Tree Biotech

Progress, prospects, and paralysis

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Plan

- The buzz from GMO crops and foods
- What is biotech?
- What is genetic engineering?
- Where might it matter for forestry?
- Some examples of progress
- The current state: Near paralysis

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

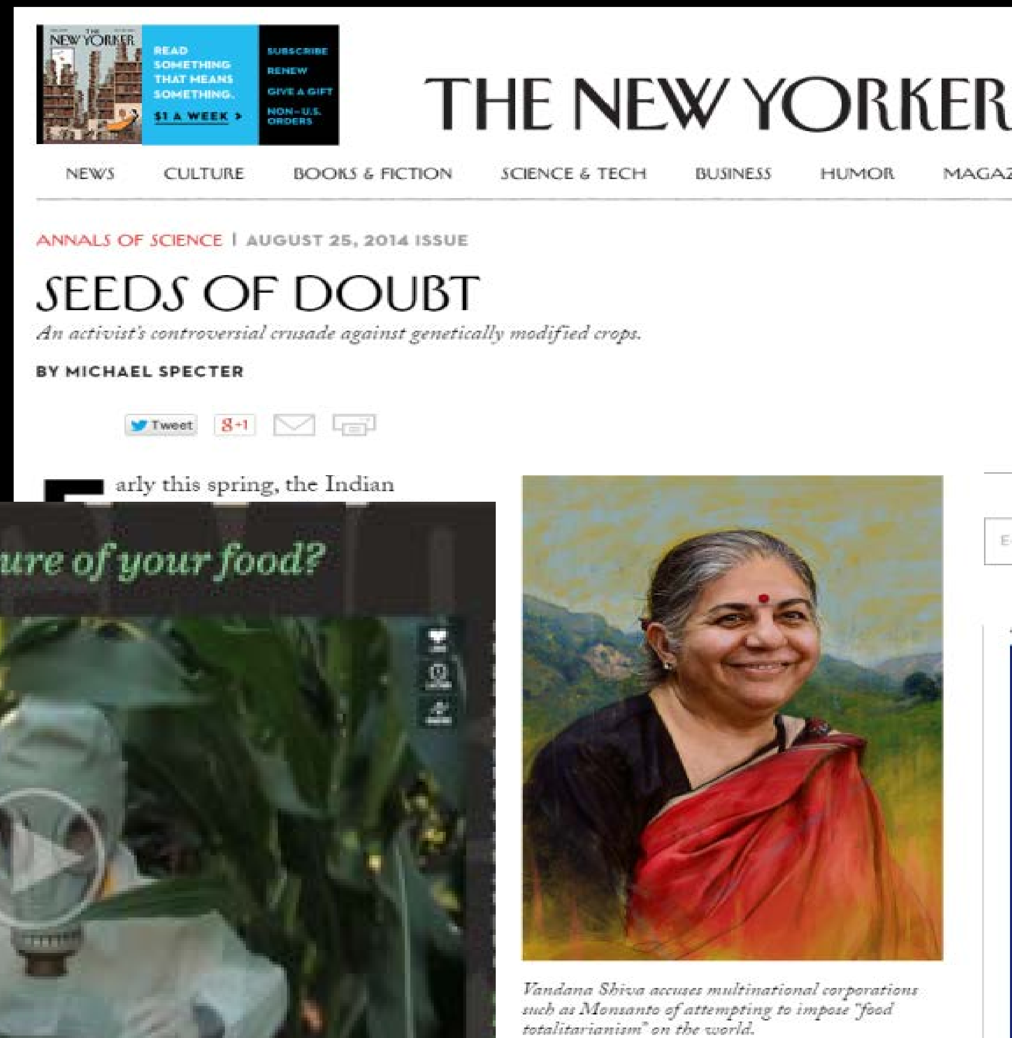
INTRODUCTION

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-

Proponents of various issues frequently distort science to influence perceptions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NEWS CULTURE BOOKS & FICTION SCIENCE & TECH BUSINESS HUMOR MAGAZI

ANNALS OF SCIENCE | AUGUST 25, 2014 ISSUE

SEEDS OF DOUBT

An activist's controversial crusade against genetically modified crops.

BY MICHAEL SPECTER

Early this spring, the Indian

Vandana Shiva accuses multinational corporations such as Monsanto of attempting to impose "food totalitarianism" on the world.

Money: Advocacy targeting conventional food & ag, often with GMO/chemical focus, is well funded and growing

- Agbiotech Info Net
- Agribusiness Examiner
- ACGA
- American Pasturage
- APHA
- Animal Protection Institute
- Beyond Pesticides
- NCRLC

- Farm Animal Reform Movement
- Farm Aid
- Farm Sanctuary
- Friends of the Earth
- GRACE
- Government Accountability Project
- Green Guide Institute
- Green Party USA

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

- Dawn Watch
- Deep Ecology
- Eco-Trust
- Economic Democracy
- Earth Spirit
- Earth First
- Environmental Defense
- Environmental Media Services
- FAIR
- Family Farm Defenders

- Organic Consumers Association
- PANNA
- PETA
- PCRM
- PIRG
- Public Citizen
- Purdey Fund
- Sierra Club
- SEAC
- Water Keeper Alliance

Institute for Social Ecology

NRDC

TIDES

PeTA

Jay Byrne, 2012, V-fluence

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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www.pewresearch.org

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

PewResearchCenter *Internet, Science & Tech*

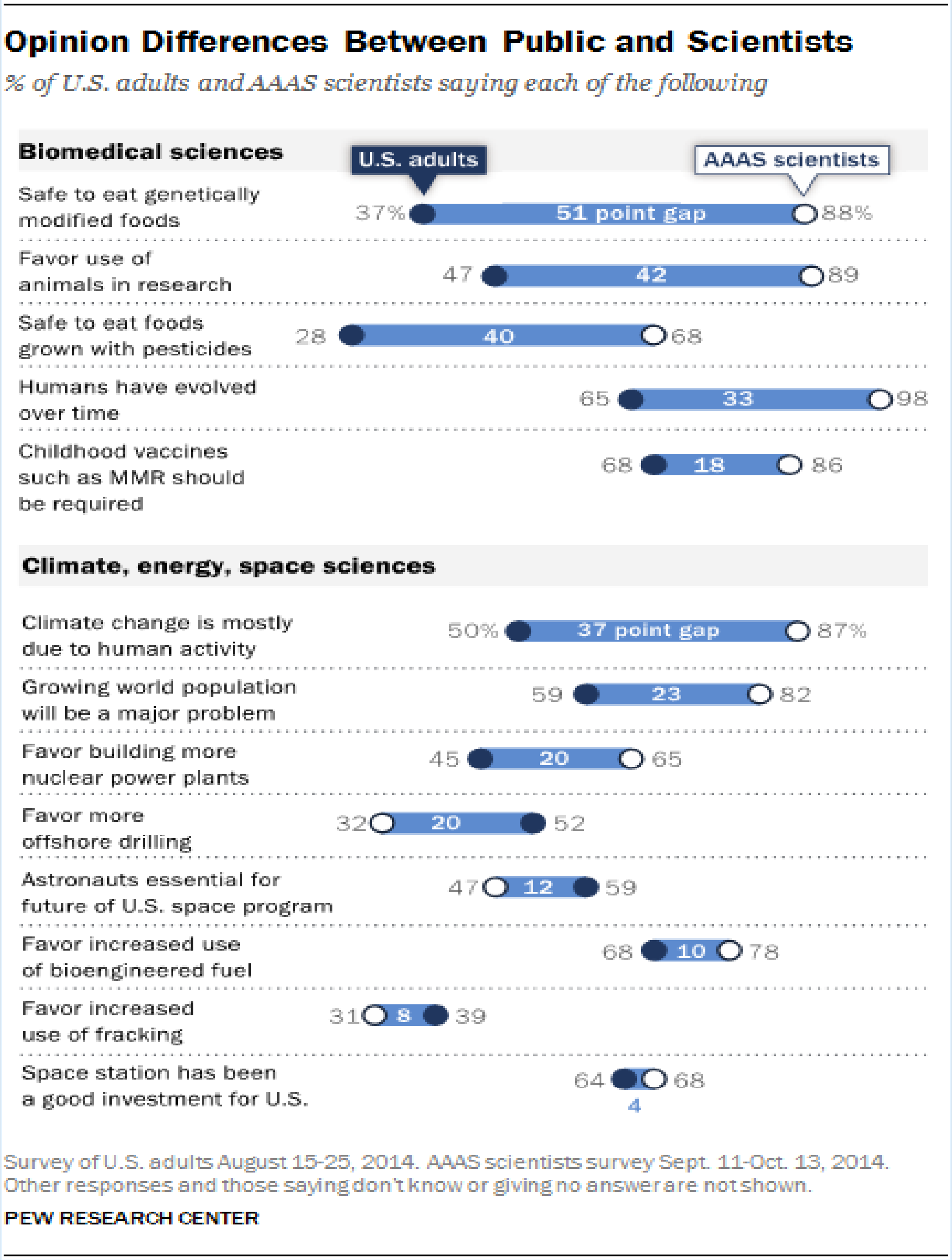
JANUARY 28, 2015

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

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

GMO issue with widest split between public and scientists



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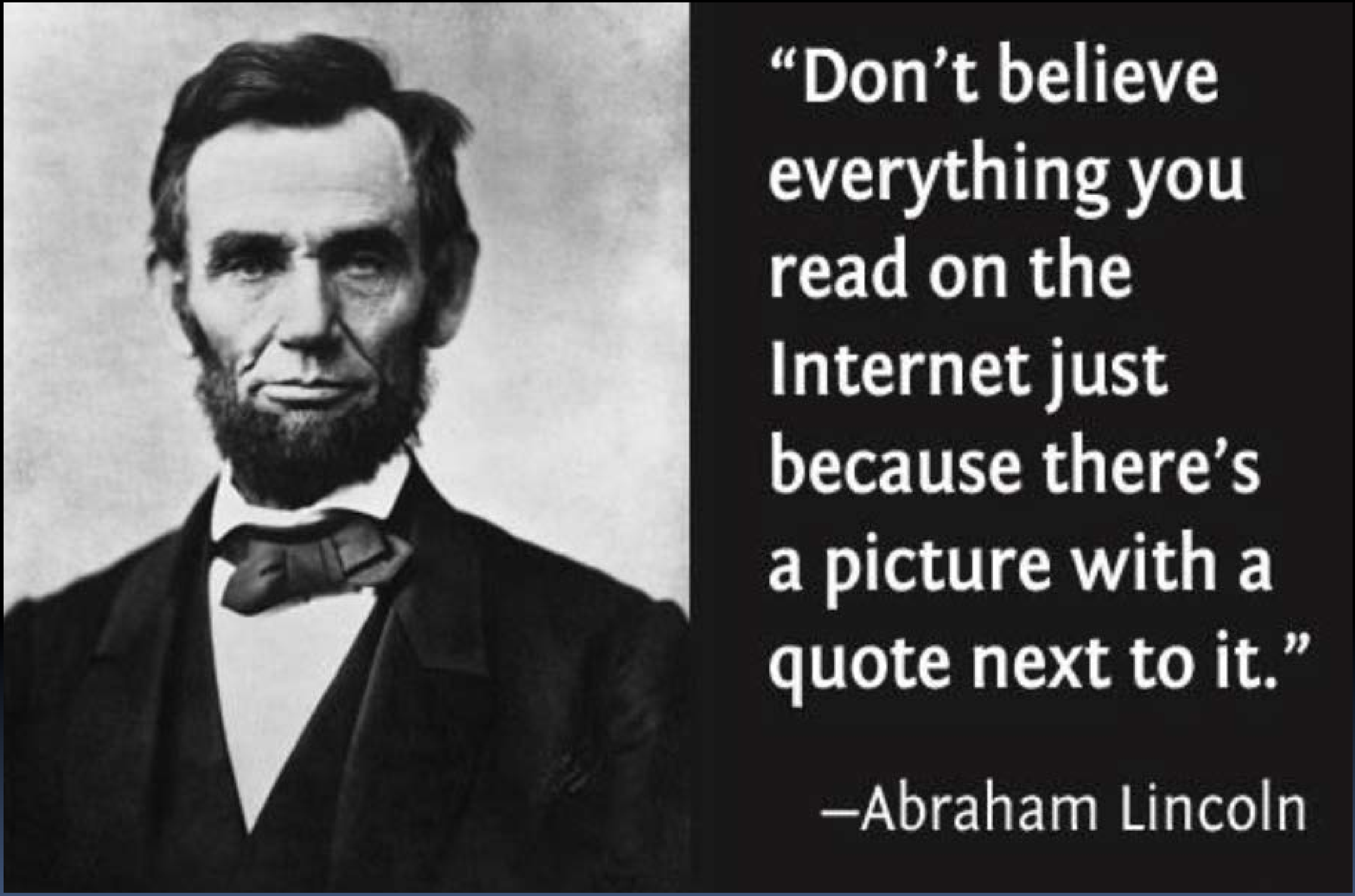

http://weknowmemes.com/2012/07/dont-believe-everything-you-read-on-the-internet

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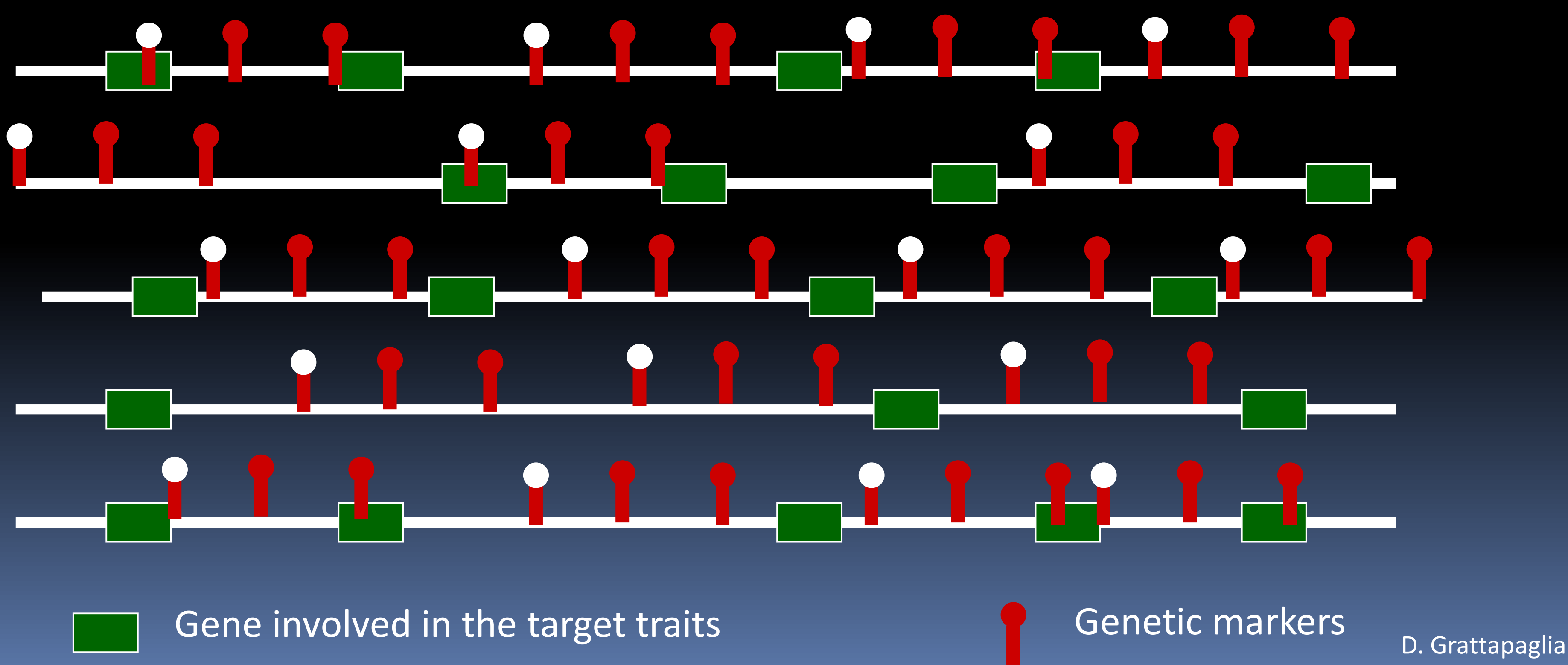
What is biotech?

- Use of biological technology for any reason
- Usually refers to genetics and genetic engineering (GE)
- But non-GE biotech powerful and non-controversial
  - Genomics, marker selection, genomic selection, etc

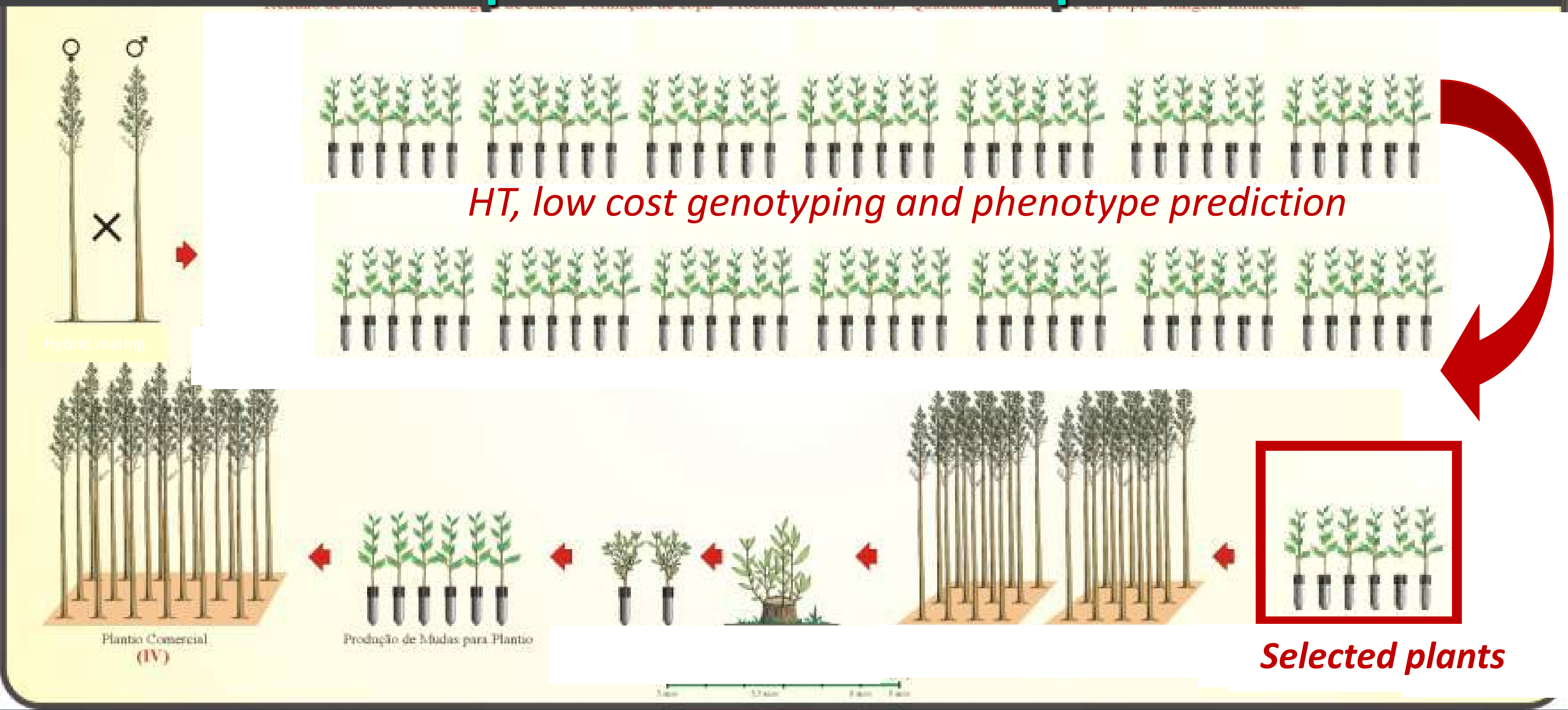

Newly selected elite clone
Currently planted elite clone
Advanced breeding and selection has a great impact on forest productivity
Grattapaglia: Fibria

Genomic Selection (GS) or Genome-Wide Selection

GS is the selection based on thousands of markers covering most of the genome



Genomic selection of new genotypes – Determine correlation between DNA and traits, then use that information to speed selection of best parents or clones



Genomic selection cuts down the time needed to select top genotypes, and reduces testing expenses

D. Grattapaglia

In Brazil, many companies are already implementing genomic selection in *Eucalyptus*

Fibria

VERACEL

Embrapa

CENIBRA

Klabin

INTERNATIONAL PAPER

Eldorado Brasil

Duratex

NIPPON PAPER GROUP

Questions about genomic selection

- Is it cost effective in the PNW?
  - Need to determine tens of thousands of DNA markers in thousands of trees
  - Up front cost, benefits much later
  - Diversity of breeding zones in the western USA
- It can move things faster based on past performance, is this always good?
  - Can it get us to <u>wrong</u> place faster given changing climates, pests, markets?

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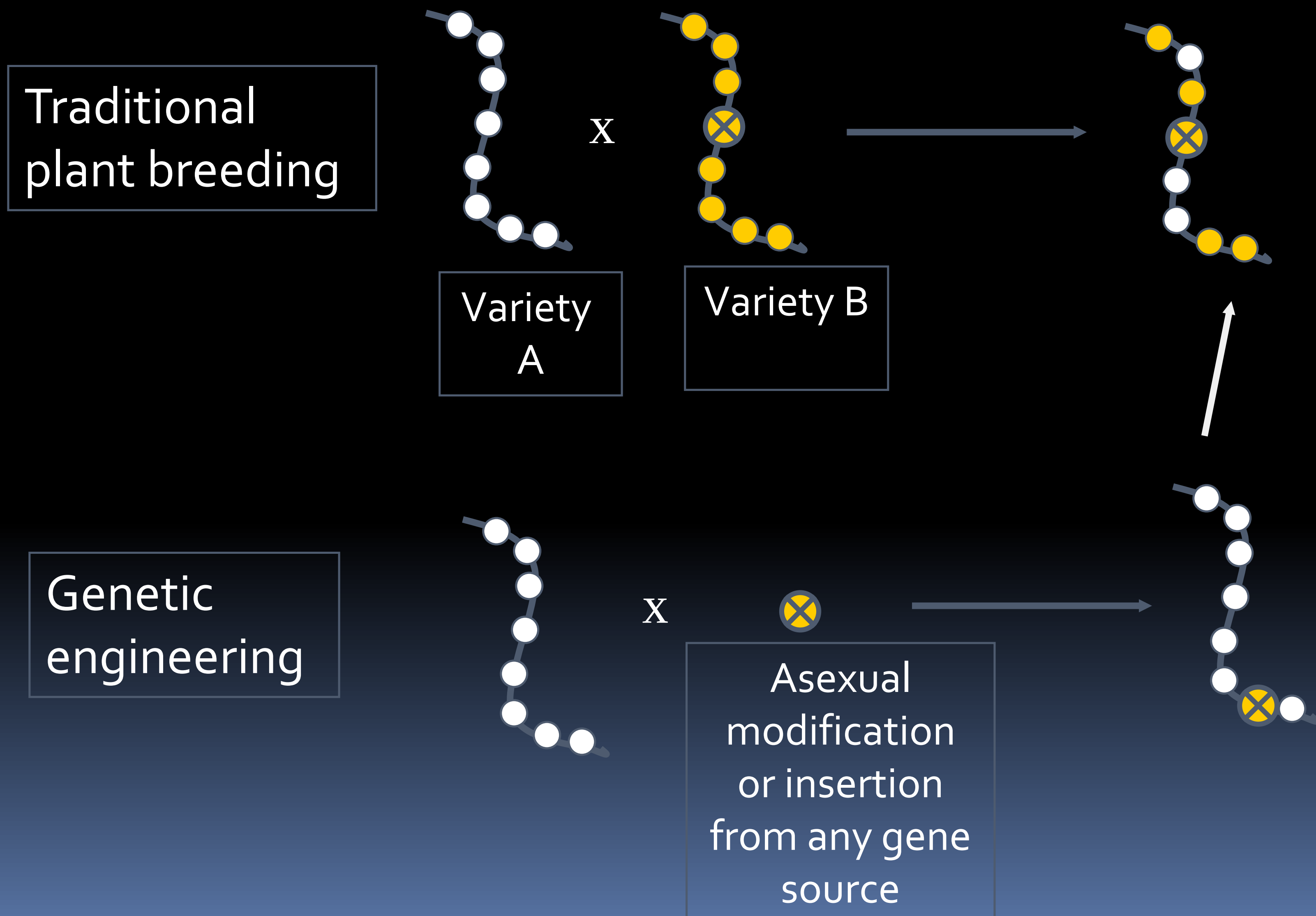
What is genetic engineering (GE)

- Direct modification of DNA
  - Vs. indirect modification in breeding and genomic selection
- Asexually modified in somatic cells
  - Then regenerated into whole organisms, usually starting in Petri dishes

GMO method (genetic engineering) defined



Regeneration of plants after introduction of DNA

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

Propagation of poplars in tissue culture

Growth in the field

Plan

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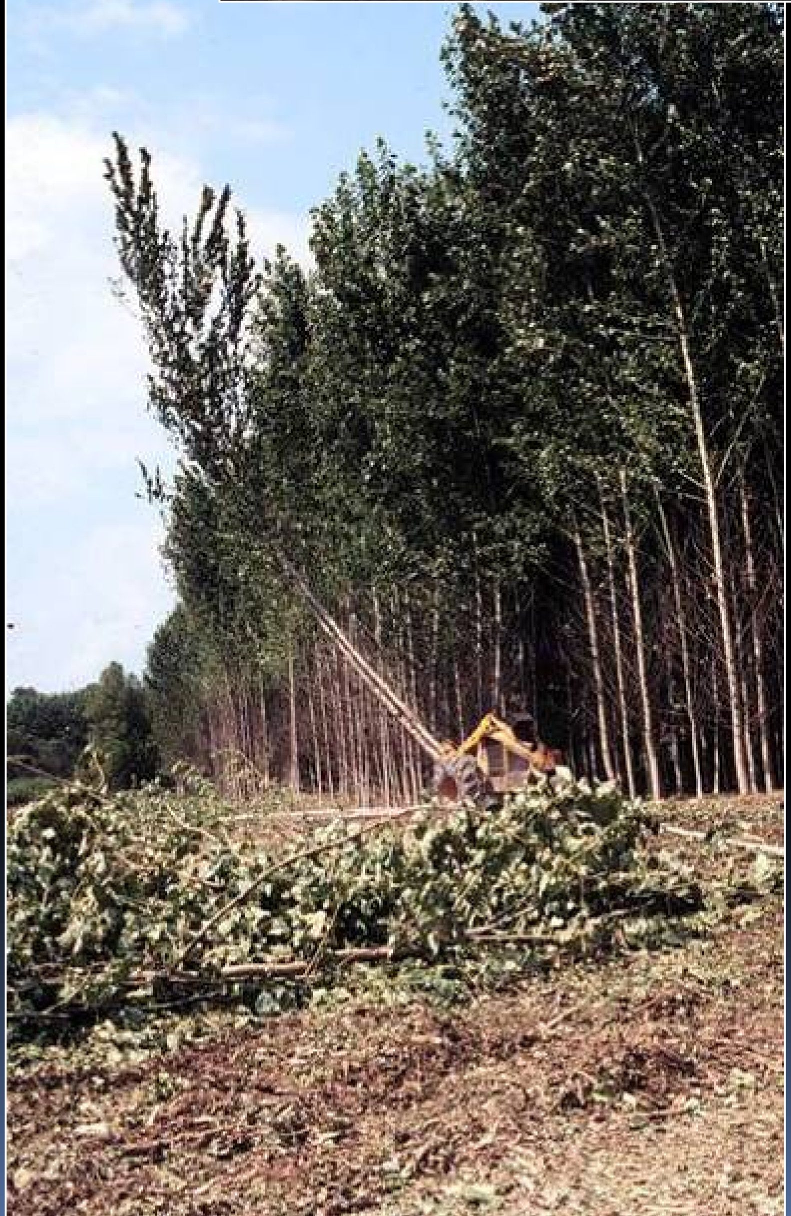
Short rotation, clonal plantations most obvious place for GE in forestry



Lignin reduced variety of poplar for pulp or biofuels

Courtesy of G. Pilate, INRA)

Lepidopteran-resistant poplars commercially approved in China - Bt *cry1*

- Trait stable
- Helps to protect non-Bt trees
- Reduced insecticide use
- Improved growth rate

Beetle resistant Bt-cottonwoods in eastern Oregon field trial

Growth benefits (10-20%) despite low insect pressure during large field trial of resistant genotypes

28

NRC Research Press

ARTICLE

Bt-Cry3Aa transgene expression reduces insect damage and improves growth in field-grown hybrid poplar

Amy L. Klocko, Richard Meilan, Rosalind R. James, Venkatesh Viswanath, Cathleen Ma, Peggy Payne, Lawrence Miller, Jeffrey S. Skinner, Brenda Oppert, Guy A. Cardineau, and Steven H. Strauss

Abstract: The stability and value of transgenic pest resistance for promoting tree growth are poorly understood. These data are essential for determining if such trees could be beneficial to commercial growers in the face of substantial regulatory and marketing costs. We investigated growth and insect resistance in hybrid poplar expressing the *cry3Aa* transgene in two field trials. An initial screening of 502 trees comprising 51 transgenic gene insertion events in four clonal backgrounds (*Populus trichocarpa* × *Populus deltoides*, clones 24-305, 50-197, and 198-434; and *P. deltoides* × *Populus nigra*, clone OP-367) resulted in transgenic trees with greatly reduced insect damage. A large-scale study of 402 trees from nine insertion events in clone OP-367, conducted over two growing seasons, demonstrated reduced tree damage and significantly increased volume growth (mean 14%). Quantification of Cry3Aa protein indicated high levels of expression, which continued after 14 years of annual or biannual coppice in a clone bank. With integrated management, the *cry3Aa* gene appears to be a highly effective tool for protecting against leaf beetle damage and improving yields from poplar plantations.

Résumé : La stabilité et la valeur de la résistance transgénique aux ravageurs pour favoriser la croissance des arbres ne sont pas bien connu
être profita
marché de

Can. J. For. Res. 44: 28–35 (2014) dx.doi.org/10.1139/cjfr-2013-0270

Published at www.nrcresearchpress.com/cjfr on 28 October 2013.

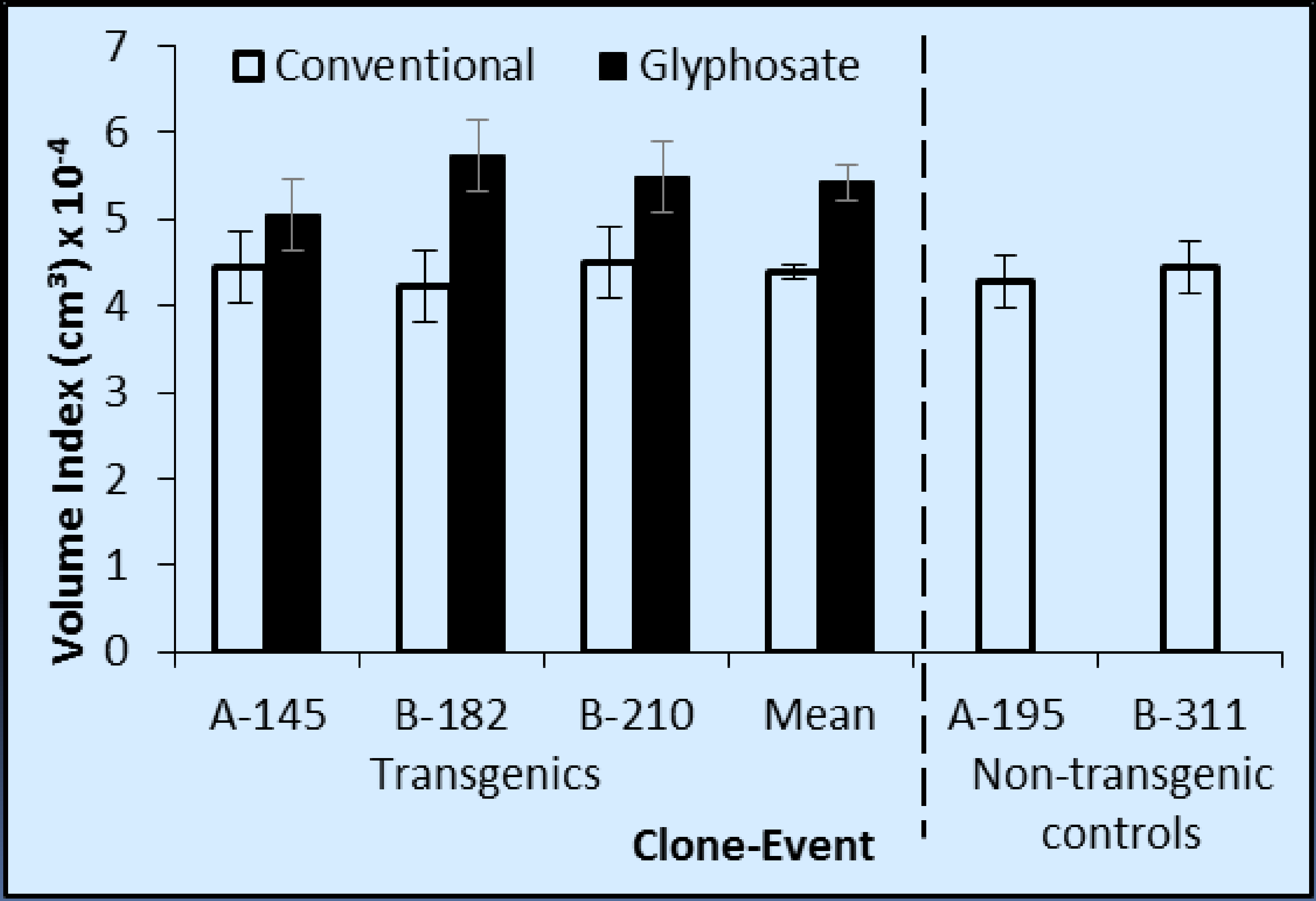
Glyphosate herbicide resistance in cottonwood

Screen of primary transformants

2 yr-old field trial

Wild type controls

Growth benefit in Roundup-resistance tailored system: ~20% volume at 2 years

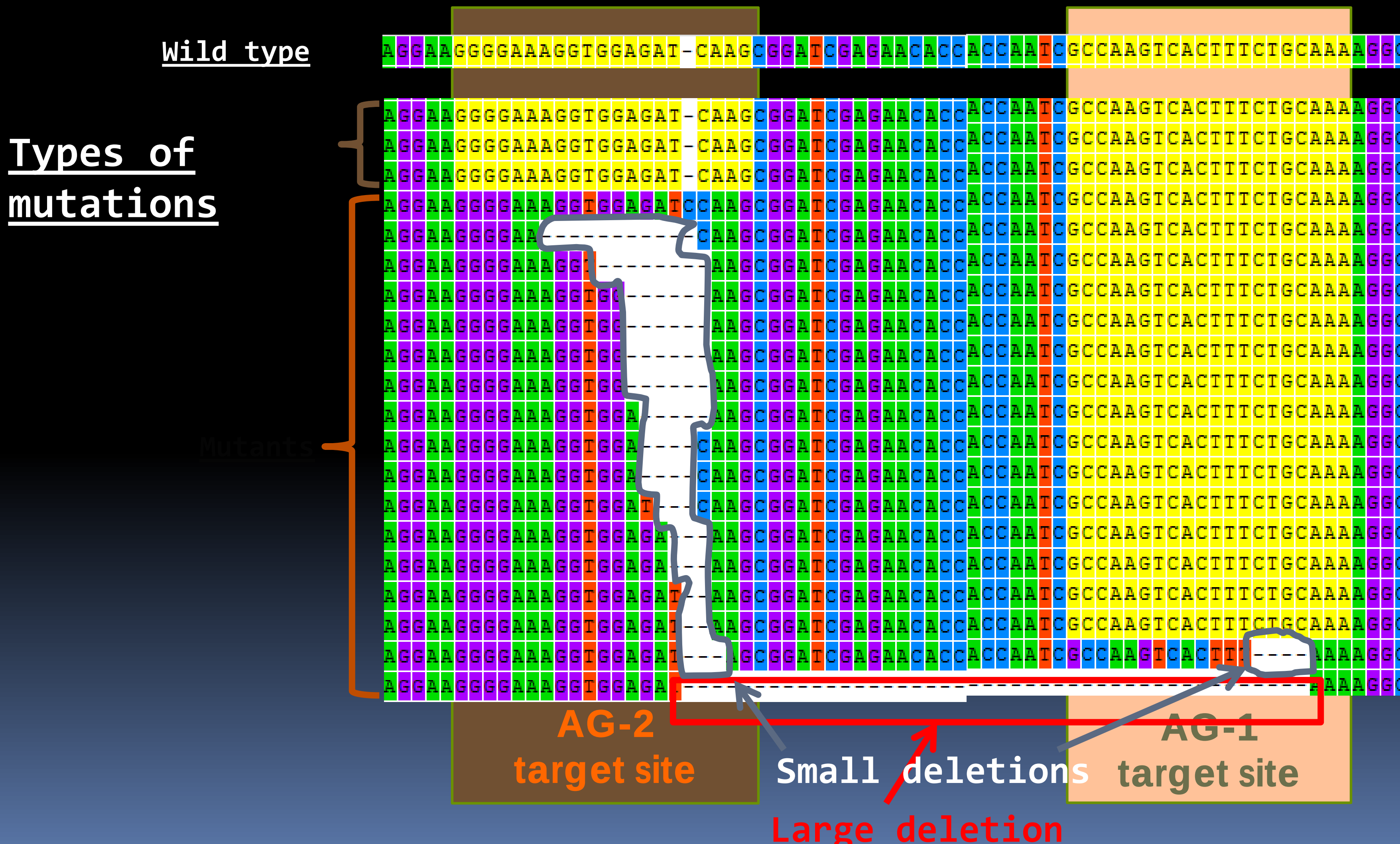


Testing genetic containment methods in the field in poplar

Complete sterility - Undeveloped catkins due to stable suppression of native "*LEAFY*" gene in poplar (RNAi)

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

Better yet, “gene editing” by CRISPRs enable predictable, stable, certain sterility? **~50% biallelic mutation rate for floral genes!**



Insect control via RNAi

Creation of a new plant gene that suppresses a critical gene in a pest using it's own machinery

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

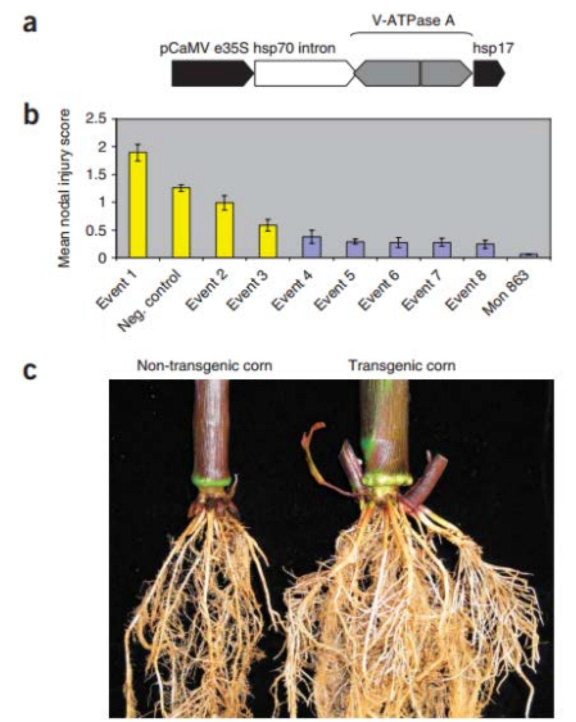


Figure 2 F1 plants expressing a V-ATPase A dsRNA are protected from WCR feeding damage. (**a**) Map of the expression cassette. (**b**) Mean root damage ratings for eight F_1 populations, the parental inbred line (negative control) and the corn rootworm–protected Cry3Bb event MON863; NIS, nodal injury 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.

Eucalypt plantation another obvious place for GE applications

Wood modification to promote growth rate – just authorized by Brazilian government for commercial use

CASSIO VASCONCELLOS/SAMBAPHOTO/GETTY

Eucalyptus plantations near São Paulo in Brazil.

BIOTECHNOLOGY

Brazil considers transgenic trees

Genetically modified eucalyptus could be a global test case.

28 AUGUST 2014 | VOL 512 | NATURE | 357

Provided by Arborgen

Cold tolerant GE *Eucalyptus*

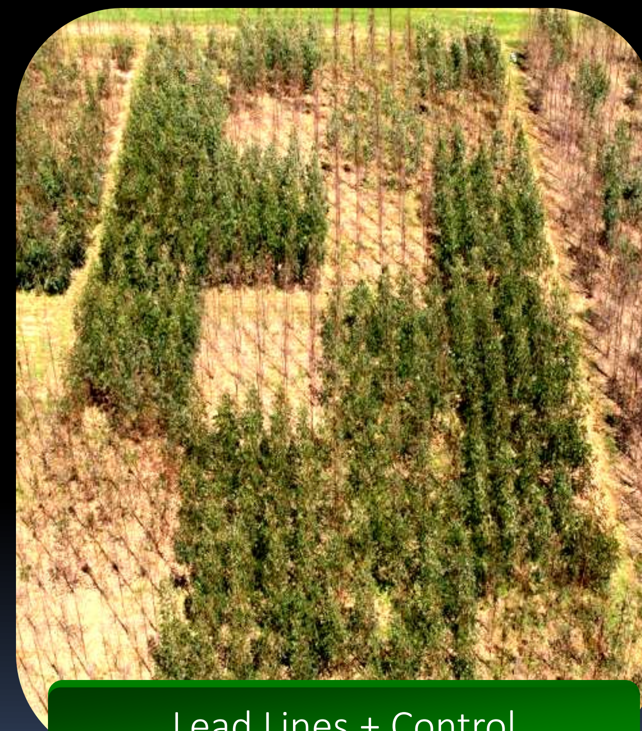
Proposed for commercial deregulation in USA

Results from first winter in South Carolina

Control

Lead Line

Results from second winter in Alabama



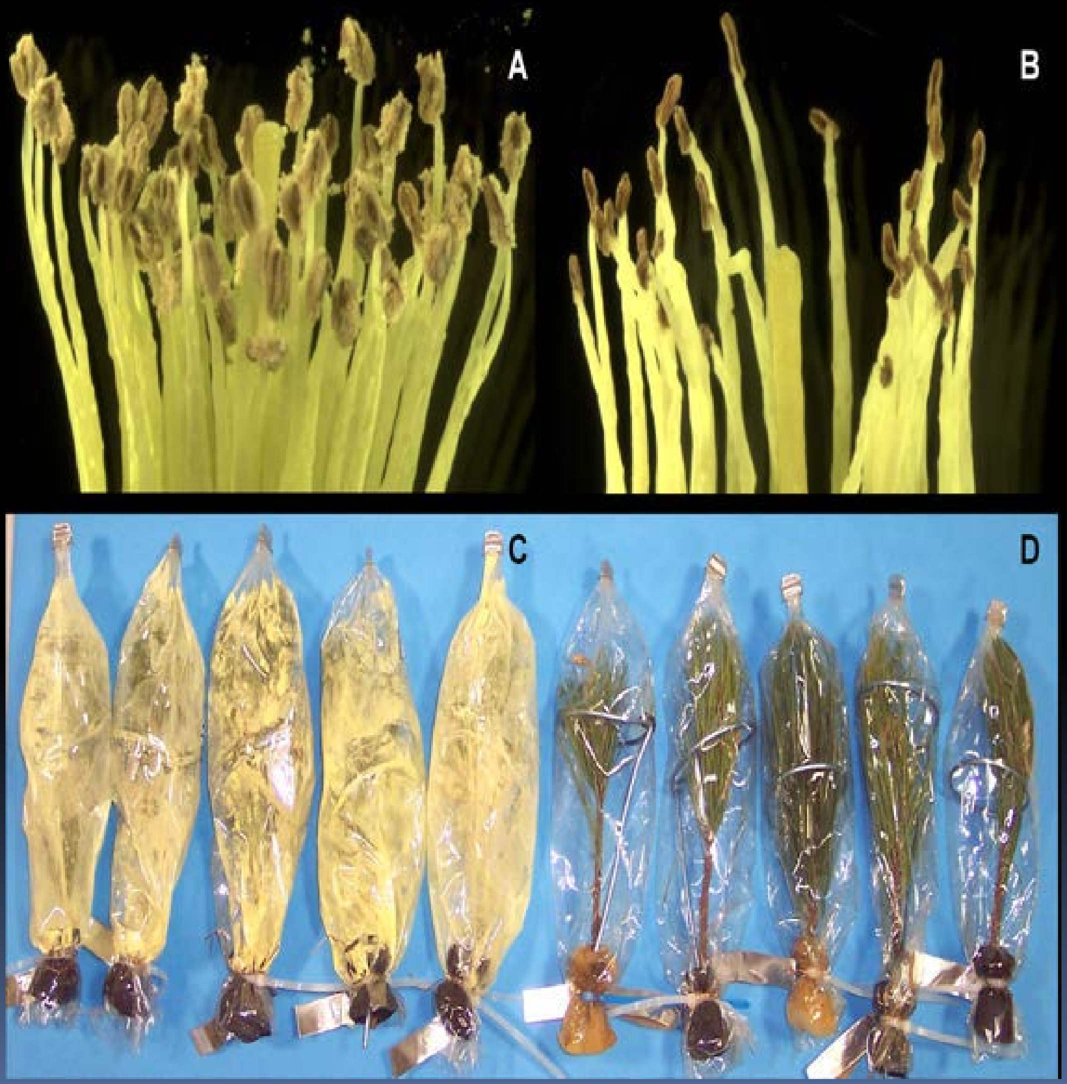
Lead Lines + Control

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

Many eucalypt field trials underway

Courtesy of Les Pearson, Arborgen

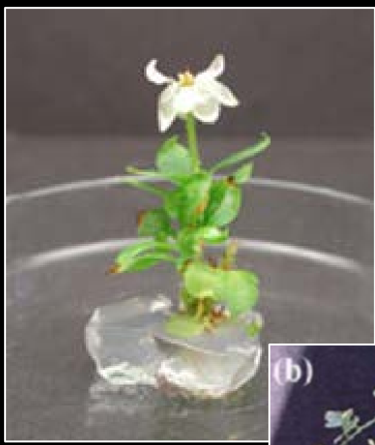
Male sterile eucalypts and pine - Arborgen



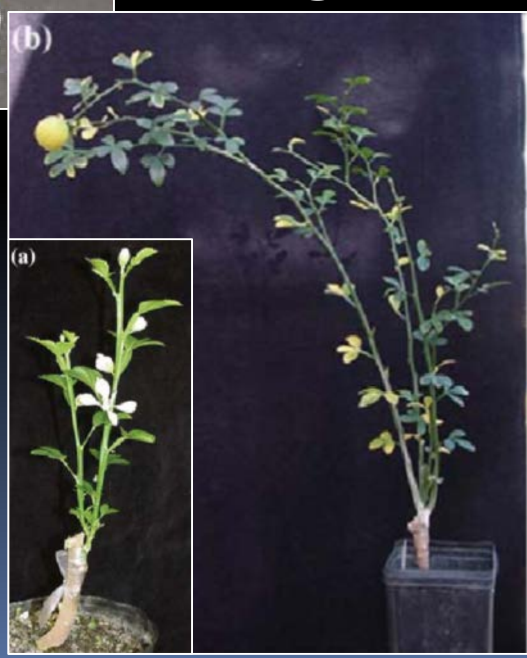
Anther-specific promoter driving expression of a strong RNAse prevents pollen maturation and release

Overexpression of endogenous flowering genes induce early flowering in several tree species

Apple



Orange



Plum

Eucalyptus

Wild forest tree protection or restoration another place for GE trees?

American Chestnut restoration with help of GE?

Forest health a global 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
pach are needed. Mitigation strategies that are effective only in
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-
(1–3). Globally,
ted to rely on

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

September 8, 2015

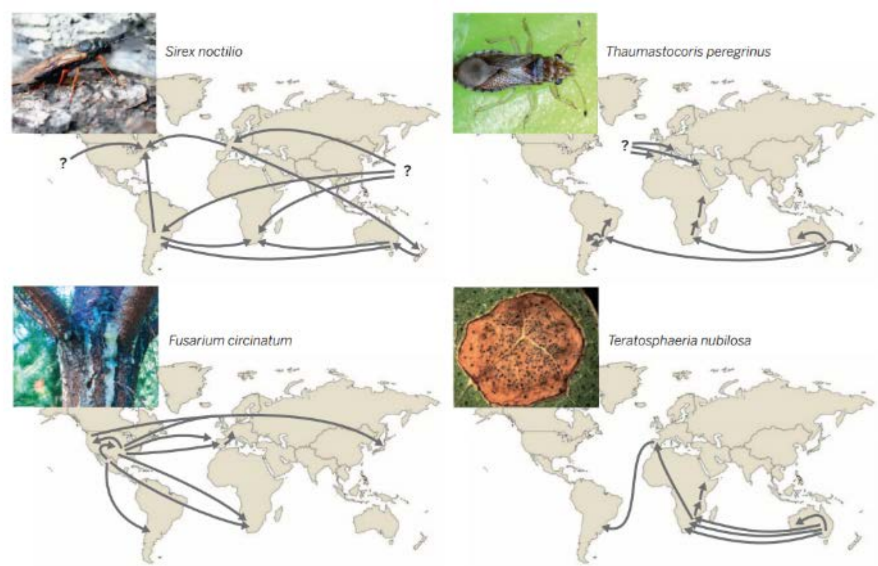


Fig. 2. Examples of invasion routes of pests of planted forests that illustrate an apparently common pattern of complex pathways of spread to new environments, including repeated introductions and with either native or invasive populations serving as source populations (*18*). Invasion routes of the 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]

834 21 AUGUST 2015 • VOL 349 ISSUE 6250 sciencemag.org SCIENCE

Many exotic diseases have severely impacted US forests

- 1892 - White pine blister rust
- 1904 - Chestnut blight
- 1923 - Port-Orford-cedar root disease
- 1920s - Beech scale complex
- 1930 - Dutch elm disease
- 1967 - Butternut canker
- 1976 - Dogwood anthracnose
- 2000s - Sudden oak death

American elm

Hemlock in US under siege today

Corrected 2 September 2015; see full text. *FOREST HEALTH* **SPECIAL SECTION**

BATTLING A GIANT KILLER

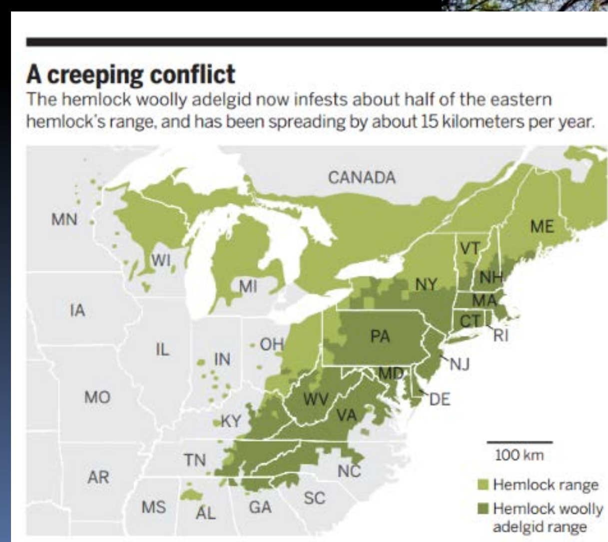
The iconic eastern hemlock is under siege from a tiny invasive insect

By **Gabriel Popkin** *in Highlands, North Carolina; photography by* **Katherine Taylor**

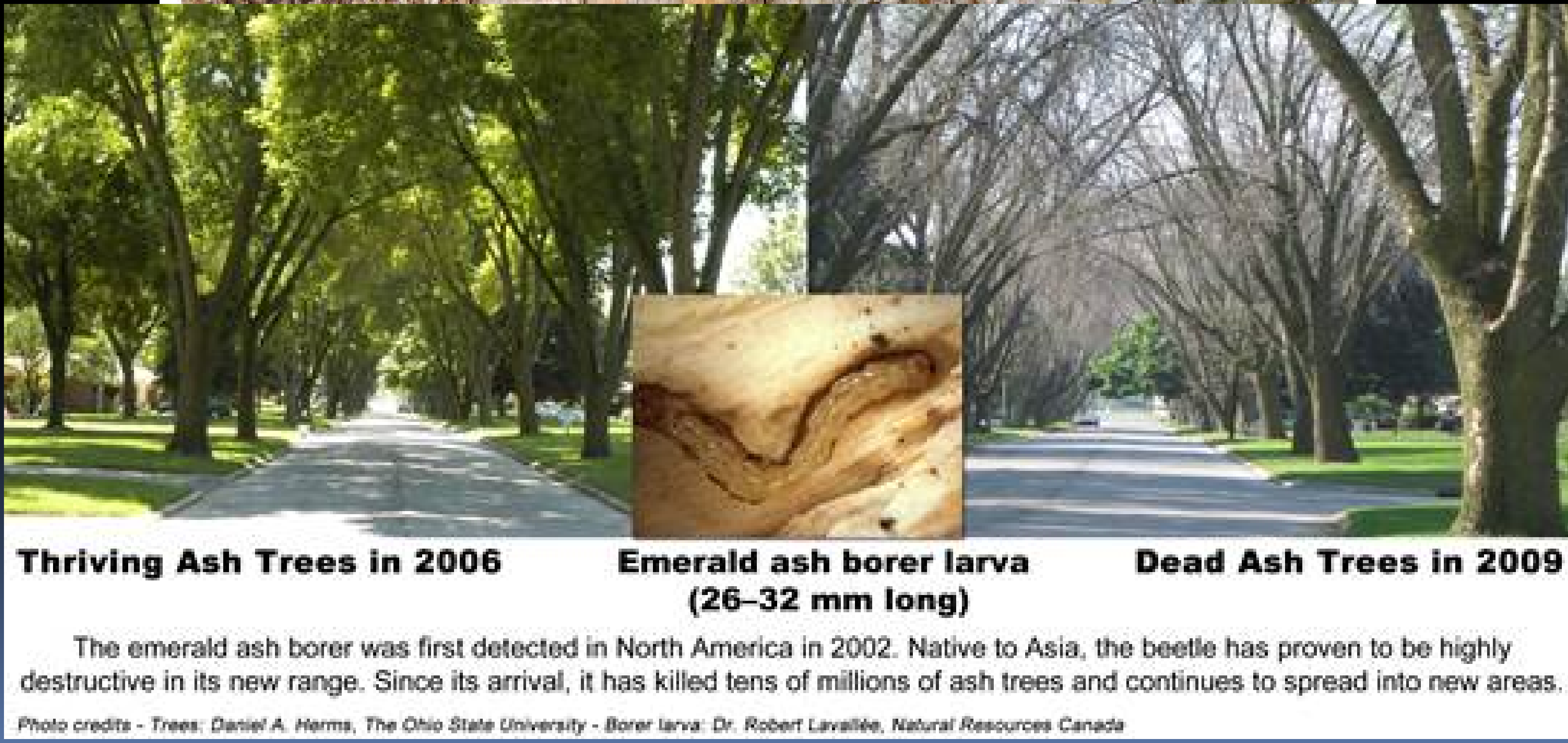
On a frigid morning this past March, arborist Will Blozan snuck behind a small church here and headed down into a gorge thick with rhododendron. He crashed through the shrubs until he spotted the

park, "are in intensive care." Like the family of a gravely ill patient, ecologists are also preparing for the possibility that these efforts will fail, and the eastern forest will lose one of its defining species.

branches, creating a thick canopy that blocks up to 99% of sunlight. Few plants grow in the gloom, but a hemlock seedling can bide its time for decades or more, waiting for a sunlit opening. Hundreds of species of insects, mites, and spiders appear to live primarily



Emerald Ash Borer: Killing ~all ashes in USA – costing billions



Swiss Needle Cast in Oregon

Douglas-fir: Breeding ~ ineffective

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The case for paralysis

(August 2015, Science)

Traces of the emerald ash borer on the trunk of a dead ash tree in Michigan, USA. This non-native invasive insect from Asia threatens to kill most North American ash trees.

BIOTECHNOLOGY

Genetically engineered trees: Paralysis from good intentions

Forest crises demand regulation and certification reform

By **Steven H. Strauss[1*], Adam Costanza[2], Armand Séguin[3]**

Intensive genetic modification is a long-standing practice in agriculture, and, for some species, in woody plant horticulture and forestry (*1*). Current regulatory systems for genetically engineered

recently initiated an update of the Coordinated Framework for the Regulation of Biotechnology (*2*), now is an opportune time to consider foundational changes.

Difficulties of conventional tree breeding make genetic engineering (GE) methods relatively more advantageous for forest trees than for annual crops (*3*). Obstacles

Although only a few forest tree species might be subject to GE in the foreseeable future, regulatory and market obstacles prevent most of these from even being subjects of translational laboratory research. There is also little commercial activity: Only two types of pest-resistant poplars are authorized for commercial use in small areas in China and two types of eucalypts, one approved in Brazil and another under lengthy review in the USA (*5*).

METHOD-FOCUSED AND MISGUIDED. Many high-level science reports state that the GE method is no more risky than conventional breeding, but regulations around the world essentially presume that GE is hazardous and requires strict containment

Forthcoming related essay in Forestry Source in November

Regulatory problems fundamental

- Presumption that all GE is harmful to environment regardless of gene, problem
  - Very hard to go beyond boutique research without very costly regulatory approval (millions of dollars)
  - Public sector, small companies cannot afford
  - USDA Forest Service hesitant to invest, engage
- Essentially impossible to do field research in many countries due to costs, politicized nature
  - Vandalism a major issue in Europe still

Market barriers large

“Green” certification of forests create severe barriers to field research, markets

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…”

Forest certification systems universally ban all GM trees – no exemptions

System	Region	GM Tree Approach / Reason
PEFC : Programme for Endorsement of Forest Certification	International	**Banned** / Precautionary approach based on lack of data
FSC : Forest Stewardship Council	International	**Banned** / Precautionary approach based on lack of data
CerFlor : Certificação Florestal	Brazil	**Banned** via PEFC registration / No additional rationale
CertFor : Certficación Forestal	Chile	**Banned** via PEFC registration / No additional rationale
SFI : Sustainable Forestry Initiative	North America	**Banned** via PEFC registration / Awaiting risk-benefit data
ATFS : American Tree Farm System	USA	**Banned** via PEFC registration / No additional rati
CSA : Canadian Standards Association	Canada	**Banned** via PEFC regi Allows public to determi
CFCC : China Forest Certification Council	China	**Banned** via PEFC regi No additional rati

Adam Costanza, Institute for Forest Biotechnology

Other constraints

- Trees often rich in diversity due to early state of domestication
  - GE often not essential, other options can be found
- Genetic engineering methods often very difficult and highly genotype-specific
  - Very limited advances outside of a few intensively studied species, public research ~halted
- Gene flow extensive, wild or feral relatives
  - Ethical questions, regulatory questions, science challenges
  - Political opponents active, powerful
- No consensus on what precaution means in relation to genetic engineering

Forest health a major and growing concern

REVIEW

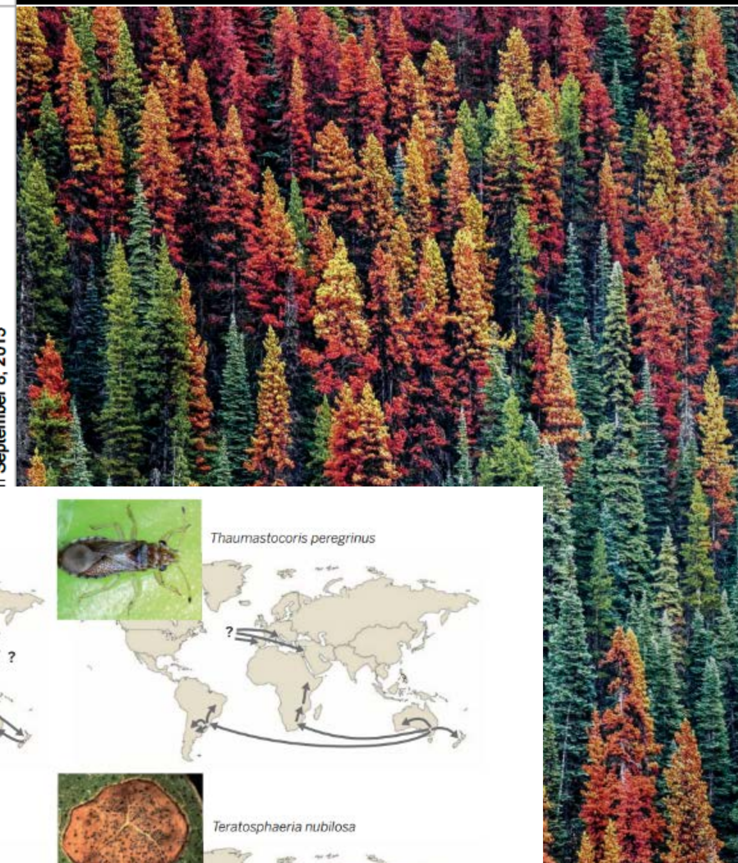
Planted forest health: The need for a global strategy

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 ...oach are needed. Mitigation strategies that are effective only in ... 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 to which they have no resistance, substantial



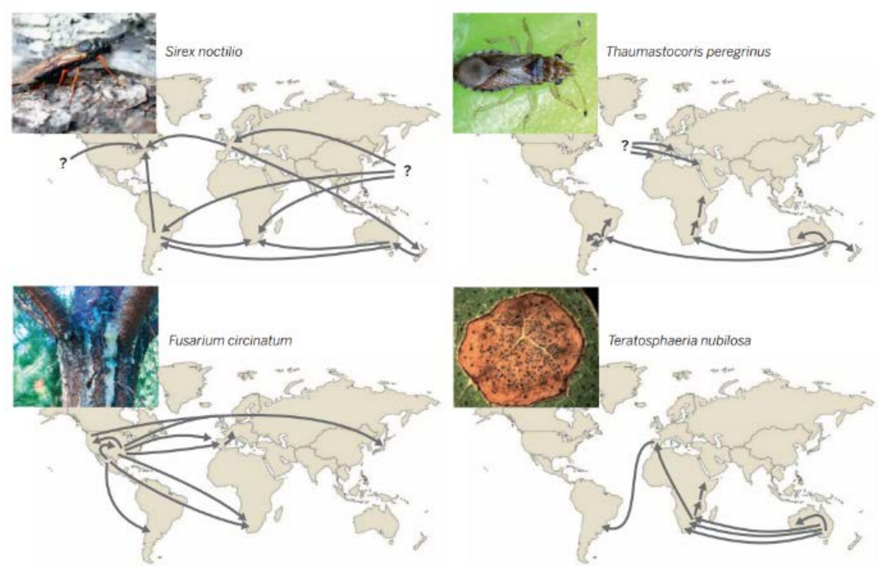


Fig. 2. Examples of invasion routes of pests of planted forests that illustrate an apparently common pattern of complex pathways of spread to new environments, including repeated introductions and with either native or invasive populations serving as source populations (18). Invasion routes of the pine 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]

No-analog scientific thinking should dominate today

PALEOECOLOGY PALEOECOLOGY PALEOECOLOGY

Novel climates, no-analog communities, and ecological surprises

John W Williams[1*] and Stephen T Jackson[2]

No-analog communities (communities that are compositionally unlike any found today) occurred frequently in the past and will develop in the greenhouse world of the future. The well documented no-analog plant communities of late-glacial North America are closely linked to "novel" climates also lacking modern analogs, characterized by high seasonality of temperature. In climate simulations for the Intergovernmental Panel on Climate Change A2 and B1 emission scenarios, novel climates arise by 2100 AD, primarily in tropical and subtropical regions. These future novel climates are warmer than any present climates globally, with spatially variable shifts in precipitation, and increase the risk of species reshuffling into future no-analog communities and other ecological surprises. Most ecological models are at least partially parameterized from modern observations and so may fail to accurately predict ecological responses to these novel climates. There is an urgent need to test the robustness of ecological models to climate conditions outside modern experience.

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How do you study an ecosystem no ecologist has ever seen? This is a problem for both paleoecologists and past or future, is heavily conditioned by our current observations and personal experience.

"No-analog communities (communities that are compositionally unlike any found today) occurred frequently in the past and will develop in the greenhouse world of the future."

Are our regulations and certification systems worrying too much about the deck chairs on the Titanic, rather than providing tools for improved navigation of the ship?

Was Voltaire talking about biotech regulations?

"The perfect is the enemy of the good"

In summary

- Many examples of progress with GE trees with a wide variety of traits, in the field
  - Mostly poplar, some eucalypts
- Extraordinary barriers based on GMO regulation, certification, and tree biology
  - Makes implementation of GE tools on a scale and speed relevant to need and benefit ~unworkable
- Growing number of forest stresses where silviculture, conventional breeding, inadequate
  - Much more expected with global travel, climate shifts
  - Is avoidance of GE precautionary or the opposite?
- Need for fundamental regulatory and market change?
  - USA reconsidering many regulations now
  - But fundamental change not likely (in my lifetime)