Tree Biotech 101

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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
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 could potentially alter the course of an entire population.”
GMO method (genetic engineering) defined

Traditional plant breeding

Genetic engineering

Asexual modification or insertion from any gene source
Regeneration of plants after introduction of DNA
Then propagated normally (seeds, cuttings) and tested for health and new qualities, incorporated into breeding programs.
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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

August 2015
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

Planted forest health: The need for a global strategy

M. J. Wingfield, E. G. Brockerhoff, B. D. Wingfield, B. Slippers

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 costs and an increased focus on the importance of and potential of planted forests, innovative solutions and a much-needed mitigation strategies that are effective only in invasions elsewhere in the world, ultimately leading to global pest problems in the future should mainly focus on integrating rather than single-country strategies. A global strategy to prevent and urgently needed.

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. Invasion routes of the pine pitchercanker pathogen (origin in Central America) (49), eucalypt leaf pathogen (origin in southwest Australia) (45), the pine woodlooper (origin in Europe) (23), and the natural host (origin in Southwest Australia) (41) were determined through historical and genetic data. (Photo credits: top left: Brett Hulley; top right: Gemma Baxter; bottom left: Juliana Ros; bottom right: Guillermo Perez).
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The case for paralysis
(August 2015, Science)

BIOTECHNOLOGY

Genetically engineered trees: Paralysis from good intentions
Forest crises demand regulation and certification reform

By Steven H. Strauss*, Adam Costanza*, Armand Séguin*

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 (5). 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 (3).

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

Genetic engineering, also called genetic modification (GGM), involves inserting genetic material into the DNA of plants and animals to create or modify the characteristics of those organisms. The Forest Stewardship Council (FSC), a leading international organization that promotes responsible forest management, has a policy that all forests certified by the FSC should be managed in a way that does not involve the use of genetically modified organisms (GMOs). This policy has created significant barriers to field research and market access for researchers and practitioners working in forest management.

Genetic modification can be important for managing forest ecosystems, especially for improving growth, quality, and resilience. However, the FSC’s ban on research involving genetically modified organisms (GMOs) is counterproductive. It limits the ability of researchers to develop new forest management techniques and products that could improve the sustainability and productivity of forests.

Plantations can relieve pressure on natural forests for exploitation and can be of great social value by supplying community and industrial wood needs and finding economic development. The environmental role of plantations is recognized by the FSC, but the FSC’s ban on research involving GMOs limits the ability of researchers to develop new forest management techniques and products that could improve the sustainability and productivity of forests.

Forest Stewardship Council

“…genetically modified trees are prohibited...”
Forest certification systems universally ban all GM trees – no exemptions

<table>
<thead>
<tr>
<th>System</th>
<th>Region</th>
<th>GM Tree Approach / Reason</th>
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<tbody>
<tr>
<td>PEFC : PEFC : Programme for Endorsement of Forest Certification</td>
<td>International</td>
<td><strong>Banned</strong> / Precautionary approach based on lack of data</td>
</tr>
<tr>
<td>FSC : FSC : Forest Stewardship Council</td>
<td>International</td>
<td><strong>Banned</strong> / Precautionary approach based on lack of data</td>
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<tr>
<td>CerFlor : CerFlor : Certificação Florestal</td>
<td>Brazil</td>
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<tr>
<td>CertFor : CertFor : Certificación Forestal</td>
<td>Chile</td>
<td><strong>Banned</strong> via PEFC registration / No additional rationale</td>
</tr>
<tr>
<td>SFI : SFI : Sustainable Forestry Initiative</td>
<td>North America</td>
<td><strong>Banned</strong> via PEFC registration / Awaiting risk-benefit data</td>
</tr>
<tr>
<td>ATFS : ATFS : American Tree Farm System</td>
<td>USA</td>
<td><strong>Banned</strong> via PEFC registration / No additional rationale</td>
</tr>
<tr>
<td>CSA : CSA : Canadian Standards Association</td>
<td>Canada</td>
<td><strong>Banned</strong> via PEFC registration / Allows public to determine approach</td>
</tr>
<tr>
<td>CFCC : CFCC : China Forest Certification Council</td>
<td>China</td>
<td><strong>Banned</strong> via PEFC registration / No additional rationale</td>
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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