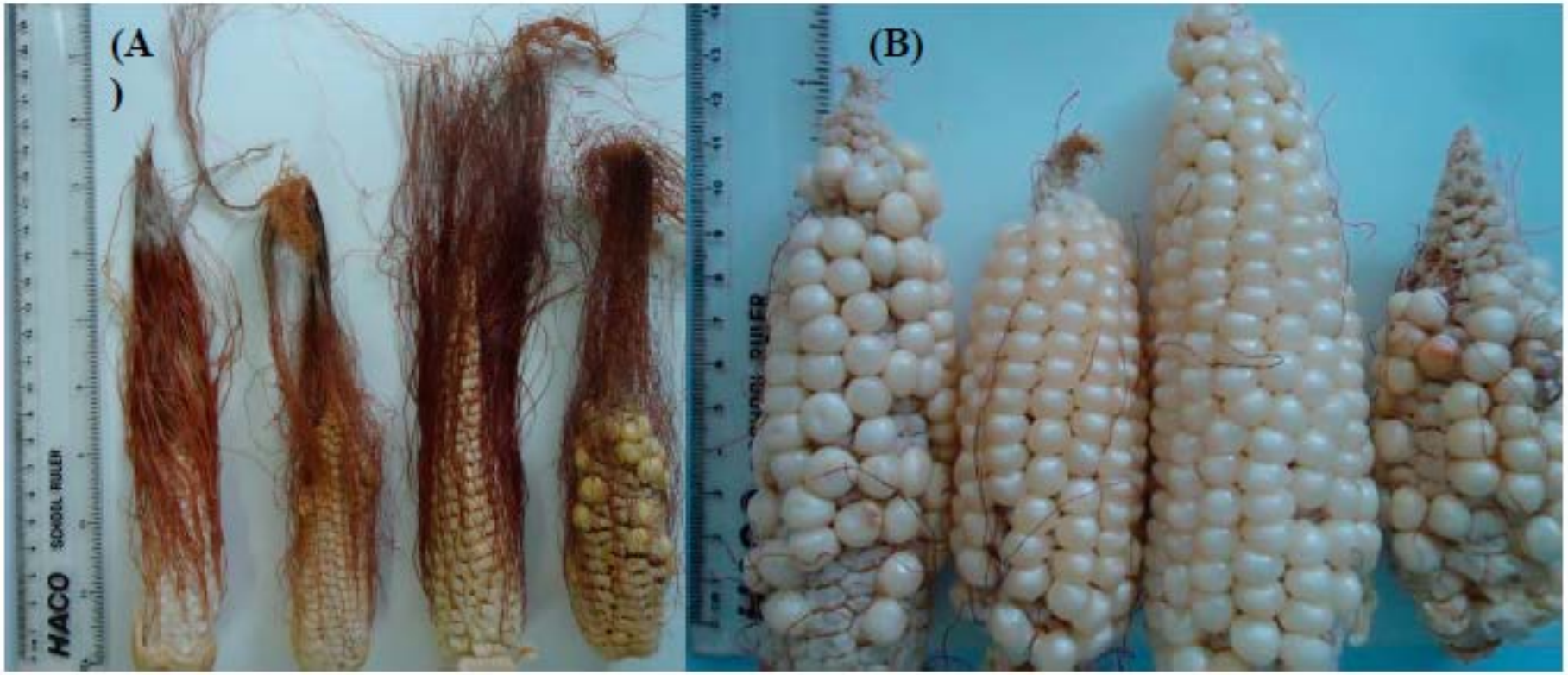
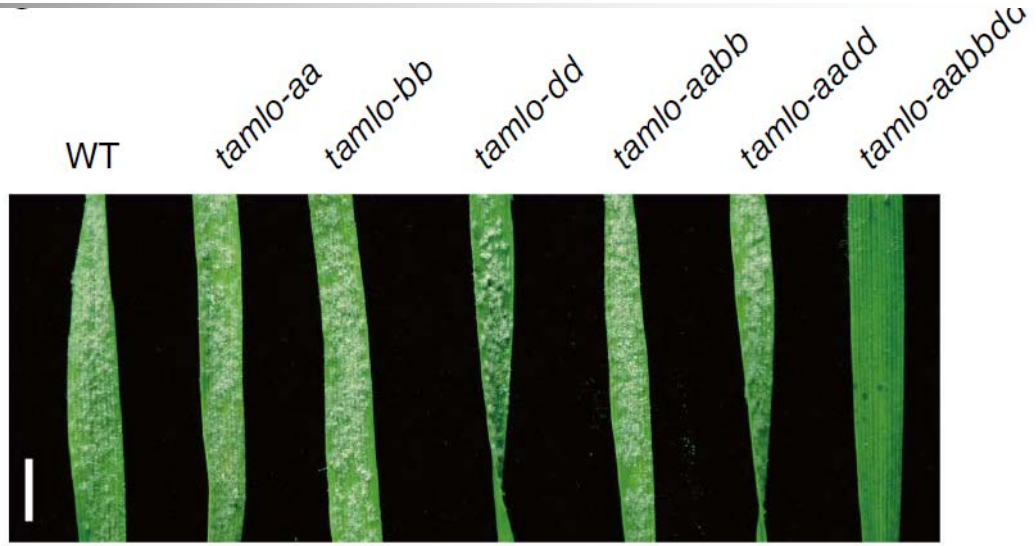


Figure 12. Ears harvested from the wild type (A) and P_{SARK}::*IPTCML216* transgenic plants (B) after watering/drought/rewatering treatments.

Bedada et al, 2016. Drought tolerant tropical maize (*Zea mays* L.) developed through genetic transformation with isopentenyltransferase gene. DOI: 10.5897/AJB2016.15228

Modest gene edits mimic Nature




```
T0-4 D1:  TCGCTGCTGCTCGCCGTgacgcagg.....atctcCGGGATATGCATCTCCGA
T0-5 D1:  TCGCTGCTGCTCGCCGTgacgcag.....aatctcCGGGATATGCATCTCCGA
T0-6 A1:  TCGCTGCTGCTCGCCGTcacgca......aatctcCGGGATATGCATCTCCCA
          TCGCTGCTGCTCGCCGTcacgcagga...aatctcCGGGATATGCATCTCCCA
          TCGCTGCTGCTCGCCGTcacgcagga....atctcCGGGATATGCATCTCCCA
          TCGCTGCTGCTCGCCGTcacgcaggac..aatctcCGGGATATGCATCTCCCA
T0-7 D1:  TCGCTGCTGCTCGCCGTgacgcaggac..aatctcCGGGATATGCATCTCCGA
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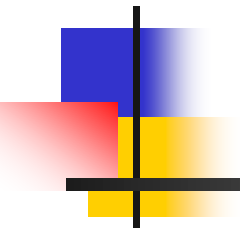
Wang et al, 2014. Simultaneous editing of three homoeoalleles in hexaploid bread wheat confers heritable resistance to powdery mildew. Nature Biotechology doi:10.1038/nbt.2969



Issues and concerns

Food safety

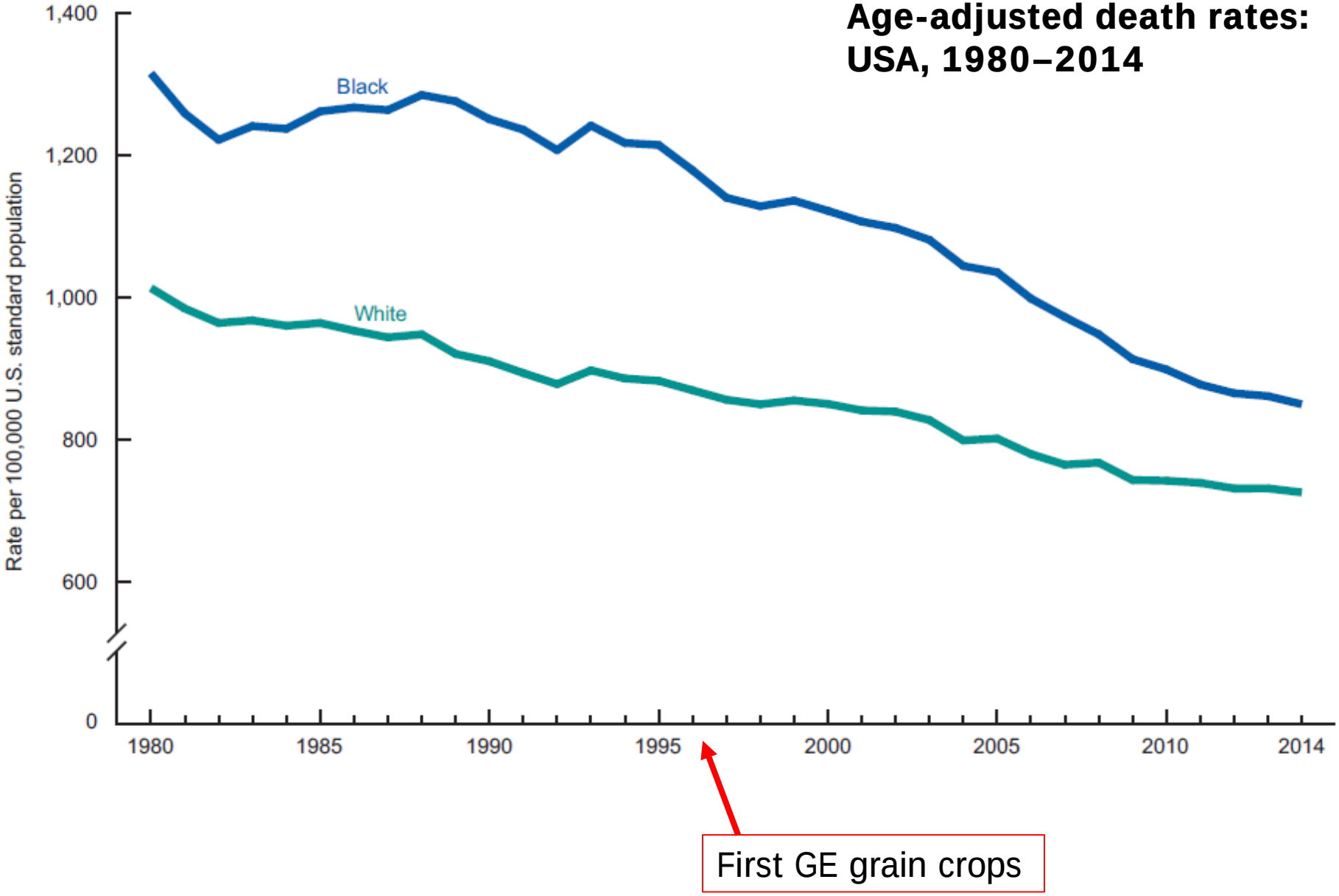
Farmers want to produce safe food.

How many deaths have been attributed to GE crops?

What about illnesses?

Hundreds of millions of people
Over 100 billion animals

Not a single case of harm



National Vital Statistics Reports, http://www.cdc.gov/nchs/data/nvsr/nvsr65/nvsr65_04.pd f

Research papers on food and feed safety

681	Unintended effects	Václavík L, Ovesná J, Ku	2013	Application of Ultra-high P	Czech Journal of Food Sc	31	4	368-75	Department of Food Analy	Supported by the Ministry of
682	Unintended effects	Ismail RM.	2013	Evaluation of genetically n	GM Crops & Food	4	1	58-66	Department of plant Gene	I would like to thank Prof Dr
683	Unintended effects	Sestili F, Paoletti F, Botti	2013	Comparative proteomic an	Journal of Cereal Science	58	1	15-22	Department of Agriculture	Not mentioned
684	Unintended effects	Zhao XX, Tang T, Liu FX,	2013	Unintended Changes in G	Journal of Integrative Agric	12	11	2013-21	Jiangsu Key Laboratory fo	This research was supported
685	Unintended effects	Arruda SC, Barbosa HS,	2013	Comparative studies focus	Journal of Proteomics	93		107-16	Laboratory of Plant Bioch	The authors thank the
686	Unintended effects	Agapito-Tenfen SZ, Guerr	2013	Comparative proteomic an	Proteome Science	11	46		CropScience Department,	The authors would like to
687	Unintended effects	Yang L, Wang C, Holst-J	2013	Characterization of GM ev	Scientific Reports	3	2839		Collaborative Innovation ce	This work was supported by
688	Animal health	Gao C, Ma Q, Zhao L, Zh	2014	Effect of Dietary Phytase	Asian-Australasian Journa	27	1	77-82	State Key Laboratory of A	This study was financed by
689	Animal health	Séralini GE, Clair E, Mes	2014	Republished study: long-t	Environmental Sciences E	26	14		Institute of Biology, EA 26	We gratefully acknowledge
690	Animal health	Delaney B, Appenzeller L	2014	Thirteen week rodent feed	Food and Chemical Toxic	66		173-84	DuPont Pioneer, Johnstor	This study was sponsored by
691	Animal health	Wang EH, Yu Z, Hu J, Jia	2014	A two-generation reproduc	Food and Chemical Toxic	65		312-20	National Institute for Nutrit	The program was supported
692	Animal health	Zhang M, Zhuo Q, Tian Y	2014	Long-term toxicity study c	Food and Chemical Toxic	63		76-83	Key Laboratory of Trace E	This study was financially
693	Animal health	Song Y, Liang C, Wang V	2014	Immunotoxicological evalu	PLoS One	9	2	e78566	Key Laboratory of Food S	The work was financially
694	Animal health	Tyshko NV, Zhminchenk	2014	Assessment of the impac	Toxicology Reports	In Press			FSBI "Institute of Nutrition	Not mentioned
695	Animal nutrition	Tripathi MK, Raghuvansi	2014	Effect of Bt-cottonseed m	African Journal of Biotechr	13	3	509-22	Division of Animal Nutritio	This research was funded by
696	Animal nutrition	Halle I, Flachowsky G.	2014	A four-generation feeding	Journal of Animal and Fee	23	1	58-63	Institute of Animal Nutritio	Not mentioned
697	Animal nutrition	Furgal-Dierzuk I, Strzetel	2014	The effect of genetically m	Journal of Animal and Fee	23	1	13-22	National Research Institut	Not mentioned
698	Animal nutrition	Castillo-Lopez E, Clark K	2014	Performance of dairy cows	Journal of Dairy Science	97	6	3832-7	Department of animal Sci	Financial support for this
699	Animal nutrition	Gu J, Bakke AM, Valen E	2014	Bt-maize (MON810) and N	PLoS One	9	6	e99932	Department of Basic Scie	The study was financed by a
700	Animal nutrition	Kosieradzka I, VaskoV, E	2014	Nutritive and Dietetic Valu	Polish Journal of Food and	64	1	35-43	Department of Animal Nut	The studies constituted a part
701	Animal nutrition	McNaughton J, Roberts M	2014	Comparison of broiler perf	Poultry Science	93		1-11	AHPharma, 116 W. Chest	Not mentioned
702	Equivalence	Zhang X, Zhao P, Wu K,	2014	Compositional Equivalenc	Journal of Agricultural and	62	19	4475-9	Institute of Tropical Biosci	This work was financially
703	Equivalence	Venkatesh TV, Breeze M	2014	Compositional analysis of	Journal of Agricultural and	62	8	1964-73	Monsanto Company, 800	Not mentioned
704	Processing	Tian F, Guan Q, Wang X,	2014	Influence of different proce	Applied Biochemistry and	172	7	3686-700	Key Laboratory of Feed Bi	This study was supported by
705	Processing	Zhang W, Xing F, Selvara	2014	Degradation of Endogenou	Journal of Food Science	79	5	T1055–65	Inst. of Agro-Products Pro	This study was supported by
706	Traceability/Digestion (DNA or	Sajjad AM, Yasmeen A,	2014	Determination of the persi	Journal of International Sc	2		448-56	Institute of Molecular Biol	Not mentioned
707	Unintended effects	La Paz JL, Pla M, Center	2014	The Use of Massive Sequ	PLoS One	9	6	e100895	Department of Molecular (	This work was funded by the
708	Unintended effects	DiLeo MV, den Bakker, M	2014	An Assessment of the Re	The Plant Genome	7	1	1-16	Boyce Thompson Institute	This work was supported by

Effective

Doesn’t represent scientific community

https://www.geneticliteracyproject.org/2015/02/10/the-original-frankenfoods/

U.S. National Academy of Science

"...no substantiated evidence that foods from GE crops were less safe than foods from non-GE crops"

http://www.nap.edu/23395

National Science Academies of the European Union

"...no validated evidence that GM crops have greater adverse impact on health and the environment than any other technology used in plant breeding."

http://www.easac.eu/home/reports-and-statements/detail-view/article/planting-the.html

GE foods are **as *safe* as** other foods

http://www.campbellsoupcompany.com/

Varied perspectives

- Social, not scientific, reasons
  - Transparency
  - Confidence in food supply
- Added cost
- Government mandate only for scientifically demonstrable risks

National Bioengineered Food Disclosure Standard, 2016

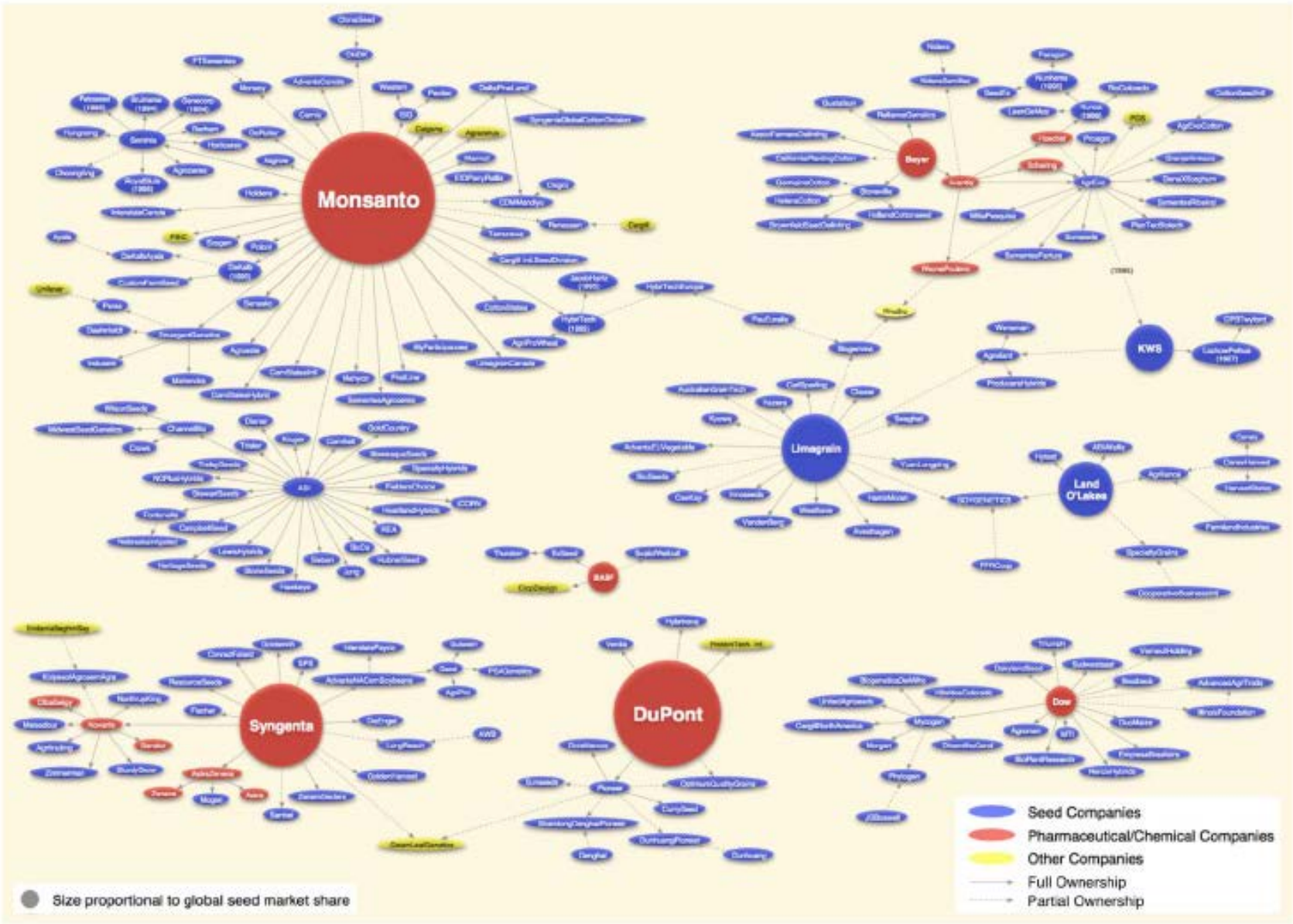
- Supersedes state laws
- Requires disclosure of bioengineered ingredients within two years
- Multiple options
  - Text labels
  - Symbols
  - Digital links (QR codes)

“Pesticide treadmill”

Alternative herbicide program

Glyphosate-tolerant marestail

Figure 2. Seed industry structure, 1996–2008.



Visualizing Consolidation in the Global Seed Industry, 1996–2008, 2009

Patents

- Corporate control of food supply
- Shutting down innovation

Patents: Not just for GMOs

One of these lettuce varieties is patented; all are non-GMO.

From: http://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1002441

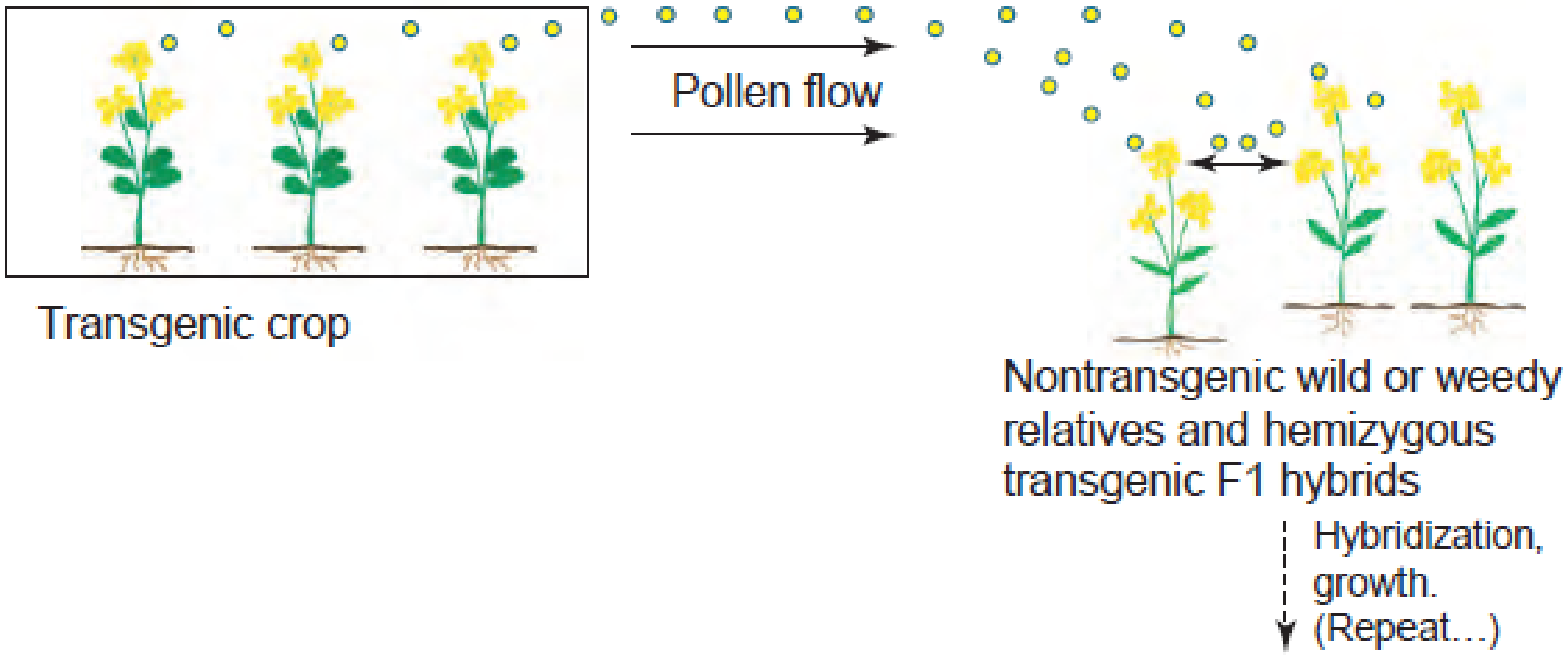
Harm to the environment?

Biodiversity on farms

"Planting of *Bt* varieties of crops tends to result in ***higher insect biodiversity*** than planting of similar varieties without the *Bt* trait that are treated with synthetic insecticides."

National Academy of Sciences report, May 2016

Transgene flow



Trends in Biotechnology, June 2011, Vol. 29, No. 6

Transgene flow

- Risk of “global ruin”?
- No
- Potential for some ecological impact?
- Yes

Kojonup farmers caught in epic legal battle over genetically modified canola contamination

Australian Story By Belinda Hawkins

Updated Sun at 9:22pm

It started in the West Australian wheat belt with tense words between neighbours at a community working bee.

It ended up in a "genetically modified (GM) versus organic" court battle that made headlines around the world.

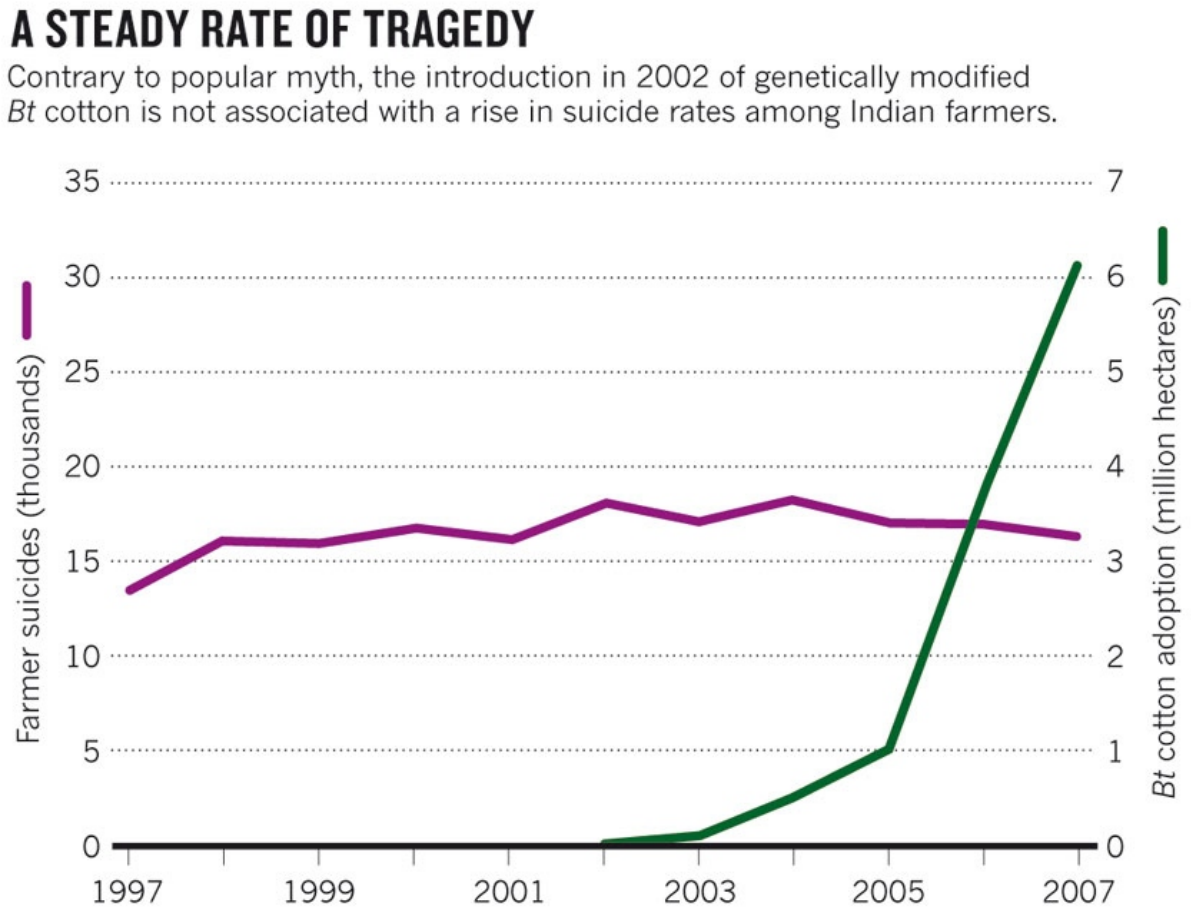
And next week, there will be a further chapter in the WA Supreme Court.

Speaking out for the first time in interviews for tonight's Australian Story, family members from the opposing sides have described the intense emotional impact of the legal battle.

PHOTO: Michael Baxter has fought a protracted legal fight with his neighbour over his use of genetically modified canola.
(Australian Story: Belinda Hawkins)

http://www.abc.net.au/news/2015-03-16/wa-farmers-describe-toll-of-cross-contamination-court-case/6320668

Farmer suicides in India



http://www.nature.com/news/case-studies-a-hard-look-at-gm-crops-1.12907

Use your voice

Terry Daynard's Blog

Comments about Agriculture, Food and the Bioeconomy @TerryDaynard

The Pluses and Minuses – What Genetically Engineered (GE) Crops Mean on Our Farm

RECENT POSTS

- The Pluses and Minuses – What Genetically Engineered (GE) Crops Mean on Our Farm
- Report by the Environmental Commissioner of Ontario on Soil Health Badly Weakened by Inaccuracies, Omissions, Superficiality and another Agenda
- How to Communicate with the Public About GMOs and Related Farm Technologies
- New Insights on Organic and Non-Organic Crops: USDA Data Show Organics Average 67% of Yield of Non-organics
- What should I as a Farmer do about Milkweeds, Monarchs and GE crops? What does Science say?

https://tdaynard.com/2016/12/10/the-pluses-and-minuses-what-genetically-engineered-ge-crops-mean-on-our-farm/

How to talk about GE crops

- “What are your top concerns?”
  - Practice active listening
  - Empathize
  - Acknowledge legitimate concerns
- Tell why you use GE crops
- Speak to values
- Be prepared to “punt”

Personalize the topic

Some resources

Handout for Indiana CCA Meeting, 13 Dec 2016
Prepared by Paul Vincelli, University of Kentucky

Twenty Points of Broad Scientific Consensus on GE Crops
Selected from an article[1] by Dr. Pamela Ronald, University of California

1. **GE crops currently on the market are safe to eat.** (See the European Commission Joint Research Centre, European Food Safety Authority, The American Medical Association, the National Academy of Sciences, and the World Health Organization)
2. **The processes of genetic engineering and conventional genetic modification pose similar risks of unintended consequences.**
3. **The risks and benefits of new traits in crops depend upon the traits themselves and not the means of their introduction, whether through GE or conventional means.**
4. **The planting of Bt cotton has reduced the use of sprayed insecticides.**
5. **The planting of Bt corn in the US has benefited growers of non-GE corn.**
6. **Planting of Bt cotton has enhanced yields in China and India.**
7. **Planting of Bt cotton has reduced insecticide poisonings of farmers and their families.**
8. **Adoption of Bt cotton enhances insect biodiversity.**
9. **If not properly managed, overuse of Bt spray or Bt crops will lead to Bt resistant insects.**
10. **Farmers need to deploy a crop diversity strategy and crop rotation to reduce the evolution of insect resistance.**
11. **US farmers that plant BT crops are required to deploy a "refuge strategy": creating refuges of crop plants that do not make Bt toxins. This promotes survival of susceptible insects and has**

Other resources

- The Science of GMOs, Purdue University, https://ag.purdue.edu/GMOs/pages/scienceofgmos.aspx#.WEwkqVw42rk
- *Genetically Engineered Crops, Emerging Opportunities*, PPA-47, http://www2.ca.uky.edu/agcomm/pubs/PPA/PPA47/PPA47.pdf
- Free online video-based curriculum on genetically engineered crops (GMOs), http://www2.ca.uky.edu/anr/Biotech/biotech.htm
- Follow me on Twitter, @pvincell
- *Talking Biotech* podcasts, http://www.talkingbiotechpodcast.com/
- *Genetically Engineered Crops, Experiences and Prospects*, 2016, by the National Academy of Sciences.
    - Full report at https://www.nap.edu/catalog/23395/genetically-engineered-crops-experiences-and-prospects
    - List of Findings and Recommendations at http://nas-sites.org/ge-crops/files/2016/05/All-Findings-and-Recommendations.pdf

Thanks for the invitation!

iStock Photos, used with permission

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10. **Farmers need to deploy a crop diversity strategy and crop rotation to reduce the evolution of insect resistance.**
11. **US farmers that plant BT crops are required to deploy a "refuge strategy": creating refuges of crop plants that do not make Bt toxins. This promotes survival of susceptible insects and has helped to delay evolution of pest resistance to Bt crops.**
12. **Global pest-monitoring data suggest that Bt crops have remained effective against most pests for more than a decade.**
13. **Failure to provide adequate refuges appears to have hastened resistance of pink bollworm in India and western corn rootworm in the US to Bt.**
14. **Effective methods for slowing the spread of insect resistance include crop rotation, intercropping and planting refuges of non-BT cotton and non-crop species.**
15. **Planting of herbicide tolerant (HT) crops has reduced the environmental impact of herbicide use. This is because the reduced tillage associated with planting of HT crops has led to reduced soil erosion and reduced greenhouse gas emissions.**
16. **The liberal use of glyphosate without proper management has spurred the evolution of weeds resistant to that herbicide.**
17. **The evolution of herbicide resistant weeds is a problem for farmers who rely on a single herbicide.**
18. **GE crops are just one of the many tools that can be used to enhance the sustainability of farms.**
19. **Papaya genetically engineered for resistance to papaya ringspot virus has protected yields against significant losses from the virus and saved the Hawaiian papaya industry.**
20. **Consumption of Golden Rice, within the normal diet of rice-dependent poor populations, could provide sufficient vitamin A to substantially reduce the 6,000 deaths caused every day**

[1] Points listed are from: http://www.biofortified.org/2013/10/20-points-of-broad-scientific-consensus-on-ge-crops/

by vitamin A deficiency and save the sight of several hundred thousand people per year in a cost efficient manner.

Other resources

- The Science of GMOs, Purdue University, https://ag.purdue.edu/GMOs/pages/scienceofgmos.aspx#.WEwkqVw42rk
- *Genetically Engineered Crops, Emerging Opportunities*, PPA-47, http://www2.ca.uky.edu/agcomm/pubs/PPA/PPA47/PPA47.pdf
- Free online video-based curriculum on genetically engineered crops (GMOs), http://www2.ca.uky.edu/anr/Biotech/biotech.htm
- Crop Hybridization and Genetic Engineering: An Illustration Using Playing Cards https://www.youtube.com/watch?v=uzD4ASf_owk
- Follow me on Twitter, @pvincell
- *Talking Biotech* podcasts, http://www.talkingbiotechpodcast.com/
- *Genetically Engineered Crops, Experiences and Prospects*, 2016, , by the National Academy of Sciences.
    - Full report at https://www.nap.edu/catalog/23395/genetically-engineered-crops-experiences-and-prospects
    - List of Findings and Recommendations at http://nas-sites.org/ge-crops/files/2016/05/All-Findings-and-Recommendations.pdf