Controlled Parentage Program Plan for the Region J Lodgepole Pine Tree Improvement Project in the Northwest Boreal Region of Alberta

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Alberta Tree Improvement and Seed Centre
Alberta Sustainable Resource Development
Smoky Lake, Alberta T0A 3CO

For further information regarding this report, please contact:

Leonard Barnhardt
Alberta Tree Improvement and Seed Centre
Alberta Sustainable Resource Development
Smoky Lake, Alberta T0A 3C0
e-mail:Leonard.Barnhardt@gov.ab.ca

Note: This report is one of a series of Controlled Parentage Program Plans being developed by Alberta Tree Improvement & Seed Centre. These reports generally follow a standard format and, where applicable, may contain duplicate information.

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1.0 INTRODUCTION

Tree improvement through selection and breeding has a long history in Canada; the earliest tree improvement programs date back to the 1950's. In Alberta, tree improvement was started in 1975. Despite modern advances in biotechnology and their widespread applications in crop breeding, tree breeding programs have remained largely conventional using traditional plant breeding methods for selection, breeding and improved seed production. Forest trees are long-lived perennial plants and have life cycles that invariably span many decades to several centuries. As a result, progress is often relatively slow and time demanding. Project development and completion timelines are often long (30 years and over) and many years may pass before any practical benefits are realized. Because of the long timelines, project plans need to have a built in flexibility to accommodate changes in objectives and methodology over a period of time and reasonable assurances must exist for project continuity and quality control through completion of various project phases.

Lodgepole pine is one of the most important commercial forestry species in Alberta. Approximately 33 million lodgepole pine trees are planted each year to regenerate harvested and denuded areas. The species is a significant vegetative component in the Lower Foothills, Subalpine and Montane Natural Subregions and a major component of the Upper Foothills and Upper Boreal Highlands Natural Subregions of Alberta. It also has a notable presence in the Boreal Subarctic Natural Subregion.

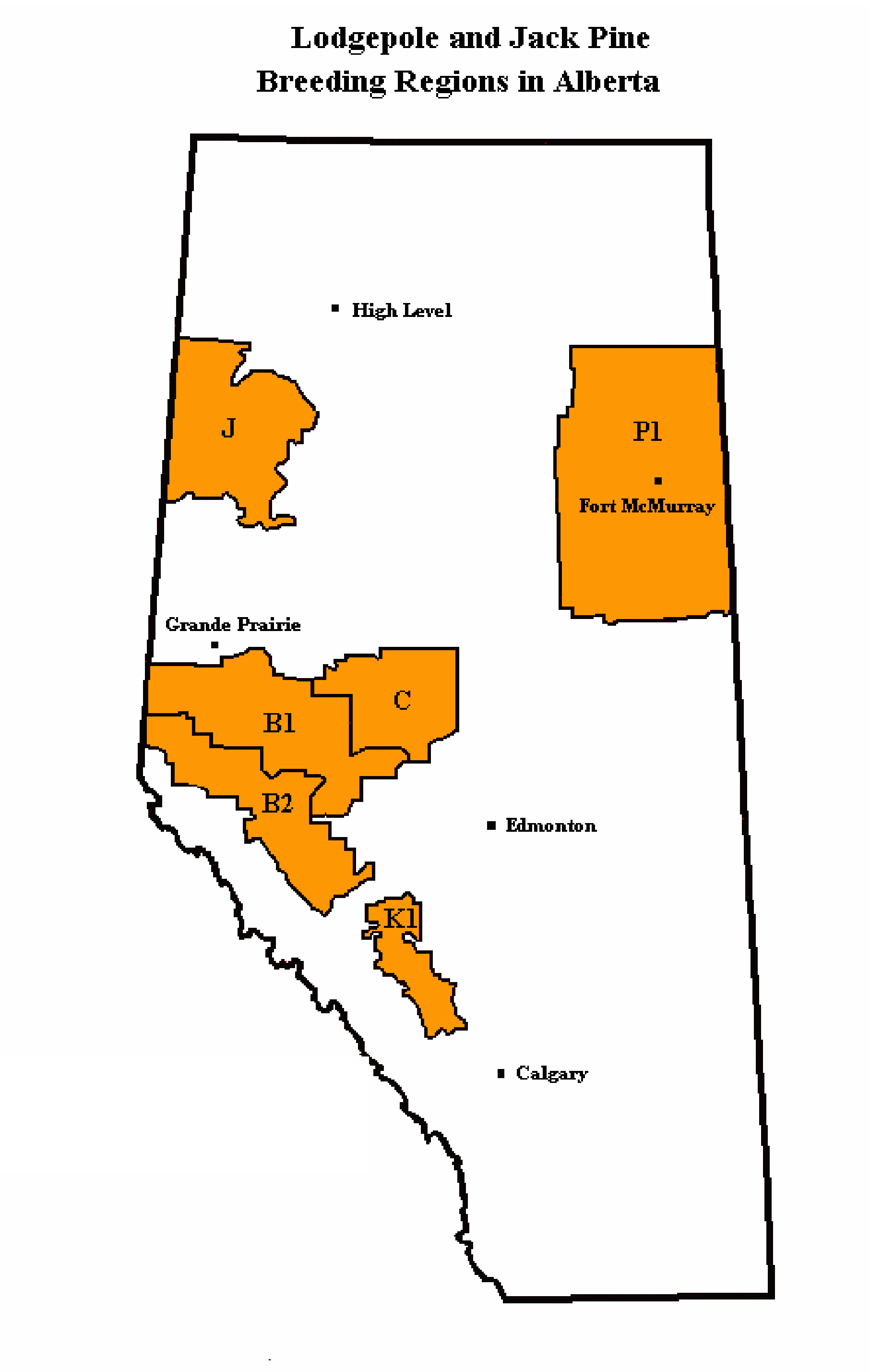
This report describes a breeding plan or Controlled Parentage Program Plan (CPP) for genetic improvement of lodgepole pine in Breeding Region J located in the northwest boreal region of Alberta (Figure. 1). There are six lodgepole pine breeding regions delineated in Alberta at present and each breeding region corresponds to a separate lodgepole pine genetic improvement project. Although Region J is designated as a lodgepole pine breeding region and is predominantly lodgepole pine, it occurs in an area of known hybridization with jack pine.

2.0 PROJECT HISTORY

The Breeding Region J lodgepole pine project was initiated in 1995 as a cooperative project with a major part of the funding provided by the Manning Diversified Forest Products (MDFP) Research Trust Fund. Other forest industries in the area were contacted for participation in the project; MDFP and Daishowa-Marubeni (DMI) were the only companies willing to participate. Canadian Forest Products (Hines Creek) was receptive to the project for some time but declined after further consideration. Fairview College participated in the project for a few years (1996-1998) with the interest that some of the project activities (mainly seed orchard management) might provide opportunities for student learning and summer employment. However, the college withdrew from the project in May 1999 after a management program review and policy change. DMI also withdrew from the project after a few years. However, during these changes, the project work continued relatively unaffected because the project was led by the Alberta Tree Improvement and Seed Centre (ATISC) supported by MDFP Research Trust Fund funding and a strong commitment by MDFP. Interim work program adjustments were made during this period and new partnerships developed which included Tolko Industries, High Level (TIHL) and the North Peace Applied Research Association (NPARA). In 2005, the Forest Genetics Alberta Association (FGAA) was formed and joined in as a new cooperator to provide program coordination and carry out several project activities on behalf of the project partners.

The project concept was revisited and its scope expanded to include additional areas belonging to the Lower Boreal Highlands Subregion to the north when TIHL joined the project in 2000. As a result, the breeding region delineation was modified in 2000 and the seed orchard genetic base was broadened with additional selections from the new area.

Figure 1: Lodgepole Pine Breeding Regions of Alberta



NOTE: Breeding region boundaries are generalized in this Figure and are not exactly as shown

3.0 COOPERATORS

At present (2006), the project has three partners, as listed below, with their share in the project.

Manning Diversified Forest Products Ltd (MDFP) - 50%
Alberta Tree Improvement and Seed Centre (ATISC) - 40%
Tolko Industries High Level (TIHL) - 10%

The project partners are the 'owners' of the project and are responsible for project operations and costs. A formal agreement defining ownership rights, roles, responsibilities and obligations of the partners is under development.

In addition, the Manning Forestry Research Fund (formerly Manning Forestry Development Research Trust Fund) has participated in the project by providing annual funding to ATISC (currently in its 11th year of renewal) for research, technology transfer and conservation aspects of the project. NPARA participates in the project through contract delivery of some technical services to the project and leasing land at its farm in North Star for the seed orchard.

There is also a cooperative arrangement with the B.C. Ministry of Forests and Range (BCMoFR) which links the work in the J project with lodgepole pine research and conservation efforts in the adjoining Peace Plateau area of northeastern British Columbia through exchange of genetic stock and scientific information.

4.0 ECOLOGY AND GENETICS OF LODGEPOLE PINE

4.1 Ecology and Reproduction

Lodgepole pine occupies a large geographic range. It extends from central Yukon southward to Mexico, although distribution is spotty south of central California and central Colorado; and from the Pacific coast eastward to the Black Hills of South Dakota. In Alberta, lodgepole pine is distributed along the mountains and foothills in the west. Outlier populations occur at higher elevations in boreal hill systems to the east and a large isolated population occurs in the Cypress Hills.

Two varieties of the species are found in Canada: *latifolia* and *contorta*. The variety *contorta* is small (up to 15 m in height) and confined to rocky ridges, coastal sand dunes and bogs in a relatively narrow strip along the Pacific coast. The variety *latifolia* is associated most commonly with mountains and foothills where it can occupy both well and poorly drained soils including those with a calcareous substrate. This is the variety of lodgepole pine found in Alberta and it is widely distributed in the Rocky Mountains and foothills of the province. It is a medium sized tree with a tall, straight, clean stem. It reaches heights of 20 - 30 m or more. It is an early successional, fire adapted and cordilleran species and commonly occurs in pure and often extensive even aged stands particularly at higher elevations. At lower elevations, in the transition to boreal, montane and parkland forests, it occurs on mixedwood ecosites as an early successional codominant with trembling aspen. In these areas, it tends to dominate on poorer and coarser textured upland soils or along bog margins where both soil drainage and nutrient status are poor. It is well adapted to the mountains and foothills of Alberta, which have shorter and cooler growing seasons but milder winters than is typical for the province. Although it is tolerant to a wide range of climatic, soil, moisture and nutrient conditions, its best growth occurs in well aerated till soils of loam texture and mixed coarse fragment size.

Lodgepole pine is a prolific seed producer and can begin producing viable seed at five to ten years of age. Thereafter, good seed crops are produced at intervals of one to three years with light production occurring during intervening years. Prolific seed production and retention due to cone serotiny leads to extremely heavy seed fall from cones opened by fire onto seed beds prepared by fire. This adaptation allows lodgepole pine to establish extremely dense stands to the exclusion of other species. With the short fire return intervals typical of Alberta, this often leads to extensive areas of fire maintained sub-climax lodgepole pine.

4.2 Genetics and Tree Breeding

Lodgepole pine is a highly variable species and is characterized by a large amount of genetic variation. Of the four varieties of lodgepole pine identified (*contorta, latifolia, murrayana, and bolanderi*) (Critchfield 1957), *latifolia* is the only variety found in Alberta.

It readily hybridizes with jack pine where the natural ranges of the two species overlap. Hybridization has been reported in a broad zone in west-central Alberta and on the slopes and tops of boreal hill systems in the north (Critchfield 1985; Rudolph and Yeatman 1982;). Hybrids tend to occupy environments intermediate to the parental species following a pattern of increased 'boreality' related to decreasing longitude and altitude. Hybrids have intermediate characteristics and can be easily identified with molecular, cone and needle characteristics (Wheeler and Guries, 1982). Hybridization with jack pine is also reported to have played a significant role in the evolution of pest resistance in lodgepole pine. A strong relationship has been reported between pest incidence in lodgepole pine populations and their distance from the western edge of the natural distribution of jack pine (Wu et al. 1996) i.e. the closer a lodgepole pine population is to the natural range of jack pine, the higher its resistance to pests.

Range-wide and regional geographic variation in lodgepole pine and the relationship of this variation to climate and geography has been studied in detail through provenance and provenance-family tests established in British Columbia (Ying et al 1985; Rehfeldt et al. 1999; Wu and Ying, 2004). The British Columbia studies are mainly based on a very comprehensive provenance trial series referred to as the Illingworth tests planted in 1974. The series consists of 140 provenances or populations planted at 60 test sites spread over 11 eco-regions in British Columbia. The tests have been measured over 20 field growing seasons for survival and growth characteristics and results have been reported in many publications. Another important study in B.C. is a combination provenance-family test (778 OP half-sib families representing 53 provenances) planted at one site near Prince George, B.C. A summary of the key results and conclusions from these trials is given below.

- Site and provenance variables markedly affect the growth of lodgepole pine. After 20 growing seasons, there was a four-fold difference in mean tree height (250 – 1012 cm) among sites reflecting a very wide range of geography and climate. Variances associated with site and provenance together accounted for 82% of the total variation, and the provenance effect was twice the magnitude of the site effect (52% vs. 24%).
- Variances due to interaction between site and provenance were statistically significant in all 12 regions except 1 but accounted for only 4% of the total phenotypic variation.
- Tree height was related to geography (latitude, longitude and elevation) with statistically significant multiple regressions fit for all sites (R^2 = 0.63 to 0.92); 72% (41) of the sites had $R^2 >$ 0.80. Provenance variation in pest resistance was also strongly related to geographic origin of the provenance and essentially followed longitudinal and elevational clines. Regression models accounted for 38% – 80% of the variation.

- There is a geographic cline oriented from southwest to northeast in British Columbia with a steep west-east longitudinal incline; the farther west the provenance site, the less the optimality of the local population. The elevational cline was much less steep but demonstrated that the higher the elevation of the site, the less the optimality of the local population. A latitudinal cline was not as apparent; local populations were optimal at nearly all sites (51 out of 53). The geographic cline parallels the general climate pattern in British Columbia. Mean annual temperature (MAT) and mean temperature of the coldest month (MTCM) were the most effective variables for predicting provenance height and the ratio of summer temperature to summer moisture was the best predictor for provenance survival at the test sites.
- Position of optimal populations also showed geographic patterns. Along the longitudinal gradient, optimal populations were east of the test sites for nearly all sites at an average directional distance of 3.05° (range 0.25°- 8.56°). Along the elevational gradient, optimal populations were mostly at lower elevations than the test sites. Where optimal populations were located at elevations higher than the test sites, they were very close to the site, mostly within 100m altitude. Non-optimality of local populations was found at high elevation sites in the southern B.C. interior, whereas local optimality prevailed mostly at mid- to low-elevation sites (below 1000 m). Along the latitudinal gradient, local optimality prevailed at almost all sites. Average absolute directional distance between the location of the optimal population and the test site was 1.05° (range: 0.11° – 4.28°) with 60% of the sites being less than 1.0° away from the optimal seed source.

A series of lodgepole pine provenance trials (G134) was established in Alberta during 1985 – 1990 at 9 test sites. The trials contain a total of 21 lodgepole pine provenances from throughout the species range in Alberta. In addition, 9 jack pine and 6 putative lodgepole-jack pine natural hybrid provenances from Alberta are also included. The trials were measured at ages 5, 10, 15 and 20 years for survival, height, diameter at breast height (dbh) and climatic and pest injury. Assessment results up to 15 years have been summarized (Rweyongeza and Yang 2005). Key results and conclusions regarding lodgepole pine provenances from the study are summarized below.

The analysis of variance revealed significant ($P < 0.01$) variation among lodgepole pine provenances for 15-year height (H15), mean annual height increment between age 5 and 15 years (MAI) and diameter at breast height (D15). The site mean and range of provenance means across sites appear in Table 1.

Table 1. Site Means and Range of Provenance Means Across Sites for the G134 Provenance Trials

Site	H15 (m)	MAI (cm)	D15 (cm)	S15 (%)	PM (%)	WGR (%)
A Calling Lk.	4.48 ± 0.21	38.2 ± 0.4	7.4 ± 0.4	89.5 ± 3.7	0.8 ± 0.2	11.0 ± 3.7
B Hay River	3.77 ± 0.21	30.1 ± 0.2	6.3 ± 0.4	59.6 ± 3.7	1.7 ± 0.2	-
D Swartz Ck.	5.63 ± 0.21	46.0 ± 0.2	9.7 ± 0.4	83.7 ± 3.7	0.4 ± 0.2	-
E Hangingstone	6.19 ± 0.21	51.0 ± 0.2	9.7 ± 0.4	89.6 ± 3.7	0.8 ± 0.2	-
G Carson Lk.	5.30 ± 0.21	42.6 ± 0.2	8.4 ± 0.4	88.8 ± 3.7	0.8 ± 0.2	53.1 ± 3.7
H Diamond H.	4.89 ± 0.21	38.3 ± 0.2	8.1 ± 0.4	90.6 ± 3.7	0.6 ± 0.2	58.1 ± 3.7
I Castle Lk	3.18 ± 0.21	25.8 ± 0.2	4.7 ± 0.4	62.6 ± 3.7	1.4 ± 0.2	7.7 ± 3.7
J Pine Ridge	3.97 ± 0.21	31.6 ± 0.2	8.2 ± 0.4	90.1 ± 3.8	0.6 ± 0.2	-
+Mean	4.68 ± 0.39	38.0 ± 0.3	7.8 ± 0.7	81.8 ± 5.0	0.9 ± 0.2	32.1 ± 3.7
++Range	3.46 – 5.12	26.0 – 43.2	5.0 – 9.0	74.0 – 90.6	0.7 – 1.1	12.3 – 59.5

+ and ++ –Overall mean and range of provenance means across sites; (-) –Data not available

Note: Trial at one site (F-Mitsue south) was damaged by fire and was excluded from analysis; one provenance was also dropped from analysis because of questionable seed origin information

H15 = height at age 15 years; MAI = mean annual increment between age 5 and 15 years; D15 = diameter breast height at age 15; PM = periodic mortality; WGR = western gall rust infection

Growth in height and diameter were significantly ($P < 0.01$) related to latitude and elevation at the place of seed origin (Figures 2 through 5). From the regression of H15 and D15 on latitude and elevation of seed origin, it was determined that provenances of highest growth potential originated from 55^o – 56^o north latitude and 1000 – 1100 m above sea level.

It should be noted that the curvilinear relationship of height and dbh growth potential with latitude and elevation as illustrated in Figures 2 through 5 results from the complex topography of Alberta where elevation increases southward, thus counteracting the effect of declining latitudes on climate (temperature). With this type of landscape, provenances of low growth potential occur both at high latitude, low elevation locations in the north and low latitude, high elevation locations in southwestern Alberta (see Figure 6). Thus, factorial regressions of H15 and D15 on provenance latitude and elevation provide equations with better predictive power and coefficients that are easily interpretable. These equations are as follows:

Height (H15):

$$H15 = 26.1071 - 0.38064 \times Lat - 0.01987 \times Elev + 0.00035645 \times Lat \times Elev \quad [1]$$

$R^2 = 0.80$ ($P < 0.0001$)

DBH (D15):

$$D15 = 60.601 - 0.94185 \times Lat - 0.04597 \times Elev + 0.00082555 \times Lat \times Elev \quad [2]$$

$R^2 = 0.78$ ($P = 0.0001$)

Where Lat and $Elev$ stand for latitude and elevation of seed origin, respectively. These equations indicate that at a given latitude, height and dbh growth potential would decline with an increase in elevation of seed origin. Likewise, at a given elevation, height and dbh growth potential would decline with an increase in latitude of seed origin. This decline in growth potential along latitudinal and elevational gradients is consistent with results of other lodgepole pine studies (see a review by Rweyongeza and Yang 2005).

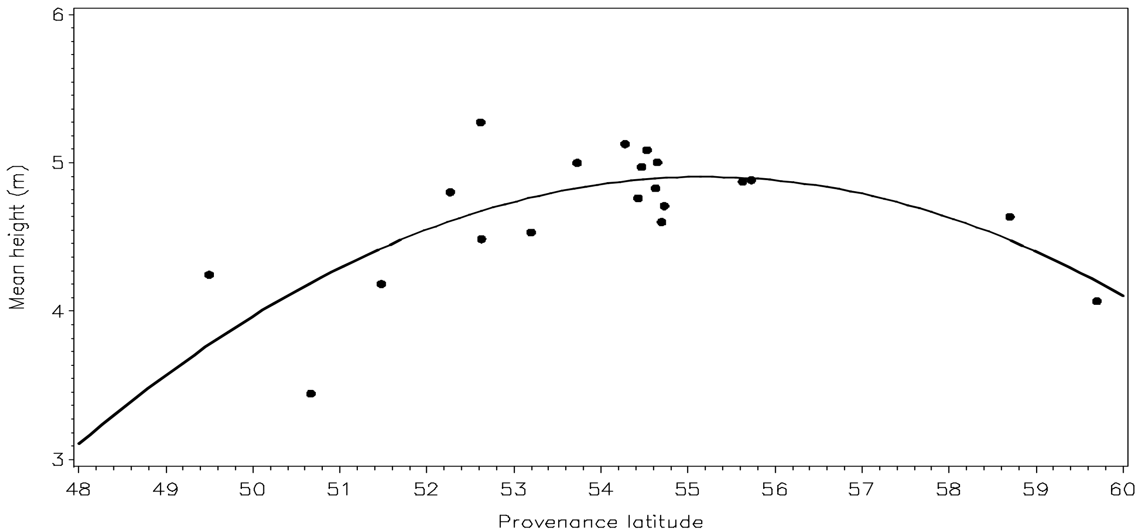


Figure 2: **Height Growth Potential in Relation to Provenance Latitude**

Equation: $H15 = -101.083 + 3.84035 \times Lat - 0.03478 \times Lat \times Lat$
$R^2 = 0.53$ ($P = 0.0016$);Optimum location: 55.2 (55°12' N)

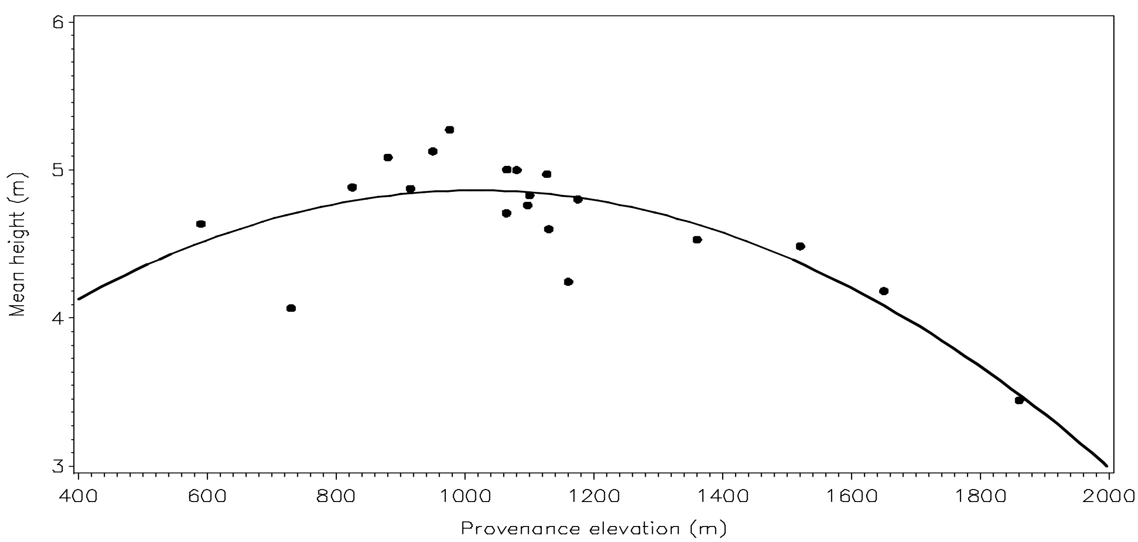


Figure 3: **Height Growth Potential in Relation to Provenance Elevation**

Equation: $H15 = 2.8665 + 0.00393 \times Elev - 0.000001935 \times Elev \times Elev$
$R^2 = 0.64$ ($P = 0.0002$);Optimum location: 1016 metres

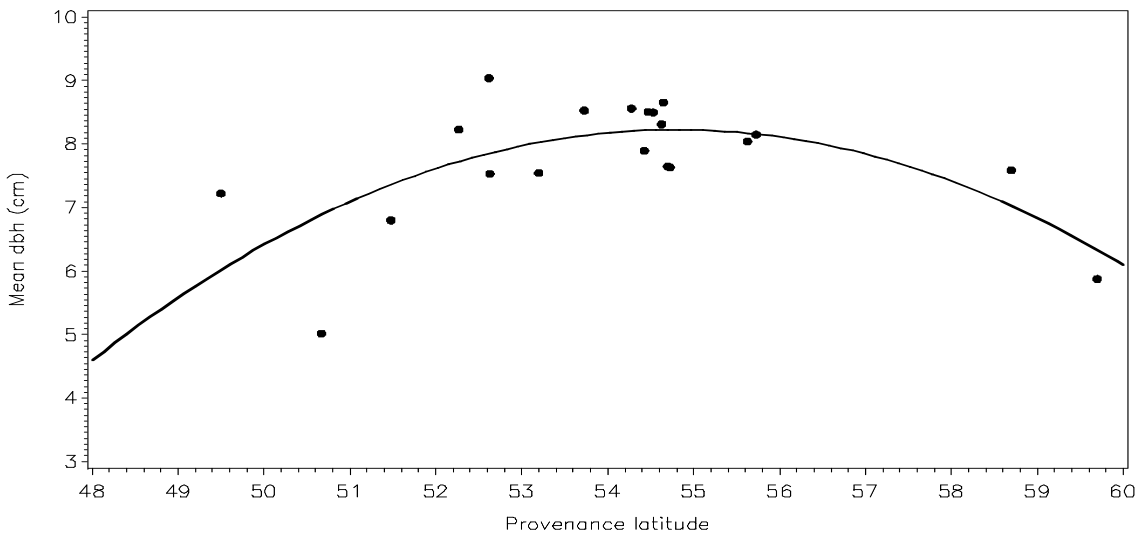


Figure 4: **Diameter Growth Potential in Relation to Provenance Latitude**

Equation: $D15 = -227.818 + 8.6153 \times Lat - 0.07861 \times Lat \times Lat$
R^2 = 0.49 (*P = 0.0034*);Optimum location: 54.8 (54°48' N)

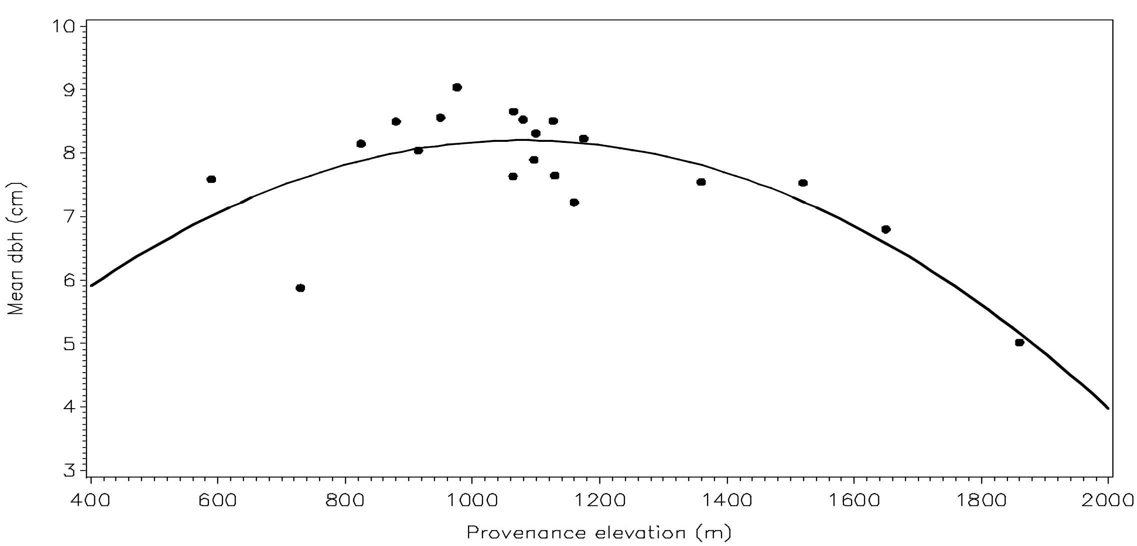


Figure 5: **Diameter Growth Potential in Relation to Provenance Elevation**

Equation: $D15 = 2.4093 + 0.01074 \times Elev - 0.000004977 \times Elev \times Elev$
R^2 = 0.62 (*P = 0.0003*);Optimum location: 1079 metres

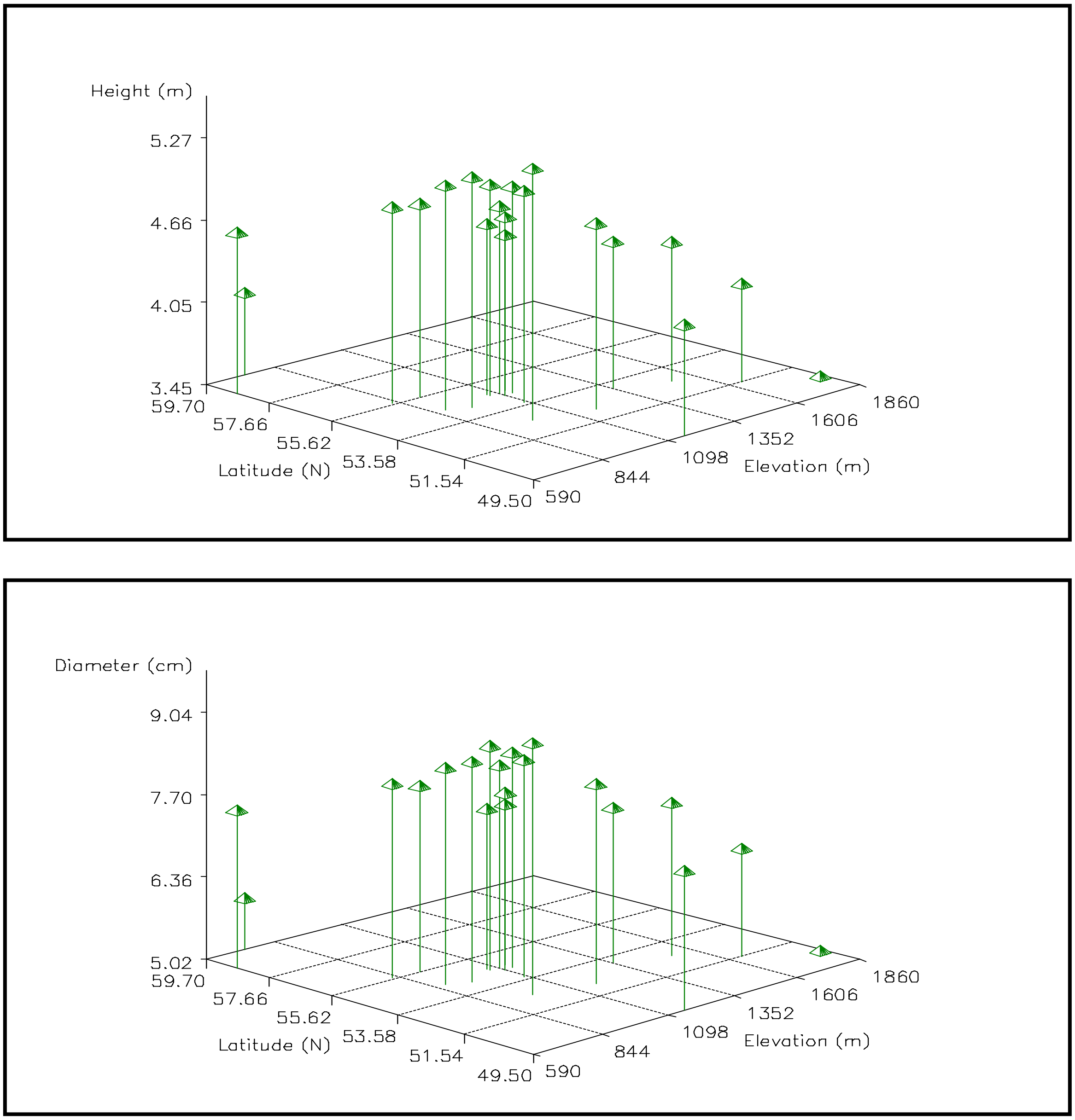


Figure 6: **Scatter Plot of 15-Year Height and Dbh of Lodgepole Pine Provenances as Related to Latitude and Elevation of Provenance Origin.**

There was no significant variation among provenances for 15-year survival (S15) and annual mortality (PM) between ages 5 and 15 years. In addition, there was no significant relationship between survival and geographic variables associated with seed origin. The incidence of western gall rust (WGR) was assessed only on four test sites, and variation among provenances was significant (12.3% – 59.5%; $P < 0.01$). Site means and the range of provenance means across sites for survival and gall rust incidence appear in Table 1.

Growth in height and diameter exhibited significant (*P < 0.0001*) provenance × site (P × S) interaction and the P × S variance was 41.6%, 36.2% and 37.0% of the provenance variance for H15, MAI and D15, respectively. P × S interaction was also significant (*P < 0.01*) for WGR and equaled 35.2% of the provenance variance component.

For the 6 putative hybrids, the range of H15 means was 4.77 – 5.02 m; this was entirely within the range of H15 means for the lodgepole pine provenances. Likewise, the range of provenance means for WGR for hybrid provenances was 15.9% – 42.4%, which is similar to that of the lodgepole pine provenances.

Fourteen years after field establishment, the G134 series of provenance trials has a high survival rate, with the exception of the northernmost (Hay River) and highest elevation (Castle Lake) sites where survival is only moderate. High genetic differentiation among provenances for growth traits has been observed, with height and growth potential varying along elevational and latitudinal gradients. This series of provenance trials has contributed significantly to our understanding of the impact of climate on the population structure of forest tree species in Alberta and of the differences in climatic adaptation between lodgepole and jack pine. This information will facilitate matching lodgepole pine provenances to planting sites to optimize production without compromising adaptation in both present and future climates.

Ecological genetics studies of lodgepole pine populations in the U.S. Rocky Mountains region were summarized by Rehfeldt (1988) who combined the results from three separate studies to describe adaptive variation of the species in the Rocky Mountain (USA) region. The studies consisted of common garden studies of a total of 173 populations representing the geographic and ecological distribution of the species in three geographic areas (central and eastern Idaho, western Wyoming and Utah). The results showed that the variation for 3-year old tree height (studied at two sites located at 900 m and 1500 m elevation), periodicity of shoot elongation of 2-year old trees in a greenhouse, and freezing tolerance in early autumn in a laboratory study followed a clinal pattern that generally reflected regional elevational and geographic gradients in the frost free period. Regression models accounted for 45% – 77% of the variance among populations. Elevation clines were steep, indicating that populations separated by as little as 300 m in elevation within the same geographic region were expected to differ significantly.

Information on genetic variation of lodgepole pine is available from biochemical studies mainly dealing with population genetics, taxonomy and evolution of the species (Wheeler and Guries 1982, Yeh et al. 1985) and field trials (Xie and Ying 1996, Wu and Ying 1997, Wu et al. 1997) established as part of lodgepole pine tree improvement programs. The main conclusions from the field trial data are that a large amount of variation exists within stands and among families for growth, pest resistance, cold hardiness and wood quality. Furthermore, these traits have poor to moderate heritability and significant genetic gains can be made through selection and breeding. A summary of results from Alberta lodgepole pine genetic testing projects is given in Table 2.

Table 2. Summary of Lodgepole Pine Genetic Studies in Alberta

Study or Reference	Materials and Field Testing	Results - Genetic Parameters
G127. Region B1 OP half-sib family test (Dhir et al. 1996)	Foothills low elevation region 400 families; 4 test sites; 6-year, 11-year and 14-year results	1. Heritabilities for height (6-yr, 11-yr and 14 yr, respectively) for combined sites analysis: h_i^2 = 0.042, 0.064, and 0.115; h_f^2= 0.25, 0.32, and 0.48; 2. Heritabilities for 14-yr Dbh for combined sites analysis: h_i^2 = 0.054, h_f^2 = 0.293; 3. Family by Site interaction was significant for all height measurements and Dbh; 4. Age-age genetic correlations for height were: 6/11 yr = 0.73, 6/14 yr = 0.662, 11/14 yr = 0.915; 5. 14-yr height/Dbh correlation: r_g = 0.823; r_p = 0.909
G128 Region C half-sib family test (Wu et al. 1997)	Swan Hills area lower elevation region 110 families (partial set of G128); 4 test sites; 9-year results	1. Heritabilities for 9-yr height (combined sites): h_i^2= 0.14, h_f^2 = 0.39; 2. Family by site interaction was significant for height and the variance component was 117% of the size of the family variance component; 3. Type B genetic correlations for height among site pairs = 0.20 to 1.08, family mean correlations among site pairs = 0.07 to 0.38.
G154 Region B2 half-sib family test (Yang et al. 1996)	Foothills high elevation region 456 families; 2 test sites; 6-year results	1. Heritabilities for height (individual sites): h_i^2 = 0.14 - 0.29, h_f^2 = 0.26 - 0.38, h_w^2 = 0.12 - 0.27; 2. Heritabilities for western gall rust incidence (WGR)(individual sites): h_i^2 = 0.14 - 0.41; h_f^2 = 0.23 - 0.53; h_w^2 = 0.12 -0.27; 3. Family x site interaction was significant for height and WGR; 4. Type B genetic correlation between sites for height = 0.18; for WGR = 0.26.
G293 Region K1 half-sib family test (Rweyongeza and Barnhardt 2004) (Hansen 2007)	Upper foothills region 102 families; two test sites; 6-year results 90 families; two test sites;11-year results	1. Heritabilities for 6-yr height (combined sites): h_i^2= 0.21, h_f^2 = 0.62, h_w^2 = 0.16; 2. Heritabilities for 11-yr height (combined sites):): h_i^2= 0.36, h_f^2 = 0.67, h_w^2 = 0.31; 3. Heritabilities for 6-yr plant vigour scores(combined sites): h_i^2 = 0.15,h_f^2 = 0.56, h_f^2 = 0.11; 4. Family by site interactions were significant for height at both 6 yr and 11 yr and the variance components were 30.5% and 23% of the family variance components at 6 yr and 11 yr, respectively; 5. Type B genetic correlations for height were 0.77 and 0.89 at 6 yr and 11yr, respectively 6. Type B family mean correlations for height were 0.47 and 0.54 at 6 yr and 11 yr, respectively 7. Type B genetic correlation for 6 yr vigor was 0.85 and family mean correlation was 0.41
G346 Region J half- sib family tests (Dhir et al. 2006)	Lower foothills region 97 families; two test sites; 6-year results	1. Heritabilities for 6-yr height (combined sites): h_i^2= 0.19, h_f^2 = 0.61, h_w^2 = 0.15; 2. Family by site interaction was significant for height and the variance component was 33.5% of the family variance component; 3. Type B genetic correlation between sites for height was 0.58, family mean correlation for height was 0.39.

h_i^2 = individual tree heritability; h_f^2 = family heritability; h_w^2 = within family heritability; r_g = genetic correlation; r_p = phenotypic correlation

5.0 PROJECT OBJECTIVES

The Breeding Region J project is required to fulfill genetically improved seed needs for reforestation of the appropriate operable areas of the breeding region for the project partners. In addition, the seed may be used for conservation and scientific needs. Deployment zones and strata for reforestation are described in the next section of the report. The total annual planting program using improved lodgepole pine seed for the breeding region is estimated to be 750,000 trees per year.

The objectives of the tree improvement project are as follows.

1. Produce regionally adapted high quality seed for reforestation planting, conservation and scientific needs in Region J. The seed must meet or exceed ecological adaptation and genetic diversity requirements specified in the Standards for Tree Improvement (STIA) for Green Area Deployment in Alberta. The seed, where appropriate, may also be used for afforestation, reclamation of denuded lands, horticulture and woodlot uses.
2. Obtain modest genetic improvement for growth and yield and climatic and pest hardiness (particularly WGR) while maintaining baseline wood quality characteristics of the wild population i.e. wood density must not decline with selection and breeding for growth traits.
3. Conserve regional wildland resources of lodgepole pine through *in situ* and *ex situ* conservation in accordance with the provincial Gene Conservation Plan for Native Trees of Alberta (ASRD 2007)
4. Carry out and support a limited amount of applied research, genetic stock development and monitoring in support of essential tree improvement activities in the region.

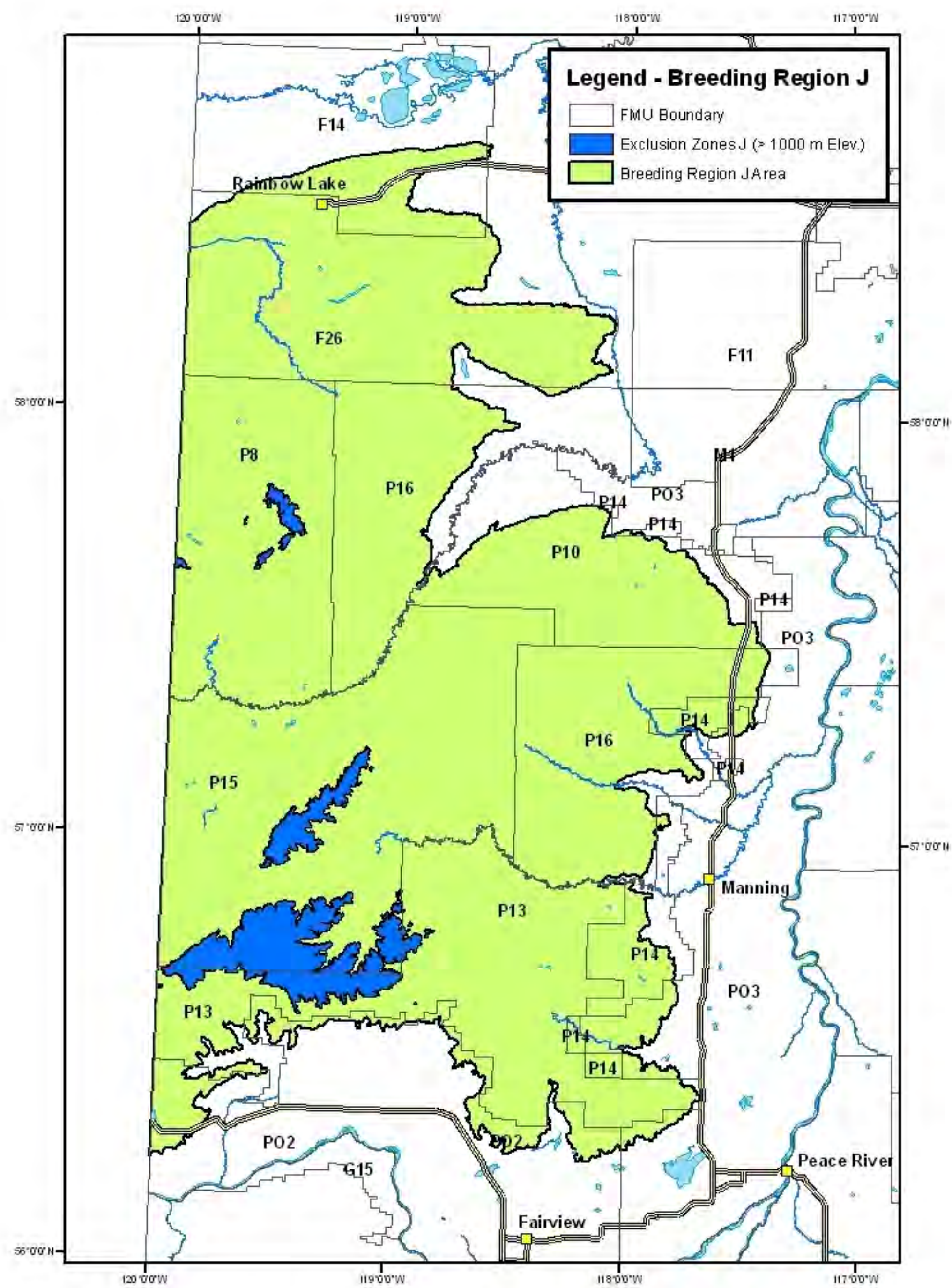
The project described here has a duration of 30 years (1995 - 2025) and is limited to first generation selection and breeding because this adequately fulfills the forest management plan objectives of the project cooperators. MDFP and TIHL are interested in deployment of genetically improved stock to enhance forest productivity and sustainability. ATISC is interested in conservation of wildland genetic resources, strategic seed supply for future needs, genetic stock development for forest improvement and knowledge creation for management of genetic resources in the present and changing climates.

Genetic gain for tree height from the deployment of the improved first generation seed is expected to be about 3% after limited genetic roguing of the seed orchard is completed. Additional genetic gains may be derived through advanced breeding, which is not being considered or proposed at present.

6.0 BREEDING REGION AND DEPLOYMENT ZONE

Breeding Region J as revised in 2000 after the project review and expansion is depicted in Figure 7.

Figure 7: Breeding Region J Map



The general parameters and limits considered in defining breeding region boundaries for the Region J project were:

- a latitudinal range not to exceed two and one-half degrees;
- the elevation range from lower to upper boundary not to exceed 500 m;
- boundaries for the region to be kept within a homogenous bioclimatic area;
- integrity of Forest Management Unit (FMU) and Forest Management Agreement (FMA) boundaries maintained.

The final upper boundary for Breeding Region J was established as the 1000 m contour while the lower boundary Ranges between 700 m in the south to 500 m in the north and follows the lower boundary of the Lower Boreal Highlands Natural Subregion.

6.1 Location and Area

Breeding Region J lies between 56°10' and 58°40' N latitude and 117°20' and 120°00' W longitude as shown in Figure 7. The total delineated area is 2,652,170 ha of which 2,449,374 ha (92%) are under tenure and 1,386,862 ha (52%) are operable. Elevations within the geographic boundaries of J range from less than 500 m along the northern base of Zama Ridge to 1,219 m at Doig Lookout on Halverson Ridge. Within J, the deployment zone and operational elevations for the project are approximately 700 m to 1000 m in the south and 500 m to 600 m at the northern limit.

6.2 Forest Cover

Based on Phase 3 inventory, within Region J, deciduous dominated forest types cover approximately 60% of the forested land area and coniferous dominated types cover approximately 40%. On the coniferous land base, coniferous cover types are 40% white spruce, 20% black spruce and 40% pine, as determined by species dominance.

Mixed and pure trembling aspen, pine, white and black spruce upland forest types make up a major portion of the vegetation of this breeding region. Balsam poplar and paper or Alaska birch are frequently a stand component on moister sites. Deciduous forest types are more common at lower elevations giving way to mixedwood forests at mid elevations and conifer forests dominated by pine at the highest elevations. White and black spruce tend to be mid succession species while balsam fir, which is uncommon due to short fire return intervals, is the climax species. Pines in this breeding region are commonly hybrids between lodgepole and jack pine, particularly in the east and at lower elevations.

Black spruce occurs on moister upland sites and is extensive in the poorly drained areas. Peatland patterned and unpatterned complexes composed of nutrient poor black spruce bogs often with a tamarack component are common.

6.3 Timber Allocation

The coniferous annual allowable cut (AAC) for this breeding region is essentially fully allocated. A breakdown of total area under tenure, operable area and target strata area for deployment of improved stock is provided in Appendix I.

6.4 Natural Regions, Subregions and Climate

Two Natural Subregions belonging to the Boreal Forest Natural Region are represented in the breeding region (see Table 3). The majority of Breeding Region J falls within the Lower Boreal Highlands Natural Subregion (89%) with the remainder falling within the Upper Boreal Highlands (11%) Natural Subregion. Detailed ecological descriptions of Natural Regions and Subregions including those for plant communities can be found in the "Natural Regions and Subregions of Alberta" report 2006, available on the web at: http://www.cd.gov.ab.ca/preserving/parks/anhic/docs/NRSRcomplete%20May_06.pdf.

Climate information based on 1961 to 1990 normals and generated by the Alberta Climate Model (Alberta Environment 2005) is provided in Table 3.

Mean annual temperatures (MAT) for this breeding region indicate that winter temperature inversions typical of the Rocky Mountains and foothills are not sufficient to offset the effect of cooler summers on MAT. In effect, lower MATs in the higher elevation Upper Boreal Highlands Subregion are an indication of the increasing influence of summer temperature lapse rates rather than winter inverse lapse rates which still occur in this area but are not as pronounced as in the southern and south central foothills where inverse lapse rates and frequent Chinooks intensify winter inversions.

The majority of annual precipitation occurs in the form of rain: the monthly maximum occurs in July and two thirds falls during the growing season (April-September). Both average growing season and mean annual precipitation for the breeding region increase with elevation but tend to decrease with latitude. Average growing season precipitation varies from around 280 mm at lower elevations to around 385 mm at higher elevations. Mean annual precipitation follows a similar geographic pattern. Moisture deficits during the growing season can occur occasionally within the Lower Boreal Highlands Subregion but are likely uncommon in the Upper Boreal Highlands section of the breeding region where precipitation amounts are higher and growing season temperatures are lower.

Growing season temperatures for region J are highest at low elevations and decrease notably with increased elevation. Growing season thermal climates for Natural Subregions are represented by growing degree days greater than 5˚C in Table 3 and these are highly and positively correlated with summer temperature variables and therefore indicative of summer temperatures.

Frost free periods (ffp) are highly variable and are quite dependent on topographical position. Frost pockets and areas of cold air drainage may have a mean ffp as low as 20 days at higher elevations and around 50 days at lower elevations. Mean ffp is between 90 and 100 days for areas in the breeding region at lower and mid elevations not affected by cold air drainage or high radiation loss.

6.5 Physiography and Soils

Breeding Region J falls within two major physiographic subregions (Pettapiece, 1986). Small inclusions at lower elevations are classified as belonging to the Northern Alberta Lowlands which consist primarily of undulating morainal plains and areas of level to depressional glaciolacustrine deposits. Parent materials in this subregion are dominantly of clay loam to clay texture and Dark Grey and Orthic Grey Luvisols are the most common upland soils. Areas of Gleysolic and Organic soils occur in poorly drained positions.

A majority of the breeding region, typically falling within the Lower Boreal Highlands Natural Subregion, is classified as belonging to the Northern Alberta Uplands. The topography of this subregion is characterized as ranging from gently rolling to hilly, morainal uplands. The most common mineral soils are Grey Luvisols and Podzols. In level to depressional areas, Organic soils are common and, in total, represent approximately 20% to 25% of the total area in the Upland Subregion. A unique area of level to depressional topography lies along the Chinchaga River drainage in the Upland Region where organic soils developed in a peat cap over till and lacustrine deposits cover approximately 60% of the surface area.

An additional small proportion of the area occurring at elevations greater than 1000 m (falling in areas classified as the Upper Boreal Highlands) is steeply ridged and formed of shallow saprolite deposits and occasional areas of rock outcrops. Dystric Brunisols and Podzols are the most common soils in these areas.

Table 3. Breeding Region J Climate Summary by Natural Subregion

Natural Subregon	*Area (ha)*	*Area (%)*	*MAT(˚)*	*MAP(mm)*	*GSP(mm)*	*GDD>5*	*AMI*	*FFP(days)*
Lower Boreal Highlands	2,354,970	89	-0.9	482	325	1086	2.3	99
Upper Boreal Highlands	297,200	11	-1.4	527	350	954	1.8	93
Breeding Region Mean			-1.1	505	337	1020	2.0	96

MAT= Mean Annual Temperature in ˚C
MAP= Mean Annual Precipitation in mm
GSP= Mean growing Season Precipitation in mm
GDD>5= Degree Days accumulation above 5˚C
AMI= Annual Moisture Index (GDD>5/MAP)
FFP= Frost Free Period in days

7.0 BREEDING PLAN FOR THE FIRST GENERATION

The breeding plan chosen for the project consists of phenotypic mass selection in wild stands within the breeding region and establishment of a clonal seed orchard. A significant amount of additional genetic material, mostly provided by the BCMoFR from the adjacent areas in northeastern British Columbia, is also included after consideration of its adaptability to the J region. Genetic testing includes half-sib family (progeny) testing of the seed orchard parents, some additional selections made within the breeding region but not included in the seed orchard design and suitable adjacent region materials available from the ATISC research and conservation collection. A schematic of the breeding plan is shown in Figures 8. Figure 9 is a chart showing breeding plan activities and timelines (1995 – 2025).

Figure 8: Region J Lodgepole Pine First Generation Tree Improvement Scheme and Timelines

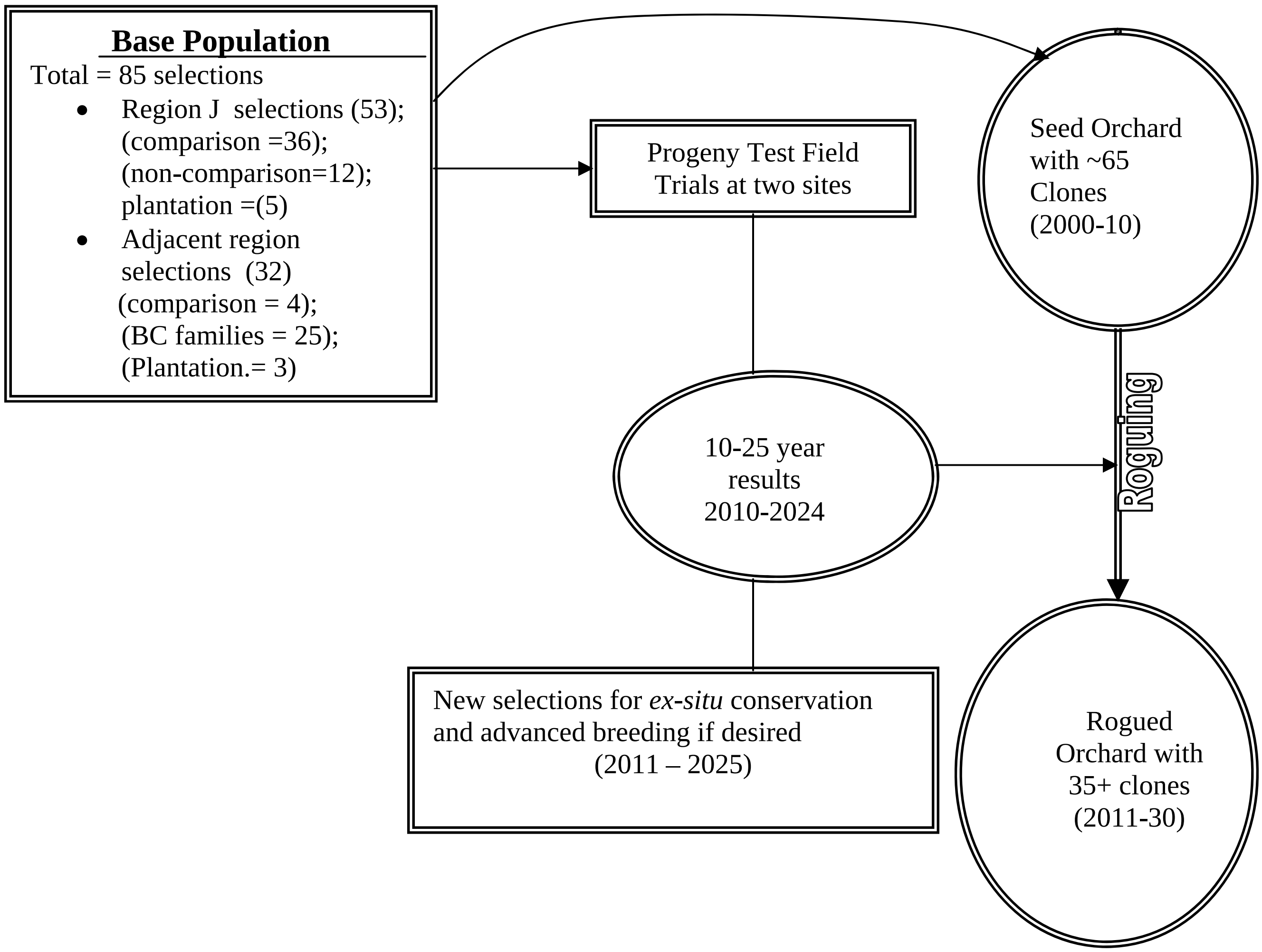
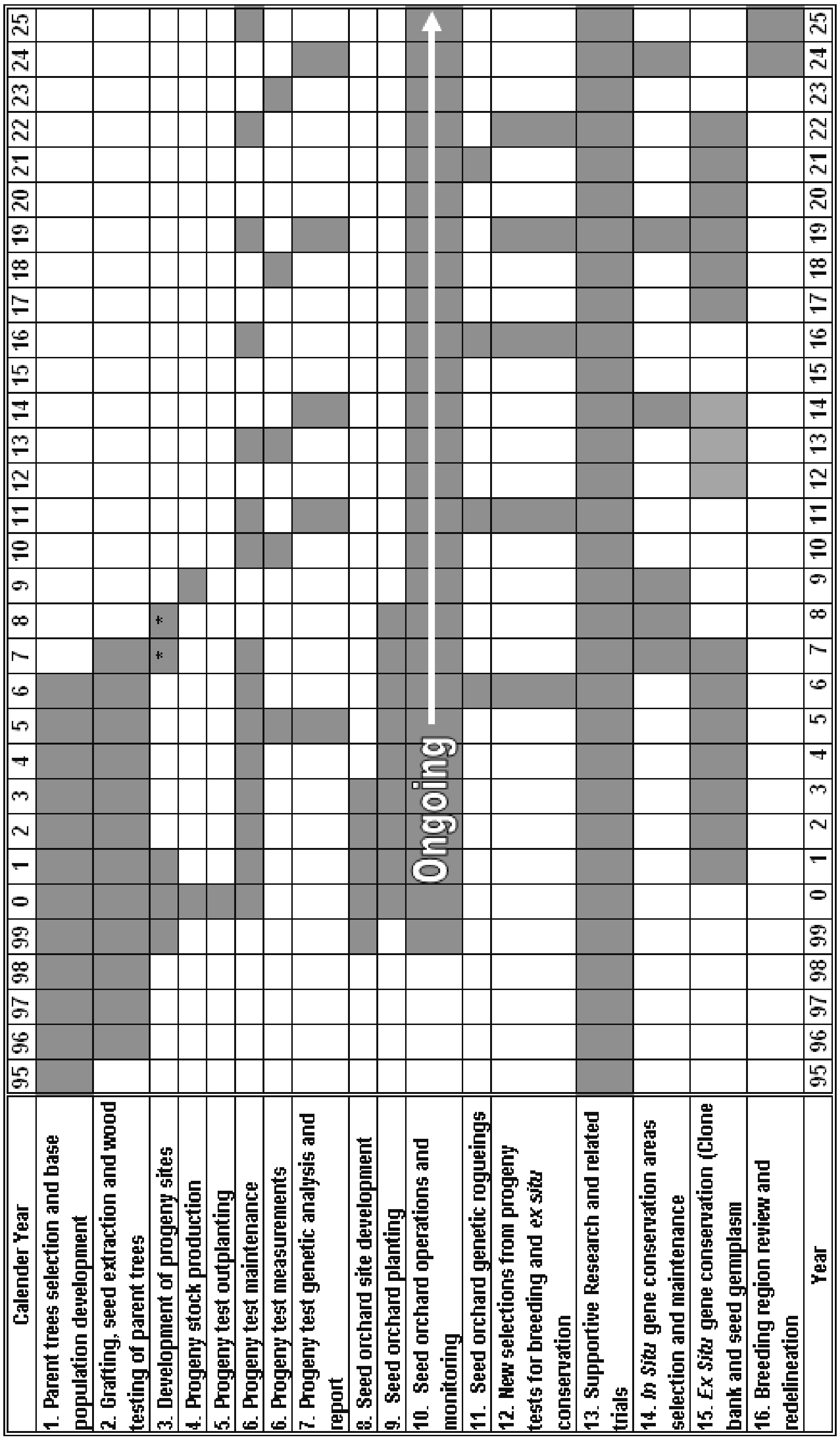


Figure 9: Region J Activities and Timelines



* Zama Ridge Site

7.1 Parent Trees Selection and Base Population Development

Base population genetic stock for the Breeding Region J project consists of 85 parent trees. A description of the parent tree selections is provided in this section and in Appendix II.

Genetic stock acquisition to provide base material for the Region J tree improvement project started in 1995. It included new wild parent tree selections as well as material from the ATISC germplasm collection that was considered to be adapted to the breeding region.

A comprehensive program of new parent tree selections for the project was commenced in 1995 and completed in 2003. As part of this work, a total of 40 parent trees were selected in accordance with the following protocol: a) methodically locate wild stands throughout the breeding region by ground and aerial surveys; b) cruise stands to identify candidate superior trees and document their superiority by the comparison trees method; and c) from each tree collect scions for vegetative propagation, wood samples for wood quality testing and cones to provide seed for genetic testing. Thirty six of these comparison tree selections were made within the breeding region and four were made from adjacent areas in the Saddle Hills.

An additional twelve non-comparison selections to provide representative geographic coverage of the breeding region were completed in December 2003 in Forest Management Units P8 and P9. These trees were documented and seed and wood sample collections made.

Seven plantation selections were made: one fast-growing juvenile tree from a naturally regenerated stand within Region J; four trees of Region J geographic origin with desirable phenotypes and superior height growth at age 10-years from the G134G provenance trial established at the Carson Lake site near Whitecourt; and two forward selections from family 4321, top performer in 6-year height growth in the G346A and G346B progeny trials and representing a parent with no surviving grafts.

In addition to the above selections, BCMoFR was approached for collections from the Peace River Plateau area in northeastern B.C. adjacent to Region J. Twenty-five suitable selections were identified after reviewing parent tree information and the availability of scions and open pollinated progeny seed for genetic testing. One forward selection from the G127A progeny trial for Breeding Region B1 was also included due to the outstanding early performance of this family in the Region J progeny tests (6 year results).

In total, 85 parental selections were made for the Region J project (53 originating within and 32 originating from areas adjacent to Region J) as itemized in Appendix II and summarized in Figure 8.

Selection of all parent trees detailed above followed standard selection methods and procedures used in ATISC cooperative tree improvement projects. All J base population selections are documented and described in 11 ATISC file reports. The file report reference pertaining to each tree is listed in Appendix II along with tree accession, tree origin, type of selection, and parent tree superiority information.

The selection criteria and methodology for parent tree selections were as follows.

<u>Wild stand selections by Comparison Tree method (also referred to as intensive selections)</u> Inventories and other sources of data are reviewed to select promising areas and stands for cruising to select superior trees. Selected stands are geographically spread to sample the target area in a reasonably representative manner and are invariably at least several kilometers apart. They are chosen based on their geographic location and condition: selected stands are well stocked, relatively even aged, healthy, actively growing,

in the mid to mature age range, free of significant damage or defects and have good site productivity. Usually, only one tree per stand is selected in order to maximize genetic sampling of the geographic area covered and to minimize the relatedness of selected trees. However, in some cases, two trees can be selected from the same stand if they are at least 50 m apart. Superior trees are selected by the comparison tree method: each selected tree is compared to three dominant trees growing in the vicinity of the selected tree. The selected trees must have superior height growth, an excellent straight stem, average or better dbh and a narrow crown with thin branches; they must be free of any noticeable insect, disease or climate damage. These standards may be relaxed to accommodate circumstances such as exceptional phenotypes for some trait(s) or limited tree selection choice. This was the predominant method for parent tree selections for the J project.

Wild stands selections made by visual selection method (referred to as geographic or non-comparison selections) These selections are made in stands representing a suitable geographic sampling of the breeding region in order to provide genetic materials for the project. The criteria for tree selection may vary from more or less random selection of a healthy dominant tree to selection of a desirable phenotype (straight stem, narrow crown, thin branches, no defects or disease) with superior height. Basic data on the selected tree (age, height and dbh) are collected in most cases but not always. This selection method provides low cost and less time demanding selections to supplement intensive selections and fill in gaps in geographic coverage of the base population. Genetic stock received through other cooperators (e.g. 25 trees received from BCMoFR) generally falls under this category.

Plantation selections: These selections are made in field trials established as part of provenance, progeny or family testing projects. The selections are invariably the best trees (top 5% - 10% or better) within the selected provenances or families. The selected trees would generally be young in age (10 – 20 years old) and would have been reviewed by ATISC for adaptation characteristics before being accepted as part of the project base population. Each selected tree is documented with genetic analysis data for the respective provenance, progeny or family for its phenotypic characteristics and breeding value where applicable.

7.2 Genetic Testing

Genetic testing is an integral part of the Region J breeding plan (Figure 8). The field trials for this purpose (G346A and G346B) are established at two sites within the breeding region. A third site for testing within the breeding region will be located in the Zama Ridge area. Site selection is in progress and will be completed by the fall of 2007. The third trial in the G346 series (G346C) is established outside the breeding region at the Whitecourt Mountain site. It is a complementary and supportive research trial and includes a portion of the progeny material and some additional provenances and families. Some of the materials in G346C may also be useful for expansion of the base population for advanced selections in the event that second generation breeding becomes desirable for the project.

7.2.1 Test site selection, development and planting

Two sites were selected and developed for progeny testing, Hotchkiss River and Sweeney Creek. The Hotchkiss River site (G346A) is located in the Lower Foothills Subregion 73 km northwest of Manning (57°08'N, 118°25'W and 750 m elevation). The Sweeney Creek site (G346B) is located near the Lower to Upper Boreal Highlands Subregion boundary in the Clear Hills, 55 km west of Worsley (56°34'N, 119°34'W and 915 m elevation). These sites are located within the breeding region boundary and are considered to be representative of the lodgepole pine forests in Breeding Region J. They were selected to represent the geography, climate and ecosites suitable for lodgepole pine regeneration in the region.

The sites were logged and prepared during 1997 – 2000 and are enclosed by a game fence. They are located on Crown land within the Green Zone and are protected under DRS or Miscellaneous Lease land reservations. Additional information on site characteristics and history is provided in Table 4 and in the establishment reports of the respective field trials, which also include Test Site Information Forms.

A third site has been tentatively selected on Zama Ridge for supplemental testing of Region J material. The site is located in the northern expansion to the breeding region made in 2000 and is intended to represent this area. The new proposed site location is Lsd. 15 Sec. 12 Twp. 110 Rge. 9 W6 at 630 m asl.

Table 4. G346 Test Site Descriptions and Climates

Test Site	Ecology and Soils	Original Stand - Site Type	Site Climate				
			MAT ^{0}C	MAP mm	MTCM ^{0}C	GDD >5^{0}C	AMI
Hotchkiss River (G346A)	Lower Boreal Highlands Subregion; Brunisolic Gray Luvisol; fine textured till; Mesic drainage	Pine mixedwood site with overstory consisting of C2PlAw to C3PlAw; UF E1.1 to E2.1	-1.0	500	-19.6	1039	2.1
Sweeney Creek (G346B)	Lower Boreal Highlands Subregion; Gleyed Eluviated Dystric Brunisol; fine texured till (clay loam); Mesic to subhygric, imperfectly drained	The overstory consisted of C3Pl (AwBw)	-0.5	509	-17.5	994	2.0
Zama Ridge*	Lower Boreal Highlands Subregion; Site classification yet to be determined						

*Site selection is to be completed in 2007. A supplementary progeny testing trial to be established in 2009 (see Section 7.2.4).

7.2.2 Experimental design, field planting and measurements

The field plantings for genetic testing for the project are referred to as the G346 series field trials or Breeding Region J lodgepole pine progeny trials. Two trials have been established within the breeding region, one at Hotchkiss River (G346A), and one at Sweeney Creek (G346B) in July 2000 using a randomized complete block design with 7 replications. Seedlots are planted in 5-tree row plots at G346A and 4-tree row plots at G346B; spacing at both sites is 2.5 m X 2.5 m. Of the 118 seedlots included, 48 are progenies (OP half-sib families) from the J base population, which consists of 85 parent trees in total (Figure 8). The Hotchkiss River trial (G346A) contains all 118 seedlots but the Sweeney Creek trial (G346B) contains only 95 seedlots; the 48 Region J seedlots are planted at both sites. In addition to the two trials established within Breeding Region J, a third trial, G346C, with a partial set of Region J families, other half-sib families and bulk provenance seedlots, was established at Whitecourt Mountain to the south for research purposes.

The 118 seedlots used in the G346 trial design included 48 progeny seedlots from the J base population and 70 additional seedlots. The additional seedlots were included as research materials for reference testing, to link the results from various lodgepole pine provenance-family tests in Alberta and B. C., and to identify additional suitable genetic stock for possible future expansion of the region J base population. Of these 70 seedlots, 49 were half-sib family seedlots: 20 northeast B.C. families; 12 Saddle Hills families; 5 Hawk Hills families; and 12 breeding region B1/B2/C superior families. The other 21 were bulk provenance seedlots: 4 northeast B.C. seedlots; 11 Alberta lodgepole pine test site seedlots; 3 Alberta G134 trial series seedlots; and 3 other Alberta regional seedlots of special interest.

Seed from the remaining 15 intensive selections and from the 12 geographic selections has been collected; seed from the 7 plantation selections, the selection from Region B1 and two B.C. selections will be obtained from grafts established in the Region J seed orchard. These are identified in Appendix II and will be included in a supplementary genetic test series for Region J to be established in 2009 (see Section 7.2.4).

The G346 series trials were established in early July 2000 using one-year-old dormant container stock grown in 220 ml copper styroblocks. Planting was done using tree planting shovels. Soil moisture during planting at Hotchkiss and Sweeney Creek was very good; at Whitecourt Mountain soil moisture was very high with some standing water. Establishment reports were written for each trial and are on file at ATISC. These are referenced below.

- Establishment Report G346A for Hotchkiss River site
- Establishment Report G346B for Sweeney Creek site
- Establishment Report G346C for Whitecourt Mountain site

The plantings are regularly weeded and brushed at 1 - 3 year intervals to keep trees in a free-to-grow condition. Test maintenance will be scheduled for a duration of 40 years. Assessments of the trials were completed at age 6 years in the fall of 2005. Survival, plant damage and height were assessed and the results are described in ATISC Technical Report ATISC 06-13 dated June, 2006. A summary of the results for the 97 half-sib families included in the test is provided in Tables 5, 6 and 7. Briefly, the trials showed excellent overall survival on individual sites (97.4%). Survival of individual families across sites varied from 58.3% – 100%. Mean height of individual families was 148 cm at Hotchkiss River and 131 cm at Sweeney Creek. Seedlings on both sites were generally healthy with about 11% of the trees on both sites showing some kind of damage. The most prevalent damage condition was stem forking likely caused by winter injury and trees are expected to recover from this.

Table 5. Six –year Performance of Lodgepole Pine Families in the Region J Progeny Trials

	G346A – Hotchkiss				G346B – Sweeney Creek			
	N	**Mean**	**Range of Family Means**	**C.V. (%)**	**N**	**Mean**	**Range of Family Means**	**C.V. (%)**
Survival (%)	97	97.4	88.6-100	2.8	74	97.4	58.3-100	6.6
Height (cm)	97	148	120-177	7.5	74	131	89-157	9.6

Table 6. Six-year Height Performance of Different Categories of Lodgepole Pine Families in the Region J Progeny Trials

Category	G346A - Hotchkiss			G346B – Sweeney Creek		
	N	Mean Ht (cm)	Range of Family Means	N	Mean Ht (cm)	Range of Family Means
Region J	25	153	133-177	25	136	120-155
B.C. (in orchard design)	23	143	126-157	23	125	89-147
B.C. (not in orchard design)	20	140	120-159	-	-	-
Saddle Hills	12	155	143-164	12	127	113-144
Hawk Hills	5	147	138-152	5	129	105-145
Regions B1, B2, C	12	152	137-165	9	140	127-157

Table 7. Six-year % Survival of Different Categories of Lodgepole Pine Families in the Region J Progeny Trials

Category	G346A - Hotchkiss			G346B – Sweeney Creek		
	N	Mean	Minimum*	N	Mean	Minimum*
Region J	25	97.8	88.6	25	98.4	92.9
B.C. (in orchard design)	23	97.1	91.7	23	94.6	58.3
B.C. (not in orchard design)	20	96.7	91.2	-	-	-
Saddle Hills	12	97.4	94.3	12	99.1	96.4
Hawk Hills	5	97.7	94.3	5	98.6	96.4
Region B1, B2, C	12	97.9	91.4	9	98.8	96.4

*maximums are all 100%

7.2.3 Future measurements

The G346 genetic tests will be measured by ATISC at 3 - 6 year intervals up to age 40 in accordance with trial measurement procedures and schedules for lodgepole pine. Measurements are planned for ages 6 (completed), 11, 15, 20, 25, 30, 35 and 40. Survival, plant damage condition, western gall rust incidence and tree height will be assessed with diameter measurements commencing at age 15. In addition, special trait assessments may be carried out on all or a part of the planted materials for research purposes or special tree breeding needs such as adaptation to climate change or pest resistance. The data from trial measurements will be analysed within 1 - 3 years of the collection date and summarized in appropriate technical reports.

7.2.4 Future Genetic Testing

A total of Thirty-seven parents in the Region J base population of 85 trees (Appendix II) are not included in the G346 series field trials established in July 2000 because seed from these trees was not available at the time of seeding. Since then, seed from 27 trees has been collected from natural stands. Seed for the remaining ten trees will be collected from grafts established in the G319 seed orchard; these collections are expected to be completed by 2008. To complete progeny testing of the base population parents, these 37 seedlots will be tested in supplementary progeny trials ,designated as the G371 series, to be established in 2009 at two sites, Zama Ridge and Hotchkiss River. Zama Ridge is a new northern site to be developed in 2007 – 2008. Hotchkiss River is an existing site; the G346A progeny test trial is established there.

The 37 seedlots to be used for the G371 progeny trials are identified in Appendix II. In addition to these seedlots, the trials will also include six bulk seedlots (Accessions 4021, 4075, 2952, 3848, 3444 and G319 seed orchard bulk seed) and up to 17 half-sib progeny seedlots from the G346 series to provide additional testing at the northern Zama Ridge site and to link the results from the two series of trials. The stock production for the two G371 trials will commence in March 2009 using the same growing guidelines as used for the G346 trials and out planting will be done in late July 2009. An experimental design similar to the G346 design will be followed.

8.0 SEED PRODUCTION PLAN

Improved seed production to provide a steady and reliable seed supply of improved seed of lodgepole pine in region J is an essential requirement of the breeding program. The seed produced must meet or exceed adaptation and genetic diversity requirements specified in the STIA. The genetic diversity objective for the orchard is to maintain an effective population size (N_e) of 30 or more in the bulked orchard seed production averaged over any 5 year period. The projected annual seed production requirements are estimated to be about 9.5 kg of seed which should be sufficient to produce about 750,000 plantable seedlings per year. This calculation is based on the following assumptions: 1000-seed weight = 5.2 g, seed germination ~94% and 2.3 seeds are required to produce one plantable seedling after nursery over sow and seedling culling requirements for quality control are taken into account.

The seed orchard for the Region J project is referred to as the G319 seed orchard. It was established at a site near North Star in 2000. Average age of the grafts established in the seed orchard at present (2006) is 7 years. Orchard seed production in 2006 was 78 g of seed (98% germination) and production is projected to progressively increase each year to meet the full production requirements in about 10 – 15 years.

8.1 Seed Orchard Site Location and Climate

The Region J lodgepole pine seed orchard (G319) is located in the Dry Mixedwood Subregion at legal land location NW¼ 32-090-23-W5M (56°51'N latitude, 117°38'W longitude, 493 m elevation) just west of North Star on farmland owned by NPARA. NPARA is a farmer owned cooperative interested in applied agricultural research and technology transfer and is interested in cooperating with the Region J tree improvement project. The location was chosen after reviewing the suitability of 6 potential regional sites. The factors considered were regional climate, soil type, potential for pollen contamination, access, irrigation water availability and labor and equipment availability. The quarter section site was purchased by NPARA, facilitated by a long-term lease agreement for the orchard site which is on a sectioned-off 10 hectare parcel within the site. The term of the lease agreement is 40 years and Region J project partners have the right of first refusal in case the land is sold. Region G2 (G318) white spruce orchard is also established at the same site.

In 1999, NPARA purchased the quarter section of land, which has been under cultivation for the last 40 years. In October 1999, Lansdowne Research & Consulting completed a detailed soil survey and Cridland & Associates Ltd completed a detailed topographic map on the quarter section. From both these surveys, the most suitable area for the 10 hectare orchard site (250 m x 400 m) was the northwest corner of the quarter section. The seed orchard is comprised primarily of Solodic Grey Luvisols (Nampa series) and Solodic Dark Grey Luvisols (Kleskun series). Orthic Humic Gleysols (Goose series) also occur in the quarter section parcel but do not fall in the orchard site.

Both the Nampa and Kleskun soil series are upland soils and are very similar in physical and chemical characteristics. The Nampa soil series occurs in level to depressional areas of lacustrine origin and has imperfect internal drainage. Slopes typically range from 0% to 0.5% and the parent material has few stones. Some mottles are found in the B horizon due to the poor internal drainage.

Nampa Soil Series

Horizon	**Depth(cm)**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Texture**	**pH**	**OM (%)**
Ap	0-15	28.4	42.0	29.6	Clay Loam	6.4	5.5
Ae	15-19	22.4	58.0	19.6	Si. Loam	6.9	2.6
Btn	20-32	18.4	16.0	65.6	H. Clay	6.7	-
BC	32-45	20.4	17.0	62.6	H. Clay	7.0	-
Csk	45+	16.4	18.0	65.6	H. Clay	7.5	-

The Kleskun soil series occurs in level to depressional positions of similar slope and also in parent materials of lacustrine origin with few stones. In this series, no mottling is found in the B horizon as these soils tend to occupy positions with better surface drainage.

Kleskun Soil Series

Horizon	**Depth(cm)**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Texture**	**pH**	**OM (%)**
Ap	0-12.5	27.4	44.0	28.6	Clay Loam	6.5	5.1
Btn	12.5-42.5	26.4	27.0	46.6	Clay	6.0	3.6
BC	42.5-60.5	28.4	34.0	37.6	Clay Loam	7.6	-
Csaca	60.5+	26.4	36.0	37.6	Clay Loam	6.9	-

In November 1999, Battle River Holdings constructed a 32 m x 73 m x 9 m dugout (1.6 million gallons) outside the fence south east of the seed orchard site.

In 2000, the main site development and improvements for the orchard commenced. An 8-foot game fence was erected by Randy Finnebraaten. with two 12-foot gates in the south west and south east corners. In May the entire orchard site was deep ripped to a depth of approximately 24 inches to improve internal soil drainage. After deep ripping, the area was cultivated and harrowed in early July to control weed establishment. In the spring of 2000, an equipment shed to be shared with NPARA was constructed north of the dugout. On July 10 and 11, a 2- row shelterbelt of Northwest poplar *(Populus x jaackii)* and lilac vilosa *(Syringa villosa)* was established along the perimeter of the fence. On July 13 and 14, 101 grafts were planted in the seed orchard. Root balls were slashed to promote lateral growth and bone meal was incorporated into each planting hole. A knife cultivator was used in late September to control weeds and prepare the area for seeding. In early October, the area was seeded with a mixture of orchard grasses. The local municipal district constructed two approaches in early October to allow access from the west and north of the orchard.

In May 2001, A&D Irrigation from Fort MacLeod designed and installed the drip irrigation system for the orchard site. The site was divided into 8 separate zones with two zones each for the spruce and pine orchards and the remaining 4 zones for expansion. ATCO Electric Ltd. installed single-phase electrical service to the equipment shed in May.

Climate for the site (1961 - 1990) using the Alberta Climate Model (AENV 2005) is estimated as follows: mean annual temperature = 0.1°C; mean annual precipitation = 493 mm; growing degree days >5°C = 1267; annual moisture index (GDD/MAP) = 3.0; frost free period = 79.5 days; mean temperature of the coldest month (January) = -19.2°C.

8.2 Orchard Design and Establishment

The Breeding Region J orchard was developed through vegetative propagation by grafting of the selected parent trees (ortets) described in Section 7.1 and Appendix II. Grafting commenced in 1995 Sixty-three trees were grafted successfully and were included in the orchard design. The orchard design is completely randomized and was generated by the SOL 32 computer program with the constraint that any 2 ramets from the same clone be separated by at least 4 ramets of unrelated clones. The orchard design has a total of 620 planting positions at 6 m (among rows) x 3 m (within rows) spacing. It occupies an area of approximately 1.1 ha.

Planting in the orchard commenced in July 2000 when 101 grafts were planted and is expected to be completed in 2008. At present (October 2006) a total of 474 positions are planted. Parent trees are currently represented by a minimum of 1 graft and a maximum of 16 grafts per clone. The imbalance in clonal representation will be corrected as the orchard is filled. In 2006, grafts from two clones were removed (X1342 and X1355) because the families from these parents were the bottom ranked performers in height growth based on 6-year G346 progeny trial results.

The initial planting is described in the G319 establishment report dated October 16, 2000 and annual addenda are written for each subsequent year These reports provide the geographic origin of the orchard trees, field layout maps, planting row and position number of individual ramets, the total number of ramets per clone, the year of planting of each graft and a record of periodic mortality and replacements.

8.3 Orchard Management and Seed Production

As of 2006 the orchard establishment is nearly complete with 474 grafts already planted and the remaining in the graft stream. Grafts range in age from about 3 to 9 years. The orchard management and operations until 2005 were carried out by NPARA on a contract basis with technical and scientific support provided by ATISC. Starting in 2006, orchard management has been carried out by the Forest Genetics Alberta Association (FGAA). The main management goals for orchard trees at this stage are growth, development, flowering enhancement, crown management and pest control. In order to achieve these goals the following management activities are completed on a routine basis:

- Tissue and soil samples are collected annually in the fall to assess nutrient levels and to provide base information for the following year's fertilization regime.
- The prescribed amount of granular fertilizer is applied over 3 applications throughout the growing season.
- Weeds are controlled by mowing, weed whipping and herbicides.
- Water is delivered to each tree with a drip irrigation system capable of providing at least 5 L of water per hour. The system is flushed each spring and all emitters are checked to ensure that the water is flowing to each tree.
- A comprehensive insect and disease survey is completed every second year and pest control is carried out annually by seasonal pesticide applications or by mechanical means.
- Crown management is carried out to promote fuller crowns and, consequently, increase flowering sites and to limit tree height growth. This is done each spring by breaking off the 'candles' of the dominant leader and tallest laterals in the first and second whorls on trees greater than 2 m in height.

All cones are picked annually by individual tree so that clonal reproductive contribution and effective population size can be determined. Cones are subsequently bulked for extraction. Germination testing is completed on the bulk seedlot. Annual cone and seed production information for the orchard is summarized in Table 8. Orchard management activities are described in detail in the annual orchard management and operations reports for the J orchard. These have been completed annually since 2000 and are on file at ATISC.

Table 8. Cone Crop and Seed Production Information – Breeding Region J Lodgepole Pine Clonal Seed Orchard (G319)

	2006	2005	2004	2003	2002
Number of trees	474	419	315	288	304
Average tree age (years from grafting)	7	6	6	5	4
Trees producing cones	204 (43%)	188 (45%)	154 (49%)	102 (35%)	9 (3%)
Number of clones	59	53	51	46	46
Clones producing cones	42 (71%)	35 (66%)	34 (67%)	27 (59%)	7 (15%)
Cone production (l)	56	30	13.8	11	0.2
Cones/tree	6	4	2	2	0
Cones/litre	47	52	50	51	55
Total number of cones	2,680	1,557	691	559	11
Clean seed (g)	77.6	41.5	24.9	8.9	0.4
Seeds/cone	5.4	5.2	5.9	2.8	6
Seeds/kg	180,832	196,858	164,199	173,103	-
Seed yield (g/hl)	139	138	181	81	-
1000 seed weight	5.53	5.08	6.09	5.78	5.19
Germination %	98	98	94	96.5	66.2
Effective population size	18	18	18	10	-

The seed production projections for the orchard were done for the period 2000 to 2028 using BCMoFR interior lodgepole pine seed orchard guidelines (3-year moving averages); an adjustment was made to graft age to reflect slower growth rates in northern Alberta. These projections, the seed to plantable seedling conversion and the amount of improved stock available to each project partner from the projected orchard production are shown in Table 9.

Table 9. Seedling Production Calculations and Seedlings Allocation to Project Partners for Breeding Region J (G319) Lodgepole Pine Seed Orchard

Year	Graft Age[1]	Actual[2] Production # seeds/Tree	Predicted[3] Production # seeds/Tree	No. Trees in Orchard	Total No. Seeds[4]	Total No. Seeds (Adjusted)[5]	Total[6] Seedling Production	Seedling Allocation to Partners[7]		
								MDFP (50%)	TIHL (10%)	ATISC (40%)
1999	1									
2000	2									
2001	3									
2002	4	0.2	0	304	0					
2003	5	5.4	0	288	0					
2004	6	12.9	7.7	315	2425.5	2,183	949	475	95	380
2005	7	19.3	15.4	419	6452.6	5,807	2,525	1,262	252	1,010
2006	8		100.1	500	50050	45,045	19,585	9,792	1,958	7,834
2007	9		277.2	580	160776	144,698	62,912	31,456	6,291	25,165
2008	10		462.0	620	286440	257,796	112,085	56,043	11,209	44,834
2008	11		693.0	620	429660	386,694	168,128	84,064	16,813	67,251
2010	12		939.4	620	582428	524,185	227,907	113,953	22,791	91,163
2011	13		1,111.5	620	689130	620,217	269,660	134,830	26,966	107,864
2012	14		1,270.5	620	787710	708,939	308,234	154,117	30,823	123,294
2013	15		1,501.5	620	930930	837,837	364,277	182,138	36,428	145,711
2014	16		1,694.0	620	1050280	945,252	410,979	205,490	41,098	164,392
2015	17		2,002.0	620	1241240	1,117,116	485,703	242,851	48,570	194,281
2016	18		2,233.0	620	1384460	1,246,014	541,745	270,873	54,175	216,698
2017	19		2,464.0	620	1527680	1,374,912	597,788	298,894	59,779	239,115
2018	20		2,616.0	620	1621920	1,459,728	634,664	317,332	63,466	253,866
2019	21		2,733.5	620	1694770	1,525,293	663,171	331,585	66,317	265,268
2020-2028	22-30		2,772.0	620	1718640	1,546,776	672,511	336,256	67,251	269,005

[1] Average graft age for orchard from cone and seed production table of orchard report with some modifications

[2] Calculated from orchard seed production data

[3] Calculated from BCMoF interior lodgepole pine 3-yrs moving average data. Also, 3 yrs were added to graft age for equivalent production

[4] Seeds/tree in [3] multipied with number of trees in the orchard

[5] Total number of seeds minus 10% upfront seed share for ASRD as per orchard agreement

[6] Total number of seeds in [5] divided by 2.3 (assumes 1 plantable seedling production needs 2 seeds per cavity sowing and some oversow); 10% of seed share for ASRD as part of the seed orchard agreement is not included in this calculation

[7] Total seedling production in [6] proportionately divided among project partners according to their orchard seed share

Note: Seed production per tree is expected to increase after 2020 but orchard genetic roguings will commence around then to reduce number of trees and maintain seed production

8.4 Permanent Sample Tree Program and Orchard Phenology Monitoring

A permanent sample tree (pst) monitoring program was started in the Region J orchard in 2001 according to STIA guidelines. The monitoring program has several objectives: a) to provide orchard-specific local data on seed orchard development, flowering, cone and seed production and seed quality; b) to provide an estimate of reproductive contribution of orchard trees and pollen contamination from outside orchard sources; c) to serve as a tool for cone crop forecasting and seed collection planning. Orchard phenology monitoring conducted in the spring evaluates and records male and female bud development on a subset of the psts to collect information on the timing and duration of pollen dissemination and female flower receptivity in the orchard.

The target number of psts for the orchard is approximately 70 or about 10% of the seed trees in the orchard. A number of new psts are added annually to proportionately represent the number of grafts planted each year. Psts are selected systematically to ensure all clones with 5 or more ramets are represented and to ensure that psts are distributed throughout the orchard. In 2006, 61 psts were established in the orchard and their age varied from 3 to 8 years. Data on psts are collected annually for the following traits: height, crown width, dbh, number of male and female flowers and number of cones. Cones per litre, seeds per cone, 1000 seed weight and seed germination are determined annually for the pst bulk cone collection and/or the bulk operational orchard collection. The results are tabulated and summarized each year in annual orchard management and operations reports. A table showing the results of 2006 pst monitoring is shown in Table 10. A brief description of methods and procedures followed in pollen and phenology monitoring is given below.

Pollen monitoring: Three wind vane type pollen monitors are installed in the orchard just prior to pollen flight, usually in mid-May. A microscope slide coated with petroleum jelly is mounted on each monitor to trap pollen and the slides are changed every one to two days for the duration of orchard receptivity. The slides are examined under a compound microscope and pollen counts are completed in a defined area of the slide for a prescribed number of samples to determine the average daily and cumulative orchard pollen density in grains/mm^2.

Pollen contamination: Outside orchard levels of pine pollen are measured with two 'regional' pollen monitors located about 600 m north and 400 m west of the orchard. Pollen density in grains/mm^2 is determined for the regional monitors as for the within orchard monitors and the ratio of outside to within orchard pine pollen density provides an estimate of the proportion of contaminant pollen in the orchard.

Phenology monitoring: Orchard phenology is monitored with a sub-sample of the psts. Each clone in the orchard with five or more ramets is sampled. Female and male bud development stages are assessed approximately every two days beginning when most reproductive buds are identifiable and continuing until all sample trees are post-receptive and pollen has flown. Phenology monitoring is done in years when a collectible crop is anticipated and data are collected for a minimum of five years after full orchard establishment. This information permits the identification of clones that are receptive or shedding pollen earlier or later than the majority of orchard clones. In conjunction with pollen monitoring, phenology data are used to relate patterns of within-orchard pollen flight to the period of orchard receptivity and to identify clones that may be unable to cross with all other clones in the orchard population.

Table 10. Summary of Seed Production and Monitoring Information for Region J Lodgepole Pine Clonal Seed Orchard (G319) – 2006

	ORCHARD CHARACTERISTICS	RESULT
1.	Orchard design capacity	620
2.	Total no. of seed trees established	474
3.	Total no. of clones/families established	59
4.	Average age	7
5.	Age range	3-9
6.	Average height (cm ± SE)	180±10
7.	Height range	55-300
8.	Average crown width (cm ± SE)	94±7
9.	Crown width range	12-256
10.	Average DBH (cm ± SE)	-
11.	DBH range	-
12.	Total no. of PSTs	59
	REPRODUCTIVE BALANCE	
13.	No. of PSTs flowering	
	Male Flowering	
14.	No. PSTs with male flowers	24
15.	Mean no. male flowers/PST	5
16.	Standard error of (15.)	2.0
17.	Range male flowers/PST	0-40
	Female Flowering	
18.	No. PSTs with female flowers	52
19.	Mean no. female flowers/PST	13
20.	Standard error of (19.)	3
21.	Range female flowers/PST	0-61
22.	Mean male:female flower production ratio	0.4
	IMMATURE CONE PRODUCTION	
23.	Date assessed	Aug-05
24.	No. PSTs producing cones	33
25.	Mean no. cones/PST	13.5
26.	Standard error of (25.)	2.3
27.	Range of cones/PST	0-64
28.	**Cone crop estimate** **(number of cones)***	6399
29.	**Cone crop estimate** **(hectolitres)****	1.7
	CONE PRODUCTION	
30.	No. of PSTs producing cones	29
31.	Mean no. cones/PST	8.6
32.	Range of cones/PST	0-70
33.	Total no. of cones collected from PSTs (max 5/tree; developing orchards only)	524 (all cones)
34.	Mean no. of cones/litre***	47
	SEED PRODUCTION * **	
35.	Seed production (g)	77.6
36.	No. of seeds/cone	5.4
37.	1000 seed weight	5.53
38.	Germination %	98

*** For all species except pine (2.) x (19.)**
*** For pine species (2.) x (25.)**
**** To estimate hectolitres divide (28.) by the appropriate factor**
For white spruce - 15000 cones/hl
For black spruce - 24000 cones/hl
For lodgepole pine - 3800 cones/hl
***** For producing orchards, lines 34-38 may be completed from operational crop data**

9.0 GENE CONSERVATION

Conservation of wild forest genetic resources is an important part of the Region J lodgepole pine improvement program. Both *in situ* and *ex situ* conservation will be carried out as part of the project in accordance with the Provincial Gene Conservation Plan (ASRD 2007).

In Situ gene conservation involves protecting representative populations of lodgepole pine on-site within its natural habitat in the two seed zones for which 15% of the seed zone total area falls within the breeding region (LBH 1.1 and 1.6). Two or more populations per seed zone are required. Guidance for the number of stands required and their desired locations will be obtained from the provincial Tree Gene Conservation Plan (ASRD 2007). The plan recommendations pertaining to the J project area are expected to be available in 2007 and will be implemented from 2007 to 2009. The stands to be selected as *in situ* gene conservation areas must contain at least 5000 lodgepole pine trees and be protected by a 500 m buffer on all sides. The stands will be documented and protected by a land reservation. For species under Controlled Parentage Program plans, conservation work will be done co-operatively by company partners; SRD; and the Parks, Conservation Recreation and Sports Division of Alberta Tourism, Parks, Recreation and Culture in accordance with STIA and the provincial tree gene conservation plan. Where applicable, stands in already designated parks and protected areas will be chosen and maintained as *in situ* reserves as a first priority.

Ex Situ gene conservation involves conserving seed and vegetative germplasm of lodgepole pine outside its natural habitat to complement *in situ* conservation. This will be limited to wild forest collections only and is already ongoing in cooperation with ATISC. Seventy-three seedlots already collected from parent trees in the Region J base population have been conserved in the seed bank. In addition, 122 grafts from 38 parent trees are established in the pine clone bank at ATISC. The G346 progeny trials at three sites described in section 7.2.2 will also serve as *ex situ* conservation plantings for the 40 year duration of the trials. Plant materials in field trials discussed in Supportive Research and Field Trials (Section 10.0) will also partially serve *ex situ* gene conservation objectives. Efforts will also be continued to select and conserve, by seed collections or vegetative propagation, wild forest germplasm from trees and stands with rare or special characteristics.

10.0 SUPPORTIVE RESEARCH AND FIELD TRIALS

A modest program of applied research to fulfill scientific information needs for the Region J breeding project will be carried out with the support of both ATISC and the Manning Forestry Research Fund (MFRF) where research projects are approved. However, with respect to this CPP plan, the work will be limited to project specific knowledge and information needs addressing adaptation, genetic diversity, improved stock deployment, breeding region verification and gene pool conservation. Much of the proposed work will be based on the studies to be carried out in the seed orchard (G319) and progeny trials (G346 series) established as part of the J project. In addition, the lodgepole – jack pine species, hybrids and outlier populations trial (G134B) established at the HRA experimental area in the NW boreal region in 1985 is of interest for scientific studies related to the project.

The 6-year results from the G346 progeny trials have been described in the 2005/2006 project progress report submitted to the Manning Forestry Research Fund and results are summarized in section 7.2. The results from G134B and eight other trials in the G134 series to age 15 are described in a technical report (Rweyongeza and Yang 2005).

The proposed research work for the J project would make use of the information and data available from the trials mentioned above and other trials to develop knowledge and increase our understanding in the following specific areas.

a) **Seed orchard management and seed production:** Flowering and seed production in the G319 seed orchard will be monitored on a regular basis to develop information on seed production, seed supply, pollen contamination and seed losses due to insects, diseases and climatic injury. Although it is considered to be isolated from major lodgepole pine contamination sources by a significant distance, pollen contamination needs to be studied and its impact on the genetic quality and adaptation characteristics of J seed evaluated. Other areas of research include orchard cultural practices, crown management, reproductive biology, supplemental pollination, genetic diversity of seed crops and cone and seed insects and diseases.

b) **Genetic diversity and adaptation:** The base population genetic stock for the breeding program is largely local in origin and considered to be adapted to the regional climate. Nevertheless, breeding region J is quite variable in topography and climate and detailed information is required on regional differentiation of lodgepole pine populations, particularly information on genetic variation in adaptive traits, natural hybridization with jack pine and the role played by climate and geography. Most of this information will be developed using data from the field experiments described earlier but some supplemental field or laboratory studies may also be established. This information will assist in decisions relating to seed source selection, improved stock deployment, genetic conservation and maintenance of forest health.

c) **Genetic selection and breeding:** Breeding values, genetic stability and rankings of individual parents and families will be determined to facilitate selection and breeding for growth, wood quality, climatic hardiness and pest resistance. Genetic gains will be estimated as per STIA requirements and complementary validation trials will be established and monitored. This information will also be used to revise or modify the project concept and as a basis for second generation breeding should this be desired at a later stage.

d) **Breeding region verification and adjustments:** The present delineation of region J is mainly based on vegetation ecology, climate and forest planning considerations. Genetic information was taken into account only indirectly as very little empirical information was available at the time of project planning in 1995. The main tree improvement objective in breeding region delineation is to identify a target environment for deployment of improved seed varieties developed through selection and breeding where field performance is relatively stable and genotype by environment interaction is minimized. Information to verify the appropriateness of the breeding region boundary will be developed through analyses of data from the field trials described earlier and will be evaluated along with similar information from the neighboring lodgepole pine breeding regions i.e. region B1 to the south and the Peace Plateau seed planning zone to the west in British Columbia. Redelineation of the breeding region (expected to be done around 2025) will also take into account climate change information and examine second generation breeding, if desired.

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Appendix I: Region J Orchard Seed Production and Landscape Deployment Plan and Production Facility Limit

1	2	3			4		5	6	7
Tenure Holder	**Total Breeding Region By Tenure**	**Operable Area**	**Strata**		**Area of Target Strata**	**Trees/ ha**	**Plants Required**	**Planned Production Limit (Ne<30)**	**Planned Production Limit (Ne> 30)**
MDFP-P16	484393.288	261032.954	C-PL-B	C-PL-BCD	6,499	1,600	10,398,928		5,199,464
			C-PL-CD	C-PL-BCD	20,141	1,600	32,225,568		16,112,784
			Total		**26,640**		**42,624,496**		**21,312,248**
FMU-P1 (P15)	Total P15 Area= 570244.819	94853.209	C-PL-P	Not in Program	16,045	0	0		0
			C-PL-S	Not in Program	13,273	0	0		0
			C-PLSB-P	Not in Program	16,096	0	0		0
			CD-PL-P	Not in Program	4,021	0	0		0
			CD-PL-S	Not in Program	4,318	0	0		0
			Total		**53,753**		**0**		**0**
FMU-P7 (P15)	Total P15 Area= 570244.819	164274.305	C-PL-P		13,988	1,600	22,380,682		11,190,341
			C-PL-S		7,751	1,600	12,401,658		6,200,829
			C-PLSB-P		6,927	1,600	11,082,579		5,541,290
			CD-PL-P		9,802	1,200	11,762,410		5,881,205
			CD-PL-S		2,083	1,200	2,499,335		1,249,667
			Total		**40,550**		**60,126,663**		**30,063,331**
FMU-P10	Total P15 Area= 570244.819	19143.1583	C-PL-P		1,336	1,600	2,137,966		1,068,983
			C-PL-S		1,589	1,600	2,542,658		1,271,329
			C-PLSB-P		927	1,600	1,482,507		741,254
			CD-PL-P		2,069	1,200	2,483,285		1,241,642
			CD-PL-S		460	1,200	551,430		275,715
			Total		**6,381**		**9,197,846**		**4,598,923**
FMU-P8 (No Harvest Area)	340464.941	166051.031	C-PL-P	No Harvest Area	57,637	0	0		0
			C-PL-S	No Harvest Area	2,453	0	0		0
			C-PLSB-P	No Harvest Area	11,196	0	0		0
			CD-PL-P	No Harvest Area	12,776	0	0		0
			CD-PL-S	No Harvest Area	644	0	0		0
			Total		**84,705**		**0**		**0**
DMI-	196226	103277.5	Pine Leading		25,011	1,400	35,014,700		17,507,350
DMI-P1S(P13)	70999.4	56795.4	Pine Leading	Not in Program	5,490	0	0		0
DMI-P2(P13)	315572.5	211051.5	Pine Leading	Not in Program	20,757	0	0		0
DMI-P11(P13)	3544.8	3242.3	Pine Leading	Not in Program	108	0	0		0
Tolko-F26	467928	307141	Pine Leading		19,875	1,400	27,825,000		13,912,500
			Total		**71,241**		**62,839,700**		**31,419,850**
	2449374	**1386862**	**Grand Total**		**283,271**		**174,788,705**		**87,394,352**

Appendix II: Breeding Region J Base Population Geographic Origins and Description of Parent Trees

Brd Pjt	Clone #	File Report#	Acc #	Tree Field #	Latitude	Long	Legal Location	Elev (M)	Type of Selection	Breeding Value**	% Superiority	2006 G319	Comments
B1	X1751[1]	03-09	n/a	8B1 G127-1111-III-9-1young selection	54°35'00"	118°11'00"	10-35-064-02-W6	945	Plantation	0	.	0	
J	X1221	96-5	3793	P7-16-95	57°10'06"	118°33'33"	05-22-094-04-W6	975	Comparison	2	16.0	6	
J	X1222	96-5	3794	P6-17-95	57°11'50"	118°21'42"	08-33-094-03-W6	802	Comparison	2	8.5	15	
J	X1223	96-5	3795	P6-18-95	57°23'24"	118°21'42"	10-02-097-03-W6	898	Comparison	2	19.6	2	
J	X1224	96-5	3796	P6-19-95	57°23'50"	118°24'57"	02-09-097-03-W6	913	Comparison	2	4.8	14	
J	X1225	96-5	3819	P7-20-95	57°10'45"	118°35'59"	02-29-094-04-W6	993	Comparison	2	4.8	10	
J	X1296	96-5	3824	G1-01-95	55°39'23"	119°40'06"	02-32-077-11-W6	785	Comparison	2	4.8	9	
J	X1297	96-5	3825	G1-02-95	55°41'07"	119°41'29"	01-07-078-11-W6	815	Comparison	2	2.2	8	
J	X1298	96-5	3826	G1-03-95	55°41'33"	119°49'40"	10-08-078-12-W6	815	Comparison	2	10.6	6	
J	X1299	96-5	3827	G1-04-95	55°41'46"	119°50'50"	16-07-078-12-W6	805	Comparison	2	25.5	7	
J	X1410	97-16	3998	P6-44-96	57°16'38"	118°26'10"	16-29-095-03-W6	782	Comparison	2	2.5	12	
J	X1414	97-16	3999	P6-45-96	57°14'53"	118°26'58"	14-17-095-03-W6	819	Comparison	2	26.4	11	
J	X1415	97-16	3996	P7-42-96	57°05'03"	118°54'55"	09-20-093-6-W6	950	Comparison	2	21.4	6	
J	X1424	97-16	3997	P6-43-96	57°16'38"	118°26'10"	16-29-095-03-W6	771	Comparison	2	6.0	12	
J	X1532	97-16	4012	P10-01-97	57°14'53"	118°26'58"	16-04-098-22-W5	665	Comparison	2	18.7	11	
J	X1533	97-16	4011	P6-02-97	57°20'05"	117°32'18"	06-06-097-22-W5	720	Comparison	2	9.4	4	
J	X1572	98-06	4076	P1D-01-97	56°33'45"	119°52'53"	13-08-088-12-W6	930	Comparison	2	8.6	15	
J	X1573	98-06	4077	P1D-02-97	56°30'43"	119°43'30"	08-30-087-11-W6	747	Comparison	2	7.5	2	
J	X1574	98-06	4078	P1D-03-97	56°29'25"	119°42'19"	15-17-087-11-W6	723	Comparison	2	4.4	11	
J	X1575	98-06	4079	P1D-04-97	56°24'13"	119°50'53"	14-16-086-12-W6	732	Comparison	2	6.9	5	
J	X1576	98-06	4080	P2D-05-97	56°28'30"	118°12'58"	08-10-089-02-W6	884	Comparison	2	2.5	3	
J	X1577	98-06	4081	P1D-06-97	56°30'43"	119°43'06"	05-29-087-11-W6	747	Comparison	0	-1.8	4	
J	X1706	99-14	4321	P02-01-99	56°19'45"	119°53'57"	09-36-084-13-W6	738	Comparison	2	8.2	0	
J	X1707	99-14	4322	P02-02-99	56°17'45"	119°51'11"	08-20-084-12-W6	707	Comparison	2	2.2	1	
J	X1708	99-14	4323	P1D-03-99	56°26'31"	119°47'04"	06-11-086-12-W6	694	Comparison	0	-2.9	4	
J	X1709	99-14	4324	P1D-04-99	56°27'40"	119°53'12"	11-18-086-12-W6	747	Comparison	2	2.2	4	
J	X1711[1]	00-16	n/a	G134G-2497-I-16-4	56°36'00"	119°42'00"	06-12-088-11-W6	960	Plantation	0	n/a	12	
J	X1712[1]	00-16	n/a	G134G-2504-IV-29-5	55°44'00"	119°40'00"	NE-05-078-11-W6	825	Plantation	0	n/a	3	
J	X1713[1]	00-16	n/a	G134G-2497-I-16-7	56°36'00"	119°42'00"	06-12-088-11-W6	960	Plantation	0	n/a	10	
J	X1714[1]	00-16	n/a	G134G-2504-III-60-7	55°44'00"	119°40'00"	NE-05-078-11-W6	825	Plantation	0	n/a	13	
J	X1811[1]	02-06	4870	F14-01-01	58°32'31"	119°21'24"	14-12-110-09-W6	619	Comparison	2	8.5	10	
J	X1812[1]	02-06	4871	F14-01-02	58°34'02"	119°18'27"	12-20-110-08-W6	637	Comparison	2	12.1	11	
J	X1813[1]	02-06	4872	F13-01-04	58°14'09"	118°55'43"	14-28-106-06-W6	579	Comparison	2	5.6	7	
J	X1814[1]	02-06	4873	F14-02-05	58°32'55"	119°10'29"	08-13-110-08-W6	594	Comparison	2	22.2	1	
J	X1815[1]	02-06	4874	F13-02-06	58°14'51"	118°53'48"	10-34-106-06-W6	583	Comparison	0	-0.8	7	

J	X1816[1]	02-07	n/a	MDFP-01-02	57°11'47"	118°25'21"	06-33-094-03-W6	760	Non-comparison	0	n/a	6	
J	n/a[1]	02-07	4955	P9-01-02	57°50'48"	118°56'05"	01-17-102-06-W6	666	Non-comparison	0	n/a	0	Only seed collected
J	n/a[1]	02-07	4956	P9-02-02	57°59'02"	118°57'59"	05-32-103-06-W6	701	Non-comparison	0	n/a	0	Only seed collected
J	n/a[1]	02-07	4957	P9-03-02	57°57'40"	118°54'40"	13-22-103-06-W6	609	Non-comparison	0	n/a	0	Only seed collected
J	n/a[1]	02-07	4958	P8-04-02	57°55'44"	119°19'52"	09-12-103-09-W6	757	Non-comparison	0	n/a	0	Only seed collected
J	n/a[1]	02-07	4959	P8-05-02	57°54'18"	119°21'02"	04-01-103-09-W6	799	Non-comparison	0	n/a	0	Only seed collected
J	n/a[1]	02-07	4960	P8-06-02	57°54'21"	119°20'58"	04-01-103-09-W6	817	Non-comparison	0	n/a	0	Only seed collected
J	n/a[1]	02-07	4961	P8-07-02	57°47'52"	119°19'20"	10-25-101-09-W6	764	Non-comparison	0	n/a	00	Only seed collected
J	n/a[1]	02-07	4962	P8-08-02	57°46'56"	119°19'06"	09-24-101-09-W6	779	Non-comparison	0	n/a	0	Only seed collected
J	n/a[1]	02-07	4963	P9-09-02	57°36'00"	119°12'52"	02-22-099-08-W6	712	Non-comparison	0	n/a	0	Only seed collected
J	n/a[1]	02-07	4964	P9-10-02	57°27'20"	119°11'42"	01-34-097-08-W6	688	Non-comparison	0	n/a	0	Only seed collected
J	n/a[1]	02-07	4965	P8-11-02	57°21'43"	119°32'37"	12-27-096-10-W6	736	Non-comparison	0	n/a	0	Only seed collected
J	n/a[1]	02-07	4966	P8-12-02	57°23'18"	119°22'25"	11-03-097-09-W6	726	Non-comparison	0	n/a	0	Only seed collected
J	X1817[1]	04-23	5442	#1-03	58°11'06"	118°52'31"	06-11-106-06-W6	588	Comparison	2	19.2	8	
J	X1818[1]	04-23	5443	#2-03	58°12'35"	118°51'46"	01-23-106-06-W6	588	Comparison	2	10	0	
J	X1819[1]	04-23	5444	#3-03	58°07'32"	118°46'49"	06-19-105-06-W6	588	Comparison	2	5.1	8	
J	X1820[1]	04-23	5445	#4-03	58°07'17"	118°49'59"	03-19-105-06-W6	588	Comparison	2	10.5	10	
J	X1821[1]	04-23	5446	#5-03	58°13'31"	119°01'41"	08-26-106-07-W6	588	Comparison	2	22.7	0	
J	X1822[1]	04-23	5447	#6-03	58°10'03"	119°01'38"	04-01-106-07-W6	588	Comparison	2	10.9	4	
J	X1823[1]	04-23	5448	#7-03	58°08'25"	119°21'59"	14-26-105-09-W6	588	Comparison	2	10.7	3	
J	X1824[1]	04-23	5449	#8-03	58°07'43"	119°41'21"	09-21-105-08-W6	588	Comparison	2	22.4	10	
J	X1825[1]	04-23	5450	#9-03	58°08'58"	119°08'01"	13-28-105-07-W6	588	Comparison	2	28.3	5	
J	X1826[1]	04-23	5451	#10-03	58°09'00"	118°49'37"	03-31-105-05-W6	588	Comparison	2	31.3	6	
J	X1852[1]	07-02	n/a	G346A-4321-II-75-4	56°19'45"	119°53'57"	09-36-084-13-W6	738	Plantation			0	
J	X1853[1]	07-02	n/a	G346B-4321-IV-24-4	56°19'45"	119°53'57"	09-36-084-13-W6	738	Plantation			0	
RC	X1338	99-23	3939	BCFS # 29	56°33'00"	121°16'00"		823	Non-comparison*	0	n/a	10	SCA Collections
RC	X1339	99-23	3940	BCFS # 30	56°44'00"	121°47'00"		914	Non-comparison*	0	n/a	11	SCA Collections
RC	X1340	99-23	3941	BCFS # 31	56°59'00"	121°16'00"		1067	Non-comparison*	0	n/a	12	SCA Collections
RC	X1341[1]	99-23	3942	BCFS # 33	57°14'00"	122°41'00"		945	Non-comparison*	0	n/a	9	SCA Collections
RC	X1342	99-23	3943	BCFS # 34	57°36'00"	122°57'00"		1250	Non-comparison*	0	n/a	0	SCA Collections
RC	X1343	99-23	3944	BCFS # 149	56°38'00"	121°34'00"		914	Non-comparison*	0	n/a	2	SK Collections
RC	X1344	99-23	3945	BCFS # 150	56°41'00"	121°41'00"		927	Non-comparison*	0	n/a	7	SK Collections
RC	X1345	99-23	3946	BCFS # 158	55°50'00"	121°37'00"		805	Non-comparison*	0	n/a	6	SK Collections
RC	X1346[1]	99-23	3947	BCFS # 160	55°45'00"	121°35'00"		945	Non-comparison*	0	n/a	8	SK Collections
RC	X1347	99-23	3948	BCFS # 162	55°36'00"	121°29'00"		911	Non-comparison*	0	n/a	0	SK Collections
RC	X1348	99-23	3949	BCFS # 680	55°10'00"	120°53'00"		1235	Non-comparison*	0	n/a	12	Cam Bartram Trees
RC	X1349	99-23	3950	BCFS # 681	55°10'00"	120°53'00"		1235	Non-comparison*	0	n/a	2	Cam Bartram Trees
RC	X1350	99-23	3951	BCFS # 684	55°10'00"	120°53'00"		1200	Non-comparison*	0	n/a	10	Cam Bartram Trees
RC	X1351	99-23	3952	BCFS # 686	55°26'00"	120°43'00"		1100	Non-comparison*	0	n/a	11	Cam Bartram Trees
RC	X1352	99-23	3953	BCFS # 687	55°26'00"	120°43'00"		1100	Non-comparison*	0	n/a	10	Cam Bartram Trees
RC	X1353	99-23	3954	BCFS # 708	56°44'00"	121°42'00"		850	Non-comparison*	0	n/a	14	Cam Bartram Trees

RC	X1354	99-23	3955	BCFS # 709	56°44'00"	121°44'00"		850	Non-comparison*	0	n/a	8	Cam Bartram Trees
RC	X1355	99-23	3956	BCFS # 710	56°55'00"	121°32'00"		920	Non-comparison*	0	n/a	0	Cam Bartram Trees
RC	X1356	99-23	3957	BCFS # 711	56°55'00"	121°32'00"		930	Non-comparison*	0	n/a	12	Cam Bartram Trees
RC	X1357	99-23	3958	BCFS # 716	58°38'00"	122°42'00"		495	Non-comparison*	0	n/a	14	Cam Bartram Trees
RC	X1715		4483	BCFS # 677	55°32'00"	121°58'00"		832	Non-comparison*	0	n/a	0	
RC	n/a		4484	BCFS # 678	55°32'00"	121°58'00"		832	Non-comparison*	0	n/a	0	
RC	n/a		4485	BCFS # 679	55°32'00"	121°58'00"		832	Non-comparison*	0	n/a	0	
RC	X1716		4486	BCFS # 707	56°44'00"	121°42'00"		850	Non-comparison*	0	n/a	0	
RC	X1717		4487	BCFS # 712	56°55'00"	121°32'00"		930	Non-comparison*	0	n/a	0	
											TOTAL	**474**	

*Original selections were mature trees grafted in B.C. clone bank during the 1970's when scions were collected for grafting
** Indicates the %lift in breeding value (BV) for height that may be used in calculating genetic gain if the tree is an 'intensive' selection and there is documented height over age superiority
1 Indicates seedlots to be tested in the G371 series supplementary progeny trials to be established in 2009