Ecological Risk Assessment and Management

A Cornerstone of the Institute of Forest Biotechnology

Genetic modification of forest trees is in its infancy compared to that of agronomic crops where the area occupied by transgenic plants has expanded from 1.7 to 52.6 million hectares from 1996 to 2001. The four major crops making up that total are soybeans (63%), maize (19%), cotton (13%) and canola (7%). Within the total, 40.6 mm ha (77%) occupy crops modified for herbicide resistance, 7.8 mm ha (15%) for insect resistance using the soil bacterium Bacillus thuringiensis, and 4.2 mm ha (8%) involved stacking for both herbicide and insect tolerance. Estimates are substantial that a reduction of pesticides has been realized than would have been the case with non-transgenic plants.

In contrast to the expanded use of agronomic transgenic plants, there are no confirmed commercial plantations of transformed forest trees. This phenomenon exists even though a report by the World Wildlife Fund-UK and WWF International showed there to be over 100 trials representing 24 forest-tree species installed from 1988 through 1999, with the majority of those being in Canada and the United States. By March 2002, the United States and Canada alone had installed 138 trials representing 52 species, many of which are representatives of the 2000 and 2001 planting years.

Three primary uses are envisioned for genetically modified (GM) trees in forestry: (1) production forestry where the objective is to grow trees with broad adaptability, fast growth rate, high resistance to pests and environmental limitations, improved tree form, and desired wood properties; (2) conservation forestry where the objective is to create an idyllic environment in which to live, work and play, and (3) reclamation forestry where species, such as American chestnut, are on the verge of extinction.

The major reason for using GM trees in production forestry is to increase productivity per unit area per unit time. The high cost of practicing this type of forestry is largely offset by the short rotations associated with intensive culture; reduced land holdings on which forestry is practiced thereby preserving natural forests for altruistic purposes; reduced capitalization, and lowered transportation costs associated with the wood being near the processing plants.

Soil, air and water pollutants adversely affect tree health and, as a result, adversely affect the biotic and abiotic elements of the environment. Trees can be genetically modified and managed to bioremediate contaminated soils, to protect water sources from sedimentation, thermal changes and turbidity, and to sequester greenhouse-warming carbon dioxide from the atmosphere while emitting life-sustaining oxygen.

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trees of heritage value have suffered from dysgenic selection that has resulted from catastrophic events, destructive harvesting practices and pests introduced by non-native species.

Traditional breeding programs are now being complemented by biotechnology, which includes genetic mapping that can aid in the efficacy of traditional breeding, and transgenes. Transgenes entail insertion of genes or gene complexes from one entity to another where the two entities are of very different phyla. An example would be Golden Rice where one gene from daffodil and one from a bacterium (*Erwinia uredovora*) are inserted into the genetic material of rice. This insertion allows for the production of provitamin A in rice. This vitamin is lacking in the diets of millions of people in developing countries and in whose absence blindness can occur.

Concern has been expressed about the ecological risk associated with the release of genetically modified forest trees. Conventional wisdom suggests that the risk is much greater for forest trees than for annual and perennial crops. The reason is that forest trees are long-lived, which means that their genes could be disseminated year after year from the time they reach sexual maturity to senility; a time that could extend from tens to hundreds of years. Other ecological issues raised about the application of forest biotechnology are potential threats to:

- Land races of the same species,
- Wild relatives of the same species,
- Ecology of the environment, both in the area where they are farmed and in the area to which they may escape.

The genotype of trees has been constantly changing from time immemorial through natural selection, mutation, hybridization and isolation. These phenomena are responsible for speciation, a never-ending process. In recent decades, traditional selection and breeding programs have been initiated by forest geneticists on species of commercial importance to improve traits such as growth, form, adaptability, wood properties, and pest resistance. Because of the long time to sexual maturity, about 10 years in most forest species, and the equally long time in assessing the genetic worth of parents and progeny, forest-tree breeding is only in its third generation. This generation cycle suggests that the genetic variation in forest trees is extremely broad compared to agronomic crops, such as corn, where the generation cycle is in excess of 300 and counting.

The escape of genes from GM plants from one provenance (land race) to another in the indigenous environment could have both positive and negative attributes. The escape of genes from a population engineered for disease resistance might convey resistance to the receiving population, but it might also adversely affect growth rate if the two traits were negatively correlated. In the first environment, the sacrifice in growth rate might be desired in order to obtain disease resistance in a disease-prone area. In the second instance, the sacrifice in growth rate might be unacceptable because of the low-disease potential.

Contamination of the wild relatives of the species of interest could also have detrimental effects similar to those of provenances (land races). This phenomenon could potentially be especially detrimental for species in the same genera. Some examples would include oaks (*Quercus* spp.), pines (*Pinus* spp.), eucalypts *(Eucalyptus* spp.), and acacias (*Acacia* spp.).

Such contamination among provenances (land races) and species could also have adverse effects on the local ecology. The GM plants might be overly aggressive in reproduction and growth, in which case they could suppress or eradicate companion species. In opposite form, they may be unfit for an unmanaged environment, in which case they would over time be deleted from the locality.

Analogies with invasive or weedy plants have often been used to denigrate the potential benefit of GM trees. Considerable evidence refutes the concept that GM trees are exotic introductions because only one or a few genes are exotic compared to the array of genes that number into the thousands in an introduced species. Still, each potential GM tree release must be assessed against well-established criteria for determining colonizing potential. The biological fitness effects of the introduced trait, rather than the trait production process, has been acknowledged as a constructive way forward in forming risk assessments for GM trees.

Regional variations in environmental conditions and the need to avoid genetic monocultures are likely to be significant factors in any large-scale deployment of GM trees. Suggestions have been made that a mixture of GM genotypes is essential to avoid catastrophic events, and some governments have adopted the recommendation. One of the more far-reaching enactments has been to include 50 genotypes to a plantation in order to avoid cataclysmic effects. Such precautions extend to the extreme, and obviate the potential gains to be realized from forest biotechnology. The recommendation is to assess the GM plants on their biological fitness as assessed against well-established populations of non-genetically modified plants.

The Institute of Forest Biotechnology will work to bring about the critical dialogues between biotechnologists, ecologists and policy makers that are needed to bridge these disciplines and provide a framework for reasoned development of ecological risk assessment and management regulation.

Ecological Risk Assessment and Management will be integrated with the other cornerstones of the Institute of Forest Biotechnology to provide a path forward for the safe, appropriate and productive development of forest biotechnology. These cornerstones concern heritage trees, charting cultural, ethical and societal perspectives, and information networking and education.

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