Green Revolution Plantations: Could Short Trees Be a Big Thing?

Amy Klocko, Brian Stanton, Cees van Oosten, and Steven H. Strauss

Semi-dwarfism is a beneficial trait in many crop species. These shorter, sturdier plants are less prone to lodging, a condition in which the plant falls over, either due to insufficient root support or stem breakage, leading to harvest losses. The benefits associated with semi-dwarfism became a part of mainstream agriculture during the "Green Revolution," which greatly improved yields of wheat and rice. Semi-dwarfism was proposed as a beneficial trait for some types of tree plantations over a decade ago[1]; however, the idea goes against the convention of maximizing single tree biomass production and growth rate during tree breeding. Genes that constrain height amidst competition for light are also hard to find in breeding populations; as such traits are strongly deleterious to natural selection. Thus, semi-dwarfism has received little experimental evaluation in forestry to date.

Like grain crops, trees are also susceptible to lodging, there termed wind-throw. However, the loss of perennial tree plantations represents years of growth and productivity, and creates costly management and harvest problems. Experience in the GreenWood Resources (GWR) breeding programs in the Pacific Northwestern USA has shown that stability under wind loading is an important management criterion, but stand vulnerability is only revealed after a decade or more of testing and development. Interestingly, wind-throw phenotypes appear to have a strong genetic component, as particular clones (and their genetic siblings) exhibit extreme susceptibility, while others are very resilient (**Figure 1**). For example, an otherwise well-performing variety in the GWR program, (*P. ×generosa* '50-197'), was found to be susceptible to wind-throw and thus could no longer be planted operationally. Although this variety exhibited a tendency to be thrown under wind stress on many sites, it was not observed until the latter part of the testing cycle. Consequently, X-ray imaging techniques are now being developed for young trees to predict how mature stands might behave.

The GWR experience with wind-throw in poplar plantations, as well as the other potential benefits of semi-dwarf trees discussed by Bradshaw and Strauss (2001), prompted researchers to take a closer look at the potential benefits of smaller, sturdier trees. A recent study[2] took a first step in this direction; it focused on evaluating hybrid poplar (*Populus tremula* X *P. alba*) that was transformed with a variety of semi-dwarfism transgene constructs. The overall goal was to evaluate their effects on plant productivity, morphology, and adaptability in plantings of varying density.

Changes in plant stature can be achieved through a variety of means (reviewed in Busov et al. 2008[3]). The Elias et al. study focused on the modification of levels and hormone signaling of gibberellin (GA), a naturally-occurring plant hormone with known effects on plant growth and structure. GA levels were modified through the use of overexpressed dominant transgenes in the GA biosynthesis and signaling pathways. The enzyme *GA 2- oxidase* (GA2) converts GA precursors and bioactive GA into inactive forms, while the proteins *GA-insensitive* (GAI) and *Repressor of GAI-Like* (RGL) function to inhibit GA signaling. All three transgenes were able to cause dwarfism in hybrid poplar, and all were shown to have strong and unique impacts on measured GA levels. Trees with mild decreases in height—approximately 75% of wild type from a prior field study after two years—were chosen for analysis, as severely stunted trees were unlikely to be of interest for practical applications. Trees were first grown in raised beds; this allowed the soil to be washed away and thus their complete root systems obtained during harvest. To speed expression of differences that would occur under competition in production stands, the trees were then grown at two densities over two growing seasons, both much higher than is normal for cultivated poplars (0.5 and 0.9 m spacing between trees).

The different transgenic constructs and lines (insertion events) varied widely in their morphology and productivity, and most differed significantly from wild-type controls. In general, the semi-dwarf trees were shorter and had thicker shoots, and produced relatively less stem biomass per unit area compared to the wild type under low density than under high density. This is similar to observations in other semi-dwarf crops. Additionally, these trees had a higher rooting ability than control trees, facilitating their propagation. Previous studies of GA dwarfs focused on the above-ground features; very little was known about the effects of semi-dwarfism genes on roots. Quantification of the root, stem, and leaf portions of the trees revealed that roots represented a larger proportion of the biomass of the semi-dwarf plants, a result that was confirmed after harvest of the two-year old plantation. Despite this morphological variation, the adaptability of the trees appeared to be unaffected by the semi-dwarfism genes; all set and flushed buds, similar to that of wild-type, and there was no evidence of winter cold damage.

Would the higher root fraction, shorter size, and greater stockiness of semi-dwarf poplars make them less susceptible to wind throw? There are data to suggest that such trees may in fact be more resilient. A triploid poplar clone *P.* × *generosa* '52-226' was wind firm (**Figure 1C**), and exhibited favorable diameter growth, but did not achieve the same early-rotation height as other clones, and thus was not selected for production. Greater emphasis on radial over height growth during all stages of selection might therefore provide an improvement in wind-firmness. Might the proportionally larger root systems make semi-dwarf trees better able to withstand droughts or to take up soil nutrients or toxicants during bioremediation? This is also unknown, and will require larger scale trials, over a variety of sites and densities, to answer. Unfortunately, doing such trials would be extremely difficult under current regulatory and market conditions. Due to the transgenic methods used in the Elias *et al.* (2012) study[2], USDA and possibly EPA regulations would consider such trees to be hazards and tightly regulated[4]. In addition, Forest Stewardship Council (FSC) certification—which is common for poplars in the northwest—presently does not allow any testing of transgenic trees, even if under strict containment and for research purposes only[5]. Until the social stigma over transgenic plants subsides, size and architecture modifications will be restricted to what can be produced during conventional breeding.

Figure 1: Wind-throw causes large-scale losses in poplar plantations.

(A) Arial view of a poplar plantation in Clatskanie Oregon. Nearly all of the trees in the foreground stand were blown over while a neighboring stand of a different clone was unaffected. (B) An advanced stage, yield verification trial of hybrid poplar in western Oregon. Pictured in the foreground is a wind-thrown nine-year-old plot of *P. ×generosa* '222-93-4144'. *P. ×generosa* '282-93-4361' shown in the background withstood the same wind loading. (C) Close up view of two nine-year-old clones from Snohomish County Washington after a 2004 wind and ice storm. Clone *P. ×generosa* '49-177' (left) and triploid *P. ×generosa* '52-226' (right) show dramatic differences in damage. Images A and B provided by Brian Stanton. Image C provided by Cees van Oosten.

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Food Science Expert: Genetically Modified Crops Are Overregulated

Bruce Chassy

CHAMPAIGN, Ill. — It has been almost 20 years since the first genetically modified foods showed up in produce aisles throughout the United States and the rest of the world, but controversy continues to surround the products and their regulation.

Bruce Chassy, a professor emeritus of food science and human nutrition at the University of Illinois at Urbana-Champaign, believes that after thousands of research studies and worldwide planting, "genetically modified foods pose no special risks to consumers or the environment" and are overregulated.

Chassy elaborated on this conclusion at the 2013 meeting of the American Association for the Advancement of Science in Boston on February 17, 2013. During his talk, "Regulating the Safety of Foods and Feeds Derived From Genetically Modified Crops," Chassy shared his view that the overregulation of GM crops actually hurts the environment, reduces global health, and burdens the consumer.

Farmers have witnessed the advantages of GM crops firsthand through increases in their yields and profit, and decreases in their labor, energy consumption, pesticide use and greenhouse gas emissions, Chassy said.

Despite these benefits, various regulatory agencies require newly developed GM crops to be put to the test with rigorous safety evaluations that include molecular characterization, toxicological evaluation, allergenicity assessments, compositional analysis and feeding studies. This extensive testing takes five to 10 years and costs tens of millions of dollars, and Chassy argues that this process "wastes resources and diverts attention from real food safety issues."

"With more than half of the world's population now living in countries that have adopted GM crops, it might be appropriate to reduce the regulatory scrutiny of GM crops to a level that is commensurate with science-based risk assessment," Chassy said.

During his talk, Chassy chronicled the scientific tests used in pre-market safety assessments of GM foods and elaborated on the evidence from thousands of research studies and expansive GM plantings that he says show these crops do not present risks to consumers or the environment. The overregulation of GM foods is a response not to scientific evidence, Chassy said, but to a global campaign that disseminates misinformation and fear about these food sources.

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