Biotechnology and Biofuel Trees

A Worrisome Science x Society Struggle

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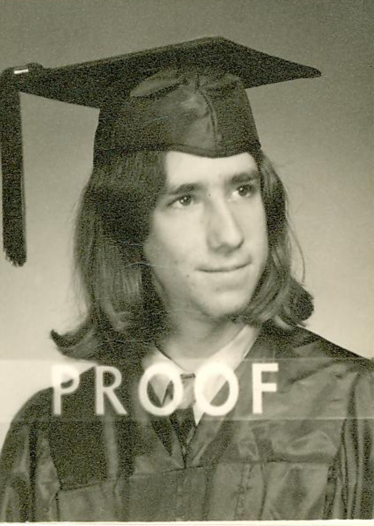
My background

- Young eco-minded person, a member of all the usual green activist groups
- Genetics, genomics, genetic engineering of trees
  - http://www.cof.orst.edu/coops/tbgrc/Staff/strauss/index.htm
- Director, Outreach in Biotechnology at OSU, 2005-20013
  - *http://oregonstate.edu/orb*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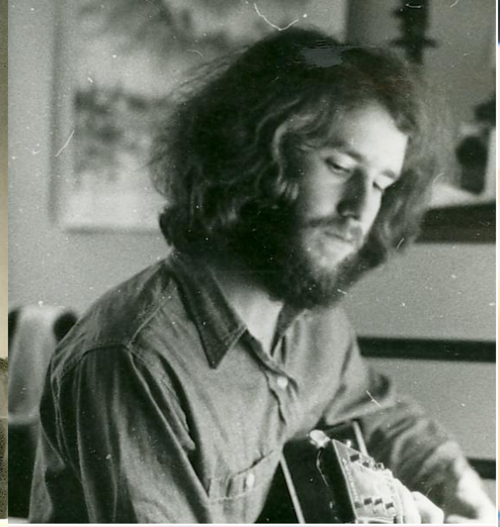
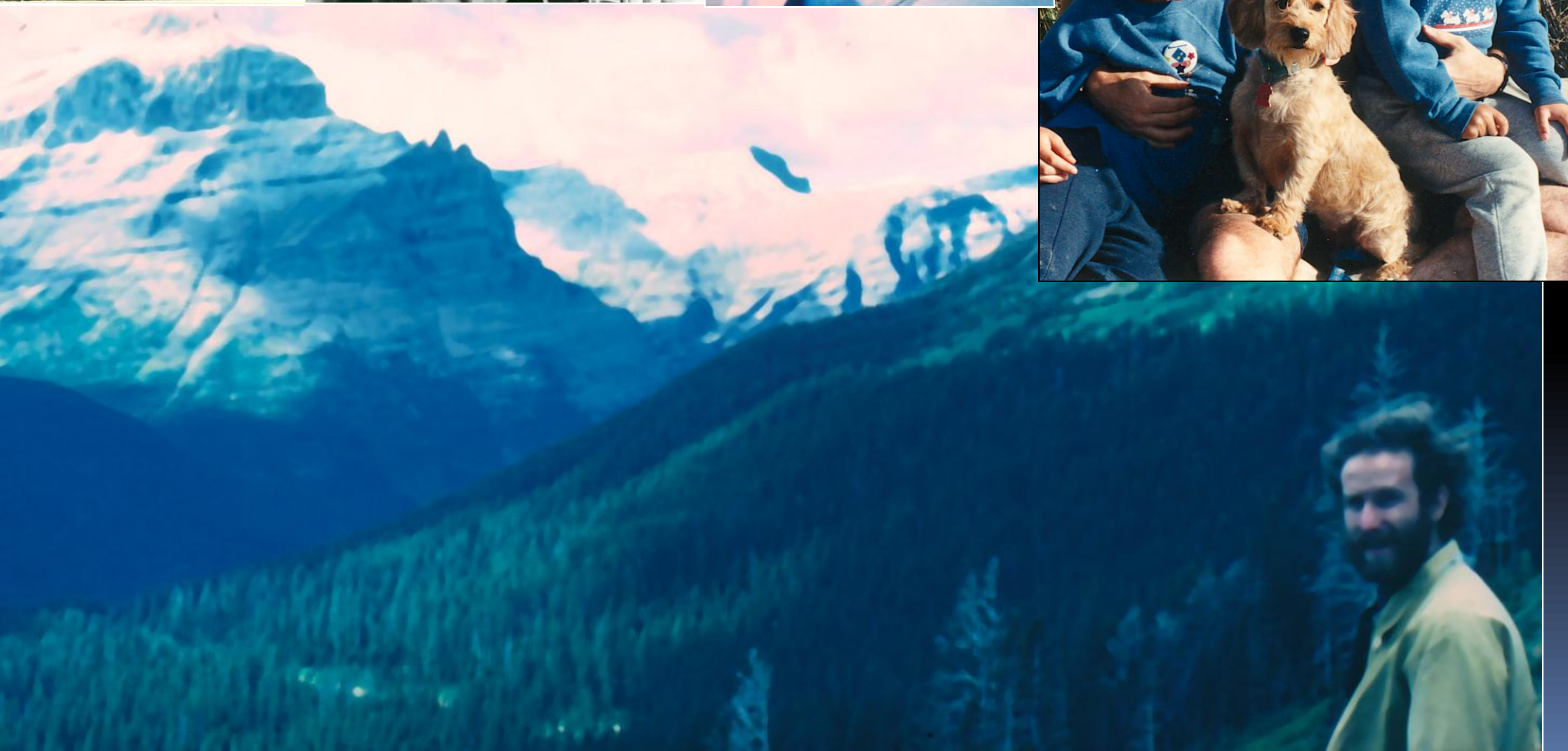
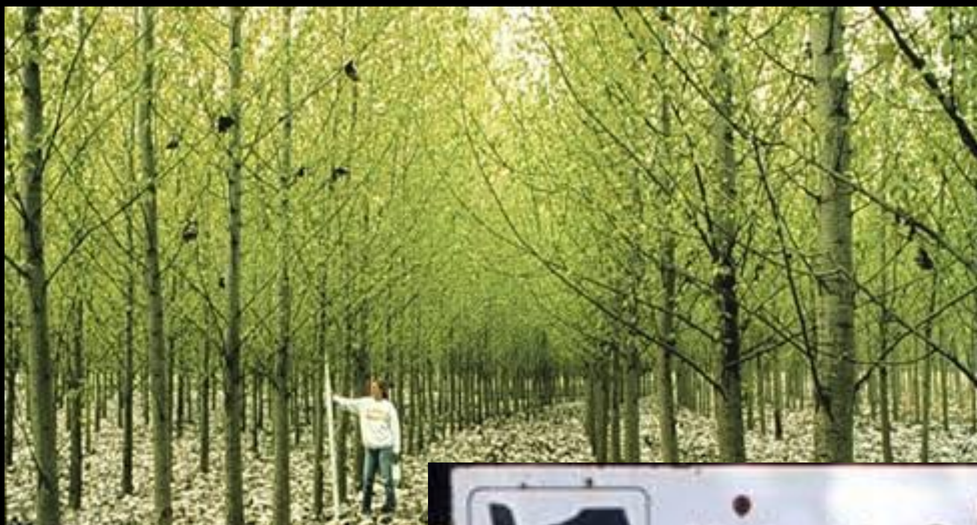



TREK


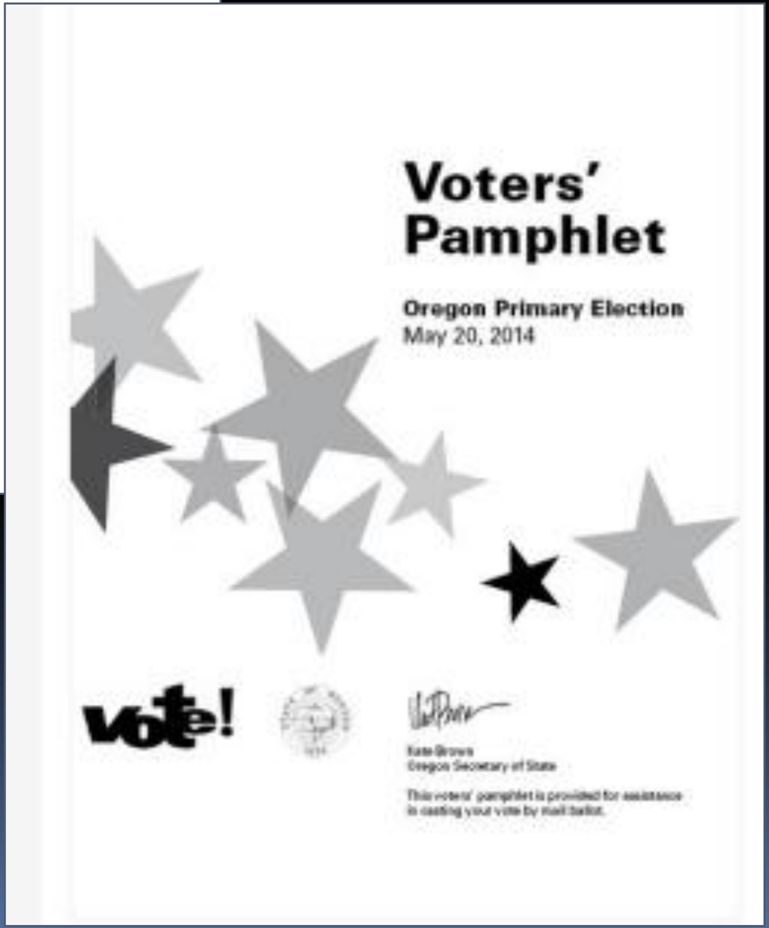
Poplars (cottonwood, aspen) a focus of my work



Public outreach on ag biotech

Engaged in broader debate about GMOs


OREGONLIVE
The Oregonian
1203 comments
Punitive GMO labels contrary to science and accepted standards: Guest opinion



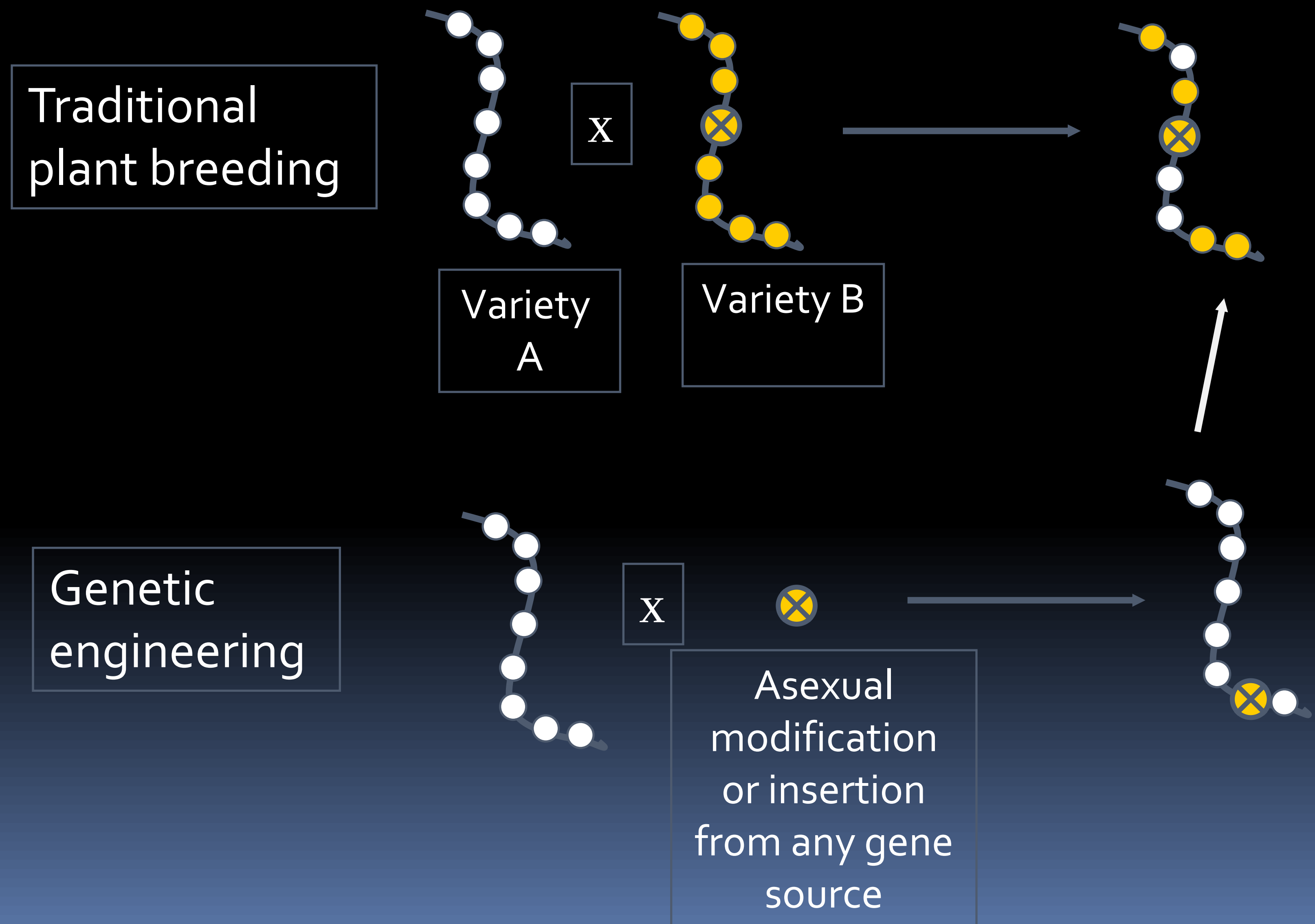
Genetics and GMO methods can make a big difference

Crop domestication the basis of agriculture, enabled civilization

Broccoli

Hybridization enabled poplars to become crops in the northwest

GMO method (genetic engineering) defined



Some GMO tree examples

Virus-resistant papaya literally saved the industry in Hawaii

No “pesticides” produced

Natural mechanism induced

“Immunization” via by implanting a viral gene in the papaya genome = RNAi (RNA interference)

Courtesy of Denis Gonsalves, formerly of Cornell University

GMO, virus-resistant trees

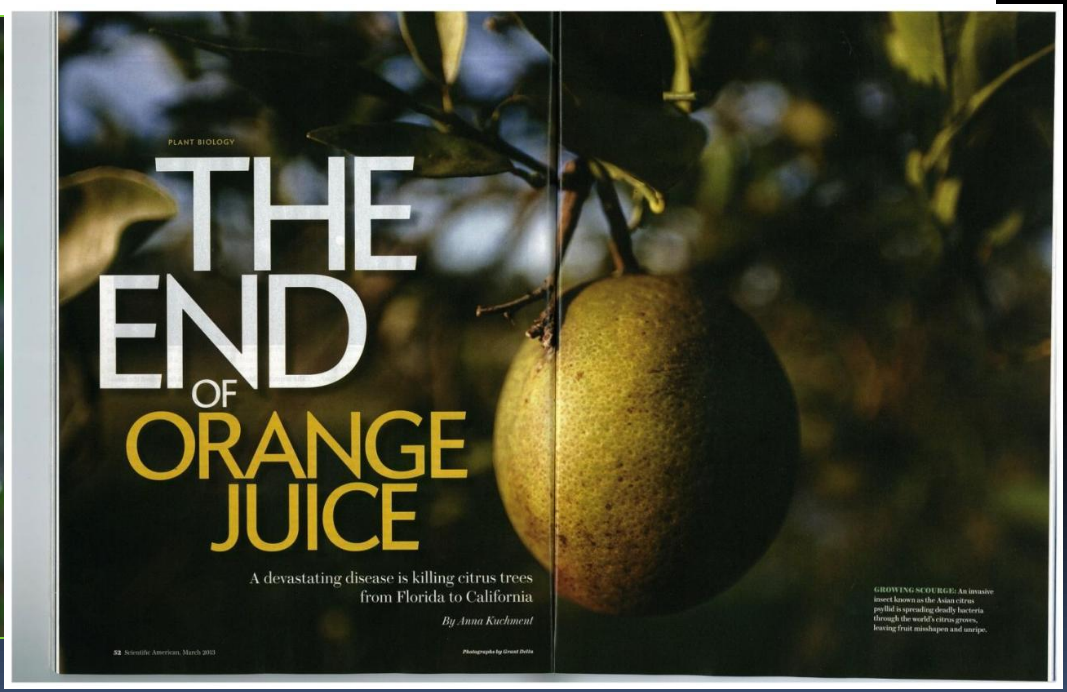
The orange industry is threatened by “citrus greening”

The New York Times

July 27, 2013

A Race to Save the Orange by Altering Its DNA

By AMY HARMON



Defensin-like proteins from spinach promising

American Chestnut devastated by an introduced disease -- a GMO solution appears to stop it

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SCIENTIFIC AMERICAN — The New Century of the Brain — See Inside

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—

More In This Article

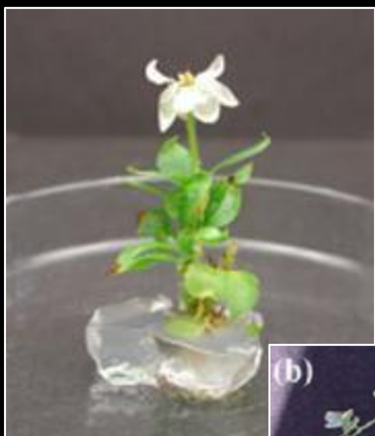
A New Generation of American Chestnut Trees May Redefine America's Forests

March 2014 issue
Scientific American

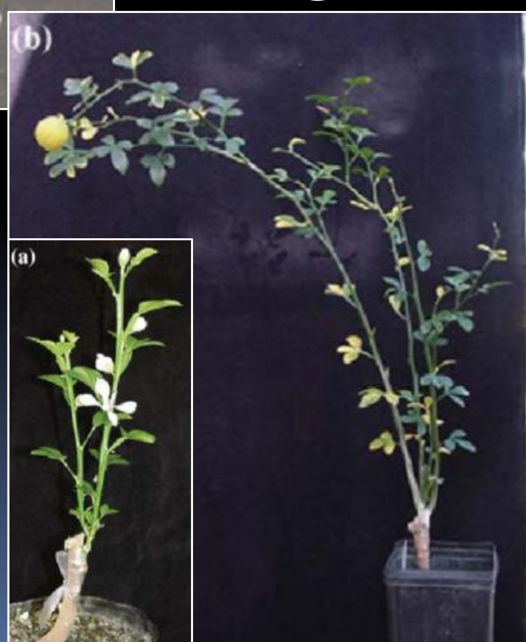
Courtesy of Bill Powell, SUNY Syracuse, USA

The many year delay in onset of flowering slows breeding in trees – GMO methods overcome it

Apple



Orange



Plum

Poplar

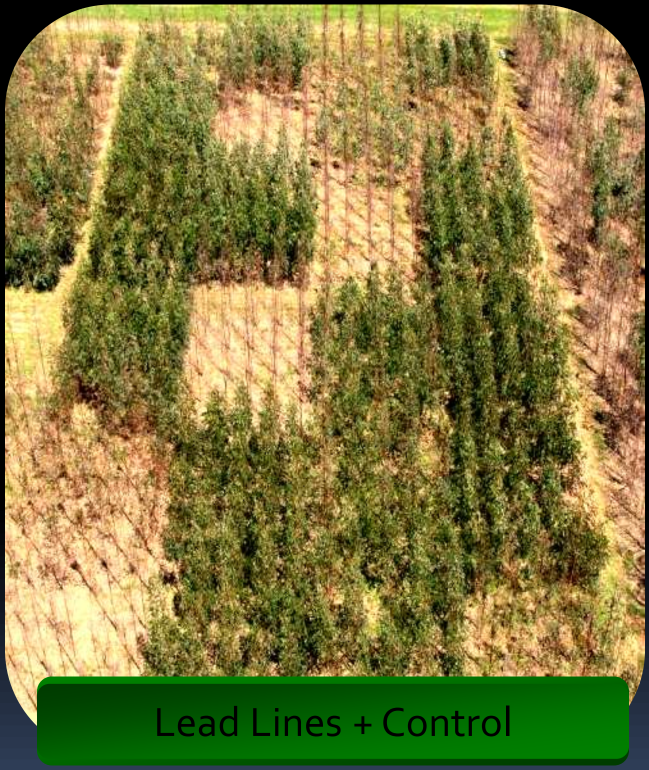
Growth benefits despite low insect pressure during large field trial of resistant genotypes

Freeze-tolerant *Eucalyptus*

Proposed for commercial deregulation in USA

Results from first winter in South Carolina

Results from second winter in Alabama



Field results indicate freezing tolerance to ~16°F (- 8° to - 9°C)

Provided by Arborgen

Trees with modified wood can produce more biofuels or pulp with less input of energy and chemicals

PNAS

Improved saccharification and ethanol yield from field-grown transgenic poplar deficient in cinnamoyl-CoA reductase

Rebecca Van Acker[a,b], Jean-Charles Leplé[c], Dirk Aerts[d], Véronique Storme[a,b], Geert Goeminne[a,b], Bart Ivens[a,b], Frédéric Légée[e], Catherine Lapierre[e], Kathleen Piens[f], Marc C. E. Van Montagu[a,b,1], Nicholas Santoro[g], Clifton E. Foster[g], John Ralph[h], Wim Soetaert[d], Gilles Pilate[c], and Wout Boerjan[a,b,1]

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Contributed by Marc C. E. Van Montagu, November 20, 2013 (sent for review March 26, 2013)

Lignin is one of the main factors determining recalcitrance to enzymatic processing of lignocellulosic biomass. Poplars (*Populus tremula* x *Populus alba*) down-regulated for cinnamoyl-CoA reductase (CCR), the enzyme catalyzing the first step in the monolignol-specific branch of the lignin biosynthetic pathway, were grown in field trials in Belgium and France under short-rotation coppice culture. Wood samples were classified according to the intensity of the red xylem coloration typically associated with *CCR* down-regulation. Saccharification assays under different pretreatment conditions (none, two alkaline, and one acid pretreatment) and simultaneous saccharification and fermentation assays showed that wood from the most affected transgenic trees had up to 161% increased ethanol yield. Fermentations of combined material from the complete set of 20-mo-old *CCR*–down-regulated trees, including bark and less efficiently down-regulated trees, still yielded ~20% more ethanol on a weight basis. However, strong down-regulation of *CCR* also affected biomass yield. We conclude that *CCR* down-regulation may become a successful strategy to improve biomass processing if the variability in down-regulation and the yield penalty can be overcome.

bioethanol | GM | second-generation bioenergy

Global warming and the depletion of fossil fuels provide a major impetus for the increased interest in renewable energy sources. Liquid biofuels, bioethanol in particular, are cur-

incorporated into the lignin polymer, respectively (5–7). Cinnamoyl-CoA reductase (CCR) catalyzes the first step of the monolignol-specific pathway. It converts the hydroxycinnamoyl-CoA esters to their corresponding hydroxycinnamaldehydes (mainly feruloyl-CoA to coniferaldehyde), and down-regulation of *CCR* typically results in reduced lignin content (8–13). *CCR*–down-regulated poplars are characterized by an orange to wine-red coloration of the xylem that often appears in patches along the stem. This pronounced coloration is associated with a reduction in lignin amount and the incorporation of low levels of ferulic acid into the polymer (13, 14).

As lignin is the most important factor limiting the conversion of plant biomass to fermentable sugars (15–17), we have evaluated whether wood from transgenic poplar, down-regulated in *CCR*, is easier to process into ethanol. Field trials were established in Belgium and France after a long process of obtaining regulatory permission (18). Field trials are an essential step in translating fundamental knowledge generated in the laboratory to conditions closer to industrial exploitation because greenhouse-derived data cannot a priori be extrapolated to field-grown trees without experimentation. For example, greenhouse-grown trees do not experience the annual cycles of growth and

Significance

In the transition from a fossil-based to a bio-based economy, bioethanol will be generated from the lignocellulosic biomass

PLANT BIOLOGY

Poplar as chemical feedstocks and biofuel sources

The Seattle Times
Winner of Nine Pulitzer Prizes

Local News

Originally published Sunday, February 9, 2014 at 9:10 PM

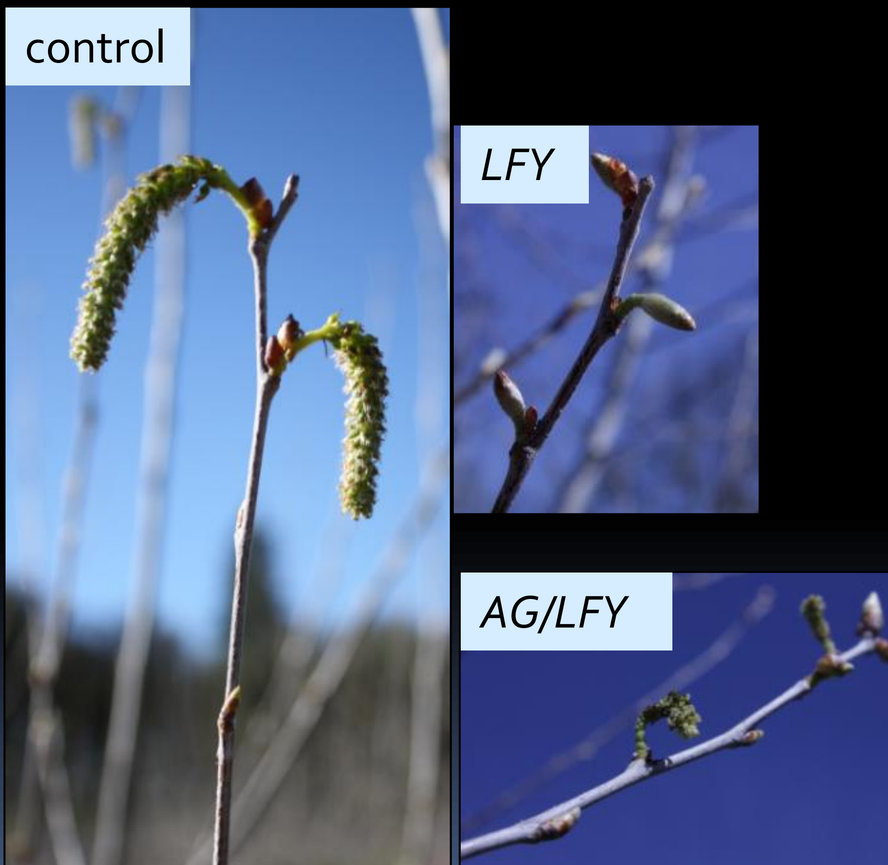
Rose scent in poplar trees? WSU turns to genetic engineering

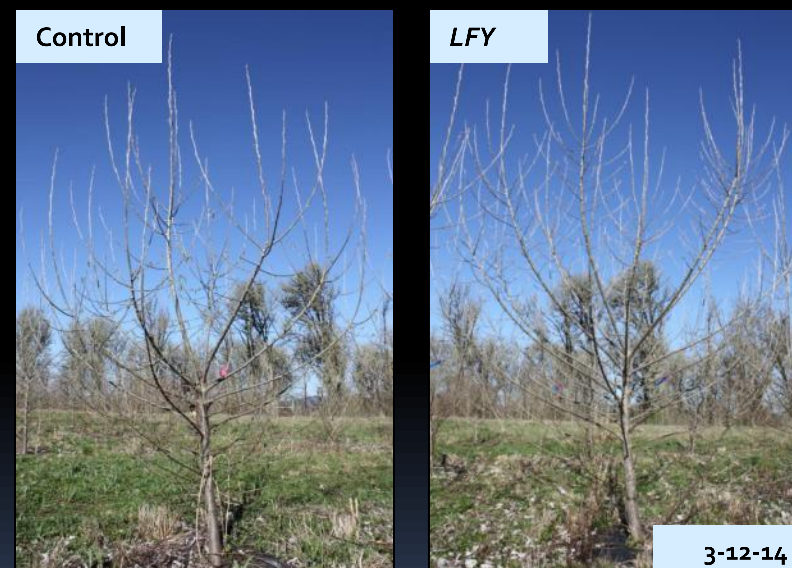
A WSU team aims to turn poplars and other fast-growing trees into living factories that churn out valuable chemicals.

By Sandi Doughton

Seattle Times science repo

Genetic containment feasible if desired or required – male and female





Klocko et al. 2014, American Soc. For Plant Biology, Portland, Oregon

So lots of promising technology,

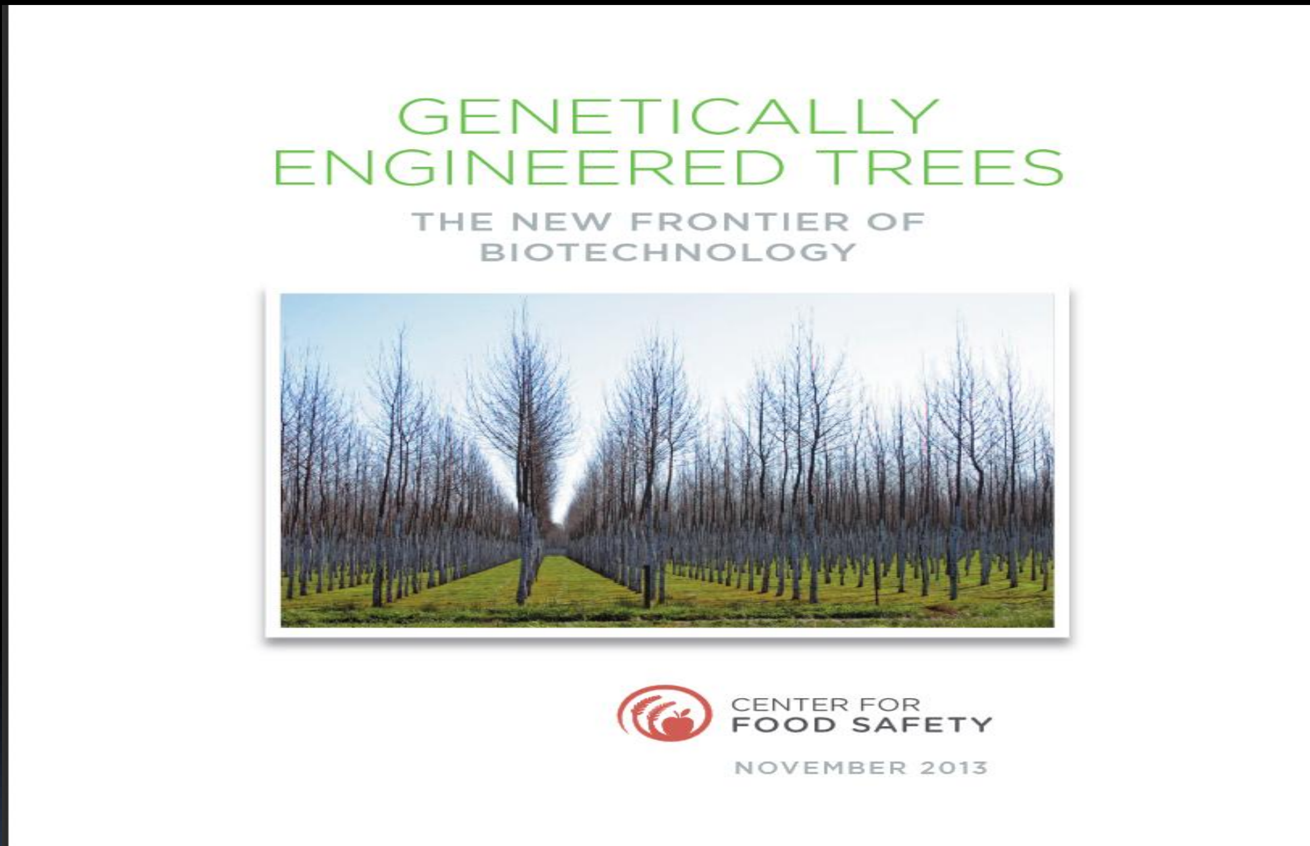
BUT…

Genetically modified arboriculture

Down in the forest, something stirs

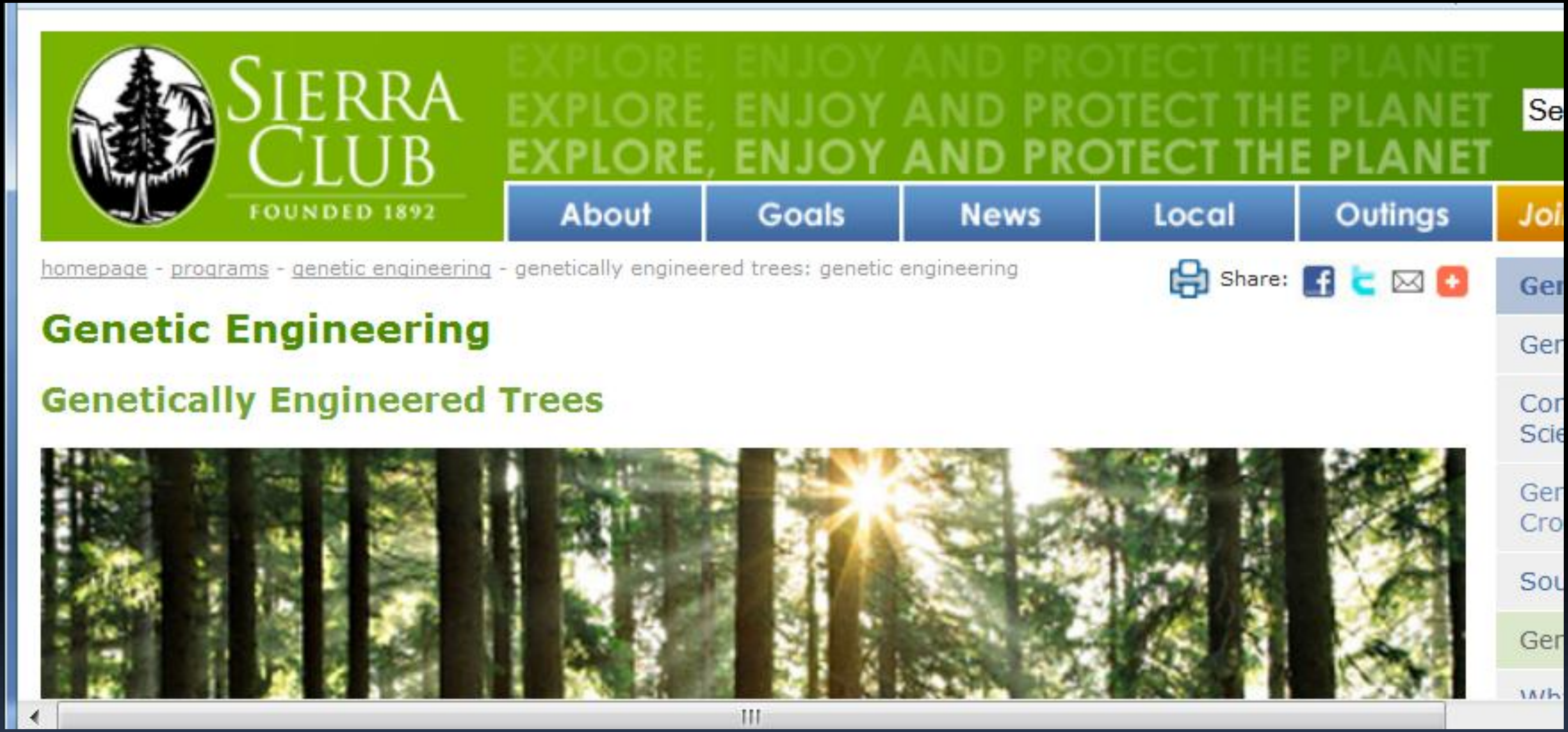
The Economist, 2005

Political pressure, negative social media, and lawsuits from anti-GMO groups



"Center for Food Safety" in USA – November 2013 report

Major environmental groups promoting wild forests dislike GE trees



"The possibility that the new genes spliced into GE trees will interfere with natural forests isn't a hypothetical risk but a certainty. …genetic engineering may do as much damage to forests and wildlife habitat as chain saws and sprawl." (11/10/13)

"Green" certification of forests create severe barriers to progress – even research

Plantation Certification & Genetic Engineering

FSC's Ban on Research Is Counterproductive

Steven H. Strauss, Malcolm M. Campbell, Simon N. Pryor, Peter Coventry, and Jeff Burley

ABSTRACT

Genetic engineering, also called genetic modification (GM), is the isolation, recombinant modification, and asexual transfer of genes. It has been banned in forest plantations certified by the Forest Stewardship Council (FSC) regardless of the source of genes, traits imparted, or whether for research or commercial use. We review the methods and goals of tree genetic engineering research and argue that FSC's ban on research is counterproductive because it makes it difficult for certified companies to participate in the field research needed to assess the value and biosafety of GM trees. Genetic modification could be important for translating new discoveries about tree genomes into improved growth, quality, sustainability, and pest resistance.

Keywords: biotechnology; entomology and pathology; ethics; genetics; silviculture

Genetic engineering, commonly called genetic modification (GM) in much of the world, is the use of recombinant DNA and asexual gene transfer methods to breed more productive or pest-resistant crops. It has been the subject of considerable controversy, with concerns raised from biological, socioeconomic, political, and ethical perspectives. Some of the issues are similar to those raised by the use of molecular biology and genetic engineering in medicine, which we see in the news headlines daily. However, genetic modification in agriculture and forestry raises environmental issues as well.

GM crops, mainly herbicide- and pest-resistant varieties of soybeans, maize, or cotton, have been vigorously adopted by farmers in North America because they are easy to manage and they improve yields, reduce costs, or reduce pesticide ecotoxicity (Carpenter and Gianessi 2001). However, the controversy, primarily embodied in regulatory barriers to trade of GM crops with Europe and Japan, has slowed their adoption considerably in recent years.

If GM trees are used in forestry in the near future, they are likely to occur primarily in intensively managed environments, such as urban forests or plantations. In urban forestry, genetic modification is expected to help trees adapt to the stresses and special demands of human-dominated systems. Examples would be trees that are more tolerant of heavy metals or other pollutants, resist urban pests or diseases, grow slower, or do not produce fruits when these create hazards in street environments (Brunner et al. 1998).

Plantations, although very different from natural forests in structure and function, are considered part of the spectrum of methods in sustainable forest management (Romm 1994). Plantations can relieve pressure on natural forests for exploitation and can be of great social value by supplying community and industrial wood needs and fueling economic development. The environmental role of plantations is recognized by the Forest Stewardship Council (FSC), an international body for certification of sustainably managed forests. FSC Principle 10 states that plantations should "complement the management of, reduce pressures on, and promote the restoration and conservation of natural forests" (FSC 2001).

FSC has certified some of the most intensively managed plantations in the world, including poplar plantations and the intensive pine and eucalypt plantations of the Southern Hemisphere. Although many environmental mitigations are built into these certified plantation systems, within the areas dedicated to wood production they function as tree farms. Such intensive plantation systems often use highly bred genotypes, possibly including exotic species, hybrids, and clones, as well as many other forms of intensive silvicultural management. It is in the context of these biointensive systems that the additional expense of GM trees is likely to be worthwhile.

However, FSC currently prohibits all uses of GM trees, and is the only certification system to have done so

Forest Stewardship Council

"…genetically modified trees are prohibited…"

Lessons

GMO tools are too valuable to discard

- Society faces *enormous* challenges due to population demands and climate change
- The enormous uptake and impact of GMOs, and many research demonstrations—for trees as well as other crops—shows their value
- There are legitimate concerns about their management and secondary impacts – *none about the method*
- A complete ban on the GMO method for trees or crops has no scientific support, and seems at odds with the precautionary principle

Lessons

Genetics matters in a big way

- Genetic innovation by conventional means has revolutionized agriculture
  - Enabled poplar as wood/biofuels crop in the Northwest and DNA based methods accelerating further now
- GMO methods can clearly enable another wave of innovation for crops and biofuels
- Urgent need and technical capacity to do it, but society is the problem
  - Romantic, simplistic, and dogmatic environmental thinking and organizations the most culpable?