Tree Planter's Notes, Volume 44, No. 3 (1993)

# Selecting Hybrid Poplars to Reduce Disease Risk May Also Reduce Biomass Yield

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*Hybrid poplars representing 107 clones were screened for growth and resistance to* Septoria musiva *to determine the cost, in terms of lost biomass, of reducing disease risk. Reducing the risk of septoria canker by selecting only highly resistant clones reduced biomass by as much as 26% after 3 years. Clones with parentage in the section Tacamahaca were generally the highest yielding; however, they were more susceptible to infection by* Septoria musiva *than clones in the section Aigeiros. When selecting poplar clones, growers need to balance growth potential with disease risk throughout the projected rotation period. Since tree death or stem breakage of susceptible clones frequently occurs, selection should be based primarily on canker resistance.* Tree Planters' Notes 44(3): 128–131; 1993.

Intensive culture of trees to provide woody biomass for a renewable source of energy is receiving much interest in several areas of the United States (Geyer and Melichar 1986). *Populus* species and hybrids are especially well suited for this intensive management because of their rapid growth, ease of vegetative propagation, coppice regeneration, and suitability for a wide range of sites.

Poplars are, however, susceptible to many biotic and abiotic damaging agents that can affect survival and growth of trees (Ostry et al. 1989b, Royle and Hubbes 1992). *Melampsora medusae* Thuem. (causing premature defoliation) and *Septoria musiva* Peck (causing stem cankers) have been the most serious pathogens of hybrid poplars in the north-central United States (Ostry and McNabb 1985). Research has shown that resistance to these pathogens varies greatly by clone.

No poplar clone can be considered immune from disease. Poplars are subject to accumulated stresses that can eventually predispose them to a succession of damaging agents. Adverse site and weather conditions, and other stress agents such as insect pests, can increase the incidence and severity of infection by one or more pathogens. Estimates of biomass yield by clone must include the potential impacts of disease to more accurately describe the suitability of individual clones (Abrahamson et al. 1990, Hansen 1990).

Information on yield and disease resistance of poplar clones from field trials will help growers decide which clones to plant to maximize biomass yield, while minimizing the risk of disease. The strategy of planting clone mixtures and the optimum number of clones to reduce the risk of disease in poplar plantations have been discussed (Libby 1982, Ostry et al. 1989a). Many high-yielding clones have good early growth but later are subject to stem breakage caused by septoria canker and cannot be coppiced because of the increased severity of canker on the stump sprouts compared to the single stems prior to harvest (Ostry et al. 1989a). Some of these clones, under certain conditions, may be grown on short rotations (< 10 years); the grower will have to replant with a different clone in the next rotation or else risk high stem mortality. Septoria stem cankers and the resulting stem breakage and tree death have led to plantation failure within 5 years after planting susceptible clones (Ostry et al. 1989a). Other clones have high resistance to disease, but yield less biomass than some of the more disease-susceptible clones (Ostry and McNabb 1985).

We screened a group of *Populus* clones for growth and resistance to *S. musiva* to determine the cost, in terms of lost biomass, of reducing disease risk by selecting only highly resistant clones. Because of the large number of clones included and limited field space, this trial was conducted in small row plots with the intent to derive relative yield rankings among the clones.

## Methods

The study site, a cleared and drained peatland soil, was located in south-central Minnesota. Existing weeds were controlled with glyphosate (Roundup). Before planting, fertilizer was applied at a rate of 100, 50, and 100 kg/ha of nitrogen, phosphorus, and potassium, respectively. Weeds were controlled mechanically during the first 2 years after planting. Weed control was not necessary after canopy closure in the second year.

Unrooted hardwood cuttings of 107 *Populus* clones representing various species and hybrids were planted in May of 1983 in a randomized complete block design at a spacing of 1 by 1 m. Ten cuttings of each clone were planted in a row. Each clone was replicated three times within the plantation.

**Development of biomass estimation equation.** We estimated tree biomass using an equation of the following form:

$$\text{mass} = e^{a + b(\ln \text{diameter})} \quad [1]$$

The data on which this equation was based were collected by destructively sampling 40 trees from the plantation. Clones were first divided into four size classes to ensure that our sample encompassed the range of tree diameters present in the plantation. Ten trees from different clones in each size class were randomly selected and stem diameters at 15 cm aboveground were measured. Trees were cut and weighed green in the field and the total green weight recorded. Subsamples of bole and branches were collected and dried to equilibrium to determine moisture content. The total ovendry weight of the trees was then calculated.

Linear regression analysis was done using the linear form of equation 1: $\ln(\text{mass}) = a + b * \ln(\text{diameter})$. Both the slope and intercept were found to differ significantly from zero, with $P$-values associated with both parameters less than 0.001. Parameter estimates are 2.40 and 3.51 for the slope and intercept, respectively. The $R^2$ of this equation after transformation of data to original scale is 0.95.

**Clone yield estimation and adjustment for competition.** We used equation 1 to estimate the biomass of all trees on a plot. Although most of these trees were single-stemmed, in some cases more than one primary stem was present. In those cases, the biomass of all stems in the clump was estimated and the total clump biomass calculated. We calculated the mean tree or clump mass of the plot accounting for mortality and expressed yield as megagrams per hectare (Mg/ha) [1 Mg = 1,000,000 g = 1,000 kg].

Because the plot configuration used in this study was a single row of 10 trees, the effects of differences in competition on estimates of clone yield was considered. We used analysis of covariance to determine the effect of adjacent plot yield and the parameters associated with those effects (Berguson and Grigal 1988). We tested the effect of plots in the four cardinal directions from each plot on which yield was being estimated. Plots adjacent to the ends of the plot had no significant influence on yield because little shading occurred ($P > 0.10$). Of the two adjacent plots parallel to each plot in question, the mass of the plot north of the plot in question was found to have a significant influence on yield with the coefficient being $-0.22$. The negative sign indicated that adjacent plot mass decreased the mass of the plot in question. The adjacent plot to the south did not significantly affect yield ($P = 0.16$). We tested for homogeneity of slopes and found no significant interaction between clone and any of the covariates ($P > 0.40$). This indicated that clones responded in the same way to competition and an adjustment for competition was possible across all clones. Analysis of covariance to adjust all clones to the mean level of competition (grand mean mass) was done using the following formula:

$$\text{mass}^{adjusted} = \text{plot mass} + (\text{mean mass} - \text{adjacent mass}) * -0.22) \quad [2]$$

In the case where a clone was adjacent to a clone having a mass higher than the grand mass, the adjustment of the plot in question was positive and the estimated yield increased. In order to make estimated yields more accurately reflect yields likely attainable in a monoculture of a particular clone, we used the yield of the plot itself in place of the adjacent plot and adjusted the yield as if the clone was in a single-clone plantation. With high-yielding clones this reduced their estimated yield, providing a more realistic estimate of plantation yield than would be the case using the adjustment shown in equation 2.

Incidence and severity of foliage and stem diseases were recorded in the fall of 1985. Estimates of melampsora leaf rust were obtained using a combined score based on severity of leaf infection and the percentage of leaves affected (Schreiner 1959). Because severe winter dieback was associated with premature defoliation caused by leaf rust ($P < .01$), severely affected clones were eliminated from further analyses. Of the 13 clones eliminated, 11 of them were *P. deltoides* × *P. trichocarpa* hybrids. All remaining trees were rated for septoria stem canker and placed in one of the following risk classes: 0 = no cankers, 1 = trees on 1 plot with stem cankers, 2 = trees on 2 plots with stem cankers, 3 = trees on all 3 plots with stem cankers. We estimated combined biomass yields of the 10 highest yielding clones without regard to canker risk (risk classes 0, 1, 2, or 3) and of the highest yielding clones resistant to septoria canker (risk class 0).

## Results and Discussion

Survival, growth, and disease resistance varied among clones. The estimated 3-year biomass yields of the surviving clones ranged from 1.3 to 38.8 Mg/ha. Pathogens affecting trees other than *Melampsora medusae* were *Marssonina brunnea* (Ellis & Everh.) Magnus, which caused a leaf anthracnose; *Venturia macularis* (Fr.:Fr.) E. Müller and Arx, which caused a leaf and shoot blight; and *Agrobacterium tumefaciens* (Smith and Townsend) Conn, which caused crown gall. None of these other pathogens caused as severe a disease problem as *S. musiva* and were not considered limiting in our study.

There was a strong clonal pattern in regards to infection by *S. musiva*. In almost all cases, trees within a plot either were all healthy or all affected by stem cankers. However, occasionally not all plots of each clone were affected. This may have been due to the trees of these plots being bordered by either resistant or severely diseased trees with a corresponding decrease or increase in inoculum. Additional research is needed on the effects of clone mixtures on disease incidence and severity. Planting random mixtures of resistant and susceptible *Populus* clones did not reduce the incidence or severity of septoria canker on highly susceptible clones in three plantations in Michigan (Ostry et al. 1989a). Planting hybrid poplar clones in mosaics of pure clonal blocks that can be managed as independent units if it becomes necessary because of a disease outbreak among susceptible clones is one way to minimize disease risk (Ostry and McNabb 1990).

The estimated biomass yield of the 10 highest yielding clones in the two groupings based on canker risk illustrates the effect that selecting for canker resistance has on potential biomass yields (tables 1 and 2). In the examples used in this study, reducing the risk of septoria canker by selecting only highly resistant poplar clones (risk class 0) reduced potential biomass yield. The 10 highest yielding clones that were completely free of canker (table 1) produced a combined estimated mean yield of 22.9 Mg/ha. This was 26% less biomass than the estimated mean yield of 30.9 Mg/ha produced by the 10 highest yielding clones that were selected without regard to canker susceptibility (table 2). Clone DN 3, however, was resistant to septoria canker and also one of the highest yielding clones.

Of the highest yielding clones without regard to canker susceptibility, all but 3 had at least one parent in section Tacamahaca (balsam poplars). In contrast, only 2 clones highly resistant to septoria canker had parents from the section Tacamahaca. The majority of the resistant clones had parents from the section Aigeiros (cottonwoods and black poplars). This is further evidence that although hybrids involving poplar species from the section Tacamahaca have rapid early growth, they are more susceptible to septoria canker than poplars in the section Aigeiros (Ostry and McNabb 1985). Additional field tests are needed on a wide range of sites to determine if site differences will affect clone selection based on reducing canker risk.

**Table 1**—*Combined estimated 3-year biomass yields of the 10 highest yielding* Populus *clones resistant to septoria canker (south-central Minnesota, 1983–1985)*

| Clone | Parentage | Estimated adjusted mass (Mg/ha) | Canker risk class |
|---|---|---|---|
| DN3 | *P deltoides* × *P. nigra* | 31.0 | 0 |
| NE10 | *P. nigra* × *P. trichocarpa* | 24.9 | 0 |
| NE20 | *P. nigra* var. *charkowiensis* × *P. nigra* var. *caudina* | 23.8 | 0 |
| S264 | *P. deltoides* var. *angulata* × *P. nigra* 'Volga' | 22.5 | 0 |
| NE383 | *P. nigra* var. *betulifolia* × *P. trichocarpa* | 22.2 | 0 |
| NE222 | *P. deltoides* × *P. nigra* var. caudina | 22.0 | 0 |
| 8MIRD | Unidentified Aigeiros clone | 21.3 | 0 |
| DN9 | *P. deltoides* × *P. nigra* | 20.8 | 0 |
| DN96 | *P. deltoides* × *P. nigra* | 20.7 | 0 |
| NE259 | *P. deltoides* var. *angulata* × *P. nigra* var. *incrassata* | 19.4 | 0 |
| Mean biomass yield | | 22.9 | |

0 = no stem cankers on trees in any plots.

**Table 2**—*Combined estimated 3-year biomass yields of the 10 highest yielding* Populus *clones without regard to septoria canker (south-central Minnesota, 1983–1985)*

| Clone | Parentage | Estimated adjusted mass (Mg/ha) | Canker risk class |
|---|---|---|---|
| L296 | Unidentified *P. trichocarpa* hybrid | 38.8 | 3 |
| NE320 | *P. nigra* var. *charkowiensis* × *P. trichocarpa* | 32.7 | 3 |
| NE32 | *P. deltoides* var. *angulata* × (*P.* × *berolinensis*) | 32.5 | 1 |
| DN3 | *P. deltoides* × *P. nigra* | 31.0 | 0 |
| DN29 | *P. deltoides* × *P. nigra* | 30.1 | 3 |
| NE55 | *P. candicans* × (*P.* × *berolinensis*) 'Maine' | 29.9 | 3 |
| NE50 | *P. maximowiczii* × (*P.* × *berolinensis*) 'Oxford' | 29.6 | 3 |
| NE252 | *P. deltoides* var. *angulata* × *P. trichocarpa* | 28.8 | 3 |
| L239 | Unidentified *P. trichocarpa* hybrid | 27.7 | 3 |
| H48 | *P. deltoides* × *P. nigra* | 27.6 | 1 |
| Mean biomass yield | | 30.9 | |

0 = no stem cankers on trees in any plots, 1 = trees on 1 plot with stem cankers, 2 = trees on 2 plots with stem cankers, 3 = trees on all 3 plots with stem cankers.

## Conclusions

Growers can reduce the risk of serious damage to trees from septoria canker by planting the resistant clones that are now available. However, this reduced risk may have an associated cost in the form of a potential biomass yield reduction. Reduced yield may lower economic returns, but on the other hand, reduced risk of disease guards against potential catastrophic losses later in the rotation. It is likely that the resistant clones would eventually produce higher biomass yields on longer rotations than the susceptible clones because of future stem breakage of the severely diseased trees. *Populus* tree breeders must use resistance to *S. musiva* as one of the major selection criteria in order to provide clones suitable for use in the north-central and northeastern United States.

## Literature Cited

Abrahamson, L. P.; White, E. H.; Nowak, C. A.; Briggs, R. D.; Robison, D. J. 1990. Evaluating hybrid poplar clonal growth potential in a three-year-old genetic selection field trial. Biomass 21:101–114.

Berguson, W. E.; Grigal, D. F. 1988. *Salix* clonal screening research on peatlands in Minnesota. Proceedings, Willow Breeding Symposium, International Energy Agency; 1987 August 31–September 1; Uppsala, Sweden. Forest Genetics, Swedish Univ. Agric. Sci. Res. Notes 41:1–6.

Geyer, W. A.; Melichar, M. W. 1986. Short-rotation forestry research in the United States. Biomass 9:125–133.

Hansen, E. 1990. Early yields of biomass plantations in the north-central U.S. Res. Note NC-353. St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station. 6 p.

Libby, W. J. 1982. What is a safe number of clones per plantation? In: Heybroek, H. M.; Stephan, B. R.; von Weissenberg, K., eds. Resistance to diseases and pests in forest trees. Proceedings, Third International Workshop on the Genetics of Host-Parasite Interactions in Forestry; 1980 September 14–21; Wageningen, the Netherlands: 342–360.

Ostry, M. E.; McNabb, H. S., Jr. 1985. Susceptibility of *Populus* species and hybrids to disease in the north-central United States. Plant Disease 69:755–757.

Ostry, M. E.; McNabb, H. S., Jr. 1990. Minimizing disease injury to hybrid poplars. Journal of Environmental Horticulture 8:96–98.

Ostry, M. E.; Wilson, L. F.; McNabb, H. S., Jr. 1989a. Impact and control of *Septoria musiva* on hybrid poplars. Gen. Tech. Rep. NC-133. St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station. 5 p.

Ostry, M. E.; Wilson, L. F.; McNabb, H.S., Jr.; Moore, L. M. 1989b. A guide to insect, disease, and animal pests of poplars. Agric. Handb. 677. Washington, DC: U.S. Department of Agriculture, Forest Service. 118 p.

Royle, D. J.; Hubbes, M. 1992. Diseases and pests in energy crop plantations. Biomass and Bioenergy 2:45–54.

Schreiner, E. J. 1959. Rating poplars for melampsora leaf rust infection. Res. Note NE-90. Broomall, PA: USDA Forest Service, Northeastern Forest Experiment Station. 3 p.