

THE POTENTIAL OF HYBRID POPLAR IN MINNESOTA AND THE MINNESOTA HYBRID POPLAR RESEARCH COOPERATIVE RESEARCH PROGRAM

Bill Berguson and Dan Buchman¹

ABSTRACT.—The Minnesota Hybrid Poplar Research Cooperative (MHPRC) was formed in 1996 to improve poplar genetics, increase yields, and provide assistance to cooperative members and the public. Fiber demand is expected to increase in the future due to population growth and resultant increased demand for forest products both nationally and globally. Hybrid poplar is a potential source of additional fiber to meet this demand. This paper explains research being done by the MHPRC including testing of native cottonwood sources, breeding of interspecific hybrids, field-testing of new poplar clones, and studies of nutritional needs and cultural practices to improve yields.

Hybrid poplar is a general term that refers to hybrids between species in the *Aeigeros* section of the *Populus* genus (black poplars) and the *Tachamahaca* section of the genus (balsam poplars). These two sections contain the species *P. balsamifera*, *deltoides*, *nigra*, *maximowiczii*, and *trichocarpa* that readily hybridize with one another. Hybrids between these species make up most of the hybrid poplars that exist today. Hybrid poplars are attractive as a plantation tree due to their fast growth rate. In addition, they can be vegetatively propagated, which captures genetic gains more quickly than seedling-propagated trees and makes it easy to produce large clonal populations for field planting.

Management of hybrid poplars is markedly different from that of white poplars (ex. *P. tremuloides*, *tremula*, *grandidentata*). Hybrid poplar culture in Minnesota has been limited to agricultural lands with little testing or success on previously harvested forest land. To date, white poplars have been targeted for improvement of productivity on harvested forest land. Also, current commercial propagation for white poplars is limited to seedling propagation. After harvesting, hybrid poplars regenerate almost exclusively from stump sprouts while root suckering in white poplars is prolific. Although it is currently unclear whether coppice will be a part of hybrid poplar management in the future, stump sprouting simplifies management of coppice plantations because rows are maintained.

BACKGROUND

Timber Demand

Two significant factors contributing to increased interest in hybrid poplar in Minnesota are the expansion of the forest products industry and resulting increased fiber demand as well as higher prices of native wood resources. The forest products industry has spent approximately \$2 billion in plant expansions and modifications in Minnesota since 1985. This expansion has led to an increased demand for all timber species as well as markets for previously non-merchantable species. Aspen harvests have risen from 900,000 cords in 1978 to 2.2 million cords currently. This increased demand and tightening supply have led to increased prices for aspen. For example, aspen stumpage prices on public auction in Itasca County, Minnesota rose from approximately \$6.00 per cord in 1991 to nearly \$30.00 per cord in 1995, a 40% annual increase (Brad Jones, personal communication). Most of this price increase took place in 1994. Stumpage prices are not as high statewide as in Itasca County due to lower demand. However, rapid price increases have occurred statewide.

As forest products companies began to search for additional fiber sources, hybrid poplar was included as a potential future fiber source. Before industries were willing to use hybrid poplar in their mills, wood quality and compatibility with existing processes and products needed to be considered. Paper production and oriented strandboard (OSB) manufacturing account for over 90% of the demand for aspen fiber in the state, and these products were of primary interest for testing. Beginning in 1994, mill trials were done by forest products companies to determine if hybrid poplar could be used as a complete or partial replacement in their manufacturing processes. Based on these tests, we estimate that hybrid poplar could be used to replace a minimum of 60% of the fiber in aspen-using processes.

¹Research Fellow and Senior Research Plot Coordinator, respectively, Natural Resources Research Institute, 5013 Miller Trunk Highway, Duluth, MN, USA 55811.

In conjunction with mill trials, we collected samples of hybrid poplar going into testing to evaluate variation in specific gravity and bark:wood ratios in this material. Specific gravity is important in both paper and OSB manufacturing because it affects fiber yield in papermaking and processes and product quality in OSB. To date, we have collected and analyzed 210 samples of *P. deltoides* X *nigra* clones harvested from plantations and shelterbelts throughout Minnesota as well as from plantations in eastern Ontario. The average wood specific gravity is 0.39, which compares favorably to native aspen. We found no evidence of decreased specific gravity with age, although effects of genetic composition are considerable. Our results as well as results of large mill trials demonstrate that hybrid poplar can be used as a replacement for aspen with little or no modification to existing processes and with no negative effect on product quality.

Future Timber Demand and Potential of Hybrid Poplar

Although it is difficult to accurately estimate the number of acres that will be planted in the future, indications are that hybrid poplar will play an important role in providing a portion of the fiber needs for the state's forest products industry. Assuming that per capita consumption of forest products remains constant over the next 15-year period and the population growth of the United States continues at the historical rate of 1% annually, domestic demand for forest products would increase by 16% over 1998 levels. Current timber harvest is 4 million cords annually in Minnesota (John Krantz, MN-DNR, personal communication). A 16% increase in domestic consumption equates to an additional demand of 650,000 cords annually, assuming Minnesota's forest products industry accounts for the same percentage of national production as is presently the case. We expect commercial hybrid poplar plantations to produce a minimum mean annual yield of 2.5 merchantable cords per acre per year. Given this productivity rate, 26,000 acres of hybrid poplar would need to be planted annually to produce 650,000 cords. The proportion of supply provided by existing natural stands versus plantation-derived fiber in the future is impossible to know with certainty. Based on biological production alone, opportunities exist to procure additional wood supplies from Minnesota's existing resource. However, the willingness of landowners to sell timber and the policy of public land management agencies to make timber available are uncertain and may not meet the total expected demand.

A pertinent question relating to hybrid poplar production in the future is availability of enough agricultural land to accommodate a significant planting program. Minnesota's agricultural land base is approximately 26 million acres in size. Of this land base, 2 million acres have been removed from production since the late 1980's through

enrollment in the federal Conservation Reserve Program (CRP). Eligibility criteria for enrollment in the CRP were based primarily on erosion potential. Typically, lands were enrolled for a 10-year period although parcels planted to trees were given a 5-year extension for a total of 15 years. New CRP guidelines and funding for the program will likely result in less acreage being eligible for renewal in the CRP. Enrollment in the CRP began in 1986 with the majority of acreage being enrolled in 1987 through 1989. The timetable for expiration of this acreage began in 1996, and most of the 2 million acres will be out of the program by 2002. This fact, as well as low agricultural commodity prices, makes it likely that hybrid poplar will be considered as an alternate crop in some portions of the agricultural zone.

Hybrid poplar is beginning to be planted on significant acreage in the state with approximately 6,000 acres planted statewide. This acreage was established by a combination of public and private organizations. One area of concentration is northwestern Minnesota where 3,000 acres have been planted through a joint project of the Agricultural Utilization Research Institute, University of Minnesota-Crookston, and Minnesota Power. An additional 1,000 acres were planted by the Minnesota Department of Natural Resources in conjunction with the Department of Energy's Biomass Feedstock Development Program near Alexandria, MN. The remainder of acreage has recently been planted by small private landowners and forest products companies. To date, the largest planting program is the one by Champion International, which is currently planting 2,400 acres per year (Mike Young, Champion International, personal communication).

Historical Perspective on Research

Research on hybrid poplar production began in Minnesota and the Lake States in the 1970's, supported by the Department of Energy's Short Rotation Woody Crops Program as well as other agencies. In Minnesota, the Legislative Commission on Minnesota Resources supported several projects to establish hybrid poplar research sites throughout the state. The focus of hybrid poplar production, and to some extent, willow, was to develop woody crops grown on short rotation as an alternate energy source. This early research focused on selection of suitable hybrids and development of techniques to grow these hybrids on very short rotations, typically 3 to 5 years. The production system was based on close plant spacings, typically ranging from 4 to 9 square feet per tree (2 ft by 2 ft, 3 ft by 3 ft), and repeated coppice harvests. Because of the small diameter of trees produced in this type of system, markets for the product were limited primarily to energy markets.

Research that began during the period 1978 through 1985 helped identify appropriate weed control techniques,

suitable clones, and potential yields of hybrid poplar in an intensive culture system. At that time, most of the clone testing and selection was being done by the USDA Forest Service, Forestry Sciences Laboratory at Rhinelander, WI. However, based on subsequent tests in other states, some of the clones that appeared to be suitable in Rhinelander were not suitable in other locations, particularly in northwestern Minnesota. Based on this observation, the University of Minnesota at Crookston, the NRRI, and the USFS began a series of clone tests and large-block yield studies at several locations throughout Minnesota to test a wider variety of hybrid poplar clones. These tests were established during the period 1986 through 1990 and included approximately 70 clones planted at 10 locations throughout Minnesota. From these trials, eight clones have been selected for commercial production that are disease resistant, winter hardy, and have high growth rates.

In addition to the need to develop clones suitable for a wider geographic range, research comparing repeated coppice production systems at high planting densities to more traditional plantation spacings (i.e., 8 ft x 8 ft and greater) demonstrated that annual increments were not significantly different. This realization caused us to reconsider the need to establish plantations at very dense spacings. Two major factors contributed to a shift in emphasis toward wider spacings. First, plant material and planting costs account for a significant portion of establishment costs, and plantations established at wider spacings are less expensive to establish than denser plantations. Secondly, markets for wood produced under a more traditional plantation management system accommodate forest products manufacturing due to the ability to efficiently debark larger diameter trees.

A series of large-block plantations was established to determine yields of hybrid poplar on wider spacings over a large geographic range. Because of availability from commercial nurseries, clones DN34 (*P. deltoides* x *nigra*, c.v. Eugenii) and DN 182 (*P. deltoides* x *nigra* c.v. Raverdeau) make up the bulk of the genetic material in these plantings. Yields of hybrid poplar range from 2.0 to 4.4 oven-dry tons per acre per year of aboveground biomass excluding leaves; the mean of all plantations is 2.4 tons mean annual increment.

THE MINNESOTA HYBRID POPLAR RESEARCH COOPERATIVE PROGRAM

Previous research identified suitable clones and management techniques to allow establishment of commercial plantations in Minnesota. However, genetics research was limited to testing and selection of non-native sources with no further breeding. To improve growth rates of cottonwood and other hybrids in the future and develop a wider genetic base, a concerted genetics program was needed.

Also, opportunities to increase yield through fertilization and other management techniques were not fully explored.

In response to increased interest in hybrid poplar and the need to conduct long-term research in this area, the Minnesota Hybrid Poplar Research Cooperative was formed in March of 1996. Its purpose is to produce genetically superior cottonwood and hybrid poplar trees, improve cultural practices, increase yield, and provide technical assistance to cooperative members and the public. The primary objective of the MHPRC is to continue to develop accurate information on yields of hybrid poplar using current clones and management techniques and to increase yields through improved genetics and management techniques. Current members of the MHPRC include the Agricultural Utilization Research Institute, Blandin Paper Company, Boise Cascade Corporation, Champion International, Potlatch Corporation, Mead Paper, Minnesota Power, Lee Nurseries, TrusJoist Macmillan, WESMIN RC+D, the University of Minnesota-Natural Resources Research Institute and Crookston campus, and the USFS.

Genetics Research

Genetic improvement research done by the MHPRC includes (1) collection of open-pollinated native eastern cottonwood, (2) field testing of native cottonwood collections and available hybrids, and (3) breeding and testing of new hybrids. The goal of our research is to select clones that have higher yield than the existing commercial clones and lay the foundation for future genetic improvement by selecting superior native *P. deltoides* parents.

Collection and Testing of Native Open-Pollinated Families

A fundamental part of our long-term strategy for genetic improvement is collection and field testing of native *P. deltoides* families. In the past, collections of native *P. deltoides* were made by Dr. Carl Mohn at the University of Minnesota and planted at a limited number of test sites. Our plans call for testing of clones from these collections as well as testing of families of open-pollinated collections recently made by the MHPRC. To date, we have made collections of 125 families of open-pollinated *P. deltoides* for evaluation in long-term field trials. The intent of this work is to select rapid-growing, disease-resistant trees and grow them to sexual maturity for breeding. Plans for the 1999 season include planting of tests of open-pollinated families at two sites. Our experience has shown that fast-growing clones can be selected with reasonable accuracy after 4 years in field tests. Also, resistance to Septoria canker in native *P. deltoides* is generally very high. As a result, we expect to

run these tests for 4 years at which time we will begin to make selections for further propagation and testing.

Hybridization Plan

Most of genetic improvement research in the MHPRC involves production of F1 hybrids between *P. deltoides*, *maximowiczii*, and *nigra*, and to a limited extent, crosses between *P. deltoides* and *P. trichocarpa* and *balsamifera*. The goal of the F1 breeding program is to perform 100 crosses each year using a factorial breeding scheme of 10 native *P. deltoides* females crossed with five *P. maximowiczii* and five *P. nigra* males. To ensure genetic diversity throughout the years of the program, the composition of males and females will change each year to produce unrelated families each breeding season. Flowers are obtained from collections of native *P. deltoides* near Grand Rapids, MN, and from stands in northwestern Minnesota. Pollen is obtained from an arboretum of pure *P. maximowiczii* and *nigra* maintained by the University of Toronto. In addition to the University of Toronto collections, we have established a collection of pure *P. maximowiczii* and *nigra* near Grand Rapids, MN, to supply pollen for our breeding program in the future. We expect that most of the families produced by our breeding program will be cold-tolerant because the females are native to Minnesota and the males have been tested in a continental climate with relatively cold winters.

In addition to F1 hybrids, we are backcrossing a number of *P. deltoides* x *maximowiczii* hybrids to *P. deltoides*. The backcross breeding strategy will be expanded as available F1 hybrids between *P. deltoides* and other species begin flowering. At this time, backcross breeding will concentrate on native *P. deltoides* as the female and DXM F1's selected from the USFS collection at Rhinelander.

We are using a bucket-crossing technique that involves collection of flowering branches of *P. deltoides* in January and rooting of these branches in pots in a greenhouse. Our early efforts in 1997 were marginally successful due to relatively poor rooting of *P. deltoides* females in pots. In 1998, we used a controlled-climate facility to heat the rooting media of the potted trees while keeping the tops sufficiently cool to prevent bud break. This allowed roots to develop prior to expansion of the floral bud. A pre-existing root system is important to support subsequent flower development and foliage growth. Using this method, rooting of female branches in 1998 was near 100%.

Clone Testing of Existing Material

Our experience has shown that performance of clones and relative ranking in tests can be highly variable among sites. However, a subset of clones exhibits high yield and

disease resistance at all test sites, and these clones have been selected for commercial planting. Our objective is to develop clones for commercial planting that are stable across a range of sites and have better form and higher growth rate than current commercial hybrids.

To accomplish the objective of stability across sites, tests are established at multiple sites and over a minimum of 2 years. Genetic material currently undergoing testing is made up of native *P. deltoides* (25 clones), *P. deltoides* x *maximowiczii* (23 clones), and two commercial controls (NM6, DN34). Native *P. deltoides* clones were obtained from a plantation of open-pollinated *P. deltoides* collected from various locations throughout southern and central Minnesota. *P. deltoides* x *maximowiczii* hybrids were produced by Carl Mohn and Don Riemenschneider in 1986 by crossing native *P. deltoides* females and *P. maximowiczii* males from Japan. These clones will be evaluated over an 8-year period at which time recommendations for scale-up for commercial planting will be made. To date, we have planted trials at nine sites on cooperator's lands in 1997 and 1998 ranging from northwestern to central Minnesota. These trials are planted as three replications of two-tree plots at each site. Because of potential difficulties with rooting of pure *P. deltoides* clones, we have used rooted material in these trials.

Although results after 2 years of testing cannot be considered conclusive, early growth in our clone trials suggests that improvements over the current commercial clones can be made. At this time, the average basal area of the 10 highest yielding clones is 60% greater than the mean of the two commercial standards. A surprising result of these and other trials is the relatively high yield of native *P. deltoides* selections. Growth rates of some clones of open-pollinated *P. deltoides* meet or exceed the current commercial standards. For this reason, we expect that improvements in yield over commercial standards will likely be attained over time as superior *P. deltoides* females are incorporated into our breeding matrix.

Field Testing of New Hybrids

A particularly interesting problem arose as we began to develop procedures for testing clones from our breeding program. Our current breeding efforts attempt approximately 150 crosses annually including F1s and backcrosses. Due to cross incompatibility and catkin abortion, we expect to have 70 families that each produce at least 100 viable seedlings annually. As a result, we have the potential to produce 7,000 new clones each year. Prior to field testing, there is no way of knowing which clones may possess commercially desirable traits. Because of the general lack of a market pull for improved hybrid poplars or cottonwood in the past, little research was done in the Lake States region that could be used to guide the

selection process. Ideally, we would like to be able to efficiently eliminate slow-growing or disease-susceptible clones or entire families prior to extensive field testing. However, correlations between nursery-grown plants and field performance at multiple sites do not currently exist. If no culling is done at the nursery stage prior to field testing, tests to adequately evaluate 7,000 clones each year would be enormous. A relatively simple design of three two-tree plots per clone would equate to 60 acres for each clone test at an 8-foot by 8-foot spacing containing 21,000 two-tree plots. Obviously, testing all clones in the field at one time is not feasible.

One of the critical questions that we considered in developing a feasible screening procedure relates to within- and between-family variance. We were particularly interested in determining whether tests of a large number of offspring could be done most efficiently at the family- or clone-level. Because of the impracticality of screening all clones individually, we began to evaluate the relationship between mean family performance and clone growth rate using data sets from poplars growing in Minnesota. We used two data sets, one from an open-pollinated collection near Grand Rapids and the other from a collection of full-sib families planted in a nursery at Grand Rapids, MN. These analyses showed a high correlation between the mean of the superior siblings (three largest in this case) and the mean of the remaining siblings with R^2 ranging from 0.78 for open-pollinated material to 0.85 for full-sib families. From these analyses, we conclude that field testing at the family level will allow us to identify families that are most likely to contain the fastest growing clones.

Based on our analyses, the screening procedure will concentrate on family-level tests consisting of 30 clones from each family replicated three times on each site. These tests will be located on a minimum of three sites each year and evaluated over a 4-year period prior to making a selection of superior families. Once superior families are identified, we will select all 100 siblings that have been archived in nursery plantings for exhaustive field testing of the remaining untested clones in the superior families. In this way, we expect to efficiently screen the output from our breeding program with minimal loss of superior clones. In addition, because we are screening a random selection of seedlings in each family for field testing, we will be able to develop correlations between nursery growth and field production at multiple sites. Assuming these correlations are sufficiently high, we will have a method to further increase the efficiency of our screening process by eliminating families at the nursery stage.

Yield Studies

Based on previous research done by NRRI, the UM-Crookston, and the USFS Forestry Sciences Laboratory at Rhinelander, WI, a set of clones has been selected and is being propagated for commercial plantations. These selections were based on multiple clone tests across a wide geographic range. However, little data exist on large-plot yields of these new selections. To evaluate these clones under conditions similar to a commercial plantation, we began a project in 1995 to plant these clones in replicated trials at various locations. To date, we have established yield tests at 17 locations throughout the state. Growth of these plantations is measured annually and will be monitored throughout the entire rotation.

Nutrition Research

An important aspect of yield improvement of hybrid poplar involves nutrition. Before the MHPRC was formed, little work had been done to quantify nutrient needs of poplar plantations in the Lake States and the potential to increase yield through fertilization. To establish a baseline understanding of nutrient needs, we began a monitoring program in older plantations to assess the current nutrient status of plantations and estimate annual nutrient requirements of poplars. Using foliar nutrient contents from this study and estimates of belowground production and uptake, we constructed a time-series of estimated nutrient uptake by poplars. This information was used to develop nutrient rates and ratios for fertilization studies.

Fertilization experiments were established at two sites in 1997 and at six sites in 1998. This phase of trials is using a "base" rate of nitrogen, phosphorus, and potassium developed through sampling of older plantations. We have selected fixed nutrient ratios at 100:10:80 of elemental nitrogen, phosphorus, and potassium, respectively, and applied the minimum treatment at 70, 7, and 60 pounds of elemental nitrogen, phosphorus, and potassium per acre, respectively. Other fertilizer treatments are applied at two and three times the base rate with a non-fertilized control treatment in each study. Treatment plots are seven- by seven-tree blocks with a two-row buffer between each treatment block. Fertilizer treatments were applied in the spring of the third growing season and will be re-applied in successive years. The starting basal area of each plot is recorded, and incremental growth due to fertilizer treatments is analyzed annually. We are using a combination of foliar nutrient levels and soil sampling to assess the nutritional status of the sites and treatments.

Preliminary results suggest that fertilization has the potential to increase yields significantly. Incremental basal area growth of hybrid poplar (clone DN34) at one site near Birchdale, MN, was 9.9 and 17.0 square feet per acre in 1998 in untreated and nitrogen-fertilized plots, respectively. Foliar concentrations of nitrogen ranged from 1.7 to 3.8% in this study. Regression analysis showed a statistically significant relationship between foliar nitrogen content as measured in August 1997 and subsequent 1998 basal area growth. Although relative response of hybrid poplar to fertilizer additions will undoubtedly be a function of inherent site fertility, we expect that additional nutrition will play a role in future management of hybrid poplars. The goal of MHPRC research is to identify those sites that will likely respond to fertilization and to develop cost-effective tools to assess nutrient status of plantations for commercial management. We expect this research to continue for a minimum of 6 years as a basic understanding of nutrition is developed and a more intensive program to assess nutrient ratios and rates is undertaken.

Cultural Management Research

A critical aspect of plantation management is early-rotation control of competing vegetation. Competition control is done using a combination of herbicides and cultivation. Labeling of herbicides for hybrid poplar is a subject of research by the MHPRC. Toxicity of a particular herbicide to poplars must be determined before approval by the manufacturer for use on plantations. Also, research needs to be done to better understand the impacts of weed competition on plantation growth after

the initial establishment phase. Work scheduled to begin in 1999 will be done to assess the effectiveness of weed control options and the impacts on plantation production.

In addition to competition control, other aspects of plantation management such as plant spacing are being evaluated. We will begin large-block studies of plantations on several sites using different plant spacings from 8 by 8 feet and wider to assess impacts of plantation spacing on production over time and mean tree size at harvest. This information will be useful in determining the optimum combination of plant spacing and rotation age to achieve a target tree size.

CONCLUSION

Hybrid poplar has only recently begun to be planted as a commercial crop in Minnesota. Increased population and associated demand for wood products and energy both domestically and worldwide will lead to higher timber demand in the future. Plantation forests of all types, both conifer and hardwood, are expected to play an increasing role in meeting this demand. Past research in Minnesota done by a variety of groups has provided the foundation from which to build a commercial hybrid poplar program. However, future improvement in yield will be dependent on a concerted research effort by the interested private companies and public agencies. In Minnesota, the Minnesota Hybrid Poplar Research Cooperative research program is an integral part of the development of improved genetics and management techniques for hybrid poplar to meet this challenge.