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Beyond myths and miracles: Biological potentials and social obstacles to use of gene modified trees in plantation forestry

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The most novel aspect of plant biotechnology is gene modification (GM), where specific genes are isolated, modified, inserted into plant DNA via asexual methods, and then trees are vegetatively propagated for use in planted forests. GM is the gold standard in all of biology and biotechnology: It allows an unparalleled degree of scientific precision, and capacity for customization, for both biological study and crop domestication. This is because genes that control important traits are specifically identified and modified to produce improved traits of interest. In contrast, during conventional breeding genes and their functions are effectively treated as black boxes; only gross phenotypes (e.g., yield, survival, density) are typically considered, and the complex structure of genetic polymorphism makes it difficult to use marker-assisted methods to improve on conventional breeding.

This scientific precision of GM challenges forestry, for which gross fiber or wood production, rather than highly customized trees, are often the only commercial goal. In many places it is also not clear to what extent wood products, rather than a myriad of other ecological and social goals, are the objectives. Without some order as to objectives of forestry systems, and some regulatory and market recognition of intensive, farm like forestry programs that include GM trees, the precision of GM will be irrelevant.

Further, the precision of GM brings many new social challenges in that evolving patent laws, regulations, activist-led market resistance, and wood product certification schemes impose new costs and risks on companies and governments that are far higher than for conventional tree improvement. These costs have so far been imposed without any proportionality to risk or novelty; all GM trees tend to be treated as though they are highly risky, even where the genes employed are already present in native genomes. The social practice of treating all GM trees alike runs squarely against the long standing advice of ecologists and geneticists, including the Ecological Society of America and the US National Academy of Sciences, who have stated repeatedly that "product not process" should be the basis of risk assessment. Because most GM trees are expected to be vegetatively propagated and effectively infertile, they should in fact be environmentally *safer* than domesticated tree farms produced via conventional breeding, hybridization, or use of exotic species and populations.

Nonetheless, "green" activists in many parts of the world have effectively “mau-maued” (a la Tom Wolfe) government and non-profit company bureaucrats in their push for regulations, and have thus effectively excluded most GM trees from agriculture and forestry, including for scientific research. This has foreclosed many opportunities for

translating the potential of genomic knowledge into advances in domestication and breeding technology. Without research, especially field trials, it will be impossible to separate myth from actual commercial potential.

Poplars are ideally suited for gene modification because of their rapid growth, small and very well known genome (DNA sequence), and amenability to gene transfer and vegetative propagation. Many of the potentials and risks from gene modification can be studied in poplars far more rapidly and precisely than in conifers or other angiosperm species. I discuss results from more than a decade of GM studies and field trials in poplar focused on wood modification, sterility for genetic containment, herbicide resistance, and pest resistance. I argue that: 1) gene transfer is highly effective, can be applied to any genotype, and results in highly stable traits and healthy trees; 2) the scientific potential for customized domestication of trees via gene modification appears considerable, and is just starting to be realized as genomic knowledge rapidly grows; 3) genetic containment technology, combined with the vast excess of wild over farmed poplars, provide a huge biosafety buffer with respect to concerns over gene flow from GM plantations in northern temperate poplar forests; 4) the patent and regulatory systems, because of their high costs and legal liabilities, effectively disenfranchises the public sector from applied GM research—even though it has historically been the source of most information and funding for tree breeding programs; and therefore 5) new public sector institutions, with the clear goal of promoting intensive and sustainable plantation productivity, freedom to operate without interference from multinational activist or agrichemical companies, and the legal and financial capacity to operate amidst complex regulations and intellectual property, will be required to translate the scientific advances in genomics into gene-based plantation technologies for public and private benefit.