Why Biotech Solutions are Needed to Address Forest Health

Steve Strauss
Oregon State University / USA

The National Academies of SCIENCES ENGINEERING MEDICINE

THE POTENTIAL FOR BIOTECHNOLOGY TO ADDRESS FOREST HEALTH

Why advocate for recDNA tech?

- **Science** – rDNA starts from nature
- **Innovation** – Builds on nature to enhance values
- **Trees** – Can enhance forests, wild and planted
- **Urgency** – Tools for growing forest health crises
- **Controversy** – Enjoy battles of ideas, interests

Key messages

- rDNA methods are powerful tools to supplement breeding in the right niches
- Serious technical and social obstacles prevent their significant use, or even research, for forest health
- In the face of forest health crises, we have an ethical obligation to create technological capacity and social conditions to enable wider use

Agenda

- Basics
- Rationales
- Constraints
- Solutions

What is rDNA biotech?

- Equivalent to genetic engineering (GE), genetic modification (GM), and including gene editing like CRISPR
- Direct modification of DNA
  - Vs. indirect modification in breeding and genomic selection
- Asexually modified, usually in somatic cells
  - Then regenerated into whole organisms, most often starting in Petri dishes


nature
THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE
Dawn of the gene-editing age
PAGE 155
CRISPR
EVERYWHERE
CONSERVATION
A WORLD OF TWO HALVES
E. O. Wilson's vision for an Earth shared with nature
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FLOWER ARRANGEMENT
An attractant/receptor pair driving pollen-tube growth
PAGES 178, 241 & 245
GROUP DYNAMICS
THE RIGHT SIZE FOR A LAB
The skills mix and head count needed for success
PAGE 263
NATURE.COM/NATURE
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High CRISPR mutation rates observed in poplar and eucalypts – Strauss laboratory

- Cas-only control events and off-target sites
  - Several dozens of gene insertions studied
  - **No mutations**
- CRISPR-Cas events
  - Hundreds of gene insertions studied
  - 80-100% with mutations
  - **50-95% biallelic knock-outs**

Agenda

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- Solutions

GMO methods of special value for trees due to breeding constraints

- Long breeding cycle
- Difficulty to inbreed and introgress new genes (genetic load)
- Hard to identify and use dominant, major genes
- Asexually propagated varieties of high value
- A powerful addition to breeding repertoire?
  - Access Mendelian genes and breeding tools

GE of special value for forest health

- Can design biotic resistance genes based on knowledge of gene function
  - General and host-specific toxins
  - Host induced gene silencing (HIGS)
  - Effector targets
  - Induced programmed cell death
- Pyramiding diverse resistance genes by recDNA
- Combining into conventionally bred and adapted ~resistant germplasm
- Tantalizing possibilities with abiotic stress tolerance as well – advanced cold and salt tolerance examples

HIGS can be effective for insect and fungal resistance

PNAS PNAS PNAS

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

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

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

Edited* by Diter von W... il 5, 2013)

Head blight, which ... genus *Fusarium*, is ... assessed the poten... the fungal cytochro... genes, which are e... fungal infection. In... vitro feeding of CY... plementary to *CYP51A*, *CYP51B*, and *CYP51C*, resulted in growth inhibition [half-maximum growth inhibition (IC_{50}) = 1.2 nM] as well as altered fungal morphology, similar to that observed after treatment with the azole fungicide tebuconazole, for which the CYP51 enzyme is a target. Expression of the same dsRNA in *Ara-bidopsis* and barley rendered susceptible plants highly resistan... to fungal infection. Microscopic analysis revealed that myceliu... formation on *CYP3RNA*-expressing leaves was restricted to the...

...rdly surprising that ...MI fungicides, has ... fungi (8–14). The ...e last few years (15) ...ntrol strategies. ...a powerful genetic ...lant biotechnology and facilitated the validation of potentially useful agronomical traits. RNAi is known as a conserved integral part of the gene-regulation processes present in all eukaryotes (16, 17); in plants, it is also named posttranscriptional gene silencing (18). Post-

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

19324–19329 | PNAS | November 26, 2013 | vol. 110 | no. 48

Domain for HIGS in pest resistance seems to keep expanding

Plant Biotechnology Journal

Plant Biotechnology Journal (2014) **12**, pp. 821–831

doi: 10.1111/pbi.12226

Review article

New wind in the sails: improving the agronomic value of crop plants through RNAi-mediated gene silencing

Aline Koch* and Karl-Heinz Kogel

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Received 13 January 2014;
revised 6 May 2014;
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Summary

RNA interference (RNAi) has emerged as a powerful genetic tool for scientific research over the past several years. It has been utilized not only in fundamental research for the assessment of gene function, but also in various fields of applied research, such as human and veterinary medicine and agriculture. In plants, RNAi strategies have the potential to allow manipulation of various aspects of food quality and nutritional content. In addition, the demonstration that agricultural pests, such as insects and nematodes, can be killed by exogenously supplied RNAi targeting their essential genes has raised the possibility that plant predation can be controlled by lethal RNAi signals generated *in planta*. Indeed, recent evidence argues that this strategy, called host-induced gene silencing (HIGS), is effective against sucking insects and nematodes; it also has been shown to compromise the growth and development of pathogenic fungi, as well as bacteria and viruses, on their plant hosts. Here, we review recent studies that reveal the enormous potential RNAi strategies hold not only for improving the nutritive value and safety of the food supply, but also for providing an environmentally friendly mechanism for plant protection.

Keywords: genetically engineered plants, host-induced gene silencing, RNA interference, plant protection, resistance.

RNA interference: discovery of a novel mechanism for gene regulation

RNA interference (RNAi) is a conserved and integral aspect of

(Hammond *et al.*, 2001a). This latter phenomenon was termed co-suppression in plants and quelling in fungi. PTGS also could be induced in plants by cytoplasmically replicating viruses (Hammond *et al.*, 2001a). Given the similar phenotypes associated with PTGS

Though presumed guilty, the rDNA method appears to be innocent

Lessons from Two Decades of Field Trials with Genetically Modified Trees in the USA: Biology and Regulatory Compliance

Steven H. Strauss, Cathleen Ma, Kori Ault and Amy L. Klocko

Abstract We summarize the many field trials that we have conducte
beginning in 1995 and continuing to this day. Under USDA APHIS
latory notifications and permits, we have planted nearly 20,000 trees
approximately 100 different constructs in more than two dozen field
The large majority of the trials were in *Populus* and included hybrid

Many field applications in literature

- A great diversity of traits, and economic and/or environmental values, have been demonstrated in field trials of trees
- After initial event sorting, stability, tree health, and trait efficacy high
- Examples of traits successfully studied in the field
  - Herbicide tolerance
  - Biotic, abiotic stresses
  - Wood or fruit quality
  - Form/stature and growth rate
  - Containment
  - Accelerated flowering
  - Bioremediation
  - Novel bioproducts

New Phytologist

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Tansley review

Reproductive modification in forest plantations: impacts on biodiversity and society

Steven H. Strauss, Kristin N. Jones, Haiwei Lu, Joshua D. Petit, Amy L. Klocko, Matthew G. Betts, Berry J. Brosi, Robert J. Fletcher Jr, Mark D. Needham

Existing 4 ha rDNA poplar trial in Oregon (2016)

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

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

Coleopteran-resistant poplars in Oregon - Bt *cry3a*

Large growth benefits (10-20%) despite little insect pressure during field trial of resistant genotypes

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.

Agenda

- Basics
- Rationales
- Constraints
- Solutions

Constraints are large

- Trees often rich in diversity due to early state of domestication
  - GE often not needed
  - Advanced phenotyping, molecular markers, genomic selection often more potent and rapid approach
- Genetic transformation methods often very difficult and highly genotype-specific
  - Very limited advances outside of a few intensively studied species – often mostly proprietary
  - Very challenging to apply to non-timber species, diverse genotypes in population
  - Training of practitioners diminishing

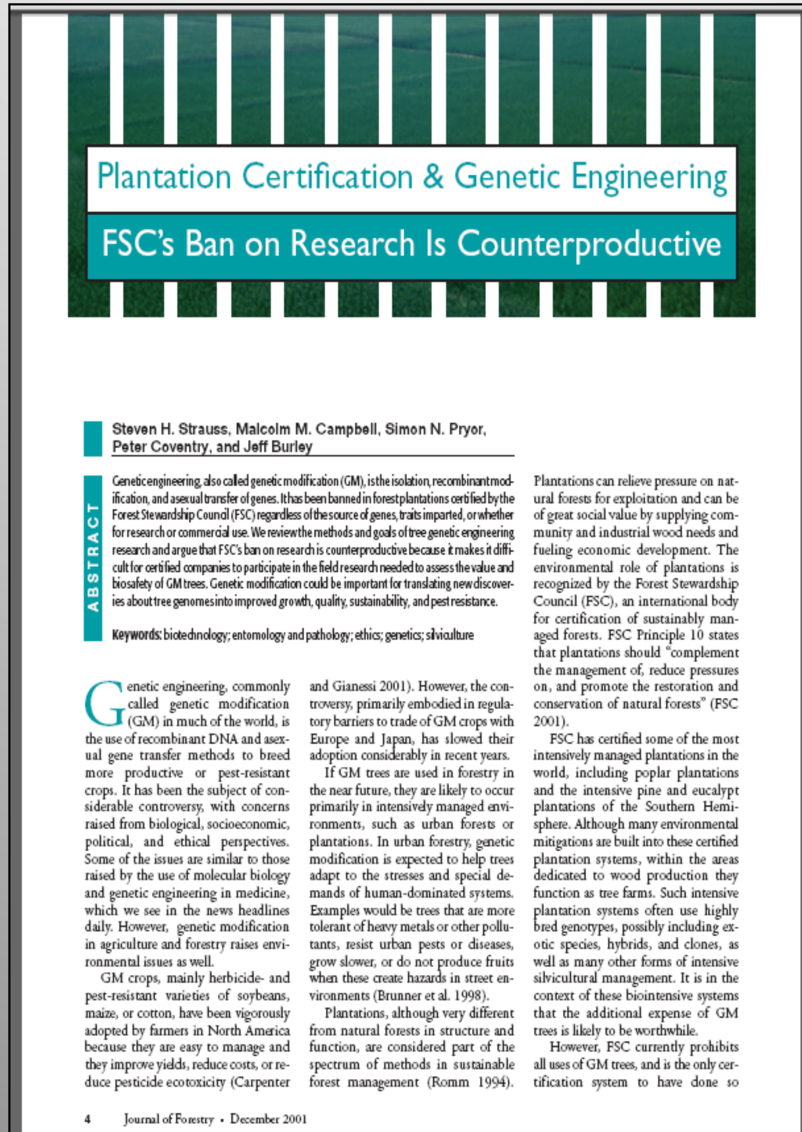
Constraints - 2

- Resistance genes controlling traits poorly known, and preferably polygenic
  - Sustainable solutions generally require polygenic resistance traits
  - Combine rDNA with conventional resistance breeding
- Economics of intensive genetics often marginal
  - Long life spans, low value products
  - GE science and technology costly
  - Patent and regulatory licenses costly or impossible
  - Unclear social license undermines public sector investment
  - Social restrictions create large risks for private investment
- Regulatory and market barriers extreme

Regulatory and market barriers

- Presumption of harm from rDNA method
- Each insertion is the subject of regulation, yet many needed for forest trees and value unclear until extensively tested in field
- Long distance gene flow during research and breeding the rule – “contamination” can have large legal and economic consequences
- Long periods of adaptive management blur research, breeding, and commercial phases
- “Green certification” exclusions of nearly all rDNA trees make field research impossible or very costly

“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

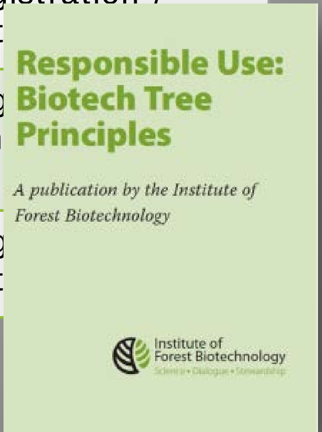
FSC

Forest Stewardship Council

“…genetically modified trees are prohibited…”

All major forest certification systems now ban all GE trees – no research 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 rat
CSA : Canadian Standards Association	Canada	**Banned** via PEFC reg Allows public to determ
CFCC : China Forest Certification Council	China	**Banned** via PEFC reg No additional rat



Adam Costanza, Institute for Forest Biotechnology

Regulations and certification render GE ineffective as a tool for forest health

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

A lesson on the risks from method-based federal regulation


802
© AP Photo/Rogelio V. Solis

Agenda

- Basics
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- Solutions

Regulatory reform essential

Regulatory analyses and proposals for change published in many places

POLICY FORUM

GENETIC TECHNOLOGIES

Genomics, Genetic Engineering, and Domestication of Crops

Steven H. Strauss

Genomic sequencing projects are rapidly revealing the content and organization of crop genomes (*1*). By isolating a gene from its background and deliberately modifying its expression, genetic engineering allows the impacts of all genes on their biochemical networks and organismal phenotypes to be discerned, regardless of their level of natural polymorphism. This greatly increases the ability to determine gene function and, thus, to identify new options for crop domestication (*2*). The organismal functions of the large majority of genes in genomic databases are unknown.

portant to agricultural goals, but poorly represented in breeding populations because they are rare or deleterious to wild progeni-

huge numerical obstacle that is normally provided by extant wild and domesticated gene pools. Despite the great diversity of genes that can comprise GGTs, many of the modified traits are familiar, having a long history of domestication and consequent reduced fitness through artificial selection. Male sterility, seedless fruits, delayed spoilage, and dwarf stature are familiar examples.

GGTs that improve abiotic stress tolerance

Confinement level	Type 1 field trials (exploratory)	Type 2 field trials (precommercial)	Examples
High	Biological and physical confinement—detailed data		Highly toxic or allergenic pharmaceuticals and proteins
Medium	FSC, basic data	FSC, detailed data	Novel pest-management genes, low toxicity pharmaceuticals and proteins
Low: Stress tolerance	FSC, basic data	FSC, detailed data	Genomics-guided transgenes
Low: Domesticating	Petition for exemption?	FSC, basic data	Genomics-guided transgenes

Categories of confinement and monitoring for small- and large-scale transgenic field trials. Biological confinement includes genetic mechanisms to preclude spread and/or reproduction. Physical confinement requires use of geographical isolation or physical barriers. FSC, farm-scale confinement; use of spatial isolation within and between farms and border crops, combined with ...oring. Detailed data include surveys of gene flow away from the site. Basic data ...hment of confinement mechanisms.

nature biotechnology

PERSPECTIVE

Regulating transgenic crops sensibly: lessons from plant breeding, biotechnology and genomics

Kent J Bradford[1], Allen Van Deynze[1], Neal Gutterson[2], Wayne Parrott[3] & Steven H Strauss[4]

The costs of meeting regulatory requirements and market restrictions guided by regulatory criteria are substantial impediments to the commercialization of transgenic crops. Although a cautious approach may have been prudent initially, we argue that some regulatory requirements can now be modified to reduce costs and uncertainty without compromising safety. Long-accepted plant breeding methods for incorporating new diversity into crop varieties, experience from two dec

Regulatory costs also play a role in the growing disparity between the expanding global adoption of the large-market transgenic maize, soybean, cotton and canola crops[1] and the so-called 'small-market' or 'specialty' crops, for which field trials and commercial releases of transgenic food crops have all but stopped[3]. In 2003, fruits, vegetables, landscape plants and ornamental crops accounted for more than $50 billion

Strangled at birth? Forest biotech and the Convention on Biological Diversity

Steven H Strauss, Huimin Tan, Wout Boerjan & Roger Sedjo

Against the Cartagena Protocol and widespread scientific support for a case-by-case approach to regulation, the Convention on Biological Diversity has become a platform for imposing broad restrictions on research and development of all types of transgenic trees.

The Convention on Biological Diversity (CBD) has become a major focus of activist groups that wish to ban field research and commercial development of all types of genetically modified (GM) trees. Recent efforts to influence CBD recommendations by such groups has led to the adoption of recommendations for increased regulatory stringency that are inconsistent with the views of most scientists and most of the major environmental organizations. We suggest that the increasingly stringent recommendations adopted by the CBD in recent years are impeding, and in many places may foreclose, much of the field research needed to develop useful and safe applications of transgenic trees. To move forward, improve-

A convention co-opted

Negotiated under the United Nations (UN) Environment Program, CBD was adopted in June 1992 and subsequently entered into force in December 1993. The CBD has been signed by 191 of the 192 members of the UN, making it one of the largest international treaties. The aim of the CBD is to promote the conservation and sustainable use of biodiversity, and the fair and equitable sharing of benefits from the use of genetic resources. Because transgenic organisms have the potential to affect biodiversity, special provisions of the CBD cover the use and trade in living modified organisms (LMOs, also known as genetically modified organisms; GMOs).

In 2000, was adopte

NATURE BIOTECHNOLOGY VOLUME 27 NUMBER 6 JUNE 2009

Far-reaching Deleterious Impacts of Regulations on Research and Environmental Studies of Recombinant DNA-modified Perennial Biofuel Crops in the United States

STEVEN H. STRAUSS, DREW L. KERSHEN, JOE H. BOUTON, THOMAS P. REDICK, HUIMIN TAN, AND ROGER A. SEDJO

October 2010 / Vol. 60 No. 9 • BioScience 729

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.

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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

Ending event-based regulation of GMO crops

To the Editor:
Getting regulation of agricultural biotechnologies right is no simple task. Stringent regulations for genetically modified organisms (GMOs) in the European Union (EU: Brussels) have nearly stifled the use of biotech crops on farms or in derived foods there, and in the United States the diversified 'Coordinated Framework' has produced a strange patchwork of rules, exceptions and lengthy delays. As the Editorial in the December issue highlights[1], the US Executive Branch has launched a process to reform its regulatory structure, calling for an integrated system that recognizes and balances safety, environment, innovation and economic growth[2]. On the heels of the release of a White House memo, the US House of Representatives passed the Safe and Accurate Food Labeling Act of 2015, which is on its way to the Senate for consideration. Contrary to current regulations, this legislation would explicitly preempt state-by-state labeling and require the US Food and Drug Administration (FDA) to conduct a safety review for all GMOs entering commerce[3]. This recent activity by both the executive and legislative branches provides a welcome opportunity to take a fresh look at

The biological constraints of forest trees collide with method- and annual crop-oriented regulatory systems and markets

Regulatory reform essential, including risk/benefit based exemptions, tolerance of gene flow during research and breeding

Technical solutions

- Public research to develop improved and less genotype-dependent transformation and gene editing systems
  - Science and mechanism focused?
  - NSF Plant Genome Program with new focus here

The Plant Cell, Vol. 28: 1998–2015, September 2016, www.plantcell.org

BREAKTHROUGH REPORT

Morphogenic Regulators *Baby boom* and *Wuschel* Improve Monocot Transformation OPEN

Keith Lowe,[a] Emily Wu,[a] Ning Wang,[a] George Hoerster,[a] Craig Hastings,[a] Myeong-Je Cho,[b] Chris Scelonge,[a] Brian Lenderts,[a] Mark Chamberlin,[a] Josh Cushatt,[a] Lijuan Wang,[a] Larisa Ryan,[a] Tanveer Khan,[c] Julia Chow-Yiu,[a] Wei Hua,[a] Maryanne Yu,[b] Jenny Banh,[b] Zhongmeng Bao,[a] Kent Brink,[d] Elizabeth Igo,[d] Bhojaraja Rudrappa,[e] PM Shamseer,[e] Wes Bruce,[f] Lisa Newman,[a] Bo Shen,[a] Peizhong Zheng,[g] Dennis Bidney,[a] Carl Falco,[a] Jim Register,[a] Zuo-Yu Zhao,[a] Deping Xu,[a] Todd Jones,[a] and William Gordon-Kamm[a,1]

[a] DuPont Pioneer, Johnston, Iowa 50131

- Accelerated identification and testing of resistance genes – HIGS and beyond
- But most grant based, applied research programs avoid GE methods and solutions
  - Focus is on risks vs. innovations/solutions (USDA Biotechnology Risk Assessment Grants - BRAG)

Ethics-based campaigns needed

- Education on degree of forest health problems and their consequences for biodiversity and public welfare
- Demonstrations of need and capacity

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.

Front Ecol Environ 2007; 5(9): 475–482, doi:10.1890/070037

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.

American Chestnut restoration – genomics and genetic engineering

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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—had evolved resistance. *C. parasitica* effectively strangles

More In This Article

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

March 2014 issue - Scientific American

Hemlock in USA 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

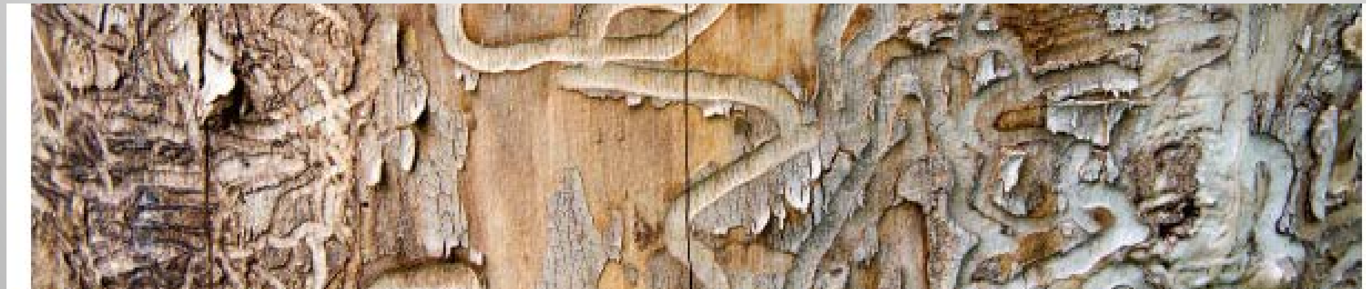
By **Gabriel Popkin** *in Highlands, North Carolina; photography by* **Katherine Taylor**

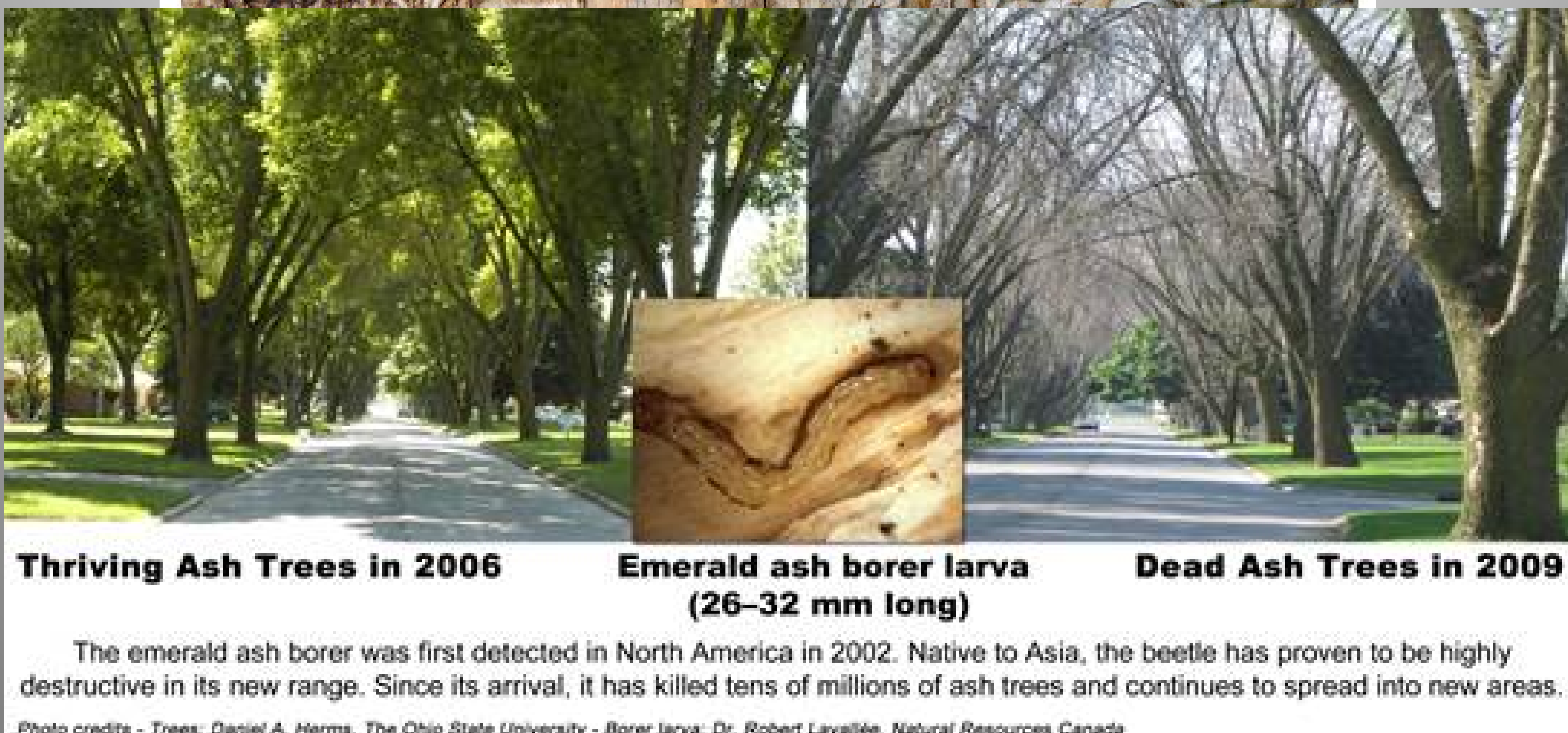
On a frigid morning this past March, arborist Will Blozan snuck behind a small church here and headed down into a gorge thick with rhododendron. He crashed through the shrubs until he spotted the

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

Science advocacy needed?

- To demand a full suite of tools, including rDNA, for coping with forest health crises
- Targets are method-based regulation and market obstacles
- Social media, legal action, the main tools?
- Who will promote and fund?
  - Foundations? Science organizations like AAAS and ASPB? USDA?

Key messages

- rDNA methods are powerful tools to supplement breeding in the right niches
- Serious technical and social obstacles prevent their significant use, or even research, for forest health
- In the face of forest health crises, we have an ethical obligation to create technological capacity and social conditions to enable wider use