Will engineered trees be the crop of the future for Indiana?

By Jenny Cutraro

Quick—name something that grows in Indiana and contributes billions of dollars to the state economy each year.

Did you guess "trees?"

If not, you're not alone. Most people recognize Indiana for its corn and soybean production, but very few realize the scope and economic importance of Indiana's forest industry. It may come as a surprise to learn that forests, which cover 20 percent of the state, contribute more than $9 billion to Indiana's economy each year. The state ranks first nationally in the production of wood office furniture, wood kitchen cabinets and hardwood veneer, according to the Indiana Department of Natural Resources (IDNR) Division of Forestry.

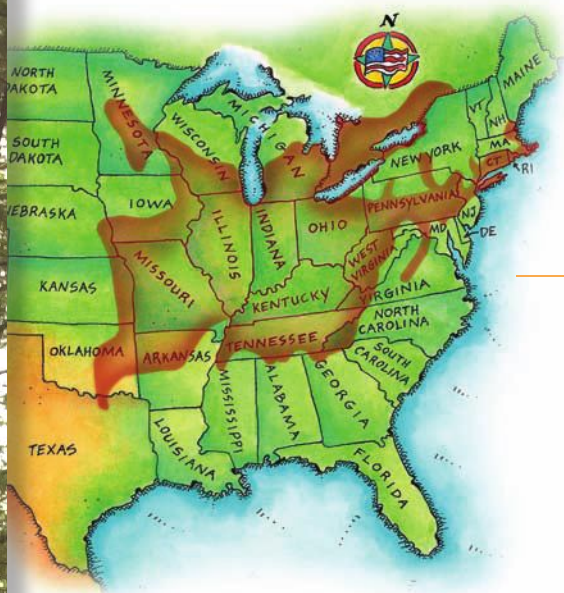
Another little-known fact: Indiana is home to some of the highest-quality hardwood trees—black walnut, northern red oak, white oak—in the nation. These trees are highly valued not only for fine furniture, paneling and veneer, but also as sources of food and shelter for wildlife.

At the Hardwood Tree Improvement and Regeneration Center (HTIRC), a joint U.S. Department of Agriculture-Purdue University research facility, a team of forestry scientists is working to make our forests even more valuable by building better trees. Their research also promises to make our forests healthier by developing trees resistant to devastating pests, such as chestnut blight and emerald ash borer. These and other efforts at improving Indiana's hardwood trees could bring together two goals not typically thought of as complementary—protecting wildlife habitat and promoting the wood products industry.

Scientists at the Hardwood Tree Improvement and Regeneration Center are developing an American chestnut hybrid that is resistant to chestnut blight. HTIRC plant breeder Jim McKenna hand-pollinates an American chestnut with blight-resistant pollen.

Hardwoods in the heartland

Tom Campbell



Research at the Hardwood Tree Improvement and Regeneration Center focuses on tree improvement for increased forest productivity and reforestation in the Central Hardwoods Region.

The future of forestry

One long-term goal of a team of Purdue tree researchers is to use their recent advances in gene discovery to develop domesticated trees, the forestry equivalent of agronomic crops like corn and soybeans.

"Our goal in gene discovery is to domesticate trees, just like corn was domesticated over thousands of years," says Rick Meilan, associate professor of molecular tree physiology at HTIRC.

"If we can produce trees for specific purposes, such as making furniture or plywood, and intensively manage those trees like agricultural row crops, we can make more efficient use of our limited land resources without treading on wilderness areas," he says. "I think this is the future of forestry."

Meilan is part of a team of HTIRC scientists working to identify genes that control qualities desirable in trees, such as insect resistance, wood quality and flower production. Once the genes are identified, Meilan and his colleagues will bring them together to develop what they call "elite" quality trees for timber production. They hope to one day produce trees with these characteristics and make them available to nurseries across the state, to be used in timber plantings by either private citizens, who wish to transform idle agricultural land into forests, or timber companies looking to replant their land.

Meilan says he sees tree domestication as a partial solution to myriad problems associated with human population growth, such as loss of agricultural lands, encroachment on wildlife areas and increased consumption of natural resources.

"I'm not suggesting that we have genetically modified trees growing in our national forests," he says. "But this kind of technology could allow us to increase our yields and create tailor-made trees to meet society's needs for forestry products without encroaching on areas that have been protected from harvest."

Meilan and other HTIRC researchers are also mindful of the controversy surrounding genetic modification and are taking safeguards throughout their research to minimize the risk of introduced genes escaping into the wild.

The potential to engineer trees and other plants with valuable characteristics is not without its critics, who point out the risk of contaminating wild stands of trees with pollen from plants carrying novel genes. An answer to those concerns, however, could lie within the process of gene discovery itself, Meilan says.

"To prevent gene flow, we could develop transgenic trees that don't flower or that flower at an unusual time. This would allow us to achieve what's known as 'bioconfinement'—preventing a gene you've introduced from escaping into the wild."

Starting from scratch

It's one thing to talk about transgenic trees, but to actually develop them is no easy task. HTIRC researchers work in a kind of scientific assembly line, each puzzling over a different challenge associated with finding and introducing genes into trees. The first step is to locate trees in the wild that naturally possess the kinds of traits deemed valuable. One approach to producing more trees with those traits is to essentially clone the tree, creating a new tree with exactly the same genetic material. This is what home gardeners do when they take cuttings from a plant like ivy, allow those cuttings to develop roots and plant them in new soil.

It's not quite so easy with trees, however. "You can't take a branch off of a walnut tree, stick it in water, have it develop roots and plant it a few weeks later," says Paula Pijut, HTIRC plant physiologist.

Pijut specializes in a technique called "tissue culture," which involves producing new plants from pieces of adult plants, like portions of a leaf or stem. "Tissue culture is one method that will allow us to clonally propagate trees so that we can eventually produce entire plantations all with the same genetic makeup," she says.

She uses various combinations of nutrients and hormones to coax small pieces of plants—generically referred to as "explants"—to start developing masses of unspecialized tissue. By applying different plant hormones, she induces these tissue masses to start developing shoots or roots, eventually producing a complete plant. This process can then be used to insert new genes into trees, producing trees with improved genetic traits.

"Our ultimate goal is to be able to take material from a 60- to 100-year-old walnut tree that exhibits superior growth form, clone that material and propagate the tree for a full plantation," she says.

Hurry up and grow

It takes a long time for trees to grow to a harvestable size, so one of the first projects for researchers is to discover how trees regulate the production of heartwood, the dark-colored wood in the interior of a tree valued by furniture and veneer makers.

"Trees like black walnut usually don't produce heartwood for the first 13 years of their life," says Charles Michler, HTIRC director. "One of our goals is to find out which genes regulate heartwood production and to use these genes to develop trees that produce it earlier in their lifecycle. By doing this, we could reduce the time it takes to grow a commercially valuable tree by up to a decade."

Purdue HTIRC

This black cherry shoot culture was produced using "tissue culture," a technique that allows researchers to propagate trees that will all have the same genetic material.

This approach would likely involve regulating the behavior of certain genes, such as turning them "on" or "off" at different times to speed up heartwood formation. "If this approach works, trees will become the most valuable crop to grow on agricultural land," Michler says.

Another approach is to introduce new genes into trees that already are of a sufficiently high quality. For example, foresters might find a tree that naturally has an ideal growth form but is susceptible to pathogens. Another tree might have pathogen resistance but doesn't grow as well. Conventional plant breeders would cross these trees together, eventually creating offspring that combine ideal traits of both parents.

This conventional approach might work well in crop plants like corn, which mature and reproduce over a few months, but hardwood trees can take decades to reach reproductive maturity. Another problem with conventional breeding is that—even if both parent plants are ideal—there's no guarantee that the next generation will exhibit the same traits.

To get around the hurdles of conventional breeding, HTIRC researchers are pinpointing genes of interest and inserting them into trees that lack them. "We're speeding up the breeding process," says Keith Woeste, HTIRC tree molecular biologist, who likens the process to outmoded audio technology of splicing new material onto cassette tapes. "This doesn't change the fundamental nature of the organism. If you think of the tree's genetic makeup like a music cassette tape, we're just adding to the playlist. We're giving the tree a song it didn't have."

Quality and quantity

These efforts at improving tree quality fit well under the broad umbrella of sustainable forestry, a model that recognizes the need for forest management and forest protection to coexist, says Dan Ernst, assistant state forester with the IDNR forestry division.

"All the communities in heavily wooded areas struggle to find the right balance between preserving the natural amenities forests provide and managing those forests for timber production," he says. Planting trees with faster growth rates and other favorable characteristics on lands set aside for timber production may be a way to ease pressure on some of Indiana's forests.

"Forests provide many products and benefits not available from any other land source," Ernst says. "Healthy forests are vital to the well-being of Indiana, and this research to improve our hardwood trees will ensure their vitality for the future." ▼