

Biotechnology and Biofuel Trees

A Worrisome Science x Society Struggle

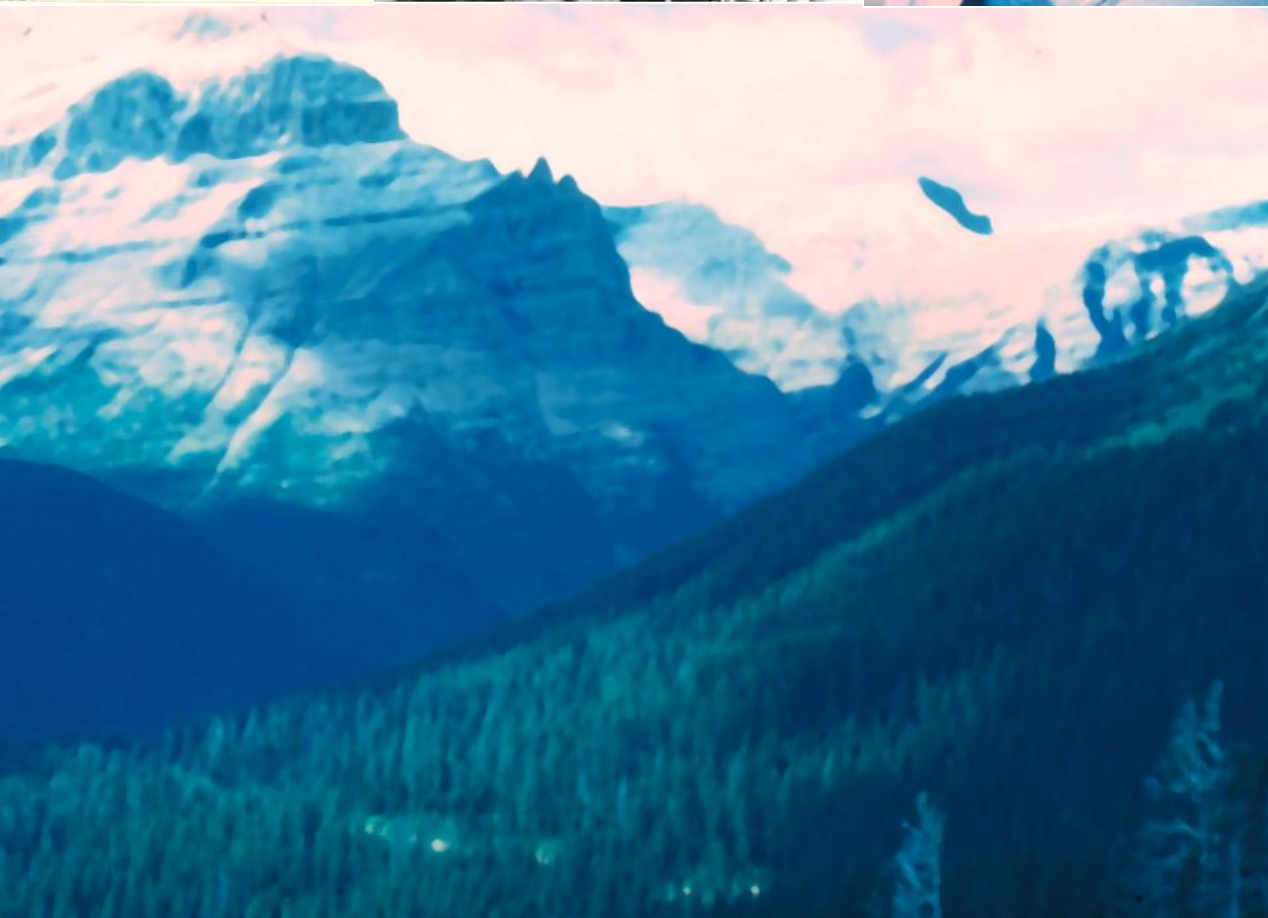
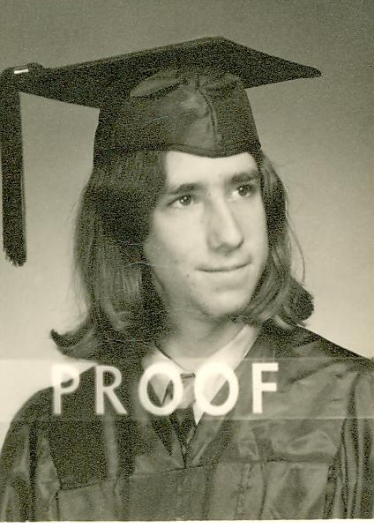
Steve Strauss
Oregon State University
Steve.Strauss@OregonState.Edu

OSU
Oregon State
UNIVERSITY



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>



Poplars (cottonwood, aspen) a focus of my work



Public outreach on ag biotech

The collage consists of 18 individual posters, each with a unique design and color scheme. The posters are arranged in three rows of six. Each poster features a central image related to its topic, such as salmon, a smartphone, a scale, a child, a banana, or a field. The text on each poster includes the event title, date, time, location (Labelli Stewart Center, OSU), and the speaker's name. The 'Food for Thought' logo is present in the top left corner of each poster. The bottom right corner of each poster features the OSU logo and the text 'Science Community Lecture'.

- Poster 1 (Top Left):** "Ethics of Animal Biotechnology: Should Genetically Engineered Salmon be Allowed?" by Dr. John H. Garver. Wednesday, Nov. 9, 7:00 - 8:30 P.M.
- Poster 2 (Top Row, 2nd):** "Natural Systems Agriculture: Shaping MIT's Emerging Programs to the Future" by Dr. David Tilman. Thursday, Oct. 6, 7:00 - 8:30 P.M.
- Poster 3 (Top Row, 3rd):** "Rethinking Green" by Stewart Brand. Thursday, Mar. 10, Labelli Stewart Center, OSU, 7:00 - 8:30 P.M.
- Poster 4 (Top Row, 4th):** "Food's Footprint: Agriculture and Climate Change" by Peter Rosset, Ph.D. Wednesday, Feb. 21, Labelli Stewart Center, OSU, 7:00 - 8:30 P.M.
- Poster 5 (Top Row, 5th):** "Setting Standards: Measuring Sustainability in Agriculture" by Nancy Mitchell. Wednesday, Nov. 17, Labelli Stewart Center, OSU, 7:00 - 8:30 P.M.
- Poster 6 (Top Row, 6th):** "At War Over Biotech Crops in Oregon" by Peter Rosset, Ph.D. Wednesday, Nov. 3, Labelli Stewart Center, OSU, 7:00 - 8:30 P.M.
- Poster 7 (Middle Row, 1st):** "Biofortifying Crops: To Reduce Food Insecurity for the Poorest Africans in 2025" by Dr. Robert Hamrick. Wednesday, Oct. 20, Labelli Stewart Center, OSU, 7:00 - 8:30 P.M.
- Poster 8 (Middle Row, 2nd):** "(Not) Business as Usual: A modest proposal for sustainable agriculture" by Dr. Robert Hamrick. Thursday, April 15, Labelli Stewart Center, OSU, 7 P.M.
- Poster 9 (Middle Row, 3rd):** "The Ethics of Modern Agriculture" by Dr. Robert Hamrick. Friday, October 28, 10:00 AM - 12:00 PM, Labelli Stewart Center, OSU.
- Poster 10 (Middle Row, 4th):** "Freezing The Footprint Of Agriculture While Feeding 9 Billion People" by Dr. Robert Hamrick. Friday, March 19, 7:00 - 8:30 P.M., Labelli Stewart Center, OSU.
- Poster 11 (Middle Row, 5th):** "THE BANANA DEAD-END" by Dr. Robert Hamrick. Friday, Tuesday, Nov. 4, 7:00 - 8:30 P.M., Labelli Stewart Center, OSU.
- Poster 12 (Middle Row, 6th):** "PLAYING GOD? Monsters, Miracles, and the Politics of Genetic Engineering" by Dr. Robert Hamrick. Tuesday, May 16, 7:00 - 8:30 P.M., Labelli Stewart Center, OSU.
- Poster 13 (Bottom Row, 1st):** "BEYOND ENVIRONMENTALISM: The Case for a New Politics" by Dr. Robert Hamrick. Wednesday, March 14, 7:00 - 8:30 P.M., Labelli Stewart Center, OSU.
- Poster 14 (Bottom Row, 2nd):** "IMPROVING FOOD AND ENVIRONMENTAL SAFETY: The Surprising Role of Genetically Modified Crops" by Dr. Robert Hamrick. January 20th @ 7 PM, Labelli Engineering Auditorium, OSU Campus.
- Poster 15 (Bottom Row, 3rd):** "People Know Not What They Eat" by Dr. William Hartman. Thursday, Oct 12, 7-9 P.M., Labelli Stewart Center, OSU.
- Poster 16 (Bottom Row, 4th):** "AGRICULTURE 2.0: Farming Systems in an Age of Climate Change" by Dr. Robert Hamrick. Sunday, January 2nd @ 11AM, Labelli Engineering Auditorium, OSU Campus.
- Poster 17 (Bottom Row, 5th):** "Tomorrow's Table: Organic Farming, Genetics, and the Future of Food" by Pam Ronald and Rosal Adamschuk. November 25th, 7 PM @ Labelli Engineering Auditorium.
- Poster 18 (Bottom Row, 6th):** "Challenging Nature: The Clash Between Biotechnology & Spirituality at the Now's Frontiers of Life" by Lee M. Silver. Monday Nov. 13, 7-9 P.M., Labelli Stewart Center, OSU.

Engaged in broader debate about GMOs

OREGONLIVE
The Oregonian

1203 comments


Punitive GMO labels contrary to science and accepted standards: Guest opinion





The image shows a man in a dark suit speaking at a podium. To his left is a large sign for Ben & Jerry's 'Food Fight! Fudge Brownie' ice cream, which includes the text 'Vermont's Finest', 'Ben & Jerry's', 'Food Fight! Fudge Brownie', and 'Chocolate Ice Cream with Fudge Brownies'. To his right, another man in a white shirt and tie holds a green sign that reads 'OVER 500,000 PETITION SIGNERS'. The background features the Oregon State Capitol building under a cloudy sky.

Voters' Pamphlet

Oregon Primary Election
May 20, 2014



vote!



Kate Brown
Oregon Secretary of State

This voters' pamphlet is provided for assistance in casting your vote by mail ballot.

**Genetics and GMO methods can
make a big difference**

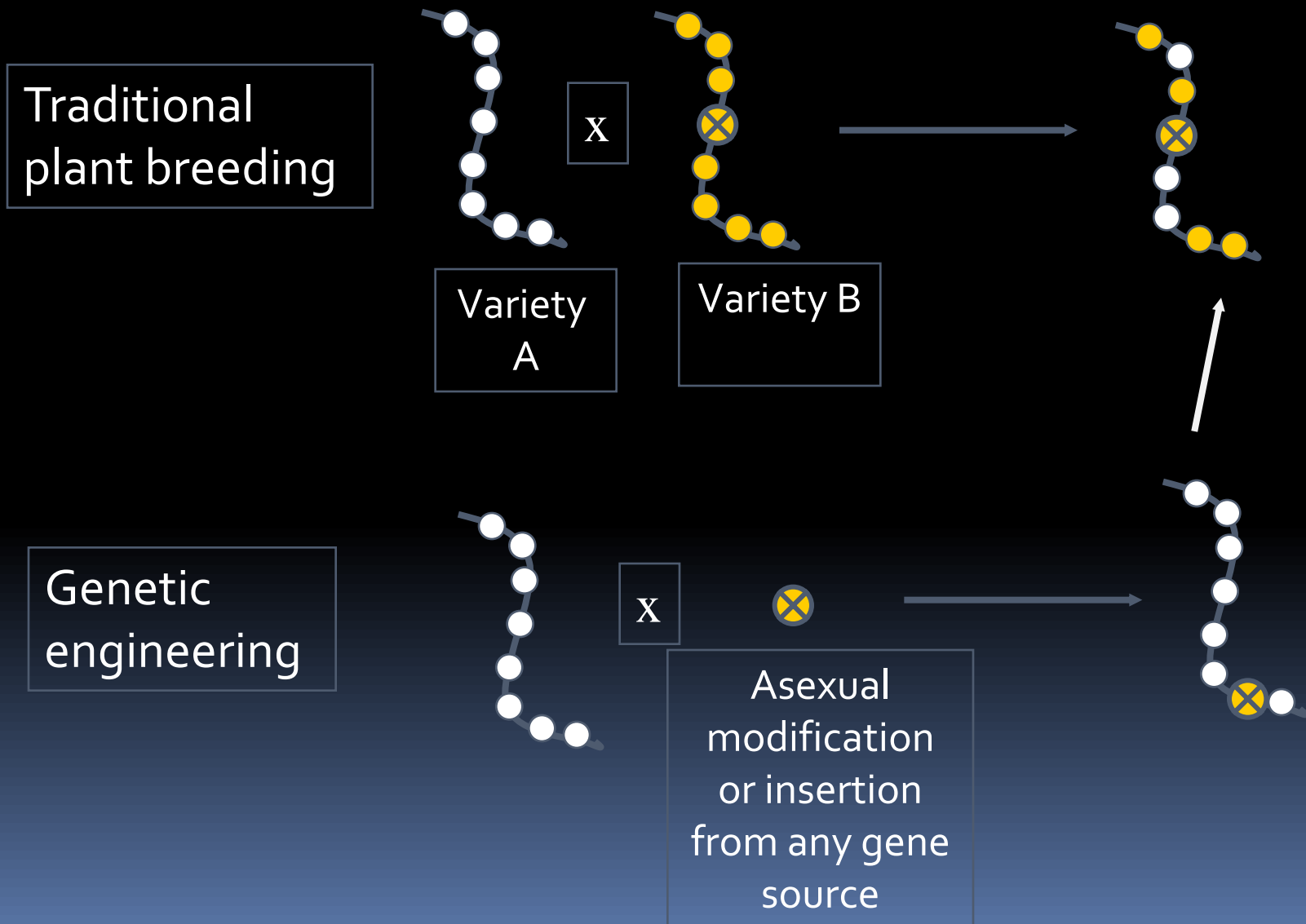
Crop domestication the basis of agriculture, enabled civilization



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

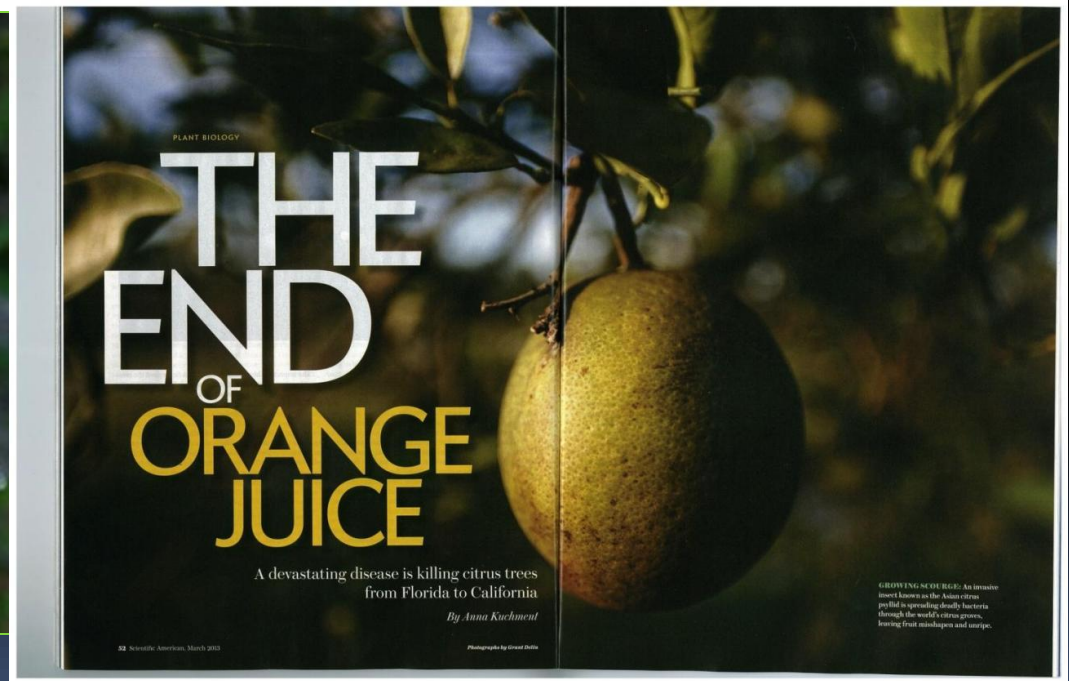
The orange industry is threatened by “citrus greening”

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



Courtesy of Eric Mirkov, Texas A & M

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

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Energy & Sustainability » Scientific American Volume 310, Issue 3  2  Email  Print



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

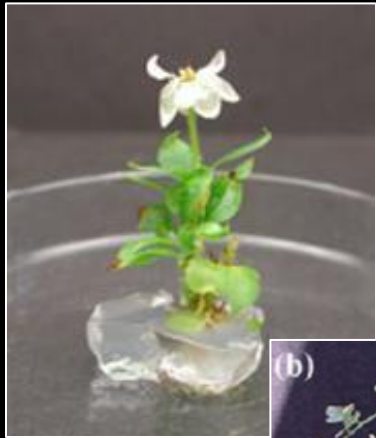
March 2014 issue
Scientific American



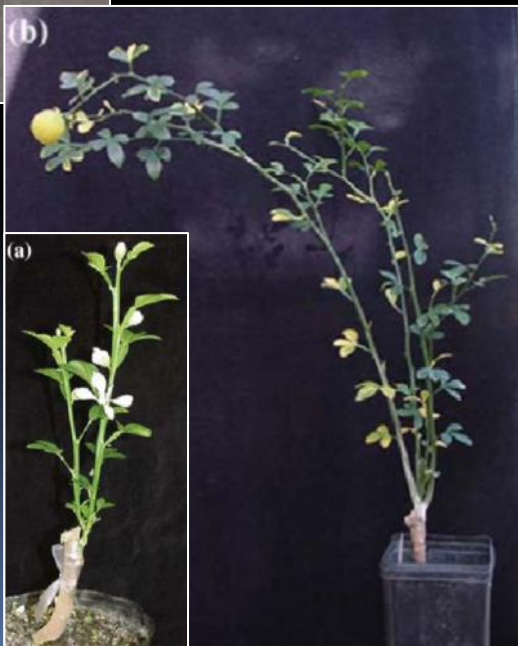
Courtesy of Bill Powell, SUNY Syracuse, USA

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

Apple



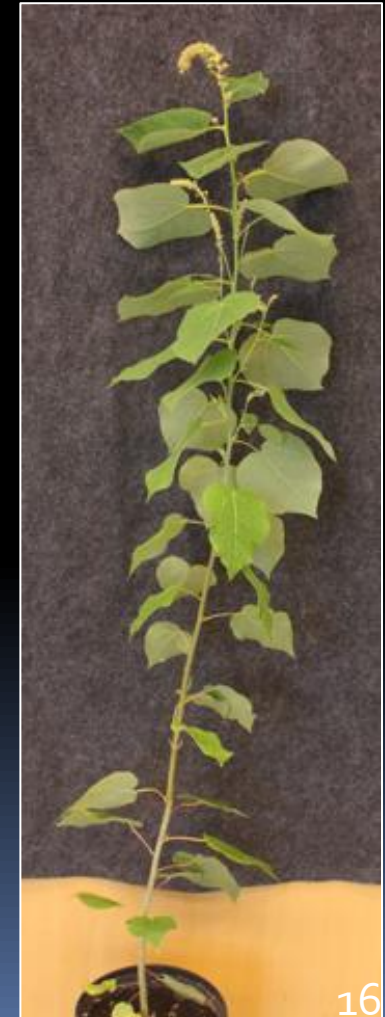
Orange



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



Control



Lead Line

Results from second winter
in Alabama



Lead Lines + Control

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

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 Lapiere^f, Kathleen Piens^g, Marc C. E. Van Montagu^{a,h,1}, Nicholas Santoro^g, Clifton E. Foster^g, John Ralphⁱ, Wim Soetaert^d, Gilles Pilate^g, and Wout Boerjan^{a,h,1}

^aDepartment of Plant Systems Biology, VIB, 9052 Ghent, Belgium; ^bDepartment of Plant Biotechnology and Bioinformatics, Ghent University, 9052 Ghent, Belgium; ^cInstitut National de la Recherche Agronomique (INRA), Unité de Recherche 0588, Amélioration, Génétique et Physiologie Forestières, 45075 Orléans, France; ^dCentre of Expertise for Industrial Biotechnology and Biocatalysis, Ghent University, 9000 Ghent, Belgium; ^eInstitut Jean-Pierre Bourgin, Unité Mixte de Recherche 1318, INRA-AgroParisTech, INRA Centre de Versailles-Grignon, 78026 Versailles, France; ^fDepartment of Biochemistry and Microbiology, Ghent University, 9000 Ghent, Belgium; ^gDepartment of Energy Great Lakes Bioenergy Research Center, Michigan State University, East Lansing, MI 48824; and ^hDepartments of Biochemistry and Biological Systems Engineering, Wisconsin Energy Institute, and the Department of Energy Great Lakes Bioenergy Research Center, University of Wisconsin-Madison, Madison, WI 53726

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 currently produced from the freshly accessible excess in biomass

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 reporter



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

GENETICALLY ENGINEERED TREES

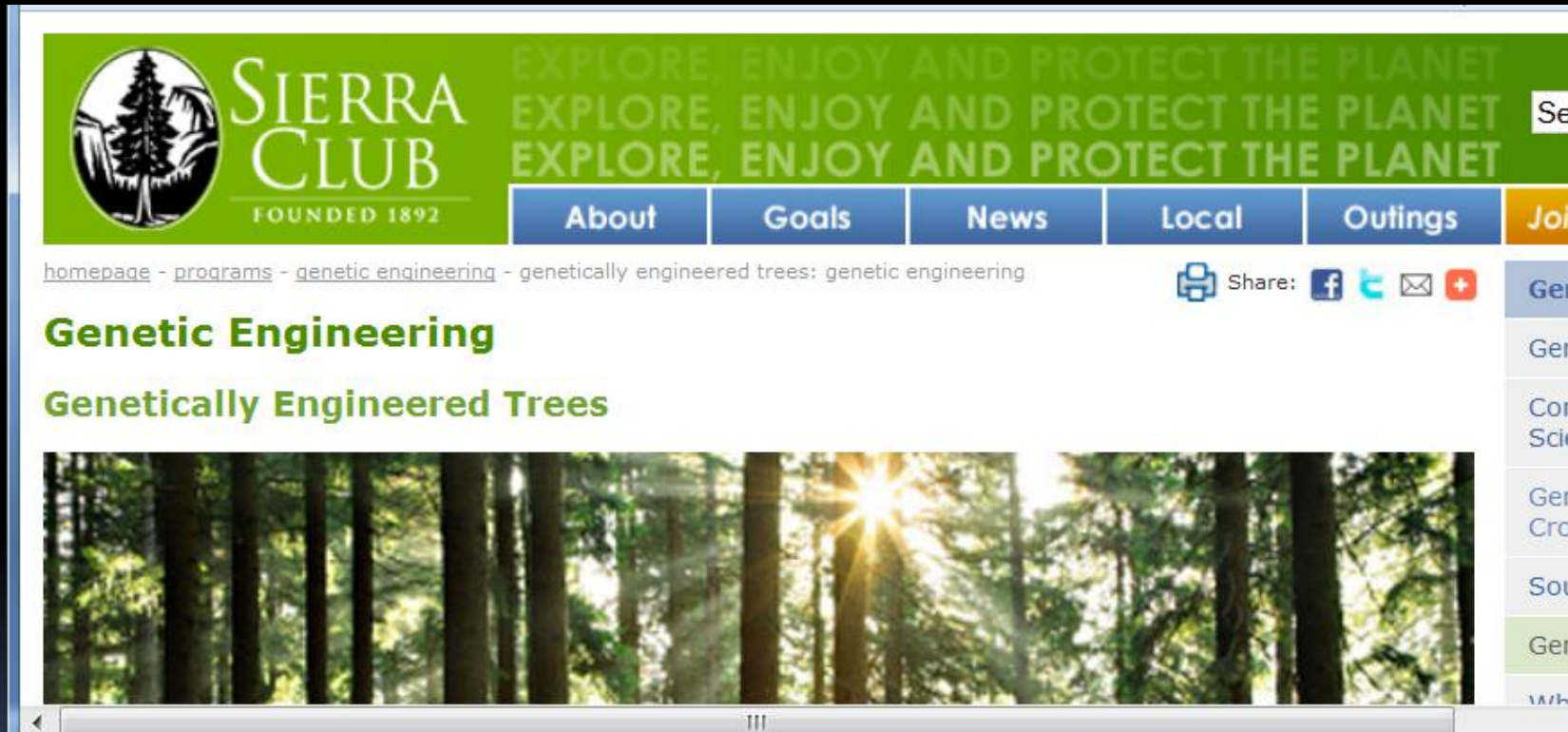
THE NEW FRONTIER OF
BIOTECHNOLOGY



 CENTER FOR
FOOD SAFETY
NOVEMBER 2013

“Center for Food Safety” in USA –
November 2013 report

Major environmental groups promoting wild forests dislike GE trees



The screenshot shows the Sierra Club website. The header features the Sierra Club logo (a tree in a circle) and the text "SIERRA CLUB FOUNDED 1892". To the right, the slogan "EXPLORE, ENJOY AND PROTECT THE PLANET" is repeated three times in a light green font. Below the header is a navigation menu with buttons for "About", "Goals", "News", "Local", "Outings", and "Join". A search bar is visible on the right side of the header. Below the navigation menu, there is a breadcrumb trail: "homepage - programs - genetic engineering - genetically engineered trees: genetic engineering". To the right of the breadcrumb trail are social media sharing icons for Facebook, Twitter, Email, and a plus sign. The main content area has a green heading "Genetic Engineering" and a sub-heading "Genetically Engineered Trees". Below the text is a large photograph of a forest with sunlight filtering through the trees. On the right side of the page, a vertical sidebar contains a list of categories, including "Gen", "Gen", "Con", "Sci", "Gen", "Cro", "Sou", "Gen", and "Wh".

“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?