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Genetically modified trees: Introduction

By Chris Lang, published by WRM and FoEI, December 2004

Back to contents

What is genetic modification?

There is a fundamental difference between traditional breeding programmes and genetic modification of plants. Using traditional breeding techniques, plant breeders (whether they are farmers, foresters or laboratory researchers) can only cross plants of the same species or of closely related species. It is not possible to cross fish with eucalyptus trees, for example.[1] Genetic modification allows scientists to modify trees by inserting genetic material from another tree of the same species, from another tree species or from another species of plant or animal altogether. Genetic modification, in other words, allows scientists to insert fish genes into eucalyptus trees.

The genetic information required to build a complete organism from individual cells is contained in a molecule inside cells called deoxyribonucleic acid (DNA).[2] The fact that the information stored in one organism's DNA can be read by any other organism, means that foreign DNA can change the way a plant species grows, functions or reproduces, when it is inserted into the plant's cells.

A gene is a segment of DNA. Genetic modification involves inserting genetic material from another species into a plant or modifying a plant's genes by manipulating the DNA molecule.[3] The total genetic information in an organism is called the genome.

Scientists have developed three techniques for inserting foreign DNA into plants.[4] The first technique involves coating gold particles with DNA and blasting them into plant cells using a "gene gun".[5] John Sanford, Edward Wolf, Nelson Allen and Theodore Klein, scientists at Cornell University, developed the first gene gun. In 1983, Sanford and Wolf used an air rifle to shoot tungsten powder into an onion. Cornell's scientists patented the technology and subsequently sold it to chemical giant DuPont, which had set up laboratories to work on plants in the early 1980s.[6]

A second technique is to use a bacterium, such as *Agrobacterium tumefaciens*, which can transfer some of its DNA into plants.[7] In nature, the bacterium causes swellings, or cancers, on host plants and transfers part of its DNA into host plant cells. Molecular biologists modify the bacterium so that it contains the desired foreign DNA. Plant cells are then infected with the bacterium and the foreign DNA is transferred to the host plant.

For example, New Zealand biotech company called Forest Research is carrying out research into insect resistant GM trees. "What we have done in the laboratory is taken out the nasty cancer-forming gene and replaced them with our favourite piece of DNA," Dr Julia Charity of Forest Research told the New Zealand Herald. "We get the bacteria to take up the DNA by giving it an electric shock. The cell walls open in absolute horror and the DNA shoots in there . . . the bacteria acts like a shuttle and basically injects its DNA into the plant cell," Dr Charity explained.[8]

A variation on this technique is to use the fact that some plant viruses insert themselves into a host plant's DNA.[9] Scientists modify the plant virus by removing the disease-causing genes and replacing them with the genes they want to insert into the host cell. The plant is infected with the virus which then expresses the foreign gene in the host plant.

A third technique is to insert the DNA into a plant protoplast, a plant cell which has had its cell wall chemically removed.[10] The desired DNA is located on a plasmid vector (a self replicating DNA molecule) which is injected into the protoplast.[11] Plant cells are grown in tissue cultures and the vector inserts the desired genes into the host plant's genome.[12]

None of these techniques is particularly precise and genetic modification can have wildly unpredictable effects. The location of foreign genes in the genome affects their function.[13] Yet there is no way of knowing exactly where the foreign gene might be inserted in the recipient cell's genome. There is no way of controlling how many copies of the DNA will be inserted or how much (or whether) the foreign genes will affect the plant's growth. Neither is there any way of knowing whether the insertion will be stable.[14] The foreign genes can interact with the host plant's genes in unexpected ways. "The process is uncontrollable, unreliable and unpredictable", as Mae-Wan Ho and Joe Cummins of the Institute for Science in Society put it.[15]

An experiment carried out by the Chinese Institute for Forestry illustrates the problem.[16] Scientists introduced genes from the bacterium *Bacillus thuringiensis* to make poplar trees resistant to insects. The same genes were inserted into all the trees, but scientists observed three different groups of results. In the first group the trees were still affected by the insects. The second group of trees were insect resistant but the leaves were more yellow and smaller than usual. In the third group, the trees grew normally and were resistant to the insects. Two years later, however, insects which were previously unknown as pests in poplar trees attacked the trees.

Brian Tokar, editor of the book *Redesigning Life?*, points out that adding genes from viruses to a plant can increase the instability of a plant's genome.[17] Genes which are needed for the normal functioning of the plant may be switched off, or silenced. Viral vectors raise the possibility of further transfer of genes to unrelated organisms. GM viruses can combine with other viruses to form new infectious viruses and diseases.[18]

Cloned trees are not necessarily genetically modified. Cloning uses part of a plant to make an exact copy of the original plant and involves no change to the DNA of the plant.[19] Often described as "genetically improved" trees, clones are reproduced from selected parent trees showing a desired trait (such as fast growth, straight stems, fewer branches or whatever trait scientists were looking for). Cloning allows forestry scientists to do something which is impossible in nature: the mass production of trees that are genetically identical to one parent tree.

The simplest form of cloning, which farmers and gardeners have been doing for centuries, is to take a cutting from a plant.

Tissue culture involves growing plant tissue in a laboratory where all inputs such as nutrients, hormones, water and oxygen can be carefully controlled. Somatic embryogenesis is a recently developed process in which scientists grow embryos from the non-reproductive cells of trees.[20] Tissue cultures or embryos can be frozen, allowing researchers to test the material and then defrost the best specimens.[21]

Forestry scientists also use various techniques, including DNA sequencing, gene mapping and gene function studies to match a particular trait, such as fast growth, with DNA sequences. Genetic maps could help tree breeders by identifying the trait out of the huge variation in different trees. For example, researchers at the University of California-Davis in the US are using genetic maps to chart which parts of a tree's genes control traits such as fast growth.[22] The next step is to breed trees (or genetically modify them) for these identified traits, using the information in the genetic maps.

While not in itself involving genetic modification, much research into trees at the genetic level is carried out with an eye on future genetic modification. For example, Forest Research, a biotech forestry firm in New Zealand, is carrying out research into how trees produce lignin, the glue that holds wood cells together and makes trees strong. Among Forest Research's long term goals is to produce GM trees with reduced lignin, or lignin that is more easily removed during the pulping process. Scientists at Forest Research are working on a technique to genetically modify wood cells to introduce specific genes and to analyse the effect on wood cell development.[23]

Companies working on producing a genetically modified tree often also produce "genetically improved" tree clones, using tissue culture and somatic embryogenesis. The sale of these trees provides an income for the company its scientists are working on GM tree development. It can also act as a commercial back up plan, in case the GM tree research fails.[24]

In 2003, scientists at a Tree Biotechnology meeting in Sweden proposed setting up a "Eucalypt Genome Initiative".[25] The beneficiaries of this research are clear from the list of pulp and paper companies that expressed an interest: Aracruz, Nippon Paper, Sappi, Mondi, ArborGen, Stora Enso, Suzano and Oji Paper.

Indeed, much of the research that scientists are conducting into GM trees is primarily of interest to the pulp and paper industry. Faster growing GM trees would in theory allow pulp mills to grow more fibre more quickly. Herbicide tolerance was one of the key areas of initial research into GM trees. Scientists have engineered insect resistant GM poplar, larch, white spruce and walnut trees. Scientists in Japan have produced GM eucalyptus trees which can grow in salty soils. GM trees with reduced lignin would make the pulping process less polluting, which would be useful for pulp industry public relations.[26] Researchers are working on GM disease resistant trees. Large scale monoculture plantations are particularly susceptible to diseases. GM trees engineered to be sterile would grow faster since the trees would focus their energy on growing rather than producing flowers. The pulp and paper industry is also interested in research into GM trees with more uniform fibre, fewer branches and straighter trunks.

Researchers are also looking into ways of engineering trees to absorb and store more carbon, as a supposed solution to climate change. Others are working on engineering trees to clean up pollution. Physicist Freeman Dyson has even suggested that within 50 years, scientists will be able to genetically engineer trees to make Mars habitable, making it an attractive destination for space tourists.[27]

Since the first GM poplars were planted in Belgium in 1988,[28] there have been several hundred field trials of GM trees – the majority in the US. Two years ago, China's State Forestry Administration approved GM poplar trees for commercial planting.[29] Well over one million insect resistant GM poplars have now been planted in China.[30]

The GM trees are part of the government's plan to cover 44 million hectares with trees by 2012, supposedly in an attempt to prevent floods, droughts and spreading deserts. Chinese forestry scientists see GM trees as a technical fix to the serious damage that insects cause to tree plantations in China. "Recent research on insect-resistant forest tree breeding shows considerable promise," wrote Wang Lida, Han Yifan and Hu Jianjun of the Chinese Academy of

Forestry in a recently published book (*Molecular Genetics and Breeding of Forest Trees* edited by Sandeep Kumar and Matthias Fladung).

But neither the government nor the scientists who produced the GM trees have any records of where the trees have been planted.

Huoran Wang represents the Chinese Academy of Forestry in Beijing on the UN Food and Agriculture Organisation's Panel of Experts on Forest Gene Resources. In November 2003, Wang told an FAO meeting that "Poplar trees are so widely planted in northern China that pollen and seed dispersal can not be prevented".[31] Attempts to prevent genetic pollution by maintaining "isolation distances" between GM and non-GM poplars is "almost impossible", Wang added. There isn't even a system in place to monitor the GM plantations that have so far been planted. Wang suggests setting up a system "to monitor the situation of the GM plantations" and their impact on surrounding ecosystems.

The dangers posed by GM trees are in some ways even more serious than those posed by GM crops. Trees live longer than crops, they are largely undomesticated and forestry scientists' knowledge about fragile forest ecosystems is poor. The risks involved are serious enough to justify the demand for a global ban on releases of GM trees.

The origins of GM trees

The development of genetically modified trees can be traced back to the mid-eighteenth century in Europe and the invention of scientific forestry. The purpose of scientific forestry was to produce a single product: timber.

Simplification of forests and ever increasing state and forest department control over forest land went hand in hand with colonisation in the tropics. The vast monoculture tree plantations marching across the Global South are the most extreme form of this model of forestry. The companies backing GM tree research are interested in the supply of large quantities of cheap, homogenous wood fibre to feed their pulp mills. Genetic modification of trees is forestry science's latest offering to its industrial masters.

GM trees are designed to be planted in large, monoculture, industrial tree plantations.[32] These plantations have serious impacts on people and forests and GM trees will increase these impacts. Local people's names for industrial tree plantations illustrate the problems that this model of forestry causes. In Thailand, farmers call eucalyptus the "selfish tree", because eucalyptus plantations remove nutrients from the soil and consume so much water that farmers cannot grow rice in neighbouring fields. Mapuche Indigenous People in Chile refer to pine plantations as "planted soldiers", because they are green, in rows and advancing. In Brazil, tree plantations are called a "green desert", and in South Africa, "green cancer".[33]

Throughout the Global South people and organisations have formed networks opposing industrial tree plantations on their land. In Brazil, a group of more than 100 organisations consisting of villagers, indigenous peoples, workers, trade unionists and environmentalists has formed the Alert Against the Green Desert Network.[34] The Network opposes the encroachment of villagers' land by monoculture plantations for pulp and charcoal production. In April this year, the Movement of Landless Peasants (MST) in Brazil protested against the pulp and paper industry's takeover of vast tracts of land. Landless people occupied areas of industrial tree plantations owned by the pulp and paper companies Veracel, Klabin, VCP, Aracruz and Trombini.[35]

In Thailand, villagers have rallied outside town halls, marched in their thousands, pulled up trees and burned down local forestry officials' houses in protest against industrial tree plantations.[36]

GM trees, if commercially developed, would intensify the problems associated with industrial tree plantations. Local people's opposition to GM tree plantations would therefore also be greater.

The next section of this book counters some of the arguments used by proponents of GM trees to promote further research and development of GM trees.

Section 3 describes some of the companies, research institutions and networks behind the development of GM tree technology. Like any other technology, research into GM trees is not neutral. Among the questions that we need to ask about this new technology are: Who is carrying out the research? Who is paying the researchers? Who stands to benefit? And who faces the risks? Ask yourself whether you trust scientists funded by pulp and paper companies to tell the truth about the dangers of GM trees, especially when the results of their research will primarily benefit the pulp and paper industry.

Section 4 explains some of the international and national regulations and legislation. Unfortunately, much of the legislation is inadequate to control the development of GM trees.

The final section outlines some of the campaigns and actions that people have already taken against GM trees. People around the world are saying "NO" to GMOs. Resistance against GM trees is growing!

Footnotes

[1] DNA can be transferred from one organism to another in nature, for example, when microrganisms in soil take up DNA from rotting plant or animal matter.
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[10] Measures Affecting the Approval and Marketing of Biotech Products, First Written Submission by the European Communities to the World Trade Organisation, Geneva 17 May 2004.

[11] Definitions of "vector" and "plasmid":
Vector: "In DNA cloning, the plasmid or phage chromosome used to carry the cloned DNA segment."
Plasmid "Autonomously replicating extra chromosomal DNA molecule. An autonomous self-replicating genetic particle usually of circular double-stranded DNA."

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[14] Measures Affecting the Approval and Marketing of Biotech Products, First Written Submission by the European Communities to the World Trade Organisation, Geneva 17 May 2004.

[15] Mae-Wan Ho and Joe Cummins, Genetically Modified Organisms 25 Years On, Third World Network, 12 October 2002.

[16] Mario Rautner, Designer Trees, *Biotechnology and Development Monitor*, No. 44, March 2001.

[17] Brian Tokar, Introduction: Challenging Biotechnology, in Brian Tokar (ed.) *Redesigning Life? The Worldwide Challenge to Genetic Engineering*, Zed Books, 2001.

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[21] Casey Woods, Here come the super trees, *Latin Trade*, May 2002.

[22] Genetic modifications have the potential to change our landscapes – and to transform forestry, *San Jose Mercury News*, 30 May 2000.

[23] Fundamental Development Pathways, Forest Research, New Zealand.

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See the University of Pretoria's web-site for more details about the Eucalypt Genome Initiative.

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[30] Huoran Wang, The State of Genetically Modified Forest Trees in China, unpublished manuscript.

[31] In response to my request for a copy of his presentation at the November 2003 meeting of the FAO's Panel of Experts on Forest Gene Resources, Huoran Wang sent me a copy of his unpublished manuscript, The State of Genetically Modified Forest Trees in China.

[32] See, for example, Jason Ford, The Perfect Neoliberal Tree, *GeneWatch*, Vol. 14, No. 3, May 2001.

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[34] See, for example, Manifesto against the green desert and in favour of life, 7 May 2004.

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[35] Patrick Knight, Investments in the Billions, *Pulp and Paper International*, August 2004.

[36] For more details about the protests and the pulp and paper industry in Thailand, see Chris Lang, The Pulp Invasion: The International Pulp and Paper Industry in the Mekong Region, World Rainforest Movement, December 2002.

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