

Commentary

Biotech and Forest Health: Creating a Path for Pragmatism

By Steve Strauss

Every forester and forest lover knows that forests, and organisms and communities that depend on them, are in trouble. In addition to catastrophic fires becoming the norm in the west, it seems that there are new pests and growing stresses from all manner of sources. These include record breaking cold, heat, flooding, wind, and drought in many places around the US and the globe. The pests include exotic diseases and insects due to long-distance transfers of species among continents, and native pest species whose range has shifted, or whose life cycles have been altered, due to climate change. The list of worrisome pests is a very long one and has been published in many places, including recent reports from the UN/FAO and as portrayed in the August 2015 special issue of *Science* dedicated to forest health. Forest lovers also know that we have few options to manage these stresses, because of the large size and long life cycle of trees, and thus the very high cost of forestry interventions. And it's expected to get much worse in coming decades, where in just one forest tree generation, "no analog" changes to forest composition and structure are expected to become the rule.

One of the most powerful tools we have for improving forest health and productivity is genetics. Scientific advances in genetics in recent decades have been nothing short of astounding, and modifying the genetic constitution of trees is one of the most cost effective means for managing problems; once a genetic change is made, its benefits usually lasts for a tree's lifetime or longer. In the area of biotechnology, rapid gene sequencing and associated computational methods are providing powerful tools for research to understand trees and ecosystems, including what makes some trees and forests susceptible to pests and stresses, and others not. As the costs of sequencing and computation continue to decline, they are also providing increasingly powerful tools to inform "assisted migration" (moving tree populations to improve future adaptation) and to accelerate conventional breeding, widely termed as "genomic selection." These methods monitor and inform methods to modify DNA of planted trees indirectly, by choosing what trees to use in reforestation whether they are produced from natural stand collections, conventional crosses, interspecies hybridization, or varietal (clonal) selection and propagation. However, they are of no value unless the genetic variation required is present in native tree gene pools, and is present at useful levels so that changes can be made rapidly

and without undue restriction of genetic diversity. Fortunately, because most forest trees have lots of genetic diversity, conventional methods often work. Unfortunately, that is not always the case, especially when the stresses and pests are spreading and evolving rapidly, as is becoming increasingly common today. One widely known case where a species' genetic diversity was inadequate was that of the American Chestnut, where, starting in the early 1900s, an introduced fungus essentially wiped it out as a forest tree throughout its natural range.

For new, rapidly spreading, and growing stresses, we know that new methods of genetic modification, widely termed "genetic engineering" (GE), can sometimes succeed when breeding fails or is too slow. For example, a single type of gene has been identified that, when combined with breeding (and ultimately additional types of genes as knowledge grows), might have enabled the planting of resistant American Chestnuts in eastern forests many decades ago—preventing its near extirpation. GE also benefits from the rapidly growing knowledge of genes by the sequencing/genomics revolution. When genes are identified that provide resistance within the species, in related species, or other species, these can be rapidly added to adapted and productive germplasm while leaving the rest of the genome essentially intact. These methods usually identify several types of resistance genes that can be combined for more robust and durable resistance and can be readily added using GE methods. In contrast, when breeders need to use genes from rare genotypes or other species, they produce hybrids that have an unacceptably narrow genetic base, or are grossly maladapted. This is precisely what happened when the American and Chinese Chestnut were hybridized in an attempt to insert the blight-resistance genes of Chinese chestnut into American chestnut. A load of "genetic baggage" came along



that made the hybrid trees unusable in eastern forests. With GE approaches, the baggage is removed up front, making the process much faster. GE approaches have also produced methods that speed the breeding cycle, so resistance genes can be moved into a wide variety of germplasm more rapidly. New genetic methods, such as RNA interference (the discovery of which led to a Nobel prize in 2006) and genome editing (perhaps the hottest thing in biology today), also make GE very efficient and precise at modifying native genes; GE is no longer just about inserting genes from far off places.

However, all forms of GE have been categorically stigmatized and ostracized in forestry, nearly halting investment in applied research and education, both by public and private sources. Regulations are extremely strict, with the underlying presumption that the GE method is inherently dangerous. As a consequence, few organizations can afford the high costs and serious liability risks during research, and the many years it takes, to obtain federal approvals. There is also a growing deficiency of young scientists and professionals trained in GE methods for trees, impairing our ability to use the technology in the future. Our regulations impose an inertia, delay, and inflexibility that makes society unable to deliver the innovation needed for so rapidly changing an area (as a result of both rapid genetic innovations and growing pest/stress developments). Unfortunately, the human mind finds it hard to visualize the losses from paths not taken, and regulatory agencies bear no responsibility to account for such lost opportunities in their rules and decisions. More details on the kinds of regulatory changes I think we need are outlined in a recent essay in the August 2015 edition of *Science* coauthored by myself and colleagues Adam Costanza and Armand Seguin (tinyurl.com/oqgwsbx).

In addition, all forest certification systems—yes I said *all*—preclude any planting of GE trees in certified forests, even for research. This preclusion takes no note of the goal, the genes, the scale of planting, the potential for gene dispersal, the urgent need for solutions to forest pest and stresses, and the possession of difficult-to-obtain government permits that insure the research is monitored and safe. FSC started this trend, but all the certification systems have followed suit. This is presumably because their markets demanded it or that they might do so. Few know that this “all GE is evil” policy is squarely against the advice of all leading scientific academies and societies worldwide, which have concluded that assessments of GE should be “case by case” and focused on the “product not the process.” Thus, these indiscriminant exclusions by certification systems are fundamentally anti-science, which few among the public seem to understand. These exclusions seem to be part of a growing marketing trend where it seems that it’s more important to know what you don’t do or don’t use, than to know what you actually produce and deliver—and for which there is solid scientific evidence—in terms of economic, ecological, and social value.

Politics, commercial self-interest, and warring ideologies clearly have a lot to do with this peculiar and worrisome situation. The notion that all GE crops and trees must be strictly regulated, labeled, or avoided has become so deeply engrained and institutionalized that it’s hard to imagine anything different in the foreseeable future. For example, it’s hard to imagine that an emerald ash borer-resistant variety of ash (*Fraxinus*), with modified genes from the same or other

ash species, or with genes whose mechanisms and safety are understood in depth, will be developed and tested, let alone widely planted, anytime soon. Meanwhile, ashes continue to be destroyed at a rampant rate with direct costs in the billions, and inestimable losses of ecological services and amenity values. And of course, beyond forest health, there are many other traits and attendant economic and ecological values that GE methods have been shown to be capable of providing to trees.

The debate is really about ethics, in particular about precaution and how we define it. Do we want a world where a powerful tool like GE is developed and available to help cope with forest health and productivity problems where it makes biological and economic sense to do so? Is this not the pragmatic choice when faced with existential threats to forests and their many economic, ecological, and social services? Or do we want to essentially avoid all GE, as we essentially do now, in the name of precaution? To me, the application of the precautionary principle—when it takes the form of indiscriminant preclusion and excess regulation—is the opposite of true precaution. And I think Thomas Jefferson, who said, “. . . the greatest service which can be rendered any country is to add a useful plant to it’s culture,” would have resoundingly agreed. Let’s get on with the work of protecting and nourishing forests and leave our ideologies at the door. Unfortunately, to do so we need to fundamentally change major provisions in our regulatory and certification systems. This is much easier said than done—it will take dedicated work at many levels, over many years, to accomplish. Unfortunately, forest pests, and our many activities that exacerbate climate change, do not seem to be slowing down.

Steve Strauss is a University Distinguished Professor in the Department of Forest Ecosystems and Society at Oregon State University. He has a joint appointment in the interdepartmental Molecular and Cellular Biology Program. Strauss is director of the Tree Biosafety and Genomics Research Cooperative (TBGRC) at OSU, a university-industry consortium conducting research on genetically engineered trees that might be useful in forestry, bioenergy, and horticulture (see tinyurl.com/cq486wp). For nine years he directed the OSU Program for Outreach in Resource Biotechnology, which is aimed at promoting public understanding of biotechnology issues.