Tree Biotech 101

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OSU
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TM

Plan

- Basic biotech science
- Examples of progress with trees
- Constraints

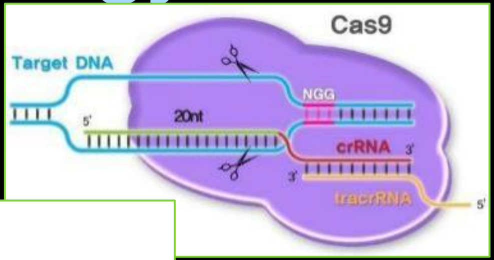
What is biotech?

- 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

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

Coming: Gene editing technology for diverse traits



Science magazine names CRISPR 'Breakthrough of the Year'

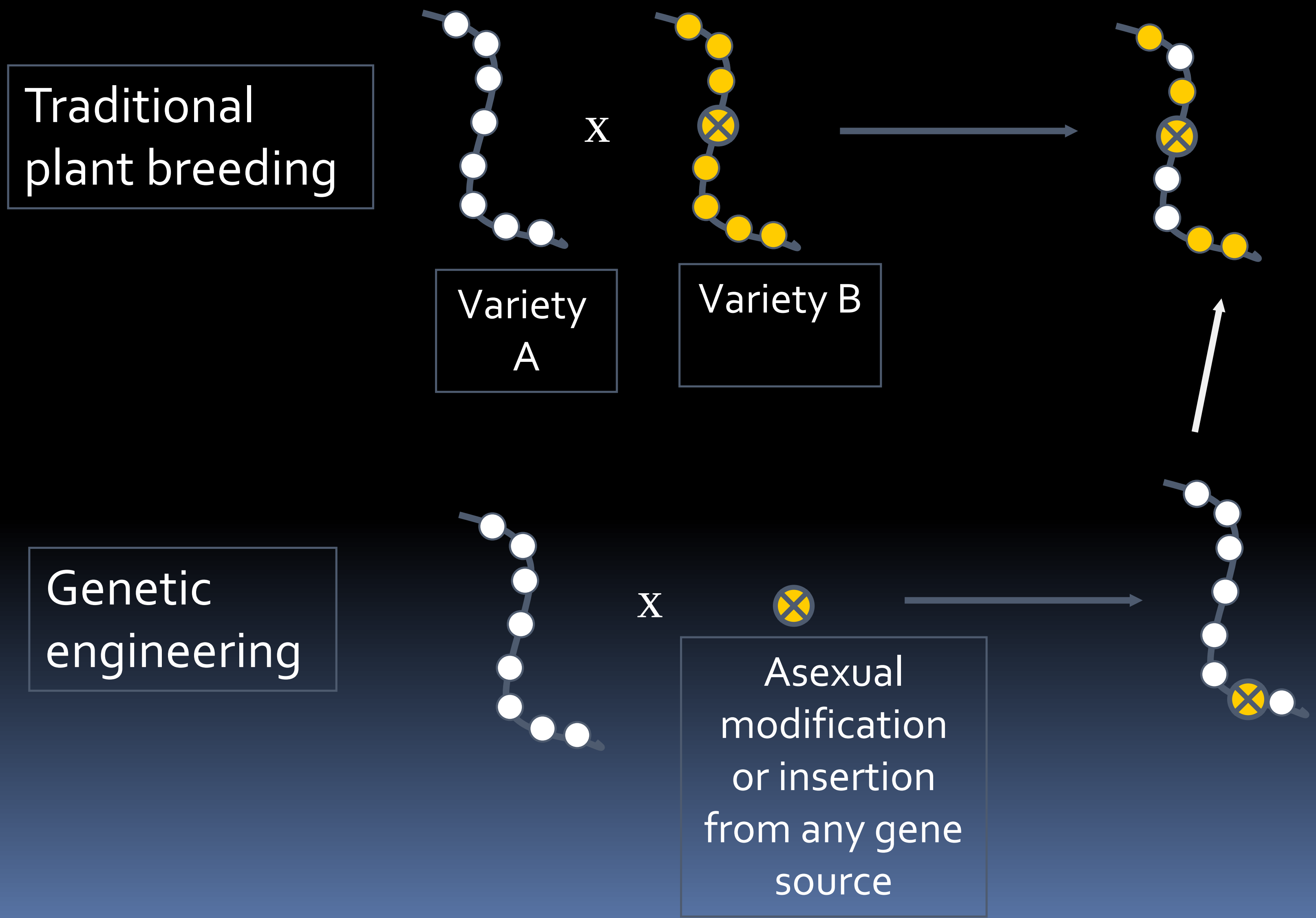
By Robert Sanders | DECEMBER 18, 2015

1K+

In its year-end issue, the journal *Science* chose the CRISPR genome-editing technology invented at UC Berkeley 2015's Breakthrough of the Year.

A runner-up in 2012 and 2013, the technology now revolutionizing genetic research and gene therapy "broke away from the pack, revealing its true power in a series of spectacular achievements," wrote *Science* correspondent John Travis in the Dec. 18 issue. These included "the creation of a long-sought 'gene drive' that

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

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

Eucalypt plantation another obvious place for GE applications

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

Genetic containment to promote social and regulatory acceptance

Undeveloped catkins due to stable suppression of native “*LEAFY*” gene in poplar (RNAi)

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

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

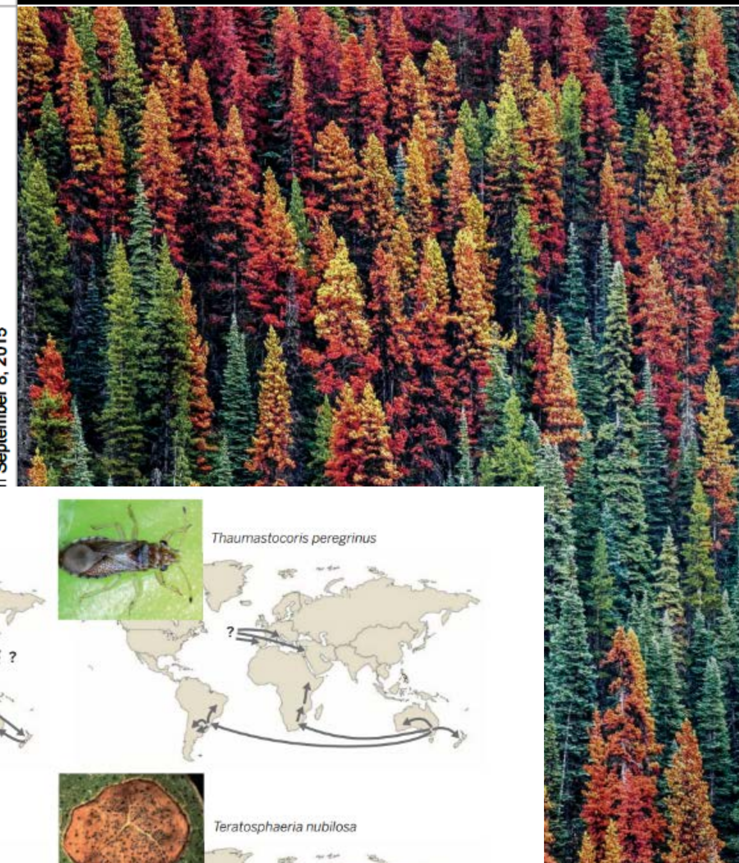
Planted forest health: The need for a global strategy

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 ...ach 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



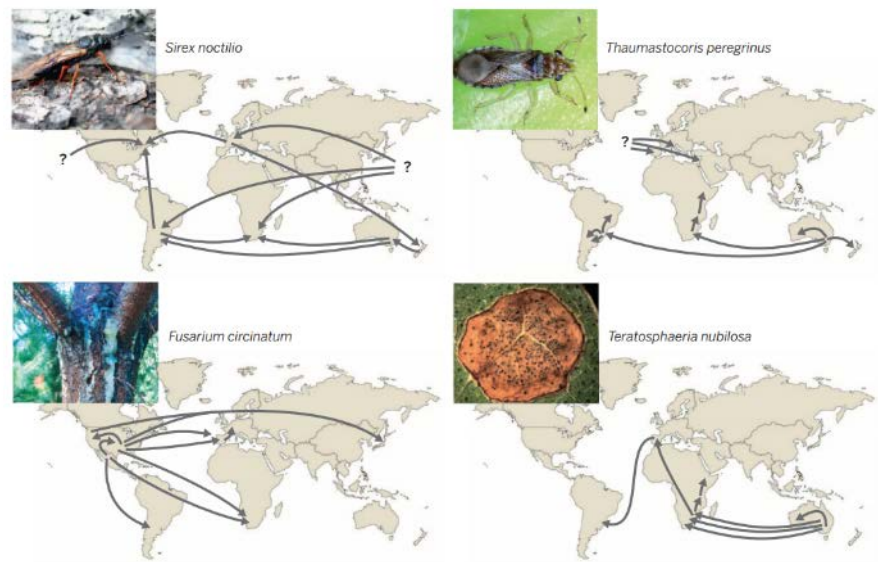


Fig. 2. Examples of invasion routes of pests of planted forests that illustrate an apparently common pattern of complex pathways of spread to new environments, including repeated introductions and with either native or invasive populations serving as source populations (18). Invasion routes of the pine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

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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

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

FSC

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
  - Conifers doable but not easy; no longer any active commercial work on conifers?
- 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