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THE FEASIBILITY OF PLANTATION SILVICULTURE USING POPLAR ON AGRICULTURAL LANDS OF WESTERN AND CENTRAL ALBERTA

1995

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ABSTRACT

The opportunity to practice plantation culture of poplar on marginal agricultural lands in western and central Alberta was examined from a largely biological perspective. The area of interest is bounded roughly by Peace River, Edson, and Lac La Biche excluding the Swan Hills.

Interviews with representatives of five forest products companies interested in poplar culture revealed a prospective program including about 2,700 hectares annually with a planting stock demand of about 3.24 million trees. A yield target of 250 m^3/ha on a rotation of 40 years or less was adopted. Three elements of increased yield relative to natural stands were identified: full site utilization, site improvement, and genetic improvement.

A research and development program to gain familiarity with poplar plantation culture was outlined. Site assessment, site preparation and maintenance, planting stock type, and selection of parents were identified as topics requiring early emphasis. Species differences in the ease with which plantation culture could be initiated were represented by different costs for research and development and for stock production. Choice of species is a critical initial decision and some criteria required to make that decision were discussed.

Some options to provide the leadership and coordination required for a structured development of opportunities for poplar culture were noted. Of central importance in reducing the risk of poplar plantation culture would be the knowledgeable management of a diverse gene pool to reduce risks of plantation failure from diseases and insects.

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BACKGROUND

Several factors have combined to prompt interest in plantation culture of deciduous species in central and western Alberta. These include industrial processes based on the existing aspen resource, costs associated with long trucking distances, projected shortfalls in fibre availability, potential expansions of mill capacity, uncertainty of future harvest rights, and the availability of agricultural land, both owned and potentially available through agreements with owners.

Interest in poplars for plantation culture is based on the high quality of aspen fibre and the potential for very high fibre production in intensively cultured poplar plantations.

In 1993, the Western Canada Poplar Users Committee (now called - Western Boreal Aspen Cooperative - WBAC) chose to sponsor a review to assist in determining whether plantation culture would be useful in supplementing fibre supplies for several forest products companies in western and central Alberta. With five members, the Committee has held several discussions on potential projects on poplar culture with particular emphasis on genetic improvement.

This report describes the opportunity for poplar culture based on published and unpublished research, interviews with Committee members and other knowledgeable individuals, and the experience and opinions of the author.

POTENTIAL PROGRAM SIZE

For purposes of estimating program size, current views were obtained on the volume of wood expected from plantations on agricultural land. An annual total volume of 675,000 m^3 was used as a basis for this analysis. Potential expanded capacity at some mills is not represented in the total.

Assuming an average merchantable yield of 250 m^3/ha of plantation per year at an age of 40 years, 2700 hectares would be planted annually. If planting is at a density of 1200 trees/ha, about 3.24 million trees would need to be produced annually.

ADVANTAGES AND DISADVANTAGES OF A PLANTATION PROGRAM

Advantages - Biological

Compared to natural stands, plantation culture would be expected to provide increased total yields on shortened rotations. There could be three components to increased yield:

A. Better site utilization (full stocking, equal spacing, reduced competition).

B. Site improvement (fertilization, irrigation).

C. Genetic improvement (growth rate, disease resistance, wood quality - if needed).

Of these components, better site utilization probably represents the largest advantage of plantations compared with natural stands. Yield increases from site improvement might vary among companies and could range from only control of early competition to irrigation with nutrients. Given the apparent need for a substantial number of trees to be planted, genetic improvement should be considered as a complement to a plantation program.

Advantages - Economic

Most of the agricultural lands under consideration are within close proximity to mills. Reduced haul cost should thus be a substantial advantage when obtaining wood from plantations. Additional advantages may also be existing road networks, possibly reduced harvest costs, summer logging to even wood flows, and reduced stain and rot due to shorter rotations.

Disadvantages - Biological

There is no experience in plantation culture of poplars for fibre yield within any of the companies or within the region. Available agricultural lands are of unknown nutritional and moisture status, stock production systems are unfamiliar, the required quality of planting stock is unknown, efficient site preparation and maintenance protocols are unknown, and cost-effective methods to reduce expected animal damage are not available. Also, the benefits of the extensive residual root system after harvest of natural poplar stands will be unavailable in plantations to provide an early growth boost. Initiation of a 10-year contract by the Aspen and Larch Cooperative (Minnesota) to investigate issues in aspen plantation establishment and management (Gary Wyckoff, pers. comm., 09/21/93) is indicative of the lack of successful protocols for aspen. In addition, there is presently no tested genetic material from which to obtain genetic improvement.

Disadvantages - Economic

Although some companies own agricultural lands, most of the production from poplar plantations is expected to come from farmers. Financial exposure through land rental agreements or purchase agreements represents an exceptional risk until protocols for successful plantation culture are available and are understood by farmers.

REQUIREMENTS FOR SUCCESSFUL PLANTATIONS

Site Selection

"The prima donna disposition of poplars derives not only from their unequivocal silvicultural requirements, but also from their exacting site requirements. Poplars are highly exploitive of water and soil nutrients and will perform to their full potential only on the best sites" (Dickmann and Stuart 1983). This truism fits well with the ecological context for cottonwoods and with the performance of plantations where abundant sun, water, and nutrients (provided by irrigation) have resulted in exceptional growth on soils where cottonwood normally would grow poorly if at all. For aspen, nutritional and moisture requirements may be less, but the importance of site quality will not be diminished if plantations are expected to "perform to their full potential."

Dickmann and Stuart (1983) list the best and worst conditions of physical soil properties, moisture and nutrient availability, and aeration for growth of poplars. They note reductions of 25% in height growth for each reduction in four soil drainage classes from well-drained to very poorly drained. Genetic differences can be utilized to compensate for some site deficiencies as shown by clonal comparisons on different soil types. Although some clones perform relatively well on several sites, clone-site matching may be needed if maximum growth is the goal or if matching could be useful to maintain a desirable level of genetic diversity in extensive clonal plantations.

Site selection is especially critical where land rent or purchase is being considered. Although most agricultural lands are adjacent to stands or windrows of poplars, the usefulness of existing methods of forest site assessment on farmed land will have to be tested.

Models based on vegetation analysis (e.g., Corns and Annas 1986) may have no direct application and models based on physical soil properties (Thorpe 1991; Fralish and Loucks 1975) need validation on lands modified chemically and physically by farming. Likewise, the comprehensive decision support system being developed for aspen stand management (Bella et al. 1991) may not be directly useful on agricultural lands.

The area being considered for plantation culture of deciduous species includes three eco-regions:

- Lower Boreal-Cordilleran;
- Low Boreal Mixedwood; and
- Mid Boreal Mixedwood.

The Lower Boreal-Cordilleran differs from the other two in being somewhat cooler in summer and with an average of about 20% more precipitation both in summer and winter (Strong 1992). The lands of interest in the Lower Boreal-Cordilleran, however, are along the eastern border of the ecoregion and, therefore, probably do not experience climatic differences as large as those between ecoregion averages. Average frost-free period differs by about 15 days and growing season (days above 5^0C) differs by about 5 days. For purposes of tree improvement planning, a single breeding zone probably would be satisfactory although genetic testing should be organized to validate that assumption.

Given the exacting nature of poplars for nutrients and moisture where high productivity is expected, differences in soils may be more important than differences in climate within the region. Soil mapping by ecodistrict shows that moisture regimes range from mesic on the sandy loams and heavier soils through much of the region to subxeric on the lighter soils between Ft. Assiniboine and Hondo (Strong 1992).

Modification of soils by agriculture introduces further variation in nutritional status and in structure. Compacted layers at plow depth and occasional mottling suggesting poor soil moisture conditions have been observed in some agricultural soils of the region. Grey Luvisolic soils predominate in the region and translocation of clay particles to the B horizon can be important where an accumulated layer may restrict roots and movement of water (Leskiw 1989).

Site Preparation and Maintenance

The futility of trying to establish poplar plantations in grassy fields is well established and planting in a weed free environment is a tenet of instructions for plantation establishment (Dickmann and Stuart 1983).

Presumably the full range of options for weed control would be available for plantation establishment. Weed control would require a carefully scheduled sequence of treatments, probably starting with tilling. No-till treatments have been shown to be moisture conserving, but also result in slower warming of soils (Crosson 1981), an effect likely to be undesirable where growing seasons are short. Current agricultural practices in the region may be appropriate for site preparation, but would have to be evaluated with respect to future requirements for weed control.

At anticipated growth rates for poplars, weed control probably would be required for 3 years after plantation establishment. Early experience with herbicides revealed a high sensitivity of poplars. More recently developed herbicides may be more useful. It should be kept in mind that there is no incentive for herbicide manufacturers to test sensitivity of poplars to their products (unless to kill poplars) and local testing would be required before recommendations could be made for large-scale use.

An additional consideration, at least with aspen plantations, is whether an initial density of 1200 trees/ha will create an environment that predisposes the trees to damaging levels of insect and disease attack. Experience in the Lake States has led to a recent plan to convert plantations which are 3 to 5 m tall to sprout stands with 50,000 to 100,000 stems/ha. The biological basis for the plan is the observation that the principal damaging agents, wood borers (Saperda spp.) and Hypoxylon canker, are organisms that are most successful in open environments (Gary Wyckoff, pers. comm., 09/21/93). Conversion of plantations to sprout stands would seem to severely reduce the advantage of better site utilization associated with reduced competition among plantation trees.

While the potential for growing agricultural crops and trees together or "agroforestry" exists in the first year or two of poplar plantation culture, it should be kept in mind that an agricultural crop represents a "weed" from the perspective of trees. Evidence that vigorous trees extend lateral roots more than 2 m during the first growing season (Hansen 1981) suggests that trade-offs between trees and agricultural crops may be important in the choice of whether to attempt agroforestry. Presumably, here the issues are mostly economic and lack the social imperatives of food-poor areas where agroforestry is practiced.

Planting Stock Production

Genetic superiority is of use in forestry only if it can be "packaged" and delivered efficiently in planting stock. Here the opportunities differ so greatly among poplar species that separate discussions are provided for aspens and cottonwoods.

Aspen Seedlings

Delivery of genetic improvement through aspen seedlings presents two challenges, seed production and seedling production. For seed production, at least five approaches are possible in increasing order of complexity and genetic potential.

1. Seed could be collected from selected, and eventually tested, parents in the field. Obvious advantages include large seed production potential and minimum facilities. Obvious disadvantages include a reduced genetic potential resulting from pollination by inferior male parents, the logistics of identifying seed maturity on many clones scattered across a large area, and collection of fragile material from tall trees.

2. Seed could be produced in a wind-pollinated seed orchard following the model for conifers. Obvious advantages include inclusion of genetically superior males, ease of following seed maturation on trees concentrated in one place, and crown control to facilitate seed collection. Disadvantages include increased cost and specialized knowledge to establish and maintain an orchard and the inability to control contamination from pollen originating outside the orchard.

3. Seed could be produced in clone banks with controlled pollinations. The high yield of aspen catkins (150 to 300 seeds each) increases the appeal of controlled pollination. Advantages include those noted in option 2 plus pollen control. Disadvantages include increased cost and specialized knowledge to establish and maintain clone banks plus the problems caused by inclement weather during the pollination period.

4. Seed could be produced on cut branches by controlled pollinations. For a few tree species which mature seed within a few weeks after pollination, cut branches about 1 m in length (bearing flower buds) can be used to produce seed. Advantages include a high degree of genetic and environmental control. Disadvantages include specialized facilities and knowledge, labour intensity, and the need to obtain new branches each year.

5. Features of option 3 and option 4 could be combined by growing grafts of parent trees in pots. Because the pots would be portable, the disadvantage of inclement weather in option 3 could be removed by using a greenhouse. There would then be no need to collect branches each year. The need for specialized knowledge would be higher in this option due to a lack of successful experience in container culture of seed orchards. For conifers in B.C., cone and pollen production of potted grafts have been adequate, but seed production has been poor. Seed production with aspen in containers, likewise, has been poor (Gary Wyckoff, pers. comm., 09/21/93). The Minnesota Department of Natural Resources, however, has produced a crop from controlled pollination on potted grafts. Grafts using only vegetative buds have begun to produce flower buds in 1993 after three growing seasons. To date, the main caution is out-of-phase dormancy in which flower buds open at the end of the growing season (Larry Miller, pers. comm., 9/22/93).

Stock production from poplar seed has been described as requiring "exacting and more or less unique nursery practice" (Schopmeyer 1974) arising from the vulnerability of the seeds to drying, washout, and disease. Much of the challenge in raising poplars from seed may have been overcome by container culture methods (Gary Wyckoff, pers. comm., 07/09/93). Bareroot stock is being produced by the Minnesota Department of Natural Resources at a level of about 50,000 seedlings annually. Although a number was not available for seedling yield per seed, it was believed to be low and the method would not be likely to be acceptable for control-pollinated seed (Larry Miller, pers. comm., 09/22/93).

Infection by Marssonina spp. has been a problem in bareroot culture. Miller suggested that a plug-plus system might be of most interest for genetically improved seed. The plug-plus approach involves growth for about 6 weeks in very small plugs followed by transplanting to a bareroot nursery. The system is being tried by the Blandin Paper Company in Grand Rapids, Minnesota. Contract growing in mini-plugs currently is at a rate of $40 per thousand seedlings.

Aspen Vegetative Propagation

At least four methods exist for vegetative propagation of aspen. All have the advantage of reproducing the parental genotype and all share the disadvantage of labour intensity, though to different degrees. Success in propagation by each of these methods varies by clone. The methods are listed in order of increasing requirements for labour and specialized knowledge.

1. Root cuttings - The ability of aspen to sprout from roots can be used to develop planting stock. Root sprouts could be collected from superior clones in the field or developed from root sections. Hall et al. (1990), working with three aspen hybrids, indicated an annual scale-up factor of about 6 from each sprout. Fifty superior clones, each providing 1000 initial root segments, thus could be multiplied to produce the required number of trees in about 4 years (only about half of the root sections produce plantable trees).

2. Root sprout cuttings - Root sections could be collected and placed in greenhouse benches or nursery beds. Very young sprouts could be severed from the root and rooted as cuttings in a propagation facility. The method has been described by Zsuffa (1971) and by Schier (1978). Zsuffa (1971) reported that scale-up factors from four, 8-inch (18 cm) root sections varied by parent from 4 to 245 shoots and rooting percentage of those shoots varied by parent from 20 to 100%. Scale-up factors, on average, would be much higher than for root cuttings. Specialized facilities and intensive monitoring would be required and differences among clones would add to the effort.

3. Greenwood cuttings - Greenwood cuttings are cuttings taken from terminal or lateral shoots in active growth. Aspen seedlings or root sprouts could be grown to heights of 0.5 to 1 m and used for production of greenwood cuttings. The scale-up factor probably would be between 5 and 10 although rooting success has varied between 20 and 100% in cuttings taken from different seedlings (Schier 1980). Specialized facilities would be needed to maintain greenwood cuttings due to their susceptibility to drying.

4. Tissue culture - Tissue from outstanding clones could be multiplied in sterile culture and induced to form shoots which are then rooted, weaned from their cultural environment, and grown as planting stock. With the annual scale-up factor of 1,250 suggested by Hasnain, et al. (1986), a production level of 4 million trees could be reached within 2 years. Ahuja (1984), however, reported that only 50% of clones entered in a tissue culture regime were successfully propagated.

Cottonwood Seedlings

Comments similar to those for aspen apply. Seedling propagation, however, is rarely used for production of planting stock. Dormant cuttings are the preferred form of planting stock because they are more simple to handle than seedlings and reproduce the parental genotype.

Cottonwood Vegetative Propagation

A variety of methods exist for vegetative propagation of cottonwoods. The choice of method depends on expected vegetative competition, animal damage, moisture availability, cost, and desired scale-up rate.

1. Unrooted dormant cuttings - Cuttings, about 30 cm in length, taken from one-year-old sprouts are the standard for establishment of cottonwood plantations where weed competition is controlled. Depending on the number of sprouts produced by a stool, scale-up factors can be from about 10 to 30. Where soil moisture deficits are expected, longer cuttings may be planted to greater depths. Where brush competition or animal browsing are expected, "whips" or cuttings up to 2 m in length are planted. Scale-up factors are reduced accordingly.

2. Rooted cuttings - Rooted dormant cuttings may be used where greater vigour is required in the first growing seasons. Consideration should be given to whether the added year of culture and somewhat greater difficulty in planting are warranted by improved growth.

3. Single-bud cuttings - Where rapid scale-up of superior clones is needed, short sections of dormant stem containing a single bud can be rooted and grown under nursery culture for one season. Scale-up rates may exceed 100 for single-bud cuttings.

Site Improvement

Poplars are known to be responsive to irrigation and fertilization (Coyne and van Cleve 1977; Wyckoff et al. 1990). Response to site amelioration is, of course, a function of the initial quality of the site. Dickmann and Stuart (1983) list some guidelines for recognizing nutrient and moisture deficiencies. At some point, if not initially, site assessment should include a recommendation on whether fertilization would be required or desirable.

Palmer (1991) identified two critical questions in fertilizing poplars as 1) whether to fertilize, and, if so, 2) when to fertilize. Tests of many rates, and timings, in Quebec indicated that phosphorus was most influential at the time of planting followed by nitrogen in the second year (Menetrier and Vallee 1980).

These studies are a good example of complex fertilizer experiments in that 40 treatments were tested.

Although growth responses to fertilization have been encouraging, increased mortality has been noted in fertilized plots (Safford and Czapowskyj 1986). Correlations between the incidence of disease or insect attack and levels of phosphorus, potassium, magnesium, iron, and aluminum in unfertilized soils also have been described (Abebe and Hart 1990). Correlations were in different directions for different combinations of elements and diseases. Increased disease in irrigated plots has been reported, perhaps as a consequence of shoot blight in an environment where humidity was enhanced by overhead irrigation (Wyckoff et al. 1990).

Plantation Spacing, Tree Size, and Yield

There is virtually no experience with the interaction of spacing, tree size, and yield for either aspen or balsam poplar plantations. Data from natural stands can provide a first approximation. Members of the Users Committee agreed that stands with an average dbh of 20 cm represent an acceptable minimal tree size for harvest. Empirical yield tables from Saskatchewan (Kirby et al. 1957) suggest that an average dbh of 20 cm can be achieved at a density of about 1000 trees/ha with merchantable yields of between 175 and 250 m^3/ha depending on site quality. With a planting survival of 80%, an initial stocking of about 1200 trees/ha would achieve the density target. Presumably, with equal and ample initial spacing, the target diameter would be reached in 40 years or less rather than the 70 to 90 years observed in the natural stands of Saskatchewan.

Depending on early experience with the first approximation for spacing, tree size and yield, a revision may be in order. Spacing trials might be required or an increase in the number of trees planted might be necessary to offset losses from animals.

Diseases and Insects

Lester (1993) noted that poplars are hosts to many pests, some of which can destroy plantations (Marssonina bruneii on clone I-214 in Europe and Septoria musiva on poplar hybrids in the mid-western United States). More recently, problems with leaf rusts (Melampsora spp.) have intensified in plantations of hybrid poplars in western Oregon. Infection of hybrid clones believed to be resistant (Brian Stanton, pers. comm., 01/93) and the identification of another species of rust (Callan 1992) have prompted more attention to the selection of resistant clones. For each of six diseases of poplars noted outside of nurseries, the use of resistant clones is recommended for disease prevention or control (Heilmann et al. 1990).

Experience worldwide with pest problems in plantation culture of poplars reinforces the need for careful management of a broadly based gene pool. Whereas relatively few clones or families may be used in plantations established in a given year, ready access to clones or families that may be substituted to counter pest problems is essential for continued success in plantation culture. The need for a comprehensive genetic approach has been well illustrated by Tessier du Cros (1984) based on centuries of European experience.

OPTIONS FOR GENETIC IMPROVEMENT

There are a variety of options for genetic improvement. They vary in ease and immediacy of implementation, required facilities and technical experience, potential yield and/or rotation length, cost, and probability of success. The following options are listed in order from the simplest to the most complex.

A summary of advantages and disadvantages is given in Table 1.

Development of Local Genetic Resources - Balsam Poplar

Selections of balsam poplar could be made throughout the region of interest, cuttings could be collected and rooted in stool-beds, and clonal testing could be initiated simultaneously with establishment of studies on plantation establishment and maintenance. After clonal evaluations at about age 5 years, the best clones could be multiplied in expanded stool-beds and operational planting with genetically proven clones could be started. Continued genetic progress would require crossing among the better clones and selection in new seedling populations. One unknown with balsam poplar is the point at which moisture availability begins to favour aspen over balsam poplar in expression of genetic potential for growth.

Table 1. Comments on options for genetic improvement of poplars in western and central Alberta.

Species	Control of Genetic Resources	Ease of Implementation	Facilities and Expertise	Potential Yield Increase	Relative Cost	Probability of Success
balsam poplar	users	relatively simple	stool-beds	moderate	lowest	high
trembling aspen (diploids - seed)	users	more complex	greenhouse	moderate	moderate	high
trembling aspen (triploids) (vegetative propagation)	users or others	complex	propagation facility, & breeding expertise	?	high	moderate to low
cottonwood (hybrids)	users and/or others	complex	greenhouse, breeding expertise	probably high	high	moderate
trembling aspen (hybrids)	users and/or others	complex	greenhouse, breeding expertise	possibly high	high	moderate

Source: D. Lester, 1993

Development of Local Genetic Resources - Aspen Diploids

Selections of aspen could be made throughout the region of interest. Propagation for testing could take either of two routes:

1. Seedlings - Selections could be propagated by one or more of the seedling techniques. Genetic testing would be by seedling family and genetic superiority should be apparent after 5 to 8 years. Note that selections which are male cannot be tested by collection of wind-pollinated seed. Continued genetic progress could be made from selection within seedling families. Raising stock production to the level of anticipated need would represent an expansion that is well beyond levels achieved by other aspen programs.

2. Vegetative propagation - Selections could be propagated by one or more of the techniques. Producing enough trees for genetic testing would be a modest undertaking. Producing trees at the level of anticipated need would require a very large effort. As for balsam poplar, crossing of the best clones and selection in seedling populations would be required for continued genetic progress.

Development of Local Genetic Resources - Aspen Triploids

A search could be made for triploid clones throughout the region. Triploids are rare, but have been found in Europe and in several places in North America (Muntzing 1936; Einspahr et al. 1963). Perhaps a few triploids would be located during the selection of diploids. Selections would have to be vegetatively propagated because triploids reproduce rarely by seed. It is unlikely that a large enough number of triploids could be located to support an operational program. In addition there would be no option for continued genetic improvement.

Development of Local Genetic Resources - Aspen - Cottonwood Hybrids

An interesting, if unlikely, possibility for combining the desirable features of aspen and balsam poplar would be hybrids between the two species. Although natural hybrids between these species have been reported (Little 1979), artificial hybrids between poplars of the Leuce and Tacamahaca sections have been difficult to produce (Zsuffa 1975). Bert Larocque (Operations Forester, Slave Lake Pulp Ltd.) has noticed trees which are difficult to assign to either species and the inclusion of such trees in a testing program would be worthwhile.

> (Comment: Larocque's observations illustrate the potential importance of local knowledge and experience in identifying and developing genetic variation.)

Development of Local and Exotic Genetic Resources - Cottonwood Hybrids

Performance of cottonwood hybrids in many parts of the world suggest that they offer the best promise for very rapid growth although they may require sites of higher quality than native species (Heilmann and Stettler 1986). Unfortunately, there does not seem to be an available reservoir of clones which are likely to be successful in the region. One approach, currently being followed by Alberta-Pacific Forest Industries Inc., is to test all available clones which may have promise. The likely outcome of this approach is to identify one or a few clones which may be adequate for initial use. These clones will not achieve the highest growth potential and the program will be vulnerable to eventual failure of the clones in use without a reserve of tested clones to be substituted. As with all clonal programs, continued genetic improvement is dependent on crossing and selection within seedling populations.

A second approach would be to make selections of native balsam poplar and to develop a crossing and testing program for the continued production of genetic improvement. Crossing could be with balsam poplar of different geographic origins or with other species.

Dhir and Mohn (1976) found increased height growth of about 8% in early growth of crosses between eastern cottonwood populations from Minnesota and Missouri.

Hybrids between eastern cottonwood (P. deltoides) and balsam poplar (often called the Jackii hybrids or P. X jackii) were among the more vigorous clones tested in the Boreal environment of Newfoundland (Khalil 1984). Farmer (1991) and Zsuffa (1991) both suggest that Jackii hybrids may have promise for the western Boreal region. Farmer noted, however, that there have been few comparisons of growth by Jackii hybrids with growth of their parents and he opposed making hybrid production and testing the main emphasis in poplar improvement for the Boreal region. Zsuffa emphasized the importance of site choice and maintenance of poplar plantations

With native selections made and a commitment to local clonal testing, a cooperative agreement with the Cottonwood Cooperative might provide for the crossing to be accomplished by the Cooperative.

Development of Local and Exotic Genetic Resources - Aspen Hybrids

Aspen hybrids showed great early promise in the Lake States (Benson 1972), but have not been widely used in plantations. Zsuffa attributes the lack of development of aspen genetic resources to problems with vegetative propagation and diseases. Wyckoff (pers. comm. 07/93) suggested that the European aspen (P. tremula) parents used in early crosses with native trembling aspen may be introducing maladaptation and that expanded testing of parents from Europe may be necessary before a successful hybridization program can proceed. Farmer (1991) also noted the early promise of aspen hybrids and pointed out that the best local representatives of trembling aspen should be used in crosses, not just convenient parents. As with balsam poplar, genetic gains might be made with crosses among trembling aspen of different origins (Johnsson 1956).

AN OUTLINE OF INITIAL RESEARCH AND DEVELOPMENT

If the major portion of expected yield increases is to come from plantation culture, rather than from genetic improvement, efforts should begin immediately to develop one or more protocols for successful plantation culture of poplars. Site quality assessment, site preparation and maintenance, and stock type each require research efforts to determine which of several possible approaches is most effective for the lands of interest to the Users Committee. These elements, along with tree improvement, should be included in an initial program of research and development. Table 2 outlines three phases in a program of poplar plantation culture. Note that issues of land procurement are not included.

Subsequent tables provide estimates of costs for research and development of systems based on unrooted dormant cuttings (Tables 3 and 4), and for stock production at the level of 3.24 million trees per year for cuttings (Table 5), and on seedlings (Table 6), and for seedlings (Table 7). Note that research and development costs are different for cuttings and seedlings. The period of higher costs for seedlings is extended to reflect the lack of knowledge on successful plantation establishment and maintenance (Table 6).

Table 8 is an attempt to organize the many issues involved in choosing one option for poplar culture on marginal agricultural lands in western and central Alberta; the columns are left blank.

Table 2. An outline of possible activities and some costs in developing poplar plantation culture for western and central Alberta.

Phase I. - year 1 to year 10

Research and development in poplar plantation culture, development of methods for site quality assessment, selection of parents, progeny testing, and scale-up of superior parents for operational planting. (Scale-up might not be complete by year 10.)

	Leadership		Labour: In-kind		Contract	
Year	Time (months)	Wages (M$)	Time (months)	Wages (M$)	Costs & Expenses (M$)	Sum (M$)
1	8	50	10	50	50	150
2	8	50	10	50	50	150
3	8	50	5	25	50	125
4	6	35	5	25	50	110
5	2	15	2	10	10	35
6	1	5	2	10	10	25
7	1	5	2	10	10	25
8	1	5	2	10	10	25
9	3	20	4	20	40	80
10	4	25	5	25	40	90

No costs are included for facilities.

Phase II. - year 4 to year 44

Assessment of potential sites for plantations, initiation of growing contracts using selected but untested parents, and early scale-up of selected parents to a level of 3.24 million trees per year assuming that major benefits are to be derived from plantation culture without genetic improvement. Production at a level of 3.24 million trees would represent a major cost, possibly ranging from $324,000 annually for unrooted cuttings to $2,660,000 for tissue-cultured trees.

Phase III. - year 8 to year 18 or longer

An additional level of genetic improvement could be developed by crossing among the best parents and selecting among seedling progeny and/or crossing the best native parents with other species.

	Leadership		Labour: In-kind		Contract	
Year	Time (months)	Wages (M$)	Time (months)	Wages (M$)	Costs & Expenses (M$)	Sum (M$)
8	3	20	12	60	?	80+
9	3	20	12	60	?	80+
10	4	30	12	60	?	90+
11	4	25	8	40	?	65+
12	4	25	8	10	?	65+
13	2	15	2	10	?	25+
14	2	15	2	10	?	25+
15	2	15	2	10	?	25+
16	3	20	5	25	40	85
17	5	30	5	25	40	95

Contract costs and expenses would include greenhouse facilities for crossing, costs of stock growing and site preparation for genetic testing, possible contract services for assessment of genetic tests for identification of diseases and insects, and costs of scale-up when promising crosses are identified.

Table 3. Costs of R&D on plantation establishment and genetic improvement using dormant, unrooted cuttings for marginal agricultural lands.

Costs are on a nominal and on a discounted (4%) basis. Expected volumes of wood produced as a consequence of genetic improvement in R&D I and II are given.

Year	Costs			Discount Factor	Discounted Cost (M$)	Incremental Wood (Mm^3)
	R&D I (M$)	R&D II (M$)	Propagation (M$)			
1	150			1.04	144.2	
2	150			1.08	138.7	
3	125			1.12	111.1	
4	110			1.17	94.0	
5	35			1.22	28.8	
6	25			1.27	19.7	
7	25			1.32	19.0	
8	25	80+		1.37	76.7+	
9	40	80+	40	1.42	112.4+	
10	50	90+	40	1.48	121.6+	
11		65+		1.54	42.2+	
12		65+		1.60	40.6+	
13		25+		1.67	15.0+	
14		25+		1.73	14.4+	
15		25+		1.80	13.9+	
16		45+	40	1.87	45.4+	
17		55+	40	1.95	48.8+	
18				2.03		
19				2.11		
20-24				2.37		
25-29				2.89		
30-34				3.51		
35-39				4.27		
40-44				5.20		
45-49				6.33		
50-54				7.70		505
55-59				9.37		505

(cont'd)

Year	R&D I (M$)	Costs R&D II (M$)	Propagation (M$)	Discount Factor	Discounted Cost (M$)	Incremental Wood (Mm^3)
60-64				11.40		844
65-69				13.87		844
70-74				16.87		844
75-80				20.94		844
Totals	**$735**	**$555+**	**$160**		**$1,086.63**	**4,386**

See Table 2 for comment on potential additional contract expenses.

Table 4. Benefits of genetic improvement in cubic meters of wood from R&D I and R&D I plus II. Estimated cost per incremental cubic meter from R&D.

Benefits

Year	Incremental R&D I (m^3)	Volume R&D II (m^3)	Discount Factor	Discounted Incremental R&D I ('000 m^3)	Volume R&D II ('000 m^3)
50-54	505	505	7.70	65.6	65.6
55-59	505	505	9.37	53.9	53.9
60-64	505	844	11.40	44.3	74.1
65-69	505	844	13.90	36.4	60.9
70-74	505	844	16.90	29.9	50.0
75-80	505	844	20.90	24.1	40.3
Totals	**$3,030**	**$4,386**		**254.3**	**344.8**

Incremental cost

R&D I - Nominal $815,000 / 3,030,000 m^3 = $0.27+
- Discounted $690,865 / 254,304 m^3 = $2.72+

R&D I and II - Nominal $1,450,000 / 4,386,000 m^3 = $0.33+
- Discounted $1,086,635 / 344,787 m^3 = $3.15+

See Table 2 for comment on potential additional contract costs

Table 5. Costs of propagation using unrooted cuttings and costs per cubic meter.

(Assuming a demand of 3.24 million trees per year at $0.10 each and benefits of plantation culture assuming an increment of 82 m^3/ha over natural stands without genetic improvement.)

Year	Propagation (M$)	Incremental Wood (Mm^3)	Discount Factor	Discounted Cost (M$)	Discounted Incremental Wood (Mm^3)
1	40		1.04	48.1	
2	324		1.08	299.6	
3	324		1.12	288.0	
4	324		1.17	277.0	
5	324		1.22	266.3	
6	324		1.27	256.1	
7	324		1.32	246.2	
8	324		1.37	236.7	
9	324		1.42	227.6	
10	324		1.48	218.9	
11	324		1.54	210.5	
12	324		1.60	202.4	
13	324		1.67	194.6	
14	324		1.73	187.1	
15	324		1.80	179.9	
16	324		1.87	173.0	
17	324		1.95	166.3	
18	324		2.03	799.7	
19	324		2.11	768.9	
20-24	1620		2.37	682.5	
25-29	1620		2.89	561.0	
30-34	1620		3.51		
35-39	1620		4.27		
40-44			5.20		
45-49		1107	6.33		259.0
50-54		1107	7.70		212.9
55-59		1107	9.37		174.9

(cont'd)

Year	Propagation (M$)	Incremental Wood (Mm^3)	Discount Factor	Discounted Cost (M$)	Discounted Incremental Wood (Mm^3)
60-64		1107	11.40		143.8
65-69		1107	13.87		118.2
70-74		1107	16.87		97.1
75-80		1107	20.94		79.8
Totals	**$12,372**	**7749**		**$6,086.1**	**1,085.7**

Cost of scale-up to produce 3.24 million cuttings.

Costs per cubic meter: Nominal - $12,372,000 / 7,749.000 m^3 = $1.60
Discounted - $ 6,086,000 / 1,086,000 m^3 = $5.60

Table 6. Costs of R&D on plantation establishment and genetic improvement. Estimated cost per incremental cubic meter from R&D.

(Using seedlings for agricultural lands in western and central Alberta. Costs are on a nominal and a discounted (4%) basis. Expected volumes of wood produced as a consequence of genetic improvement in R&D I and II are given.)

Costs of R&D

Year	R&D I (M$)	R&D II (M$)	Propagation (M$)	Discount Factor	Discounted Cost (M$)
1	150			1.04	144.2
2	150			1.08	138.7
3	150			1.12	133.9
4	150			1.17	128.2
5	110			1.22	90.2
6	110			1.27	86.6
7	25			1.32	19.0
8	25			1.37	18.3
9	40		18	1.42	40.8
10	50		6	1.48	37.8
Totals	**$960**	**$555**	**$48**		**$1,204.2**

See Table 2 for comment on potential additional contract costs.

Complete table follows the format of Table 3.

Assumptions are 800 grafts in years 9 and 16, 400 grafts in years 10 and 17. Grafts, based on experience with conifers, are estimated to cost \$20 each. Number of grafts is derived from an assumption of 4000 seedlings to be produced by each graft from a female parent.

Estimated incremental cost of genetic improvement per cubic meter

R&D I - Nominal \$984,000 / 3,030,000 m^3 = \$0.32+
- Discounted \$837,668 / 254,304 m^3 = \$3.29+

R&D I and II - Nominal \$1,563,000 / 4,386,000 m^3 = \$0.36+
- Discounted \$1,204,247 / 344,787 m^3 = \$3.49+

Volumes are derived in Table 4.

Table 7. Costs per cubic meter of propagation.

(Using one-year-old seedlings assuming a demand of 3.24 million trees per year at \$0.20 each and assuming an increment of 82 m^3/ha over natural stands without genetic improvement. Calculations follow the format of Table 5.)

Costs per cubic meter

Nominal - \$23,352,000 / 7,749,000 = \$ 3.01
Discounted - \$12,907,000 / 1,085,744 = \$11.88

Table 8. Preliminary decision matrix for choosing the best "species" for poplar plantation culture in western and central Alberta.

		Alternatives		
Criteria	Trembling Aspen	Balsam Poplar	Aspen Hybrids	Cottonwood Hybrids
Adaptation to proposed lands	**Information by species to be determined by specific site per region.**			
- soil type				
- growing season				
- insects				
- diseases				
Average growth rate (unimproved)				
Potential for genetic improvement				
Ease of propagation				
Ease of plantation culture				
Available material of good genetic quality				
Complementarity with expected inventory in 50 years				
Costs to ameliorate wood quality flaws				
Match with proprietary interests				
Other criteria?	**To be determined by land manager.**			

Site Assessment

A method for site assessment might be obtained through contracting with a specialist in agricultural soils. At this time, the level of detail represented in the soil survey for the Daishowa-Maribeni Experimental Farm (Leskiw 1989) may not be necessary. It would be important, however, to identify those soils which can be recommended without reservation, those which may require extensive management, and those to be avoided. (Comment: In Table 2, $25,000 is allocated in years one and two for development of a site classification method.)

Site Preparation and Maintenance

Research in site preparation and early maintenance is needed immediately. Fortunately, most of the members of the Users Committee have designated areas for experimental work. A first step would be to estimate how representative those lands are of candidate lands for poplar culture.

> (Comment: Close coordination among the members of the Users Committee in using a representative sample of lands for research and development is very important. To illustrate, the heavier alluvial soils along the Athabasca River near Whitecourt and the aeolian sands around Hondo may represent extremes in the range of soils to be sampled. Experimental areas of Millar Western and Slave Lake Pulp might thus represent the extremes while not representing soils of greatest interest to each of those companies. Information from "extreme" sites, however, is important in defining the range of acceptable sites and the range of available genetic variation. The productivity of clones which would grow well on aeolian sands may not be recognizable on silt loams.)

When a sample of sites is agreed upon, comparative tests of site preparation and maintenance methods should be initiated. The actual treatments should represent a range of local practices modified for the perennial nature of poplars and their known responses to herbicides. The extent to which fertilizer treatments are included would, in part, depend on results of site assessments.

> (Comment: There should be a common set of treatments in each experiment. Individual companies might want to test additional treatments. Planning and supervision is included in costs represented in Table 2. I cannot estimate contract costs for implementation at this time. Especially critical will be the question of whether fencing of experimental areas is needed to reduce animal damage.)

Stock Type

Choice of planting stock type is not independent of protocols for plantation culture. An initial test, however, could estimate the growth potential of different stock types under one or a few standard treatments. Aspen seedlings and root sprouts, dormant unrooted and rooted cuttings, and whips of balsam polar should be compared. Inclusion of seedlings of paper birch from a few of the best stands could be useful as well. Planning and supervision are included in costs shown in Table 2.

Stock Production for Operational Planting

Stock production at the level of 3.24 million trees annually is a major undertaking. The approaches for balsam poplar and for aspen are different and they are discussed separately below.

Balsam Poplar

Propagation of balsam poplar by stem cuttings could utilize the long and successful experience with this approach. Using a scale-up factor of 10, 324,000 stools would be needed to produce 3.24 million, 12"-unrooted cuttings annually. The scale-up factor perhaps could be raised by cultural treatments. Establishment of a stool might cost about $0.25 and cuttings for operational planting might be about $0.10 each. A cost of $0.10 per unrooted cutting was described as "not unreasonable" by an industrial producer (Brian Stanton, pers. comm., 07/21/93).

At the indicated scale-up rate, and a spacing of about 0.3 by 1.2 m, about 12 hectares of stool-bed would be needed. Costs might be reduced by collection of cuttings from branches in operational plantations a few years after establishment. Table 5 outlines the financial implications of the lowest-cost option for stock production. Stock production (and stock type) is thus one of the major leverage points in financial aspects of poplar culture. Seedling costs probably would be similar to those for aspen as discussed below.

Trembling Aspen

All seedling options would require substantial labour. To produce 4.9 million seeds (1.5 seeds per plantable tree) by controlled pollination on selected aspen parents might require 800 grafts or older rooted cuttings from female clones and 400 grafts or older rooted cuttings of male clones, assuming that each clone flowers regularly. Conifer grafts are estimated to cost about $40 each over a twenty year period. Seedling growing costs are estimated at $0.20 per seedling (Gary Wyckoff, pers. comm., 07/93), or $648,000 annually for 3.24 million seedlings. Hasnain et al. (1986) similarly estimated seedling growing at $0.20 per seedling. The costs are summarized in Table 7.

Vegetative propagation of aspen at the scale of 3.24 million trees would be a substantial challenge. Hall et al. (1990) estimated a cost of $0.30 per tree from root sprouts and a cost of $0.80 per tree from tissue culture. Hasnain et al. (1986) used a cost of $0.49 per tree for tissue culture. Hasnain et al. (1986), in comparing seedlings with trees produced by tissue culture, found (under the financial assumptions that they used) that unrealistic genetic gains were required to achieve cost/benefit ratios of one or greater on a rotation length of 60 years. Break-even was achieved (at 7% discounting) when rotation length was reduced from 60 to 51 years, a genetic gain of 30%. In addition to rotation length, the outcome of financial analysis was especially sensitive to yield of tissue cultured plants. Discount rate, of course, would have a major impact of such analyses.

Species Choice

As indicated above, if dormant, unrooted cuttings could be used for plantation establishment there would be major differences among species in the ease with which planting stock could be produced. Planting stock production, with unrooted cuttings of balsam poplar would be relatively easy. Seed and seedling production of aspen would be appreciably more difficult and vegetative propagation of aspen would be the most difficult. Considerations of genetic gain in native populations probably are similar for balsam poplar and aspen.

Unfortunately, the choice between balsam poplar and aspen involves more than ease of stock production and potential genetic gain. Two major issues are ecological amplitude and wood quality.

Although balsam poplar is the second most common deciduous species in Alberta (Winship 1991) and although balsam poplar and aspen occur together in many of the forests, comparative performance of both species is unknown across the range of sites to be considered for poplar plantations. Silvical descriptions of each species would suggest that balsam poplar would be most productive on wetter sites whereas aspen would grow better on drier sites. Perhaps existing inventory data could be analyzed to provide a quantitative answer.

The issue of wood quality is a perplexing one. Winship (1991) has listed several negative features of balsam poplar and has discussed the implications of preference for aspen in stands where it is mixed with balsam poplar. Pfaff (1988) stated that balsam poplar could be included up to a content of 5% in waferboard whereas Ondro (1989) reported that the content of balsam poplar and black cottonwood had been increased to 50% while producing a good quality product without reducing the speed of the waferizing process. Thomas (1987) noted that balsam poplar "gave higher strength paper products than aspen, but slightly lower pulping yields."

> (Comment: Resolution of the issue of species choice is central to the feasibility of poplar plantation culture. There seems to be general agreement that wood and fibre quality of the two species are different for several characteristics. It is not clear, however, whether those differences should carry much weight in choosing the species to emphasize. For some members of the Users Committee, the differences probably are unimportant. For others, questions of proprietary advantage may be significant. Data, particularly cost estimates, may be available to help in measuring the trade-offs between species. A format which might be useful in reaching a decision is outlined in Table 8. The Table, one element in a formal decision process called "choice analysis", requires data to be entered for each combination of criteria and alternative. Combinations where data are unavailable are left blank and serve to emphasize weaknesses in the information base. After completion of the table, the best alternative usually is apparent from the sum of best choices. The process can be carried further to assess risks and ways to reduce risks.)

Genetic Improvement

Although genetic improvement is not likely to be the single largest component of yield improvement in poplar plantation culture, the long lead-time required for tree improvement means that the program should be initiated simultaneously with research on site assessment and plantation culture techniques. Table 3 assumes that selection of about 300 clones occurs in the first two years and genetic testing is initiated immediately. Genetic tests are maintained for several years and are evaluated in time to identify superior parents by years 9 and 10. Scale-up to operational levels probably would start somewhat earlier as exceptionally promising parents are noted.

A labour expense of $40,000 each in years 9 and 10 represents estimated costs of scaling up tested clones to produce planting stock at operational levels (Table 3). The comparable cost for scale-up for seedling production is $24,000 (Table 6). For either stock production system, this plan has a projected genetic gain in volume of 15% as shown by the 505,000 m^3 of wood added in by genetic improvement in the years 45-50 ((250 m^3/ha * 15%)* 2700 ha * 5 years) in Table 5. This gain is a part of the projected average yield of 250 m^3/ha from plantation culture.

When outstanding native parents have been identified, additional genetic gain could be sought through development of hybrids. A second phase of improvement including crossing and testing would culminate in about 10 years with an estimated additional genetic gain of 10%. Much higher gains with hybrids can be noted in published literature, but it should be remembered that exceptional gains to date have been in climates less harsh than those of the Boreal region. The additional 10% in volume would add 25 m^3/ha and raise total yield to 275 m^3/ha. Incremental volume resulting from genetic improvement thus would be 37.5 plus 25 m^3/ha for a total of 844,000 m^3 added by tree improvement ((37.5 m^3 + 25 m^3) * 2700 ha * 5 years) (Table 4).

Cost estimates for initial research on plantation culture and tree breeding along with projected incremental volumes of wood from genetic improvement are discounted at 4% in Tables 3, 4 and 6. Recall that none of the considerable costs for stock production are represented. Those costs, with the exception of costs incurred for scaling up genetically superior parents, would be balanced against the incremental volumes produced by plantation culture independently of genetic gains (Tables 5 and 7).

If research and development costs for plantation culture and genetic improvement are carried together in the outlined program, nominal cost per cubic meter for genetic improvement would be in the range of $0.27 to $0.36/$m^3$ and discounted cost in the range from $2.72 to $3.49/$m^3$. Adding propagation costs, nominal costs range from $1.87 to $3.37/$m^3$ and discounted costs range from $8.32 to $15.37/$m^3$. Note that the main element (excluding discount rate) influencing cost is the cost of stock production.

A more comprehensive financial analysis of hybrid poplar plantations on marginal agricultural land for rotations of 5 to 10 years or 15 years in the Lake States concluded that in most areas they were a high-risk, low-return investment. Many of the assumptions were substantially different than those used in the present report. The discount rate was 8%, average yields were about 115 m^3/ha, and a variety of additional costs were included.

The authors did sensitivity analyses for several factors (not including planting stock cost). They concluded that investment performance was most sensitive to product value (their average was about $21/m^3), yields, irrigation costs and harvest costs. Of particular relevance to plantation culture of poplars in western Alberta, the impact of size and distribution of plantations on costs of administration and of harvesting. It was suggested that costs would increase if plantations were smaller than about 40 ha.

ORGANIZATIONAL OPTIONS

An earlier report to the Users Committee (Lester 1993) noted the need for access to leadership and to technical expertise in operating a successful tree improvement cooperative. The following options consider how the Users Committee might meet those needs. Three members of the Users Committee have indicated that the creation of a staff position dedicated to plantation culture and tree improvement within their company is unlikely. One company is planning to have such a position and one company has filled a position with a person having some experience in plantation establishment and culture.

Internal

1. The Users Committee could finance a leadership position, either within one of the member companies or as a staff position for the Users Committee.

   (Comment: The workload associated with a project to conduct research and development in preparation for the production of 2700 hectares of genetically improved plantations annually may be within the organizational ability of one person though far beyond the physical ability. As a consequence, substantial contributions of time and money would be required from each cooperator.)

2. The Users Committee could finance a small team to do the whole job with minimal inputs from cooperators.

External

Perhaps the Users Committee could access leadership and technical expertise through:

1. Alberta Forestry, Lands and Wildlife

   (Comment: Extensive experience exists in tree improvement, a plan has been written for a program of tree improvement in poplars (Rajora 1991), and components of land assessment and plantation culture perhaps could be added. A program of the size described here would attract some interest at the provincial level.)

2. University of Alberta

   (Comment: Technical expertise may be available but active leadership might be more difficult to obtain unless a dedicated position was established.)

3. Existing Tree Improvement Poplar Cooperatives

(Comment: Extensive experience and expertise is available for tree breeding and plantation culture. Some of the required technical activities could be accomplished with minimal local input and access to a broader range of genetic materials could be obtained. Strong local leadership would be required.)

4. Consultants

(Comment: Technical expertise is potentially available from several sources. A successful program relying on consultants would need to satisfy the need for leadership, either by extensive participation of consultants in early program development, or by strong local leadership. Extensive in-kind contributions <u>delivered when needed</u> also would be required.)

LIST OF CONTACTS

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