Breeding and Nursery Propagation of Cottonwood and Hybrid Poplars for Use in Intensively Cultured Plantations[1]

Don E. Riemenschneider[2]

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INTRODUCTION

Intensively cultured poplar plantations are well known in the Southern and Northwestern United States where they have made significant contributions to industrial fiber supplies. Intensively cultured plantations are less well known in the Northeastern United States, where research and pilot-scale studies have focused on the production of alternative fuels. But, several factors have recently combined to increase interest in intensively cultured plantations in the North Central region, especially in Minnesota. In response, about 10,000 acres of hybrid poplar plantings have been established as of 1997. A few operational scale plantings are as old as age seven years, but most are three to four-years-old or younger. In addition, interest is increasing in using hybrid poplars to aid in the restoration of stream and river-side vegetation. In response to the aforementioned needs, much work has been done in breeding and selecting new fast growing, disease resistant poplars. In the following sections I present a brief description of the genus *Populus*, the kinds of inter and intra-specific breeding that is being done, and how hybrid poplars are propagated in nursery operations. For additional information the reader is referred to a recently published, extensive review of the biology of *Populus* (Stettler et a]. 1996).

TERMINOLOGY

The terminology surrounding poplars can be confusing. The term "poplar" is generally used in reference to members of two sections of the genus *Populus*, section *Aigeiros* and section *Tacamahaca*. Section *Aigeiros* contains Eastern cottonwood, which is native to the Eastern United States. The aforementioned sections contain several other cottonwoods (Table 1), most of which can be hybridized, although not always without difficulty. Hybrids between species have commonly been referred to as "hybrid poplars". Hybrids between members of the same species, such as Eastern cottonwoods, are not commonly referred to as hybrid poplars, or even as hybrids, although they should be if rigorous crop nomenclature guidelines are applied. Thus, to avoid confusion in the following, I refer to hybrids between cottonwood species as "hybrid poplars" and to Eastern cottonwoods as "cottonwoods".

Table 1. Sections and species of the genus Populus. Species names without brackets are according to Zsuffa (1995). Species names within brackets represent the alternative classification according to Echenwalder (1996).

Section	**Species**
Abaso Echenwalder	*P. mexicana*
Turanga Bunge	*P. euphratica* Olivier
	P. ilicifolia (Engler) Rouleau
	P. pruinosa Schrenk
Leucoides Spach	*P. lasiocarpa* Oliver
	P. wilsonii Schneider [*P. glauca* Haines]
	P. heterophylla L.
Aigeiros Duby	*P. nigra* L.
	P. deltoides Marshall
	P. fremontii S. Wantson
	P. sargentii Dode [*P. deltoides,* s.l.]
	P. wislizenii Sargent [*P. deltoide*s, s.l.]
Tacamahaca Spach	*P. angustifolia* James
	P. balsamifera L.
	P. cathayana Rehder [*P. suaveolens,* s.l.]
	P. ciliata Royle
	P. koreana Rehder [*P. suaveolens,* s.l.]
	P. laurifolia Ledebour
	P. maximowiczii A. Henry [*P. suaveolens*, s.l.]
	P. simonii Carriere
	P. suaveolens Fischer
	P. szechuanica Schneider
	P. trichocarpa T. & G.
	P. yunnanensis Dode
Populus	*P. adenopoda* Maximowicz
	P. alba L.
	P. davidiana (Dode) Schneider [*P. tremula*]
	[*P. gamblei* Haines]
	P. grandidentata Michaux
	[*P. guzmanantlensis* Vazquez & Cuevas]
	[*P. monticola* Brandegee]
	P. sieboldii Miquel
	[*P. simaroa* Rzedowski]
	P. tremula L.

	P. tremuloides Michaux

THE GENUS *POPULUS*

The genus *Populus* is represented by as many as 30 species in six sections (Table 1). Species are found throughout the northern hemisphere, including North America, Europe, and Asia. However, no species are found naturally in the southern hemisphere. Taxonomic classification within the genus is debated, like all classifications. For example, different authorities recognize as few as 22 to as many as 85 species (Eckenwalder 1996). Part of the discrepancy is due to the presence of hybrids, which should not be assigned as species. The remaining differences are due to the ongoing debate between taxonomic "lumpers" and "splitters" (Eckenwalder 1996) which can probably not be resolved in the short term. There is general agreement for the species commonly used in cottonwood and hybrid poplar breeding. One exception is the species commonly referred to as *P. maximowiczii* (Zsuffa 1995) which is considered by Eckenwalder (1996) to be a member of the species *P suaveolens*.

BREEDING *POPULUS* IN THE NORTHEASTERN UNITED STATES

Poplar breeding in the Northeast has been pursued, off and on, for at least 60 years. The breeding objective has been to produce selected clones with demonstrated growth potential, resistance to *Septoria* stem canker (and other diseases), and ability to form roots from dormant unrooted hardwood cuttings (Riemenschneider et al. 1996). Species and species hybrids differ in the extent to which they meet the above criteria and because of this several approaches have been pursued simultaneously.

Most recent breeding research in the Northeast has been targeted towards the development of fast growing, disease resistant Eastern cottonwood (*P deltoides*). Extensive collections of Eastern cottonwood open-pollinated families have been made. Progenies have been tested in replicated trials and clonal selections have been made based on test results. Early results from regional trials conducted at Westport, Minnesota; Ames, Iowa; Madison, Wisconsin; and East Lansing, Michigan suggest that pure Eastern cottonwood selections may be competitive with some hybrids in growth rate. One limiting factor to pure Eastern cottonwood is that rooting ability of hardwood cuttings is often erratic, with variation due to clone, site, and annual weather fluctuations often contributing to the unpredictable response. Because of unpredictable rooting, recent attention has been given to exploring two additional breeding approaches: the production of new interspecific F1 hybrids, and incorporating rooting ability into Eastern cottonwood through backcrossing.

Inter-specific breeding and selection among poplars in the Northeastern United States has actually been pursued since about 1930, beginning with the work of E. Schriener at Oxford Paper Company. That breeding eventually gave rise to the commercial hybrids that are today identified with the prefix NE (i.e. NE222, see Hansen et al (1994) for recent test results). More recent breeding research has been conducted with the specific aim of producing new clones for the North Central region, including Minnesota (Mohn et al. 1994). For example, several hybrid families between Eastern cottonwood and balsam poplar (*P balsamifera*), European black cottonwood (*P nigra*), and Japanese cottonwood (*P maximowiczii*) were produced (Mohn et al. 1994). Early results suggested that hybrids between Eastern cottonwood and Japanese cottonwood had very high growth potential, but might be susceptible to *Septoria* canker.

An alternative to the development of first generation interspecific (F_1) hybrids is advanced generation backcrossing. In such a breeding scheme a recurrent species of primary interest (Eastern cottonwood) is hybridized with a non-recurrent species that contributes one or more traits of interest. Then, the hybrid progeny are backcrossed to the recurrent parent repeatedly to capture most of the original genotype while artificial selection is applied to each generation of progeny to maintain the trait(s) of interest from the non-recurrent species. We have implemented this strategy by crossing Eastern cottonwood with black cottonwood (*P trichocarpa*) a species whose hybrids readily produce a root system from hardwood cuttings. Then, selected F_1, progeny were hybridized back to Eastern cottonwood. We currently have over 600 first generation backcross (BC_1) progeny from 10 families with which to begin a selection program. The original BC_1 trees are located at the Forestry Sciences Laboratory at Rhinelander, Wisconsin while cuttings from each original tree have been used to establish a replicated clonal trial of the same genotypes at Grand Rapids, Minnesota.

Overall, breeding research has produced several hundred new clones of pure Eastern cottonwood, F, hybrids, and backcross progeny which are in clonal trials. In addition, the formation of the new Minnesota Hybrid Poplar Research Cooperative has allowed us to produce about 20,000 new progeny of pure Eastern cottonwood and poplar hybrids. Overall, past and newly emerging breeding research will be used to develop an extensive breeding program to support the need for fast growing, disease resistant poplars in the North Central United States.

PROPAGATION STRATEGIES

Multiplication of select Eastern cottonwood and hybrid poplar clones is based on vegetative propagation, for several reasons. First, vegetative propagation allows all forms of genetic variation to be exploited, thereby speeding genetic improvement. Genetic variation in a plant population can be divided into several sources. It is not important to understand the theoretical basis for such a division. It is, however, important to understand how those sources affect the relation between propagation strategies and breeding strategies. Plants that can only be propagated by seed can be genetically improved, as evidenced by modem agriculture. But, seed-based propagation generally restricts genetic improvement to utilization of additive genetic variation, which can be a small portion of total genetic variation. Vegetative propagation, in contrast, permits utilization of all forms of genetic variation because the intact genotype, or clone, can be transferred from the breeding population to commercial deployment without sexual recombination.

Second, unrooted cuttings can be planted at very low cost, compared to seedlings. Hybrid poplar cuttings are now offered in commercial quantities at prices that range from $0.11 to $0.15, depending on quality control specifications. Cuttings can also be field planted very quickly compared to seedlings. Last, deployment of poplars as monoclonal blocks results in highly uniform stands that can be managed, harvested and processed very efficiently compared to intensively cultured seedling populations or compared to natural forest stands.

Requisite genetic diversity in field plantings can be achieved by establishing a mosaic of different clones, with each clone in its own monoclonal block.

As an intermediate propagation strategy, some genotypes that are difficult to root in field plantings can be planted as cuttings in the nursery, then field planted as 1 -0 rooted plants the next year. Our experience has been that a 1 -0 rooted plant can outperform an unrooted cutting of the same genotype, which can offset the additional cost associated with the nursery propagation step.

Propagation for commercial plantings consists of several processes. First, cuttings of a desired clone are planted at close (say, 0.3m x 0.3m) spacing and grown for I year. Then, tops are harvested from December through about February, depending on location, and the current terminal is subdivided into cuttings. We recommend that cuttings be 8 to 10 inches (20 cm to 25 cm) long with a basal diameter no greater than 3/4inch (1 cm) and no less than 3/8 inch (2 cm) (Dickmann et al. 1980). Cuttings are bundled, bagged in plastic and stored refrigerated or frozen until Just prior to the onset of adequate planting conditions. Cut stumps sprout (coppice growth) the next spring, producing an aggressive plant usually with multiple shoots which can be harvested annually. Such a cutting production planting is referred to as a stool bed and can remain in production for 5 to 10 years.

Prior to planting cuttings are removed from cold storage and soaked in water for 3 to 5 days until root primordia are visible as bumps on the cutting, but not so long as to induce actual root emergence. Site preparation and planting guidelines have been given in great detail elsewhere (Hansen et al. 1993).

Hansen et al. (1986) recommend planting hybrid poplar cuttings in the field when soils have warmed to 10°C (50°F). Guidelines for planting Eastern cottonwood in relation to soil temperature have not been previously developed. However, current research suggests that Eastern cottonwood can be reliably propagated if soil temperatures are allowed to reach about 18°C (65°F) (Figure 1). In this study, we planted cuttings of 30 clones of Eastern cottonwood at three soil temperatures maintained by buried heating pads. Soil temperature not only affected rooting ability (Figure 1), but also affected shoot growth, leaf growth, total plant biomass accumulation, and the relative distribution of growth between roots and shoots (Figure 1). In addition, not all clones performed the same across all soil temperatures (genotype x environment interactions were significant). I present these preliminary results because it is important to know that conditions exist wherein a difficult-to-root species (Eastern cottonwood) can be induced to root reliably. It is also important to note that rooting and

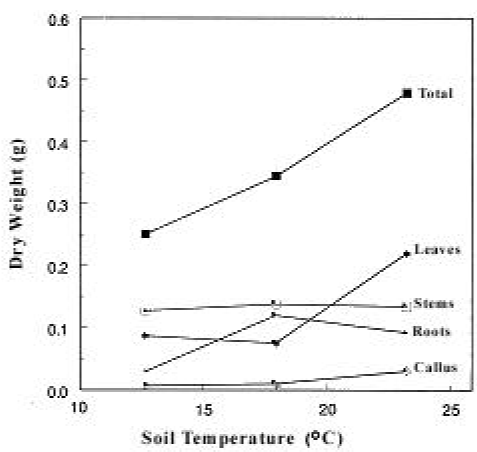

Figure 1.Soil temperature affects total dry weight growth and the distribution of dry weight among leaves, stems, roots, and wound callus. Data are from a nursery experiment where 31 clones of Eastern cottonwood and two interspecific hybrids were planted under controlled soil temperatures, then harvested for dry weight determination after two weeks.

growth distribution are complex traits that clearly require further study.

Overall, commercial deployment of intensively cultured hybrid poplar can significantly augment existing aspen fiber supplies. In addition, production of hybrid poplar cuttings for direct field planting and production of 1 -0 rooted cuttings for field planting present the opportunity for a new, potentially valuable nursery crop. For example, consider an intensive culture program of 100,000 acres. On a 10 year rotation, about 10,000 acres would be planted annually providing a demand for nearly 7,000,000 cuttings if field plantings are established at a spacing of 8 feet x 8 feet. If the average price per cutting were $0.12, then the total cutting crop would be worth about $800,000 annually. Nursery operators thus stand to profit significantly from an intensively cultured hybrid poplar program. Nursery operators also stand to influence the success or failure of such a program because quality of planting stock in many ways predetermines survival, growth and uniformity of commercial stands. Nursery operators are also responsible for ensuring that clonal identities are not confused during propagation so that genotypes are propagated without error and sold as advertised. Above all, no clone should be brought to market unless its growth, rooting ability, and especially disease resistance have been established by long term field testing.

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[2]*USDA Forest Service Forestry Sciences Lab. 5985 Hwy. K, Rhinelander, W1 54501; Tel: 715/362-7474.*

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