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Guiding Douglas-fir seed selection in Europe under changing climates: bioclimatic envelope model predictions versus growth observed in provenance trials

by

Miriam Isaac-Renton

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Abstract

Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco) is one of the most ecologically and economically important tree species in both its native range in North America and in its introduced range in Europe. The aim of this research is to inform the European Douglas-fir reforestation strategy under changing climates. This was done by 1) synthesizing results from a wealth of provenance experiments that have never been analyzed in a comprehensive manner, 2) by showing that a bioclimatic envelope model developed for North America was generally capable of predicting the observed provenance performance in diverse planting sites, and 3), using the model to map suitable populations for planting under climate change scenarios. The practical recommendations can be used as a decision-making tool to help European forest professionals target well-suited populations to ensure continued forest health and productivity.

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1. Introduction

Douglas-fir (*Pseudotsuga menziesii* [Mirbel] Franco) is an ecologically and economically important tree species in its native range in North America (e.g. St Clair 2005). In the coastal part of its native range, it is known for its high productivity: in natural stands, for example, it has been reported to have a mean annual increment of 4 to 14 m^3 per hectare (ha) at age 50, while managed stands have been reported as attaining increments of up to to 18.6 m^3/ha at age 45 (Hermann and Lavender 1999). Although native to Western North America, Douglas-fir has also been planted around the world due to this high productivity and its excellent wood quality, wind firmness and resistance to root rot (Martinsson 1990, Kleinschmit and Bastien 1992, Hermann and Lavender 1999). In Europe, it contributes to income and employment, aesthetics, recreation, and carbon sequestration.

Douglas-fir is one of the most widespread tree species in Western North America, where it stretches over 4500 km discontinuously through the interior from 55° N in British Columbia (BC) to 19° N in Mexico, and more than 2500 km continuously from coastal British Columbia to northern California (Orr-Ewing 1966). Douglas-fir occurs up to 750 m in elevation on the coast, up to 1700 m in the south-coast, and up to 3300 m east of the Cascades (Kleinschmit and Bastien 1992). Although there are several species of *Pseudotsuga* around the world, the two most commonly recognized varieties of *Pseudotsuga menziesii* in Western North America are the “coastal” or “green” variety (*P. menziesii* var. *menziesii,* formerly also called var. *viridis*), and the “interior”, “Rocky Mountain” or “blue” variety (*P. menziesii* var. *glauca*) (Frothingham 1909). The coastal variety occurs in the moist maritime regions west of the Coast and Cascade mountain ranges, and the interior variety occurs in the drier, higher-elevation areas east of these mountains (Frothingham 1909).

While the genus *Pseudotsuga* is known to have occurred in Europe in the Tertiary period 65 million to 2.6 million years ago, it disappeared due to the glaciations of the Pleistocene (Kleinschmit and Bastien 1992, König 2005). Its history in Europe only began anew when Archibald Menzies “discovered” the tree in 1792, after which it quickly attracted the interest of European foresters due to its impressive height and diameter (Kleinschmit and Bastien 1992, König 2005). It was reported to have been introduced to Europe by David Douglas between 1826 and 1827 and was subsequently introduced to many European countries (e.g. Holm 1940, Popa-Costea 1973, Kriek 1974, Ducci and Tocci 1987, Tigerstedt 1990, Kleinschmit and Bastien 1992, Kranenborg and de Vries 1995, Ots 2002, König 2005, Rutter and Fenster 2007, Weller 2011). Since these early introductions, it has become one of the most important tree species in Europe. The highly successful initial plantations garnered more interest in the species, but the exact locations of the initial seed collections are not known; there are only indications that they originated from the mouth of the Columbia river in south Washington (Kranenborg and de Vries 1995, König 2005). When subsequent plantations from different seed sources proved to be much less vigorous, it was realized that the source of seed strongly affected performance at planting sites (Kranenborg and de Vries 1995, König 2005).

To address the issue of adaptation to introduced areas in Europe, provenance trials comparing different North American Douglas-fir seed sources began across Europe. Although regional Douglas-fir provenance tests began in the early 1910’s (e.g. Schober 1959, Stimm 2001, Weller 2011), an internationally coordinated effort to test Douglas-fir in provenance trials around the world began under the direction of the International Union of Forest Research Organizations (IUFRO): seeds were collected from across the native range from 1966-1968; 15 cones were collected per tree, from 1818 trees that exhibited straight stems, minimal branchiness and no disease (Magnesen 1986, Kantarli 1989, Martinsson 1990). This seed-stock was then distributed to 55-59 institutes in 33-36 participating countries (Brunet 1985, Breidenstein et al. 1990, Kleinschmit and Bastien 1992). In many countries, Douglas-fir was shown to out-perform other leading tree species (e.g. Badoux 1926, Sika 1980, Chylarecki 1986, Tigerstedt 1990, Hermann and Lavender 1999). These studies have also often indicated that, to date, the best performing provenances often originate from the coast of southern Washington or northern Oregon in the United States (e.g. Kenk and Thren 1958, Birot and Burzynski 1981, Kleinschmit and Bastien 1992, Ballian et al. 2002, Isajev and Lavadinovi 2007, Peric 2009). Although these countries have conducted research within their own areas, and despite original attempts at creating a common database (Brunet 1985, Breidenstein et al. 1990), to the authors' knowledge, no comprehensive database of results was ever fully realized, nor was a general planting strategy developed.

Given the productivity of these plantations in Europe, Douglas-fir will continue to be an important species in the long-term (Kleinschmit and Bastien 1992). A testament to the value of Douglas-fir are the widespread provenance trials that have been maintained for decades around the world: provenance studies are only implemented for the most valuable tree species (Gylander 2011). There continues to be a strong commitment to using Douglas-fir as a forestry species among many countries in Europe. For example, there is a coordinated effort underway among experts in 16 European countries to fill research gaps regarding Douglas-fir and climate change. Due to long rotation times, high costs and limited adaptive capacity, it is particularly important for forest managers to evaluate the promise of Douglas-fir under changing climates, and to incorporate these results into adaptation strategies to maintain productivity and health. Climate change could cause mismatches to develop between top-performing planting-stock and suitable planting locations, potentially rendering obsolete all the extensive and expensive IUFRO provenance trial research. Such mismatches would also carry large consequences on the economic, carbon and recreational benefits from Douglas-fir. New planting opportunities, however, could emerge in more northern latitudes if suitable seed sources are identified for appropriate planting locations. Given a general northward shift of coniferous habitats under projected climate change, countries in the southern part of the European range may also need to source drought-adapted populations, presumably from more southern locations.

Recent applications of bioclimatic modeling techniques in North America for Douglas-fir under changing climates have shown that its climatically-suitable niche space is projected to increase, but to re-distribute substantially: large losses are projected for the coastal and southern-interior part of the range, with gains being expected primarily in the interior (Hamann and Wang 2006, Weiskittel 2012, Flower et al. 2013, Gray and Hamann 2013). The populations in these regions, however, may not be genetically suited to the new climate conditions (Gray and Hamann 2013). Although trees are able to physiologically respond to changing environments, it is likely that these abilities will be exceeded, which could lead to suboptimal productivity and a higher vulnerability to pests and diseases. This is especially concerning given a rising demand for wood products as the world's population continues to increase.

Given the limited ability of tree species to migrate (Aitken et al. 2008), they likely cannot keep pace with the rapid habitat shift (Hamann and Wang 2006), especially across Europe's fragmented landscape (Honnay et al. 2002). In fact, assisted migration and a re-evaluation of Douglas-fir seed transfer guidelines in Europe should thus be considered. Human intervention has already been suggested as being necessary to ensure continued productivity and health in its native range given that coastal Douglas-fir habitats could shift substantially: from ~ 400-700 km in latitude and a ~40-320 m change in elevation by the 2050's, as estimated by Gray and Hamann (2013); or from ~200-500 km in latitude and ~450- 660 m in elevation by the end of the century, as estimated by St Clair and Howe (2007). European forest professionals, however, need to know more about the adaptive capacity for Douglas-fir planted in Europe under changing climates and its relation to genetic differences among populations (Makkonen-Spiecker 2012). The challenge is therefore to predict the most suitable seed sources for planting in diverse European environments under changing climates to better inform the European reforestation strategy.

The aim of this research is to inform the European Douglas-fir reforestation strategy under changing climates. The first objective is to synthesize results from a wealth of provenance experiments, which have been published or reported as individual studies, but never analyzed in a comprehensive manner. Secondly, we want to test correlative climate models that have been used to predict suitable habitat and provenance performance of Douglas-fir in North America. In a sense, European provenance trials are an ideal climate change laboratory to examine how Douglas-fir populations behave when exposed to new climatic conditions when planted as an introduced species. This also involves testing whether European climate conditions correspond to North American conditions or whether they may be entirely novel combinations of climate variables. The third objective, if the predictive model performance proves to be satisfactory, is to map suitable planting sites for Douglas-fir in Europe using a bioclimatic envelope model and derive practical reforestation guidelines for Douglas-fir in Europe for current climate conditions and under projected climate change scenarios to help European forest professionals target well-suited populations to ensure continued forest health and productivity.

2. Literature review

2.1. Global climate change

Globally, the average surface air temperature has increased by 0.74ºC over the last century and 1998 and 2005 were the two warmest years on record, while 2002, 2003 and 2004 are reported as being the third, fourth and fifth warmest years since 1850 (Trenberth 2007). These warming trends are expected to continue, but the global average air temperature projections vary depending on future developments: more optimistic scenarios project an increase of 1.1ºC, whereas the most pessimistic models project an increase of up to 6.4ºC by the end of the century (Meehl 2007). Projected increases in temperature depends on continued greenhouse gas and aerosol emission scenarios and also the model used for the projection (Hamann and Wang 2006, Mote 2010). The Intergovernmental Panel on Climate Change (IPCC) outlines four different “Special Report on Emissions Scenarios” (SRES) scenario families: A1, describing a world with rapid economic growth and population peaking mid-century; A2, describing regionally-oriented economic development and steadily increasing population; B1, in which economic structures shift toward a service and information economy and population peaks mid-century; and B2, where economies move toward the service and information economies, but populations continue increasing (Lenny Bernstein 2007).

2.2. Climate change in Western North America

According to the Intergovernmental Panel on Climate Change, warming is very likely across North America, and, in most areas, to be greater than the global mean (Christensen et al. 2007). Winter warming is projected to increase the most in northern latitudes, with the lowest temperatures expected to increase more than the winter average (Christensen et al. 2007). Conversely, summer warming most in the southwest United States of America (USA), with the warmest summer temperatures likely to increase more than the summer average (Christensen et al. 2007). British Columbia (BC), Canada’s western-most province, has experienced an increase in mean annual air temperature of 0.7ºC or 0.8ºC over the twentieth century (Hamann and Wang 2006, Griesbauer and Green 2010, Mote 2010). Such trends are projected to continue for the Pacific Northwest: Mote and Salathé (2010) found the coolest scenario predicts an increase of 1.6°C and the warmest scenario an increase of 5.4°C by the year 2080 using 21 global climate models for different scenarios in the Pacific Northwest, comparing results to an average from 1970 to 1999.

Most areas in Canada and the north-east region of the USA are projected to increase in precipitation, while southwestern USA is expected to experience less precipitation (Christensen et al. 2007, Mote 2010). Southern Canada is also projected as having reduced summer precipitation, but as having higher winter and spring precipitation (Christensen et al. 2007). Variability in the precipitation modeling, however, arise from uncertainties regarding cyclone behaviour (Christensen et al. 2007). Most models (68-90%) used by Mote and Salathé (2010) project a consistent decrease in summer precipitation of 14-40% by the year 2080 compared to the average from 1970 to 1999, which will affect evaporative demand. By contrast, a majority of the models (50-80%) predict increases in winter precipitation compared to the average from 1970 to 1999 (Mote 2010).

2.3. Climate change in Europe

Similar to North America, overall temperatures in Europe are predicted to be above the global mean, which will manifest differently across Europe. As in North America, winter warming will be greater in higher latitudes: winter Northern Europe is predicted to see most of its warming in winter compared to the Mediterranean region, where summer is projected to increase temperatures (Hanssen-Bauer et al. 2005, Christensen et al. 2007). In Germany, the duration of snow cover has already been reported as decreasing by 30-40% at lower elevations (below 300 m) and by 10-20% in mid-elevations (300-800 m) since 1950, although higher elevations (above 800 m) are reported as showing only a small decrease in snow cover duration (Zebisch 2005). The coldest temperatures in winter are likely to increase the most (Christensen et al. 2007). Although precipitation projections can vary significantly among models, most models indicate: increased precipitation in northern latitudes (>55°N); an increase in winter precipitation and a decrease in summer precipitation in Central Europe;

and decreased precipitation in southern areas, for example, in the Mediterranean (Christensen et al. 2007). Given these projected changes in precipitation, and, more reliably, the projected increases in temperatures, drought is expected to become a more common occurrence in Central Europe and the Mediterranean (Christensen et al. 2007).

Increases in extreme precipitation across Europe is expected (Christensen et al. 2007), while projected to be more severe in the Scandinavian countries and less so in the Mediterranean (Kendon et al. 2010). Hot and dry summers have already been seen in Central Europe in 1992, across Western Europe in 1995, and the summer heat-wave and drought in Western Europe in 2003 is considered one of the worst on record (Pal et al. 2004). Such heat-waves are expected to increase in intensity, frequency and duration (Christensen et al. 2007). A reduced number of precipitation days can also lead to increased severe flooding in some regions of Europe (Kendon et al. 2010), as was already experienced by many European areas in 2002, 1998 and 1997 (Pal et al. 2004).

Although these warming trends may vary with changes to North Atlantic Meridional Overturning Circulation (i.e. Gulf Stream), even with modelled movement changes, warming is still expected across Europe (Christensen et al. 2007). Patterns of local topography (scales of < 2000 km), however, may alter the expression of these general trends.

2.4. Forestry under changing climates: risks of maladaptation

Since forests are highly influenced by climatic conditions, seemingly minor changes in temperatures and precipitation can seriously impact forests. Higher winter temperatures could also cause a change in phenology, affecting bud burst (Beaubien and Hamann 2011) and seed germination due to seed chilling requirements. Increased drought events are projected for both Europe and southwestern North America, where it has even been predicted that forests in the southwestern United States could be experiencing temperature-driven drought stresses by the 2050s more severe than what has occurred in the last 1000 years (Williams 2013). In Europe, the expected increases in summer drought will likely be problematic for the forest industry, by leading to reduced tree growth and increased mortality (Meier et al. 2008, Dalla-Salda et al. 2009, Eilmann and Rigling 2012, Rozenburg 2012). In addition, a leading tree species in many European countries, Norway spruce (*Picea abies*), has a low tolerance to aridity (Zebisch 2005). Thus, Norway spruce may no longer be suitable for planting in valley bottoms or south-facing slopes. In addition, Norway spruce is particularly susceptible to pest outbreaks and windthrow, both of which are indirect effects of climate change (Zebisch 2005). Given the expected declines in Norway spruce, Douglas-fir has been identified as a drought-resistant alternative (Zebisch 2005, Eilmann and Rigling 2012), thereby potentially increasing the adaptive capacity of European forests to climate change.

With relatively rapid changes in climate, trees will become increasingly maladapted to their environments as changing climates are expected to correspond to shifting tree habitats (e.g.Hamann and Wang 2006, O'Neill et al. 2008). For some North American conifers, this shift is predicted to be approximately 100 km per decade (Hamann and Wang 2006). In fact, a northward shift of climate habitat over the last ~25 years for several North American species has *already* been averaged as being ~130 km, or approximately 60 m upward in elevation (Gray and Hamann 2013). Given such a rapid rate of shift, it is not possible for the distribution to naturally keep pace, or for trees to evolve or adapt *in situ*. Such rapid shifts in trees environmental conditions could also quickly surpass trees' capacity for trees to respond physiologically to changing environmental stressors. The result could be an adaptation lag, defined as the disparity between genetic adaptations and environments due to rapid environmental change (Gray et al. 2011). The associated risks of are reduced growth, survivability and health (Gray et al. 2011).

In Western North America, an increase in 0.7ºC or 0.8ºC over the twentieth century has already been linked to BC's unprecedented mountain pine beetle attack, increased needle blight damage, increased reforestation failures and increased and wildfire (Hamann and Wang 2006). As reported by the Swedish Commission on Climate Change and Vulnerability (2007), European forests are expected to experience more overall damage is from fire, fungi, insects and herbivory. All of these considerations have the potential to seriously affect forest industries, unless forest professionals begin to plan for the new situations. Indeed, forestry is considered to be a moderately vulnerable industry to climate change given limited adaptive capacity from long rotation times and high costs (Zebisch 2005). It is therefore important for forest managers to evaluate the vulnerability of various species and begin planning now for adaptation strategies to maintain ecological resilience and productivity (Spittlehouse 2008).

2.5. No-analogue climates

An additional challenge presented to foresters and ecologists under climate change is the probability that entirely novel climate combinations will emerge.

Climates with no modern equivalent are called “no-analogue” climates (e.g. Overpeck et al. 1992, Williams and Jackson 2007). No-analogue climates have occurred in the past, and were in fact very widespread before the Holocene, and these dissimilar climates were associated with no-analogue vegetation compositions (Overpeck et al. 1992, Williams and Jackson 2007). Although some may argue that future greenhouse-driven no-analogue climates will differ from past no-analogue climates (Overpeck et al. 1992), it is clear that future novel climates will lead to novel ecosystems (Williams and Jackson 2007).

In Western North America, the accuracy of the back-predicting biome models validated against fossil and pollen records was found to vary throughout the Holocene, likely corresponding to no-analogue climates (Roberts and Hamann 2012a). Climate dissimilarities begin to appear in very minor coastal areas of the Pacific Northwest under future climate change scenarios, so the authors conclude that the accuracy of forward-projections of these biomes is not compromised (Roberts and Hamann 2012a). In Europe, comparisons of fossil and contemporary pollen show that no-analogue biomes and major vegetation changes occurred since the early Holocene, with changes in vegetation being attributed to macro-climate changes (Huntley 1990). Major vegetation changes were reported, with no-analogue biomes peaking around 10,000 - 13,000 and 1,000 years before present (Huntley 1990). Arguments that these no-analogue biomes reflect anthropogenic disturbance regime were dismissed, as no evidence of the spread of cereal cultivation from the south-east to the north-west from 9000 to 5000 years before present was seen: changes in vegetation are therefore taken to reflect changes in climate, which likely correspond to reductions in continentality (Huntley 1990).

Although these novel ecosystems and their associated no-analog climates are becoming increasingly important around the world, they remain relatively unstudied (Hobbs et al. 2006). One other aspect to consider is the application of no-analogue climates in Europe using North America as a baseline to measure climate dissimilarities across space. By quantifying the degree of similarity in climates between Europe and North America, it helps to understand how Douglas-fir seed sources will respond to introduced, and potentially entirely novel, planting environments. There then also exists the opportunity to project these climate dissimilarities forward under various climate change scenarios with different General Circulation Models (GCMs) to analyse potentially emerging novel climates. This analysis of climate dissimilarity is also an important first step in understanding the uncertainty and applicability of bioclimatic envelope models developed for the native range of North America to Europe.

2.6. Bioclimatic envelope models

Bioclimatic envelope models usually involve identifying the conditions of a species' realized niche (its "envelope") and projecting these conditions to other areas or under future climate scenarios. Some researchers use bioclimatic envelope models solely for the purposes of identifying the most important habitat variables for a species, while others use them to make predictions of suitable habitat (Araujo et al. 2005). These models have been used for a variety of purposes, for example: conservation prioritization, guiding invasive species management, understanding disease movements (Pearson et al. 2006), and as an approach to target adapted planting stock for reforestation (Mbogga 2010, Gray et al. 2011, Gray and Hamann 2011).

The accuracy of bioclimatic envelope models has been challenged under situations where no-analogue climates can potentially occur (Williams and Jackson 2007). Recent work addressing this exact question for North America indicated that, although no-analogue biomes varied in accuracy as assessed by the fossil pollen record throughout the Holocene, future projections show a minor extent of no-analog climates, so bioclimatic envelope models can still be used for approximating future conditions (Roberts and Hamann 2012a).

Bioclimatic envelope models have also been criticized for making many simplifying assumptions. For example, bioclimatic envelope models do not incorporate the physiological effects on plant growth from a doubling or tripling of atmospheric carbon dioxide (Sage and Coleman 2001). Most plants are adapted to lower levels of carbon dioxide than is currently present, and increases are expected to increase a plant's ability to grow under moderate drought conditions (Sage and Coleman 2001). In this case, however, the models will in fact be more conservative. Limitations to species dispersal are also a strong criticism of bioclimatic envelope models (e.g. Hampe 2004, Araujo et al. 2005, Williams and Jackson 2007): as a climate space shifts, if a species cannot reach these new habitats fast enough, a serious lag in species adaptation will occur. This is a major concern in forest ecology, where long-lived tree species can migrate at only a tenth the rate that their habitat is shifting (see Hamann and Wang 2006, Aitken et al. 2008). Since planting stock is already being moved for forestry purposes, however, these models are again applicable because managers can adapt as quickly as the models suggest. Yet another criticism of bioclimatic envelope models is that they fail to account for competition (Hampe 2004). Thus, the models are based only on the realized niche, which is the true space occupied by a species, as compared to the fundamental niche, which is the climate space a species could occupy if it were not for other biotic limitations (Guisan and Zimmermann 2000). Again, this criticism is less potent in a forestry context, where spacing and silvicultural treatments are often aimed at reducing competition (Mbogga 2010). This is especially true for many introduced timber species in other parts of the world, for example, in Europe.

There are many different statistical approaches applied to bioclimatic envelope modelling, each with their own strengths and weaknesses: an excellent overview is provided by Heikkinen et al. (2006) and Guisan and Zimmermann (2000). One popular statistical technique is to use Random Forests, a procedure that grows a large number of classification and regression trees from a randomly chosen subset of predictors (Prasad et al. 2006). In a comparison against Regression Tree Analysis, Bagging Trees, and Multivariate Adaptive Regression Splines, Random Forests were found to be the most accurate, as measured with a kappa value, and for providing visually reasonable future spatial projections (Prasad et al. 2006). A disadvantage of Random Forests, however, is that this procedure has reduced transparency because they take an average "vote" from hundreds to thousands of trees, and the user cannot examine the values from any individual tree (Prasad et al. 2006). However, it does produce data that can be used in overall model evaluation: variable importance as compared to random permutations can be seen to better understand which predictor variables are relatively more important (Prasad et al. 2006). The main advantage of Random Forest models is that they reduce over-fitting the data because a large number of trees are grown (Pearson et al. 2006, Prasad et al. 2006).

It is highly advisable to evaluate the models through cross-validation or, preferably, with independent data (Roberts and Hamann 2012a, 2012b). Significant variability in magnitude and direction of various models highlight the importance of model validation, and in using absence as well as presence data when building the model (Pearson et al. 2006). Validation is especially important when they are used as support tools for making societal decisions (Araujo et al. 2005). Cross-validation involves various options for sub-setting the data for training the model, then applying the model to another set of the original data. Although generally regarded as acceptable, validation with independent data is considered more robust as it helps to overcome the concerns of spatial and temporal auto-correlation in the training dataset and the test dataset (Araujo et al. 2005). To the author's knowledge, models have so far been validated against fossil and pollen records (e.g. Huntley 1990, Roberts and Hamann 2012a) and observed breeding-bird species distributions (Araujo et al. 2005). A forestry-specific opportunity is to compare the performance of a model trained with presence-absence data against independent tree growth data. Despite the increased confidence from validation, however, it is recommended that models should be considered useful only as a "first approximation" and applied to policy cautiously (Araujo et al. 2005).

Applied cautiously, then, the Douglas-fir bioclimatic envelope models developed herein and applied to Europe can be used to suggest areas suitable for planting. While it is important to choose the right *species* for a planting site, it is also essential to match the right *seed-source* for planting, since silviculture can never fully compensate for using mal-adapted seed. Thus, there also exists the need to project locally adapted North American populations onto Europe, to identify the most suitable seed-sources for planting in each region.

2.7. Provenance trials

The classical approach for identifying seed sources for reforestation programs is through provenance trials[1], also known as common garden experiments: planting material is collected from different populations across the native range and tested at various planting sites. Because conditions are relatively uniform at each planting site, and any within-site variability is removed through careful experimental design, planting-stock performance represents true genetic responses to the site's environmental conditions. Thus, by removing the environmental components from the phenotype, provenance trials help reveal the genetic component to a population's adaptive traits such as growth, resistance to insects and disease, and survival (Gylander 2011). The longer the period of observation, the better the representation of environmental conditions, and the more confident researchers can be that the genetic response truly reflects climatic adaptations instead of a response to weather anomalies. It has been recommended to observe provenance trials until mid-rotation, since it may take several years for a climatically-driven selective pressure to begin affecting the response of these

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[1] In this paper, the term "provenance" is used to indicate the seed source in North America, as this study only includes provenances with a known North American origin. This definition may differ with some practitioners in Europe, who may use the term "origin" to represent the location where the seed was originally collected in the native range. The European practitioners contrast "origin" with "provenance", which denotes seed collected from any site – often in an introduced plantation. For example, a "provenance" may be sourced from Denmark, but its "origin" could be unknown.

genotypes. If correlations exist between genetic variation and environmental differences, then it suggests genetic adaptation to their environments (St Clair 2005). High variability in performance suggest gains can be made by selecting the best provenances (Kantarli 1989). Although provenance trials were originally designed to determine the genotypes with the best growth for a particular region, for determining seed transfer guidelines, and for studying genetic clines in variation, they have more recently also emerged as a method of evaluating species' response to climate change (Leites et al. 2012).

2.8. Theory of local optimality for seed transfer

Given that populations are often genetically adapted to the climates in which they grow, guidelines for the movement of seed and planting stock have been established on the assumption that local seed sources should have the best performance. This theory of local optimality has driven past seed zone boundary delineation and seed transfer guidelines (Campbell 1974). Seed zones are boundaries within which planting stock must stay, whereas seed transfer guidelines apply distance and elevation rules to allow movement of seed from any given location. These more flexible guidelines are better suited to species showing clinal variation in genetics, or a smooth progression of genetic change corresponding to geographic, topographic or climatic variables. Seedzones and seed transfer guidelines are designed to maximize production and minimize risk from mal-adaption of populations within species (Hamann et al. 2011).

Since the ecological optima for many tree species is expected to shift north by 100 km (Hamann and Wang 2006), and since post-glacial tree species' migration has been estimated to be 100 m per year (Aitken et al. 2008), a tenfold adaptation lag could be developing. This is especially concerning in fragmented landscapes, for example in Europe, where forest species' ability to migrate is much reduced (Honnay et al. 2002). The effects of climate change on adaptation lag will likely be further compounded by genetic adaptation of *populations* to local environments *within* a species' range. Thus, the consequences of shifting optimums under climate change will not be present only on the species' southern trailing edge, but for every population. In fact, a recent empirical study analysing tree-ring growth concluded, unexpectedly, that northern populations of Douglas-fir would be most vulnerable to climate change compared to southern populations (Chen et al. 2010). Lodgepole pine (*Pinus contorta*) was also shown to have an additional 20-30% decrease in growth due to maladaptation when the models incorporated populations (O'Neill et al. 2008). Changing climates may therefore invalidate the theory of local optimality as a valid assumption for guiding planting-stock transfer. In fact, there may already be a lag in adaptation in some tree species, as seen when southerly provenances from within the wide-spread range perform better when moved northward (e.g. Gray et al. 2011, Schreiber et al. 2011).

With the risk of maladaptation from climate change, forest practitioners are now re-evaluating seed zones and seed transfer guidelines. There is also discussion regarding assisted migration, which involves moving seed judiciously ahead of the main front of shifting habitat to maintain ecosystem health and productivity (Gray et al. 2011). This has been argued as an important climate change adaptation technique for forestry since long-lived trees need a longer planning horizon, compared to other industries, to account for changing climates. In BC, some well-tested populations originating from outside their historical range are already allowed to be planted on public land, ensuring a continuation of forest benefits (B.C. Ministry of Forests 2010).

Anticipating objections regarding the reforestation strategy of a non-native species in Europe, it is important to note that Canadian forests are managed differently from European forests, where it is more common to plant with non-native species. The different styles of forest management in Canada and Europe likely stem from historical legacies: in Europe, forests were overexploited over centuries (Hermann and Lavender 1999); ecological restoration was borne out of a strategic need for wood supply, not ecology (Dr. Weetman, pers. comm., 07.08.2011); and trees have been grown outside their native ranges in Europe for centuries, even millennia (Svenning and Skov 2004). There is thus a different management paradigm than in Canada, which has a comparatively much younger forest history, and still has intact native ecosystems upon which to tie species and seed choice for reforestation.

3. Methods

3.1. Provenance data acquisition

Results from European Douglas-fir provenance trials were compiled from 39 journal publications and technical reports. The resulting database represents approximately 714 North American seed collection sites tested at 120 European planting sites (Appendices 1 and 2). Height was used as a measure of performance as these data were consistently reported, since reduced growth can be detected earlier than mortality (Littell 2008), and since height is more independent of confounding factors like tree spacing. All provenance locations and test site locations were checked in Geographic Information System (GIS; ESRI 2011) for matching with their descriptions. In case of discrepancies (e.g. coordinates point to a different state than reported), data was corrected if the error could unambiguously be resolved, otherwise removed. Further data checks for far outliers were conducted in the R programming environment (R Development Core Team 2013). To simplify reporting and to make regional recommendations for forest managers, we grouped test sites into 17 different regions according to political boundaries and similar climates (Fig 1, Tab 1). Similar climate conditions for groupings were determined by means of principle component analysis (data not shown). All North American seed collection sites were similarly assigned to groups that represent genetically differentiated populations (Fig 2, Tab 2). As additional information for what may be locally adapted populations, we grouped all North American collection locations according to similar climate conditions with principal component analysis. We also used multivariate regression tree analysis to cluster genotypes according to Hamann et al (2011). This technique is only applicable to individual provenance trials or trial series with complete replication of genotypes. The final groupings were subjectively determined based on climatic groupings, multivariate regression trees for a number of large European trials, and previous knowledge of patterns of genetic differentiation from North American provenance trials (e.g. St Clair 2005).

The purpose of these groupings are also to facilitate communication about where seed should be sourced, so we used administrative boundaries where possible, resulting in the 13 groups shown in Figure 2. British Columbian (BC), Washington (WA), Oregon (OR) Coast populations correspond to lower-elevation coastal areas and seaward-facing slopes with high precipitation (>1500 mm). The WA and OR Dry Coast populations correspond to low-elevation areas (≤600m) that have mild temperatures from the maritime influence, but that generally receive less precipitation than those areas designated as "Coast" (≤1500 mm of mean annual precipitation). The WA and OR Coast Cascade populations represent the higher elevation areas (>600 m) in the wind-ward side of the Cascade mountain range. The California (CA) Low-Elevation group represents areas less than 1000 m above sea level, while CA High-Elevation represents areas above this altitude. Interior populations were split primarily by latitude: the influence of latitude and elevation on height growth are more important for interior varieties than coastal varieties (Kantarli 1989), and strong differentiation is reported between northern and southern interior groups (Li 1989). The Interior North population occurs in BC, east of the Coast mountain range, greater than 50° latitude. The Interior population occupies drier areas of BC, WA, Idaho (ID) and Montana (MT) east of the Coast-Cascade ranges, between 45° and 50° latitude. The Interior South population occurs in southern states, and is thus exposed to much drier conditions and a more continental climate. Finally the Interior Cascades population occurs on the lee-ward side of the Coast-Cascade mountain ranges, in areas with low precipitation (<900 mm). The number of provenances represented by each group varies, with the most provenances represented in coastal populations, which reflects the bias in Europe toward using these seed sources based on their preliminary results. However, coastal areas tend to be more environmentally heterogeneous, so this sampling intensity is therefore appropriate (St Clair 2005).

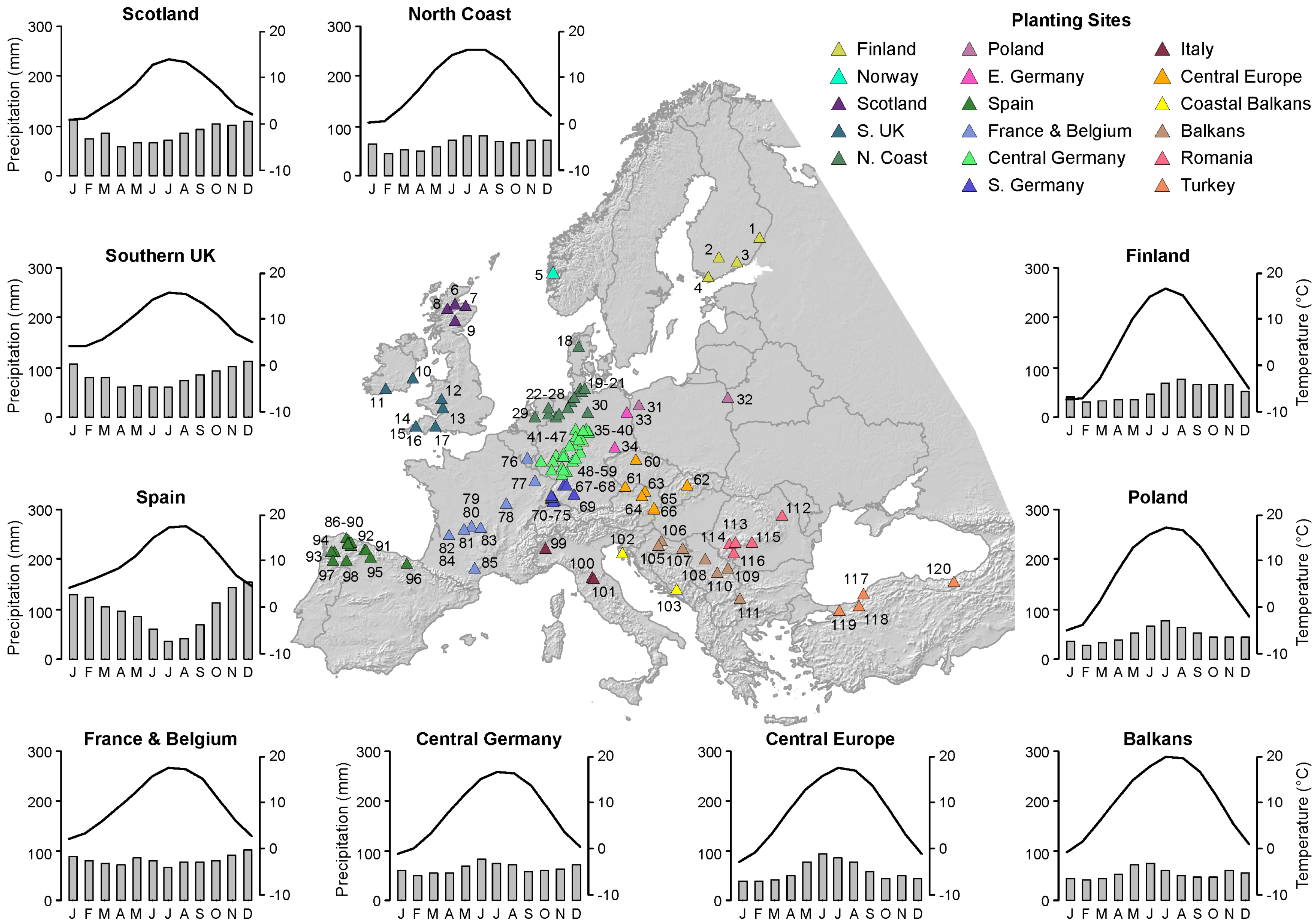

Figure 1. Map of Europe with numbered planting sites coloured by region, with climate diagrams displaying average monthly temperature (°C) and average monthly precipitation.

Table 1. Properties of the European regions, indicating the number of sites represented (*No of Sites*), the number of North American populations tested (*No of Pop*), the number of provenances tested (*N of Prov*), mean annual precipitation (*MAP*), mean summer precipitation (*MSP*), precipitation as snow (*PAS*), mean annual temperature (*MAT*), mean warmest month temperature (*MWMT*), mean coldest month temperature (*MCMT*), degree-days above 5°C (*DD5*), and Hargreaves climatic moisture deficit (*CMD*).

Regions Units	No of Sites	No of Pop	N of Prov	MAP (mm)	MSP (mm)	PAS (mm)	MAT (°C)	MWMT (°C)	MCMT (°C)	DD5 (days)	CMD
Central Europe	7	8	89	701	394	69	7.8	17.5	-3.0	144	144
Coastal Balkans	2	6	11	1150	420	38	11.4	20.5	2.7	105	105
Balkans	8	11	94	655	307	38	10.3	19.9	-0.8	334	334
Southern UK	8	12	88	981	342	25	9.6	15.9	4.2	68	68
Central Germany	25	11	206	770	357	74	8.1	16.6	-1.1	117	117
Eastern Germany	2	11	59	600	315	53	8.1	17.1	-1.6	150	150
Finland	4	3	8	620	295	174	4.5	16.8	-7.4	115	115
France & Belgium	10	8	97	969	384	44	9.8	17.6	2.1	151	151
Italy	3	12	71	1063	385	50	10.0	19.6	1.4	131	131
North Coast	14	13	209	778	356	49	8.4	16.2	0.4	88	88
Norway	1	10	51	2080	787	174	7.1	13.9	0.9	0	0
Poland	2	9	27	579	311	89	7.0	17.2	-5.0	162	162
Romania	5	7	10	803	450	67	8.6	18.1	-2.4	101	101
Southern German	9	7	18	1131	499	146	7.8	16.6	-1.0	39	39
Scotland	4	7	35	1034	384	87	7.1	14.0	1.0	35	35
Spain	13	13	144	1155	293	36	10.3	17.6	4.2	234	234
Turkey	4	10	36	758	236	33	10.9	19.3	1.8	353	353

Table 2. Properties of the North American Douglas-fir populations, indicating the number of provenances collected (*No of Provs*), the number of European planting sites (*No of Sites*), mean annual precipitation (*MAP*), mean summer precipitation (*MSP*), precipitation as snow (*PAS*), mean annual temperature (*MAT*), mean warmest month temperature (*MWMT*), mean coldest month temperature (*MCMT*), degree-days above 5°C (*DD5*), and Hargreaves climatic moisture deficit (*CMD*).

Seedzone Units	No of Provs	No of Sites	MAP (mm)	MSP (mm)	PAS (mm)	MAT (°C)	MWMT (°C)	MCMT (°C)	DD5 (days)	CMD
BC Coast	61	17	2289	397	192	8.4	16.3	1.4	1677	138
OR Coast	48	14	1963	261	55	10.7	17.6	4.7	2261	317
WA Coast	138	16	2223	376	118	9.7	17.5	2.5	2010	204
OR Coast Cascades	62	15	1621	271	190	8.2	16.9	1.0	1703	342
WA Coast Cascades	54	15	2157	382	417	7.0	16.0	-1.0	1500	189
WA Dry Coast	74	16	1189	252	44	9.9	17.3	3.3	2018	285
OR Dry Coast	36	13	1314	207	35	11.1	18.9	4.1	2369	432
CA High Elevation	28	4	1341	120	77	10.6	20.3	2.8	2347	635
CA Low Elevation	26	6	1372	96	27	12.3	20.0	5.8	2801	623
Interior North	83	16	640	247	201	5.3	16.6	-6.9	1510	319
Interior	49	9	650	206	191	6.6	18.0	-4.7	1723	430
Interior Cascades	35	11	621	96	124	8.0	18.2	-1.1	1840	569
Interior South	19	4	454	234	73	7.3	17.9	-2.4	1810	630

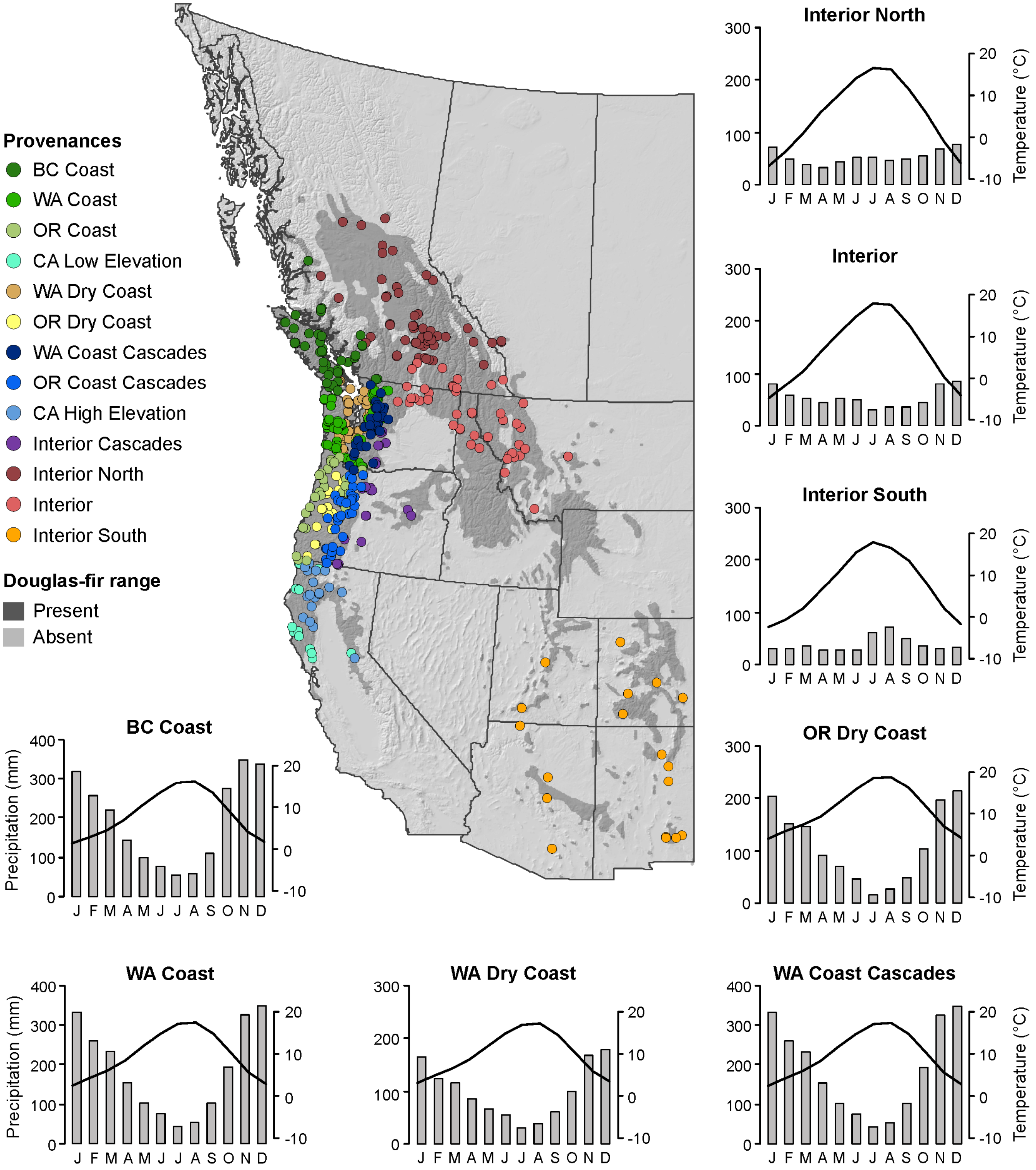

Figure 2. Map of Western North America, with dots representing seed collection sites coloured by population. Dark grey indicates the Douglas-fir range. Climate graphs indicate average monthly temperature (°C) and average monthly precipitation (mm) for populations.

3.2. Climate data acquisition

Biologically-relevant climate variables were generated using two custom software packages, ClimateWNA for western North America (Wang et al. 2012) and ClimateEU, an equivalent, unpublished software package for Europe[2]. The ClimateWNA and ClimateEU are software front-ends for large interpolated climate databases that extract custom historical data that can be scaled to various spatial resolutions and geographic projections. Here, we use a 30-year baseline climate period (1961-1990 normal) to represent climate conditions prior to an anthropogenic warming signal. In addition, ensemble predictions from multiple GCMs (the CMIP3 multi-model dataset of the fourth IPCC assessment report) were used to represent potential future climates for the 2020s, 2050s, and 2080s. The software packages generate interpolated climate surfaces based on the Parameter-elevation Regressions on Independent Slopes Model (Daly et al. 2008). We queried climate data for collection and planting sites used in this study, which are provided in Appendices 1 and 2, and we further generated interpolated surfaces at 1km resolution for habitat projections in Albers Equal Area Projection.

3.3. No-analogue climates

To evaluate dissimilarities between European and North American populations, we used a multivariate Mahalanobis distance measure. Mahalanobis distances are more appropriate here than the Euclidean distances, because they distill highly

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[2] The ClimateWNA and ClimateEU software packages are made freely available at http://ualberta.ca/~ahamann/data.html and http://www.ualberta.ca/~ahamann/data/climateeu.html.

correlated climate variables into a single unit, thereby avoiding over-representation of our otherwise highly correlated climate variables. A distance matrix for North American climate variables from 1961-1990 and climate averages from 770 North American ecosystems was created. Distance calculations were then performed with PROC DISTANCE and PROC PRINCOMP in the SAS statistical software package (2010), and the resulting raster grid was displayed using ESRI's ArcGIS software (2011). This process was repeated for European climate variables from 1961-1990, then projected forward to the 2071-2100 climate window (hereinafter referred to as 2080) under the most pessimistic A2 scenario to evaluate the most extreme no-analogue conditions possible for Europe.

3.4. Bioclimatic envelope modeling and validation

A bioclimatic envelope model for Douglas-fir was developed for Western North America using the *randomForest* software package v.4.6-6 in the R programming environment (R Development Core Team 2013). This package runs several regression trees and, through these analyses, determines the relative importance of each predictor variable on the dependent variable's response. As training data for the model, we used various sub-samples of the Douglas-fir presence data-set for North America as the dependent variable. This presence-absence data is based on >50,000 forest inventory plots in the United States and Canada. Using presence/absence data is considered more robust than using presence alone, since both abiotic and biotic factors limiting the realized niche are inherent in the absence data (Pearson et al. 2006). The predictor variables in this model were biologically relevant climate variables: mean annual precipitation (MAP; mm), mean summer precipitation (MSP; mm), precipitation as snow (PAS; mm), mean annual temperature (MAT; °C), mean warmest month temperature (MWMT; °C), mean coldest month temperature (MCMT; °C), degree-days after 5°C (DD5; days), and Hargreaves climatic moisture deficit (CMD). While more climate variables can be generated by the software packages, we avoid highly inter-correlated climate variables for the Random Forest analysis, as was suggested by Heikkinen (2006), to avoid issues of multi-collinearity among climate variables.

The model was then applied across North America, and the output was exported as a raster file with each cell representing a probability of presence based on the climatic variables for that particular location. The North American species distribution model was then applied under European climate conditions, making habitat projections both at the species level and for genetically differentiated populations (as described above). Resulting raster grids were displayed using ESRI’s ArcGIS software (2011).

3.5. Data analysis

Average population height data were normalized for each planting site to account for varying ages of the provenance trials: population performance was thus evaluated based on deviations from the mean height at each planting site. An analysis of variance (ANOVA) was performed using a mixed linear model implemented with PROC MIXED of the SAS statistical software package (Inc 2010). This model was run twice: the first run involved specifying North American groups of provenances (i.e., populations or climatypes) and European regions as fixed effects and planting sites and provenances were specified as random factors for the estimation of height and standard errors for groups of North American provenances by groups of European sites. Using least-squares means estimates accounted for the imbalanced sampling design. These estimates are the basis for a dotplot comparing performance of Douglas-fir seed sources in Europe. The second run of the model involved specifying all effects as random to obtain variance components for all main effects and their interactions.

4. Results

4.1. Observed provenance performance

The results of the ANOVA indicate that the growth response among North American populations, European regions, and the interaction between the two are statistically different (Tab 3). The variation explained by sites is zero because height was normalized for each site. The effect size for regions is just slightly above zero, because not all provenances were planted at all sites, but is inconsequential (should be regarded as zero) because the normalization was carried out to cancel main effects, which are confounded with age, as well as unique factors at each planting site such as soil type, nutrient and moisture regimes. More importantly, the combined effects of populations and regions by populations account for approximately 27% of the total variation, indicating that our North American groupings (Populations in Tab 3), indicating strong genetic differentiation captured by our groupings. Genetic differences in provenances within the populations represent 15.5% of the total variation in response, while 60% of the variation is explained and includes higher-level interactions and environmental variation.

Table 3. Results of an Analysis of Variance using a mixed linear model in SAS statistical software: "Regions" indicates European regions, "Populations" indicates North American populations, "Site" indicates European planting sites, and "Provenance" indicates North American seed collection sites.

Source	Num DF	Den DF	Mean Square	F-Value	P-value	Varcomp (%)
Regions	16	104	0.637194	4.34	<0.0001	1.1
Populations	12	645	9.984314	3.34	<0.0001	21.0
Regions * Populations	113	1896	1.191445	2.24	<0.0001	5.7
Site (Region)	104	–	0.342159	–	–	0.0
Provenance (Population)	645	–	1.116246	–	–	15.5
Residual	1896	–	0.609904	–	–	60.0

Least squares means (LSMeans) of North American provenance groups by European regions are shown in the upper dotplot in Figure 3 (dotplot based on the LSMeans and standard errors reported in Appendix 3). Northern sources from Washington and British Columbia perform well in northern European sites such as Finland, Norway, Scotland, and Southern UK. Seed sources from the higher elevation regions of the Washington Coast Cascades perform well in some areas of Northern Europe, Central Europe and interior regions in the Balkans. Across Western Europe, coastal Washington populations perform well, with dry coastal sources emerging as good performers in more eastern (i.e., Poland, Eastern Germany) and southern areas (i.e., Spain and Italy). Note that results from the coastal Balkans, Romania and Turkey should be interpreted cautiously since they have large standard errors. The high variation in results leading to relatively high standard error can likely be attributed to a low number of provenances and test sites.

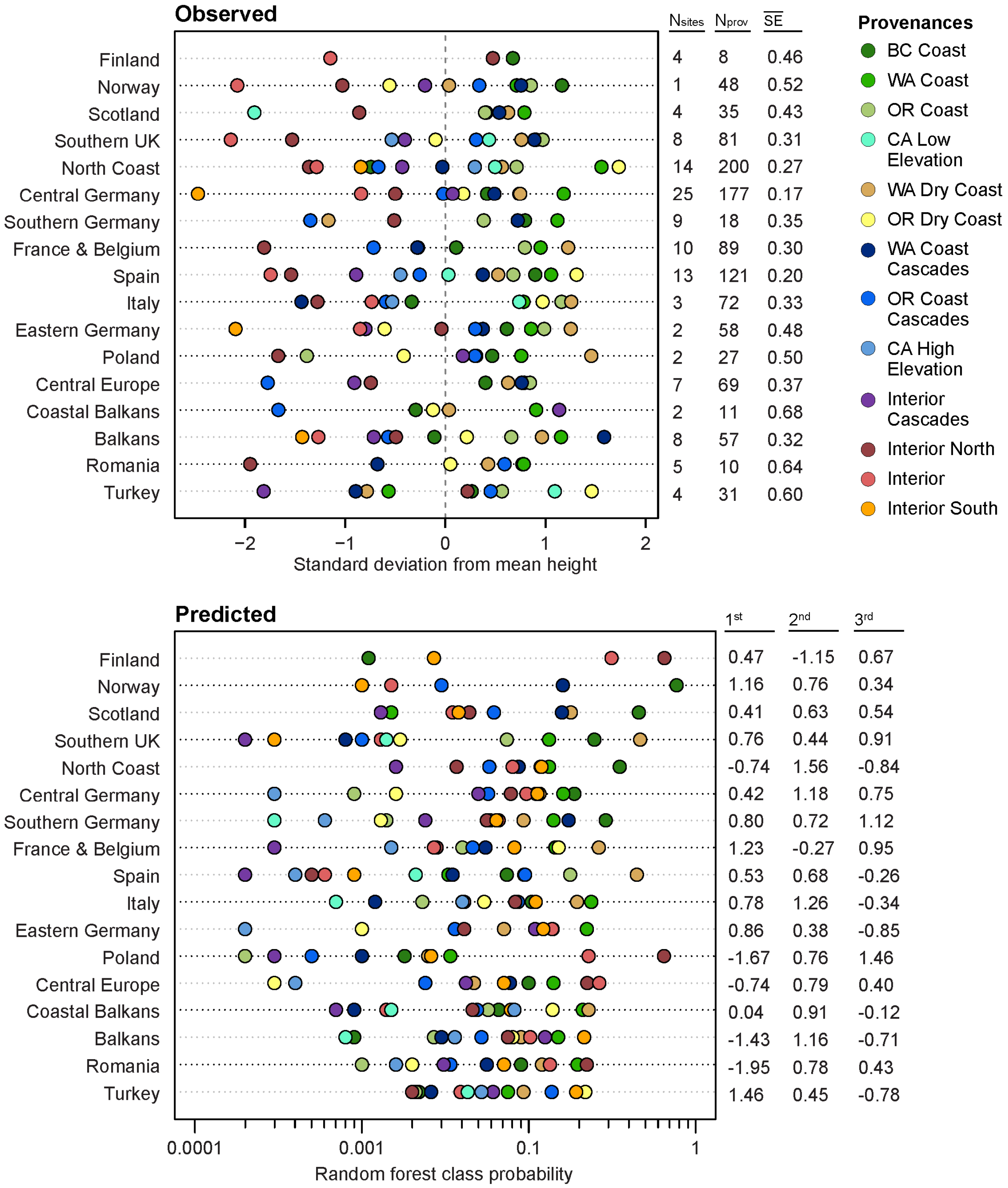

Figure 3. The upper dot-plot displays the observed performance of North American populations in European regions, as tested in 120 common gardens across Europe. Performance is reported in normalized height, in units of standard deviation from the mean: dots to the right of the dashed line indicate better than average populations for that region. The first column on the right indicates the number of planting sites representing the European region, the second column indicates the number of provenances tested in that region, and the third reports the standard error for all populations averaged within that region. The lower dotplot displays the predicted climate matches of the North American populations in the European regions under the Random Forest bioclimatic envelope model. Performance of populations is reported as the probability of model prediction for that region: the dots that are furthest to the right are top-ranking predictions in that region. The first column on the right shows the observed normalized heights for the top three-ranked populations.

4.2. Random Forest provenance predictions

The most important climate variables that characterize the climate envelope of Douglas-fir populations, according to the Random Forest model, are shown in Table 4: those variables with a higher importance value, which is a relative, unit-less measure, are considered more important to the model. The model is most influenced by mean annual precipitation (mm), mean coldest month temperature (°C) and the difference between the mean warmest and coldest month temperatures (°C) – a measure of continentality (Tab 4). When the model is used to project general habitat in Europe using recent climate baselines (see coloured regions in the first and second panels of Figure 4), suitable areas for planting are predicted as stretching from the Scandinavian countries in the north to Turkey, Spain and Italy in the south; from the United Kingdom in the west to Poland and Romania in the east. This distribution is projected to shift northward under future climate change scenarios (Fig 4).

Table 4. The climate predictor variables used in the Random Forest bioclimatic envelope model with their respective importance values. The units are meaningless; it is only a relative measure, with higher values indicating a higher importance in the model.

Climate predictor variable	RF Importance
Mean Annual Temperature (°C)	273
Degree-days above 5°C (days)	261
Mean Warmest Month Temperature (°C)	168
Mean Coldest Month Temperature (°C)	375
Temperature Difference (°C)	352
Mean Annual Precipitation (mm)	403
Mean Summer Precipitation (mm)	266
Hargreaves climatic moisture deficit index	346

Figure 4 also shows the best climatic match for Douglas-fir *populations* within the generally-suitable habitat in Europe, represented by colors. The population projections under the observed 1961-1990 climate period show coastal Douglas-fir populations being expected as the top-ranked seed source in Western Europe, but populations from drier and more southerly locations performing as being better in more southerly locations in Europe. Interior Douglas-fir, on the other hand, are ranked by the model as best matching provenances in the more continental climates of eastern Europe, with southerly populations similarly predicted as being top-ranking in the south. The population predictions under the observed 1995-2009 climate period are relatively similar to those of the 2020s predictions, with a trend towards more southerly and dry populations shifting northward clearly evident. For example, dry coastal provenances from Oregon are predicted to be the top-ranked population in more northern areas in France, while provenances from the dry southern interior of North America show an increased habitat match in the east.

Continuing along this trajectory under a strongly warming climate modelled with the A2 scenario under the 2080 average time period, the model predicts a general shift northward: the dry Oregon coast population is expected to shift from southwestern France to Belgium, the Netherlands, northern Germany, and the southern UK. Similarly, dry coastal Washington populations are expected to shift from northern France to Sweden. In fact, by the end of the century, France is expected to lose much Douglas-fir habitat, which is concerning given Douglas-fir is a commonly planted tree in this country. Similarly, Douglas-fir habitat is lost by the end of the century in Italy, the Balkans and in Turkey. As climatically-suitable habitat shifts northward, provenances from the south-interior of the United States appear even as far north as Poland and Belarus.

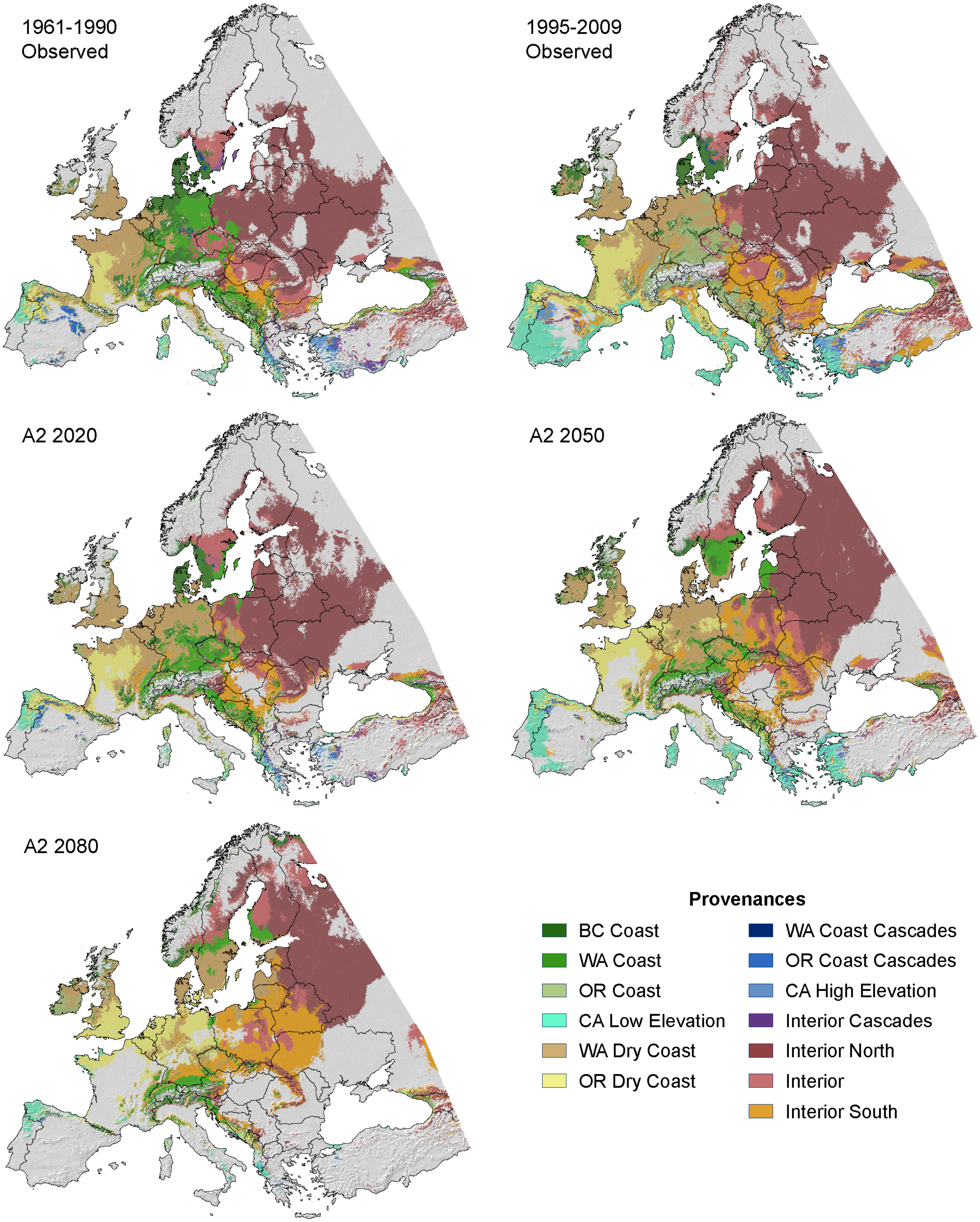

Figure 4. Predictions of climatically best matching North American Douglas-fir populations as projected using a Random Forest bioclimatic envelope model for past climate (1961-1990), a recent 15-year climate average (1995-2009) and the 2020's, 2050's and 2080's under an A2 scenario.

4.3. Validation of projections

For validation, the results of the Random Forest bioclimatic envelope model population predictions were compared to the observed population performance. The model's predictions are reported as the probability of predicting each population's relative rank, and are displayed by region using a logarithmic scale in the lower dotplot of Figure 3: any populations with probabilities less than 0.0001 are not shown in the dotplot. The columns to the right of the dotplot indicate the observed normalized height of the model's top-three ranked climatic matches of populations for a region: negative numbers usually indicate that the model determined a good climate match for a provenance group that actually shows inferior growth. Probabilities of Random Forest model predictions broken down by individual planting site are reported in Appendix 4.

Figure 3 shows a generally high agreement among the model's top-ranked populations and observed provenance trial growth. In regions where the predicted top-ranked population performs below average in the common garden experiments, the second-ranked predicted population is often a top performer. There are clear mismatches as well, however. This is true in Poland, Central Europe, the interior Balkans and Romania, for example. In Finland, where it is relatively dry and where temperatures are more extreme, the model predicts interior populations, specifically the northern interior populations, as being most suitable. This intuitive result, however, is not validated by the four provenance trials in this region, which unexpectedly show the BC Coast population, known for its cool and moist climate, as being the top performer in Finland. At the four planting sites in Finland, however, only 8 provenances were tested, so it is possible that provenances unrepresentative of the whole population were planted: there is a higher probability that seed-stock from drier, cooler or higher elevation sites within this population are over-represented. In the North Coast region, the model predicts coastal BC provenances as best, but the provenance trials in this region indicate that they actually perform below average. Although the Oregon dry coast population is the top climate match at North Coast sites, the model predicted them as having such a low probability of being the top climate match that it is not even represented in the dotplot (Fig 3).

4.4. No analogue climates

The maps in Figure 5 show the dissimilarity between European and North American climates, using 1961-1990 climate data as a baseline. These maps show only few areas of high climate dissimilarity between these two continents, occurring most prominently in the in Georgia, bordering the Black Sea. Areas of moderate dissimilarity occur at the base of the Alps, in the very south of Germany, in some areas of Austria, covering most of Slovenia and Croatia, some areas in Bosnia, and the very north of Italy. Under an A2 scenario projected to the 2080’s, projected climate dissimilarities are moderate in southern Germany, Austria and Switzerland, south-west France, north-central Spain, in the north-central part of Germany and Belgium. Climate dissimilarities also appear in the Carpathian Mountains in east-Central Europe and in north-eastern Europe, covering Estonia, Latvia, Lithuania, Belarus, western Russia and southern Finland. Since Europe and North American climates are relatively similar, even under a strongly warming climate projection, the bioclimatic envelope model should not be compromised by extrapolating into climate conditions that are far beyond coverage of training data (Roberts and Hamann 2012b).

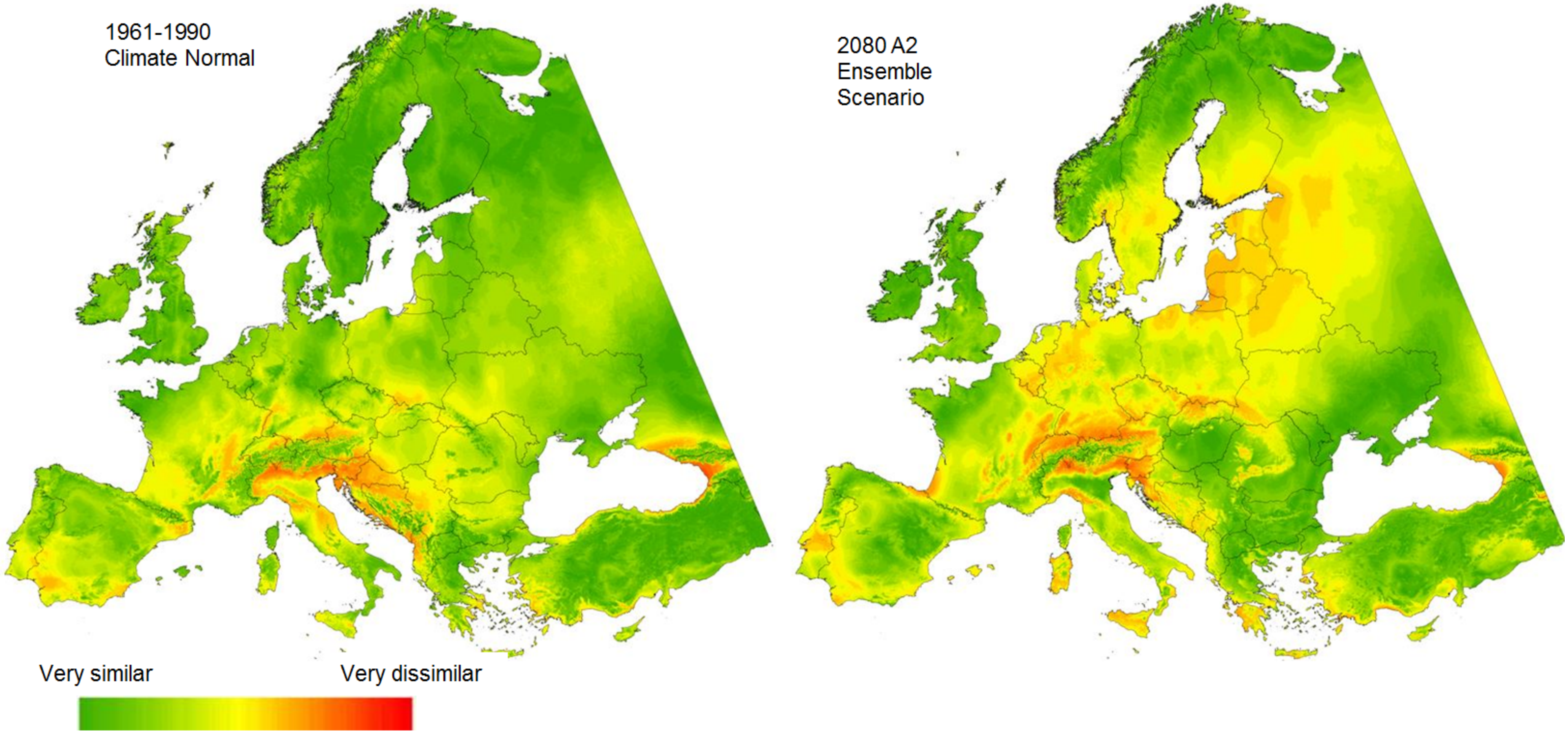

Figure 5. Dissimilarities of European climates in 2080 compared to North American climates using a 1961-1990 baseline. Red indicates highly dissimilar climates while green indicates high similarities.

5. Discussion

5.1. Moving seed based on climate match

The different responses of North American populations, as observed in common garden sites and as predicted by the model, underline the importance of managing for populations that are genetically adapted to their local environments: 21% of all variance among performance can be attributed to populations alone, and another 5.7% to their interaction with sites. The population predictions from the bioclimatic envelope model applied to Europe are generally accurate when validated against height growth data from diverse planting sites. Deviations between observed and predicted were most often seen in more northern areas with higher temperatures, for example in Central Europe, Romania, Finland and Poland. Many of these regions, however, have larger standard errors than other regions from a lower number of provenances tested at fewer sites, so other populations observed to have close performance may in fact be top-ranking. Also, when there is a discrepancy in the top-performing populations, the second-ranked population is often predicted accurately. Furthermore, model predictions are often a highly intuitive match based on climate. Using Finland as an example, the top performer was observed to be from a mild and moist climate, while the model predicted that a northern interior population would perform best in these regions. This is a reasonable prediction given similar levels of precipitation and temperatures (Fig 1, 2). In addition, the interior north population was a close second, and could in fact be a top-performer given the average standard error for Finland is greater than the difference in performance. Since the model appears relatively sound, and genetic adaptation has guided the seed transfer guidelines for reforestation in North America, we recommend that this model can be used cautiously as another decision-making tool to help European forest managers select the most appropriate seed sources for their region.

Although the theory of local optimality has guided seed transfer, it is becoming increasingly recognized that an adaptation lag may already exist: provenances perform better when moved northward by a few degrees latitude (e.g. Gray et al. 2011, Schreiber et al. 2011), but the opposite is seen with southward seed movement. Such adaptation lags will become wider since tree species have limited ability to migrate and cannot keep pace with such rapid shifts in habitat. For populations within the range, this could equate with reduced health and productivity throughout the range, and not simply at the species' trailing edge (O'Neill et al. 2008). It is important to note, however, that a shifting climate space will not necessarily lead to immediate mortality, since trees can adapt physiologically to changing conditions that they may experience in their long life-times. However, populations do have an optimum, which can be seen with reduced growth when they are transferred along a given environmental or geographical gradient. The shifts away from their climatic optimum will lead to maladaptation resulting in sub-optimal productivity and reduced health.

For Douglas-fir in North America, climatypes in the north may actually be more vulnerable under climate change than those in the south. To ensure continued productivity and health, human intervention has already been promoted in the Douglas-fir native range: depending on the planning time-frame, seed sources have been recommended to be sourced from hundreds of kilometers south and lower in elevation (St Clair and Howe 2007, Gray and Hamann 2013). The results of the projected rapid shifts in the climate envelope for top-ranking Douglas-fir populations in Europe (Fig 4) highlight that natural regeneration may not be the most suitable reforestation option, and forest managers should instead rely on reforestation with populations that are the most suitable seed sources under observed climate change and also considering future projections for the choice of appropriate provenances. The Figure 3 dotplot and Figure 4 projections combined can be used to regionally select provenances that have proven to be good performers under past/current climate conditions (Fig 3 top), but that also may be a good climate match in the future (Fig 4).

Moving species to prevent losses under changing climates, also known as assisted migration, is considered controversial. Different objectives, however, colour the debate: those with a conservation purpose dispute the balance between the risks of potential species extinction versus invasiveness (e.g. McLachlan et al. 2007, Ricciardi and Simberloff 2009), while those in the field of forestry discuss the risks of maladaptation versus unintended ecosystem alterations (e.g. O'Neill et al. 2008, Aubin et al. 2011, Gray et al. 2011). Here, it is useful to use the definitions used by Gray et al. (2011), who describe long-distance transfers outside of a species' range for conservation purposes as *assisted colonization,* and refer to *assisted migration* as movements within a species range, or just ahead of the leading-edge. Assisted migration within a species range is sometimes referred to as *assisted population migration*, while moving planting-stock just ahead of the current range is occasionally referred to as *assisted range expansion* (Aubin et al. 2011). In a forestry context, Aubin et al. (2011) suggest that assisted range expansion can cause unintended stress in introduced regions, potentially even causing the extirpation of other species. The underlying objective here, however, is to prevent losses in productivity in European Douglas-fir: a tree species that has been introduced more than 185 years ago and, while showing the ability to naturally regenerate, has not proven to be invasive in the highly managed forests of Europe. Another criticism of both assisted population migration and assisted range expansion is that planting-stock could be maladapted should the climate change projections on which the transfer guidelines were based do not occur as predicted (Aubin et al. 2011). Here, however, the meta-analysis of provenance trials in Europe indicates that our North American populations have reasonable within-population genetic diversity (15.5 % – see Tab 4), which act as insurance against serious consequences from predicting a slightly sub-optimal population.

5.2. Growth versus survival adaptation

When selecting provenances for plantation forestry, growth performance is an important criterion, but growth may not always reflect evolutionary fitness, especially in short-term provenance trials. Important adaptive traits should be considered as well. For example, trees may invest resources in cold hardiness mechanisms and perhaps limit their growing season to avoid frost. As a consequence the tree may show reduced productivity but also has a higher safety margin for survival. Such an evolutionary advantage of cold adaptation may not have fully played out in the provenance experiments, if the trees were not exposed to rare extreme frosts. The following sections discuss instances where the discrepancy between Random Forest predictions and observed growth performance may point to cases of growth versus survival adaptations that should be considered when selecting provenances for reforestation.

5.2.1. Precipitation and dryness limitations to growth

Overall levels of precipitation have been reported as being a primary limiting factor to productivity in Douglas-fir’s interior range (Griesbauer and Green 2010).

The results of a tree-ring analysis by Chen et al. (2010) also found interior populations to be limited by overall low precipitation and high growing season temperatures. A negative correlation has been reported between drought resistance and height growth in Douglas-fir (Beran 1996), with the more drought-tolerant interior variety being assumed as being a better perfomer in drier areas like the Czech Republic (Beran 1996, Cafourek 2001). Also important to the present study's model is a moisture deficient index. Although mean annual precipitation may seem unrelated to summer dryness, the previous year's fall and winter precipitation can also be important as they increase early season soil moisture availability (Griesbauer and Green 2010). However, Chen et al. (2010) found that the strength of such positive correlations between growth and winter precipitation weakened in late winter, likely a trade-off between higher winter precipitation contributing to soil moisture and winter precipitation falling as snow. Compared to reports that *interior* populations are limited by overall precipitation, some studies indicate that *coastal* Douglas-fir is more limited by dryness: growing season dryness is reported as a primary limiting factor for coastal populations by Chen et al. (2010). Coastal Douglas-fir seedlings have been reported by Larsen (1981) as being less resistant to winter drought-stress in Europe, when frozen soils limit transpiration on windy or sunny days. Perhaps coastal populations are particularly susceptible to frost-drought since they are adapted to higher levels of winter precipitation than is commonly seen in Europe (Fig 1, 2). Seemingly in contrast, the models developed by Coops et al. (2011) found that drought was not present on the coast, due to ample precipitation. Perhaps this partially explains why, in a multivariate analysis comparing growth and phenological traits of coastal provenances, St Clair et al. (2005) found summer drought to be of less importance than winter temperatures and frost dates.

It could, however, simply be a matter of overall productivity: coastal populations may indeed be limited by dryness, but, in absolute terms, may be more productive than interior populations, which are limited year-round by reduced precipitation. In many areas in Europe, precipitation levels appear relatively low, but constant: perhaps this is why coastal populations are top performers in many areas of Europe.

While climate change models have a high level of uncertainty when predicting precipitation, it is much more certain that, even if there is not an overall decrease in precipitation, there will be an increased frequency of summer drought and extreme events for many areas in Europe under climate change. Trees with improved drought tolerance should therefore be selected to prevent consequences for industries and communities. In fact, the heat-wave and associated drought of 2003 is cited as being an indicator of future extremes (Meehl 2007). Although Douglas-fir growth was found to be significantly affected by this drought, as indicated by a tree-ring analysis, these trees were found to be plastic enough to recover in 2004 to show ring characteristics similar to those observed in 2002 (Meier et al. 2008). The response to this drought event appeared to be under genetic control (Meier et al. 2008), importantly indicating that there is the potential to select populations with greater tolerance for expected future drought events (Dalla-Salda et al. 2009). In a drier valley of Switzerland, where some die-back in European larch has already been attributed to drought, Douglas-fir has also been reported as much more drought-resistant species compared to other leading tree species (Eilmann and Rigling 2012). These studies did not indicate coastal and interior varieties, however, so perhaps under more intense drought conditions, coastal Douglas-fir populations could become increasingly limited relative to interior populations, as would be supported by our model projections (Fig 4).

5.2.2. Cold limitations to growth

In general, Leites et al. (2012) found that the minimum temperature of the coldest month was the best variable for models guiding appropriate provenance transfer distances. For Douglas-fir, St Clair et al (2005) found that the strongest correlations in coastal populations were to minimum winter temperatures and frost dates. Balduman et al. (1999) also indicated that cold hardiness unrelated to phenology is important, and that it decreases with increasing elevation and distance from ocean. This could be related to coastal populations having a longer chilling requirement and a higher heat sum accumulation. Chilling-requirement is the sum of cool temperature days thought to prevent pre-mature flushing where environments are prone to mid-winter warming (Beaubien and Hamann 2011). Douglas-fir is said to have a winter chilling requirement of less than 80 days at less than 10°C, according to Campbell (1974). Using seedling growth and basal-area as proxies for phenological in coastal Douglas-fir provenance trial, Gould et al. (2011) confirmed that growth initiation was primarily controlled by air temperatures during the dormant period. Coastal and interior varieties, however, appear to have different chilling requirements when tested outside of its native range, however: Douglas-fir sourced from areas with a highly maritime influence and grown in France and Germany showed much later bud burst than interior provenances, thereby being much less susceptible to late spring frosts (Weisgerber 1978, Michaud 1981). Although no data were provided by Kleinschmit and Bastien (1992), they also confirm these general conclusions by stating that Douglas-fir bud-flushing is ecotypic between the varieties – with coastal flushing earlier than interior populations.

Bud-burst, or flushing, is an important phenological adaptation that balances maximizing growth and minimizing risk from frost damage or drought (Balduman et al. 1999): Earlier bud-burst allows a tree to begin growing before summer drought, but increases risk of damage by late-spring frosts. Interior varieties may be more adapted to early bud-burst due to their precipitation limitations. Coastal populations, however, grow under generally moist maritime winter conditions, where precipitation is less limiting, and where a greater chilling requirement is required to insure against late spring frost. Perhaps late spring frosts, then, are the reason for the general success of coastal populations in Europe, even in northern areas where interior populations would be more intuitive: perhaps late spring frost damages the growth of interior seedlings in these regions. Since warming climates have already been linked to earlier flushing of up to two weeks – based on an analysis of seven decades of plant flowering dates across the province of Alberta in Canada – there could be an increased susceptibility to late-spring frosts (Beaubien and Hamann 2011). Contrary to the growth-precipitation trade-off, then, this may actually indicate that later-flushing coastal populations will remain good performers in higher latitudes under a warming climate trend.

5.3. Non-climatic biotic factors

Although climate variables are a significant factor affecting Douglas-fir growth, there are also confounding factors that could not be accounted for. We did not account for mycorrhizal associations, which have been suggested as helping their associated coastal varieties increase carbohydrate uptake and reduce heavy metal toxicity in Germany (Leinemann 1998). Likewise, we cannot rule out unreported competition or allelopathy, nor could we account for disease. Indeed, the fungal needle cast *Rhabdocline pseudotsugae* is a concern in many European plantations, where it has been introduced from North America; with the literature indicating interior populations from more continental climates are much more susceptible (e.g. Otto 1990, Tigerstedt 1990, Konnert and Fussi 2012). Without the presence of this and other pathogens, or with mycorrhizal associations, interior varieties might have shown a greater overall success in the European provenance trials. However, maladapted trees are more under more stress, potentially leading to a greater susceptibility to biotic disturbances.

5.4. Non-climatic abiotic factors

We also could not account for the influence of aspect or shelter that can affect microclimatic extremes, nor could we account for local soil conditions. These are known to influence the realized niche, but we were not able to apply them as predictors in the model to the European landscape. Thus, European forest practitioners should account for nutrient availability and soil conditions in their reforestation strategies as it is an important factor governing Douglas-fir growth: it is recommended to avoid planting sites with heavy clays, hard podzols, or a high water table, due to the increased likelihood of wind-throw from a superficial rooting pattern, and that limestone soils should be avoided due to potential chlorosis (Otto 1990). Our model also does not incorporate the physiological effects on plant growth from a doubling or tripling of atmospheric carbon dioxide, which are expected to increase a plant's ability to grow under moderate drought conditions (Sage and Coleman 2001). In this case, however, the models will in fact be more conservative, which is preferable when planning for uncertainty.

Photo-period was also not accounted for in the model, while it is known to induce dormancy and increase cold hardiness in Douglas-fir (McCreary 1976). Although some of the winter growth that may be important in some coastal Douglas-fir populations (Chen 2010) is sacrificed, moving seedlings northward could help increase cold hardiness as long as the photo-period induces dormancy before potentially earlier fall frosts. Perhaps this can help explain why Douglas-fir can grow in areas representing more than a 10°N latitudinal transfer from its native range. These variables perhaps could account for some unexpected outcomes when matching North American populations to European planting sites based solely on our climatic analysis.

5.5. Model limitations

A common criticism of bioclimatic envelope modeling is that they appear overly optimistic when users assume that species can migrate as quickly as the shifting climate space (e.g. Hampe 2004, Araujo et al. 2005, Williams and Jackson 2007). However, the recognition that that there is an increasingly large disparity between tree population adaptations and their climatic optimum is in fact the very foundation for the analysis here, with the assumption that we must target the most suitable seed-source under different climate change scenarios to minimize maladaptation as much as possible. Another criticism of bioclimatic envelope models is that they do not incorporate competition (Hampe 2004), thereby modeling the realized niche only, not the fundamental niche. This, however, is less relevant in a forestry context, especially for an introduced species in highly managed forests of Europe, since competition is often controlled at planting sites (Mbogga 2010). Further, by modeling the realized niche, the models are made more conservative. One final criticism of bioclimatic envelope models is that they do not incorporate the physiological effects on plant growth from increasing atmospheric carbon dioxide, but this will again make the model here more conservative, by under-predicting suitable habitat.

Habitat projections based on climate for the observed decadal average (1995-2009) match the magnitude of the A2 climate projections from the 1961-1990 baseline, so we can be reasonably confident in future projections. There remains, however, uncertainty in our models from not being able to account for biotic and abiotic factors. There is also uncertainty relating to GCMs, although they have improved in recent years, and with the emission scenarios. It is therefore important to continue with such verifications in future analysis, because it is important to adapt to actual changing climates, not simply predicted changes.

Diversity, from both an ecological and management perspective, has also been suggested as helping to increase adaptive capacity. Mixed forests can balance risks and opportunities, and are also good for gene conservation (Zebisch 2005). Multipurpose forestry and varied ownership can lead to higher adaptive capacity, since diverse management objectives can lead to a more adaptable economic portfolio, since we cannot predict future economies and the cyclical nature of some forest-dependant industries. However, smaller, privately-owned forests may have less of an ability to develop their own adaptation strategies, and may need special support (Zebisch 2005): this is important across Europe, given much of the forested land is owned by smaller private companies or families.

6. Conclusions and Recommendations

The variable performance of Douglas-fir populations observed across Europe highlights the importance of finding suitable genetic populations within a widespread species range for reforestation purposes. Although this was emphasized here for an introduced species, this is also true for normal forestry operations; and is likewise critical when considering reforestation strategies to address shifting optimums under changing climates.

The top performing Douglas-fir populations under past climates (1961-1990) generally conformed to previously published results: coastal Washington sources (both from high precipitation areas adjacent to the coast, as well as sources from dry areas further inland) have been top performers across Western Europe. In addition, we could demonstrate that dry coastal sources were more successful in southern and eastern planting sites; and seed sources from more northern locations have performed well in more northern planting locations. Under the observed 1995-2009 climate period, however, there is already an overall trend toward more southerly and dry populations shifting northward, with similar trends projected to a 2020 climate scenario. Thus, changes to the reforestation strategy across Europe appear warranted.

While future projections for the 2020s already appear to conform well to recent climate trends represented by the 1995-2009 climate average, it should be kept in mind that all projections from general circulation models come with inherent uncertainty that increases toward the end of the century. A reforestation strategy to safeguard against such uncertainty is to use a short term 10-20 year planning horizon (Gray et al. 2011). This is especially true given seedlings are most vulnerable to sub-optimal climates, and since they must survive through contemporary climates to reach optimal future climates (Gray et al. 2011). In this way, the seeds are likely to be suitable now and at least part of the rotation length. While this may be an imperfect solution and genotypes may continue to lag behind their climatic optima in the future, we can certainly recommend this adaptation option over the status quo of management based on historic climates that already appear unsuitable.

Projections of suitable climate in Europe for North American populations often conformed well to growth of provenances at test sites. Where the observed provenance experiment population performance significantly diverges from the climate-based predictions (e.g. coastal Balkans, Romania and Turkey), the model results, but also the provenance results, should be interpreted cautiously. For example, coastal sources generally performed well in European regions with continental climate. Foresters may choose to plant coastal sources in these regions, but the diverging model predictions may point toward significant risk factors. For instance, interior sources may be more cold hardy and survive rare extreme cold events that may never have occurred while provenances were grown in test plantations. The importance of these risks may change under climate warming: for example, frost-hardiness trade-offs may become less important while drought-resistance trade-offs may become more significant. Ideally, seed-stock should be targeted for a region based on both performance and similarities of climate, thereby reducing such risks.

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Appendix 1 – European planting site information

Table 5. Planting site data is reported here, listed alphabetically by country and reference, specifically: site number (*Site*), site name (*Name*); age of the plantation (*Age*); average plantation height (*Avg Height*); latitude (*Lat*); longitude (*Long*); elevation (*Elev*), and assigned European group (*Region*)

Country & Site	Name	Age	Avg Height (m)	Lat	Long	Elev	Region
Austria- Ruetz & Nather (1987)							
63	Manhartsberg	8	3.7	48.53	15.73	487	Central Europe
64	Dunkelsteinerwald	6	2.7	48.28	15.42	600	Central Europe
65	Lackendorf	5	2.1	47.59	16.50	291	Central Europe
66	Drassmarkt	5	3.0	47.51	16.40	351	Central Europe
Belgium - Nanson (1978)							
76	Freux	22	10.8	49.97	5.45	460	France & Belgium
Bosnia - Ballian et al. (2002)							
103	Blinje	32	20.1	43.08	18.05	951	Coastal Balkans
Bulgaria - Popov (2002)							
111	Kjustendil	8	1.5	42.28	22.69	521	Balkans
Croatia - Peric et al. (2005)							
106	Kutina	34	24.9	45.55	16.72	145	Balkans
Croatia - Peric et al. (2009)							
102	Kontija	38	26.2	45.13	13.90	337	Coastal Balkans
Croatia - Peric et al. (2011)							
104	Slatki	42	23.1	45.76	17.05	141	Balkans
105	Mikleuska	45	35.3	45.55	16.72	145	Balkans
107	Durgutovica	40	24.9	45.32	18.65	106	Balkans
Czech Republic - Sika & Pav (1990)							
60	Jizbice	20	8.9	50.26	14.99	600	Central Europe
61	Hurka	20	10.5	48.75	14.08	450	Central Europe
Denmark - Holm (1940)							
18	Egelund	25	12.8	56.35	9.08	38	North Coast
Finland - Silander et al. (2000)							
1	Punkaharju	69	26.6	61.76	29.39	83	Finland
2	Aulanko	70	29.3	61.02	24.45	103	Finland
3	Ruotsinkylaan	67.6	24.6	60.61	26.46	20	Finland
4	Solbole	68.4	27.2	60.05	23.04	20	Finland
France - Aussenac (1980)							
77	Arboretum	16	8.0	48.74	6.35	227	France & Belgium
France - Bastien et al. (1987)							
84	Cendrieux2	12	6.8	45.03	0.08	220	France & Belgium
France - Birot & Burzynski (1981)							
79	Peyrat	7	2.1	45.82	1.75	470	France & Belgium
France - Christophe & Birot (1979)							
82	Cendrieux	8	2.5	45.03	0.08	220	France & Belgium
France - Michaud et al. (1992)							
78	Chassenoix	10	4.4	47.38	4.18	475	France & Belgium
81	Douillac	10	5.2	45.56	1.17	340	France & Belgium
83	Giat	10	4.6	45.80	2.47	775	France & Belgium
85	LaBayssette	10	4.2	43.56	2.56	850	France & Belgium
France - Rozenberg (1993)							
80	SaintJulienlePetit	25	*	45.82	1.73	450	France & Belgium

Appendix 1 – continued

Country & Site	Name	Age	Avg Height (m)	Lat	Long	Elev	Region
Germany - Herrmann (1973)							
26	Itterbeck	11	1.8	52.50	6.83	55	North Coast
Germany - Jestaedt (1980)							
42	Gahrenberg	8	1.1	51.42	9.58	170	Central Germany
43	BadSooden	8	0.8	51.23	9.87	750	Central Germany
44	Wanfried	8	0.6	51.17	10.22	443	Central Germany
45	Rotenberg	8	1.4	51.02	9.70	270	Central Germany
46	Rauschenberg	8	1.0	50.90	9.00	340	Central Germany
48	Waldsolms	8	1.0	50.42	8.55	355	Central Germany
50	BadHomburgAbt49	8	0.8	50.25	8.53	403	Central Germany
51	Sinntal	8	1.3	50.23	9.63	310	Central Germany
55	Bensheim	8	1.0	49.63	8.53	95	Central Germany
58	Hirschhorn	8	1.7	49.45	8.92	255	Central Germany
Germany - Kenk & Thren (1958)							
56	Weinheim	22	13.8	49.55	8.66	107	Central Germany
59	Wiesloch	22	13.6	49.25	8.64	105	Central Germany
67	Calw	22	13.3	48.72	8.83	590	Southern Germany
68	Sindelfingen	22	12.5	48.71	9.01	590	Southern Germany
69	Ehingen	22	9.8	48.28	9.73	537	Southern Germany
70	Mooswald	22	15.1	48.05	7.82	230	Southern Germany
72	Illenberg	22	14.8	47.95	7.86	500	Southern Germany
73	Schauinsland	22	9.9	47.91	7.89	1159	Southern Germany
74	Schluchsee	22	10.0	47.84	8.12	1050	Southern Germany
75	Schopfheim	22	11.5	47.72	8.00	940	Southern Germany
Germany - Kleinschmit et al. (1985)							
19	Neumuenster	14	4.5	54.07	9.98	23	North Coast
22	Bremervoerde	14	4.2	53.49	9.14	8	North Coast
34	Frankenberg	14	4.2	50.91	13.04	288	Eastern Germany
47	Hilders	14	4.3	50.57	10.00	517	Central Germany
49	Katzenelnbogen	14	5.4	50.27	7.98	290	Central Germany
54	Heigenbrocken	14	4.4	50.03	9.37	285	Central Germany
Germany - Schober (1954)							
33	Freienwalde	18	4.2	52.78	14.04	13	Eastern Germany
39	Braunlage	24	8.6	51.72	10.61	569	Central Germany
41	Gahrenberg	24	11.0	51.42	9.58	170	Central Germany
71	Kirchzarten	23	3.5	47.96	7.96	394	Southern Germany
Germany - Stimm & Dong (2001)							
57	Kaiserlautern	90	33.5	49.42	7.67	375	Central Germany
Germany - Weller (2010)							
20	Rantzau783	38	23.3	54.02	9.67	20	North Coast
21	Rantzau225	38	22.2	53.87	9.79	32	North Coast
23	Harsefeld	38	22.6	53.25	8.86	45	North Coast
24	Ahlhorn	38	25.7	52.93	8.60	33	North Coast
27	Ankum1093	38	23.0	52.52	7.80	45	North Coast
28	Ankum35	38	25.0	52.38	7.53	30	North Coast
30	Oerrel	38	22.2	52.71	10.51	70	North Coast
35	Seesen	38	20.0	51.83	10.38	580	Central Germany

Appendix 1 – continued

Country & Site	Name	Age	Avg Height (m)	Lat	Long	Elev	Region
36	Neuhaus	38	21.6	51.78	9.54	495	Central Germany
37	Westerhof	38	24.6	51.76	10.12	300	Central Germany
38	Riefensbeek	38	26.4	51.76	10.40	310	Central Germany
40	Lauterberg	38	21.0	51.65	10.67	570	Central Germany
52	Trier	38	23.1	49.85	6.70	380	Central Germany
53	Soonwald	38	23.6	49.92	7.74	400	Central Germany
Ireland - Lally & Thompson (1998)							
11	Rathdrum	24	16.3	51.98	-8.22	65	Southern UK
Ireland - O’Driscoll (1978)							
10	Glenealy	6	3.5	52.97	-6.14	77	Southern UK
Italy - De Vecchi (1978)							
99	Turin	10	1.8	45.09	7.76	325	Italy
Italy - Ducci & Tocci (1987)							
100	Vallombrosa	16	10.1	43.73	11.56	965	Italy
101	Faltona	16	8.2	43.62	11.76	754	Italy
Netherlands - Kranenborg & de Vries (1995)							
25	Sleenerzand	20	11.1	52.80	6.81	18	North Coast
29	Sprielderbos	20	10.4	52.25	5.66	55	North Coast
Norway - Magnesen (1986)							
5	Moberglien	13	3.2	60.17	5.45	100	Norway
Poland - Birot & Burzynski (1981)							
31	Dolice	7	2.0	53.23	15.20	43	Poland
Poland - Mejnartowicz (1999)							
32	Karcz	6	1.0	53.38	23.57	169	Poland
Romania - Popa-Costea et al (1973)							
112	Fintinele	5	1.2	46.58	26.83	225	Romania
113	Zaicani	6	2.5	45.42	22.83	650	Romania
114	Turnu Rueni	7	3.0	45.33	22.38	710	Romania
115	Onofrea	5	2.2	45.33	24.17	525	Romania
116	Dobra	8	2.3	44.83	22.58	705	Romania
*Note: Pietroasa was removed due to an incorrectly reported location							
Serbia - Isajev & Lavadinovi (2007)							
109	Tanda	12	3.9	44.06	22.10	370	Balkans
110	Juhor	12	4.6	43.81	21.26	670	Balkans
Serbia - Popovic et al. (2001)							
108	Sremcica	11	2.2	44.68	20.39	216	Balkans
Slovakia - Holubcik (1983)							
62	Kmetova	7	0.6	48.80	19.28	500	Central Europe
Spain - Hernandez et al. (1993)							
86	Fragavella	5	0.4	43.45	-7.45	580	Spain
87	Regavella	5	0.4	43.27	-7.35	450	Spain
88	SierradeMeira	5	0.5	43.22	-7.23	850	Spain
89	Gamalleira	5	1.0	43.27	-7.07	660	Spain
90	Valdemadeiro	5	0.6	43.12	-6.95	920	Spain
91	LaGallina	5	1.2	43.18	-5.84	600	Spain
92	Confercal	5	1.8	43.12	-5.88	850	Spain
94	CastroDozon	5	0.8	42.55	-8.05	750	Spain

Appendix 1 – continued

Country & Site	Name	Age	Avg Height (m)	Lat	Long	Elev	Region
95	LaVecilla	5	1.0	42.82	-5.36	1160	Spain
96	SalinasdeLeniz	5	1.1	42.98	-2.54	900	Spain
97	Bande	5	5.1	42.03	-7.95	900	Spain
Spain - Toval (1985)							
93	LaHermida	6	0.7	42.52	-8.28	700	Spain
98	SierradelEje	6	0.4	42.28	-6.97	1360	Spain
Turkey - Şimşek (1987)							
117	Zonguldak	13	6.3	41.38	31.87	520	Turkey
118	Duzce	14	5.8	40.80	31.30	520	Turkey
119	Izmit	14	5.7	40.82	29.80	440	Turkey
120	Giresun	13	4.5	40.73	38.42	1340	Turkey
UK (Scotland) - Lines (1978)							
6	Culloden	6	2.3	57.47	-4.13	175	Scotland
7	Rosarie	6	1.9	57.53	-3.04	228	Scotland
8	Inchnacardoch	6	2.3	57.15	-4.75	381	Scotland
UK (Scotland) Lines & Samuel (1987)							
9	Craigvinean	10	3.7	56.58	-3.65	138	Scotland
UK (Southern) - Lines & Samuel (1987)							
12	Radnor	16	10.0	52.25	-3.02	226	Southern UK
13	Dean	16	10.8	51.82	-2.67	60	Southern UK
14	Bodmin East	11	6.7	50.47	-4.67	92	Southern UK
15	Bodmin South	11	6.8	50.47	-4.67	92	Southern UK
16	Bodmin North	11	6.4	50.47	-4.67	92	Southern UK
17	Charmouth	12	7.2	50.77	-2.95	138	Southern UK

Bibliography for Appendix 1

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Appendix 2 – North American collection site (provenance) information

Table 6. Provenance data is reported here by reference and provenance name (*Provenance Name (ID)*); US state or Canadian province (*State*); latitude in decimal degrees (*Lat*); longitude in decimal degrees (*Long*); elevation (*El*); International Union of Forest Research Organizations 166-1968 Douglas-fir provenance collection number, if provided (*IUFRO ID*); the name of the site at which the provenance was tested (*Site Name*) and the site's ID (*Site ID*), which corresponds to the Site ID in Appendix 1; height as originally reported in the article, in meters (*Height*), unless already normalized in the article; and normalized height, expressed as standard deviations from the mean planting site height (*Norm Height*). *See Appendix 1 for bibliography.

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Austria - Ruetz & Nather (1987)									
Adams Lake	BC	51.170	-119.570	575	-	Lackendorf	65	1.68	-1.45
						Drassmarkt	66	1.88	-3.35
						Manhartsberg	63	3.31	-1.85
Ashford Elbe 1	WA	46.796	-122.179	425	-	Dunkelsteinerwald	64	2.50	-0.19
						Manhartsberg	63	3.48	-0.95
Ashford Elbe 2	WA	46.796	-122.179	575	-	Manhartsberg	63	4.03	1.91
						Lackendorf	65	2.18	0.33
Castle Rock	WA	46.317	-122.867	150	1088	Manhartsberg	63	3.64	-0.15
Cathlamet	WA	46.300	-123.267	200	1089	Manhartsberg	63	3.62	-0.26
Cle Elum	WA	47.195	-120.939	725	-	Manhartsberg	63	3.49	-0.93
Concrete 1	WA	48.539	-121.746	76	-	Dunkelsteinerwald	64	2.76	0.60
Concrete 2	WA	48.540	-121.750	575	-	Lackendorf	65	2.49	1.43
Concrete, Pressentin Creek	WA	48.517	-121.852	120	-	Drassmarkt	66	3.15	0.42
Concrete, Jackmann Creek	WA	48.517	-121.852	160	-	Drassmarkt	66	3.02	0.04
Darrington 1	WA	48.255	-121.602	425	-	Manhartsberg	63	3.84	0.90
Darrington 2	WA	48.255	-121.602	575	-	Manhartsberg	63	3.51	-0.84
Darrington 3	WA	48.255	-121.602	1025	-	Drassmarkt	66	2.97	-0.11
Darrington 4	WA	48.260	-121.600	208	-	Lackendorf	65	2.37	1.00
Darrington 5	WA	48.260	-121.600	425	-	Lackendorf	65	2.15	0.22
Darrington 6	WA	48.260	-121.600	725	-	Lackendorf	65	2.25	0.58
Darrington 7	WA	48.260	-121.600	875	-	Lackendorf	65	2.08	-0.03
Darrington 8	WA	48.260	-121.600	1030	-	Lackendorf	65	2.42	1.18
Darrington, Round Mountain	WA	48.326	-121.750	250	-	Drassmarkt	66	3.16	0.45
Darrington, Suiattle	WA	48.368	-121.474	70	-	Drassmarkt	66	3.25	0.73
Darrington, Texas Pond	WA	48.372	-121.585	340	-	Drassmarkt	66	3.24	0.70
Enumclaw	WA	47.267	-121.933	240	1075	Manhartsberg	63	3.62	-0.24
Forks	WA	47.983	-124.400	90	1062	Manhartsberg	63	3.94	1.45
Granite Falls	WA	48.083	-122.033	90	1057	Manhartsberg	63	4.09	2.26
Humptulips	WA	47.317	-123.900	140	1073	Manhartsberg	63	3.49	-0.94
Lake Crescent	WA	48.067	-124.000	300	1058	Manhartsberg	63	3.75	0.43
Marblemount	WA	48.583	-121.400	120	1050	Manhartsberg	63	3.68	0.06
Matlock	WA	47.238	-123.408	120	-	Drassmarkt	66	3.22	0.63
Mineral	WA	46.717	-122.182	650	-	Drassmarkt	66	2.89	-0.34
Morton, Randle Peterm. H.	WA	46.558	-122.275	800	-	Drassmarkt	66	3.14	0.38
North Bend	WA	47.467	-121.750	150	1069	Manhartsberg	63	3.48	-0.98
North Bend, Black Lake	WA	47.496	-121.787	400	-	Drassmarkt	66	3.28	0.80
North Bend, Klaus Lake	WA	47.583	-121.755	330	-	Drassmarkt	66	3.24	0.67
Pe Ell, Sand Creek	WA	46.563	-123.281	270	-	Drassmarkt	66	2.95	-0.17
Randle 1	WA	46.535	-121.957	425	-	Manhartsberg	63	3.46	-1.09

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Randle 2	WA	46.535	-121.957	575	-	Manhartsberg	63	3.81	0.77
Randle 3	WA	46.540	-121.960	425	-	Lackendorf	65	1.94	-0.53
Randle 4	WA	46.550	-122.050	340	1085	Manhartsberg	63	3.72	0.28
Randle, Packword Woods	WA	46.535	-121.957	800	-	Drassmarkt	66	3.18	0.52
Salmon Arm	BC	50.700	-119.280	925	-	Lackendorf	65	1.71	-1.35
						Drassmarkt	66	2.24	-2.28
Sequim	WA	48.033	-123.033	60	1060	Manhartsberg	63	3.64	-0.13
Shuswap Lake	BC	50.960	-119.260	600	-	Lackendorf	65	1.46	-2.24
Skykomish, Beckler River	WA	47.715	-121.339	300	-	Drassmarkt	66	3.01	0.00
Skykomish, Foss River	WA	47.705	-121.306	340	-	Drassmarkt	66	2.96	-0.14
Skykomish, Miller River	WA	47.720	-121.398	270	-	Drassmarkt	66	2.92	-0.25
Snoqualmie	WA	47.390	-121.400	350	-	Lackendorf	65	2.16	0.26
Snoqualmie Falls	WA	47.540	-121.840	400	-	Lackendorf	65	1.97	-0.42
Snoqualmie Pass 1	WA	47.390	-121.400	725	-	Lackendorf	65	2.08	-0.03
						Drassmarkt	66	2.81	-0.59
Snoqualmie Pass 2	WA	47.390	-121.400	875	-	Dunkelsteinerwald	64	2.54	-0.07
						Manhartsberg	63	3.76	0.48
Snoqualmie River 1	WA	47.527	-121.825	425	-	Drassmarkt	66	3.01	0.02
						Lackendorf	65	2.24	0.52
Snoqualmie River 2	WA	47.668	-121.916	575	-	Dunkelsteinerwald	64	2.94	1.15
						Manhartsberg	63	3.63	-0.21
Sultan, Olney Creek	WA	47.863	-121.817	220	-	Drassmarkt	66	3.41	1.21
Wynnoochee, Satsop	WA	47.003	-123.484	160	-	Drassmarkt	66	3.09	0.25
Yacolt, Spotted Deer	WA	45.770	-122.378	600	-	Drassmarkt	66	3.15	0.41
Yale	WA	46.000	-122.367	120	-	Manhartsberg	63	3.69	0.12
Yelm	WA	47.017	-122.733	60	-	Manhartsberg	63	3.65	-0.06
<u>Belgium - Nanson (1978)</u>									
Ashford (54/13)	WA	46.758	-122.031	500	-	Freux	76	11.23	0.60
Camano Island (54/22)	WA	48.174	-122.545	100	-	Freux	76	10.48	-0.38
Castle Rock 1 (54/18)	WA	46.317	-122.867	170	-	Freux	76	9.94	-1.08
Castle Rock 2 (54/15)	WA	46.317	-122.867	430	-	Freux	76	11.45	0.88
Chehalis (46/4)	WA	46.662	-122.964	150	-	Freux	76	11.12	0.46
Cottage Grove (54/17)	OR	43.798	-123.060	260	-	Freux	76	11.99	1.58
Darrington (54/5)	WA	48.255	-121.602	170	-	Freux	76	11.45	0.88
Elma (54/8)	WA	47.003	-123.409	170	-	Freux	76	12.10	1.72
Enunclaw 1 (54/10)	WA	47.204	-121.992	160	-	Freux	76	11.12	0.46
Enunclaw 2 (54/16)	WA	47.204	-121.992	500	-	Freux	76	11.45	0.88
Estacada (54/20)	OR	45.289	-122.334	530	-	Freux	76	10.48	-0.38
Forks (54/12)	WA	47.983	-124.400	130	-	Freux	76	10.48	-0.38
Gates-Detroit (46/2)	OR	44.756	-122.417	520	-	Freux	76	10.69	-0.10
Graham (54/23)	WA	47.053	-122.295	250	-	Freux	76	10.69	-0.10
Grande Ronde (46/3)	OR	45.060	-123.610	230	-	Freux	76	9.83	-1.22
Hoquiam (54/1)	WA	46.981	-123.889	100	-	Freux	76	12.53	2.27
Louella 1 (54/7)	WA	48.036	-123.039	330	-	Freux	76	10.58	-0.24
Louella 2 (54/4)	WA	48.036	-123.039	470	-	Freux	76	11.12	0.46
Lowell (54/25)	OR	43.919	-122.784	250	-	Freux	76	9.07	-2.19
Molalla (46/6)	OR	45.147	-122.577	150	-	Freux	76	9.50	-1.63
Orting (46/5)	WA	47.098	-122.204	150	-	Freux	76	10.48	-0.38

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Parkdale (46/1)	OR	45.520	-121.597	615	-	Freux	76	10.26	-0.66
San Juan (54/21)	WA	48.551	-123.078	100	-	Freux	76	10.04	-0.94
Santiam River (54/14)	OR	44.784	-122.706	500	-	Freux	76	9.72	-1.36
Sequim (54/6)	WA	48.080	-123.102	70	-	Freux	76	10.04	-0.94
Snowscreek (54/3)	WA	46.619	-122.267	415	-	Freux	76	10.80	0.04
Tenino (54/19)	WA	46.857	-122.853	100	-	Freux	76	11.23	0.60
Veronia (54/9)	OR	45.859	-123.193	260	-	Freux	76	10.91	0.18
Wind River (54/2)	WA	45.944	-121.938	500	-	Freux	76	10.58	-0.24
Yacolt (54/11)	WA	45.866	-122.406	400	-	Freux	76	11.02	0.32
Yelm (54/24)	WA	47.017	-122.733	100	-	Freux	76	11.45	0.88
Bosnia - Ballian et al. (2002)									
Alberni	BC	49.317	-124.850	150	1036	Blinje	103	20.37	0.39
Grand Ronde Agency	OR	45.100	-123.600	200	1100	Blinje	103	19.80	-0.44
Thasis	BC	49.783	-126.633	17	1029	Blinje	103	19.33	-1.13
Vasko Pine Grove	OR	45.100	-121.383	800	1099	Blinje	103	20.90	1.18
Bulgaria - Popov (2002)									
(4)	WA	48.083	-121.083	667	-	Kjustendil	111	2.10	2.65
(5)	WA	48.083	-121.083	500	-	Kjustendil	111	1.88	1.63
(6)	WA	48.000	-121.083	1167	-	Kjustendil	111	1.77	1.12
(7)	WA	48.000	-121.083	1000	-	Kjustendil	111	1.73	0.93
(8)	WA	48.000	-121.083	833	-	Kjustendil	111	1.76	1.07
(9)	WA	47.133	-121.050	525	-	Kjustendil	111	1.80	1.27
(10)	WA	47.117	-123.000	600	-	Kjustendil	111	1.74	0.97
(11)	WA	47.117	-123.083	450	-	Kjustendil	111	1.72	0.88
(12)	WA	47.083	-124.000	600	-	Kjustendil	111	1.72	0.89
(13)	WA	46.083	-121.050	1050	-	Kjustendil	111	1.54	0.03
(14)	OR	45.083	-121.083	1650	-	Kjustendil	111	1.63	0.47
(15)	OR	45.083	-121.117	1500	-	Kjustendil	111	1.56	0.12
(16)	OR	45.083	-121.083	1350	-	Kjustendil	111	1.63	0.45
(17)	OR	45.083	-121.083	1200	-	Kjustendil	111	1.39	-0.69
(18)	OR	45.083	-121.083	1050	-	Kjustendil	111	1.40	-0.60
(19)	OR	45.083	-121.083	900	-	Kjustendil	111	1.76	1.08
(20)	OR	45.083	-121.083	750	-	Kjustendil	111	1.73	0.92
(24)	OR	45.000	-122.000	1050	-	Kjustendil	111	1.59	0.26
(25)	OR	45.000	-122.000	1200	-	Kjustendil	111	1.43	-0.47
(26)	OR	45.000	-122.000	1050	-	Kjustendil	111	1.48	-0.25
(27)	OR	45.000	-122.000	900	-	Kjustendil	111	1.33	-0.94
(28)	OR	45.000	-122.000	1333	-	Kjustendil	111	1.26	-1.30
(29)	OR	45.000	-122.000	750	-	Kjustendil	111	1.79	1.23
(30)	OR	45.000	-122.000	750	-	Kjustendil	111	1.51	-0.12
(31)	OR	45.000	-122.000	750	-	Kjustendil	111	1.82	1.36
(32)	OR	45.000	-122.000	900	-	Kjustendil	111	1.61	0.37
(33)	OR	45.000	-121.083	667	-	Kjustendil	111	1.49	-0.18
(34)	OR	44.100	-123.133	150	-	Kjustendil	111	1.75	1.03
(38)	OR	44.050	-121.100	1125	-	Kjustendil	111	1.38	-0.70
(39)	OR	44.050	-121.133	1500	-	Kjustendil	111	1.45	-0.39
(40)	OR	44.000	-122.000	1667	-	Kjustendil	111	1.31	-1.04
(41)	OR	44.000	-122.000	1500	-	Kjustendil	111	1.25	-1.32

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
(42)	OR	44.000	-122.000	1333	-	Kjustendil	111	1.42	-0.54
(43)	OR	44.000	-122.000	900	-	Kjustendil	111	1.68	0.70
(44)	OR	43.133	-122.083	1350	-	Kjustendil	111	1.52	-0.06
(45)	OR	43.133	-122.083	1200	-	Kjustendil	111	1.31	-1.03
(46)	OR	43.133	-122.083	1500	-	Kjustendil	111	1.32	-1.01
(47)	OR	43.050	-121.133	1650	-	Kjustendil	111	1.31	-1.06
(48)	OR	43.050	-122.000	1500	-	Kjustendil	111	1.21	-1.53
(49)	OR	42.117	-122.083	1200	-	Kjustendil	111	1.29	-1.15
(50)	OR	42.083	-122.083	1050	-	Kjustendil	111	1.33	-0.95
(51)	OR	42.100	-122.133	900	-	Kjustendil	111	1.34	-0.89
(52)	OR	42.000	-124.083	833	-	Kjustendil	111	1.52	-0.06
(53)	OR	42.000	-124.083	667	-	Kjustendil	111	1.37	-0.78
(54)	AZ	35.083	-111.100	2550	-	Kjustendil	111	1.43	-0.49
(55)	NM	33.000	-105.133	750	-	Kjustendil	111	1.13	-1.87
Croatia - Peric et al. (2005)									
Ashland	OR	42.190	-122.710	597	-	Kutina	106	24.21	-1.35
Cascadia	OR	44.397	-122.485	254	-	Kutina	106	25.48	1.00
Centralia	WA	46.716	-122.954	58	-	Kutina	106	25.16	0.42
Cottage Grove	OR	43.798	-123.060	197	-	Kutina	106	24.90	-0.07
Croatia - Peric et al. (2009)									
Castle Rock (T)	WA	46.275	-122.908	23	-	Kontija	102	25.25	-0.57
Corvalis (B)	OR	44.583	-123.267	16	-	Kontija	102	26.34	0.07
Elma (E)	WA	47.000	-123.500	150	-	Kontija	102	27.58	0.81
Pe All (M)	WA	46.750	-123.250	225	-	Kontija	102	27.38	0.69
Shady Cove (C)	OR	42.600	-122.833	1350	-	Kontija	102	23.11	-1.85
Shelton (A)	WA	47.183	-123.167	90	-	Kontija	102	27.98	1.05
Yelm (N)	WA	46.750	-122.667	75	-	Kontija	102	25.89	-0.20
Croatia - Peric et al. (2011)									
Alder (H)	WA	46.800	-122.290	300	-	Durgutovica	107	26.42	0.80
Ashland (4)	OR	42.190	-122.710	597	-	Mikleuska	105	34.76	-0.74
Cascadia (3)	OR	44.397	-122.485	254	-	Mikleuska	105	35.40	0.09
Castle Rock (T)	WA	46.280	-122.910	17	-	Durgutovica	107	25.73	0.43
						Slatki	104	24.22	0.31
Centralia (2)	WA	46.716	-122.954	58	-	Mikleuska	105	36.40	1.38
Cottage Grove (1)	OR	43.798	-123.060	197	-	Mikleuska	105	34.76	-0.74
Corvalis (B)	OR	44.583	-123.267	75	-	Slatki	104	22.47	-0.20
Elma (E)	WA	47.000	-123.050	150	-	Durgutovica	107	25.73	0.43
						Slatki	104	27.50	1.26
Matlock (G)	WA	47.238	-123.408	25	-	Durgutovica	107	26.11	0.63
Merville Black (I)	BC	49.792	-125.049	15	-	Durgutovica	107	25.49	0.30
						Slatki	104	22.55	-0.17
Pe All (M)	WA	46.750	-123.250	225	-	Slatki	104	25.60	0.71
Republic (K)	WA	48.650	-118.740	782	-	Durgutovica	107	23.81	-0.60
Salmon Arm (L)	BC	50.083	-119.017	525	-	Slatki	104	18.18	-1.43
						Durgutovica	107	20.70	-2.27
Shady Cove (C)	OR	42.600	-122.083	1350	-	Durgutovica	107	23.90	-0.55
						Slatki	104	16.31	-1.98
Shelton (A)	WA	47.183	-123.017	90	-	Slatki	104	25.28	0.62

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Tenino (D)	WA	46.750	-122.067	150	-	Durgutovica	107	26.47	0.83
						Slatki	104	25.03	0.54
Yelm (N)	WA	46.942	-122.606	106	-	Slatki	104	24.32	0.34
Czech Republic - Sika & Pav (1990)									
Alberni	BC	49.325	-124.850	140	1036	Hurka	61	10.70	0.40
Bacon Point	WA	48.600	-121.383	505	1049	Hurka	61	10.20	-0.50
						Jizbice	60	9.70	0.81
Barriere	BC	51.204	-120.163	420	1010	Hurka	61	10.20	-0.50
						Jizbice	60	10.40	1.55
Clallam, Lake Crescent	WA	48.067	-124.000	300	1058	Hurka	61	10.50	0.04
Clallam, Louella Gua. Sta.	WA	48.000	-123.083	460	1061	Hurka	61	10.10	-0.68
						Jizbice	60	8.60	-0.34
Coquille	OR	43.200	-124.017	75	1103	Hurka	61	10.90	0.76
D'Arcy	BC	50.557	-122.500	270	1021	Hurka	61	9.40	-1.95
						Jizbice	60	8.00	-0.97
Forbidden Plat.	BC	49.663	-125.156	610	1033	Hurka	61	10.80	0.58
						Jizbice	60	9.30	0.39
King, Enumclaw	WA	47.267	-121.933	240	1075	Hurka	61	11.20	1.30
						Jizbice	60	9.20	0.29
King, North Bend	WA	47.467	-121.750	150	1069	Hurka	61	11.40	1.66
Klina Klini	BC	51.117	-125.596	5	1012	Hurka	61	10.30	-0.32
						Jizbice	60	9.10	0.18
Nimpkish	BC	50.317	-126.883	90	1025	Hurka	61	9.80	-1.23
						Jizbice	60	6.90	-2.13
Revelstoke	BC	51.000	-118.200	600	1013	Hurka	61	11.50	1.84
San Juan	BC	48.581	-124.080	210	1043	Hurka	61	10.00	-0.86
Skagit, Marble Mnt	WA	48.583	-121.400	120	1050	Hurka	61	10.50	0.04
Skykomish	WA	47.700	-121.333	300	1067	Hurka	61	9.90	-1.05
Squamish	BC	49.778	-123.150	15	1030	Hurka	61	10.90	0.76
						Jizbice	60	9.70	0.81
Stuie	BC	52.367	-126.000	16	1004	Hurka	61	10.00	-0.86
						Jizbice	60	9.00	0.08
Wahkiakum, Cathlamet	WA	46.300	-123.267	195	1089	Hurka	61	10.90	0.76
						Jizbice	60	8.30	-0.66
Yamhill, Grande Ronde Ag.	OR	45.100	-123.600	180	1100	Hurka	61	10.40	-0.14
Denmark - Holm (1940)									
Cascade (I - F Nr 10)	OR	43.717	-122.450	400	-	Egelund	18	14.10	0.60
Colville (II - o Nr 9)	WA	48.533	-119.183	900	-	Egelund	18	10.20	-1.13
Couer d'Alene 1 (II - r Nr 19)	ID	47.667	-116.783	1100	-	Egelund	18	11.50	-0.55
Couer d'Alene 2 (II - q Nr 15)	ID	47.700	-116.783	1100	-	Egelund	18	10.50	-1.00
Lolo 1 (II - u Nr 20)	MT	46.883	-114.000	1100	-	Egelund	18	9.30	-1.53
Lolo 2 (II - v Nr 16)	MT	46.883	-114.000	1100	-	Egelund	18	11.50	-0.55
Louella (I - l Nr 8)	WA	48.000	-123.067	350	-	Egelund	18	14.70	0.86
Siskiyou (I - H Nr 11)	OR	42.033	-123.667	500	-	Egelund	18	14.50	0.77
Siuslaw (I - G Nr 17)	OR	43.733	-124.183	400	-	Egelund	18	14.20	0.64
Snoqualmie 1 (I - h Nr 12)	WA	48.850	-121.933	300	-	Egelund	18	16.90	1.83
Trinity 1 (l - N Nr 22)	CA	40.733	-122.933	800	-	Egelund	18	13.20	0.20
Trinity 2 (I - M Nr 21)	CA	40.733	-122.933	1100	-	Egelund	18	14.40	0.73

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Trinity 3 (I - L Nr 18)	CA	40.733	-122.933	1400	-	Egelund	18	10.80	-0.86
Finland - Silander et al. (2000)									
Craigellachie (4)	BC	50.967	-118.717	420	-	Solbole	4	27.60	0.12
Crows Nest Pass (10)	AB	49.650	-114.683	1550	-	Aulanko	2	27.40	-0.71
						Punkaharju	1	23.90	-1.04
						Ruotsinkylaan	3	20.30	-1.37
						Solbole	4	19.20	-2.26
Larch Hill (5)	BC	50.833	-119.000	900	-	Punkaharju	1	26.80	0.08
						Ruotsinkylaan	3	28.40	1.23
						Solbole	4	27.80	0.18
Luis Creek (2)	BC	51.117	-120.117	780	-	Ruotsinkylaan	3	22.80	-0.57
						Solbole	4	29.90	0.78
Prince George (1)	BC	53.883	-122.767	575	-	Solbole	4	31.00	1.09
Salmon River (6)	BC	50.250	-126.000	660	-	Aulanko	2	31.20	0.71
						Punkaharju	1	29.10	0.96
						Ruotsinkylaan	3	26.00	0.46
						Solbole	4	27.10	-0.02
Shuswap Lake (3)	BC	51.133	-119.117	435	-	Solbole	4	26.70	-0.13
Tete Jaune (9)	BC	52.966	-119.430	750	-	Ruotsinkylaan	3	25.40	0.26
						Solbole	4	28.00	0.24
France - Aussenac (1980)									
Campbell River (1)	BC	50.029	-125.274	11	-	Arboretum	77	7.11	-1.69
Darrington I (10)	WA	48.260	-121.600	171	-	Arboretum	77	7.93	-0.11
Darrington II (9)	WA	48.260	-121.600	171	-	Arboretum	77	8.34	0.68
Granit Falls (11)	WA	48.084	-121.969	124	-	Arboretum	77	9.03	2.01
Marion Creek (6)	OR	44.620	-121.950	771	-	Arboretum	77	7.50	-0.94
Molalla (7)	OR	45.147	-122.577	117	-	Arboretum	77	8.19	0.38
Seaquest (5)	WA	46.301	-122.817	188	-	Arboretum	77	8.00	0.01
Shelton (2)	WA	47.250	-123.200	90	-	Arboretum	77	7.98	-0.02
Tennas Creek (4)	WA	48.333	-121.500	485	-	Arboretum	77	8.18	0.36
Timber (8)	OR	45.800	-123.383	270	-	Arboretum	77	7.64	-0.67
France - Bastien et al. (1987)									
Arlington	WA	48.217	-122.067	90	1054	Cendrieux2	84	7.07	1.40
Castle Rock	WA	46.317	-122.867	150	1088	Cendrieux2	84	6.90	0.45
Darrington	WA	48.267	-121.633	150	1053	Cendrieux2	84	6.83	0.06
Enumclaw	WA	47.267	-121.933	240	1075	Cendrieux2	84	6.99	0.96
Gold bar	WA	47.850	-121.650	120	1063	Cendrieux2	84	6.79	-0.16
Granite Falls	WA	48.083	-122.033	90	1057	Cendrieux2	84	6.59	-1.28
Marblemount	WA	48.583	-121.400	120	1050	Cendrieux2	84	6.56	-1.45
Sedro-woolley	WA	48.533	-122.317	60	1051	Cendrieux2	84	7.01	1.07
Skykomish	WA	47.700	-121.333	300	1067	Cendrieux2	84	6.81	-0.05
Sloan Creek	WA	48.083	-121.300	650	1090	Cendrieux2	84	6.64	-1.00
France - Birot & Burzynski (1981)									
Alder Lake	WA	46.800	-122.283	430	1081	Peyrat	79	2.52	0.85
Arlington	WA	48.217	-122.067	100	1054	Peyrat	79	2.63	1.06
Bacon Point	WA	48.583	-121.383	550	1049	Peyrat	79	2.56	0.92
Brookings	OR	42.117	-124.200	330	1104	Peyrat	79	2.42	0.66
Cherryville	OR	45.317	-122.133	700	1097	Peyrat	79	2.26	0.36

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Cle Elum	WA	47.217	-121.117	700	1078	Peyrat	79	1.67	-0.75
D'Arcy	BC	50.550	-123.050	300	1021	Peyrat	79	1.90	-0.32
Merritt	BC	50.067	-120.850	950	1028	Peyrat	79	1.10	-1.83
Perry Creek	WA	48.133	-121.467	700	1059	Peyrat	79	2.21	0.26
Salmon Arm	BC	50.733	-119.217	500	1018	Peyrat	79	1.68	-0.73
Skykomish	WA	47.700	-121.033	230	1067	Peyrat	79	2.55	0.91
Stella Lake	BC	50.283	-125.467	160	1026	Peyrat	79	2.41	0.64
Upper Soda	OR	44.383	-122.200	1150	1102	Peyrat	79	2.04	-0.06
Williams Lake	BC	52.100	-122.000	630	1005	Peyrat	79	1.02	-1.98
France - Christophe & Birot (1979)									
Alder Lake	WA	46.800	-122.283	420	1081	Cendrieux	82	2.44	-0.14
Arlington	WA	48.217	-122.067	90	1054	Cendrieux	82	2.62	0.78
Bacon-point	WA	48.600	-121.383	500	1049	Cendrieux	82	2.41	-0.30
Castle Rock	WA	46.317	-122.867	150	1088	Cendrieux	82	2.63	0.84
Chester morse lake	WA	47.367	-121.667	600	1072	Cendrieux	82	2.36	-0.56
Concrete	WA	48.650	-121.717	470	1047	Cendrieux	82	2.60	0.68
Cougar	WA	46.083	-122.300	500	1090	Cendrieux	82	2.46	-0.04
Darrington	WA	48.267	-121.633	150	1053	Cendrieux	82	2.64	0.86
Denny creek	WA	47.400	-121.533	550	1070	Cendrieux	82	2.42	-0.25
Diablo-dam	WA	48.717	-121.117	420	1046	Cendrieux	82	1.99	-2.46
Enumclaw	WA	47.267	-121.933	240	1075	Cendrieux	82	2.76	1.51
Gold bar	WA	47.850	-121.650	120	1063	Cendrieux	82	2.56	0.48
Granite Falls	WA	48.083	-122.033	90	1057	Cendrieux	82	2.72	1.30
Marblemount	WA	48.583	-121.400	120	1050	Cendrieux	82	2.47	0.01
North Bend	WA	47.467	-121.750	150	1069	Cendrieux	82	2.55	0.42
Packwood I	WA	46.567	-121.667	650	1083	Cendrieux	82	2.28	-0.97
Packwood II	WA	46.567	-121.700	300	1084	Cendrieux	82	2.33	-0.74
Parkway	WA	47.033	-121.567	790	1079	Cendrieux	82	2.13	-1.74
Perry creek	WA	48.050	-121.467	610	1059	Cendrieux	82	2.14	-1.69
Prindle	WA	45.617	-122.133	450	1089	Cendrieux	82	2.43	-0.20
Randle	WA	46.550	-122.050	330	1085	Cendrieux	82	2.57	0.53
Sedro-woolley	WA	48.533	-122.317	60	1051	Cendrieux	82	2.69	1.15
Skykomish	WA	47.700	-121.333	300	1067	Cendrieux	82	2.57	0.50
Sloan Creek	WA	48.083	-121.300	650	1090	Cendrieux	82	2.23	-1.23
Yale	WA	46.000	-122.367	120	1091	Cendrieux	82	2.58	0.58
Yelm	WA	47.017	-122.733	60	1080	Cendrieux	82	2.60	0.68
France - Michaud et al. (1992)									
Arlington 1 (108)	WA	48.183	-122.133	130	-	Douillac	81	5.09	-0.53
Arlington 2 (109)	WA	48.217	-122.133	130	-	Chassenoix	78	4.37	-0.30
Darrington (110)	WA	48.183	-121.602	169	-	Douillac	81	5.17	0.01
						Giat	83	4.59	0.34
						LaBayssette	85	4.18	-0.93
Jefferson (112)	WA	47.117	-123.000	450	-	Chassenoix	78	4.75	1.44
						Douillac	81	4.99	-1.20
						Giat	83	4.62	0.78
						LaBayssette	85	4.20	-0.13
Lane (113)	OR	44.000	-124.000	600	-	Chassenoix	78	4.38	-0.25
						Douillac	81	5.39	1.50

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Lane (113)	OR	44.000	-124.000	600	-	Giat	83	4.49	-1.13
						LaBayssette	85	4.23	1.06
Matlock (111)	WA	47.250	-123.408	139	-	Chassenoix	78	4.24	-0.89
						Douillac	81	5.20	0.22
France - Rozenberg (1993)									
Ashford 1 (1)	WA	46.800	-123.000	458	-	SaintJulienlePetit	80	-	0.32
Cameron Lake (2)	BC	49.250	-124.667	200	-	SaintJulienlePetit	80	-	-0.56
Darrington 2 (3)	WA	48.167	-121.583	520	-	SaintJulienlePetit	80	-	0.90
Glacier (4)	WA	48.833	-122.000	670	-	SaintJulienlePetit	80	-	0.70
Granite Falls (5)	WA	48.083	-122.000	520	-	SaintJulienlePetit	80	-	0.90
Humptulips (6)	WA	47.200	-123.917	50	-	SaintJulienlePetit	80	-	0.32
Marion Creek (7)	OR	44.583	-121.917	875	-	SaintJulienlePetit	80	-	-2.02
Molalla (8)	OR	45.250	-122.417	250	-	SaintJulienlePetit	80	-	0.12
Nanaimo (9)	BC	49.167	-124.000	40	-	SaintJulienlePetit	80	-	0.32
Santiam (10)	OR	44.450	-121.967	1100	-	SaintJulienlePetit	80	-	-1.83
Shelton (11)	WA	47.217	-123.167	100	-	SaintJulienlePetit	80	-	0.90
Skykomish (12)	WA	47.733	-121.217	650	-	SaintJulienlePetit	80	-	-0.08
Germany - Herrmann (1973)									
Band area (21)	OR	44.333	-121.750	1070	-	Itterbeck	26	2.02	0.36
Big Cimarron River Drainage (41)	CO	38.250	-107.550	2770	-	Itterbeck	26	1.42	-0.68
Big Prairie Ranger St. (12)	MT	47.333	-113.500	1410	-	Itterbeck	26	1.33	-0.83
Black Rock (42)	OR	44.833	-123.500	400	-	Itterbeck	26	1.56	-0.43
Brown's Gulch (29)	MT	45.000	-112.500	1980	-	Itterbeck	26	1.09	-1.25
Buck Mtn. (52)	WA	48.417	-119.750	1520	-	Itterbeck	26	1.34	-0.82
Camano area (55)	WA	48.250	-122.333	20	-	Itterbeck	26	2.67	1.49
Cascadia (37)	OR	44.417	-122.667	240	-	Itterbeck	26	2.70	1.55
Clinton (6)	MT	46.833	-113.750	1520	-	Itterbeck	26	1.54	-0.47
Cloudcraft (24)	NM	32.967	-105.833	2640	-	Itterbeck	26	2.34	0.92
Corvallis area (49)	OR	44.500	-123.667	580	-	Itterbeck	26	1.98	0.30
Curango (10)	CO	37.500	-107.750	2590	-	Itterbeck	26	1.32	-0.85
EastDennis-Paldy Mtn. ridge (20)	ID	47.067	-115.650	1080	-	Itterbeck	26	2.09	0.49
Enumclaw (36)	WA	47.250	-122.000	400	-	Itterbeck	26	2.49	1.18
Fish Lake (53)	WA	48.583	-119.667	610	-	Itterbeck	26	1.62	-0.33
Fredonia (39)	AZ	36.950	-112.500	2740	-	Itterbeck	26	1.21	-1.04
Granite Falls (34)	WA	48.083	-122.000	180	-	Itterbeck	26	2.90	1.89
Grannough (8)	MT	46.917	-113.417	1220	-	Itterbeck	26	1.96	0.26
Hungry Horse 1 (27)	MT	47.950	-113.517	1120	-	Itterbeck	26	1.51	-0.52
Hungry Horse 2 (4)	MT	48.083	-113.750	1370	-	Itterbeck	26	1.61	-0.35
Jewell (38)	OR	45.833	-123.417	210	-	Itterbeck	26	2.79	1.70
Kalispell (9)	MT	48.167	-114.500	910	-	Itterbeck	26	1.83	0.03
Kananaskis For. Exp.St. (25)	AB	51.033	-115.000	1520	-	Itterbeck	26	1.16	-1.13
Madford area (54)	OR	42.333	-122.500	1520	-	Itterbeck	26	1.92	0.19
Marble Creek (17)	ID	47.167	-116.117	910	-	Itterbeck	26	2.12	0.54
Mason (40)	WA	47.250	-123.417	100	-	Itterbeck	26	3.81	3.48
Mayhill (28)	NM	32.917	-105.417	2005	-	Itterbeck	26	2.18	0.64
Medford area 1 (35)	OR	42.333	-122.500	760	-	Itterbeck	26	1.64	-0.30
Medford area 2 (47)	OR	42.333	-122.500	760	-	Itterbeck	26	1.57	-0.42
Medford area 3 (46)	OR	42.333	-122.500	1070	-	Itterbeck	26	1.58	-0.40

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Medford area 4 (44)	OR	42.333	-122.500	1220	-	Itterbeck	26	1.60	-0.37
Medford area 5 (45)	OR	42.333	-122.500	1220	-	Itterbeck	26	1.75	-0.10
Medford area 6 (43)	OR	42.333	-122.500	1370	-	Itterbeck	26	1.54	-0.47
Miller Creek near Neeker (11)	CO	40.167	-107.917	2500	-	Itterbeck	26	1.09	-1.25
Missoula (1)	MT	47.000	-113.833	1830	-	Itterbeck	26	1.52	-0.50
Molalla area (56)	OR	45.250	-122.250	30	-	Itterbeck	26	2.38	0.99
Neihart (2)	MT	47.000	-110.833	1540	-	Itterbeck	26	1.00	-1.41
Paysen (13)	AZ	34.317	-111.117	1680	-	Itterbeck	26	1.77	-0.07
Potunk Creek (30)	UT	37.583	-112.500	2520	-	Itterbeck	26	1.10	-1.23
Rock Creek (33)	MT	47.500	-115.250	1220	-	Itterbeck	26	2.05	0.42
Sacramento Mtns (32)	NM	32.917	-105.833	2530	-	Itterbeck	26	2.35	0.94
Salmon Lake (3)	MT	47.167	-113.167	1520	-	Itterbeck	26	1.58	-0.40
Salt Creek Drainage (31)	OR	43.667	-122.500	910	-	Itterbeck	26	1.91	0.17
Santa Catalina Mts. (23)	AZ	32.450	-110.783	2560	-	Itterbeck	26	1.96	0.26
Shelton area (48)	WA	47.250	-123.000	90	-	Itterbeck	26	3.05	2.15
Shoshons Camp (22)	ID	47.500	-116.000	910	-	Itterbeck	26	2.08	0.47
Spencer Creek Snoqualmie (15)	WA	46.800	-120.667	900	-	Itterbeck	26	1.60	-0.37
Spruce Hale (14)	UT	39.333	-111.500	2440	-	Itterbeck	26	0.97	-1.46
St. Mary (5)	MT	48.833	-113.467	1370	-	Itterbeck	26	1.10	-1.23
Strong Indian Reserve (26)	AB	51.067	-115.000	1370	-	Itterbeck	26	1.14	-1.16
Tillamook area (50)	OR	45.500	-123.500	580	-	Itterbeck	26	1.96	0.26
Tonascat area (51)	WA	48.583	-119.500	760	-	Itterbeck	26	1.43	-0.66
Trestle Creek 1 (18)	ID	48.317	-116.250	1070	-	Itterbeck	26	2.02	0.36
Trestle Creek 2 (19)	ID	48.333	-116.233	1340	-	Itterbeck	26	2.09	0.49
Trout Creek Drainage (16)	WA	48.867	-118.750	1250	-	Itterbeck	26	1.09	-1.25
Whitefish (7)	MT	48.417	-114.667	1220	-	Itterbeck	26	1.94	0.23
Germany - Jestaedt (1980)									
Adler Lake	WA	46.800	-122.283	425	1081	Bensheim	55	0.80	-0.69
						Rauschenberg	46	1.08	0.36
Alberni	BC	49.325	-124.850	140	1036	BadHomburgAbt49	50	0.85	-0.02
						BadSooden	43	0.85	-0.02
						Bensheim	55	1.30	1.39
						Gahrenberg	42	1.37	1.32
						Hirschhorn	58	1.96	0.80
						Rauschenberg	46	0.97	-0.02
						Waldsolms	48	1.14	0.69
						Wanfried	44	0.67	0.24
Alexandria	BC	52.684	-122.433	274	1003	Gahrenberg	42	0.75	-1.78
						Hirschhorn	58	1.55	-0.42
						Rauschenberg	46	0.95	-0.10
						Rotenberg	45	1.23	-0.53
						Sinntal	51	1.09	-0.58
						Waldsolms	48	1.03	0.26
						Wanfried	44	0.77	0.88
Alta	BC	50.200	-122.883	630	1027	Gahrenberg	42	1.39	1.42
						Rauschenberg	46	0.65	-1.14
						Rotenberg	45	1.49	0.19
						Sinntal	51	1.35	0.08

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Ashland	OR	42.083	-122.650	1480	1126	Wanfried	44	0.56	-0.43
Babine Lake	BC	54.450	-125.450	820	1107	Bensheim	55	0.86	-0.43
						Hirschhorn	58	1.34	-1.03
						Rauschenberg	46	0.69	-1.03
						Waldsolms	48	0.76	-0.78
Bacon Point	WA	48.600	-121.383	505	1049	Bensheim	55	0.76	-0.87
						Gahrenberg	42	1.20	0.45
						Rauschenberg	46	1.30	1.13
						Rotenberg	45	1.83	1.20
						Sinntal	51	1.87	1.44
Barriere	BC	51.204	-120.163	420	1010	BadHomburgAbt49	50	0.89	0.31
						BadSooden	43	0.89	0.31
						Bensheim	55	0.56	-1.69
						Gahrenberg	42	1.09	-0.09
						Hirschhorn	58	1.38	-0.92
						Rauschenberg	46	0.84	-0.49
						Rotenberg	45	0.99	-1.25
						Sinntal	51	0.84	-1.23
						Waldsolms	48	0.69	-1.06
						Wanfried	44	0.59	-0.29
Blind Bay	BC	50.883	-119.400	405	1015	BadHomburgAbt49	50	0.86	0.11
						BadSooden	43	0.86	0.11
						Bensheim	55	1.33	1.55
						Gahrenberg	42	1.18	0.37
						Hirschhorn	58	1.68	-0.02
						Rauschenberg	46	1.10	0.41
						Waldsolms	48	0.97	0.01
						Wanfried	44	0.74	0.73
Brookings	OR	42.117	-124.200	300	1104	Rauschenberg	46	1.77	2.77
						Wanfried	44	0.29	-2.22
Burnt Woods	OR	44.600	-123.700	319	1116	Wanfried	44	0.85	1.44
Cassidy	BC	49.058	-123.950	200	1040	BadHomburgAbt49	50	0.73	-0.97
						BadSooden	43	0.73	-0.97
						Bensheim	55	0.82	-0.61
						Gahrenberg	42	1.37	1.31
						Hirschhorn	58	1.51	-0.54
						Rauschenberg	46	1.20	0.77
						Waldsolms	48	0.96	-0.01
						Wanfried	44	0.47	-1.06
Cave Junction	OR	42.183	-123.667	460	1125	Wanfried	44	0.74	0.73
Caycuse	BC	48.924	-124.433	210	1041	BadHomburgAbt49	50	0.95	0.83
						BadSooden	43	0.95	0.83
						Bensheim	55	1.05	0.38
						Gahrenberg	42	1.50	1.96
						Hirschhorn	58	2.05	1.07
						Rauschenberg	46	1.32	1.18
						Waldsolms	48	1.27	1.16
						Wanfried	44	0.72	0.55

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Cherryville	OR	45.317	-122.300	210	1097	BadHomburgAbt49	50	0.85	0.00
						BadSooden	43	0.85	0.00
						Hirschhorn	58	1.98	0.84
						Rauschenberg	46	0.80	-0.64
						Rotenberg	45	1.72	0.87
						Sinntal	51	1.71	1.02
						Waldsolms	48	1.04	0.29
						Wanfried	44	0.47	-1.01
Chester morse lake	WA	47.367	-121.667	610	1072	BadHomburgAbt49	50	1.01	1.25
						BadSooden	43	1.01	1.25
						Rauschenberg	46	1.33	1.25
						Wanfried	44	0.71	0.54
Chilliwack 1	BC	49.073	-121.800	170	1039	Gahrenberg	42	1.20	0.46
Chilliwack 2	BC	49.100	-121.700	910	1038	Bensheim	55	1.13	0.69
						Gahrenberg	42	1.20	0.46
						Hirschhorn	58	2.23	1.58
						Rauschenberg	46	1.43	1.58
						Waldsolms	48	1.33	1.40
						Wanfried	44	0.74	0.72
Chiwaukum	WA	47.683	-120.733	549	1068	BadHomburgAbt49	50	0.98	1.02
						BadSooden	43	0.98	1.02
						Rauschenberg	46	0.95	-0.09
						Wanfried	44	0.67	0.23
Clallam, Lake Crescent	WA	48.067	-124.000	300	1058	BadHomburgAbt49	50	0.96	0.88
						BadSooden	43	0.96	0.88
						Bensheim	55	1.19	0.96
						Gahrenberg	42	0.86	-1.25
						Hirschhorn	58	2.11	1.23
						Rauschenberg	46	0.97	-0.03
						Waldsolms	48	1.31	1.32
						Wanfried	44	0.66	0.19
Clallam, Louella Gua. Sta.	WA	48.000	-123.083	460	1061	BadHomburgAbt49	50	0.96	0.87
						BadSooden	43	0.96	0.87
						Hirschhorn	58	2.19	1.48
						Rauschenberg	46	1.27	1.00
						Waldsolms	48	1.31	1.32
						Wanfried	44	0.61	-0.15
Clallam, Sequim	WA	48.033	-123.033	60	1060	Bensheim	55	1.09	0.52
						Gahrenberg	42	0.90	-1.04
						Rauschenberg	46	1.14	0.58
						Wanfried	44	0.70	0.47
Cle Elum	WA	47.217	-121.117	640	1078	Bensheim	55	1.54	2.39
						Rauschenberg	46	0.65	-1.17
						Rotenberg	45	1.29	-0.37
						Sinntal	51	1.20	-0.30
Clearwater	BC	51.657	-120.000	450	1007	BadHomburgAbt49	50	1.07	1.78
						BadSooden	43	1.07	1.78
						Bensheim	55	1.02	0.23

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Clearwater	BC	51.657	-120.000	450	1007	Gahrenberg	42	0.92	-0.94
						Hirschhorn	58	1.92	0.68
						Rauschenberg	46	1.09	0.39
						Rotenberg	45	1.64	0.66
						Sinntal	51	1.17	-0.37
						Waldsolms	48	1.33	1.41
						Wanfried	44	0.81	1.19
Clinton	BC	51.150	-121.500	1030	1112	Bensheim	55	1.05	0.36
						Hirschhorn	58	1.55	-0.41
						Rauschenberg	46	0.58	-1.41
						Rotenberg	45	1.05	-1.08
						Sinntal	51	1.18	-0.36
						Waldsolms	48	0.64	-1.26
Concrete	WA	48.650	-121.717	465	1047	Gahrenberg	42	1.10	-0.06
						Hirschhorn	58	1.94	0.73
						Rauschenberg	46	0.79	-0.65
						Waldsolms	48	1.09	0.48
Coquille	OR	43.200	-124.167	60	1103	Rauschenberg	46	1.11	0.47
Cougar	WA	46.083	-122.300	550	1090	BadHomburgAbt49	50	0.81	-0.35
						BadSooden	43	0.81	-0.35
						Bensheim	55	0.95	-0.05
						Rauschenberg	46	0.89	-0.33
						Rotenberg	45	1.73	0.90
						Sinntal	51	1.49	0.45
						Wanfried	44	0.57	-0.36
Courtenay	BC	49.696	-125.064	70	1032	BadHomburgAbt49	50	0.84	-0.07
						BadSooden	43	0.84	-0.07
						Bensheim	55	1.18	0.89
						Gahrenberg	42	0.93	-0.89
						Hirschhorn	58	2.09	1.18
						Rauschenberg	46	1.32	1.19
						Waldsolms	48	1.25	1.10
						Wanfried	44	0.84	1.39
Cowlitz, Castle Rock	WA	46.317	-122.867	150	1088	Hirschhorn	58	1.85	0.46
						Rauschenberg	46	0.56	-1.48
						Rotenberg	45	1.63	0.62
						Sinntal	51	1.70	0.99
						Waldsolms	48	1.42	1.77
D'Arcy	BC	50.557	-122.500	270	1021	Bensheim	55	0.62	-1.44
						Gahrenberg	42	1.09	-0.09
						Hirschhorn	58	1.73	0.11
						Rauschenberg	46	1.03	0.16
						Waldsolms	48	1.00	0.15
						Wanfried	44	0.79	1.02
Denny creek	WA	47.400	-121.533	540	1070	Bensheim	55	1.23	1.12
						Rauschenberg	46	1.09	0.37
						Rotenberg	45	1.71	0.84
						Sinntal	51	2.12	2.08

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Denny creek	WA	47.400	-121.533	540	1070	Wanfried	44	0.67	0.23
Detroit	OR	44.733	-122.167	480	1114	Wanfried	44	0.48	-0.96
Diablo Dam	WA	48.717	-121.117	440	1046	Gahrenberg	42	1.23	0.60
						Rauschenberg	46	0.97	-0.04
						Rotenberg	45	1.32	-0.29
						Sinntal	51	1.02	-0.76
						Wanfried	44	0.50	-0.85
Duncan	BC	48.750	-123.750	60	1042	BadHomburgAbt49	50	0.91	0.47
						BadSooden	43	0.91	0.47
						Bensheim	55	1.37	1.70
						Gahrenberg	42	1.40	1.46
						Rauschenberg	46	0.99	0.04
Dunster	BC	53.117	-119.833	50	1109	Bensheim	55	0.71	-1.08
						Hirschhorn	58	1.39	-0.89
						Rauschenberg	46	0.55	-1.50
						Waldsolms	48	0.81	-0.58
						Wanfried	44	0.40	-1.49
Eagle Bay	BC	50.933	-119.217	480	1014	Bensheim	55	0.66	-1.29
						Gahrenberg	42	0.96	-0.74
						Hirschhorn	58	2.12	1.26
						Rauschenberg	46	1.33	1.22
						Waldsolms	48	1.27	1.18
						Wanfried	44	1.10	3.04
Eugene	OR	44.017	-123.383	210	1119	Wanfried	44	0.49	-0.88
Fly Hill	BC	50.533	-119.400	750	1022	BadHomburgAbt49	50	0.59	-2.10
						BadSooden	43	0.59	-2.10
						Bensheim	55	1.13	0.70
						Gahrenberg	42	1.12	0.05
						Hirschhorn	58	1.09	-1.75
						Rauschenberg	46	0.60	-1.31
						Rotenberg	45	0.77	-1.88
						Sinntal	51	0.74	-1.49
						Waldsolms	48	0.65	-1.22
						Wanfried	44	1.05	2.75
Forbidden Plat.	BC	49.663	-125.156	610	1033	Gahrenberg	42	1.19	0.40
						Rauschenberg	46	1.35	1.31
						Wanfried	44	0.80	1.07
Fort St. James	BC	54.483	-124.250	850	1106	Hirschhorn	58	1.46	-0.68
						Rauschenberg	46	0.79	-0.68
						Waldsolms	48	0.94	-0.08
Franklin River	BC	49.100	-124.767	150	1037	Bensheim	55	0.77	-0.82
						Gahrenberg	42	0.96	-0.73
						Hirschhorn	58	1.30	-1.15
						Rauschenberg	46	0.59	-1.36
						Waldsolms	48	0.71	-0.99
						Wanfried	44	0.41	-1.44
Glenwood	WA	46.000	-121.017	480	1092	Rauschenberg	46	0.80	-0.62
Gold River	BC	49.750	-126.067	90	1031	Bensheim	55	1.06	0.39

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Gold River	BC	49.750	-126.067	90	1031	Gahrenberg	42	1.48	1.88
						Wanfried	44	0.70	0.47
Golden	BC	51.383	-117.000	880	1008	Bensheim	55	1.25	1.18
						Gahrenberg	42	1.06	-0.25
						Hirschhorn	58	1.15	-1.60
						Rauschenberg	46	0.79	-0.66
						Rotenberg	45	0.78	-1.86
						Sinntal	51	0.63	-1.77
						Waldsolms	48	0.64	-1.25
						Wanfried	44	0.29	-2.20
Grays Harbor, Humptulips	WA	47.317	-123.900	140	1073	BadHomburgAbt49	50	0.96	0.91
						BadSooden	43	0.96	0.91
						Hirschhorn	58	2.18	1.45
						Rauschenberg	46	1.23	0.87
						Rotenberg	45	2.14	2.10
						Sinntal	51	1.98	1.72
						Waldsolms	48	1.36	1.53
						Wanfried	44	0.64	0.06
Horsefly	BC	52.300	-121.317	820	1111	Bensheim	55	0.75	-0.90
						Hirschhorn	58	1.79	0.28
						Rauschenberg	46	0.98	0.01
						Rotenberg	45	1.25	-0.49
						Sinntal	51	1.19	-0.32
						Waldsolms	48	0.89	-0.26
						Wanfried	44	0.79	1.02
Jefferson, Hoh River	WA	47.800	-123.967	240	1064	BadHomburgAbt49	50	1.05	1.57
						BadSooden	43	1.05	1.57
						Bensheim	55	0.73	-0.98
						Rauschenberg	46	1.32	1.19
						Wanfried	44	0.82	1.24
Jeune Landing	BC	50.450	-127.450	170	1023	BadHomburgAbt49	50	0.64	-1.67
						BadSooden	43	0.64	-1.67
						Bensheim	55	0.73	-0.96
						Gahrenberg	42	1.02	-0.46
						Rauschenberg	46	1.05	0.25
						Wanfried	44	0.66	0.16
Jordan River	BC	48.468	-124.233	240	1044	Gahrenberg	42	1.39	1.40
Keechelus Lake	WA	47.383	-121.367	790	1071	Rauschenberg	46	0.83	-0.51
						Rotenberg	45	1.35	-0.21
						Sinntal	51	1.28	-0.09
						Wanfried	44	0.61	-0.13
King, Enumclaw	WA	47.267	-121.933	240	1075	Bensheim	55	0.98	0.07
						Rauschenberg	46	1.01	0.11
						Rotenberg	45	1.48	0.18
						Sinntal	51	1.66	0.89
Klina Klini 1	BC	51.117	-125.596	5	1012	Gahrenberg	42	1.21	0.51
Klina Klini 2	BC	51.133	-125.600	150	1011	Gahrenberg	42	1.07	-0.20
Klina Klini 3	BC	51.233	-125.583	600	1009	Gahrenberg	42	1.14	0.14

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Lewis Packwood	WA	46.567	-121.667	650	1083	BadHomburgAbt49	50	0.69	-1.27
						BadSooden	43	0.69	-1.27
						Rauschenberg	46	0.88	-0.35
						Rotenberg	45	1.42	0.00
						Sinntal	51	1.38	0.16
						Wanfried	44	0.48	-0.99
Lewis, Randle	WA	46.550	-122.050	335	1085	BadHomburgAbt49	50	0.84	-0.05
						BadSooden	43	0.84	-0.05
						Rauschenberg	46	1.20	0.76
						Rotenberg	45	1.78	1.04
						Sinntal	51	1.79	1.23
						Wanfried	44	0.55	-0.49
Marion Forks	OR	44.500	-122.000	1060	1117	Rauschenberg	46	0.89	-0.30
						Wanfried	44	0.48	-1.00
Marys Peak	OR	44.500	-123.567	980	1118	BadHomburgAbt49	50	0.86	0.10
						BadSooden	43	0.86	0.10
						Wanfried	44	0.62	-0.06
Mason, Matlock	WA	47.250	-123.417	120	1076	Bensheim	55	1.30	1.42
						Hirschhorn	58	2.24	1.61
						Rauschenberg	46	1.60	2.18
						Waldsolms	48	1.48	1.97
						Wanfried	44	0.67	0.24
Mason, Shelton	WA	47.250	-123.200	90	1077	BadHomburgAbt49	50	0.86	0.06
						BadSooden	43	0.86	0.06
						Hirschhorn	58	2.13	1.29
						Rauschenberg	46	1.01	0.11
						Rotenberg	45	1.87	1.32
						Sinntal	51	1.73	1.07
						Waldsolms	48	1.35	1.49
						Wanfried	44	0.76	0.82
Matlock	WA	47.300	-123.933	504	1074	BadHomburgAbt49	50	0.84	-0.05
						BadSooden	43	0.84	-0.05
						Hirschhorn	58	2.07	1.10
						Rauschenberg	46	1.20	0.76
						Waldsolms	48	1.11	0.57
						Wanfried	44	0.56	-0.43
McLeod Lake	BC	54.867	-122.883	760	1105	Hirschhorn	58	1.28	-1.20
						Rauschenberg	46	0.84	-0.48
						Waldsolms	48	0.96	0.00
Merritt	BC	50.067	-120.850	880	1028	Gahrenberg	42	0.80	-1.54
						Hirschhorn	58	1.84	0.45
						Rauschenberg	46	0.91	-0.26
						Rotenberg	45	1.40	-0.06
						Sinntal	51	1.02	-0.77
						Waldsolms	48	0.83	-0.52
						Wanfried	44	0.51	-0.81
Mill City	OR	44.800	-122.700	150	1113	Bensheim	55	0.71	-1.04
						Wanfried	44	0.57	-0.38

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Monte Creek	BC	50.617	-119.900	630	1019	BadHomburgAbt49	50	0.76	-0.70
						BadSooden	43	0.76	-0.70
						Bensheim	55	0.62	-1.45
						Gahrenberg	42	1.13	0.09
						Hirschhorn	58	1.65	-0.13
						Rauschenberg	46	0.70	-0.97
						Rotenberg	45	1.40	-0.06
						Sinntal	51	1.17	-0.37
						Waldsolms	48	0.73	-0.91
						Wanfried	44	0.65	0.14
Nelson	BC	49.500	-117.267	820	1035	BadHomburgAbt49	50	1.00	1.22
						BadSooden	43	1.00	1.22
						Bensheim	55	1.08	0.47
						Gahrenberg	42	1.19	0.42
						Hirschhorn	58	1.51	-0.53
						Rauschenberg	46	0.97	-0.04
						Waldsolms	48	0.86	-0.39
						Wanfried	44	0.81	1.15
Newport	WA	48.200	-117.050	720	1055	BadHomburgAbt49	50	0.87	0.14
						BadSooden	43	0.87	0.14
						Bensheim	55	0.82	-0.60
						Gahrenberg	42	1.00	-0.55
						Hirschhorn	58	1.52	-0.51
						Rauschenberg	46	0.75	-0.78
						Rotenberg	45	1.14	-0.82
						Sinntal	51	1.21	-0.26
						Waldsolms	48	0.79	-0.65
						Wanfried	44	0.66	0.17
Nimpkish	BC	50.317	-126.883	90	1025	Gahrenberg	42	1.15	0.20
						Rauschenberg	46	0.81	-0.59
						Wanfried	44	0.77	0.90
Oakridge	OR	43.900	-122.367	880	1120	Wanfried	44	0.57	-0.38
Owl Creek	BC	50.333	-122.725	210	1024	BadHomburgAbt49	50	0.69	-1.23
						BadSooden	43	0.69	-1.23
						Bensheim	55	0.85	-0.49
						Gahrenberg	42	1.33	1.09
						Rauschenberg	46	0.59	-1.37
						Wanfried	44	0.51	-0.79
Packwood	WA	46.567	-121.700	300	1084	Bensheim	55	1.09	0.53
						Rauschenberg	46	1.16	0.63
						Rotenberg	45	1.57	0.43
						Sinntal	51	1.50	0.46
						Wanfried	44	0.61	-0.14
Parkway	WA	47.033	-121.567	730	1079	Bensheim	55	0.94	-0.08
						Hirschhorn	58	1.64	-0.15
						Rauschenberg	46	1.06	0.28
						Rotenberg	45	1.22	-0.57
						Sinntal	51	1.26	-0.15

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Parkway	WA	47.033	-121.567	730	1079	Waldsolms	48	1.10	0.52
						Wanfried	44	0.62	-0.04
Perry creek	WA	48.050	-121.467	600	1059	BadHomburgAbt49	50	0.84	-0.09
						BadSooden	43	0.84	-0.09
						Bensheim	55	1.09	0.54
						Gahrenberg	42	0.75	-1.81
						Rauschenberg	46	0.99	0.04
						Wanfried	44	0.89	1.67
Pillar Lake	BC	50.583	-119.633	910	1020	Bensheim	55	0.92	-0.17
						Gahrenberg	42	1.32	1.05
						Hirschhorn	58	1.14	-1.61
						Rauschenberg	46	0.54	-1.52
						Rotenberg	45	0.99	-1.23
						Sinntal	51	0.72	-1.53
						Waldsolms	48	0.57	-1.50
						Wanfried	44	0.40	-1.48
Pine Grove	OR	45.100	-121.383	730	1099	Bensheim	55	1.25	1.20
						Hirschhorn	58	2.03	0.99
						Rauschenberg	46	1.19	0.75
						Waldsolms	48	1.12	0.59
Prindle	WA	45.617	-122.133	460	1095	BadHomburgAbt49	50	0.97	0.98
						BadSooden	43	0.97	0.98
						Rauschenberg	46	0.81	-0.61
						Rotenberg	45	1.49	0.22
						Sinntal	51	1.55	0.59
						Wanfried	44	0.46	-1.14
Republic	WA	48.600	-118.733	730	1048	BadHomburgAbt49	50	0.70	-1.19
						BadSooden	43	0.70	-1.19
						Gahrenberg	42	1.12	0.08
						Hirschhorn	58	0.99	-2.05
						Rauschenberg	46	0.69	-1.00
						Rotenberg	45	0.90	-1.52
						Sinntal	51	0.73	-1.50
						Waldsolms	48	0.63	-1.30
						Wanfried	44	0.57	-0.39
Revelstoke	BC	51.000	-118.200	600	1013	BadHomburgAbt49	50	0.67	-1.43
						BadSooden	43	0.67	-1.43
						Bensheim	55	0.78	-0.75
						Gahrenberg	42	1.02	-0.44
						Hirschhorn	58	1.31	-1.11
						Rauschenberg	46	0.84	-0.50
						Rotenberg	45	1.09	-0.95
						Sinntal	51	1.01	-0.80
						Waldsolms	48	0.84	-0.46
						Wanfried	44	0.61	-0.11
Rimrock	WA	46.667	-121.033	760	1082	Bensheim	55	0.59	-1.56
						Hirschhorn	58	1.51	-0.53
						Rauschenberg	46	0.81	-0.57

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Rimrock	WA	46.667	-121.033	760	1082	Waldsolms	48	0.72	-0.95
						Wanfried	44	0.41	-1.46
Roseburg	OR	43.317	-123.500	310	1123	Wanfried	44	0.56	-0.47
Salmon Arm	BC	50.733	-119.217	470	1018	BadHomburgAbt49	50	0.70	-1.18
						BadSooden	43	0.70	-1.18
						Bensheim	55	1.10	0.56
						Gahrenberg	42	1.06	-0.24
						Hirschhorn	58	1.40	-0.85
						Rauschenberg	46	0.69	-1.01
						Rotenberg	45	0.91	-1.48
						Sinntal	51	0.76	-1.43
						Waldsolms	48	0.67	-1.14
						Wanfried	44	0.37	-1.69
San Juan	BC	48.581	-124.080	210	1043	BadHomburgAbt49	50	0.88	0.22
						BadSooden	43	0.88	0.22
						Gahrenberg	42	1.40	1.48
						Rauschenberg	46	0.77	-0.73
						Rotenberg	45	1.53	0.34
						Sinntal	51	1.49	0.44
Scenic	WA	47.717	-121.133	940	1066	Rauschenberg	46	0.77	-0.72
						Wanfried	44	0.67	0.28
Sechelt	BC	49.511	-123.882	180	1034	Bensheim	55	1.07	0.45
						Gahrenberg	42	1.00	-0.56
						Hirschhorn	58	2.10	1.21
						Rauschenberg	46	1.32	1.18
						Rotenberg	45	1.62	0.58
						Sinntal	51	1.75	1.13
						Waldsolms	48	1.21	0.93
						Wanfried	44	0.68	0.29
Skagit, Marble Mnt	WA	48.583	-121.400	120	1050	Bensheim	55	0.80	-0.67
						Gahrenberg	42	0.80	-1.55
						Rauschenberg	46	1.35	1.28
						Wanfried	44	0.87	1.56
Skagit, Sedro Woolley	WA	48.533	-122.317	60	1051	BadHomburgAbt49	50	0.99	1.13
						BadSooden	43	0.99	1.13
						Gahrenberg	42	0.90	-1.04
						Rauschenberg	46	1.20	0.78
						Wanfried	44	0.76	0.85
Skykomish	WA	47.700	-121.333	300	1067	BadHomburgAbt49	50	0.95	0.79
						BadSooden	43	0.95	0.79
						Bensheim	55	1.35	1.60
						Hirschhorn	58	1.76	0.20
						Rauschenberg	46	0.73	-0.89
						Waldsolms	48	0.93	-0.13
						Wanfried	44	0.51	-0.76
Sloan Creek	WA	48.083	-121.300	650	1056	BadHomburgAbt49	50	0.85	-0.01
						BadSooden	43	0.85	-0.01
						Gahrenberg	42	1.02	-0.44

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Sloan Creek	WA	48.083	-121.300	650	1056	Hirschhorn	58	1.81	0.34
						Rauschenberg	46	1.03	0.20
						Waldsolms	48	1.08	0.46
						Wanfried	44	0.68	0.31
Snohomish, Arlington	WA	48.217	-122.067	90	1054	Gahrenberg	42	1.08	-0.12
						Rauschenberg	46	1.21	0.81
						Rotenberg	45	1.74	0.94
						Sinntal	51	1.81	1.26
						Wanfried	44	0.54	-0.56
Snohomish, Darrington	WA	48.267	-121.633	150	1053	Gahrenberg	42	0.81	-1.47
Snohomish, Gold Bar	WA	47.850	-121.650	120	1063	Rauschenberg	46	1.87	3.12
						Rotenberg	45	2.32	2.63
						Sinntal	51	2.10	2.03
Snohomish, Granite Falls	WA	48.083	-122.033	90	1057	Gahrenberg	42	0.98	-0.64
Sooke	BC	48.400	-123.733	45	1045	BadHomburgAbt49	50	0.67	-1.42
						BadSooden	43	0.67	-1.42
						Gahrenberg	42	1.14	0.14
						Rauschenberg	46	1.88	3.15
						Wanfried	44	0.68	0.29
Spokane	WA	47.783	-117.200	600	1065	BadHomburgAbt49	50	0.66	-1.53
						BadSooden	43	0.66	-1.53
						Hirschhorn	58	1.21	-1.41
						Rauschenberg	46	0.55	-1.49
						Rotenberg	45	0.98	-1.27
						Sinntal	51	0.77	-1.41
						Waldsolms	48	0.54	-1.63
						Wanfried	44	0.40	-1.47
Squamish	BC	49.778	-123.150	15	1030	BadHomburgAbt49	50	0.67	-1.46
						BadSooden	43	0.67	-1.46
						Gahrenberg	42	0.95	-0.80
						Hirschhorn	58	1.94	0.73
						Rauschenberg	46	0.83	-0.52
						Rotenberg	45	1.33	-0.26
						Sinntal	51	1.18	-0.36
						Waldsolms	48	0.92	-0.15
						Wanfried	44	0.59	-0.28
Squilax	BC	50.833	-119.567	580	1017	BadHomburgAbt49	50	1.08	1.81
						BadSooden	43	1.08	1.81
						Bensheim	55	0.89	-0.30
						Gahrenberg	42	1.13	0.10
						Hirschhorn	58	1.71	0.07
						Rauschenberg	46	0.88	-0.34
						Rotenberg	45	1.44	0.05
						Sinntal	51	1.35	0.07
						Waldsolms	48	1.18	0.81
						Wanfried	44	0.94	1.98
Steamboat	OR	43.367	-122.517	1590	1121	Wanfried	44	0.65	0.15
Stella Lake	BC	50.283	-125.467	150	1026	BadHomburgAbt49	50	0.67	-1.45

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Stella Lake	BC	50.283	-125.467	150	1026	BadSooden	43	0.67	-1.45
						Gahrenberg	42	1.41	1.50
						Rauschenberg	46	1.41	1.50
						Rotenberg	45	1.84	1.23
						Sinntal	51	1.60	0.74
						Wanfried	44	0.64	0.08
Stoner	BC	53.618	-122.675	570	1001	BadHomburgAbt49	50	0.98	1.00
						BadSooden	43	0.98	1.00
						Bensheim	55	1.08	0.50
						Hirschhorn	58	1.54	-0.44
						Rauschenberg	46	0.78	-0.71
						Rotenberg	45	1.33	-0.26
						Sinntal	51	1.12	-0.51
						Waldsolms	48	0.76	-0.79
						Wanfried	44	0.63	0.01
Stuie	BC	52.367	-126.000	16	1004	Bensheim	55	0.98	0.07
						Gahrenberg	42	1.20	0.47
						Rauschenberg	46	1.02	0.15
						Wanfried	44	0.81	1.17
Tatla	BC	51.733	-124.733	880	1006	Gahrenberg	42	1.16	0.28
						Hirschhorn	58	1.68	-0.04
						Rauschenberg	46	0.65	-1.16
						Rotenberg	45	1.04	-1.11
						Sinntal	51	1.11	-0.54
						Waldsolms	48	0.99	0.12
						Wanfried	44	0.79	1.06
Thasis	BC	49.792	-126.639	15	1029	Gahrenberg	42	1.49	1.89
Thurston, Yelm	WA	47.017	-122.733	60	1080	Hirschhorn	58	1.96	0.78
						Rauschenberg	46	0.95	-0.11
						Waldsolms	48	0.88	-0.34
						Wanfried	44	0.53	-0.67
Tillamook, Hebo	OR	45.217	-123.850	150	1098	BadHomburgAbt49	50	0.79	-0.44
						BadSooden	43	0.79	-0.44
						Rauschenberg	46	0.83	-0.53
						Wanfried	44	0.58	-0.35
Twisp	WA	48.383	-120.400	790	1052	BadHomburgAbt49	50	0.92	0.55
						BadSooden	43	0.92	0.55
						Gahrenberg	42	0.76	-1.74
						Hirschhorn	58	1.43	-0.75
						Rauschenberg	46	1.11	0.46
						Rotenberg	45	1.41	-0.04
						Sinntal	51	0.98	-0.86
						Waldsolms	48	0.74	-0.87
						Wanfried	44	0.64	0.07
Upper Soda	OR	44.383	-122.200	993	1102	Bensheim	55	0.61	-1.48
						Rauschenberg	46	0.73	-0.87
						Rotenberg	45	1.70	0.81
						Sinntal	51	1.43	0.30

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Wahkiakum, Cathlamet	WA	46.300	-123.267	195	1089	Rauschenberg	46	0.87	-0.37
						Rotenberg	45	1.60	0.53
						Sinntal	51	1.31	-0.02
						Wanfried	44	0.45	-1.16
Wahkiakum, Skamokawa	WA	46.350	-123.500	210	1087	Wanfried	44	0.75	0.75
Waldport	OR	44.400	-123.867	60	1101	Bensheim	55	1.19	0.94
						Rauschenberg	46	1.01	0.11
						Rotenberg	45	1.82	1.15
						Sinntal	51	1.69	0.96
						Wanfried	44	0.53	-0.68
Wansa Lake	BC	53.767	-122.100	880	1108	Bensheim	55	0.68	-1.19
						Rauschenberg	46	0.73	-0.86
						Wanfried	44	0.75	0.77
Washington, Vernonia	OR	45.767	-123.217	210	1094	BadHomburgAbt49	50	0.95	0.76
						BadSooden	43	0.95	0.76
						Rauschenberg	46	1.10	0.42
						Rotenberg	45	1.77	1.04
						Sinntal	51	1.80	1.24
						Wanfried	44	0.73	0.67
White Lake	BC	50.117	-119.250	510	1016	BadHomburgAbt49	50	0.90	0.42
						BadSooden	43	0.90	0.42
						Bensheim	55	0.98	0.08
						Gahrenberg	42	1.10	-0.06
						Hirschhorn	58	1.47	-0.65
						Rauschenberg	46	0.99	0.05
						Rotenberg	45	1.16	-0.76
						Sinntal	51	1.05	-0.68
						Waldsolms	48	0.72	-0.92
						Wanfried	44	0.57	-0.42
Willard	WA	45.800	-121.683	495	1093	BadHomburgAbt49	50	0.82	-0.23
						BadSooden	43	0.82	-0.23
						Rauschenberg	46	0.85	-0.46
						Rotenberg	45	1.26	-0.47
						Sinntal	51	0.94	-0.97
						Wanfried	44	0.47	-1.07
Williams Lake	BC	52.117	-122.000	600	1005	BadHomburgAbt49	50	0.82	-0.27
						BadSooden	43	0.82	-0.27
						Bensheim	55	0.65	-1.30
						Gahrenberg	42	0.81	-1.50
						Hirschhorn	58	1.23	-1.36
						Rauschenberg	46	0.50	-1.69
						Rotenberg	45	0.99	-1.23
						Sinntal	51	0.80	-1.33
						Waldsolms	48	0.43	-2.04
						Wanfried	44	0.38	-1.61
Wolf Creek	OR	42.683	-123.383	427	1124	Wanfried	44	0.59	-0.28
Yamhill, Grande Ronde Ag.	OR	45.100	-123.600	180	1100	Hirschhorn	58	1.97	0.83
						Rauschenberg	46	0.90	-0.29

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Yamhill, Grande Ronde Ag.	OR	45.100	-123.600	180	1100	Rotenberg	45	1.48	0.17
						Sinntal	51	1.48	0.43
						Waldsolms	48	1.14	0.66
						Wanfried	44	0.52	-0.73
<u>Germany - Kenk & Thren (1958)</u>									
Cameron Lake 5 (5)	BC	49.250	-124.667	210	-	Calw	67	13.70	0.30
						Ehingen	69	9.30	-0.78
						Illenberg	72	14.00	-1.53
						Mooswald	70	15.40	0.83
						Schauinsland	73	10.30	1.05
						Schluchsee	74	10.10	0.34
						Schopfheim	75	11.00	-0.72
						Sindelfingen	68	11.80	-0.98
						Weinheim	56	13.50	-0.58
						Wiesloch	59	13.40	-0.46
Conrad Creek D.3 (9)	WA	48.250	-121.500	280	-	Calw	67	14.50	0.86
						Ehingen	69	10.30	0.71
						Illenberg	72	15.60	1.45
						Mooswald	70	15.20	0.35
						Schauinsland	73	10.40	1.28
						Schluchsee	74	10.10	0.34
						Schopfheim	75	12.50	1.62
						Sindelfingen	68	13.50	1.30
						Weinheim	56	14.30	1.15
						Wiesloch	59	14.50	2.08
Duncan Paldi (7)	BC	48.780	-123.710	260	-	Calw	67	13.40	0.09
						Ehingen	69	9.20	-0.93
						Illenberg	72	14.70	-0.23
						Mooswald	70	15.20	0.35
						Schauinsland	73	9.20	-1.54
Gold Hill D.1 (8)	WA	48.333	-121.500	150	-	Illenberg	72	15.40	1.07
						Mooswald	70	14.40	-1.59
						Schauinsland	73	10.20	0.81
						Schluchsee	74	10.00	-0.20
						Sindelfingen	68	11.90	-0.85
						Wiesloch	59	14.00	0.92
Greenwater (22)	WA	47.133	-121.500	600	-	Illenberg	72	14.40	-0.78
						Mooswald	70	14.90	-0.38
						Schauinsland	73	10.10	0.58
						Schluchsee	74	10.20	0.88
						Sindelfingen	68	13.40	1.17
						Wiesloch	59	13.30	-0.69
Pamelia Creek (39)	OR	44.667	-121.833	750	-	Calw	67	13.70	0.30
						Illenberg	72	14.90	0.14
						Mooswald	70	14.90	-0.38
						Schauinsland	73	9.80	-0.13
						Schopfheim	75	11.60	0.22
						Sindelfingen	68	11.80	-0.98

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Salmon Arm 31/102 (4)	BC	50.650	-119.217	580	-	Schluchsee	74	9.70	-1.83
						Sindelfingen	68	12.60	0.09
						Wiesloch	59	13.30	-0.69
Salmon Arm LH (3)	BC	50.833	-119.167	650	-	Calw	67	10.00	-2.29
						Ehingen	69	10.50	1.01
						Schluchsee	74	10.30	1.42
						Sindelfingen	68	12.70	0.23
						Wiesloch	59	13.30	-0.69
Santiam River (40)	OR	44.667	-121.967	800	-	Calw	67	12.70	-0.40
						Illenberg	72	14.30	-0.97
						Mooswald	70	14.50	-1.35
						Schauinsland	73	9.80	-0.13
						Schluchsee	74	9.90	-0.74
						Schopfheim	75	11.30	-0.25
						Sindelfingen	68	11.60	-1.25
						Weinheim	56	13.50	-0.58
						Wiesloch	59	13.40	-0.46
Tenas Creek D.4a (10)	WA	48.333	-121.500	485	-	Calw	67	14.10	0.58
						Illenberg	72	15.30	0.89
						Mooswald	70	15.40	0.83
						Schauinsland	73	9.40	-1.07
						Sindelfingen	68	12.50	-0.04
						Wiesloch	59	13.30	-0.69
Timber Oregon (32)	OR	45.800	-123.383	270	-	Calw	67	14.10	0.58
						Illenberg	72	14.80	-0.04
						Mooswald	70	15.60	1.32
						Schauinsland	73	9.50	-0.84
						Schluchsee	74	10.00	-0.20
						Schopfheim	75	10.90	-0.87
						Sindelfingen	68	13.50	1.30
						Wiesloch	59	13.90	0.69
Germany - Kleinschmit et al. (1985)									
Adler Lake	WA	46.800	-122.283	425	1081	Bremervoerde	22	2.89	-1.50
Alberni	BC	49.325	-124.850	140	1036	Bremervoerde	22	4.59	0.47
						Heigenbrocken	54	4.43	0.04
						Hilders	47	4.46	0.25
Alexandria	BC	52.684	-122.433	274	1003	Bremervoerde	22	4.28	0.10
						Frankenberg	34	3.97	-0.53
						Hilders	47	4.80	0.75
						Katzenelnbogen	49	4.98	-0.58
						Neumuenster	19	5.19	0.91
						Heigenbrocken	54	4.39	-0.02
Alta	BC	50.192	-122.868	630	1027	Heigenbrocken	54	4.34	-0.08
						Bremervoerde	22	3.76	-0.50
						Frankenberg	34	3.94	-0.60
Babine Lake	BC	54.450	-125.450	820	1107	Bremervoerde	22	3.07	-1.29
						Hilders	47	3.86	-0.64
Bacon Point	WA	48.600	-121.383	505	1049	Bremervoerde	22	5.53	1.56

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Bacon Point	WA	48.600	-121.383	505	1049	Frankenberg	34	4.48	0.72
						Heigenbrocken	54	4.81	0.55
						Katzenelnbogen	49	5.87	0.65
						Neumuenster	19	4.49	-0.06
Barriere	BC	51.204	-120.163	420	1010	Bremervoerde	22	4.23	0.05
						Frankenberg	34	3.99	-0.47
						Heigenbrocken	54	3.97	-0.58
						Hilders	47	4.46	0.25
						Katzenelnbogen	49	5.13	-0.37
						Neumuenster	19	4.80	0.37
Blind Bay	BC	50.883	-119.400	405	1015	Bremervoerde	22	4.32	0.15
						Heigenbrocken	54	4.67	0.36
						Hilders	47	5.44	1.69
						Katzenelnbogen	49	6.04	0.89
						Neumuenster	19	4.57	0.05
Brookings	OR	42.117	-124.200	300	1104	Bremervoerde	22	2.36	-2.11
						Heigenbrocken	54	3.70	-0.95
Cassidy	BC	49.058	-123.950	200	1040	Bremervoerde	22	2.80	-1.61
						Heigenbrocken	54	3.73	-0.91
						Hilders	47	3.90	-0.59
Caycuse	BC	48.924	-124.433	210	1041	Bremervoerde	22	4.04	-0.17
						Heigenbrocken	54	4.55	0.20
						Hilders	47	4.78	0.72
						Katzenelnbogen	49	6.13	1.02
						Neumuenster	19	4.69	0.22
Cherryville	OR	45.317	-122.300	210	1097	Bremervoerde	22	5.03	0.97
						Frankenberg	34	4.08	-0.27
						Hilders	47	5.25	1.41
						Heigenbrocken	54	5.73	1.80
Chester morse lake	WA	47.367	-121.667	610	1072	Bremervoerde	22	5.55	1.58
						Heigenbrocken	54	5.32	1.25
						Katzenelnbogen	49	5.94	0.75
						Neumuenster	19	5.67	1.56
Chilliwack	BC	49.100	-121.700	910	1038	Bremervoerde	22	4.88	0.81
						Heigenbrocken	54	4.36	-0.06
						Hilders	47	5.03	1.09
Chiwaukum	WA	47.683	-120.733	549	1068	Bremervoerde	22	4.29	0.12
						Heigenbrocken	54	3.62	-1.05
						Katzenelnbogen	49	5.24	-0.22
						Neumuenster	19	4.73	0.26
Clallam, Lake Crescent	WA	48.067	-124.000	300	1058	Bremervoerde	22	6.12	2.25
						Heigenbrocken	54	4.13	-0.37
						Hilders	47	4.57	0.41
Clallam, Louella Gua. Sta.	WA	48.000	-123.083	460	1061	Bremervoerde	22	5.20	1.18
						Heigenbrocken	54	4.40	0.00
						Hilders	47	4.26	-0.06
						Katzenelnbogen	49	5.79	0.54
						Neumuenster	19	4.54	0.01

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Clallam, Sequim	WA	48.033	-123.033	60	1060	Bremervoerde	22	3.56	-0.72
						Heigenbrocken	54	4.22	-0.25
						Katzenelnbogen	49	5.21	-0.26
						Neumuenster	19	2.66	-2.58
Cle Elum	WA	47.217	-121.117	640	1078	Heigenbrocken	54	4.21	-0.26
						Bremervoerde	22	4.42	0.27
						Frankenberg	34	4.03	-0.37
Clearwater	BC	51.657	-120.000	450	1007	Bremervoerde	22	3.61	-0.67
						Frankenberg	34	4.77	1.43
						Heigenbrocken	54	4.05	-0.47
						Hilders	47	5.23	1.39
						Katzenelnbogen	49	5.85	0.63
						Neumuenster	19	5.04	0.70
Clinton	BC	51.100	-121.500	1030	1112	Heigenbrocken	54	4.10	-0.40
						Bremervoerde	22	3.48	-0.82
						Frankenberg	34	3.92	-0.64
						Hilders	47	3.83	-0.69
Concrete	WA	48.650	-121.717	465	1047	Bremervoerde	22	4.09	-0.11
						Heigenbrocken	54	4.54	0.18
						Hilders	47	4.50	0.30
						Katzenelnbogen	49	5.88	0.67
Coquille	OR	43.200	-124.167	60	1103	Bremervoerde	22	3.09	-1.27
						Heigenbrocken	54	4.26	-0.19
Cougar	WA	46.083	-122.300	550	1090	Heigenbrocken	54	5.28	1.19
						Bremervoerde	22	5.21	1.19
						Frankenberg	34	4.71	1.29
Courtenay	BC	49.696	-125.064	70	1032	Bremervoerde	22	5.14	1.10
						Heigenbrocken	54	4.04	-0.49
						Hilders	47	4.40	0.15
						Katzenelnbogen	49	5.44	0.06
						Neumuenster	19	4.77	0.32
Cowlitz, Castle Rock	WA	46.317	-122.867	150	1088	Bremervoerde	22	4.83	0.75
						Frankenberg	34	4.30	0.28
						Heigenbrocken	54	5.14	1.00
						Hilders	47	3.33	-1.42
D'Arcy	BC	50.557	-122.500	270	1021	Bremervoerde	22	4.86	0.78
						Heigenbrocken	54	4.23	-0.23
						Hilders	47	4.15	-0.21
Denny creek	WA	47.400	-121.533	540	1070	Bremervoerde	22	4.98	0.93
						Frankenberg	34	4.78	1.46
						Heigenbrocken	54	5.73	1.81
						Katzenelnbogen	49	5.95	0.76
						Neumuenster	19	5.15	0.84
Detroit	OR	44.733	-122.167	480	1114	Bremervoerde	22	3.74	-0.52
Diablo Dam	WA	48.717	-121.117	440	1046	Bremervoerde	22	4.88	0.81
						Frankenberg	34	3.39	-1.94
						Katzenelnbogen	49	4.79	-0.84
						Neumuenster	19	3.37	-1.60

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Diablo Dam	WA	48.717	-121.117	440	1046	Heigenbrocken	54	3.84	-0.76
Duncan	BC	48.750	-123.750	60	1042	Bremervoerde	22	2.99	-1.39
						Heigenbrocken	54	3.97	-0.58
						Katzenelnbogen	49	5.99	0.82
Dunster	BC	53.117	-119.833	50	1109	Bremervoerde	22	2.99	-1.39
						Hilders	47	4.05	-0.37
						Katzenelnbogen	49	5.06	-0.47
						Neumuenster	19	4.19	-0.47
Eagle Bay	BC	50.933	-119.217	480	1014	Heigenbrocken	54	5.16	1.03
						Bremervoerde	22	4.06	-0.14
						Hilders	47	5.03	1.09
						Katzenelnbogen	49	5.81	0.58
						Neumuenster	19	4.46	-0.10
Fly Hill	BC	50.533	-119.400	750	1022	Bremervoerde	22	4.08	-0.13
						Frankenberg	34	3.78	-0.99
						Heigenbrocken	54	3.93	-0.64
						Hilders	47	3.16	-1.68
						Katzenelnbogen	49	5.47	0.10
						Neumuenster	19	4.08	-0.62
Forbidden Plat.	BC	49.663	-125.156	610	1033	Bremervoerde	22	3.73	-0.52
						Heigenbrocken	54	5.24	1.14
						Katzenelnbogen	49	4.83	-0.79
						Neumuenster	19	4.25	-0.39
Fort St. James	BC	54.483	-124.250	850	1106	Bremervoerde	22	3.38	-0.93
						Hilders	47	4.11	-0.27
						Katzenelnbogen	49	3.73	-2.30
						Neumuenster	19	3.96	-0.80
Franklin River	BC	49.100	-124.767	150	1037	Bremervoerde	22	3.85	-0.39
						Hilders	47	3.72	-0.85
Glenwood	WA	46.000	-121.017	480	1092	Bremervoerde	22	3.61	-0.67
						Frankenberg	34	3.78	-0.98
						Heigenbrocken	54	4.41	0.02
Golden	BC	51.383	-117.000	880	1008	Heigenbrocken	54	3.76	-0.87
						Bremervoerde	22	3.64	-0.63
						Frankenberg	34	3.79	-0.97
						Hilders	47	3.39	-1.34
						Katzenelnbogen	49	4.95	-0.62
						Neumuenster	19	4.19	-0.47
Grays Harbor, Humptulips	WA	47.317	-123.900	140	1073	Bremervoerde	22	6.11	2.23
						Frankenberg	34	4.74	1.36
						Heigenbrocken	54	5.25	1.15
						Hilders	47	5.49	1.76
						Katzenelnbogen	49	6.68	1.77
						Neumuenster	19	5.19	0.91
Horsefly	BC	52.300	-121.317	820	1111	Bremervoerde	22	4.23	0.05
						Frankenberg	34	4.43	0.60
						Hilders	47	4.46	0.24
						Katzenelnbogen	49	5.62	0.31

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Horsefly	BC	52.300	-121.317	820	1111	Neumuenster	19	4.78	0.34
Jefferson, Hoh River	WA	47.800	-123.967	240	1064	Bremervoerde	22	5.40	1.41
						Heigenbrocken	54	6.00	2.17
						Katzenelnbogen	49	6.80	1.93
						Neumuenster	19	5.75	1.68
Jeune Landing	BC	50.450	-127.450	170	1023	Bremervoerde	22	4.82	0.74
						Heigenbrocken	54	4.20	-0.28
						Katzenelnbogen	49	4.36	-1.43
						Neumuenster	19	4.28	-0.35
Keechelus Lake	WA	47.383	-121.367	790	1071	Heigenbrocken	54	4.85	0.61
						Bremervoerde	22	4.49	0.36
						Frankenberg	34	3.85	-0.81
King, Enumclaw	WA	47.267	-121.933	240	1075	Bremervoerde	22	5.17	1.14
						Frankenberg	34	4.64	1.12
						Heigenbrocken	54	5.49	1.48
						Katzenelnbogen	49	5.95	0.77
						Neumuenster	19	3.97	-0.78
Lewis Packwood	WA	46.567	-121.667	650	1083	Heigenbrocken	54	4.77	0.50
						Bremervoerde	22	1.98	-2.55
						Frankenberg	34	4.16	-0.07
Lewis, Randle	WA	46.550	-122.050	335	1085	Frankenberg	34	4.12	-0.17
						Heigenbrocken	54	4.00	-0.54
Marion Forks	OR	44.500	-122.000	1060	1117	Heigenbrocken	54	4.38	-0.02
						Bremervoerde	22	3.84	-0.40
Mason, Matlock	WA	47.250	-123.417	120	1076	Bremervoerde	22	6.43	2.60
						Heigenbrocken	54	5.82	1.93
						Hilders	47	5.03	1.08
						Katzenelnbogen	49	5.57	0.24
						Neumuenster	19	5.03	0.68
Mason, Shelton	WA	47.250	-123.200	90	1077	Bremervoerde	22	4.18	0.00
						Frankenberg	34	4.53	0.84
						Heigenbrocken	54	5.76	1.84
						Hilders	47	5.18	1.30
						Katzenelnbogen	49	5.65	0.34
						Neumuenster	19	5.10	0.78
Matlock	WA	47.300	-123.933	504	1074	Bremervoerde	22	4.62	0.51
						Hilders	47	5.25	1.42
						Katzenelnbogen	49	5.93	0.74
						Neumuenster	19	5.84	1.80
						Heigenbrocken	54	5.10	0.95
McLeod Lake	BC	54.867	-122.883	760	1105	Bremervoerde	22	3.10	-1.26
						Hilders	47	3.41	-1.31
Merritt	BC	50.067	-120.850	880	1028	Bremervoerde	22	3.34	-0.98
						Frankenberg	34	4.40	0.52
						Hilders	47	5.00	1.05
						Katzenelnbogen	49	5.16	-0.33
						Neumuenster	19	4.39	-0.20
						Heigenbrocken	54	3.33	-1.45

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Monte Creek	BC	50.617	-119.900	630	1019	Bremervoerde	22	3.64	-0.63
						Frankenberg	34	4.74	1.36
						Heigenbrocken	54	3.91	-0.66
						Hilders	47	4.78	0.72
						Katzenelnbogen	49	4.50	-1.24
						Neumuenster	19	4.40	-0.19
Nelson	BC	49.500	-117.267	820	1035	Heigenbrocken	54	4.16	-0.33
						Bremervoerde	22	3.09	-1.27
						Hilders	47	4.75	0.68
						Katzenelnbogen	49	5.54	0.19
						Neumuenster	19	4.03	-0.70
Newport	WA	48.200	-117.050	720	1055	Bremervoerde	22	4.14	-0.06
						Frankenberg	34	4.19	0.01
						Heigenbrocken	54	3.86	-0.73
						Hilders	47	3.69	-0.90
						Katzenelnbogen	49	4.63	-1.06
						Neumuenster	19	4.80	0.36
Nimpkish	BC	50.317	-126.883	90	1025	Bremervoerde	22	4.17	-0.02
						Heigenbrocken	54	4.47	0.10
Owl Creek	BC	50.333	-122.725	210	1024	Bremervoerde	22	3.78	-0.47
						Heigenbrocken	54	3.95	-0.61
						Katzenelnbogen	49	4.23	-1.62
						Neumuenster	19	4.03	-0.70
Packwood	WA	46.567	-121.700	300	1084	Bremervoerde	22	3.10	-1.26
						Frankenberg	34	4.14	-0.10
						Heigenbrocken	54	5.29	1.20
Parkway	WA	47.033	-121.567	730	1079	Bremervoerde	22	4.16	-0.04
						Frankenberg	34	4.26	0.19
						Heigenbrocken	54	4.49	0.12
						Hilders	47	3.29	-1.48
Perry creek	WA	48.050	-121.467	600	1059	Bremervoerde	22	5.65	1.69
						Heigenbrocken	54	5.39	1.34
Pillar Lake	BC	50.583	-119.633	910	1020	Heigenbrocken	54	3.93	-0.64
						Bremervoerde	22	4.13	-0.06
						Frankenberg	34	2.88	-3.20
						Hilders	47	3.34	-1.40
						Katzenelnbogen	49	4.30	-1.52
						Neumuenster	19	4.27	-0.36
Pine Grove	OR	45.100	-121.383	730	1099	Heigenbrocken	54	4.35	-0.07
						Bremervoerde	22	5.05	1.00
						Hilders	47	5.00	1.05
Prindle	WA	45.617	-122.133	460	1095	Bremervoerde	22	4.36	0.21
						Frankenberg	34	4.27	0.21
						Heigenbrocken	54	4.17	-0.32
Republic	WA	48.600	-118.733	730	1048	Heigenbrocken	54	2.27	-2.89
						Bremervoerde	22	2.75	-1.66
						Frankenberg	34	3.36	-2.01
						Hilders	47	3.51	-1.16

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Republic	WA	48.600	-118.733	730	1048	Katzenelnbogen	49	3.57	-2.53
						Neumuenster	19	3.36	-1.62
Revelstoke	BC	51.000	-118.200	600	1013	Bremervoerde	22	4.35	0.19
						Frankenberg	34	4.09	-0.23
						Heigenbrocken	54	3.99	-0.56
						Hilders	47	3.55	-1.10
						Katzenelnbogen	49	5.33	-0.09
						Neumuenster	19	4.26	-0.38
Rimrock	WA	46.667	-121.033	760	1082	Heigenbrocken	54	3.79	-0.83
						Bremervoerde	22	3.08	-1.28
						Hilders	47	3.31	-1.45
Salmon Arm	BC	50.733	-119.217	470	1018	Heigenbrocken	54	4.12	-0.37
						Bremervoerde	22	5.12	1.08
						Frankenberg	34	3.81	-0.92
						Hilders	47	4.39	0.14
						Katzenelnbogen	49	5.84	0.61
						Neumuenster	19	5.06	0.73
San Juan	BC	48.581	-124.080	210	1043	Bremervoerde	22	4.52	0.39
						Frankenberg	34	4.24	0.14
						Heigenbrocken	54	4.81	0.55
						Katzenelnbogen	49	6.09	0.96
						Neumuenster	19	5.50	1.33
Scenic	WA	47.717	-121.133	940	1066	Heigenbrocken	54	4.06	-0.46
						Bremervoerde	22	4.09	-0.11
Sechelt	BC	49.511	-123.882	180	1034	Bremervoerde	22	4.83	0.75
						Frankenberg	34	4.33	0.34
						Heigenbrocken	54	2.63	-2.40
						Hilders	47	4.43	0.20
						Katzenelnbogen	49	6.16	1.06
						Neumuenster	19	4.36	-0.24
Skagit, Marble Mnt	WA	48.583	-121.400	120	1050	Bremervoerde	22	5.99	2.09
						Heigenbrocken	54	5.40	1.35
Skagit, Sedro Woolley	WA	48.533	-122.317	60	1051	Bremervoerde	22	4.25	0.08
						Heigenbrocken	54	4.06	-0.47
						Katzenelnbogen	49	5.84	0.61
						Neumuenster	19	6.05	2.09
Skykomish	WA	47.700	-121.333	300	1067	Bremervoerde	22	3.61	-0.67
						Heigenbrocken	54	4.87	0.64
						Hilders	47	4.18	-0.17
Sloan Creek	WA	48.083	-121.300	650	1056	Bremervoerde	22	3.78	-0.47
						Hilders	47	4.66	0.53
						Katzenelnbogen	49	4.87	-0.73
						Neumuenster	19	2.40	-2.94
						Heigenbrocken	54	4.27	-0.18
Snohomish, Arlington	WA	48.217	-122.067	90	1054	Bremervoerde	22	4.64	0.53
						Frankenberg	34	4.79	1.48
						Heigenbrocken	54	5.37	1.31
Snohomish, Gold Bar	WA	47.850	-121.650	120	1063	Bremervoerde	22	5.58	1.61

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Snohomish, Gold Bar	WA	47.850	-121.650	120	1063	Frankenberg	34	4.55	0.89
						Heigenbrocken	54	5.83	1.94
						Katzenelnbogen	49	6.35	1.31
						Neumuenster	19	3.77	-1.05
Sooke	BC	48.400	-123.733	45	1045	Bremervoerde	22	4.03	-0.18
						Heigenbrocken	54	4.01	-0.52
						Katzenelnbogen	49	6.46	1.47
						Neumuenster	19	4.30	-0.32
Spokane	WA	47.783	-117.200	600	1065	Bremervoerde	22	4.55	0.42
						Frankenberg	34	3.64	-1.33
						Heigenbrocken	54	3.92	-0.65
						Hilders	47	3.20	-1.62
						Katzenelnbogen	49	4.76	-0.88
						Neumuenster	19	4.86	0.45
Squamish	BC	49.778	-123.150	15	1030	Bremervoerde	22	3.77	-0.48
						Frankenberg	34	4.40	0.53
						Heigenbrocken	54	3.38	-1.39
						Hilders	47	3.63	-0.98
Squilax	BC	50.083	-119.567	580	1017	Heigenbrocken	54	4.10	-0.41
						Bremervoerde	22	4.69	0.58
						Frankenberg	34	4.41	0.55
						Hilders	47	4.77	0.71
						Katzenelnbogen	49	6.05	0.90
						Neumuenster	19	4.10	-0.59
Stella Lake	BC	50.283	-125.467	150	1026	Bremervoerde	22	4.51	0.37
						Frankenberg	34	4.65	1.14
						Heigenbrocken	54	5.03	0.86
						Katzenelnbogen	49	5.71	0.44
						Neumuenster	19	5.14	0.84
Stoner	BC	53.618	-122.675	570	1001	Bremervoerde	22	4.23	0.05
						Frankenberg	34	4.12	-0.15
						Heigenbrocken	54	3.96	-0.59
						Hilders	47	4.00	-0.43
						Katzenelnbogen	49	5.06	-0.47
						Neumuenster	19	4.63	0.14
Stuie	BC	52.367	-126.000	16	1004	Bremervoerde	22	4.19	0.01
						Heigenbrocken	54	3.95	-0.61
Tatla	BC	51.733	-124.733	880	1006	Heigenbrocken	54	3.54	-1.16
						Bremervoerde	22	3.96	-0.26
						Frankenberg	34	4.19	0.02
						Hilders	47	5.17	1.29
						Katzenelnbogen	49	4.90	-0.68
						Neumuenster	19	4.37	-0.22
Thurston, Yelm	WA	47.017	-122.733	60	1080	Bremervoerde	22	3.44	-0.86
						Heigenbrocken	54	4.81	0.56
						Hilders	47	3.51	-1.15
Tillamook, Hebo	OR	45.217	-123.850	150	1098	Bremervoerde	22	3.43	-0.88
						Heigenbrocken	54	3.60	-1.08

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Twisp	WA	48.383	-120.400	790	1052	Heigenbrocken	54	2.98	-1.93
						Bremervoerde	22	3.02	-1.35
						Frankenberg	34	3.84	-0.85
						Hilders	47	4.26	-0.05
						Katzenelnbogen	49	4.37	-1.42
						Neumuenster	19	3.68	-1.18
Upper Soda	OR	44.383	-122.200	980	1102	Heigenbrocken	54	4.25	-0.20
						Bremervoerde	22	5.00	0.94
						Frankenberg	34	4.28	0.24
Wahkiakum, Cathlamet	WA	46.300	-123.267	195	1089	Bremervoerde	22	4.31	0.15
						Frankenberg	34	4.19	0.02
						Katzenelnbogen	49	5.86	0.64
						Neumuenster	19	5.41	1.21
Waldport	OR	44.400	-123.867	60	1101	Bremervoerde	22	3.42	-0.88
						Frankenberg	34	4.38	0.48
						Heigenbrocken	54	5.72	1.79
Wansa Lake	BC	53.767	-122.100	880	1108	Bremervoerde	22	3.52	-0.77
Washington, Vernonia	OR	45.767	-123.217	210	1094	Bremervoerde	22	4.28	0.11
						Frankenberg	34	4.53	0.83
						Heigenbrocken	54	4.66	0.35
White Lake	BC	50.117	-119.250	510	1016	Bremervoerde	22	4.24	0.06
						Frankenberg	34	4.50	0.77
						Heigenbrocken	54	4.01	-0.53
						Hilders	47	4.81	0.76
						Katzenelnbogen	49	5.48	0.12
						Neumuenster	19	5.03	0.69
Willard	WA	45.800	-121.700	495	1093	Heigenbrocken	54	4.24	-0.22
						Bremervoerde	22	3.59	-0.69
Williams Lake	BC	52.100	-122.000	600	1005	Heigenbrocken	54	3.11	-1.75
						Bremervoerde	22	3.80	-0.45
						Frankenberg	34	3.49	-1.70
						Hilders	47	3.42	-1.29
						Katzenelnbogen	49	4.35	-1.45
						Neumuenster	19	4.26	-0.38
Yamhill, Grande Ronde Ag.	OR	45.100	-123.600	180	1100	Bremervoerde	22	5.09	1.05
						Frankenberg	34	4.37	0.44
						Heigenbrocken	54	4.93	0.72
						Hilders	47	4.42	0.19
Germany - Schober (1954)									
Beulah (100)	CO	38.083	-104.950	2500	-	Gahrenberg	42	7.80	-1.59
Buckhorn (92)	WA	46.417	-123.250	700	-	Gahrenberg	42	12.50	0.76
Buena Vista 1 (4)	CO	38.667	-106.167	2134	-	Braunlage	39	3.90	-2.42
						Freienwalde	33	1.50	-2.02
Buena Vista 2 (99)	CO	38.667	-106.167	2500	-	Gahrenberg	42	6.80	-2.09
Cascadia (13)	OR	44.417	-122.500	853	-	Braunlage	39	8.20	-0.21
						Freienwalde	33	3.90	-0.21
Elma 1 (94)	WA	46.333	-123.250	350	-	Gahrenberg	42	12.80	0.91
Elma 2 (8)	WA	47.000	-123.333	91	-	Braunlage	39	9.90	0.67

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Elma 2 (8)	WA	47.000	-123.333	91	-	Freienwalde	33	4.50	0.24
Howe Sound (106)	BC	49.500	-123.500	100	-	Gahrenberg	42	11.40	0.21
Kamloops 1 (1)	BC	50.667	-120.500	610	-	Braunlage	39	10.30	0.87
						Freienwalde	33	4.80	0.47
Kamloops 2 (96)	BC	50.667	-120.500	1100	-	Gahrenberg	42	11.60	0.31
Lebanon 1 (11)	OR	44.583	-122.833	457	-	Braunlage	39	8.80	0.10
						Freienwalde	33	2.90	-0.97
Lebanon 2 (22)	OR	44.583	-122.833	616	-	Kirchzarten	71	3.39	-0.39
Mt. St. Helens 1 (95)	WA	46.250	-122.250	1100	-	Gahrenberg	42	11.00	0.01
Mt. St. Helens 2 (23)	WA	46.250	-122.250	1676	-	Kirchzarten	71	3.80	0.83
Ryderwood 1 (9)	WA	46.333	-123.250	152	-	Braunlage	39	9.50	0.46
						Freienwalde	33	5.60	1.07
Ryderwood 2 (21)	WA	46.333	-123.250	305	-	Kirchzarten	71	3.25	-0.80
Salmon Arm 1 (2)	BC	50.667	-119.667	914	-	Kirchzarten	71	3.46	-0.18
Salmon Arm 2 (3)	BC	50.667	-119.667	1524	-	Braunlage	39	9.90	0.67
						Freienwalde	33	5.60	1.07
Salmon Arm 3 (98)	BC	50.667	-119.500	700	-	Gahrenberg	42	11.40	0.21
Shuswap Lake Area (107)	BC	50.833	-119.333	450	-	Gahrenberg	42	10.50	-0.24
Snoqualmie Pass (16)	WA	47.500	-121.250	1676	-	Braunlage	39	9.10	0.26
						Freienwalde	33	3.90	-0.21
Spirit Lake 1 (25)	WA	46.167	-122.250	1067	-	Kirchzarten	71	3.80	0.83
Spirit Lake 2 (14)	WA	46.167	-122.250	1372	-	Braunlage	39	7.80	-0.41
						Freienwalde	33	4.90	0.55
Stella (20)	WA	46.250	-123.250	61	-	Kirchzarten	71	3.93	1.22
Stella Cufoula (91)	WA	46.250	-123.250	40	-	Gahrenberg	42	13.30	1.16
Sweet Home 1 (93)	OR	44.417	-122.667	400	-	Gahrenberg	42	11.60	0.31
Sweet Home 2 (24)	OR	44.417	-122.667	762	-	Kirchzarten	71	3.01	-1.52
Germany - Stimm & Dong (2001)									
Bitterrot (6)	MT	46.247	-114.155	1091	-	Kaiserlautern	57	32.90	-0.16
Lilo (7)	MT	46.758	-114.082	974	-	Kaiserlautern	57	30.60	-0.83
Pecos (4)	NM	35.575	-105.675	2118	-	Kaiserlautern	57	31.90	-0.45
Snoqualmie (15)	WA	47.583	-121.825	150	-	Kaiserlautern	57	38.40	1.44
Germany - Weller (2010)									
Alder	WA	46.800	-122.250	350	-	Rantzau225	21	22.80	0.44
						Trier	52	22.00	-0.59
Ashford	WA	46.800	-122.000	460	-	Ankum35	28	26.10	1.31
						Lauterberg	40	21.50	0.62
						Neuhaus	36	21.70	0.11
						Rantzau225	21	23.70	1.10
						Rantzau783	20	24.00	0.51
						Soonwald	53	23.80	0.18
						Trier	52	23.40	0.15
Baker	WA	46.033	-122.583	300	-	Ankum1093	27	22.50	-0.56
						Ankum35	28	25.70	0.82
						Harsefeld	23	23.50	0.53
						Lauterberg	40	21.20	0.26
						Neuhaus	36	22.60	1.10
						Oerrel	30	22.60	0.27

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Baker	WA	46.033	-122.583	300	-	Rantzau225	21	22.00	-0.16
						Rantzau783	20	23.50	0.17
						Riefensbeek	38	27.00	0.55
						Seesen	35	20.10	0.20
						Trier	52	21.50	-0.86
						Westerhof	37	24.90	0.32
Breightenbush	OR	44.750	-122.083	740	-	Neuhaus	36	21.30	-0.34
						Rantzau225	21	21.50	-0.52
Cameron Lake	BC	49.250	-124.667	210	-	Ahlhorn	24	24.80	-0.86
						Lauterberg	40	19.10	-2.28
						Neuhaus	36	21.50	-0.11
						Rantzau225	21	21.50	-0.52
						Trier	52	20.30	-1.50
Carson	OR	45.700	-121.667	280	-	Ahlhorn	24	25.50	-0.19
						Lauterberg	40	20.90	-0.10
						Rantzau225	21	22.00	-0.16
						Trier	52	24.20	0.58
Conrad Creek	WA	48.250	-121.500	280	-	Ankum1093	27	22.30	-0.81
						Lauterberg	40	21.80	0.98
						Neuhaus	36	20.80	-0.89
						Rantzau225	21	22.60	0.29
						Rantzau783	20	23.90	0.45
						Soonwald	53	24.00	0.38
						Trier	52	24.80	0.90
Coombs	BC	49.033	-124.417	80	-	Rantzau225	21	22.10	-0.08
Detroit	OR	44.067	-122.167	530	-	Ankum1093	27	24.00	1.27
						Neuhaus	36	21.40	-0.22
						Rantzau225	21	21.70	-0.38
						Trier	52	21.60	-0.80
Duncan Paldi	BC	48.750	-123.833	260	-	Ankum1093	27	22.80	-0.20
						Ankum35	28	24.60	-0.51
						Harsefeld	23	20.60	-1.28
						Lauterberg	40	19.60	-1.68
						Neuhaus	36	21.40	-0.22
						Oerrel	30	20.00	-1.45
						Rantzau225	21	20.70	-1.12
						Rantzau783	20	21.80	-1.01
						Soonwald	53	22.70	-0.88
						Trier	52	20.70	-1.28
						Westerhof	37	24.40	-0.27
Fraser River	BC	52.500	-121.500	750	-	Neuhaus	36	19.30	-2.54
						Rantzau225	21	18.00	-3.11
						Trier	52	18.90	-2.24
Gates	OR	44.750	-122.500	500	-	Ahlhorn	24	27.10	1.34
						Neuhaus	36	22.40	0.88
						Trier	52	25.70	1.38
Gold Hill	WA	48.033	-121.500	150	-	Ahlhorn	24	25.60	-0.10
						Lauterberg	40	21.80	0.98

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Gold Hill	WA	48.033	-121.500	150	-	Neuhaus	36	22.40	0.88
						Rantzau225	21	23.00	0.58
						Rantzau783	20	23.30	0.03
						Soonwald	53	24.50	0.86
						Trier	52	23.50	0.21
Greenwater	WA	47.133	-121.500	600	-	Ahlhorn	24	26.80	1.05
						Lauterberg	40	21.70	0.86
						Rantzau225	21	23.00	0.58
						Trier	52	23.60	0.26
Humptulips	WA	47.200	-123.917	55	-	Ankum1093	27	23.20	0.29
						Ankum35	28	26.00	1.19
						Harsefeld	23	24.00	0.85
						Lauterberg	40	22.00	1.23
						Neuhaus	36	22.90	1.43
						Oerrel	30	23.60	0.94
						Rantzau225	21	25.10	2.13
						Rantzau783	20	24.50	0.86
						Riefensbeek	38	28.20	1.60
						Seesen	35	18.50	-2.24
						Trier	52	25.40	1.22
						Westerhof	37	24.40	-0.27
Joyce	WA	47.017	-123.583	85	-	Rantzau225	21	22.00	-0.16
						Trier	52	22.10	-0.54
Louella	WA	48.133	-123.167	85	-	Lauterberg	40	20.10	-1.07
						Neuhaus	36	21.60	0.00
						Rantzau225	21	22.40	0.14
						Rantzau783	20	23.20	-0.04
						Soonwald	53	24.60	0.96
						Trier	52	24.10	0.53
Marion Creek	OR	44.583	-121.917	870	-	Lauterberg	40	21.20	0.26
						Rantzau225	21	21.80	-0.30
						Trier	52	22.30	-0.43
Mineral	WA	46.700	-122.183	470	-	Trier	52	23.50	0.21
Molalla	OR	45.250	-122.417	260	-	Ahlhorn	24	27.50	1.72
						Ankum1093	27	24.20	1.51
						Ankum35	28	25.10	0.10
						Harsefeld	23	22.70	0.03
						Lauterberg	40	21.20	0.26
						Neuhaus	36	21.40	-0.22
						Oerrel	30	24.20	1.33
						Rantzau225	21	22.00	-0.16
						Rantzau783	20	24.00	0.51
						Riefensbeek	38	26.60	0.20
						Seesen	35	20.20	0.35
						Soonwald	53	23.90	0.28
						Trier	52	22.60	-0.27
						Westerhof	37	24.60	-0.04
Mt. Hood	OR	45.050	-121.583	800	-	Rantzau225	21	21.90	-0.23

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Mt. Hood	OR	45.050	-121.583	800	-	Trier	52	23.00	-0.06
Mte. Cristo Lake	WA	48.000	-121.500	610	-	Ahlhorn	24	25.90	0.19
						Ankum35	28	24.20	-0.99
						Neuhaus	36	22.20	0.66
						Rantzau225	21	21.70	-0.38
						Trier	52	24.20	0.58
Orting	WA	47.083	-122.233	130	-	Ahlhorn	24	24.90	-0.77
						Rantzau225	21	23.60	1.03
						Trier	52	20.70	-1.28
Pamelia Creek	OR	44.067	-121.833	750	-	Lauterberg	40	20.90	-0.10
						Neuhaus	36	21.70	0.11
						Rantzau225	21	21.70	-0.38
						Trier	52	25.30	1.17
Salmon Arm I	BC	50.650	-119.217	580	-	Ahlhorn	24	24.30	-1.34
						Neuhaus	36	21.10	-0.56
						Rantzau225	21	21.00	-0.89
						Trier	52	20.50	-1.39
Salmon Arm II	BC	50.083	-119.167	650	-	Ankum1093	27	21.30	-2.03
						Neuhaus	36	19.60	-2.21
						Rantzau783	20	19.50	-2.60
						Riefensbeek	38	24.90	-1.28
						Soonwald	53	21.80	-1.74
Santiam River	OR	44.583	-121.967	800	-	Ankum1093	27	22.00	-1.18
						Ankum35	28	24.20	-0.99
						Harsefeld	23	21.50	-0.71
						Neuhaus	36	21.20	-0.45
						Oerrel	30	20.10	-1.38
						Rantzau225	21	22.10	-0.08
						Rantzau783	20	22.90	-0.25
						Riefensbeek	38	25.10	-1.10
						Seesen	35	20.30	0.50
						Soonwald	53	21.90	-1.65
						Trier	52	21.90	-0.64
						Westerhof	37	23.10	-1.81
Seaquest	WA	46.033	-122.750	140	-	Rantzau225	21	22.30	0.07
						Trier	52	24.50	0.74
Silver Lake	WA	46.033	-122.800	350	-	Neuhaus	36	22.80	1.32
						Trier	52	25.50	1.27
South Wellington	BC	49.117	-123.917	60	-	Ahlhorn	24	24.70	-0.96
						Ankum1093	27	22.60	-0.44
						Ankum35	28	23.50	-1.83
						Harsefeld	23	19.90	-1.71
						Lauterberg	40	20.90	-0.10
						Neuhaus	36	20.70	-1.00
						Rantzau225	21	20.50	-1.26
						Rantzau783	20	21.90	-0.94
						Riefensbeek	38	25.00	-1.19
						Soonwald	53	22.90	-0.68

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
South Wellington	BC	49.117	-123.917	60	-	Trier	52	20.80	-1.23
						Westerhof	37	24.00	-0.74
Stella	WA	46.217	-123.167	100	-	Ankum1093	27	23.50	0.66
						Ankum35	28	25.60	0.70
						Harsefeld	23	23.70	0.66
						Neuhaus	36	22.50	0.99
						Oerrel	30	22.80	0.41
						Rantzau783	20	25.10	1.28
						Riefensbeek	38	27.00	0.55
						Seesen	35	20.10	0.20
						Soonwald	53	24.70	1.05
						Trier	52	25.70	1.38
						Westerhof	37	24.40	-0.27
Suiattle River	WA	48.033	-121.500	165	-	Rantzau225	21	23.50	0.95
						Trier	52	26.00	1.54
Tenas Creek	WA	48.033	-121.500	485	-	Ahlhorn	24	25.60	-0.10
						Neuhaus	36	21.50	-0.11
						Rantzau225	21	22.80	0.44
						Trier	52	23.60	0.26
Timber	OR	45.800	-123.383	270	-	Ankum1093	27	23.30	0.41
						Ankum35	28	24.90	-0.14
						Harsefeld	23	24.40	1.10
						Neuhaus	36	22.00	0.44
						Oerrel	30	22.40	0.14
						Rantzau783	20	23.20	-0.04
						Riefensbeek	38	26.30	-0.06
						Seesen	35	20.40	0.65
						Soonwald	53	23.90	0.28
						Trier	52	22.60	-0.27
						Westerhof	37	25.10	0.55
Vader	WA	46.417	-123.000	110	-	Ankum1093	27	23.20	0.29
						Ankum35	28	25.30	0.34
						Harsefeld	23	23.50	0.53
						Lauterberg	40	20.90	-0.10
						Neuhaus	36	22.50	0.99
						Oerrel	30	21.80	-0.26
						Rantzau225	21	25.10	2.13
						Rantzau783	20	24.80	1.07
						Riefensbeek	38	27.20	0.73
						Seesen	35	20.20	0.35
						Soonwald	53	24.60	0.96
						Trier	52	25.00	1.01
						Westerhof	37	25.00	0.44
Vernonia	OR	46.000	-123.000	300	-	Ankum1093	27	23.60	0.78
						Westerhof	37	26.40	2.09
Ireland - Lally & Thompson (1998)									
Cathlamet	WA	46.300	-123.270	245	-	Rathdrum	11	17.20	1.62
Coquille	OR	43.180	-124.190	18	-	Rathdrum	11	16.50	0.34

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Courtenay	BC	49.690	-124.990	12	-	Rathdrum	11	16.10	-0.39
Forks	WA	47.980	-124.400	90	-	Rathdrum	11	16.50	0.34
Granite Falls	WA	48.084	-121.969	124	-	Rathdrum	11	16.10	-0.39
Humptulips	WA	47.230	-123.960	46	-	Rathdrum	11	17.10	1.44
Juene Landing	BC	50.443	-127.495	80	-	Rathdrum	11	16.50	0.34
Nasselle	WA	46.370	-123.810	10	-	Rathdrum	11	16.00	-0.57
Prindle	WA	45.620	-122.130	455	-	Rathdrum	11	15.70	-1.12
Sequim	WA	48.030	-123.030	90	-	Rathdrum	11	16.20	-0.21
Shelton	WA	47.250	-123.200	90	-	Rathdrum	11	16.70	0.71
Squamish	BC	49.700	-123.160	6	-	Rathdrum	11	16.00	-0.57
Upper Soda	OR	44.410	-122.280	478	-	Rathdrum	11	15.10	-2.22
Vernonia	OR	45.860	-123.190	188	-	Rathdrum	11	16.10	-0.39
Waldport	OR	44.400	-123.870	90	-	Rathdrum	11	16.90	1.07
Ireland - O'driscoll (1978)									
Brookings	OR	42.117	-124.200	1000	1104	Glenealy	10	4.08	0.84
Cassidy	BC	49.055	-123.950	650	1040	Glenealy	10	3.20	-0.55
Cathlamet	WA	46.300	-123.267	650	1089	Glenealy	10	3.92	0.59
Chilliwack	BC	49.071	-121.800	550	1039	Glenealy	10	4.02	0.75
Coquille	OR	43.200	-124.167	250	1103	Glenealy	10	4.58	1.64
Courtenay	BC	49.691	-125.055	220	1032	Glenealy	10	3.57	0.03
Dean	BC	52.800	-126.955	20	1002	Glenealy	10	3.99	0.70
Forks	WA	47.983	-124.400	300	1062	Glenealy	10	3.71	0.26
Glenwood	WA	46.000	-121.167	1600	1092	Glenealy	10	3.67	0.19
Granite Falls	WA	48.083	-122.033	300	1057	Glenealy	10	4.26	1.13
Humtulips	WA	47.317	-123.900	450	1073	Glenealy	10	3.61	0.10
Jeune Landing	BC	50.450	-127.450	550	1023	Glenealy	10	3.43	-0.19
Jordan River	BC	48.472	-124.233	800	1044	Glenealy	10	3.23	-0.50
Naselle	WA	46.367	-123.733	150	1086	Glenealy	10	3.79	0.38
Nelson	BC	49.500	-117.267	2700	1035	Glenealy	10	2.60	-1.50
Nimkish	BC	50.317	-126.883	300	1025	Glenealy	10	4.01	0.73
Pine Grove	OR	45.100	-121.383	2400	1099	Glenealy	10	3.35	-0.31
Prindle	WA	45.617	-122.133	1500	1095	Glenealy	10	3.27	-0.44
Republic	WA	48.600	-118.733	2400	1048	Glenealy	10	1.70	-2.93
Rimrock	WA	46.667	-121.033	2500	1082	Glenealy	10	2.93	-0.98
Salmon Arm	BC	50.733	-119.217	1550	1018	Glenealy	10	3.22	-0.52
Sandy	OR	45.383	-122.300	900	1096	Glenealy	10	4.08	0.84
Sechelt	BC	49.507	-123.876	600	1034	Glenealy	10	3.86	0.49
Sedro Wooley	WA	48.533	-122.317	200	1051	Glenealy	10	4.16	0.97
Sequim	WA	48.033	-123.033	200	1060	Glenealy	10	3.66	0.18
Shelton	WA	47.250	-123.200	300	1077	Glenealy	10	3.48	-0.11
Squamish	BC	49.773	-123.150	50	1030	Glenealy	10	3.78	0.37
Thasis	BC	49.788	-126.637	50	1029	Glenealy	10	3.38	-0.27
Upper Soda	OR	44.383	-122.200	3250	1102	Glenealy	10	3.44	-0.17
Vernonia	OR	45.767	-123.217	700	1094	Glenealy	10	3.65	0.16
Waldport	OR	44.400	-123.867	200	1101	Glenealy	10	4.15	0.95
Williams Lake	BC	52.108	-122.000	2000	1005	Glenealy	10	1.76	-2.84
Italy - De Vecchi (1978)									
Bacon Point	WA	48.600	-121.383	503	1049	Turin	99	2.02	0.90

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Clallam, Forks	WA	47.983	-124.400	90	1062	Turin	99	1.53	-1.33
Concrete	WA	48.650	-121.717	473	1047	Turin	99	1.88	0.26
Cougar	WA	46.083	-122.300	550	1090	Turin	99	2.01	0.85
Courtenay	BC	49.696	-125.064	70	1032	Turin	99	1.47	-1.60
Cowlitz, Yale	WA	46.000	-122.367	120	1091	Turin	99	1.96	0.63
D'Arcy	BC	50.557	-122.500	270	1021	Turin	99	1.42	-1.83
Golden	BC	51.383	-117.000	880	1008	Turin	99	1.65	-0.78
King, North Bend	WA	47.467	-121.750	150	1069	Turin	99	1.94	0.54
Lewis, Randle	WA	46.550	-122.050	335	1085	Turin	99	1.95	0.58
Nelson	BC	49.500	-117.267	820	1035	Turin	99	1.76	-0.28
Packwood	WA	46.567	-121.700	304	1084	Turin	99	2.16	1.54
Republic	WA	48.600	-118.733	730	1048	Turin	99	1.52	-1.37
Revelstoke	BC	51.000	-118.200	600	1013	Turin	99	1.92	0.45
Scenic	WA	47.717	-121.133	940	1066	Turin	99	2.00	0.81
Sloan Creek	WA	48.083	-121.300	650	1056	Turin	99	1.61	-0.96
Snohomish, Darrington	WA	48.267	-121.633	150	1053	Turin	99	2.03	0.95
Spokane	WA	47.783	-117.200	600	1065	Turin	99	1.77	-0.24
Squamish	BC	49.778	-123.150	15	1030	Turin	99	2.15	1.49
Twisp	WA	48.383	-120.400	790	1052	Turin	99	1.66	-0.74
Waldport	OR	44.400	-123.867	60	1001	Turin	99	1.75	-0.33
Willard	WA	45.800	-121.683	502	1093	Turin	99	1.92	0.45
Italy - Ducci & Tocci (1987)									
Adler Lake	WA	46.800	-122.283	425	1081	Faltona	101	8.60	0.20
						Vallombrosa	100	10.61	0.47
Alder Springs	CA	39.650	-122.750	1370	1146	Faltona	101	9.41	0.66
Arcata 1	CA	40.900	-123.767	880	1140	Faltona	101	9.47	0.70
						Vallombrosa	100	8.89	-1.20
Arcata 2	CA	40.917	-123.917	490	1138	Faltona	101	8.78	0.31
						Vallombrosa	100	10.11	-0.02
Ashland	OR	42.083	-122.650	551	1126	Vallombrosa	100	9.62	-0.49
Big Bar 1	CA	40.717	-123.300	1070	1142	Faltona	101	8.86	0.35
						Vallombrosa	100	8.46	-1.61
Big Bar 2	CA	40.783	-123.200	1300	1141	Faltona	101	8.24	0.00
						Vallombrosa	100	8.73	-1.35
Brookings	OR	42.117	-124.200	300	1104	Faltona	101	9.94	0.96
						Vallombrosa	100	11.13	0.97
Burney	CA	41.083	-121.650	1100	1137	Faltona	101	8.58	0.19
						Vallombrosa	100	10.27	0.14
Burnt Woods	OR	44.600	-123.700	319	1116	Vallombrosa	100	11.01	0.85
Castle Rock	WA	46.317	-122.867	50	1088	Vallombrosa	100	12.44	2.24
Cave Junction	OR	42.183	-123.667	460	1125	Vallombrosa	100	10.02	-0.11
Cherryville	OR	45.317	-122.300	210	1097	Vallombrosa	100	11.30	1.14
Cle Elum	WA	47.217	-121.117	630	1078	Faltona	101	2.01	-3.54
						Vallombrosa	100	8.89	-1.20
Coquille	OR	43.200	-124.167	60	1103	Faltona	101	9.54	0.74
						Vallombrosa	100	12.03	1.84
Cougar	WA	46.083	-122.300	550	1090	Vallombrosa	100	11.12	0.96
Covelo 1	CA	39.800	-122.933	1550	1145	Vallombrosa	100	9.41	-0.69

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Covelo 2	CA	39.917	-123.300	900	1144	Vallombrosa	100	9.65	-0.46
Detroit	OR	44.733	-122.167	480	1114	Faltona	101	9.29	0.59
						Vallombrosa	100	9.60	-0.50
Duncan	BC	48.750	-123.750	60	1042	Faltona	101	9.40	0.66
						Vallombrosa	100	9.85	-0.27
Dunsmuir	CA	41.200	-122.300	1100	1136	Vallombrosa	100	9.68	-0.43
Eugene	OR	44.017	-123.383	210	1119	Vallombrosa	100	10.91	0.76
Forks	WA	47.983	-124.400	90	1062	Vallombrosa	100	9.98	-0.15
Gasquet	CA	41.850	-123.983	120	1128	Vallombrosa	100	12.11	1.92
Gold River	BC	49.750	-126.067	90	1031	Faltona	101	7.44	-0.45
						Vallombrosa	100	9.91	-0.21
Gran Ronde Agency	OR	45.100	-123.600	180	1100	Vallombrosa	100	9.51	-0.59
Granite Falls	WA	48.083	-122.033	90	1057	Vallombrosa	100	10.30	0.16
Happy Camp	CA	41.650	-123.517	1250	1133	Vallombrosa	100	9.42	-0.68
Hebo	OR	45.217	-123.850	150	1098	Vallombrosa	100	11.43	1.26
Humptulips	WA	47.317	-123.900	135	1073	Vallombrosa	100	9.99	-0.13
Lower Lake	CA	38.833	-122.700	960	1149	Vallombrosa	100	11.45	1.28
Marblemount	WA	48.583	-121.400	120	1050	Faltona	101	8.92	0.39
						Vallombrosa	100	10.84	0.69
Marion Forks	OR	44.500	-122.000	1015	1117	Vallombrosa	100	9.81	-0.30
Matlock	WA	47.250	-123.417	120	1076	Faltona	101	8.93	0.39
Merritt	BC	50.022	-120.850	870	1028	Faltona	101	6.59	-0.94
						Vallombrosa	100	7.75	-2.29
Mill City	OR	44.800	-122.700	150	1113	Vallombrosa	100	10.65	0.51
Naselle	WA	46.367	-123.733	50	1086	Vallombrosa	100	10.06	-0.06
Nimkish	BC	50.317	-126.883	90	1025	Vallombrosa	100	8.90	-1.18
North Bend	WA	47.467	-121.750	150	1069	Vallombrosa	100	10.52	0.38
Oakridge	OR	43.900	-122.367	880	1120	Vallombrosa	100	9.43	-0.67
Randle	WA	46.550	-122.050	335	1085	Vallombrosa	100	11.34	1.18
Roseburg	OR	43.317	-123.500	310	1123	Vallombrosa	100	9.80	-0.31
Saltillo	MX	27.283	-100.583	2392	1151	Faltona	101	5.63	-1.48
						Vallombrosa	100	8.54	-1.53
Sandy	OR	45.383	-122.300	270	1096	Faltona	101	9.51	0.72
						Vallombrosa	100	11.57	1.40
Scott Bar	CA	41.733	-123.100	1100	1131	Faltona	101	8.29	0.03
						Vallombrosa	100	9.12	-0.97
Shelton	WA	47.250	-123.200	90	1077	Vallombrosa	100	9.79	-0.32
Steamboat	OR	43.367	-122.517	1600	1121	Vallombrosa	100	9.29	-0.81
Upper Soda	OR	44.383	-122.200	990	1102	Vallombrosa	100	9.62	-0.49
Vernonia	OR	45.750	-123.217	210	1094	Faltona	101	9.07	0.47
						Vallombrosa	100	10.35	0.21
Weaversville	CA	40.900	-122.733	1120	1139	Vallombrosa	100	8.81	-1.27
Wildwood	CA	40.383	-123.000	1170	1143	Vallombrosa	100	9.14	-0.95
Willits	CA	39.383	-123.417	550	1148	Faltona	101	7.93	-0.17
						Vallombrosa	100	11.51	1.33
Yale	WA	46.000	-122.367	120	1091	Faltona	101	6.86	-0.78
						Vallombrosa	100	10.96	0.81
Yelm	WA	47.017	-122.733	60	1080	Vallombrosa	100	10.90	0.75

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Netherlands - Kranenborg & de Vries (1995)									
Alberni	BC	49.325	-124.850	140	1036	Sleenerzand	25	10.30	-1.32
						Sprielderbos	29	10.10	-0.40
Cassidy	BC	49.058	-123.950	200	1040	Sleenerzand	25	9.90	-1.96
						Sprielderbos	29	9.70	-0.98
Caycuse	BC	48.924	-124.433	210	1041	Sleenerzand	25	10.70	-0.68
						Sprielderbos	29	10.20	-0.26
Chilliwack 1	BC	49.073	-121.800	170	1039	Sleenerzand	25	11.20	0.12
						Sprielderbos	29	11.00	0.90
Chilliwack 2	BC	49.100	-121.700	910	1038	Sleenerzand	25	11.00	-0.20
						Sprielderbos	29	10.50	0.18
Clackamas, Sandy	OR	45.383	-122.300	270	1096	Sleenerzand	25	11.20	0.12
						Sprielderbos	29	10.90	0.75
Clallam, Forks	WA	47.983	-124.400	90	1062	Sleenerzand	25	12.30	1.88
						Sprielderbos	29	10.40	0.03
Clallam, Lake Crescent	WA	48.067	-124.000	300	1058	Sleenerzand	25	11.10	-0.04
						Sprielderbos	29	10.30	-0.11
Clallam, Louella Gua. Sta.	WA	48.000	-123.083	460	1061	Sleenerzand	25	11.60	0.76
						Sprielderbos	29	10.40	0.03
Clallam, Sequim	WA	48.033	-123.033	60	1060	Sleenerzand	25	9.90	-1.96
						Sprielderbos	29	10.00	-0.54
Courtenay	BC	49.696	-125.064	70	1032	Sleenerzand	25	10.70	-0.68
						Sprielderbos	29	10.40	0.03
Cowlitz, Castle Rock	WA	46.317	-122.867	150	1088	Sleenerzand	25	11.20	0.12
						Sprielderbos	29	10.80	0.61
Cowlitz, Yale	WA	46.000	-122.367	120	1091	Sleenerzand	25	11.10	-0.04
						Sprielderbos	29	11.30	1.33
D'Arcy	BC	50.557	-122.500	270	1021	Sleenerzand	25	9.90	-1.96
						Sprielderbos	29	9.00	-1.98
Dean	BC	50.800	-126.958	20	1002	Sleenerzand	25	11.00	-0.20
						Sprielderbos	29	9.90	-0.69
Duncan	BC	48.750	-123.750	60	1042	Sleenerzand	25	11.00	-0.20
						Sprielderbos	29	10.40	0.03
Forbidden Plat.	BC	49.663	-125.156	610	1033	Sleenerzand	25	11.10	-0.04
						Sprielderbos	29	9.30	-1.55
Franklin River	BC	49.100	-124.767	150	1037	Sleenerzand	25	11.40	0.44
						Sprielderbos	29	10.30	-0.11
Gold River	BC	49.750	-126.067	90	1031	Sleenerzand	25	10.30	-1.32
						Sprielderbos	29	10.20	-0.26
Grays Harbor, Humptulips	WA	47.317	-123.900	140	1073	Sleenerzand	25	11.90	1.24
						Sprielderbos	29	11.80	2.05
Jefferson, Hoh River	WA	47.800	-123.967	240	1064	Sleenerzand	25	12.00	1.40
						Sprielderbos	29	10.90	0.75
Jeune Landing	BC	50.450	-127.450	170	1023	Sleenerzand	25	10.90	-0.36
						Sprielderbos	29	8.90	-2.13
King, Enumclaw	WA	47.267	-121.933	240	1075	Sleenerzand	25	11.60	0.76
King, North Bend	WA	47.467	-121.750	150	1069	Sleenerzand	25	11.70	0.92
						Sprielderbos	29	10.50	0.18

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Klina Klini	BC	51.117	-125.596	5	1012	Sleenerzand	25	10.40	-1.16
						Sprielderbos	29	9.70	-0.98
Lewis, Randle	WA	46.550	-122.050	335	1085	Sleenerzand	25	11.40	0.44
						Sprielderbos	29	10.90	0.75
Mason, Matlock	WA	47.250	-123.417	120	1076	Sleenerzand	25	12.40	2.04
						Sprielderbos	29	11.20	1.19
Mason, Shelton	WA	47.250	-123.200	90	1077	Sleenerzand	25	11.50	0.60
						Sprielderbos	29	10.30	-0.11
Nimpkish	BC	50.317	-126.883	90	1025	Sleenerzand	25	10.80	-0.52
Owl Creek	BC	50.333	-122.725	210	1024	Sleenerzand	25	9.90	-1.96
						Sprielderbos	29	9.10	-1.84
Pacific, Naselle	WA	46.367	-123.733	45	1086	Sleenerzand	25	11.70	0.92
San Juan	BC	48.581	-124.080	210	1043	Sleenerzand	25	10.50	-1.00
						Sprielderbos	29	10.10	-0.40
Sechelt	BC	49.511	-123.882	180	1034	Sleenerzand	25	11.10	-0.04
						Sprielderbos	29	10.60	0.32
Skagit, Marble Mnt	WA	48.583	-121.400	120	1050	Sleenerzand	25	11.30	0.28
Skagit, Sedro Woolley	WA	48.533	-122.317	60	1051	Sleenerzand	25	11.20	0.12
						Sprielderbos	29	11.00	0.90
Snohomish, Arlington	WA	48.217	-122.067	90	1054	Sleenerzand	25	12.20	1.72
						Sprielderbos	29	10.70	0.46
Snohomish, Darrington	WA	48.267	-121.633	150	1053	Sleenerzand	25	12.00	1.40
						Sprielderbos	29	11.10	1.04
Snohomish, Gold Bar	WA	47.850	-121.650	120	1063	Sleenerzand	25	11.40	0.44
						Sprielderbos	29	10.50	0.18
Snohomish, Granite Falls	WA	48.083	-122.033	90	1057	Sleenerzand	25	11.80	1.08
						Sprielderbos	29	11.40	1.47
Sooke	BC	48.400	-123.733	45	1045	Sleenerzand	25	11.00	-0.20
						Sprielderbos	29	10.40	0.03
Squamish	BC	49.778	-123.150	15	1030	Sleenerzand	25	10.90	-0.36
						Sprielderbos	29	11.00	0.90
Stella Lake	BC	50.283	-125.467	150	1026	Sleenerzand	25	11.20	0.12
						Sprielderbos	29	10.00	-0.54
Stuie	BC	52.367	-126.000	16	1004	Sleenerzand	25	10.20	-1.48
						Sprielderbos	29	8.80	-2.27
Thasis	BC	49.792	-126.639	15	1029	Sleenerzand	25	10.40	-1.16
Thurston, Yelm	WA	47.017	-122.733	60	1080	Sleenerzand	25	11.20	0.12
Tillamook, Hebo	OR	45.217	-123.850	150	1098	Sleenerzand	25	11.30	0.28
Upper Soda	OR	44.383	-122.200	993	1102	Sprielderbos	29	9.30	-1.55
Wahkiakum, Cathlamet	WA	46.300	-123.267	195	1089	Sleenerzand	25	11.50	0.60
						Sprielderbos	29	11.20	1.19
Wahkiakum, Skamokawa	WA	46.350	-123.500	210	1087	Sleenerzand	25	11.50	0.60
						Sprielderbos	29	10.60	0.32
Waldport	OR	44.400	-123.867	60	1101	Sprielderbos	29	10.90	0.75
Washington, Vernonia	OR	45.767	-123.217	210	1094	Sleenerzand	25	11.50	0.60
Yamhill, Grande Ronde Ag.	OR	45.100	-123.600	180	1100	Sleenerzand	25	10.90	-0.36
						Sprielderbos	29	10.60	0.32

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Norway - Magnesen (1986)									
Alta (14)	BC	50.200	-122.883	630	1027	Moberglien	5	3.31	0.09
Ashland (51)	OR	42.083	-122.650	1480	1126	Moberglien	5	3.18	-0.06
Babine Lake (43)	BC	54.450	-125.450	820	1107	Moberglien	5	2.19	-1.20
Caycuse (24)	BC	48.917	-124.433	201	1041	Moberglien	5	3.78	0.62
Chilliwack 1 (23)	BC	49.067	-121.800	170	1039	Moberglien	5	4.88	1.89
Chilliwack 2 (22)	BC	49.100	-121.700	910	1038	Moberglien	5	3.92	0.79
Clackamas, Sandy (38)	OR	45.383	-122.300	270	1096	Moberglien	5	3.04	-0.22
Clallam, Louella Gua. Sta. (30)	WA	48.000	-123.083	450	1061	Moberglien	5	2.99	-0.28
Cle Elum (34)	WA	47.217	-121.117	640	1078	Moberglien	5	4.00	0.88
Clinton (46)	BC	51.150	-121.500	1030	1112	Moberglien	5	1.59	-1.89
Courtenay (18)	BC	49.700	-125.067	70	1032	Moberglien	5	4.21	1.12
Dean (1)	BC	52.800	-126.967	6	1002	Moberglien	5	3.45	0.25
Duncan (25)	BC	48.750	-123.750	60	1042	Moberglien	5	3.58	0.40
Forbidden Plat. (19)	BC	49.667	-125.150	600	1033	Moberglien	5	4.63	1.60
Fort St. James (42)	BC	54.483	-124.250	850	1106	Moberglien	5	2.60	-0.73
Franklin River (21)	BC	49.100	-124.767	150	1037	Moberglien	5	4.34	1.27
Gold River (17)	BC	49.750	-126.067	90	1031	Moberglien	5	3.76	0.60
Golden (4)	BC	51.383	-117.000	880	1008	Moberglien	5	2.18	-1.21
Horsefly (45)	BC	52.300	-121.317	820	1111	Moberglien	5	2.16	-1.23
Keechelus Lake (33)	WA	47.383	-121.367	790	1071	Moberglien	5	3.59	0.41
Klina Klini 1 (7)	BC	51.117	-125.600	3	1012	Moberglien	5	4.28	1.20
Klina Klini 2 (6)	BC	51.133	-125.600	150	1011	Moberglien	5	3.27	0.04
Klina Klini 3 (5)	BC	51.233	-125.583	600	1009	Moberglien	5	3.71	0.54
Lewis Packwood (37)	WA	46.567	-121.667	650	1083	Moberglien	5	3.76	0.60
Marion Forks (47)	OR	44.500	-122.000	1060	1117	Moberglien	5	3.53	0.34
Marys Peak (48)	OR	44.500	-123.567	980	1118	Moberglien	5	3.82	0.67
McLeod Lake (41)	BC	54.867	-122.883	760	1105	Moberglien	5	2.85	-0.44
Merritt (15)	BC	50.067	-120.850	880	1028	Moberglien	5	2.06	-1.35
Nelson (20)	BC	49.500	-117.267	820	1035	Moberglien	5	2.61	-0.72
Nimpkish (13)	BC	50.317	-126.883	90	1025	Moberglien	5	4.58	1.54
Oakridge (49)	OR	43.900	-122.367	880	1120	Moberglien	5	3.11	-0.14
Owl Creek (12)	BC	50.333	-122.733	210	1024	Moberglien	5	3.57	0.38
Parkway (35)	WA	47.033	-121.567	730	1079	Moberglien	5	3.58	0.40
Pillar Lake (11)	BC	50.583	-119.633	910	1020	Moberglien	5	2.11	-1.29
Pine Grove (39)	OR	45.100	-121.383	730	1099	Moberglien	5	3.68	0.51
Republic (26)	WA	48.600	-118.733	730	1048	Moberglien	5	1.29	-2.23
Revelstoke (8)	BC	51.000	-118.200	600	1013	Moberglien	5	2.61	-0.72
Rimrock (36)	WA	46.667	-121.033	760	1082	Moberglien	5	2.59	-0.74
Salmon Arm (10)	BC	50.733	-119.217	470	1018	Moberglien	5	3.45	0.25
Scenic (32)	WA	47.717	-121.133	940	1066	Moberglien	5	3.84	0.69
Sloan Creek (29)	WA	48.083	-121.300	650	1056	Moberglien	5	2.83	-0.47
Snohomish, Darrington (28)	WA	48.267	-121.633	150	1053	Moberglien	5	3.80	0.65
Spokane (31)	WA	47.783	-117.200	600	1065	Moberglien	5	2.08	-1.33
Squilax (9)	BC	50.833	-119.567	580	1017	Moberglien	5	2.50	-0.84
Steamboat (50)	OR	43.367	-122.517	1590	1121	Moberglien	5	3.21	-0.03
Stuie (2)	BC	52.367	-126.000	230	1004	Moberglien	5	4.71	1.69
Tatla (3)	BC	51.733	-124.733	880	1006	Moberglien	5	2.34	-1.03

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Thasis (16)	BC	49.800	-126.633	15	1029	Moberglien	5	4.07	0.96
Twisp (27)	WA	48.383	-120.400	790	1052	Moberglien	5	1.76	-1.69
Upper Soda (40)	OR	44.383	-122.200	980	1102	Moberglien	5	3.99	0.87
Wansa Lake (44)	BC	53.767	-122.100	880	1108	Moberglien	5	2.04	-1.37
Poland - Birot & Burzynski (1981)									
Alder Lake	WA	46.800	-122.283	430	1081	Dolice	31	2.11	0.54
Arlington	WA	48.217	-122.067	100	1054	Dolice	31	2.36	1.39
Bacon Point	WA	48.583	-121.383	550	1049	Dolice	31	2.13	0.60
Brookings	OR	42.117	-124.200	330	1104	Dolice	31	1.62	-1.14
Cherryville	OR	45.317	-122.133	700	1097	Dolice	31	2.16	0.71
Cle Elum	WA	47.217	-121.117	700	1078	Dolice	31	1.76	-0.66
D'Arcy	BC	50.550	-123.050	300	1021	Dolice	31	2.01	0.19
Merritt	BC	50.067	-120.850	950	1028	Dolice	31	1.44	-1.75
Perry Creek	WA	48.133	-121.467	700	1059	Dolice	31	2.08	0.43
Salmon Arm	BC	50.733	-119.217	500	1018	Dolice	31	1.77	-0.62
Skykomish	WA	47.700	-121.033	230	1067	Dolice	31	2.17	0.74
Stella Lake	BC	50.283	-125.467	160	1026	Dolice	31	2.28	1.12
Upper Soda	OR	44.383	-122.200	1150	1102	Dolice	31	1.98	0.09
Williams Lake	BC	52.100	-122.000	630	1005	Dolice	31	1.47	-1.65
Poland - Mejnartowicz (1999)									
Cherryville (879-97 II.3/2)	OR	45.317	-122.300	210	-	Karcz	32	0.91	-0.23
Chilliwack (848-38 I.1/3)	BC	49.073	-121.800	170	-	Karcz	32	1.03	0.36
Chilliwack (849-38 I.1/2)	BC	49.073	-121.800	170	-	Karcz	32	0.76	-1.00
Chilliwack (850-39 V. 3/1)	BC	49.073	-121.800	170	-	Karcz	32	1.13	0.86
Chilliwack (851-39 II.2/2)	BC	49.073	-121.800	170	-	Karcz	32	1.41	2.24
Clearwater (826-7 I.1/1)	BC	51.657	-120.000	450	-	Karcz	32	0.72	-1.19
Clearwater (827-7 II.1/2)	BC	51.657	-120.000	450	-	Karcz	32	0.85	-0.58
Clearwater (828-7 IV. 4/3)	BC	51.657	-120.000	450	-	Karcz	32	0.71	-1.23
Clearwater (829-7 II.3/4)	BC	51.657	-120.000	450	-	Karcz	32	0.78	-0.92
Dean (822-2 I.2/3)	BC	50.800	-126.958	20	-	Karcz	32	0.88	-0.38
Glenwood (865-92 I.1/5)	WA	46.000	-121.017	480	-	Karcz	32	1.02	0.28
Glenwood (866-92 V.1/2)	WA	46.000	-121.017	480	-	Karcz	32	1.04	0.38
Glenwood (867-92 III.4/1)	WA	46.000	-121.017	480	-	Karcz	32	0.88	-0.40
Glenwood (868-92 II.3/5)	WA	46.000	-121.017	480	-	Karcz	32	1.03	0.33
Glenwood (869-92 IV.4/3)	WA	46.000	-121.017	480	-	Karcz	32	0.81	-0.77
Granite Falls (854-57 I.5/2)	WA	48.083	-122.033	90	-	Karcz	32	1.36	2.03
Keechelus Lak (861-71 1.5/1)	WA	47.383	-121.367	790	-	Karcz	32	1.10	0.71
North Bend (860-69 I.1/1)	WA	47.467	-121.750	150	-	Karcz	32	1.18	1.13
Prindle (872-95 I.2/1)	WA	45.617	-122.133	460	-	Karcz	32	0.88	-0.39
Prindle (873-95 I.2/5)	WA	45.617	-122.133	460	-	Karcz	32	1.18	1.10
Prindle (874-95 I.4/1)	WA	45.617	-122.133	460	-	Karcz	32	1.01	0.25
Prindle (877-95 I.4/2)	WA	45.617	-122.133	460	-	Karcz	32	0.94	-0.09
Prindle (878-95 II.5/5)	WA	45.617	-122.133	460	-	Karcz	32	1.08	0.60
Salmon Arm (842-18 1.5/2)	BC	50.733	-119.217	470	-	Karcz	32	0.83	-0.66
Salmon Arm (844-18 III.5/3)	BC	50.733	-119.217	470	-	Karcz	32	1.02	0.30
Squamish (847-30 II.5/4)	BC	49.778	-123.150	15	-	Karcz	32	1.13	0.87
Squilax (840-17 I.4/1)	BC	50.833	-119.567	580	-	Karcz	32	0.70	-1.33
Squilax (841-17 III.3/2)	BC	50.833	-119.567	580	-	Karcz	32	0.56	-2.02

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Willard (870-93 IV.1/2)	WA	45.800	-121.683	495	-	Karcz	32	0.74	-1.10
Willard (871-93 I.4/4)	WA	45.800	-121.683	495	-	Karcz	32	1.13	0.84
Romania - Popa-Costea et al. (1973)									
5-3 Camano-Island (1)	WA	48.250	-122.333	15	-	Zaicani	113	2.46	-0.65
6-7 Glacier (2)	WA	48.833	-122.000	270	-	Dobra	116	2.46	0.40
						Fintinele	112	1.29	0.71
						Onofrea	115	2.28	1.15
						Zaicani	113	2.65	1.52
6-9 Stevens-Pass (3)	WA	47.750	-121.083	1100	-	Fintinele	112	1.16	-0.71
						Onofrea	115	2.18	-0.49
						Zaicani	113	2.42	-1.11
7-6 Tenino (4)	WA	46.750	-122.667	200	-	Dobra	116	2.56	0.64
						Turnu Rueni	114	3.06	0.71
7-7 Lewis (5)	WA	46.750	-123.250	300	-	Zaicani	113	2.51	-0.08
8-3 Palmer (6)	WA	45.833	-122.250	25	-	Zaicani	113	2.43	-1.00
8-8 Cottage-Grove (8)	OR	43.833	-123.000	450	-	Dobra	116	2.43	0.32
						Turnu Rueni	114	2.99	-0.71
9-5 Jackson (9)	OR	42.500	-122.500	800	-	Dobra	116	2.47	0.42
						Onofrea	115	2.17	-0.66
						Zaicani	113	2.60	0.95
B 1-2 Courtenay (11)	BC	50.250	-125.250	65	-	Zaicani	113	2.55	0.38
B 2-2 Shuswap-Lake (10)	BC	50.833	-119.167	335	-	Dobra	116	1.56	-1.78
Serbia - Isajev & Lavadinovi (2007)									
New Mexico - 14 (14)	NM	35.000	-105.700	2682	-	Juhor	110	3.94	-0.73
						Tanda	109	3.94	0.00
New Mexico - 15 (15)	NM	36.000	-106.000	2667	-	Juhor	110	3.70	-1.01
						Tanda	109	3.46	-0.58
Oregon - 8 (8)	OR	42.500	-122.500	1200	-	Juhor	110	4.72	0.18
						Tanda	109	3.91	-0.04
Oregon - 17 (17)	OR	42.600	-122.800	900	-	Juhor	110	4.86	0.34
						Tanda	109	3.98	0.05
Oregon - 18 (18)	OR	42.700	-122.500	1050	-	Juhor	110	4.63	0.07
						Tanda	109	3.46	-0.58
Oregon - 1 (1)	OR	43.700	-123.000	750	-	Juhor	110	5.16	0.69
						Tanda	109	3.90	-0.05
Oregon - 6 (6)	OR	43.800	-122.500	1050	-	Juhor	110	5.06	0.58
						Tanda	109	4.20	0.31
Oregon - 2 (2)	OR	43.800	-122.500	1200	-	Juhor	110	5.17	0.70
						Tanda	109	4.01	0.08
Oregon - 7 (7)	OR	44.200	-122.200	600	-	Juhor	110	5.24	0.79
						Tanda	109	4.63	0.83
Oregon - 16 (16)	OR	44.300	-118.800	1500	-	Juhor	110	2.86	-2.00
						Tanda	109	2.39	-1.87
Oregon - 10 (10)	OR	44.500	-119.000	1350	-	Juhor	110	3.53	-1.21
						Tanda	109	2.98	-1.16
Oregon - 3 (3)	OR	45.000	-122.400	450	-	Juhor	110	5.58	1.18
						Tanda	109	4.81	1.05
Oregon - 19 (19)	OR	45.000	-121.500	900	-	Juhor	110	4.69	0.14

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Oregon - 19 (19)	OR	45.000	-121.500	900	-	Tanda	109	3.67	-0.33
Oregon - 4 (4)	OR	45.000	-121.000	600	-	Juhor	110	4.99	0.49
						Tanda	109	4.77	1.00
Oregon - 12 (12)	OR	45.300	-123.800	300	-	Juhor	110	5.37	0.94
						Tanda	109	4.84	1.08
Oregon - 13 (13)	OR	45.300	-123.000	150	-	Juhor	110	5.10	0.62
						Tanda	109	4.75	0.98
Washington - 9 (9)	WA	47.600	-121.700	600	-	Juhor	110	5.16	0.69
						Tanda	109	4.31	0.44
Washington - 20 (20)	WA	47.700	-123.000	300	-	Juhor	110	5.29	0.84
						Tanda	109	5.47	1.84
Washington - 11 (11)	WA	49.000	-120.000	750	-	Juhor	110	3.48	-1.27
						Tanda	109	2.82	-1.35
Washington - 5 (5)	WA	49.000	-119.000	1200	-	Juhor	110	2.82	-2.04
						Tanda	109	2.53	-1.70
Serbia - Popovic et al. (2001)									
Benton Creek (13)	BC	49.200	-117.417	933	-	Sremcica	108	2.17	0.04
Cooke Creek (12)	BC	50.633	-118.817	900	-	Sremcica	108	2.95	1.44
Cranbrook (1)	BC	49.417	-115.333	1050	-	Sremcica	108	1.88	-0.48
Gavia Lake (4)	BC	50.933	-116.583	1070	-	Sremcica	108	2.18	0.04
Inonoaklin (2)	BC	49.833	-118.167	671	-	Sremcica	108	3.13	1.76
Mann Creek (3)	BC	51.583	-120.167	600	-	Sremcica	108	2.72	1.02
Mara Lk (9)	BC	50.800	-119.000	488	-	Sremcica	108	2.83	1.22
Michell Cr (7)	BC	49.900	-119.617	1035	-	Sremcica	108	1.58	-1.03
Monte Crk (10)	BC	50.617	-119.867	701	-	Sremcica	108	1.93	-0.39
Nine Bay (5)	BC	50.967	-115.533	975	-	Sremcica	108	1.82	-0.59
Salmo (8)	BC	49.250	-117.500	793	-	Sremcica	108	1.46	-1.24
Sheep Creek (11)	BC	49.167	-117.250	1000	-	Sremcica	108	2.22	0.13
Sun Creek (14)	BC	50.133	-115.867	1000	-	Sremcica	108	1.75	-0.73
Trout Cr (6)	BC	49.667	-119.867	884	-	Sremcica	108	1.49	-1.19
Slovakia - Holubcik (1983)									
Alberni	BC	49.317	-124.850	450	1036	Kmetova	62	0.64	0.13
Alder Lake	WA	46.800	-122.283	1400	1081	Kmetova	62	0.40	-1.46
Bacon Point	WA	48.600	-121.383	1650	1049	Kmetova	62	0.76	0.85
Barrier	BC	51.200	-120.167	1400	1010	Kmetova	62	0.57	-0.32
Cathlamet	WA	46.300	-123.267	700	1089	Kmetova	62	0.63	0.06
Cle Elum	WA	47.217	-121.117	2100	1078	Kmetova	62	0.40	-1.43
D'Arcy	BC	50.550	-122.500	900	1021	Kmetova	62	0.64	0.13
Enumclaw	WA	47.267	-121.933	800	1075	Kmetova	62	0.86	1.55
Forbidden Pl.	BC	49.667	-125.150	2000	1033	Kmetova	62	0.65	0.20
Grand Ronde A.	OR	45.100	-123.600	600	1100	Kmetova	62	0.62	0.00
Klina Klini	BC	51.200	-125.600	10	1012	Kmetova	62	0.61	-0.10
Louella G. Sta.	WA	48.000	-123.000	1500	1061	Kmetova	62	0.65	0.17
Marblemount	WA	48.583	-121.400	400	1050	Kmetova	62	0.80	1.10
Merritt	BC	50.067	-120.850	2850	1028	Kmetova	62	0.25	-2.38
Nimkish	BC	50.317	-126.883	300	1025	Kmetova	62	0.61	-0.07
North Bend	WA	47.467	-121.750	152	1069	Kmetova	62	0.79	1.09
San Juan	BC	48.583	-124.083	700	1043	Kmetova	62	0.63	0.02

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Skykomish	WA	47.700	-121.333	1000	1067	Kmetova	62	0.64	0.08
Squamish	BC	49.783	-123.150	50	1030	Kmetova	62	0.80	1.13
Stuie	BC	52.367	-126.000	750	1004	Kmetova	62	0.75	0.82
Upper Soda	OR	44.383	-122.200	3250	1102	Kmetova	62	0.38	-1.57
<u>Spain - Hernandez et al. (1993)</u>									
Alexandria (3)	BC	52.690	-122.430	730	1003	Regavella	87	0.35	-1.13
Arcata 1 (138)	CA	40.920	-123.830	520	1138	Confercal	92	1.88	0.14
						Regavella	87	0.44	0.12
Arcata 2 (140)	CA	40.900	-123.770	885	1140	Bande	97	8.85	1.06
Arlington (54)	WA	48.220	-122.070	90	1054	Confercal	92	2.07	0.71
						Fragavella	86	0.51	1.25
Ashland (126)	OR	42.080	-122.650	1495	1126	Regavella	87	0.39	-0.57
Big Bar 1 (141)	CA	40.780	-123.200	1370	1141	Confercal	92	1.49	-1.03
Big Bar 2 (142)	CA	40.720	-123.300	990	1142	Confercal	92	1.65	-0.55
						SalinasdeLeniz	96	1.04	-0.35
						Valdemadeiro	90	0.62	0.00
Big River (NP)	CA	39.320	-123.620	60	-	LaGallina	91	1.38	0.52
						LaVecilla	95	0.68	-1.38
						Valdemadeiro	90	0.63	0.09
Brookings (104)	OR	42.120	-124.200	365	1104	Bande	97	3.65	-0.43
						Gamalleira	89	1.23	0.61
						Regavella	87	0.39	-0.57
						SalinasdeLeniz	96	1.05	-0.26
Burnt Woods (116)	OR	44.600	-123.700	335	1116	Fragavella	86	0.44	0.63
						SalinasdeLeniz	96	0.88	-1.82
Cassidy (40)	BC	49.060	-123.950	200	1040	Bande	97	2.00	-0.90
						Confercal	92	1.75	-0.25
						Gamalleira	89	0.90	-0.45
						SalinasdeLeniz	96	1.10	0.20
						Valdemadeiro	90	0.58	-0.33
Castle Rock (88)	WA	46.320	-122.870	150	1088	Gamalleira	89	1.19	0.48
						LaGallina	91	1.47	0.80
Cathlamet (89)	WA	46.300	-123.270	245	1089	CastroDozon	94	0.88	0.49
						Confercal	92	1.88	0.14
						LaVecilla	95	1.02	0.26
						SalinasdeLeniz	96	1.06	-0.17
						Valdemadeiro	90	0.70	0.67
Cave Junction (125)	OR	42.180	-123.670	455	1125	Fragavella	86	0.52	1.34
						Regavella	87	0.40	-0.44
						Valdemadeiro	90	0.69	0.59
Cherryville (97)	OR	45.320	-122.130	730	1097	Bande	97	7.30	0.62
						SalinasdeLeniz	96	1.20	1.11
Chester Morse (72)	WA	47.370	-121.670	670	1072	CastroDozon	94	0.87	0.43
						LaVecilla	95	1.14	0.84
Chilliwack (39)	BC	49.070	-121.800	170	1039	Confercal	92	2.68	2.54
						Fragavella	86	0.43	0.54
						Gamalleira	89	1.48	1.41
						SalinasdeLeniz	96	1.19	1.02

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Chilliwack (39)	BC	49.070	-121.800	170	1039	Valdemadeiro	90	0.68	0.50
Chiwaukum (68)	WA	47.680	-120.730	550	1068	Confercal	92	1.44	-1.17
						LaGallina	91	0.75	-1.50
Cle Elum (78)	WA	47.220	-121.120	640	1078	Bande	97	6.40	0.36
						Confercal	92	1.61	-0.67
						Gamalleira	89	0.79	-0.80
						LaGallina	91	0.80	-1.34
Coquille (103)	OR	43.200	-124.170	120	1103	Fragavella	86	0.52	1.34
						Regavella	87	0.47	0.53
Courtenay (32)	BC	49.700	-125.060	65	1032	Gamalleira	89	1.31	0.87
						Regavella	87	0.49	0.81
Covelo 1 (144)	CA	39.920	-123.300	915	1144	Bande	97	9.15	1.15
						Regavella	87	0.33	-1.40
Covelo 2 (145)	CA	39.800	-122.930	1555	1145	LaGallina	91	0.89	-1.06
						Valdemadeiro	90	0.56	-0.50
Darrington (53)	WA	48.270	-121.630	150	1053	LaVecilla	95	0.98	0.07
						SalinasdeLeniz	96	0.94	-1.27
						Valdemadeiro	90	0.86	2.01
Dunsmuir (136)	CA	41.200	-122.300	1005	1136	Fragavella	86	0.43	0.54
Eagle Bay (14)	BC	50.930	-119.220	490	1014	SierradeMeira	88	0.45	-0.83
Enumclaw (75)	WA	47.270	-121.930	245	1075	SierradeMeira	88	0.70	1.41
						Valdemadeiro	90	0.65	0.25
Eugene (119)	OR	44.020	-123.380	215	1119	Regavella	87	0.44	0.12
Forks (62)	WA	47.980	-124.400	90	1062	LaGallina	91	1.50	0.90
Fort Bragg (147)	CA	39.500	-123.720	60	1147	Fragavella	86	0.34	-0.26
						SalinasdeLeniz	96	1.05	-0.26
Fresh Pond (KB)	CA	38.760	-120.540	1250	-	Confercal	92	1.68	-0.46
						Gamalleira	89	0.82	-0.71
						LaGallina	91	1.21	-0.03
						Valdemadeiro	90	0.54	-0.66
Gasquet (128)	CA	41.850	-123.980	12	1128	Fragavella	86	0.38	0.10
						SierradeMeira	88	0.58	0.33
Georgetown (NK)	CA	38.920	-120.750	855	-	Bande	97	8.55	0.97
						Valdemadeiro	90	0.36	-2.16
Glenwood (92)	WA	46.000	-121.170	490	1092	Fragavella	86	0.35	-0.17
Gold bar (63)	WA	47.850	-121.650	120	1063	Gamalleira	89	1.19	0.48
Gold River (31)	BC	49.750	-126.070	90	1031	Fragavella	86	0.42	0.45
Grand Ronde (100)	OR	45.100	-123.600	215	1100	Fragavella	86	0.22	-1.32
						SalinasdeLeniz	96	0.95	-1.18
Happy Camp 1 (127)	CA	41.950	-123.500	975	1127	Regavella	87	0.37	-0.85
Happy Camp 2 (133)	CA	41.650	-123.520	1250	1133	Gamalleira	89	0.75	-0.93
Hawkinsville (130)	CA	41.780	-123.670	1065	1130	Bande	97	10.65	1.57
Hebo (98)	OR	45.220	-123.850	185	1098	Bande	97	1.85	-0.94
						Gamalleira	89	1.29	0.80
						Valdemadeiro	90	0.66	0.34
Hoh River (64)	WA	47.800	-123.970	245	1064	Bande	97	2.45	-0.77
						Fragavella	86	0.43	0.54
						SierradeMeira	88	0.63	0.78

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Hoh River (64)	WA	47.800	-123.970	245	1064	Valdemadeiro	90	0.40	-1.83
Humptulips (73)	WA	47.320	-123.900	135	1073	Fragavella	86	0.41	0.36
						Regavella	87	0.44	0.12
						SalinasdeLeniz	96	1.20	1.11
						SierradeMeira	88	0.57	0.24
Lake Crescent (58)	WA	48.070	-124.000	305	1058	Fragavella	86	0.34	-0.26
Louella GS (61)	WA	48.000	-123.080	455	1061	SierradeMeira	88	0.51	-0.29
Marblemount (50)	WA	48.580	-121.400	120	1050	LaGallina	91	1.29	0.23
Marys Peak (118)	OR	44.500	-123.570	1005	1118	Confercal	92	2.03	0.59
Matlock (76)	WA	47.250	-123.420	120	1076	Bande	97	1.20	-1.13
						Gamalleira	89	1.26	0.71
Mill City (113)	OR	44.800	-122.700	170	1113	Valdemadeiro	90	0.75	1.09
Mt St Helena (150)	CA	38.670	-122.600	760	1150	LaGallina	91	1.27	0.16
						Regavella	87	0.38	-0.71
Naselle (86)	WA	46.370	-123.730	60	1086	Fragavella	86	0.31	-0.52
						LaVecilla	95	0.75	-1.04
						Regavella	87	0.57	1.92
						SalinasdeLeniz	96	1.13	0.47
Oakridge (120)	OR	43.900	-122.370	885	1120	Regavella	87	0.40	-0.44
Owl Creek (24)	BC	50.330	-122.720	215	1024	Bande	97	2.15	-0.86
						SierradeMeira	88	0.38	-1.46
Perry creek (59)	WA	48.050	-121.470	640	1059	Bande	97	6.40	0.36
Pine Grove (99)	OR	45.100	-121.380	730	1099	Bande	97	7.30	0.62
						Fragavella	86	0.22	-1.32
Prindle (95)	WA	45.620	-122.130	455	1095	CastroDozon	94	0.89	0.54
						Gamalleira	89	1.05	0.03
						SalinasdeLeniz	96	1.28	1.85
						SierradeMeira	88	0.48	-0.56
Randle (85)	WA	46.550	-122.050	335	1085	LaGallina	91	1.30	0.26
Republic (48)	WA	48.600	-118.730	730	1048	Fragavella	86	0.12	-2.20
						Gamalleira	89	0.23	-2.60
Rimrock (82)	WA	46.670	-121.030	760	1082	LaGallina	91	0.98	-0.77
						LaVecilla	95	0.75	-1.04
						SierradeMeira	88	0.35	-1.73
Saltillo (151)	MX	25.280	-100.580	2515	1151	Fragavella	86	0.35	-0.17
Sandy (96)	OR	45.380	-122.300	275	1096	Confercal	92	2.11	0.83
						LaGallina	91	1.79	1.83
						SalinasdeLeniz	96	1.08	0.01
Sawyers Bar 1 (134)	CA	41.280	-123.130	1190	1134	Bande	97	11.90	1.93
Scott Bar (131)	CA	41.730	-123.100	1035	1131	Confercal	92	1.53	-0.91
						Regavella	87	0.38	-0.71
Sechelt (34)	BC	49.510	-123.880	185	1034	Confercal	92	2.04	0.62
						Gamalleira	89	1.25	0.67
Sedro Woo lley (51)	WA	48.530	-122.320	60	1051	Gamalleira	89	1.20	0.51
						LaVecilla	95	1.05	0.41
						Regavella	87	0.57	1.92
Seiad Valley (129)	CA	41.800	-123.000	855	1129	Regavella	87	0.35	-1.13
						SierradeMeira	88	0.47	-0.65

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Seiad Valley (129)	CA	41.800	-123.000	855	1129	Valdemadeiro	90	0.63	0.09
Sequim (60)	WA	48.030	-123.030	90	1060	Bande	97	0.90	-1.21
						Confercal	92	1.90	0.20
Shelton (77)	WA	47.250	-123.200	90	1077	LaVecilla	95	1.32	1.71
Sooke (45)	BC	48.400	-123.730	45	1045	Regavella	87	0.53	1.36
Spokane (65)	WA	47.780	-117.200	670	1065	Bande	97	6.70	0.44
						Fragavella	86	0.18	-1.67
Ukiah (NO)	CA	39.200	-123.350	490	-	Bande	97	4.90	-0.07
						CastroDozon	94	0.45	-1.78
						Confercal	92	1.55	-0.85
						Gamalleira	89	0.59	-1.45
						Valdemadeiro	90	0.55	-0.58
Upper Soda (102)	OR	44.380	-122.200	1065	1102	Gamalleira	89	0.87	-0.55
						Valdemadeiro	90	0.53	-0.75
Vernonia (94)	OR	45.770	-123.220	215	1094	Fragavella	86	0.46	0.81
						SierradeMeira	88	0.54	-0.03
Waldport (101)	OR	44.400	-123.870	90	1101	Bande	97	0.90	-1.21
						Gamalleira	89	1.37	1.06
						Valdemadeiro	90	0.78	1.34
Weaverville (139)	CA	40.900	-122.730	1190	1139	Confercal	92	1.40	-1.29
Wildwood (143)	CA	40.380	-123.000	1190	1143	Gamalleira	89	0.71	-1.06
						SierradeMeira	88	0.56	0.15
Willard (93)	WA	45.800	-121.680	550	1093	Valdemadeiro	90	0.60	-0.16
Willits (148)	CA	39.380	-123.420	550	1148	Regavella	87	0.52	1.22
						SierradeMeira	88	0.71	1.50
Wolf Creek (124)	OR	42.680	-123.380	425	1124	Bande	97	4.25	-0.26
						Regavella	87	0.42	-0.16
Yale (91)	WA	46.000	-122.370	120	1091	Confercal	92	2.29	1.37
						Gamalleira	89	1.34	0.96
						LaVecilla	95	1.00	0.17
Yelm (80)	WA	47.020	-122.730	60	1080	Bande	97	0.60	-1.30
						CastroDozon	94	0.85	0.33
						Gamalleira	89	1.03	-0.03
						SalinasdeLeniz	96	1.03	-0.45
						SierradeMeira	88	0.67	1.14
Spain - Toval (1985)									
Alexandria	BC	52.692	-122.433	715	1003	LaHermida	93	0.34	-2.41
						SierradelEje	98	0.26	-1.38
Arcata 1	CA	40.917	-123.917	490	1138	LaHermida	93	0.68	0.04
						SierradelEje	98	0.40	0.20
Arcata 2	CA	40.900	-123.767	880	1140	LaHermida	93	0.71	0.27
						SierradelEje	98	0.36	-0.27
Ashland	OR	42.083	-122.650	1480	1126	LaHermida	93	0.53	-1.04
						SierradelEje	98	0.29	-1.05
Big Bar 1	CA	40.717	-123.300	1070	1142	LaHermida	93	0.57	-0.75
						SierradelEje	98	0.34	-0.48
Big Bar 2	CA	40.783	-123.200	1300	1141	LaHermida	93	0.54	-0.93
						SierradelEje	98	0.32	-0.76

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Brookings	OR	42.117	-124.200	300	1104	LaHermida	93	0.82	1.07
						SierradelEje	98	0.35	-0.40
Burney	CA	41.083	-121.650	1100	1137	LaHermida	93	0.53	-1.02
						SierradelEje	98	0.26	-1.40
Burnt Woods	OR	44.600	-123.700	319	1116	LaHermida	93	0.74	0.48
						SierradelEje	98	0.41	0.26
Cassidy	BC	49.058	-123.950	200	1040	LaHermida	93	0.84	1.20
						SierradelEje	98	0.42	0.38
Cave Junction	OR	42.183	-123.667	460	1125	LaHermida	93	0.67	-0.03
						SierradelEje	98	0.45	0.73
Cherryville	OR	45.317	-122.300	210	1097	LaHermida	93	0.71	0.29
						SierradelEje	98	0.36	-0.26
Chester morse lake	WA	47.367	-121.667	665	1072	LaHermida	93	0.93	1.81
						SierradelEje	98	0.51	1.42
Chilliwack	BC	49.073	-121.800	170	1039	LaHermida	93	0.67	-0.04
						SierradelEje	98	0.36	-0.30
Chiwaukum	WA	47.683	-120.733	600	1068	LaHermida	93	0.52	-1.08
						SierradelEje	98	0.34	-0.53
Clackamas, Sandy	OR	45.383	-122.300	270	1096	LaHermida	93	0.89	1.52
						SierradelEje	98	0.39	0.05
Clallam, Forks	WA	47.983	-124.400	90	1062	LaHermida	93	0.80	0.89
						SierradelEje	98	0.44	0.62
Clallam, Lake Crescent	WA	48.067	-124.000	300	1058	LaHermida	93	0.64	-0.26
						SierradelEje	98	0.49	1.18
Clallam, Louella Gua. Sta.	WA	48.000	-123.083	460	1061	LaHermida	93	0.64	-0.22
						SierradelEje	98	0.26	-1.42
Clallam, Sequim	WA	48.033	-123.033	60	1060	LaHermida	93	0.67	-0.05
						SierradelEje	98	0.44	0.56
Cle Elum	WA	47.217	-121.117	640	1078	LaHermida	93	0.62	-0.36
						SierradelEje	98	0.39	0.06
Coquille	OR	43.200	-124.167	60	1103	LaHermida	93	0.55	-0.85
						SierradelEje	98	0.42	0.34
Corvallis	OR	44.700	-123.217	80	1115	LaHermida	93	0.85	1.28
						SierradelEje	98	0.54	1.71
Courtenay	BC	49.696	-125.064	70	1032	LaHermida	93	0.93	1.80
						SierradelEje	98	0.37	-0.15
Covelo 2	CA	39.800	-122.933	1550	1145	LaHermida	93	0.60	-0.55
						SierradelEje	98	0.41	0.26
Covelo 1	CA	39.917	-123.300	1555	1144	LaHermida	93	0.63	-0.34
						SierradelEje	98	0.28	-1.21
Cowlitz, Castle Rock	WA	46.317	-122.867	150	1088	LaHermida	93	0.79	0.83
						SierradelEje	98	0.26	-1.39
Cowlitz, Yale	WA	46.000	-122.367	120	1091	LaHermida	93	1.06	2.76
						SierradelEje	98	0.41	0.25
Detroit	OR	44.733	-122.167	480	1114	LaHermida	93	0.65	-0.16
						SierradelEje	98	0.43	0.47
Dunsmuir	CA	41.200	-122.300	1100	1136	LaHermida	93	0.81	0.96
						SierradelEje	98	0.37	-0.22

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Eagle Bay	BC	50.933	-119.217	480	1014	LaHermida	93	0.44	-1.66
						SierradelEje	98	0.30	-0.94
Eugene	OR	44.017	-123.383	210	1119	LaHermida	93	0.71	0.26
						SierradelEje	98	0.41	0.25
Fort Bragg	CA	39.500	-123.717	65	1147	LaHermida	93	0.76	0.60
						SierradelEje	98	0.35	-0.45
Gasquet	CA	41.850	-123.983	120	1128	LaHermida	93	0.67	-0.05
						SierradelEje	98	0.38	-0.08
Glenwood	WA	46.000	-121.167	530	1092	LaHermida	93	0.64	-0.27
						SierradelEje	98	0.44	0.56
Gold River	BC	49.750	-126.067	90	1031	LaHermida	93	0.61	-0.46
						SierradelEje	98	0.28	-1.14
Grays Harbor, Humptulips	WA	47.317	-123.900	140	1073	LaHermida	93	0.95	2.00
						SierradelEje	98	0.45	0.70
Happy Camp 1	CA	41.950	-123.500	1065	1127	LaHermida	93	0.55	-0.90
						SierradelEje	98	0.26	-1.46
Happy Camp 2	CA	41.650	-123.517	1250	1133	LaHermida	93	0.41	-1.90
						SierradelEje	98	0.30	-0.92
Hawkinsville	CA	41.783	-122.667	1165	1130	LaHermida	93	0.46	-1.55
						SierradelEje	98	0.17	-2.43
Jefferson, Hoh River	WA	47.800	-123.967	240	1064	LaHermida	93	0.72	0.36
						SierradelEje	98	0.53	1.63
King, Enumclaw	WA	47.267	-121.933	240	1075	LaHermida	93	0.56	-0.82
						SierradelEje	98	0.41	0.26
Lewis, Randle	WA	46.550	-122.050	335	1085	LaHermida	93	0.68	0.02
						SierradelEje	98	0.42	0.37
Lower Lake	CA	38.833	-122.700	960	1149	LaHermida	93	0.54	-0.94
						SierradelEje	98	0.49	1.21
Marys Peak	OR	44.500	-123.567	980	1118	LaHermida	93	0.57	-0.73
						SierradelEje	98	0.59	2.24
Mason, Matlock	WA	47.250	-123.417	120	1076	LaHermida	93	0.75	0.52
						SierradelEje	98	0.29	-1.04
Mason, Shelton	WA	47.250	-123.200	90	1077	LaHermida	93	1.00	2.35
						SierradelEje	98	0.35	-0.40
Mill City	OR	44.800	-122.700	150	1113	LaHermida	93	0.97	2.12
						SierradelEje	98	0.60	2.40
Oakridge	OR	43.900	-122.367	880	1120	LaHermida	93	0.53	-0.99
						SierradelEje	98	0.31	-0.87
Owl Creek	BC	50.333	-122.725	210	1024	LaHermida	93	0.52	-1.06
						SierradelEje	98	0.44	0.60
Pacific, Naselle	WA	46.367	-123.733	45	1086	LaHermida	93	0.67	-0.01
						SierradelEje	98	0.36	-0.29
Packwood	WA	46.567	-121.700	330	1084	LaHermida	93	0.69	0.09
						SierradelEje	98	0.50	1.27
Perry creek	WA	48.050	-121.467	665	1059	LaHermida	93	0.67	-0.01
						SierradelEje	98	0.38	-0.12
Pine Grove	OR	45.100	-121.383	730	1099	LaHermida	93	0.48	-1.35
						SierradelEje	98	0.26	-1.36

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Prindle	WA	45.617	-122.133	500	1095	LaHermida	93	0.83	1.15
						SierradelEje	98	0.38	-0.08
Republic	WA	48.600	-118.733	730	1048	LaHermida	93	0.49	-1.32
						SierradelEje	98	0.14	-2.78
Rimrock	WA	46.667	-121.033	760	1082	LaHermida	93	0.54	-0.99
						SierradelEje	98	0.32	-0.79
Roseburg	OR	43.317	-123.500	310	1123	LaHermida	93	0.69	0.11
						SierradelEje	98	0.40	0.13
Saltillo	MX	27.283	-100.583	2392	1151	LaHermida	93	0.63	-0.29
						SierradelEje	98	0.26	-1.40
Sawyers Bar 1	CA	41.283	-123.133	1265	1134	SierradelEje	98	0.32	-0.71
Sawyers Bar 2	CA	41.267	-123.150	1583	1135	LaHermida	93	0.58	-0.68
						SierradelEje	98	0.41	0.29
Scott Bar	CA	41.733	-123.100	1100	1131	LaHermida	93	0.55	-0.90
						SierradelEje	98	0.46	0.81
Sechelt	BC	49.511	-123.882	180	1034	LaHermida	93	0.63	-0.32
						SierradelEje	98	0.36	-0.24
Seiad Valley	CA	41.800	-123.000	865	1129	LaHermida	93	0.58	-0.70
						SierradelEje	98	0.34	-0.56
Skagit, Marble Mnt	WA	48.583	-121.400	120	1050	LaHermida	93	0.61	-0.49
						SierradelEje	98	0.46	0.78
Skagit, Sedro Woolley	WA	48.533	-122.317	60	1051	SierradelEje	98	0.38	-0.02
Snohomish, Arlington	WA	48.217	-122.067	90	1054	LaHermida	93	0.74	0.48
						SierradelEje	98	0.38	-0.03
Snohomish, Darrington	WA	48.267	-121.633	150	1053	LaHermida	93	0.86	1.34
						SierradelEje	98	0.48	1.05
Snohomish, Gold Bar	WA	47.850	-121.650	120	1063	LaHermida	93	0.76	0.65
						SierradelEje	98	0.59	2.26
Sooke	BC	48.400	-123.733	45	1045	LaHermida	93	0.83	1.15
						SierradelEje	98	0.41	0.22
Spokane	WA	47.783	-117.200	600	1065	LaHermida	93	0.47	-1.46
						SierradelEje	98	0.26	-1.40
St Helena Mt	CA	38.667	-122.600	780	1150	LaHermida	93	0.66	-0.09
						SierradelEje	98	0.32	-0.69
Steamboat 1	OR	43.367	-122.517	1590	1121	LaHermida	93	0.52	-1.07
						SierradelEje	98	0.34	-0.55
Steamboat 2	OR	43.333	-122.700	565	1122	LaHermida	93	0.71	0.29
						SierradelEje	98	0.42	0.37
Thurston, Yelm	WA	47.017	-122.733	60	1080	LaHermida	93	0.68	0.06
						SierradelEje	98	0.53	1.62
Tillamook, Hebo	OR	45.217	-123.850	150	1098	LaHermida	93	0.59	-0.61
						SierradelEje	98	0.49	1.21
Upper Soda	OR	44.383	-122.200	993	1102	LaHermida	93	0.68	0.02
						SierradelEje	98	0.42	0.41
Wahkiakum, Cathlamet	WA	46.300	-123.267	195	1089	LaHermida	93	0.89	1.57
						SierradelEje	98	0.52	1.53
Waldport	OR	44.400	-123.867	60	1101	LaHermida	93	0.79	0.80
						SierradelEje	98	0.47	0.89

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Washington, Vernonia	OR	45.767	-123.217	210	1094	LaHermida	93	0.71	0.29
						SierradelEje	98	0.46	0.82
Weaversville	CA	40.900	-122.733	1120	1139	LaHermida	93	0.62	-0.40
						SierradelEje	98	0.36	-0.27
Wildwood	CA	40.383	-123.000	1170	1143	LaHermida	93	0.72	0.35
						SierradelEje	98	0.40	0.18
Willard	WA	45.800	-121.683	550	1093	LaHermida	93	0.68	0.02
						SierradelEje	98	0.41	0.30
Willits	CA	39.383	-123.417	550	1148	LaHermida	93	0.62	-0.35
						SierradelEje	98	0.36	-0.34
Wolf Creek	OR	42.683	-123.383	427	1124	LaHermida	93	0.67	-0.04
						SierradelEje	98	0.49	1.19
Yamhill, Grande Ronde Ag.	OR	45.100	-123.600	180	1100	LaHermida	93	0.78	0.75
						SierradelEje	98	0.29	-1.02
Turkey - Simsek (1987)									
Bacon Point	WA	48.600	-121.383	505	1049	Duzce	118	6.51	0.85
						Giresun	120	4.74	0.22
						Izmit	119	5.59	-0.14
						Zonguldak	117	6.60	0.37
Castle Rock	WA	46.317	-122.867	150	1088	Duzce	118	4.96	-0.91
						Giresun	120	3.26	-1.04
						Zonguldak	117	6.08	-0.23
						Izmit	119	6.13	0.72
Caycuse	BC	48.583	-124.433	213	1041	Zonguldak	117	7.10	0.93
Cheryville	OR	45.320	-122.130	730	1097	Izmit	119	6.64	1.52
Chester morse lake	WA	47.367	-121.667	610	1072	Duzce	118	5.89	0.15
						Giresun	120	6.70	1.89
						Izmit	119	5.69	0.02
						Zonguldak	117	6.39	0.13
Chiwaukum	WA	47.683	-120.733	549	1068	Duzce	118	4.94	-0.93
						Giresun	120	4.59	0.09
						Izmit	119	4.70	-1.53
						Zonguldak	117	5.89	-0.44
Cle Elum	WA	47.217	-121.117	630	1078	Giresun	120	4.23	-0.22
						Izmit	119	6.18	0.79
Clinton	BC	51.100	-121.500	1040	1112	Zonguldak	117	7.08	0.91
Columbia Vernonia	OR	45.767	-123.217	210	1094	Zonguldak	117	7.48	1.36
Concrete	WA	48.650	-121.717	465	1047	Duzce	118	5.64	-0.13
						Giresun	120	5.03	0.46
						Izmit	119	5.78	0.16
						Zonguldak	117	4.92	-1.54
Diablo Dam	WA	48.717	-121.000	440	1046	Izmit	119	5.56	-0.18
						Duzce	118	6.53	0.86
						Giresun	120	2.60	-1.60
						Zonguldak	117	6.91	0.72
Enumclaw	WA	47.267	-121.933	244	1075	Duzce	118	7.01	1.42
						Giresun	120	3.70	-0.67
						Zonguldak	117	7.15	0.99

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Gasquet [sic]	CA	41.846	-123.970	112	1123 [sic]	Duzce	118	7.26	1.69
Hoh River	WA	47.800	-123.967	244	1064	Duzce	118	7.20	1.63
						Giresun	120	4.28	-0.18
						Izmit	119	4.99	-1.08
						Zonguldak	117	6.24	-0.04
Humptulips	WA	47.317	-123.900	137	1073	Duzce	118	5.30	-0.52
						Giresun	120	6.23	1.49
						Izmit	119	5.49	-0.29
						Zonguldak	117	4.05	-2.52
Josephine Wolf Creek	OR	42.683	-123.383	420	1124	Izmit	119	6.96	2.03
Koochelus Lake	WA	47.383	-121.367	549	1071	Izmit	119	6.02	0.54
Lake Croscent	WA	48.067	-124.000	300	1058	Duzce	118	5.49	-0.30
						Giresun	120	2.53	-1.67
						Izmit	119	6.11	0.69
						Zonguldak	117	6.01	-0.30
Lewis Packwood	WA	46.567	-121.667	645	1083	Giresun	120	5.00	0.44
						Zonguldak	117	8.16	2.14
Marblemount	WA	48.583	-121.400	120	1050	Duzce	118	5.20	-0.64
						Giresun	120	6.05	1.34
						Izmit	119	5.34	-0.52
						Zonguldak	117	6.86	0.66
Matlock	WA	47.300	-123.933	504	1074	Izmit	119	6.54	1.36
Packwood	WA	46.567	-121.667	645	1083	Duzce	118	4.92	-0.95
						Izmit	119	5.59	-0.13
Parkway	WA	47.033	-121.567	730	1079	Duzce	118	4.09	-1.89
						Giresun	120	4.83	0.29
						Izmit	119	4.44	-1.95
						Zonguldak	117	5.44	-0.95
Perry creek	WA	48.050	-121.467	600	1059	Duzce	118	5.95	0.21
						Giresun	120	4.90	0.36
						Izmit	119	5.55	-0.19
						Zonguldak	117	5.98	-0.33
Prindle	WA	45.617	-122.133	460	1095	Duzce	118	5.17	-0.67
						Giresun	120	4.60	0.10
						Izmit	119	6.21	0.84
						Zonguldak	117	5.38	-1.02
Rimrock	WA	46.667	-121.033	750	1082	Duzce	118	4.59	-1.33
						Giresun	120	2.88	-1.37
						Izmit	119	4.78	-1.41
						Zonguldak	117	5.65	-0.71
Sedro Woolley	WA	48.533	-122.317	61	1051	Duzce	118	5.23	-0.60
						Giresun	120	4.84	0.31
						Izmit	119	5.68	0.00
						Zonguldak	117	6.07	-0.24
Skykomish	WA	47.700	-121.333	300	1067	Zonguldak	117	5.58	-0.79
Skykomish	WA	47.700	-121.333	300	1076 [sic]	Duzce	118	6.96	1.35

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Sloan Creek	WA	48.083	-121.300	655	1056	Duzce	118	5.89	0.15
						Giresun	120	4.00	-0.41
						Izmit	119	5.84	0.26
						Zonguldak	117	6.70	0.48
Willard	WA	45.800	-121.700	495	1093	Duzce	118	5.63	-0.15
						Giresun	120	5.90	1.21
						Zonguldak	117	6.68	0.46
						Izmit	119	4.72	-1.50
Yelm	WA	47.017	-122.733	60	1080	Duzce	118	6.40	0.72
						Izmit	119	5.66	-0.02
						Zonguldak	117	6.24	-0.04
UK (Northern) - Lines & Samuel (1987)									
Alder Lake	WA	46.800	-122.283	425	1081	Craigvinean	9	3.75	0.04
Alder Springs	CA	39.650	-122.750	549	1146	Craigvinean	9	2.57	-2.52
Alta	BC	50.200	-122.883	630	1027	Craigvinean	9	3.26	-1.01
Brookings	OR	42.117	-124.200	300	1104	Craigvinean	9	3.62	-0.23
Clallam, Forks	WA	47.983	-124.400	90	1062	Craigvinean	9	4.17	0.94
Coquille	OR	43.200	-124.167	60	1103	Craigvinean	9	4.17	0.95
Eagle Bay	BC	50.933	-119.217	480	1014	Craigvinean	9	2.83	-1.96
Jeune Landing	BC	50.450	-127.450	170	1023	Craigvinean	9	3.71	-0.04
King, Enumclaw	WA	47.267	-121.933	240	1075	Craigvinean	9	4.43	1.50
Klina Klini	BC	51.117	-125.596	5	1012	Craigvinean	9	3.29	-0.96
Lewis Packwood	WA	46.567	-121.667	650	1083	Craigvinean	9	3.62	-0.24
Pacific, Naselle	WA	46.367	-123.733	45	1086	Craigvinean	9	4.29	1.21
Revelstoke	BC	51.000	-118.200	600	1013	Craigvinean	9	3.36	-0.81
San Juan	BC	48.581	-124.080	210	1043	Craigvinean	9	4.25	1.11
Skagit, Marble Mnt	WA	48.583	-121.400	120	1050	Craigvinean	9	3.86	0.27
Skagit, Sedro Woolley	WA	48.533	-122.317	60	1051	Craigvinean	9	3.41	-0.69
Sloan Creek	WA	48.083	-121.300	650	1056	Craigvinean	9	3.67	-0.13
Snohomish, Arlington	WA	48.217	-122.067	90	1054	Craigvinean	9	4.18	0.97
Snohomish, Darrington	WA	48.267	-121.633	150	1053	Craigvinean	9	3.96	0.50
Snohomish, Gold Bar	WA	47.850	-121.650	120	1063	Craigvinean	9	3.41	-0.70
Squamish	BC	49.778	-123.150	15	1030	Craigvinean	9	4.01	0.60
Stuie	BC	52.367	-126.000	16	1004	Craigvinean	9	3.84	0.24
Tatla	BC	51.733	-124.733	880	1006	Craigvinean	9	3.45	-0.61
Thasis	BC	49.792	-126.639	15	1029	Craigvinean	9	3.95	0.48
Tillamook, Hebo	OR	45.217	-123.850	150	1098	Craigvinean	9	3.66	-0.16
Wahkiakum, Cathlamet	WA	46.300	-123.267	195	1089	Craigvinean	9	4.44	1.54
Waldport	OR	44.400	-123.867	60	1101	Craigvinean	9	3.46	-0.59
Washington, Vernonia	OR	45.767	-123.217	210	1094	Craigvinean	9	4.29	1.21
Yamhill, Grande Ronde Ag.	OR	45.100	-123.600	180	1100	Craigvinean	9	3.30	-0.93
UK (Northern) - Lines (1978)									
Caycuse	BC	48.924	-124.433	213	1041	Culloden	6	2.10	-1.23
						Inchnacardoch	8	2.10	-1.23
						Rosarie	7	2.05	1.35
Clallam, Lake Crescent	WA	48.067	-124.000	305	1058	Culloden	6	2.32	0.40
						Inchnacardoch	8	2.32	0.40
Franklin River	BC	49.100	-124.767	150	1037	Culloden	6	2.22	-0.34

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Franklin River	BC	49.100	-124.767	150	1037	Inchnacardoch	8	2.22	-0.34
						Rosarie	7	1.91	0.37
Grays Harbor, Humptulips	WA	47.317	-123.900	137	1073	Culloden	6	2.45	1.37
						Inchnacardoch	8	2.45	1.37
						Rosarie	7	1.83	-0.19
Jefferson, Hoh River	WA	47.800	-123.967	244	1064	Culloden	6	2.41	1.07
						Inchnacardoch	8	2.41	1.07
						Rosarie	7	1.62	-1.65
Mason, Matlock	WA	47.250	-123.417	500	1076	Culloden	6	2.12	-1.08
						Inchnacardoch	8	2.12	-1.08
						Rosarie	7	1.81	-0.32
Squamish	BC	49.778	-123.150	15	1030	Culloden	6	2.24	-0.19
						Inchnacardoch	8	2.24	-0.19
						Rosarie	7	1.92	0.44
UK (Southern) - Lines & Samuel (1987)									
Alder Lake	WA	46.800	-122.283	425	1081	Bodmin East	14	7.28	0.35
						Bodmin North	16	6.37	-0.05
						Bodmin South	15	7.42	0.45
						Charmouth	17	7.13	-0.02
						Dean	13	10.60	-0.24
						Radnor	12	10.30	0.33
Alder Springs	CA	39.650	-122.750	549	1146	Bodmin East	14	5.53	-0.74
						Bodmin North	16	5.92	-0.44
						Bodmin South	15	5.67	-0.85
						Dean	13	10.00	-0.95
Alta	BC	50.200	-122.883	630	1027	Bodmin East	14	6.23	-0.30
						Bodmin North	16	6.18	-0.21
						Bodmin South	15	5.67	-0.85
						Charmouth	17	7.20	0.03
						Dean	13	9.90	-1.07
						Radnor	12	9.00	-0.95
Ashland	OR	42.083	-122.650	1480	1126	Bodmin East	14	6.09	-0.39
						Bodmin North	16	5.79	-0.55
						Bodmin South	15	7.07	0.19
						Charmouth	17	5.62	-1.10
Brookings	OR	42.117	-124.200	300	1104	Dean	13	11.90	1.30
						Radnor	12	10.40	0.43
Clallam, Forks	WA	47.983	-124.400	90	1062	Bodmin East	14	7.91	0.74
						Bodmin North	16	7.80	1.18
						Bodmin South	15	7.70	0.65
						Charmouth	17	9.07	1.36
						Dean	13	11.40	0.71
						Radnor	12	11.20	1.21
Coquille	OR	43.200	-124.167	60	1103	Charmouth	17	9.29	1.52
						Dean	13	12.20	1.65
						Radnor	12	11.30	1.31
Covelo	CA	39.917	-123.300	1555	1144	Bodmin East	14	5.60	-0.69
						Bodmin North	16	5.59	-0.72

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Covelo	CA	39.917	-123.300	1555	1144	Bodmin South	15	6.51	-0.23
						Charmouth	17	5.98	-0.84
						Dean	13	10.40	-0.48
Dean	BC	50.800	-126.958	20	1002	Bodmin East	14	5.18	-0.95
						Bodmin North	16	6.11	-0.27
						Bodmin South	15	6.58	-0.18
Dunster	BC	53.117	-119.833	50	1109	Charmouth	17	4.32	-2.02
						Radnor	12	8.30	-1.64
Eagle Bay	BC	50.933	-119.217	480	1014	Bodmin East	14	4.62	-1.30
						Bodmin North	16	4.68	-1.50
						Bodmin South	15	6.23	-0.43
						Charmouth	17	5.98	-0.84
						Dean	13	10.10	-0.83
						Radnor	12	9.30	-0.65
Fort St. James	BC	54.483	-124.250	850	1106	Dean	13	8.30	-2.96
Gold River	BC	49.750	-126.067	90	1031	Bodmin East	14	6.79	0.04
						Bodmin North	16	6.11	-0.27
						Bodmin South	15	7.00	0.14
Hawkinsville	CA	41.783	-123.667	1067	1130	Charmouth	17	5.90	-0.89
						Radnor	12	9.30	-0.65
Jeune Landing	BC	50.450	-127.450	170	1023	Bodmin East	14	6.93	0.13
						Bodmin North	16	6.83	0.34
						Bodmin South	15	7.28	0.34
						Charmouth	17	7.49	0.23
						Dean	13	10.90	0.11
						Radnor	12	8.90	-1.05
King, Enumclaw	WA	47.267	-121.933	240	1075	Bodmin East	14	9.38	1.65
						Bodmin North	16	7.61	1.01
						Bodmin South	15	7.28	0.34
						Charmouth	17	8.28	0.80
						Dean	13	11.30	0.59
						Radnor	12	10.60	0.62
Klina Klini	BC	51.117	-125.596	5	1012	Bodmin East	14	6.51	-0.13
						Bodmin North	16	6.50	0.06
						Bodmin South	15	6.58	-0.18
						Charmouth	17	8.06	0.64
						Dean	13	10.50	-0.36
						Radnor	12	9.80	-0.16
Lewis Packwood	WA	46.567	-121.667	650	1083	Bodmin East	14	7.07	0.22
						Bodmin North	16	6.70	0.23
						Bodmin South	15	7.28	0.34
						Charmouth	17	8.21	0.75
						Dean	13	11.20	0.47
						Radnor	12	10.50	0.53
Marys Peak	OR	44.500	-123.567	980	1118	Dean	13	10.70	-0.12
Pacific, Naselle	WA	46.367	-123.733	45	1086	Bodmin East	14	8.33	1.00
						Bodmin North	16	7.28	0.73
						Bodmin South	15	7.77	0.70

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Pacific, Naselle	WA	46.367	-123.733	45	1086	Charmouth	17	9.29	1.52
						Dean	13	11.80	1.18
						Radnor	12	10.30	0.33
Revelstoke	BC	51.000	-118.200	600	1013	Bodmin East	14	4.69	-1.26
						Bodmin North	16	5.72	-0.61
						Bodmin South	15	5.18	-1.21
						Charmouth	17	4.61	-1.82
						Radnor	12	9.20	-0.75
San Juan	BC	48.581	-124.080	210	1043	Charmouth	17	7.63	0.34
						Dean	13	10.70	-0.12
						Radnor	12	10.10	0.13
Sawyers Bar	CA	41.267	-123.150	1464	1135	Charmouth	17	5.47	-1.20
						Dean	13	9.60	-1.42
Skagit, Marble Mnt	WA	48.583	-121.400	120	1050	Bodmin East	14	7.70	0.61
						Bodmin North	16	7.28	0.73
						Bodmin South	15	6.93	0.08
						Charmouth	17	6.98	-0.12
						Dean	13	10.70	-0.12
Skagit, Sedro Woolley	WA	48.533	-122.317	60	1051	Charmouth	17	6.91	-0.18
						Dean	13	11.80	1.18
						Radnor	12	11.20	1.21
Sloan Creek	WA	48.083	-121.300	650	1056	Bodmin East	14	6.79	0.04
						Bodmin North	16	6.50	0.06
						Bodmin South	15	7.63	0.60
						Charmouth	17	7.27	0.08
						Dean	13	10.60	-0.24
						Radnor	12	9.50	-0.46
Snohomish, Arlington	WA	48.217	-122.067	90	1054	Bodmin East	14	8.61	1.17
						Bodmin North	16	7.15	0.62
						Bodmin South	15	7.77	0.70
						Charmouth	17	8.28	0.80
						Dean	13	11.00	0.23
						Radnor	12	10.60	0.62
Snohomish, Darrington	WA	48.267	-121.633	150	1053	Bodmin East	14	7.28	0.35
						Bodmin North	16	7.02	0.51
						Bodmin South	15	7.21	0.29
						Charmouth	17	7.49	0.23
						Dean	13	11.50	0.82
						Radnor	12	10.70	0.72
Snohomish, Gold Bar	WA	47.850	-121.650	120	1063	Bodmin East	14	7.70	0.61
						Bodmin North	16	7.61	1.01
						Bodmin South	15	8.68	1.38
						Charmouth	17	7.63	0.34
						Dean	13	11.30	0.59
						Radnor	12	9.20	-0.75
Squamish	BC	49.778	-123.150	15	1030	Bodmin East	14	7.91	0.74
						Bodmin North	16	6.63	0.18
						Bodmin South	15	7.21	0.29

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Squamish	BC	49.778	-123.150	15	1030	Charmouth	17	8.50	0.95
						Dean	13	11.10	0.35
						Radnor	12	10.00	0.03
St Helena Mt	CA	38.500	-122.500	721	1150	Bodmin East	14	6.09	-0.39
						Bodmin North	16	6.83	0.34
						Bodmin South	15	7.07	0.19
Stuie	BC	52.367	-126.000	16	1004	Bodmin East	14	6.51	-0.13
						Bodmin North	16	5.59	-0.72
						Bodmin South	15	5.18	-1.21
						Charmouth	17	5.98	-0.84
						Dean	13	10.20	-0.71
						Radnor	12	9.80	-0.16
Tatla	BC	51.733	-124.733	880	1006	Bodmin East	14	3.43	-2.04
						Bodmin North	16	3.58	-2.45
						Bodmin South	15	3.78	-2.24
						Charmouth	17	3.60	-2.53
						Dean	13	9.00	-2.13
						Radnor	12	8.30	-1.64
Thasis	BC	49.792	-126.639	15	1029	Bodmin North	16	7.61	1.01
						Bodmin South	15	8.19	1.01
						Charmouth	17	8.14	0.70
						Dean	13	10.80	0.00
						Radnor	12	8.90	-1.05
Tillamook, Hebo	OR	45.217	-123.850	150	1098	Charmouth	17	7.92	0.54
						Dean	13	11.00	0.23
						Radnor	12	10.10	0.13
Wahkiakum, Cathlamet	WA	46.300	-123.267	195	1089	Bodmin East	14	9.31	1.60
						Bodmin North	16	8.39	1.68
						Bodmin South	15	8.61	1.32
						Charmouth	17	7.49	0.23
						Dean	13	11.60	0.94
						Radnor	12	10.90	0.92
Waldport	OR	44.400	-123.867	60	1101	Bodmin East	14	8.47	1.08
						Bodmin North	16	6.70	0.23
						Bodmin South	15	8.40	1.17
						Charmouth	17	8.28	0.80
						Dean	13	11.80	1.18
						Radnor	12	11.10	1.11
Washington, Vernonia	OR	45.767	-123.217	210	1094	Bodmin East	14	7.70	0.61
						Bodmin North	16	7.22	0.68
						Bodmin South	15	7.00	0.14
						Charmouth	17	7.63	0.34
						Dean	13	11.00	0.23
						Radnor	12	10.30	0.33
Williams Lake	BC	52.117	-122.000	600	1005	Bodmin East	14	2.38	-2.69
						Bodmin North	16	2.93	-3.01
						Bodmin South	15	2.24	-3.38
						Radnor	12	7.60	-2.32

Appendix 2 – continued

Provenances Name (ID)	State	Lat	Long	Elev	IUFRO ID	Site Name	Site ID	Height (m)	Height (stdev)
Willits	CA	39.383	-123.417	549	1148	Radnor	12	12.40	2.39
Wolf Creek	OR	42.683	-123.383	427	1124	Bodmin East	14	5.81	-0.56
						Bodmin North	16	5.79	-0.55
						Bodmin South	15	6.72	-0.07
						Radnor	12	9.50	-0.46
Yamhill, Grande Ronde Ag.	OR	45.100	-123.600	180	1100	Bodmin East	14	7.70	0.61
						Bodmin North	16	7.22	0.68
						Bodmin South	15	7.49	0.50
						Charmouth	17	7.49	0.23
						Dean	13	10.80	0.00
						Radnor	12	10.30	0.33

Appendix 3 – Height results of populations tested in European regions

Table 7. For each combination of European region (*Regions*) and North American population (*Populations*), the following are reported: estimated normalized height (*Norm Height*), standard error (*SE*), the number of sites used for testing in each combination (*Sites*), and the number of provenances tested in each column (*Provs*)

Regions	Populations	Norm Height	SE	Sites	Provs
Balkans	BC Coast	0.064	0.670	2	1
	OR Coast	0.572	0.294	5	7
	WA Coast	0.900	0.344	3	5
	OR Coast Cascades	-0.240	0.164	7	25
	WA Coast Cascades	1.185	0.363	3	5
	OR Dry Coast	0.280	0.375	6	5
	WA Dry Coast	0.775	0.261	7	10
	Interior	-0.698	0.257	4	10
	Interior Cascades	-0.334	0.178	3	21
	Interior North	-0.188	0.288	3	8
	Interior South	-0.806	0.375	3	4
Central Germany	BC Coast	0.094	0.100	21	41
	OR Coast	0.286	0.138	19	22
	WA Coast	0.551	0.080	25	60
	OR Coast Cascades	-0.169	0.178	16	15
	WA Coast Cascades	0.138	0.139	19	22
	OR Dry Coast	-0.048	0.242	12	9
	WA Dry Coast	0.291	0.124	20	24
	Interior	-0.660	0.163	14	12
	Interior Cascades	-0.112	0.233	10	8
	Interior North	-0.456	0.079	20	63
	Interior South	-1.636	0.433	3	4
Central Europe	BC Coast	-0.024	0.212	3	12
	OR Coast	0.282	0.482	2	3
	WA Coast	0.245	0.124	7	28
	OR Coast Cascades	-1.535	0.851	1	1
	WA Coast Cascades	0.226	0.221	5	12
	WA Dry Coast	0.132	0.221	7	12
	Interior Cascades	-0.934	0.670	1	1
	Interior North	-0.820	0.213	6	11
Coastal Balkans	BC Coast	-0.367	0.612	1	2
	WA Coast	0.927	0.612	1	2
	OR Coast Cascades	-1.845	0.865	1	1
	OR Dry Coast	-0.184	0.612	2	2
	WA Dry Coast	-0.012	0.496	1	3
	Interior Cascades	1.176	0.865	1	1
Eastern Germany	BC Coast	0.252	0.360	1	5
	OR Coast	0.543	0.464	1	3
	WA Coast	0.440	0.227	2	13
	OR Coast Cascades	0.004	0.587	2	2
	WA Coast Cascades	0.064	0.338	2	6
	OR Dry Coast	-0.701	0.588	2	2

Appendix 3 – continued

Regions	Populations	Norm Height	SE	Sites	Provs
	WA Dry Coast	0.750	0.461	1	3
	Interior	-0.893	0.412	1	4
	Interior Cascades	-0.853	0.832	1	1
	Interior North	-0.258	0.191	2	19
	Interior South	-1.866	0.852	1	1
Finland	BC Coast	0.526	0.548	4	1
	Interior	-1.344	0.548	4	1
	Interior North	0.322	0.297	3	6
France & Belgium	BC Coast	-0.340	0.384	3	5
	OR Coast	0.090	0.335	8	5
	WA Coast	0.189	0.137	10	37
	OR Coast Cascades	-0.858	0.353	4	6
	WA Coast Cascades	-0.583	0.269	4	10
	OR Dry Coast	-0.580	0.306	2	8
	WA Dry Coast	0.363	0.143	10	35
	Interior North	-1.543	0.492	1	3
Italy	BC Coast	-0.355	0.365	3	4
	OR Coast	0.575	0.247	3	8
	WA Coast	0.339	0.181	3	20
	OR Coast Cascades	-0.514	0.425	1	4
	WA Coast Cascades	-1.038	0.424	3	3
	OR Dry Coast	0.458	0.303	2	7
	WA Dry Coast	0.635	0.316	2	5
	CA High Elevation	-0.475	0.237	2	10
	Interior	-0.602	0.412	1	4
	Interior North	-0.937	0.380	3	4
	CA Low Elevation	0.313	0.294	2	6
North Coast	BC Coast	-0.307	0.121	11	37
	OR Coast	0.285	0.151	13	24
	WA Coast	0.630	0.100	14	45
	OR Coast Cascades	-0.277	0.197	9	17
	WA Coast Cascades	-0.016	0.228	5	10
	OR Dry Coast	0.700	0.361	6	4
	WA Dry Coast	0.225	0.136	14	28
	CA High Elevation	0.115	0.530	2	2
	Interior	-0.528	0.142	5	32
	Interior Cascades	-0.180	0.353	3	5
	Interior North	-0.558	0.118	9	35
	Interior South	-0.348	0.261	1	11
	CA Low Elevation	0.197	0.865	1	1
Norway	BC Coast	0.935	0.231	1	13
	OR Coast	0.708	0.813	1	1
	WA Coast	0.603	0.793	1	1
	OR Coast Cascades	0.331	0.375	1	5
	WA Coast Cascades	0.637	0.336	1	6

Appendix 3 – continued

Regions	Populations	Norm Height	SE	Sites	Provs
	OR Dry Coast	-0.325	0.818	1	1
	WA Dry Coast	0.111	0.588	1	2
	Interior	-1.438	0.412	1	4
	Interior Cascades	-0.065	0.582	1	2
	Interior North	-0.670	0.207	1	16
Poland	BC Coast	0.345	0.304	2	8
	OR Coast	-1.251	0.850	1	1
	WA Coast	0.594	0.273	2	10
	OR Coast Cascades	0.196	0.603	1	2
	WA Coast Cascades	0.206	0.484	2	3
	OR Dry Coast	-0.418	0.807	1	1
	WA Dry Coast	1.197	0.483	2	3
	Interior Cascades	0.090	0.463	1	5
	Interior North	-1.499	0.257	2	11
Romania	BC Coast	0.376	0.865	1	1
	WA Coast	0.388	0.463	4	2
	OR Coast Cascades	0.236	0.592	3	1
	WA Coast Cascades	-0.770	0.592	3	1
	OR Dry Coast	-0.192	0.670	2	1
	WA Dry Coast	0.105	0.452	3	3
	Interior North	-1.777	0.865	1	1
Scotland	BC Coast	0.082	0.226	4	9
	OR Coast	0.069	0.334	1	6
	WA Coast	0.437	0.217	4	10
	WA Coast Cascades	0.203	0.569	1	2
	WA Dry Coast	0.284	0.403	1	4
	Interior North	-1.105	0.401	1	4
	CA Low Elevation	-2.086	0.840	1	1
Southern Germany	BC Coast	0.377	0.364	8	1
	OR Coast	0.203	0.358	7	1
	WA Coast	0.514	0.227	9	5
	OR Coast Cascades	-0.529	0.289	8	4
	WA Coast Cascades	0.346	0.356	6	3
	WA Dry Coast	-0.453	0.520	5	1
	Interior North	-0.176	0.359	5	3
Southern UK	BC Coast	0.113	0.133	8	19
	OR Coast	0.596	0.162	8	12
	WA Coast	0.538	0.138	8	12
	OR Coast Cascades	-0.005	0.378	5	3
	WA Coast Cascades	0.521	0.252	7	4
	OR Dry Coast	-0.370	0.426	5	2
	WA Dry Coast	0.404	0.184	8	8
	CA High Elevation	-0.765	0.334	6	3
	Interior	-2.218	0.612	1	2
	Interior Cascades	-0.647	0.612	1	2

Appendix 3 – continued

Regions	Populations	Norm Height	SE	Sites	Provs
	Interior North	-1.664	0.164	7	9
	CA Low Elevation	0.114	0.365	5	3
Spain	BC Coast	0.358	0.180	9	12
	OR Coast	0.221	0.153	10	17
	WA Coast	0.457	0.114	13	32
	OR Coast Cascades	-0.365	0.241	7	8
	WA Coast Cascades	0.031	0.247	8	7
	OR Dry Coast	0.618	0.179	9	14
	WA Dry Coast	0.126	0.175	12	13
	CA High Elevation	-0.486	0.144	10	24
	Interior	-1.299	0.317	5	4
	Interior Cascades	-0.764	0.263	8	7
	Interior North	-1.170	0.277	5	6
	CA Low Elevation	-0.186	0.145	13	21
Turkey	BC Coast	0.935	0.865	1	1
	OR Coast	1.209	0.793	1	1
	WA Coast	0.175	0.144	4	13
	OR Coast Cascades	1.106	0.839	1	1
	WA Coast Cascades	-0.124	0.210	4	6
	OR Dry Coast	2.031	0.865	1	1
	WA Dry Coast	-0.024	0.237	4	4
	Interior Cascades	-0.965	0.354	4	2
	Interior North	0.896	0.847	1	1
	CA Low Elevation	1.692	0.865	1	1

Appendix 4 – Random Forest Predictions

Table 8. Random Forest Bioclimatic Envelope model predictions for the population with the best climate match (*RF Popn's Pred*) by planting site number (*Site*) and name (*Name*). The probability of prediction for each population is also listed: Coastal British Columbia (*C_BC*), Coastal Oregon (*C_OR*), Coastal Washington (C_WA), Coast Cascades Oregon (*CC_OR*), Coast Cascades Washington (*CC_WA*), Dry Coast Oregon (*DC_OR*), Dry Coast Washington (*DC_WA*), Interior (*I*), Interior Cascades (*IC*), Interior North (*IN*), Interior South (*IS*), Low-elevation California (*LE_CA*), and High-elevation California (*HE_CA*)

Site	Name	RF Pop'n Pred	C_BC	C_OR	C_WA	CC_OR	CC_WA	DC_OR	DC_WA	I	IC	IN	IS	LE_CA	HE_CA
Austria															
63	Manhartsberg	I	0.07	0.00	0.20	0.04	0.10	0.01	0.01	0.30	0.10	0.10	0.09	0.00	0.00
64	Dunkelsteinerwald	I	0.06	0.00	0.06	0.00	0.13	0.00	0.01	0.35	0.07	0.21	0.12	0.00	0.00
65	Lackendorf	IN	0.02	0.01	0.16	0.03	0.04	0.01	0.11	0.21	0.07	0.23	0.13	0.00	0.01
66	Drassmarkt	IN	0.02	0.01	0.16	0.02	0.07	0.00	0.11	0.22	0.02	0.30	0.08	0.00	0.01
Belgium															
76	Freux	C_BC	0.41	0.00	0.10	0.08	0.19	0.00	0.11	0.05	0.00	0.05	0.03	0.00	0.00
Bosnia															
103	Blinje	DC_WA	0.09	0.04	0.28	0.09	0.02	0.05	0.29	0.03	0.01	0.04	0.07	0.01	0.02
Bulgaria															
111	Kjustendil	IS	0.00	0.04	0.10	0.07	0.03	0.13	0.02	0.07	0.23	0.00	0.25	0.02	0.06
Croatia															
102	Kontija	DC_WA	0.06	0.07	0.18	0.03	0.01	0.19	0.20	0.01	0.01	0.05	0.09	0.02	0.12
104	Slatki	C_WA	0.02	0.02	0.21	0.07	0.03	0.08	0.18	0.06	0.07	0.07	0.20	0.00	0.03
105	Mikleuska	IS	0.01	0.04	0.15	0.05	0.01	0.02	0.14	0.12	0.04	0.20	0.22	0.00	0.04
106	Kutina	IS	0.01	0.04	0.15	0.05	0.01	0.02	0.14	0.12	0.04	0.20	0.22	0.00	0.04
107	Durgutovica	IS	0.01	0.03	0.11	0.03	0.01	0.06	0.07	0.18	0.04	0.20	0.28	0.01	0.02
Czech Republic															
60	Jizbice	I	0.14	0.00	0.00	0.00	0.09	0.00	0.02	0.45	0.04	0.13	0.15	0.00	0.00
61	Hurka	C_BC	0.25	0.00	0.22	0.05	0.12	0.01	0.03	0.22	0.02	0.10	0.01	0.00	0.01
Denmark															
18	Egelund	C_BC	0.25	0.00	0.08	0.07	0.16	0.00	0.08	0.09	0.06	0.10	0.14	0.00	0.00
Finland															
1	Punkaharju	IN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.83	0.01	0.00	0.00
2	Aulanko	IN	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.73	0.01	0.00	0.00
3	Ruotsinkylaan	IN	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.74	0.01	0.00	0.00
4	Solbole	IN	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.51	0.06	0.00	0.00
France															
77	Arboretum	DC_WA	0.07	0.04	0.23	0.04	0.03	0.06	0.33	0.05	0.03	0.03	0.12	0.01	0.01
78	Chassenoix	DC_WA	0.10	0.05	0.25	0.07	0.01	0.05	0.33	0.04	0.01	0.04	0.08	0.00	0.01
79	Peyrat	DC_WA	0.07	0.00	0.19	0.06	0.01	0.09	0.40	0.01	0.00	0.03	0.12	0.00	0.05
80	SaintJulienlePetit	DC_WA	0.08	0.00	0.18	0.06	0.01	0.09	0.40	0.01	0.00	0.03	0.12	0.00	0.05

Appendix 4 – continued

Site	Name	RF Pop'n Pred	C_BC	C_OR	C_WA	CC_OR	CC_WA	DC_OR	DC_WA	I	IC	IN	IS	LE_CA	HE_CA
81	Douillac	DC_WA	0.01	0.03	0.19	0.02	0.01	0.21	0.43	0.01	0.00	0.02	0.08	0.00	0.03
82	Cendrieux	DC_OR	0.01	0.11	0.10	0.02	0.00	0.38	0.26	0.02	0.00	0.02	0.10	0.00	0.01
83	Giat	C_BC	0.32	0.00	0.21	0.07	0.11	0.00	0.19	0.04	0.01	0.02	0.06	0.00	0.00
84	Cendrieux2	DC_OR	0.01	0.11	0.10	0.02	0.00	0.38	0.26	0.02	0.00	0.02	0.10	0.00	0.01
85	LaBayssette	DC_WA	0.08	0.01	0.32	0.05	0.01	0.03	0.32	0.01	0.00	0.02	0.11	0.00	0.08
Germany															
19	Neumuenster	C_BC	0.30	0.00	0.15	0.06	0.10	0.00	0.07	0.09	0.03	0.05	0.17	0.00	0.00
20	Rantzau783	C_BC	0.38	0.00	0.15	0.07	0.06	0.00	0.07	0.10	0.01	0.05	0.13	0.00	0.00
21	Rantzau225	C_BC	0.34	0.00	0.13	0.07	0.08	0.00	0.06	0.10	0.03	0.06	0.16	0.00	0.00
22	Bremervoerde	C_BC	0.35	0.00	0.18	0.04	0.06	0.00	0.07	0.08	0.02	0.04	0.18	0.00	0.00
23	Harsefeld	C_BC	0.34	0.00	0.17	0.04	0.09	0.00	0.08	0.09	0.02	0.04	0.16	0.00	0.00
24	Ahlhorn	C_BC	0.32	0.00	0.17	0.07	0.09	0.01	0.09	0.08	0.02	0.05	0.12	0.00	0.00
26	Itterbeck	C_BC	0.41	0.00	0.09	0.05	0.11	0.00	0.18	0.08	0.01	0.02	0.07	0.00	0.00
27	Ankum1093	C_BC	0.39	0.00	0.15	0.10	0.10	0.01	0.10	0.06	0.01	0.04	0.05	0.00	0.00
28	Ankum35	DC_WA	0.20	0.02	0.19	0.08	0.05	0.03	0.23	0.05	0.02	0.04	0.09	0.01	0.00
30	Oerrel	C_WA	0.09	0.00	0.32	0.08	0.11	0.01	0.09	0.11	0.03	0.03	0.15	0.00	0.00
33	Freienwalde	C_WA	0.02	0.01	0.27	0.04	0.08	0.04	0.13	0.13	0.11	0.10	0.08	0.00	0.01
34	Frankenberg	C_WA	0.13	0.00	0.22	0.04	0.15	0.01	0.06	0.14	0.11	0.03	0.13	0.00	0.00
35	Seesen	C_BC	0.39	0.00	0.01	0.03	0.31	0.00	0.09	0.11	0.01	0.06	0.02	0.00	0.00
36	Neuhaus	C_BC	0.36	0.00	0.01	0.04	0.20	0.00	0.09	0.08	0.04	0.17	0.03	0.00	0.00
37	Westerhof	C_BC	0.21	0.00	0.12	0.05	0.18	0.00	0.07	0.11	0.08	0.10	0.11	0.00	0.00
38	Riefensbeek	C_BC	0.34	0.00	0.13	0.07	0.20	0.00	0.09	0.07	0.01	0.08	0.03	0.00	0.00
39	Braunlage	C_BC	0.40	0.00	0.00	0.03	0.26	0.00	0.08	0.12	0.01	0.08	0.03	0.00	0.00
40	Lauterberg	C_BC	0.30	0.00	0.00	0.06	0.23	0.00	0.08	0.13	0.02	0.17	0.03	0.00	0.00
41	Gahrenberg	C_WA	0.18	0.02	0.23	0.06	0.03	0.04	0.20	0.07	0.03	0.05	0.09	0.01	0.00
43	BadSooden	C_BC	0.38	0.00	0.00	0.02	0.17	0.00	0.11	0.17	0.02	0.13	0.02	0.00	0.00
44	Wanfried	C_BC	0.21	0.00	0.03	0.03	0.19	0.00	0.06	0.11	0.12	0.19	0.09	0.00	0.00
45	Rotenberg	C_WA	0.11	0.00	0.31	0.07	0.10	0.01	0.07	0.12	0.04	0.03	0.17	0.00	0.00
46	Rauschenberg	C_BC	0.31	0.00	0.13	0.07	0.09	0.00	0.05	0.11	0.05	0.07	0.14	0.00	0.00
47	Hilders	CC_WA	0.11	0.00	0.05	0.04	0.26	0.00	0.05	0.15	0.15	0.12	0.09	0.00	0.00
48	Waldsolms	C_BC	0.34	0.00	0.13	0.09	0.08	0.00	0.06	0.10	0.02	0.07	0.14	0.00	0.00
49	Katzenelnbogen	C_WA	0.16	0.00	0.25	0.07	0.13	0.01	0.10	0.10	0.02	0.02	0.16	0.00	0.00
50	BadHomburgAbt49	C_BC	0.33	0.00	0.12	0.08	0.11	0.00	0.09	0.11	0.02	0.09	0.08	0.00	0.00
51	Sinntal	C_WA	0.06	0.02	0.28	0.04	0.07	0.05	0.16	0.10	0.06	0.08	0.11	0.00	0.01
52	Trier	C_WA	0.20	0.00	0.25	0.05	0.10	0.00	0.07	0.10	0.02	0.02	0.20	0.00	0.00
53	Soonwald	CC_WA	0.14	0.00	0.16	0.06	0.22	0.00	0.08	0.13	0.02	0.03	0.19	0.00	0.00
54	Heigenbrocken	C_WA	0.04	0.02	0.33	0.05	0.06	0.04	0.17	0.07	0.05	0.07	0.11	0.00	0.02
55	Bensheim	DC_WA	0.03	0.06	0.15	0.13	0.02	0.06	0.24	0.05	0.05	0.03	0.17	0.01	0.02

Appendix 4 – continued

Site	Name	RF Pop'n Pred	C_BC	C_OR	C_WA	CC_OR	CC_WA	DC_OR	DC_WA	I	IC	IN	IS	LE_CA	HE_CA
56	Weinheim	DC_WA	0.02	0.04	0.20	0.11	0.02	0.06	0.24	0.05	0.05	0.02	0.19	0.01	0.03
57	Kaiserlautern	C_WA	0.12	0.00	0.24	0.05	0.15	0.00	0.07	0.12	0.05	0.02	0.20	0.00	0.00
58	Hirschhorn	DC_WA	0.05	0.03	0.23	0.04	0.05	0.04	0.29	0.05	0.06	0.05	0.13	0.00	0.01
59	Wiesloch	DC_WA	0.02	0.03	0.20	0.07	0.02	0.04	0.24	0.05	0.08	0.03	0.22	0.00	0.03
67	Calw	C_BC	0.32	0.00	0.17	0.11	0.08	0.00	0.07	0.11	0.01	0.08	0.07	0.00	0.00
68	Sindelfingen	C_BC	0.32	0.00	0.13	0.05	0.09	0.00	0.06	0.12	0.07	0.06	0.12	0.00	0.00
69	Ehingen	C_BC	0.27	0.00	0.22	0.05	0.05	0.01	0.04	0.13	0.08	0.07	0.11	0.00	0.00
70	Mooswald	C_WA	0.07	0.03	0.23	0.10	0.01	0.04	0.21	0.05	0.04	0.05	0.16	0.02	0.02
71	Kirchzarten	DC_WA	0.15	0.07	0.21	0.11	0.01	0.02	0.23	0.03	0.01	0.08	0.07	0.00	0.03
72	Illenberg	C_WA	0.20	0.04	0.27	0.07	0.04	0.05	0.17	0.06	0.02	0.07	0.03	0.00	0.01
73	Schauinsland	CC_WA	0.46	0.00	0.02	0.01	0.46	0.00	0.02	0.03	0.00	0.03	0.00	0.00	0.00
74	Schluchsee	C_BC	0.46	0.00	0.01	0.02	0.43	0.00	0.01	0.05	0.00	0.04	0.01	0.00	0.00
75	Schopfheim	CC_WA	0.41	0.00	0.02	0.02	0.45	0.00	0.00	0.04	0.00	0.08	0.01	0.00	0.00
<u>Ireland</u>															
10	Glenealy	DC_WA	0.36	0.11	0.09	0.02	0.01	0.03	0.36	0.01	0.01	0.02	0.01	0.01	0.00
11	Rathdrum	C_BC	0.34	0.17	0.13	0.01	0.01	0.02	0.30	0.01	0.00	0.01	0.00	0.03	0.00
<u>Italy</u>															
99	Turin	IS	0.02	0.04	0.15	0.03	0.01	0.06	0.12	0.09	0.02	0.19	0.22	0.03	0.06
100	Vallombrosa	C_WA	0.18	0.03	0.30	0.09	0.02	0.05	0.19	0.03	0.01	0.06	0.04	0.00	0.03
101	Faltona	DC_WA	0.03	0.01	0.18	0.15	0.00	0.08	0.30	0.02	0.01	0.04	0.17	0.00	0.05
<u>Netherlands</u>															
25	Sleenerzand	C_BC	0.37	0.00	0.09	0.08	0.11	0.00	0.17	0.08	0.01	0.03	0.08	0.00	0.00
29	Sprielderbos	C_BC	0.44	0.00	0.07	0.05	0.09	0.00	0.22	0.08	0.01	0.02	0.04	0.00	0.00
<u>Norway</u>															
5	Moberglien	C_BC	0.77	0.00	0.02	0.03	0.16	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00
<u>Poland</u>															
31	Dolice	IN	0.04	0.01	0.09	0.01	0.02	0.02	0.08	0.19	0.01	0.50	0.06	0.00	0.00
32	Karcz	IN	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.25	0.00	0.72	0.01	0.00	0.00
<u>Romania</u>															
112	Fintinele	IN	0.02	0.01	0.06	0.00	0.00	0.01	0.07	0.26	0.01	0.42	0.16	0.00	0.00
113	Zaicani	C_WA	0.15	0.02	0.27	0.06	0.05	0.03	0.15	0.06	0.03	0.12	0.04	0.00	0.04
114	Turnu Rueni	C_WA	0.12	0.01	0.21	0.03	0.09	0.02	0.14	0.15	0.04	0.15	0.05	0.00	0.01
115	Onofrea	IN	0.07	0.01	0.12	0.03	0.06	0.00	0.10	0.18	0.02	0.34	0.09	0.00	0.01
116	Dobra	IN	0.04	0.01	0.19	0.02	0.08	0.03	0.12	0.16	0.05	0.25	0.09	0.00	0.00
<u>Scotland</u>															
6	Culloden	C_BC	0.39	0.00	0.02	0.09	0.09	0.00	0.17	0.07	0.03	0.07	0.10	0.00	0.00
7	Rosarie	C_BC	0.40	0.00	0.04	0.08	0.09	0.00	0.24	0.06	0.02	0.05	0.05	0.00	0.00
8	Inchnacardoch	C_BC	0.65	0.00	0.00	0.03	0.26	0.00	0.04	0.01	0.00	0.02	0.01	0.00	0.00

Appendix 4 – continued

Site	Name	RF Pop'n Pred	C_BC	C_OR	C_WA	CC_OR	CC_WA	DC_OR	DC_WA	I	IC	IN	IS	LE_CA	HE_CA
9	Craigvinean	C_BC	0.44	0.00	0.02	0.06	0.17	0.00	0.21	0.03	0.01	0.05	0.03	0.00	0.00
<u>Serbia</u>															
108	Sremcica	IS	0.01	0.01	0.08	0.03	0.01	0.08	0.07	0.17	0.05	0.16	0.29	0.02	0.03
109	Tanda	C_WA	0.03	0.03	0.19	0.05	0.03	0.05	0.19	0.08	0.10	0.05	0.19	0.01	0.03
110	Juhor	C_WA	0.02	0.01	0.28	0.04	0.07	0.04	0.13	0.15	0.07	0.12	0.09	0.00	0.01
<u>Slovakia</u>															
62	Kmetova	IN	0.14	0.00	0.07	0.01	0.04	0.00	0.02	0.26	0.01	0.46	0.02	0.00	0.00
<u>Spain</u>															
86	Fragavella	C_OR	0.02	0.36	0.01	0.00	0.00	0.22	0.34	0.00	0.00	0.00	0.00	0.06	0.00
87	Regavella	DC_OR	0.01	0.21	0.01	0.00	0.00	0.29	0.24	0.00	0.00	0.00	0.02	0.21	0.02
88	SierradeMeira	DC_WA	0.02	0.07	0.06	0.00	0.00	0.08	0.76	0.01	0.00	0.00	0.00	0.02	0.01
89	Gamalleira	DC_WA	0.01	0.15	0.02	0.00	0.00	0.28	0.54	0.01	0.00	0.00	0.00	0.01	0.00
90	Valdemadeiro	DC_WA	0.06	0.00	0.02	0.01	0.00	0.02	0.89	0.01	0.00	0.00	0.00	0.00	0.00
91	LaGallina	DC_WA	0.01	0.24	0.01	0.00	0.00	0.33	0.36	0.01	0.00	0.01	0.01	0.03	0.01
92	Confercal	DC_WA	0.00	0.01	0.03	0.01	0.00	0.02	0.92	0.01	0.00	0.02	0.00	0.00	0.00
93	LaHermida	C_OR	0.02	0.44	0.03	0.00	0.00	0.09	0.40	0.00	0.00	0.00	0.02	0.01	0.01
94	CastroDozon	DC_WA	0.06	0.37	0.04	0.00	0.00	0.17	0.37	0.00	0.00	0.00	0.00	0.01	0.01
95	LaVecilla	DC_WA	0.06	0.02	0.07	0.28	0.01	0.03	0.36	0.04	0.04	0.03	0.04	0.03	0.02
96	SalinasdeLeniz	DC_WA	0.08	0.02	0.09	0.01	0.01	0.00	0.78	0.01	0.00	0.01	0.01	0.00	0.00
97	Bande	DC_WA	0.02	0.18	0.13	0.01	0.00	0.10	0.54	0.01	0.00	0.01	0.00	0.00	0.02
98	SierradelEje	CC_OR	0.23	0.00	0.02	0.35	0.14	0.00	0.24	0.01	0.01	0.01	0.01	0.00	0.00
<u>Turkey</u>															
117	Zonguldak	DC_OR	0.00	0.04	0.07	0.10	0.01	0.37	0.13	0.02	0.02	0.03	0.19	0.02	0.04
118	Duzce	IS	0.00	0.02	0.10	0.17	0.01	0.20	0.07	0.03	0.08	0.01	0.26	0.03	0.04
119	Izmit	DC_OR	0.00	0.03	0.05	0.08	0.01	0.28	0.09	0.02	0.04	0.02	0.17	0.12	0.13
120	Giresun	CC_OR	0.10	0.00	0.10	0.22	0.09	0.00	0.09	0.11	0.13	0.03	0.15	0.00	0.00
<u>United Kingdom (southern)</u>															
12	Radnor	C_BC	0.41	0.00	0.13	0.04	0.04	0.00	0.34	0.02	0.01	0.02	0.01	0.00	0.00
13	Dean	DC_WA	0.25	0.02	0.15	0.00	0.00	0.02	0.53	0.03	0.00	0.02	0.00	0.01	0.00
14	Bodmin East	DC_WA	0.11	0.11	0.16	0.00	0.00	0.03	0.56	0.00	0.00	0.01	0.01	0.03	0.00
15	Bodmin South	DC_WA	0.11	0.11	0.16	0.00	0.00	0.03	0.56	0.00	0.00	0.01	0.01	0.03	0.00
16	Bodmin North	DC_WA	0.11	0.11	0.16	0.00	0.00	0.03	0.56	0.00	0.00	0.01	0.01	0.03	0.00
17	Charmouth	DC_WA	0.34	0.03	0.11	0.02	0.02	0.00	0.45	0.04	0.01	0.02	0.00	0.00	0.00