Pocket K

Biotech/GM Trees

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TREES provide man's basic needs for food, fuel, and shelter and many other uses in industry and pharmaceuticals. They can be found naturally in forests or cultivated together with other plants. With the current attention on climate change and global warming, preservation and care for trees has become a global interest. This is because trees are known to effectively and efficiently sequester CO2 and other greenhouse gases found in the atmosphere and slow down the rate of global warming.

Biotechnology in general, and genetic engineering in particular, are tools that are acknowledged to contribute to the improvement of crops and trees. Genetically modified (GM) trees are woody plants improved through recombinant DNA technology. They are conferred with useful traits to lower production costs of wood products, increase productivity, and improve the economics of tree plantations through creation of suitable raw materials, decreased pesticide use, disease resistance, and rehabilitation of degraded lands. These GM trees may be useful for the lumber, pulp and paper industry; assure quality and nutritious fruits; and improve forest covers.

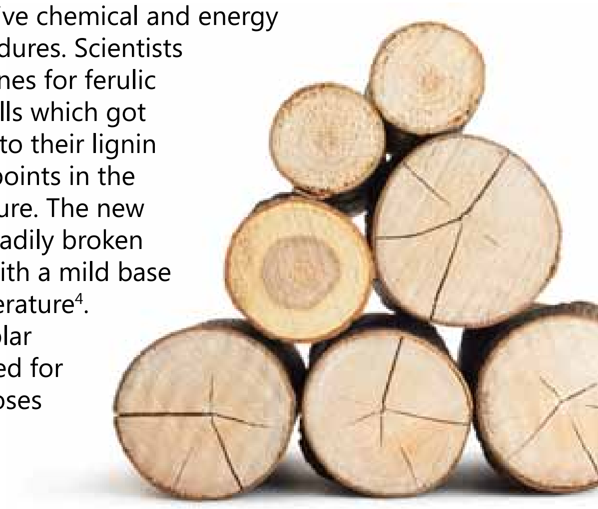
GM Trees for Industrial Uses

TREES can be engineered to improve wood traits for various purposes. Trees that grow faster and denser, and straighter is desirable for lumber companies. This can be achieved by developing trees with more cellulose and less lignin. Such trees can also be used as non food crop-based biofuel feedstocks which are significantly easier to convert into liquid fuels.

The company FuturaGene has developed GM eucalyptus and poplar trees that contain genes that alter the structure of plant cell walls to stimulate the natural growth process. The GM eucalyptus which was given approval for commercialization in Brazil in 2015[1] can grow 5 meters a year, with 20%-30% more mass at shorter time than normal eucalyptus trees[2]. The yield increase provided by the GM eucalyptus will provide economic, environmental, and social benefits to the country.

Loblolly pines are used for lumber, plywood and paper. Arborgen, a tree seedling company, has developed a GM cultivar that has higher density. Higher wood density in trees is generally associated with strength and durability in lumber as well as higher energy content for biomass uses. The genes from Monterey pine, the American sweet gum tree, mouse ear cress and *E. coli* were introduced through gene gun. As none of these gene sources are plant pest risks, the USDA deregulated the GM loblolly pine which can be cultivated without undergoing environmental studies[3].

Poplar tree was also improved to easily break down lignin, which is commonly removed from wood through extensive chemical and energy intensive procedures. Scientists inserted the genes for ferulic acid into the cells which got incorporated into their lignin creating weak points in the chemical structure. The new lignin can be readily broken when treated with a mild base and high temperature[4]. Hence, GM poplar can be processed for industrial purposes easily.



GM TREES TO COMBAT INVASIVE THREATS

Engineering trees to make them more resilient to changing climates and are better able to defend against pests and diseases is critical to keep our forests and trees healthy. Here are some of the most important GM trees.

Papaya Ringspot Virus Resistant Papaya

Hawaii in 1997 suffered a devastating economic loss of nearly 40% due to the prevalence of papaya ringspot virus (PRSV). The US$17 million papaya industry was saved in 1998 by the US government agencies' (Environment Protection Agency [EPA], Food and Drug Administration [FDA], and USDA Animal and Plant Health Inspection Service [APHIS]) approval of GM papaya Rainbow resistant to the PRSV disease. Researchers from Cornell University and the University of Hawaii developed the resistant papaya by expressing the virus-derived coat protein gene, and within four years of its introduction, papaya production returned to previous level[5]. An additional PRSV Papaya X1' 7-2 was deregulated in the US on September 2, 2009[6]. In 2016, GM papaya occupies 1,000 hectares in Hawaii, and 8,475 hectares in China[7].

Insect Resistant Poplar

In China, poplar trees are cultivated for use in furniture, boat-making, paper, chopstick and many others because of its flexibility and close wood grain. The emergence of Asian longhorn beetle devastated the 7.04 million hectares of poplar in China. In 2003, China commercialized GM poplar trees that contain cry1a genes from *Bacillus thuringiensis* and later with a proteinase inhibitor from *Sagittaria sagittifolia* to control the beetle[8]. In 2016, a total of 543 hectares GM poplar was cultivated in China[7].

Virus Resistant Plum

In 2007, the US Department of Agriculture (USDA) deregulated C5 “HoneySweet” plum tree engineered to be resistant to the plum pox virus through the introduction of virus-derived coat protein gene[9]. The HoneySweet Plum was issued a letter of “no further questions” by the US FDA in January 2009, which is effectively an approval to use. The US EPA has conditionally registered this tree by August 8, 2011. While not made commercially available as of August 2013, the USDA is posed to make the tree available if it is needed to combat the plum pox virus.

Blight Resistant American Chestnut

Cryphonectria parasitica is is the causal organism of the chestnut blight disease that extremely affected the American chestnut forest by the late 19th century. Researchers discovered that the chestnut blight is caused by oxalic acid which the pathogen releases during infection. By transferring a wheat gene that encodes oxalate oxidase, researchers at State University of New York (Syracuse) and University of Georgia were able to develop blight resistant chestnut trees. Field trials of these transgenic trees with wheat genes, cisgenic biotech chestnut (containing resistant genes from Chinese chestnuts into an American chestnut tree), as well as hybrids of Asiatic and American chestnut trees conducted in May 2013 were promising[10]. Approval by the USDA, the EPA, and the FDA is needed to conduct a field trial. The process of obtaining those approvals is expected to take at least five years. The researchers expect they can have as many as 10,000 of the trees ready to plant by the time the approval occurs[11].

Citrus Greening Resistant Citrus

A new disease in citrus caused by the bacteria *Candidatus liberibacter asiaticus* and spread by psyllids was recorded in the early 70's. The disease turns oranges into green, misshapen, and bitter-tasting fruits. Millions of acres of citrus crops have already been lost in the US and overseas, and 80% of Florida's citrus trees are infected and declining. The bacterial disease incubates in the tree's roots, moves back up the trunk in full force, causing nutrient flows to seize up. Florida's US$5.1 billion citrus industry could be a complete loss unless it soon finds a way to fight the disease. Cocktails of chemical sprays to kill the vector psyllids are no longer effective. A Texas A&M scientist, with funds from Southern Gardens – a large citrus growing company – inserted a spinach gene to fight the bacteria. A five-year successive small field trials of the transgenic trees have shown high degree of resistance. A successful two-year larger trial of second- and third-generation trees was completed in 2013. Southern Gardens is now seeking to deregulate these oranges for free use, anticipating first commercial planting in three to four years[12].

One of the clearest indication of an Asian psyllid infestation is the presence of psyllid nymphs and their white, waxy excretions on citrus plants. (Photo: USDA APHIS)

Citrus greening disease on mandarin oranges. (Photo courtesy of USDA APHIS)

GM Tree for Adverse Temperature

A one of a kind GM eucalyptus tree that can withstand extremely low temperature was developed by Arborgen, Inc. and was deregulated in the USA in 2010. The GM tree contains a cold-inducible promoter driving a C-repeat binding protein from *Arabidopsis thaliana*. Selected transgenic lines were tested in 21 replicated field trials across eight different locations with various freezing temperatures. Transgenic freeze tolerant eucalyptus can grow up to 52.4 feet at 16.8°F, compared to the control trees which grew only 0.3 feet. There is no evidence from the literature or from the field trials which indicated that GM eucalyptus event EH1-427 would be invasive or negatively impact endangered species[13].

GM Tree for Consumers

New generation GM traits are targeted for consumer preference. The “non-browning apple” Arctic® Apple from Okanagan Specialty Fruits of Canada is the first GM tree with consumer-targeted trait to be commercialized. Polyphenol oxidase (PPO) renders the apple brown upon oxidation when bruised, bitten, or cut. Hence, GM apple was developed by silencing the three main polyphenol oxidase genes making the apple with little or no PPO enzyme, such that cell disruption doesn’t lead to browning[14].

In February 2015, the Arctic® Apples (Granny and Golden varieties) were granted commercial approval by the USDA APHIS[15] and the Fuji variety by 2016. The first commercial harvest of these apples commenced in 2016 and sold in North America in 2017. Some 70,000 Arctic® apple trees were planted in 201616.

The Future

Future GM trees will continue to contain traits for feedstock biofuels, timber industry, to resist pest and diseases, to save contaminated environments (phytoremediation), and with new traits such as drought and salinity tolerance. It can be foreseen that R&D of GM forest trees will develop even faster in the near future and there is no doubt that GM forest trees will be grown on a large scale in plantation forestry and for land reclamation in China, Brazil and the USA as long as some technical obstacles are overcome in the coming years. Regulations in planting GM trees are also needed in many countries to ensure environmental safety before commercialization.

References

1. FuturaGene's eucalyptus is approved for commercial use in Brazil. 2015. http://www.futuragene.com/FuturaGene-eucalyptus-approved-for-commercial-use.pdf
2. USDA Approves Genetically Modified Trees for Trial Planting. 2010. http://gmo-journal.com/index.php/2010/05/15/usda-approves-genetically-modified-trees-for-trial-planting/
3. Capital Press. 2015. USDA cannot restrict GMO pine. January 28. 2015. http://www.capitalpress.com/Timber/20150128/usda-cannot-restrict-gmo-pine
4. Wilkerson CG, SD Mansfield, F Lu, S Withers, J-Y Park, SD Karlen, E Gonzales-Vigil, D Padmakshan, F Unda, J Rencorer, and J Ralph. 2014. Monolignol ferulate transferase introduces chemically labile linkages into the lignin backbone. Science 344(6179): 90-93. http://www.sciencemag.org/content/344/6179/90
5. Hawaii Grown Papayas. 2015. The rainbow papaya story. http://www.hawaiipapaya.com/rainbow.html accessed May 24, 2015.
6. USDA APHIS. 2009. Finding of no significant impact. Petition for Non regulated status for University of Florida X17-2 Papaya. http://www.aphis.usda.gov/brs/aphisdocs2/04_33701p_ea.pdf)
7. ISAAA. 2016. Global Status of Commercialized Biotech/GM Crops: 2016. ISAAA Brief 52. ISAAA. Ithaca, NY. http://www.isaaa.org
8. FAO, 2003. Advances in tree engineering in China. 2003. http://www.fao.org/docrep/ARTICLE/WFC/XII/0280-B2.HTM
9. APHIS, 2007. Approval of USDA-ARS request seeking a determination of non-regulated status for C5 plum resistant to plum pox virus. http://www.aphis.usda.gov/brs/aphisdocs/04_26401p_ea.pdf.
10. The Economist. 2013. Genetically modified trees – into the wild. 2013. http://www.economist.com/news/science-and-technology/21577033-gm-species-may-soon-be-liberated-deliberately-wildwood, 2013
11. ARS Technica. 2014. GMO trees could rescue American chestnut from invasive fungus. http://arstechnica.com/science/2014/11/gmo-trees-could-rescue-american-chestnut-from-invasive-fungus/
12. Food Safety News. 2013. USDA Steps up citrus greening fight as GMO fix looks promising. http://www.foodsafetynews.com/2013/12/usda-steps-up-citrus-greening-fight-that-ultimately-may-require-a-gmo-fix/#.VV7AuPmqqko, 2013.
13. Hinchee, M. C Zhang, S Chang, M Cunningham, W Hammond and N Nehra. 2011. Biotech Eucalyptus can sustainably address society's need for wood: the example of freee tolerant eucalyptus in the southeaster US. BioMed Central Proceedings 2011 (5 Suppl 7):124. http://www.biomedcentral.com/1753-6561/5/S7/I24/
14. Okanagan Specialty Fruits. Getting to the bottom of browning, and how to solve it. http://www.okspecialtyfruits.com/arctic-apples/browning-and-nonbrowning-science, accessed May 24, 2015.
15. Press Release: Non browning Arctic® Apples to be granted approval. http://www.arcticapples.com/blog/joel/press-release-nonbrowning-arctic%C2%AE-apples-be-granted-approval/
16. Intrexon. 2016. First ever commercial harvest of Okanagan Specialty Fruits Arctic® Golden Apples Completed. http://investors.dna.com/2016-10-03-First-Ever-Commercial-Harvest-of-Okanagan-Specialty-Fruits-Arctic-Golden-Apples-Completed

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