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Genetically modified arboriculture

Down in the forest, something stirs

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GM trees are on their way

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IN SEPTEMBER 2004, a group of scientists from around the world announced that they had deciphered yet another genome. By and large, the world shrugged and ignored them. The organism in question was neither cuddly and furry, nor edible, nor dangerous, so no one cared. It was, in fact, the black cottonwood, a species of poplar tree, and its was the first arboreal genome to be unravelled. But perhaps the world should have paid attention, because unravelling a genome is a step towards tinkering with it. And that, in the end, could lead to genetically modified forests.

The black cottonwood was given the honour of being first tree because it and its relatives are fast-growing and therefore important in forestry. For some people, though, they do not grow fast enough. As America's Department of Energy, which sponsored and led the cottonwood genome project, puts it, the objective of the research was to provide insights that will lead to “faster growing trees, trees that produce more biomass for conversion to fuels, while also sequestering carbon from the atmosphere.” It might also lead to trees with “phytoremediation traits that can be used to clean up hazardous waste sites.”

It is also pretty sure to lead to a lot of environmental protest—hence, perhaps, the environmental emphasis of the energy department's mission statement. Given the argument about genetically modified field-crops that has taken place in some parts of the world, genetically modified forests are likely to provoke an incandescent response. Soya, maize, cotton and the like were already heavily modified for human use before biotechnologists got their hands on them. One result is that they do not do very well in the big, bad, competitive world outside the farmer's field. But trees, even the sorts favoured by foresters, are wild organisms. GM trees really might do well against their natural conspecifics.

The wood and the trees

Lofty mission statements aside, the principal commercial goals of arboreal genome research are faster growth and more useful wood. The advantage of the former is obvious: more timber more quickly. More useful wood, in this context, mainly means wood that is more useful to the paper industry, an enormous consumer of trees. In particular, this industry wants to reduce the amount of lignin in the wood it uses.

Lignin is one of the structural elements in the walls of the cells of which wood is composed. Paper is made from another of those elements, cellulose. The lignin acts as a glue, binding the cellulose fibres together, so an enormous amount of chemical and mechanical effort has to be expended on removing it. The hope is that trees can be modified to make less lignin, and more cellulose.

In a lucky break, it looks as though it might be possible to achieve both goals simultaneously. A few years ago a group of researchers at Michigan Technological University, led by Vincent Chiang, started the ball rolling. They produced aspens, another species of poplar, that have 45% less lignin and 15% more cellulose than their wild brethren, and grow almost twice as fast, as well. The mixture the team achieved leaves the combined mass of lignin and cellulose in the trunk more or less unchanged and, contrary to the expectations of many critics, the resulting trees are as strong as unmodified ones.

The trick Dr Chiang and his colleagues used was to suppress the activity of one of the genes in the biochemical pathway that trees employ to make lignin. They did this using so-called “antisense” technology.

Antisense technology depends on the fact that the message carried by a gene is encoded in only one of the two strands of the famous DNA double helix. Because of the precise pairing between the components of the two strands, the other strand carries what can, in essence, be described as an “antimessage”. The message itself is copied into a single-stranded messenger molecule which carries it to the protein-making parts of the cell, where it is translated. But if this messenger meets a single-stranded “antimessenger” before it arrives, the two will pair up. That silences the messenger. Dr Chiang therefore inserted into his aspens a gene that makes antimessengers to the lignin gene in question.

Wood can be improved in other ways, too. When it comes to papermaking, long fibres of cellulose are preferable to short ones. Thomas Moritz, of the Umea Plant Science Centre in Sweden, and his colleagues, have found out how to make hybrid poplars that reflect this industrial preference. In this case they did it by making a gene work overtime, rather than by suppressing its activity. The gene they chose is involved in the synthesis of a hormone called gibberellin and, once again, a side-effect of the alteration was to cause the trees to grow faster.

How such genetically modified trees would fit in with the natural environment is, of course, an important question—and it is important for two reasons. The first is political. The row about GM crops shows that people have to be persuaded that such technology will have no harmful effects before they will permit its introduction. But there is also a scientific reason. Trees have complex interactions with other species, some of which are necessary for their healthy growth.

Claire Halpin, of Dundee University in Scotland, and her colleagues have been looking into the question of environmental interactions using hybrid poplars that contain antisense versions of two other genes for enzymes involved in the production of lignin. The trees were grown for four years at two sites in France and England, in order to see how they fitted in with the local environment.

The trees and the bugs

The answer seems to be that they fitted in reasonably well. They grew normally and had normal diplomatic relations with the local insects and soil microbes. They also produced high-quality pulp.

A tree's interactions with soil microbes are often beneficial to it (the microbes provide nutrients) so this is an important result. But insects are frequently hostile, and some researchers are looking for ways to protect trees from them. Lynette Grace of Forest Research in Rotorua, New Zealand, for example, has taken an approach based on introducing the gene for *Bacillus thuringiensis* (*Bt*) toxin, a natural insecticide. This gene is already used to produce versions of crops such as cotton that do not require the application of synthetic insecticides. Dr Grace and her colleagues adapted it to the radiata pine, which is plagued by the caterpillars of the painted apple moth.

Genetic modifications based on *Bt* are environmentally controversial. On the one hand, they reduce the amount of pesticide needed. On the other, there is a fear that the gene might “escape” from crops into wild plants that form the foodstuffs of benign insects. In the case of trees it might not even be necessary for the gene to jump species. GM trees, with immunity to insect pests and faster growth rates than their unmodified competitors, might simply spread by the normal processes of natural selection. That really would be survival of the fittest.