Biotechnology: Scientific Advances That Could Save Our Native Forests

In the last issue of Kentucky Woodland Magazine we described what biotechnology is and how it is being applied. This is the second article in our featured series exploring the use of modern genetic technologies in forestry. In this article, we profile several research projects that are using biotechnology to help protect and restore native trees at risk of disappearing due to invasive pests.

by Ellen Crocker

Forests at Risk

Invasive insects and diseases are serious threats to the health of our forests and woodlands. These pests are exotic, many originating in Asia and Europe, and are accidentally or intentionally brought to the United States. While most of the exotic species that wind up in the United States are not a problem, many are, wreaking havoc on native plants that lack necessary defenses. Unfortunately, the number of new invasives will likely continue to increase as global trade provides ample opportunities for new introductions. As we plan ahead, better solutions are needed for both current problems and future infestations.

Already, invasive pests have decimated many of our important tree species. For example, the American chestnut once dominated eastern forests but since the introduction of Asian chestnut blight in the early 1900s, this species has been nearly eradicated. More recently, the emerald ash borer has spread throughout the Midwest and into the Southeast and Northeast, leaving millions of dead ash trees in its wake. Introduced to North America from China just 14 years ago, the emerald ash borer is a clear example of how rapidly these invasives can spread and kill.

Unfortunately, our tree species are not able to adapt quickly enough to fend off these insects and diseases. Many scientists fear that our native trees lack both the defenses to fight these threats now and the time to evolve resistance before it is too late.

Chestnut blight is caused by a fungus that forms cankers and kills American chestnut trees like the one shown here.

Photo courtesy: Linda Haugen, USDA Forest Service, Bugwood.org

Tree Restoration 2.0

In the past, restoration efforts following invasive attacks relied on time consuming (and in many cases unsuccessful) searches for resistant trees or cross-breeding with related species that happen to be resistant to the threat. More often, the losses of individual tree species were accepted as sad but unavoidable.

As the onslaught of exotic species increases, we no longer have the liberty of watching it occur unchecked. We must find ways to fight that are more effective and efficient than before. Unfortunately, keeping these pests out of the U.S. has proven difficult, as has control once they are here. Even breeding programs, trying to find and develop resistance, have been largely ineffective and take too much time. New methods must be developed to help us quickly develop resistant native species.

The use of biotechnology may prove to be of great

Invasive insects and diseases can cause extensive tree mortality, as seen in this aerial photo of ash trees killed by the emerald ash borer.

Photo courtesy: Troy Kimoto, Canadian Food Inspection Agency, Bugwood.org

Photo courtesy: Ellen Crocker

Can these white oak seedlings defend themselves against invasive pests? New scientific approaches to testing resistance may provide a better (and faster) answer.

assistance in fighting invasive tree threats.

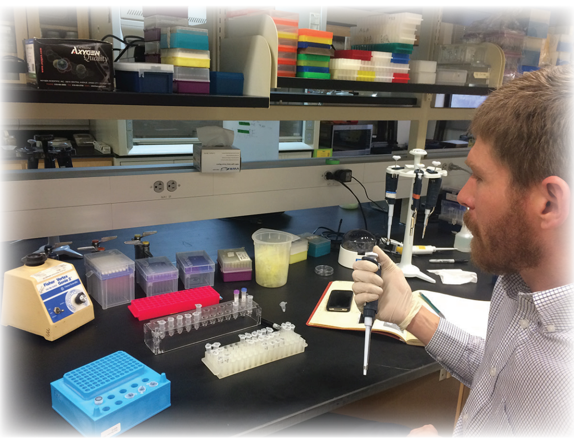
Biotechnology is a broad term that encompasses a wide range of techniques. It is often equated with the development of genetically modified organisms (GMOs). While the development of genetically modified (GM) plants that are resistant to invasive insects and diseases is one use of biotechnology, it is only one of many ways in which biotechnology can be used by researchers to help us fight invasive pests.

Many researchers view biotechnology as the only reasonable way to restore native species that have been decimated as well as protect species from decline or ultimately from extinction. Here we will profile several different projects that use the same building blocks of molecular biology with the specific goal of giving native trees an advantage against invasive enemies.

Finding the Needle in the Haystack

One of the biggest challenges in restoring forests after the introduction of an invasive pest is identifying resistant trees. In a given population of trees, just as with a group of people, genetic diversity (variation) gives each tree slightly different traits. Even if most of the trees in a stand die, hopefully some trees will be less susceptible to or more tolerant of a particular pest and survive.

Finding these lingering resistant individual trees after a pest has swept through is an important first step. But, understanding the genetic basis for this resistance is key to long-term restoration. It allows us to rapidly screen a large number of trees that linger after the invasion for resistance. This screening is important as some trees are persisting due to luck while others may posses a genetic resistance. Previously, identifying genetically resistant individuals was a long process that involved growing the offspring of lingering trees to an age where they could be infected to see if genetic (inherited) resistance was present.



Forestry researchers, such as Dr. Tyler Dreaden shown here, are using a wide variety of molecular biology techniques to better understand and improve forest health.

Photo courtesy: Ellen Crocker

Fortunately, scientists are developing new tools to narrow down which trees are resistant to insects or diseases. One approach, called chemical fingerprinting, allows scientists to analyze all of the chemicals present in a plant and distinguish plants that can defend themselves against invasives from those that can not. Dr. Anna Conrad, a scientist based at the University of Kentucky's Forest Health Research and Education Center, is testing this technique to screen chestnut seedlings for resistance. Her goal is to decipher the chemical code of chestnut resistance. This approach allows researchers to screen many chestnut seedlings over a relatively short period of time—minutes instead of months. With this information, resistant trees could be strategically and quickly deployed to populate eastern forests with healthier, hardier American chestnuts. Dr. Conrad hopes that her work will *"reduce the time and resources needed to identify disease resistant trees"* and suggests that the trees identified in chemical fingerprinting will provide good *"candidates for forest-restoration efforts."*

UK researcher Dr. Anna Conrad, shown here, is using chemical fingerprinting to find resistant chestnuts

Photo courtesy: Ellen Crocker

Quicker Tree Breeding

Biotechnology not only helps us find the best (and most resistant) trees for restoration use, but is also being applied to test and breed trees faster, speeding the potential rate of forest recovery from invasive pests. Right now, one of the biggest challenges in breeding resistant trees comes down to basic biology—trees grow very slowly. Even in optimal conditions, many of our native eastern forest trees take five to seven years to flower and much longer to grow to the stage where they are affected by diseases and insects in the field.

The slow development of trees means that breeding programs also progress slowly. It takes decades to grow seedlings, test their susceptibility and then propagate another generation. This process has been a major bottleneck in breeding resistant trees. If breeding programs are to help in the battle against invasive threats, we need accelerated tree-breeding techniques.

In light of this challenge, Dr. Shenghua Fan, another Forest Health Center scientist, is working to breed trees faster

Below and bottom courtesy: USDA Forest Service Southern Research Station, USDA Forest Service, SRS, Bugwood.org

Tree breeding programs can take many years, as seedlings, like the one shown here, must grow to maturity, which can take a long time for trees.

using biotechnology. He is piloting a new approach, called rapid cycle breeding, which uses a virus to add certain flowering genes to laboratory test trees. This method causes early flowering which speeds up traditional breeding programs. The seeds that result from rapid cycle breeding are not genetically modified thus alleviating worries from those in the public who are concerned about GMOs. Although a transgenic virus induces the rapid flowering, Dr. Fan notes that its effect is *"not passed to next generations through seeds"* and in that way is more temporary than most applications of transgenic technology. Dr. Fan hopes that by improving the techniques for rapid cycle breeding his research *"will help breeders quickly respond to threats and develop new varieties for rapidly changing environments."*

Building Better Trees

When thinking about biotechnology, GM trees, as discussed above, might be one of the first things that comes to mind. But, as you can see, it is actually only a small part of how biotechnology is being used to help with forest restoration. Nonetheless, it cannot be overlooked as an important and promising way to make trees more resistant to invasive insects and diseases.

In most cases, when researchers turn to transgenic breeding for forest restoration, it is because they have exhausted other options. The slow pace of tree breeding combined with a lack of existing genetic resistance in native trees has long hampered traditional breeding approaches. With biotechnology, researchers can now use a strategy similar to traditional breeding but take a much more direct route, specifically adding certain genes to make trees resistant with less of the searching and waiting.

For example, Drs. Bill Powell and Charles Maynard at the State University of New York College of Environmental Science and Forestry in Syracuse, N.Y., have found a way to make American chestnuts that are resistant to the invasive fungal blight using biotechnology. They did this by adding a few wheat genes previously known to be important in wheat fungal defenses to native American chestnuts. The genes enable the trees to break down oxalic acid, a compound that the blight fungus uses to infect the trees, and thereby make the trees resistant to blight.

While the disease resistance of these GM chestnuts is clear, their future role in forest restoration remains uncertain. These trees are still in a trial phase and will not be released until they have passed the necessary government approval processes. However, it is unknown whether the public will support the use of these trees in restoration. While these trees are transgenic, the argument could be made that they are more similar to native American chestnuts than the traditionally bred Chinese-American hybrids, containing only a few additional wheat genes instead of the high number of novel Chinese chestnut genes found in the hybrids. Decisions regarding the use of transgenic trees in forest restoration will need to be made in the near future, and it is increasingly important that woodland owners, land managers, policy makers, and the general public seriously consider this issue.

Traditional chestnut breeding programs have relied on searching for resistant native trees (shown in this photo) as well as hybridizing native chestnuts with Asian chestnuts resistant to blight.

Photo courtesy: Joseph OBrien, USDA Forest Service, Bugwood.org

Conclusions

As these case studies show, new biotechnological techniques are changing the way we approach forest restoration. From helping researchers pick resistant trees faster to speeding up breeding efforts to adding particular resistance genes, biotechnology is providing scientists and land managers with a bigger toolbox for responding to invasive insects and diseases. However, in each case, the end goal of stronger native trees and more resilient woodlands and forests remains constant.

Many hope that the American chestnut will once again be an important component of eastern hardwood forests. The development of new biotechnological techniques, combined with traditional breeding programs, may help make this dream a reality.

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