Controlled Parentage Program Plan for the Region G2 White Spruce Tree Improvement Project in the Northwest Boreal Region in Alberta

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NOTE: This report is one of a series of Controlled Parentage Program Plans being developed by the 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 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.

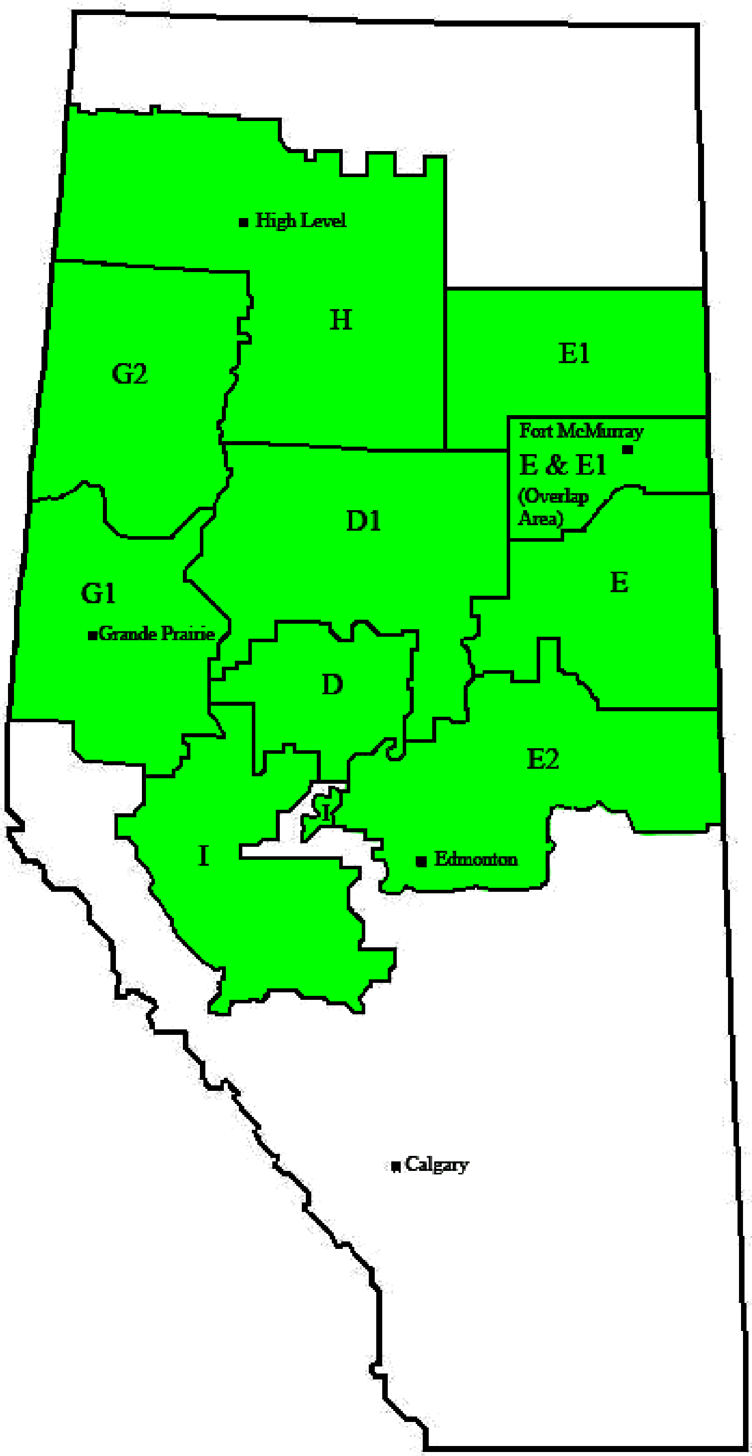
White spruce is one of the most important commercial forestry species in Alberta. Approximately 43 million white spruce trees are planted each year to regenerate harvested and denuded areas. The species is a dominant component of the Boreal and Foothills Natural regions in Alberta and a significant component of the Parklands and Rocky Mountain Natural regions.

This report describes the breeding plan or Controlled Parentage Program Plan (CPP) for genetic improvement of white spruce in Breeding Region G2 located in the northwest boreal region of Alberta (Figure 1). There are nine white spruce breeding regions delineated in Alberta at present and each breeding region corresponds to a separate white spruce genetic improvement project.

2.0 PROJECT HISTORY

The Breeding Region G2 white spruce project is derived from the earlier region G1 white spruce project in west central Alberta. The G1 project concept was modified around 1990 to exclude the northern area, mainly the Peace region, which was a provisional reserve for the proposed FMA expansion of Procter and Gamble Cellulose, Ltd (now Weyerhaeuser, Grande Prairie). The FMA expansion proposal was not successful and, as a result, the provisional reserve area was opened for other development proposals. Under this process, Manning Diversified Forest Products (MDFP) was a successful bidder. The G2 project was initiated at the request of MDFP in 1995 as a cooperative project with a major part of the funding provided by the MDFP Research Trust Fund. Other forest industries in the area were contacted for participation in the project. Canadian Forest Products (Hines Creek) and Daishowa-Marubeni initially agreed to participate in the project but after a few years both companies withdrew due to business reasons. Fairview College also 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. Fairview College also withdrew from the project in 1999 after a management program review and policy change. 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 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.

Figure 1: White Spruce Breeding Regions in 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 along with their share in the project.

Manning Diversified Forest Products Ltd (MDFP) - 72%
Alberta Tree Improvement and Seed Centre (ATISC) - 24%
Tolko Industries High Level (TIHL) - 4%

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

In addition, Manning Forestry Research Fund (formerly Manning Forestry Development Research Trust Fund) participates 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 G2 project with the white spruce project in the adjoining Peace Plateau area of northeastern British Columbia through exchange of genetic stock, scientific information, and cooperative genetic testing and research.

4.0 ECOLOGY AND GENETICS OF WHITE SPRUCE

4.1 Ecology and Reproduction

White spruce (*Picea glauca* (Moench) Voss) is a major component of the boreal forest. Its range stretches across the continent from the northern limit of tree growth in Alaska to near 45°N latitude in Atlantic Canada. In Alberta, it is one of the most abundant and widely distributed tree species. It has nearly continuous distribution in the boreal forest in northern Alberta. The southern limit of its distribution in the province varies from east to west: starting in the east, its natural distribution limit is a few kilometers north of Lloydminster; the southern limit then veers southwest, with spurs along the Battle, Red Deer, and Bow Rivers; it then extends west from Calgary and along the foothills of the Rocky Mountains. In addition, a substantial outlier or "island" forest of white spruce occurs in the Cypress Hills in the southeast corner of Alberta. At higher elevations (1200 – 1800 m) in the foothills, white spruce hybridizes with Engelmann spruce (*Picea Engelmannii)* forming a hybrid complex, which eventually gives way to pure Engelmann spruce forest types at the highest elevations. As the climate becomes more severe at higher latitudes in the boreal forest in northern Alberta, white spruce is increasingly replaced by black spruce on many sites. The best development for white spruce occurs on loam to clay loam alluvial or lacustrine deposits and in water discharge areas where well-aerated water and adequate nutrients are available. It is well-adapted to boreal areas with a continental climate (warm summers and cold winters), but is also quite plastic in its ability to tolerate extremes of both climate and soil conditions.

White spruce is moderately shade tolerant, occupies a wide range of soils and can behave either as a pioneer species in disturbed habitats or as a climax species following aspen in mixed stands. It is common in mixtures with aspen, balsam poplar, black spruce and lodgepole pine and, to a lesser extent, with white birch and Douglas-fir in early- to mid-succession stands of boreal, foothills and montane forests. In mid- to late-succession stands, it may form pure stands or occur with components of black spruce and balsam fir. In the Parklands, it is often limited to north facing slopes and small populations on moister sites along the southern and eastern edge of its range.

White spruce is a monoecious species. Reproductive bud differentiation occurs in the year prior to flowering and is enhanced by hot dry weather at the time of differentiation. Female flowers tend to be distributed in the upper crown and male flowers are more common in the lower crown. Pollination occurs in the spring followed by fertilization in 2-3 weeks. After fertilization, cones develop rapidly and embryo development is usually complete by early to late August, but timing can vary by several weeks from year to year depending on the seasonal weather. Cone ripening and seed release occur in late August to early September. Mature seed is winged and wind dispersed but seed loading falls dramatically with distance from the source. White spruce seed shows conditional dormancy and does not germinate readily below 10^0C.

Although individual trees in natural stands may produce seed as early as ten years of age, good seed production generally starts around 30 years of age. Seed production is periodic with good crops occurring every 2 – 6 years where the climate is favorable. The quantity, quality and periodicity of seed crops are highly dependent on climate and weather. At high elevations and latitudes, the periodicity of good crops may be 10 – 12 years due to cool growing seasons, which disrupt pollination and retard and damage embryo development. Good yielding seed crops are generally of better quality than poor crops. White spruce reproduces naturally only by seed and dispersal is mainly by wind. Seedbed moisture is the most important factor in establishment from seed but dense growth of competing vegetation on the seedbed is also an important factor.

Harvest rotation age for white spruce forests in Alberta is generally in the range of 90 – 120 years. Reforestation is most commonly achieved by planting. White spruce is also an important species for wildlife habitat, especially for providing thermal shelter during winter, and its seeds are an important source of food for many species of birds and squirrels.

A good review on the silviculture and ecology of white spruce is provided by Nienstaedt and Zasada (1990).

4.2 Genetics and Tree Breeding

As might be expected from a species with a transcontinental range growing in a wide range of environments, white spruce is a highly variable species. Genetic variation in the species has been extensively studied through provenance trials and progeny testing as part of forest genetics research and tree breeding programs. A good review on genetics, reproduction and evolution of white spruce is provided by Nienstaedt and Teich (1971). A good discussion of geographic variation in forest trees (including white spruce), its genetic basis, and applications in forest practice is provided by Morgenstern (1996).

At the provenance or population level the species is characterized by extensive geographic variation, which is essentially clinal and related to geography and climate at seed origin. Patterns of variation in growth, phenology and cold hardiness show a gradual change over distance or altitude. Tree growth is generally reduced with increase of latitude and altitude of the seed provenance. White pine weevil damage (unpublished data, ATISC) also shows clinal variation along a longitudinal gradient, with damage increasing from east to west.

Geographic variation and climate relationships of white spruce provenances (see Rweyongeza et al. 2007) have been studied in Alberta through the G103 series of provenance trials established by ATISC from

1980 – 1984 at 12 field sites. These trials contained a total of 46 provenances and each trial contained 26 – 30 provenances. At present, 8 trials are surviving and all have been measured at three year intervals between ages 12 - 27 years for survival, growth, climatic and pest damages. Genetic analyses of 24-year results have been completed (Rweyongeza and Yang 2005) and the results show that there are large differences among provenances and test sites for growth traits. On an individual site basis, variation among provenances across sites accounted for 7.7 – 20.7 percent of the total variance for height and 6.4 – 15.3 percent of the total variance for diameter at breast height (dbh). Variation among provenances across sites was 6.1 percent and 4.2 percent of the total variance for height and dbh, respectively. The provenance x site component was significant for both traits and amounted to 62.2 percent and 74.0 percent of the provenance variance for height and dbh, respectively. Survival differences at age 24 were significant only at two sites. Height and dbh growth were related to latitude and elevation of seed origin. However, the strength of these relationships differed among test sites. No specific geographic pattern could be established for provenance survival.

The relationship between 24-year growth and survival of the provenances and climate of the provenance origins for the G103 series trials was also examined. Eight climate variables were used: mean annual temperature (MAT), mean temperature of the coldest month (MTCM), mean temperature of the warmest month (MTWM), degree days below 0^0C (NDD), degree days above 5^0C (GDD), degree of continentality (CI = MTWM-MTCM), mean annual precipitation (MAP) and annual moisture index (AMI = GDD/MAP). Multivariate (principle components) analysis subdivided the provenances into three categories according to their region of origin: a) northern provenances characterized by a dry and highly continental climate with cold winters at low elevations; b) central region provenances characterized by a warm and moist climate at middle elevations; and c) southern provenances characterized by a moist and less continental climate with cooler summers and milder winters at higher elevations in the Rocky Mountain foothills. Within these regions, variation for height and dbh was found to be strongly clinal with respect to winter temperatures, continentality and annual precipitation. Clines were highly pronounced especially in the northern region where height growth declined with increasing CI ($r = -0.94$), decreasing MTCM ($r = 0.96$) and decreasing MAP ($r = 0.90$). Clines were also pronounced in the southern region and generally showed growth potential decline with increased elevation of seed origin. Because of the large elevation effect in the southern region, climatic gradients are opposite to those in the northern region showing increased height growth with an increase in CI ($r = 0.85$), a decrease in MTCM ($r = -0.68$) and a decrease in MAP ($r = -0.78$). Clines are weak in the central region. Overall, growth potential of provenances in Alberta appears to have no meaningful relationship with summer temperatures (MTWM and GDD). Growth and survival on test sites were largely controlled by a balance between MAP and GDD as expressed by AMI.

Genetic variation and adaptation of Alberta white spruce populations to regional geography and climate has also been examined with the northern areas white spruce provenance-family trials (G133 series) consisting of three trials located at Hay River, Chinchaga River and Red Earth Creek. Established in 1988, these trials contain a total of 125 open-pollinated, half-sib families sampled from stands and natural subregions across northern Alberta.

Eighteen-year data analysis indicated that stands did not differ significantly in survival at any of the sites and the site by stand interaction was also not significant for survival. Stands differed significantly in 18-year height at Hay River ($p=0.0012$) and Chinchaga ($p=0.0061$) but not at Red Earth. In the combined sites analysis, stand differences in 18-year height were significant ($p=0.0024$) but the interaction term site x stand was not significant.

The correlations between stand mean height across sites and stand longitude and elevation were negative and significant. Correlation coefficients (r) and associated probabilities were -0.59 ($p=0.0028$) and -0.51 ($p=0.0138$), respectively. Scatter graphs showing the relationships are given in Figures 2 and 3.

Figure 2: Correlation Between Stand Height and Stand Longitude
r = -0.59

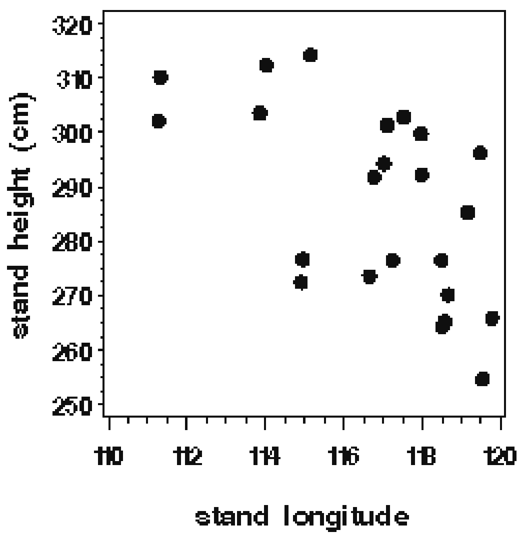
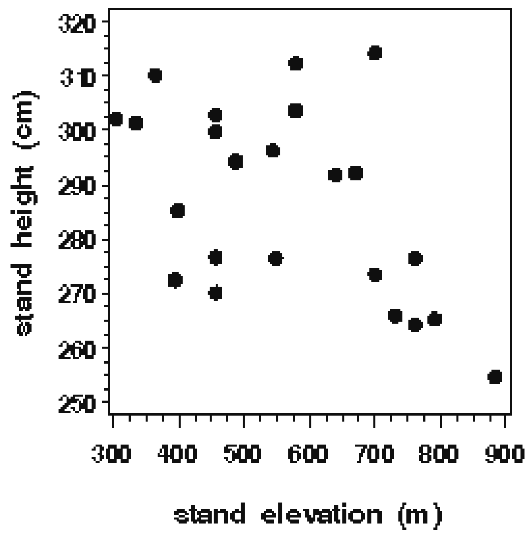


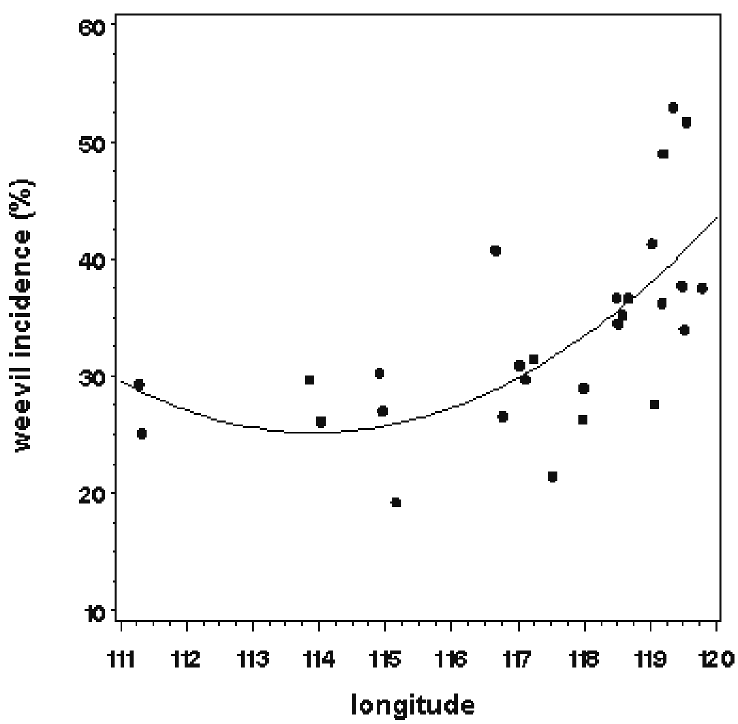
Figure 3: Correlation Between Stand Height and Stand Elevation
r = -0.51



Stand variation in white pine weevil attack was significant at both Hay River and Red Earth but attack incidence at Chinchaga was too low for any stand variation to be detectable.

Using data from the Hay River site only, the quadratic regression of weevil incidence on longitude of seed source was significant (R^2=0.45) with incidence of attack increasing with longitude (Figure 4).

Figure 4: Regression of White Pine Weevil Incidence on Longitude of Stand Origin
r^2 = 0.45



Superior provenances of white spruce have been reported in studies carried out in eastern Canada and the U.S.A. Generally these originate in southeastern Ontario and the Ottawa valley area. Many of these eastern provenances are also being tested in field trials in Alberta and some, particularly from southern Manitoba, seem to be promising.

A summary of results from genetic studies of white spruce in Alberta available from ATISC is presented in Table 1. In general these indicate significant variation among half-sib families for height and dbh growth, tree vigour, and white pine weevil incidence and low to moderate heritabilities for height and dbh growth and white pine weevil resistance.

Table 1. **Summary of White Spruce Genetic Studies in Alberta**

Study or Reference	Materials and Field Testing	Results - Genetic Parameters
G132 series half-sib family tests for region D and D1 (ATISC unpublished data)	150 half-sib families; 4 test sites; Central mixedwood region; 10 and 15-year results.	1. Heritabilities for 10-year height(combined sites): h_i^2 = 0.19; h_f^2 = 0.73 2. Heritabilities for 15-year height(combined sites, 3 sites data): h_i^2 = 0.24; h_f^2 = 0.73 3. Site by family interaction for height significant at 10-years representing 1% of total variation; not significant at 15-years (Carson Lake site, in Reg D, not included in analysis) 4. White pine weevil (WPW) incidence, family heritability at 10 and 15-years = 0.48 and 0.62 respectively (based on two sites with 32.7% and 27.1% incidence at 10-years and 14.4% and 21.6% incidence at 15-years; family mean correlations between sites = 0.31 and 0.45 for 10 and 15-year assessments, respectively 5. Genetic and phenotypic correlations 10yr/15 yr height 0.98 and 0.94, respectively 6. Range of Type B genetic correlations among site pairs = 0.42-0.71 (10-yr), 0.46-0.79 (15-yr) and family mean correlations = 0.34-0.54 (10-yr) and, 0.41-0.66 (15-yr)
G135 half-sib family tests for region G1/G2 (ATISC reports TIC 96-11 and 1996 report to MDFP Research Trust Fund)	69 - 71 families; 2 test sites (G135 A and G135B); Peace River region (Boreal mixedwood); 11-year results 69 families; 1 test site (G135A); 18-Yr results	1. Heritabilities for 11-year height (individual sites): h_i^2 = 0.12 – 0.23 ; h_f^2 = 0.28 – 0.42 (combined site analysis has not been carried out) 2. Heritabilities for 18-year height: h_i^2 = 0.16; h_f^2 = 0.30. Heritabilities for 18-year Dbh: h_i^2 =0.16; h_f^2 = 0.31; genetic and phenotypic correlations between 18-year height and Dbh were 0.91 and 0.96 respectively. Genetic and phenotypic correlations between 11 and 18-year height were 0.88 and 0.89, respectively (one site data at G135A site) 3. 11-yr height/tree vigor score correlations: r_p = 0.76; r_g = 0.68 (one site data) 4. WPW incidence at two sites at 11-year assessment varied from 2.0% to 8.6% 5. WPW incidence at 18-year age on G135A site was 5.7 percent and family effects were not significant
G156 series half-sib family field tests for region E (ATISC report ATISC 04-22)	53 families; 3 test sites; NE Boreal region (Boreal mixedwood); 11-year results	1. Heritability for 11-year height (combined sites): h_i^2=0.18; h_f^2=0.63 2. Site by family interaction for height not significant (0% of total variance) at 11-years age 3. Range of Type B genetic correlations among site pairs for 11-yr height = 0.30-0.70; family mean correlations for 11-yr height = 0.41-0.67 4. Type B family mean correlations between sites for 11-year survival were not significant (r = -0.05 to 0.18). Family mean correlations between 11-yr height and survival were also not significant (r = -0.6 to 0.14) 5. WPW incidence at age 11 at three sites was 1.2% (G156A), 1.4%(G156B) , and 30.1% (G156C). Family mean correlation between one site pair (G156B and G156C) was significant (r = 0.37) 6. Heritability for WPW for the site with highest WPW: h_i^2=0.19, h_f^2=0.60 7. Correlation between 11-year height and mature parent tree wood density was not significant (r =-.12, R^2 = 0.014)

G133 provenance-family tests for northern Alberta (ATISC report 05-17)	125 families from 23 stands represented by 4-10 families per stand; 3 test sites located in NW Boreal region; materials were collected from NE and NW Boreal regions; 11-12, and 18-year results	1. Heritabilities for 12-year height (combined sites): h_i^2 = 0.09; h_f^2 = 0.36; h^2_w = 0.07 2. Heritabilities for 18-year height (combined sites): h_i^2 = 0.08; h_f^2 = 0.35; h^2_w = 0.06 3. Heritabilities for 18-year dbh (combined sites): h_i^2 = 0.08; h_f^2 = 0.36 4. Coefficient of additive genetic variation = 9.57% and 9.62% , respectively for 12-year and 18 year height 5. Stand variation component was significant and amounted to 70.2% and 96.6% of family- within-stands variance component for 12-yr and 18-yr height, respectively 6. Site by families-in-stands interaction was not significant for 12-yr and 18-yr height and dbh 7. WPW incidence at age 18 at three sites was 28.1% (G133A), 4.0% (G133B) , and 14.1% (G133C). Family mean correlations among site pairs were significant and varied from 0.34 to 0.42 8. Heritability for WPW at 18-yr for the site with highest WPW: h_i^2=0.18, h_f^2=0.45
G157 half-sib family field test for region H (ATISC unpublished data)	50 families; 3 test sites; NW Boreal region (Boreal mixedwood); 11-year results	1. Heritability for 11-year height (individual sites): h_i^2=0.07 to 0.15; h_f^2=0.23 to 0.38 2. Heritability for 11-year height (combined sites): h_i^2=0.03; h_f^2=0.21 3. Site by family interaction for height was significant (1.5% of total variance) at 11-years age and was 250% of the family variance component 4. Type B family mean correlations between site pairs for 11-year height were not significant (r = 0.03 to 0.19) 5. WPW incidence at age 11 at three sites was 27.8% (G157A), 8.1% (G157B), and 10.4% (G157C).
h_i^2 = individual tree heritability; h_f^2 = family heritability; h^2_w = within family heritability; r_g = genetic correlation; r_p = phenotypic correlation		

5.0 PROJECT OBJECTIVES

The project is required to fulfill genetically improved seed needs for reforestation of the appropriate operable areas of the G2 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 white spruce seed for the G2 breeding region is estimated to be 2 million 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 G2. 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 white pine weevil) 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 white spruce through *in situ* and *ex situ* conservation in accordance with the provincial Gene Conservation Plan for Native Trees of Alberta.
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 planned duration of 30 years (1995-2025) and is limited to first generation selection and breeding; 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 5% after 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

As discussed in earlier sections, the original region G white spruce tree improvement project delineated in 1977 was split into a southern G1 and northern G2 section based on changes in forest tenure and cooperating partners. Breeding Region G2 as currently delineated is depicted in Figure 5.

The general parameters and limits considered in defining breeding region boundaries for the G2 project were as follows:

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

6.1 Location and Area

Breeding Region G2 lies between 55°53' and 58°15' N latitude and 117°00' and 120°00' W longitude as shown in Figure 5. The total delineated area is 3,073,195 ha of which 2,067,624 ha (67%) are under tenure and 1,135,928 ha (37%) are operable. Elevations within the geographic boundaries of G2 range from less than 500 m along the Peace River valley to 1,219 m at Doig Lookout on Halverson Ridge. Within G2, the deployment zone and operational elevations for the white spruce project are 500 to 900 m. As a result, about 18% of the geographic area within region G2 is excluded (approximately 10% of the area is below 500 m and 8% is above 900 m).

6.2 Forest Cover

Within G2, deciduous dominated forest types cover approximately 60% of the forested land area and coniferous dominated types cover approximately 40% based on phase 3 inventory. On the coniferous land base, coniferous cover types are 40% white spruce, 20% black spruce and 40% pine, as determined by species dominance.

On upland sites, mixed and pure stands of trembling aspen, white and black spruce and pine 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. Conifer forest types dominated by pine occur 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.

Sandy upland sites and rapidly drained sites at lower elevations are frequently occupied by jack pine. 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

Five Natural Subregions belonging to the Boreal Forest and Parkland Natural Regions are represented in the breeding region (see Table 2). The majority of the region G2 area falls within the Lower Boreal Highlands Natural Subregion (67%) and the second largest area falls within the Dry Mixedwood Subregion (24%). Smaller areas fall within the Peace River Parkland (4%), Central Mixedwood (3%) and Upper Boreal Highlands (2%) Natural Subregions. 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 internet 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 2.

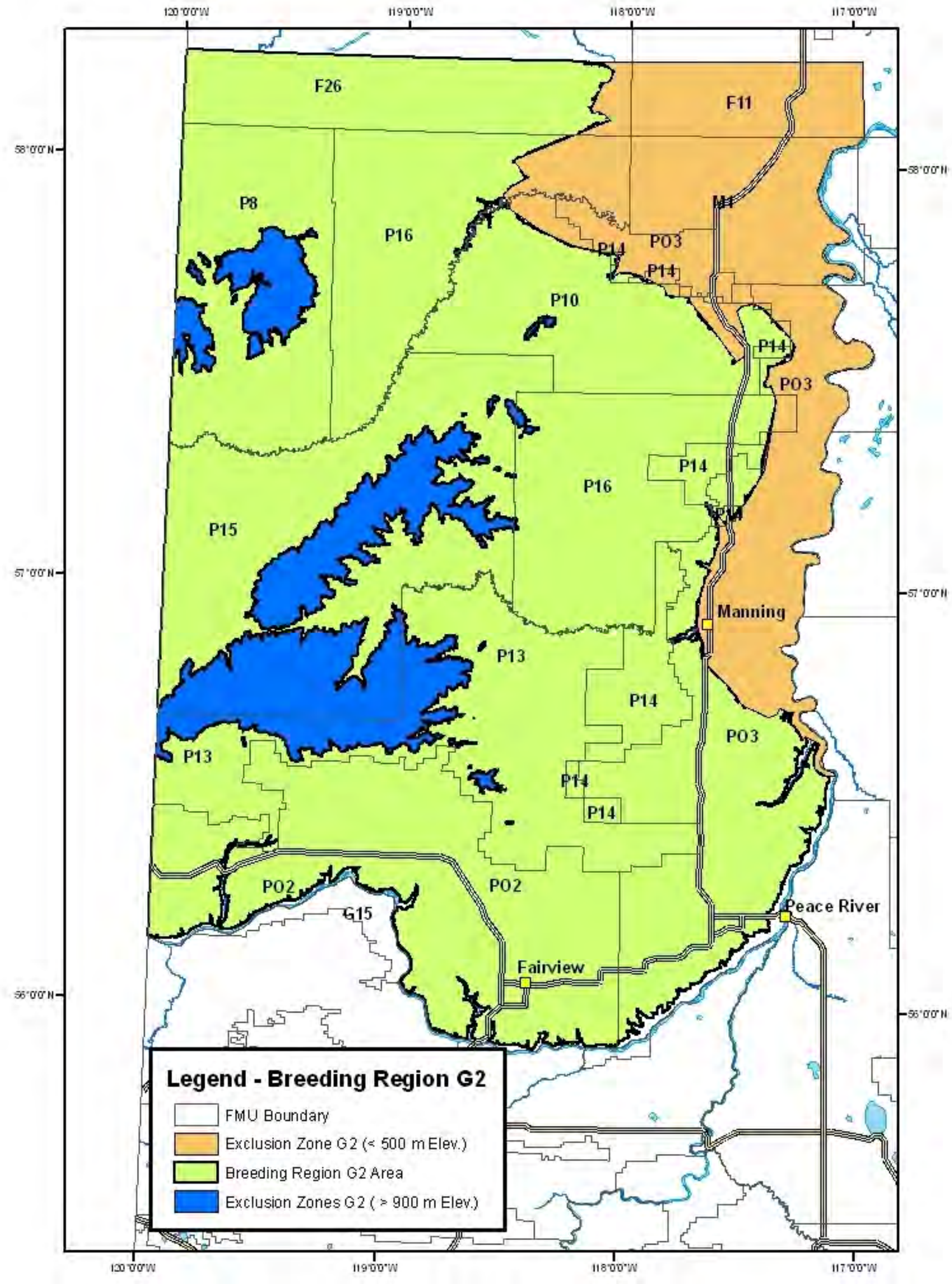
Mean annual temperatures in the area decline with latitude and increase with elevation. As mean annual temperature is more highly correlated with winter than summer temperatures, this indicates that milder winters occur at higher elevations (winter inversions).

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 through September. Both growing season precipitation and annual precipitation increase with elevation and latitude. Average growing season precipitation varies from around 250 mm at lower elevations in the south of the region to around 295 mm at lower elevations in the northwest and increases to around 385 mm at higher elevations. Mean annual precipitation follows a similar geographic pattern. Water deficiencies during the late spring and summer can occur throughout the region but are likely not as common at higher elevations where precipitation amounts are higher and growing season temperatures are lower.

Growing season temperatures for region G2 are highest at low elevations in the south and decrease notably with elevation and more gently with latitude. Growing season thermal climates for Natural Subregions are represented by growing degree days greater than 5˚C in Table 2 and these are highly correlated with summer temperature variables.

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

Figure 5: Breeding Region G2 Map



6.5 Physiography and Soils

Breeding Region G2 falls within two major physiographic subregions (Table 2) (Pettapiece 1986). Lower areas of the breeding region, commonly within the Dry Mixedwood Subregion, are classified as belonging to the Northern Alberta Lowlands which consists primarily of undulating morainal plain 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. Significant areas of Gleysolic and Organic soils occur in poorly drained positions. Occasional Brunisols are present on sandy upland sites and there is a substantial area associated with the Peace River Valley which includes steep slopes and terraces of both glacial and modern origin.

Higher elevations in the breeding region, commonly within the Lower Boreal Highlands Natural Subregion, are classified as belonging to the Northern Alberta Uplands. The topography of this subregion is characterized as 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 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 breeding region occurring at elevations greater than 1000 m and within 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 2. Breeding Region G2 Climate Summary by Natural Subregion

Natural Subregon	*Area (ha)*	*Area (%)*	*MAT(˚)*	*MAP(mm)*	*GSP(mm)*	*GDD>5*	*AMI*	*FFP(days)*
Lower Boreal Highlands	2,064,720	67	-0.9	484	326	1080	2.2	99
Dry Mixedwood	739,000	24	0.3	433	288	1222	2.8	95
Peace River Parkland	111,975	4	1.2	422	282	1340	3.2	104
Central Mixedwood	87,625	3	-0.9	467	317	1156	2.5	97
Upper Boreal Highlands	69,875	2	-1.4	510	341	974	1.9	95
Breeding Region Mean			-0.3	463	311	1155	2.5	98

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 small amount of additional genetic material, provided by the BCMoFR from adjacent areas in northeastern British Columbia, is also included after consideration of its adaptability to the G2 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 Figure. 6. Breeding plan activities and timelines (1995 – 2025) are given in Figure. 7.

Figure 6: Region G2 White Spruce First Generation Tree Improvement Scheme & Timelines

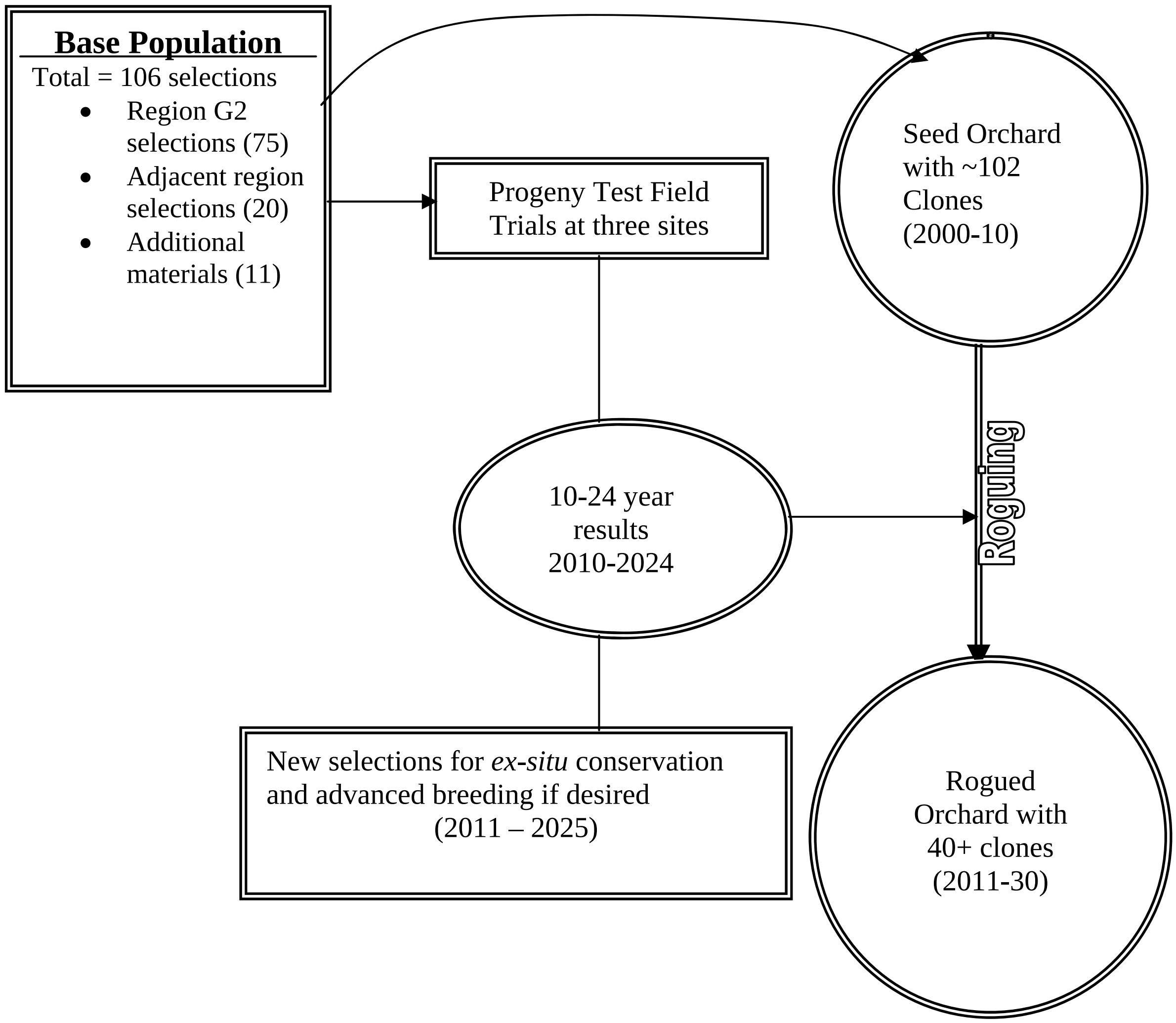
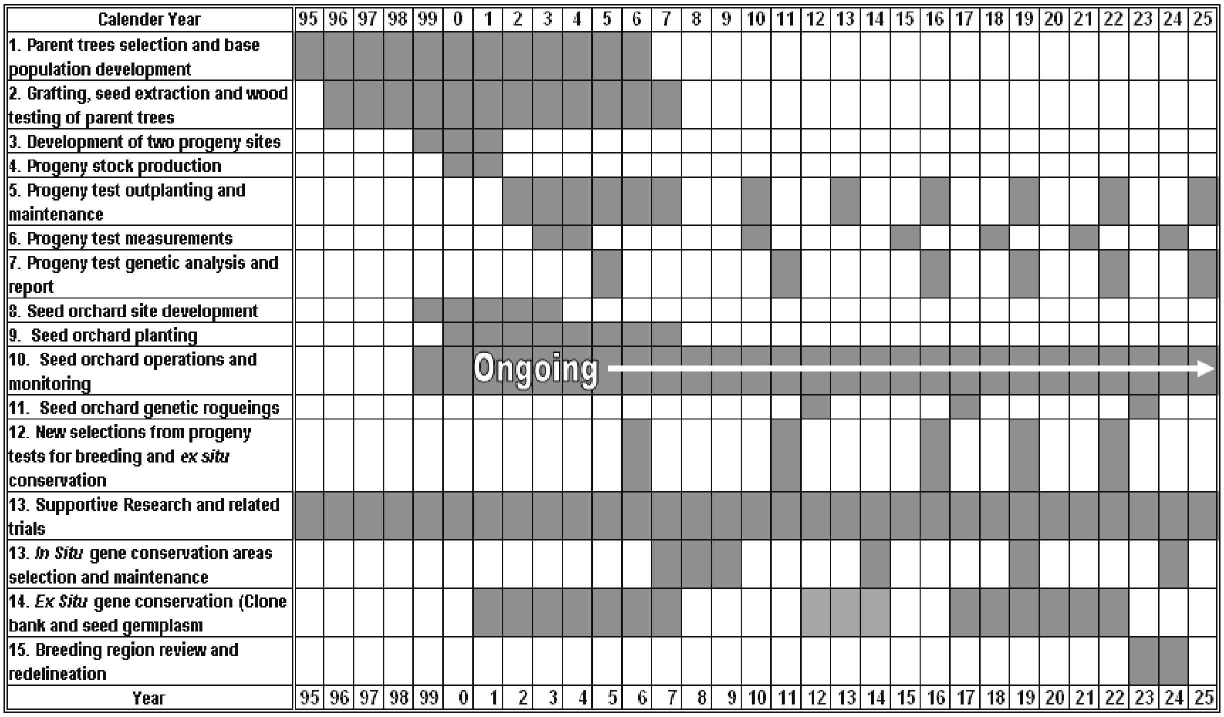


Figure 7: Region G2 Activities and Timelines



7.1 Parent Trees Selection and Base Population Development

Base population genetic stock for the region G2 project consists of 106 parent trees. Descriptions of the parent tree selections are provided in this section and in Appendix II.

Genetic stock acquisition to provide base material for the region G2 tree improvement project dates back to 1980 when parent tree selections commenced for the G1 white spruce project. At that time, Breeding Region G1 extended north, covering a part of the area which now falls into Breeding Region G2 (see Section 2.0 Project History). When the G2 project was initiated in 1995, the ATISC germplasm collection was reviewed for genetic stock adapted to the G2 breeding region. A total of 20 selections, made between 1980 - 1989, were available from adjacent breeding regions (17 from region G1, 2 from region H and 1 from region D1). After reviewing parent tree information and determining availability of scions and open pollinated progeny seed for genetic testing, these selections were rolled into the project base population.

A comprehensive program of parent tree selections for the G2 project was commenced in 1996 and completed in 1998. As part of this work, a total of 70 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; c) from each tree collect scions for vegetative propagation, wood samples for wood quality testing and cones to provide seed for genetic testing. Wood sample and cone collections continued until 2005. Cone collections were not obtained from seven trees due to the absence of a cone crop or because the tree was logged or destroyed by other industrial activity.

Five trees of G2 geographic origin were selected from the G103G provenance research trial established by ATISC at the Chinchaga River genetics site. These selections, referred to as plantation selections, exhibited desirable phenotypes and had superior height growth when the trial was assessed at age 15 years. Only one tree per seed source, usually the best, was selected. Four forward selections came from the region G1 half-sib family test established at the Saddle Hills site (G135B). Based on 11-year field performance, all trees in the trial were ranked according to a selection index combining among and within family information. The best trees in the top four families were selected. Seven geographic selections originated from the Peace Plateau area in northeastern British Columbia adjacent to region G2. Selection of all parent trees detailed above followed standard selection methods and procedures used in ATISC cooperative tree improvement projects. All G2 base population selections (a total of 106) are documented and described in ATISC file reports. There are a total of 12 such 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 stands 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 G2 project.

<u>Wild stands selections made by visual selection method (also referred to as geographic selections):</u> 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 comparison selections and fill in gaps in geographic coverage of the base population. Genetic stock received through other cooperators (e.g. seven trees received from BCMoFR) generally falls under this category.

<u>Plantation selections</u>: 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 G2 breeding plan (Figure 6). The field trials for this purpose are established at three sites within the breeding region. In addition to the G2 first generation base population progenies, these trials also contain some additional provenance and family materials for research purposes. Some of this material may also be useful for expansion of the base population for advanced selections if second generation breeding becomes desirable for the project.

7.2.1 Test site selection, development and planting

The three test sites selected were Hotchkiss River, Battle Hill and Sweeney Creek. The Battle Hill test site (G352A) is located in the Boreal Dry Mixedwood subregion 19 km north and 10 km west of Manning (57°07'N, 117°38'W and 515 m elevation). The Hotchkiss River site (G352B) is located in the Lower Foothills subregion approximately 73 km northwest of Manning (57°08'N, 118°25'W and 750 m elevation). The Sweeney Creek site is located in the Lower to Upper Foothills subregion transition in the Clear Hills, 55 km west of Worsley (56°34'N, 119°34'W and 915 m elevation). The 3 sites are located within the breeding region boundary and are considered to be representative of the white spruce forests in the G2 breeding region; they were selected to represent the geography, climate and ecosites suitable for white spruce regeneration in the region. Additional information on site characteristics and history is provided in Table 3 and in the establishment reports of the respective field trials, which also include Test Site Information Forms.

Table 3. G352 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
Battle Hill (G352A)	Dry Mixedwood subregion; Solonetzic Gray Luvisol with clay loam to clay texture; Moderately well to imperfect drainage	Immature aspen (C2Aw) with some larger aspen and a small component of Sw	-0.3	418	-19.9	1223	2.9
Hotchkiss River (G352B)	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 Ecosite	-1.0	500	-19.6	1039	2.1
Sweeney Creek (G352C)	Lower Boreal Highlands subregion; Gley 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

The sites were logged and prepared during 1997 – 2000 and are enclosed by a game fence. The Battle Hill site is located on wooded farmland owned by MDFP and covered by a land access and use agreement for the G2 project. The Hotchkiss River and Sweeney Creek sites are located on Crown land within the Green Zone and are protected under a Miscellaneous Lease and a DRS land reservation.

7.2.2 Experimental design, field planting and measurements

The field plantings for genetic testing for the project are referred to as the G352 series field trials or Breeding Region G2 White Spruce Progeny Trials. Three trials were established in the spring of 2002 at Battle Hill (G352A), Hotchkiss River (G352B), and Sweeney Creek (G352C). The experimental design chosen for the 3 plantings was an Alpha Design (balanced incomplete block design). The trials consist of 138 seedlots in 8 replications with 14 incomplete blocks per replication and 9 or 10 seedlots per block. Seedlots are planted in 3-tree or 4-tree row plots at 2.5 m x 2.5 m spacing. The 138 seedlots used in the trial design comprised 86 open pollinated (OP) half-sib families (progeny) from the G2 base population and 52 additional seedlots included as research materials for reference testing and to link the results from various white spruce and provenance-family tests in Alberta and northeastern British Columbia. The 52 seedlots included the following material: 8 top performing families from the Northern Areas Provenance OP Family Test (G133B) at the Chinchaga genetics test site; 30 northeastern B.C. selections considered to be potentially promising for the G2 project but requiring adaptation testing; 6 B.C. bulk provenance seedlots; and 8 Alberta bulk provenance seedlots. Twenty parents that are in the G2 base population as listed in Appendix II are not included in the G352 series trials because seed was not available in 2001 when the trial was seeded. These are identified in Appendix II and will be established in a supplementary trial series to be established in 2009 or 2010 after the seed collections are completed from parent ortets in natural stands or from grafts established in the G2 seed orchard.

The trials were established in early June 2002 using one-year-old dormant container stock (Styroblock 615A, 340 ml). Planting was done using tree planting shovels. Soil moisture during planting at the sites varied from good to excellent. Establishment reports were written for each trial and are on file at ATISC. These are referenced below.

- Establishment Report G352A for Battle Hill site
- Establishment Report G352B for Hotchkiss River site
- Establishment Report G352C for Sweeney Creek 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 four years. Survival, plant damage and height were assessed and the results are described in ATISC Technical Report ATISC 05-17 dated June, 2005. A summary of the results for the 124 families included in the tests is provided in Table 4. Briefly, the trials showed excellent overall survival (98.5% – 99.0%). Survival of individual families across sites varied from 95.5% – 100%. Mean height varied from 41.0 cm at Hotchkiss River to 57.1 cm at Battle Hill. Mean height of individual families across sites varied from 42.3 cm to 54.6 cm. Mean damage to seedlings varied from 11.4% at Battle Hill to 41.6% at Sweeney Creek. The most prevalent damage condition was forking due to winter injury and drought and trees are expected to recover from this.

Table 4. Means and Range of Family Means for 4-year Performance of Families in G352 Progeny Trials

Trait	Parameter	Test Site			
		Battle Hill (G352A)	Sweeney Creek (G352B)	Hotchkiss River (G352C)	Combined Sites (352A,B&C)
Height (cm)	Mean	57.1 ± 0.21	45.2 ± 0.17	41.0 ± 0.20	48.4 ± 0.13
	Range	47.9 – 66.2	37.5 – 52.2	33.0 – 49.5	42.3 – 54.6
Survival (%)	Mean	99.0 ± 0.16	98.7 ± 0.18	98.5 ± 0.23	98.8 ± 0.11
	Range	90.6 – 100	90.6 – 100	87.5 – 100	95.5 – 100
Damage (%)	Mean	11.4 ± 0.50	41.6 ± 0.78	35.0 ± 0.87	28.8 ± 0.43
	Range	0.0 – 31.3	12.5 – 81.3	0.0 – 75.0	13.6 – 50.0

- Number of common families on all sites is 124.

7.2.3 Future measurements

The G352 genetic tests will be measured by ATISC at 3 - 6 year intervals up to age 40 in accordance with trial assessment procedures and schedules for white spruce. Assessments are planned for ages 10, 15, 18, 21, 24, 30, 35 and 40. Measured traits will include survival, plant damage condition, white pine weevil incidence and tree height with diameter measurement being added at age 18-years. 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 analyzed within 1 - 3 years of the collection date and summarized in an appropriate technical report format.

8.0 SEED PRODUCTION PLAN

Improved seed production to provide a steady and reliable seed supply of white spruce in region G2 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 seedlot averaged over any five year period. The projected annual seed production requirements are estimated to be about 16 kg of seed which should be sufficient to produce about 2.0 million plantable seedlings per year. This calculation is based on the following assumptions: 1000-seed weight = 3.2 g, seed germination ~93% and 2.3 seeds are required to produce one plantable seedling after nursery oversow and seedling culling requirements for quality control are taken into account.

The seed orchard for the G2 project is referred to as the G318 seed orchard. It was established at a site near North Star in 2000. It commenced commercial seed production in 2005 with a sizeable seed crop of 5.7 kg.

8.1 Seed Orchard Site Location and Climate

The region G2 white spruce seed orchard (G318) is located in the Peace River Dry Mixedwood Plains physiographic 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 G2 forestry 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 G2 project partners have the right of first refusal in case the land is sold.

In 1999, NPARA purchased the quarter section of land, which had 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. Based on these surveys, the most suitable area for the ten 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). Another soil series found in the quarter section but not within the orchard site was the Goose series, an Orthic Humic Gleysol.

Both the Nampa and Kleskun soil series are upland soils which are very similar in physical and chemical characteristics. The Nampa soil series usually occurs in level to depressional lacustrine deposits with imperfect drainage and slopes ranging from 0 to 0.5%. The series has few stones and the B horizon usually has some mottles indicating poor internal drainage.

Table 5. 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 also occurs in level to depressional lacustrine deposits with imperfect drainage and is very similar to the Nampa series with the exception that there is no mottling in the B horizon usually indicating that it occupies a slope position where surface drainage is better.

Table 6. 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. Two 12-foot gates were installed 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 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, 455 grafts were planted in the 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 improvement 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 eight separate zones with two zones each for the spruce and pine orchards and the remaining four zones for expansion. ATCO Electric Ltd. installed single-phase electrical service to the equipment shed in May.

Climate for the site (1961-90) using the Alberta climate model (AENV 2005) is estimated as follows:

Mean Annual Temperature (°C)	0.1
Mean Annual Precipitation (mm)	421
Mean Temperature Coldest Month (°C)	-19.2
Growing Degree Days >5°C	1267
Annual Moisture Index (GDD/MAP)	3.0

8.2 Orchard Design and Establishment

The G2 orchard was developed through vegetative propagation by grafting of selected parent trees (ortets) described in section 7.1 and Appendix II. The grafting of trees commenced in 1995. Out of the 103 trees in the base population, 102 were grafted successfully and are included in the orchard design. The orchard design is completely random 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 800 planting positions at 6 m (among rows) x 3 m (within rows) spacing.

Planting in the orchard commenced in July 2000 when 455 grafts were planted and is nearing completion with a total of 789 grafts currently established in 2006. Parent trees are represented by a minimum of 2 grafts and a maximum of 12 grafts per clone. The planting is described in the G318 establishment report dated October 16, 2000 and in annual addenda written each year after that. 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

In 2006 the orchard establishment was nearly complete with 789 grafts already planted and the remaining in the graft stream. Grafts range in age from 4 to 11 years. Until 2005, orchard management and operations were carried out by NPARA on a contract basis with technical and scientific support provided by ATISC. Starting in 2006, orchard management was carried out by the 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 three applications throughout the growing season.
- Weeds are controlled by mowing and by the application of herbicides.
- Water is delivered to each tree with a drip irrigation system capable of providing at least 5 L (1 gal) 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. Grafts are assessed throughout the growing season for the occurrence of insects and diseases but are particularly monitored when infestations of specific insects are known to occur.
- Crown management is carried out on grafts greater than 3 m in height to promote fuller crowns and thereby increase flowering sites and to limit tree height growth. The trees are topped with a pruning saw immediately above an internode with vigorous lateral branches.

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 7. Orchard management activities are described in detail in the Annual Orchard Management and Operations reports for the G2 orchard. These have been completed annually since 2000 and are on file at ATISC.

Table 7. Cone Crop and Seed Production Information

Region G2 White Spruce Clonal Seed Orchard (G318)

	2006*	2005	2004	2003	2002	2001
Number of trees	789	773	742	628	581	520
Average tree age (years from grafting)	9	8	7	7	6	6
Trees producing cones	-	595 (77%)	101 (14%)	306 (49%)	161 (28%)	15 (3%)
Number of clones	-	100	100	95	89	81
Clones producing cones	-	96 (96%)	48 (48%)	77 (81%)	54 (61%)	14 (17%)
Cone production (l)	-	493	3	84	24.8	0.3
Cones/tree	9	153	1	23	9	0.2
Cones/litre	149	240	271	168	205	287
Total number of cones	-	118,313	812	14,149	5,068	86
Clean seed (g)	-	5,670	0.13	591.7	135.7	0.8
Seeds/cone	6.9	25	0.07	17	12.7	4.3
Seeds/kg	335,570	524,658	438,528	405,712	473,463	444,820
Seed yield (g/hl)	313	1150	4.3	704	548	274
1000 seed weight	2.98	1.91	2.28	2.46	2.16	2.25
Germination %	98	93	84	97	89	88.5
Effective population size	-	42	6	29	23	8

*data from psts only

The seed production projections for the orchard were done for the period 2000 to 2027 using pooled data (4-year moving averages) from 6 Alberta white spruce seed orchards over a 12-year period. These projections, the seed to plantable seedling conversion and the amount of improved stock available to each project partner from the projected orchard production is shown in Table 8.

Table 8. G2 Orchard Seed Production Estimates and Seedlings Allocation to Project Partners

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 (72%)	TIHL (4%)	ATISC (22%)
2000	5		4.6	455	2,093	1,884	819	590	33	180
2001	6	0.7	13.8	520	7,176	6,458	2,808	2,022	112	618
2002	6	110.8	"	581						
2003	7	383.0	41.0	628	25,748	23,173	10,075	7,254	403	2,217
2004	7	0.1	"	742						
2005	8	2326.5	121.3	773	93,765	84,388	36,691	26,417	1,468	8,072
2006	9		352.7	800	282,160	253,944	110,410	79,496	4,416	24,290
2007	10		979.4	800	783,520	705,168	306,595	220,748	12,264	67,451
2008	11		2422.3	800	1,937,840	1,744,056	758,285	545,965	30,331	166,823
2009	12		4786.8	800	3,829,440	3,446,496	1,498,477	1,078,903	59,939	329,665
2010	13		7115.6	800	5,692,480	5,123,232	2,227,492	1,603,794	89,100	490,048
2011	14		8502.5	800	6,802,000	6,121,800	2,661,652	1,916,390	106,466	585,563
2012	15		9096.9	800	7,277,520	6,549,768	2,847,725	2,050,362	113,909	626,500
2013-2027	16-30		9096.9	.	7,277,520	6,549,768	2,847,725	2,050,362	113,909	626,500

[1] Average graft age for orchard from cone and seed production table of annual orchard report. Note graft age may be the same in consecutive years because greater numbers of younger grafts were planted in the latter year eg 2003 and 2004

[2] Calculated from orchard seed production data

[3] Calculated from ATISC Cooperative Sw seed orchards 4-year moving average data and logistic regression of the data for curve smoothing

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

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

[6] Total number of seeds in [5] divided by 2.3 (assumes production of 1 plantable seedling requires sowing 2 seeds per cavity and some oversow); 10% 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 2012 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

According to STIA guidelines, a permanent sample tree (pst) monitoring program was started in the region G2 orchard in 2001 for the following purposes: to provide orchard-specific local data on seed orchard development, flowering, cone and seed production and seed quality; to provide an estimate of reproductive contribution of orchard clones; and to serve as a tool for cone crop forecasting and seed collection planning. In the spring, orchard phenology is monitored by evaluating and recording male and female bud development on the psts to develop information on the timing and duration of pollen dissemination and female flower receptivity in the orchard.

There are currently 119 psts assigned in the orchard with each planting year being proportionately represented. This exceeds the sample size stipulated by STIA (10% of the intended number of trees) and provides a buffer in the event of any mortality. Psts are selected systematically to ensure all clones represented by 5 or more ramets are included and to ensure all areas of the orchard are sampled. Data are collected on the following traits: height, crown width, dbh, number of male and female flowers, number of cones, cones per litre, seeds per cone, 1000 seed weight and seed germination. The results are tabulated and summarized each year in the annual orchard management and operations reports. The results of 2005 pst monitoring are shown in Table 9. Brief descriptions of methods and procedures followed in pollen and phenology monitoring are given below.

<u>Pollen monitoring:</u> 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 spruce pollen are measured with two 'regional' pollen monitors located north and west of the orchard. The regional monitors are more than 300 m away from the orchard boundary. 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 spruce 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 9. Summary of 2006 Seed Production & Monitoring Information for Region G2 White Spruce Clonal Seed Orchard (G318)

	ORCHARD CHARACTERISTICS	RESULT
1.	Orchard design capacity	800
2.	Total no. of seed trees established	789
3.	Total no. of clones/families established	102
4.	Average age	9
5.	Age range	4-11
6.	Average height (cm ± SE)	-
7.	Height range	-
8.	Average crown width (cm ± SE)	-
9.	Crown width range	-
10.	Average DBH (cm ± SE)	-
11.	DBH range	-
12.	Total no. of PSTs	119
	REPRODUCTIVE BALANCE	
13.	No. of PSTs flowering	91
	Male Flowering	
14.	No. PSTs with male flowers	81
15.	Mean no. male flowers/PST	27
16.	Standard error of (15.)	6
17.	Range male flowers/PST	0-300
	Female Flowering	
18.	No. PSTs with female flowers	56
19.	Mean no. female flowers/PST	7
20.	Standard error of (19.)	2
21.	Range female flowers/PST	0-100
22.	Mean male:female flower production ratio	3.9
	IMMATURE CONE PRODUCTION	
23.	Date assessed	na
24.	No. PSTs producing cones	na
25.	Mean no. cones/PST	na
26.	Standard error of (25.)	na
27.	Range of cones/PST	na
28.	**Cone crop estimate (number of cones)***	5523
29.	**Cone crop estimate (hectolitres)****	0.4
	CONE PRODUCTION	
30.	No. of PSTs producing cones	56
31.	Mean no. cones/PST	9
32.	Range of cones/PST	0-234
33.	Total no. of cones collected from PSTs	1066 (all cones)
34.	Mean no. of cones/litre	149
	SEED PRODUCTION	
35.	Seed production (g)	21.9
36.	No. of seeds/cone	6.9
37.	1000 seed weight	2.98
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 G2 white spruce 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 white spruce on-site within its natural habitat in the 4 seed zones (LBH 1.6, LBH 1.1, DM 1.2 and PRP 1.1) having more than 15% of their area within the breeding region. Populations of white spruce identified for conservation will be selected based on STIA requirements for *In Situ* conservation of species covered under CPP programs and in accordance with the provincial Gene Conservation Plan for Native Trees of Alberta. Identification, selection, documentation management and protection of these stands will be a cooperative effort between company partners, ASRD and Alberta Tourism, Parks, Recreation and Culture (ATPRC).

Ex Situ gene conservation involves conserving seed and vegetative germplasm of white spruce 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. Eighty-three seedlots already collected from parent trees in the G2 base population have been conserved in the seed bank and collections from the remaining 20 trees will be completed over the next few years. In addition, 257 grafts from 69 parent trees are established in the white spruce clone bank at ATISC. The G352 progeny test field trials at 3 sites described in section 7.2.2 will also serve as *ex situ* conservation plantings for the duration (40 years) of the trials. Plant materials in field trials discussed in Supportive Research and Field Trials (Section 10.0) will also partially fulfill *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 G2 breeding project will be carried out with the support of ATISC and the Manning Forestry Research Fund (MFRF) where there is MFRF research project approval. 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 (G318) and progeny trials (G352 series) established as part of the G2 project. In addition, the following white spruce field trials established in the G2 breeding region by ATISC and its cooperators are of interest for scientific studies related to the project.

- **G103G White Spruce Provenance Trial** Established at the Chinchaga River experimental site in 1982, the trial contains 28 Alberta white spruce provenances. It was measured at age 12-years and at 3-year intervals after that to age 27. The trial is one of a province-wide series of 8 white spruce provenance trials.

- **G133B White Spruce Northern Areas Provenance-Family Trial** Established at the Chinchaga River Experimental Area in 1988, the trial contains 125 OP half-sib families sampled from 23 stands across northern Alberta. The purpose of the trial is to study white spruce genetic variation and the adaptation of populations to regional geography and climate. The trial has been measured at 15, 18 and 21-years of age. There are 2 other trials in this series (G133A and G133C) established at the HRA and Red Earth Experimental sites.

- **G135A White Spruce Progeny Trial for Region G** Established at the Chinchaga River Experimental area in 1988, the trial contains 69 half-sib families collected from parent trees selected within the original region G, now divided into regions G1 and G2. The trials have been measured at 15, 18 and 21 years of age. These families are represented in one other trial (G135B) established at the Saddle Hills Experimental area.

- **G347B White Spruce Provenance and Family Testing – B.C., Quebec and Alberta Materials** Established at the Battle Hill site in 2001, the trial contains 88 seedlots (32 bulk collections and 56 single tree collections) from British Columbia, Quebec and Alberta. The Quebec material represents the 20 best families in Quebec's white spruce breeding program. This material is represented in 1 other trial (G347A) established at the Diamond Hills Experimental area near Rocky Mountain House.

The results from the above trials have been periodically described in ATISC technical reports and included in Manning Forestry Research Fund annual progress reports from 1996 – 2006. Results are also briefly summarized in section 4.2 and Table 1.

The proposed research for the G2 project would make use of the information and data available from all the trials mentioned above and other trials to develop knowledge and increase understanding in the following specific areas.

a) **Seed orchard management and seed production:** Flowering and seed production in the G318 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 significant wild white spruce stands and pollen contamination sources by approximately 10 km, pollen contamination needs to be studied and its impact on the genetic quality and adaptation characteristics of G2 seed evaluated as isolated trees and stands occur to the west along an adjacent creek and occur in farm shelterbelts in the area. 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 G2 is quite variable in topography and climate and detailed information is required on regional differentiation of white spruce populations, particularly information on genetic variation in adaptive traits 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 G2 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 white spruce breeding regions i.e. region H to the north, region D1 to the east, region G1 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.

11.0 ACKNOWLEDGEMENTS

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Appendix I: Region G2 Orchard Seed Production and Landscape Deployment Plan

1	2	3			4		5	6	7
Tenure Holder	**Total Breeding Region By Tenure**	**Operable Area**	**Strata**	**Transition Strata**	**Area of Target Strata**	**Trees/ ha**	**Plants Required**	**Planned Production <30**	**Planned Production > 30**
MDFP-P16	536556.859	291541.824	C-SW-B	C-SW-CD	29,994	1,600	47,991,042		23,995,521
			C-SW-CD	C-SW-CD	27,758	1,600	44,413,242		22,206,621
			MW-CD-B	CD-BCD	2,916	1,200	3,499,651		1,749,826
			MW-CD-CD	CD-BCD	9,797	1,200	11,756,369		5,878,184
			MW-CDU-B	CD-BCD	4,144	1,200	4,972,879		2,486,440
			MW-CDU-CD	CD-BCD	3,620	1,200	4,344,337		2,172,169
			MW-DC-B	DC-BCD	2,163	800	1,730,162		865,081
			MW-DC-CD	DC-BCD	4,463	800	3,570,690		1,785,345
			MW-DCU-B	DC-BCD	5,029	800	4,023,167		2,011,584
			MW-DCU-CD	DC-BCD	7,729	800	6,182,854		3,091,427
			Du-A (conifer)	DC-BCD	28,809	800	23,046,954		11,523,477
			Du-A (deciduous)	DC-BCD	28,809	800	23,046,954		11,523,477
			Du-BCD	CD-BCD	39,514	1,200	47,416,764		23,708,382
			Total		**194,745**		**225,995,064**		**112,997,532**
FMU-P1N (P15)	Total P15 Area= 423967.639	47522.145	C-SBSW-P	Not in Program	10,849	0	0		0
			C-SW-S	Not in Program	5,807	0	0		0
			CD-SW-S	Not in Program	3,511	0	0		0
			CD/DC-SW-P	Not in Program	2,307	0	0		0
			DC-A-S	Not in Program	2,455	0	0		0
			Total		**24,929**		**0**		**0**
FMU-P7 (P15)	Total P15 Area= 423967.639	132592.436	C-SBSW-P		13,434	1,600	21,494,686		10,747,343
			C-SW-S		10,079	1,600	16,126,046		8,063,023
			CD-SW-S		10,868	1,200	13,041,596		6,520,798
			CD/DC-SW-P		13,102	1,200	15,722,606		7,861,303
			DC-A-S		14,936	800	11,948,931		5,974,466
			Total		**62,419**		**78,333,867**		**39,166,933**
FMU-P10 (P15)	Total P15 Area= 423967.639	19143.1583	C-SBSW-P		2,259	1,600	3,614,338		1,807,169
			C-SW-S		374	1,600	598,858		299,429
			CD-SW-S		198	1,200	237,974		118,987
			CD/DC-SW-P		396	1,200	475,241		237,620
			DC-A-S		3,379	1,000	3,379,498		1,689,749
			Total		**6,607**		**8,305,908**		**4,152,954**
FMU-P8 (No Harvest Area)	284170.471	136188.276	C-SBSW-P	No Harvest Area	19,408	0	0		0
			C-SW-S	No Harvest Area	4,927	0	0		0
			CD-SW-S	No Harvest Area	1,837	0	0		0
			CD/DC-SW-P	No Harvest Area	3,914	0	0		0
			DC-A-S	No Harvest Area	12,419	0	0		0
			Total		**42,505**		**0**		**0**
DMI-P10D(P13)	253743	125629.1	>20% Sw		31,575	1,400	44,205,000		22,102,500
DMI-P1S(P13)	59548.8	46534.5	>20% Sw	Not in Program	12,691	0	0		0
DMI-P2(P13)	282771.9	188961.8	>20% Sw	Not in Program	67,296	0	0		0
DMI-P11(P13)	14310.5	8872.8	>20% Sw	Not in Program	2,470	0	0		0
Tolko-F26(P13)	212555	138942	>20% Sw		77,666	1,400	108,732,400		54,366,200
			Total		**191,697**		**152,937,400**		**76,468,700**
	2067624	1135928	Grand Total		522,903		465,572,240		232,786,120

Appendix II: Breeding Region G2 Base Population Geographic Origins and Description of Parent Trees

	Breeding Region	Clone #	File Report #	Seed Acc. #	Latitude ^{0}N	Longitude ^{0}W	Elev (M)	Type of Selection	Breeding Value[1]	% height Superiority	2006 G318[2]
1	G1	X0110	19802	2049	55°38'00"	119°44'00"	855	Comparison	2	47	**8**
2	G1	X0115	19802	2054	55°35'00"	119°32'00"	885	Comparison	2	17.7	**8**
3	G1	X0121	19802	1927	55°24'00"	119°29'00"	520	Comparison	2	16.4	**7**
4	G1	X0122	19802	1926	56°24'00"	119°29'00"	520	Comparison	0	-8.1	**8**
5	G1	X0124	19802	1934	56°16'00"	119°16'00"	425	Comparison	0	-11.3	**10**
6	G1	X0125	19802	1936	56°15'00"	119°02'00"	400	Comparison	2	5.1	**10**
7	G1	X0129	19802	2342	54°31'00"	118°42'00"	885	Comparison	2	8.3	**8**
8	G1	X0138	19802	2345*	54°37'00"	118°37'00"	825	Comparison	0	-5.1	**9**
9	G1	X0152	19812	2452	55°34'00"	119°22'00"	880	Comparison	2	10.6	**0**
10	G1	X0157	19811	2454	55°38'30"	119°41'00"	850	Comparison	2	37.9	**8**
11	G1	X0166	19811	2460	55°41'00"	119°22'00"	850	Comparison	2	22.1	**8**
12	G1	X0193	19812	2355	55°33'00"	119°52'00"	823	Comparison	0	-2.2	**7**
13	G1	X0194	19812	2356*	55°34'00"	119°53'00"	823	Comparison	2	10	**8**
14	G1	X0198	19812	2476	55°29'00"	119°35'00"	854	Comparison	2	3.1	**12**
15	G1	X0199	19812	2477	55°35'00"	119°56'00"	793	Comparison	0	-2.8	**10**
16	G1	X0200	19812	2357	55°35'00"	119°55'00"	854	Comparison	2	7.8	**6**
17	G1	X0202	19812	2479	55°36'00"	119°47'00"	762	Comparison	2	29.8	**8**
18	H	X0356	19864	3048	58°20'00"	118°56'20"	500	Comparison	2	21.9	**8**
19	H	X0482	19874	n/a*	58°14'51"	118°09'13"	518	Comparison	2	5.1	**9**
20	RC	X0683	19901	n/a*	56°31'00"	116°02'00"	610	Comparison	2	18.4	**8**
21	G2	X1226	96-06	4331	57°01'35"	117°58'07"	735	Comparison	2	3	**10**
22	G2	X1227	96-06	4242	57°01'48"	117°58'07"	755	Comparison	2	6	**10**
23	G2	X1228	96-06	4247	56°58'19"	117°52'29"	644	Comparison	2	13.8	**6**
24	G2	X1230	96-06	4334	57°13'08"	118°15'12"	741	Comparison	2	15.2	**8**
25	G2	X1231	96-06	4248	57°05'57"	118°19'29"	851	Comparison	2	7.5	**0**
26	G2	X1232	96-06	4338	57°02'54"	118°15'03"	798	Comparison	2	24.1	**8**
27	G2	X1233	96-06	4332	57°13'08"	118°15'12"	756	Comparison	0	-2	**4**
28	G2	X1234	96-06	4340	57°08'08"	118°20'17"	795	Comparison	2	0.1	**5**
29	G2	X1235	96-06	4243	57°07'15"	118°06'11"	678	Comparison	2	2	**6**
30	G2	X1236	96-06	4244	57°07'15"	118°03'23"	702	Comparison	0	-0.6	**6**
31	G2	X1237	96-06	3979	57°16'12"	118°33'04"	840	Comparison	2	19.6	**5**
32	G2	X1238	96-06	4337	57°20'59"	118°28'12"	814	Comparison	2	6.3	**8**
33	G2	X1278	96-06	5667*	57°03'59"	118°14'39"	794	Comparison	2	6.9	**10**
34	G2	X1279	96-06	4339	57°19'54"	119°03'08"	720	Comparison	2	10.1	**12**
35	G2	X1280	96-06	4333	57°22'18"	118°21'18"	814	Comparison	2	9.3	**11**
36	G2	X1281	96-06	4335	57°23'11"	118°20'28"	823	Comparison	2	13.9	**6**
37	G2	X1282	96-06	4336	57°14'27"	118°16'49"	759	Comparison	2	26.6	**11**

	Breeding Region	Clone #	File Report #	Seed Acc. #	Latitude ⁰N	Longitude ⁰W	Elev (M)	Type of Selection	Breeding Value[1]	% height Superiority	2006 G318[2]
38	G2	X1283	96-06	3980	57°04'25"	117°55'18"	681	Comparison	2	15.2	**12**
39	G2	X1284	96-06	4342	57°19'41"	119°01'30"	751	Comparison	2	3.5	**12**
40	G2	X1285	96-06	4341	57°23'50"	118°55'49"	810	Comparison	2	0.7	**9**
41	G2	X1326	96-06	3981	57°38'41"	117°25'46"	778	Comparison	2	2.9	**11**
42	G2	X1327	96-06	3982	57°37'22"	117°26'35"	676	Comparison	2	8	**6**
43	G2	X1328	96-06	4343	57°22'05"	118°59'53"	659	Comparison	2	2.7	**8**
44	G2	X1329	96-06	4352	57°10'06"	118°33'09"	903	Comparison	2	11.6	**9**
45	G2	X1390	96-06	n/a*	57°36'56"	117°29'52"	548	Comparison	2	13.4	**7**
46	G2	X1391	96-06	4245	57°21'52"	118°39'58"	931	Comparison	0	-3.1	**0**
47	RC	X1392	97-11	n/a*	54°37'00"	118°37'00"	825	Plantation			**3**
48	RC	X1393	97-11	n/a*	55°34'00"	119°53'00"	823	Plantation			**2**
49	RC	X1394	97-11	n/a*	55°34'00"	119°22'00"	880	Plantation			**7**
50	RC	X1395	97-11	n/a*	55°35'00"	119°56'00"	793	Plantation			**3**
51	G2	X1534	97-18	n/a*	57°36'00"	117°31'00"	460	Plantation	0		**7**
52	G2	X1535	97-18	n/a*	55°35'00"	118°18'00"	640	Plantation	0		**8**
53	G2	X1536	97-18	n/a*	56°34'00"	119°40'00"	762	Plantation	0		**8**
54	G2	X1537	97-18	n/a*	54°27'00"	118°38'00"	838	Plantation	0		**5**
55	G2	X1538	97-18	n/a*	55°29'00"	116°05'00"	610	Plantation	0		**6**
56	G2	X1405	98-01	4365	57°04'20"	118°49'48"	760	Comparison	2	18.8	**9**
57	G2	X1406	98-01	4370	57°01'35"	118°49'15"	750	Comparison	2	13.4	**10**
58	G2	X1407	98-01	4354	57°02'54"	118°56'59"	770	Comparison	2	17.9	**6**
59	G2	X1408	98-01	4356	57°03'22"	118°49'40"	755	Comparison	2	7.6	**7**
60	G2	X1409	98-01	4366	56°39'32"	117°58'43"	701	Comparison	2	52.7	**6**
61	G2	X1411	98-01	5668*	57°25'18"	119°14'52"	760	Comparison	2	22.7	**6**
62	G2	X1412	98-01	4249	57°25'18"	119°14'52"	760	Comparison	2	16.4	**2**
63	G2	X1413	98-01	4367	57°00'43"	118°51'13"	846	Comparison	2	0.7	**5**
64	G2	X1423	98-01	4362	56°39'49"	118°00'20"	853	Comparison	2	4.9	**7**
65	G2	X1322	98-02	n/a*	56°27'51"	119°29'16"	533	Comparison	2	8.8	**9**
66	G2	X1323	98-02	4353	56°26'01"	117°57'45"	686	Comparison	2	10	**11**
67	G2	X1324	98-02	4347	56°26'57"	118°03'42"	709	Comparison	2	15.3	**7**
68	G2	X1325	98-02	4348	56°20'24"	118°04'29"	831	Comparison	2	15.2	**6**
69	G2	X1335	98-02	4350	56°26'17"	118°08'50"	686	Comparison	2	14.8	**8**
70	G2	X1336	98-02	4346	56°34'08"	118°45'13"	709	Comparison	2	13.7	**8**
70	G2	X1337	98-02	4349	56°23'37"	117°56'57"	609	Comparison	2	12.2	**6**
72	G2	X1378	98-02	4344	56°37'50"	119°34'40"	716	Comparison	2	20.9	**0**
73	G2	X1379	98-02	4351	56°22'31"	117°58'32"	800	Comparison	2	15.3	**6**
74	G2	X1380	98-02	4345	56°26'04"	118°02'07"	709	Comparison	2	12.2	**10**
75	G2	X1433	98-02	4357	56°45'57"	118°19'39"	732	Comparison	2	41.4	**6**
76	G2	X1434	98-02	4355	56°26'15"	118°25'08"	823	Comparison	2	24.6	**7**
77	G2	X1435	98-02	n/a*	56°45'41"	118°21'31"	792	Comparison	2	17.5	**4**
78	G2	X1436	98-02	4358	56°47'19"	118°25'59"	762	Comparison	2	21	**7**

	Breeding Region	Clone #	File Report #	Seed Acc. #	Latitude ⁰N	Longitude ⁰W	Elev (M)	Type of Selection	Breeding Value[1]	% height Superiority	2006 G318[2]
79	G2	X1437	98-02	4368	56°47'47"	118°26'28"	762	Comparison	2	17	**6**
80	G2	X1445	98-02	4371	56°53'28"	118°35'03"	756	Comparison	2	9.9	**8**
81	G2	X1446	98-02	4374	56°53'21"	118°34'19"	756	Comparison	2	22.2	**3**
82	G2	X1447	98-02	4364	56°37'25"	118°52'57"	999	Comparison	2	19.1	**6**
83	G2	X1448	98-02	4363	56°39'36"	118°33'31"	841	Comparison	2	5.6	**7**
84	G2	X1449	98-02	4373	56°49'50"	118°01'09"	668	Comparison	2	6.7	**5**
85	G2	X1470	98-02	5413*	56°23'43"	117°56'45"	655	Comparison	2	8.1	**12**
86	G2	X1471	98-02	4375	56°24'05"	117°50'01"	820	Comparison	2	10.9	**8**
87	G2	X1472	98-02	4360	56°35'25"	118°24'45"	777	Comparison	2	8.7	**6**
88	G2	X1473	98-02	4359	56°35'26"	118°24'29"	777	Comparison	2	9.1	**11**
89	G2	X1475	98-02	4361	56°24'02"	117°52'45"	808	Comparison	2	3.2	**6**
90	G2	X1476	98-02	4376	56°22'02"	117°56'22"	789	Comparison	2	12.2	**12**
91	G2	X1477	98-02	4372	56°42'19"	118°24'13"	765	Comparison	2	0.9	**12**
92	G2	X1478	98-02	4369	57°25'35"	119°59'57 "	838	Comparison	2	11.2	**7**
93	G2	X1525	98-02	4382	57°26'17"	119°50'32"	792	Comparison	2	8	**10**
94	G2	X1526	98-02	4378	57°52'21"	119°51'54"	777	Comparison	2	0.8	**11**
95	G2	X1527	98-02	4379	56°22'09"	118°04'33"	850	Comparison	2	15.7	**9**
96	G2	X1528	98-02	4381	56°41'37"	118°23'00"	738	Comparison	2	22.6	**11**
97	G2	X1529	98-02	4377	56°57'05"	118°28'36"	628	Comparison	0	-2.2	**9**
98	G2	X1530	98-02	4380	56°58'07"	118°30'26"	634	Comparison	2	13.1	**11**
99	G2	X1531	98-02	5414*	56°35'04"	118°25'56"	777	Comparison	2	9.7	**8**
100	RC	X1490	98-03	4093	57°17'00"	121°40'00"	762	Geographic			**6**
101	RC	X1491	98-03	4094	56°46'00"	121°48'00"	914	Geographic			**9**
102	RC	X1497	98-03	4100	56°56'00"	121°02'00"	853	Geographic			**7**
103	RC	X1498	98-03	4101	56°50'00"	121°30'00"	853	Geographic			**6**
104	RC	X1506	98-03	4109	56°42'00"	121°15'00"	853	Geographic			**7**
105	RC	X1510	98-03	4113	57°15'00"	121°25'00"	756	Geographic			**5**
106	RC	X1516	98-03	4118	56°26'00"	120°23'00"	792	Geographic			**9**

[1] Indicates the %lift in breeding value (Bv) for height that may be used in calculating genetic gain if the tree is a 'Comparison' selection and there is documented height over age superiority.
[2] Indicates the number of ramets or grafts established in the G318 seed orchard in 2006.

* Seedlots (total=20) not included in G352 progeny trials because seed was unavailable; these parents will be tested in new trials once seed collections are completed from parent trees or seed orchard grafts