Washington, Oregon or Queen Charlotte Islands? Which is the best provenance of Sitka spruce (*Picea sitchensis*) for Ireland?

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Abstract

Perceived reductions in both productivity and timber quality in faster growing Washington and Oregon Sitka spruce seed sources have led to the widespread use of Queen Charlotte Islands (QCI) sources in Irish forestry. The belief is that the more northerly sources provide slower and more consistent growth, superior wood qualities, increased stability and protection against frost damage. However, none of these assertions is supported by results from over 40 years of provenance testing in Sitka spruce in Ireland. The widely held belief that QCI origins are less prone to late spring frost damage is not supported by field trial results. The use of Washington origins will result in at least a one Yield Class (2 m^{-3} ha^{-1} $year^{-1}$) increase in wood production over QCI origins without any significant increase in frost risk. Therefore, the continued planting of large amounts of QCI origins in Ireland is not justified. For commercial plantations of Sitka spruce in Ireland, Washington and Oregon sources are the recommended sources.

Keywords: Sitka spruce, *Picea sitchensis,* provenance, origin, seed sources, frost damage, wood quality.

Introduction

Current opinions on the best provenance or seed origin of Sitka spruce (*Picea sitchensis*) for use in Ireland are not based on the results of formal provenance trials, but rather on the perceived risks associated with using more southerly provenances. These concerns are that more southerly sources:

1. grow too rapidly,
2. produce poor quality wood,
3. have an increased incidence of lammas growth,
4. suffer from poor stability,
5. are at increased risk of frost damage, and
6. show rapid initial growth rates which decline over the rotation.

Another important consideration is that the Forestry Commission in Britain has in the past recommended QCI sources.

Because QCI is always readily available and Washington less common, QCI has been planted on poorer, more exposed sites than Washington, and as a result it has developed an undeserved reputation of being more robust than Washington.

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The objective of this paper is to summarise over 40 years of provenance research in Ireland with Sitka spruce and to demonstrate that none of these concerns is sufficient to justify the current planting of large amounts of QCI material.

Background

Sitka spruce was first recorded by the Scottish botanist Archibald Menzies in the Puget Sound area, near Seattle (in Washington State), in 1792. About 1831 the first seeds were imported to Europe by another Scottish botanist, David Douglas. Most of the original seed was planted in arboreta and gardens throughout Britain and Ireland. Some of the first Sitka spruce planted in Ireland was in about 1843, at Curraghmore, Co Waterford (Fitzpatrick 1966). The performance of Sitka spruce in gardens and arboreta attracted interest as a potential commercial timber species and the first experimental planting in Ireland was in Avondale in 1905; commercial planting began in the 1920s (Fitzpatrick 1966).

The suitability of the species on a wide range of sites and soil types in this country has led to it becoming the most widely utilised species in Ireland (Joyce and OCarroll 2002). Currently, it accounts for about 57% of the national forest estate, comprising 60% of the Coillte, and 50% of the private forest estates, respectively.

Sitka spruce is native to a long, narrow coastal strip that adjoins the Pacific Ocean, from south-central Alaska (61°N) to northern California (39°N), a distance of about 3,000 km. Initial commercial imports of seed to Britain and Ireland were mainly from Oregon and Washington, but later imports, especially to the UK, were predominantly from the Queen Charlotte Islands, located off the coast of British Columbia, Canada (Fletcher 1990). This was mainly because of the similarity of latitude, climate and ecological conditions between Scotland and the Queen Charlotte Islands. Unfortunately, this practice completely ignored the influence of the Gulf Stream on the climate of the British Isles, which, as will be shown later, plays a considerable role in determining the most suitable seed origins, especially for Ireland.

During the period 1922 to 1990 approximately 85% of the Sitka spruce planted in Britain was of QCI origin (Fletcher 1990), while in Ireland during the period 1930 to 1970 the origins planted in State forestry were 45% QCI, 36% Washington, 14% home-collected and 5% unknown (Pfeifer 1983).

One reason why so much QCI has been planted is the fact that it is easier to grow in the nursery than either Washington or Oregon sources, because it tends to stop growing earlier in the autumn. As a result, it is less susceptible to early autumn frost damage, which can be a problem in nurseries, but not in young plantations (see discussion later on frost susceptibility). For this reason QCI plants are generally readily available in most years.

Because both QCI and Washington material had performed well under most conditions, and because there were no obvious differences between provenances, very little attention was paid to the effect of seed origin (Fletcher 1990). In fact, no detailed study of the effect of seed origin was undertaken until 1960, when a series of trials testing 10 provenances (from Alaska to mid-Oregon) was organised by the

Forestry Commission in Britain, with one replicate being established in Ireland near Killarney. After 10 growing seasons the more southerly Washington and Oregon provenances showed superior growth rate, compared with QCI sources (O'Driscoll 1977).

In 1970, under the auspices of the IUFRO (International Union of Forest Research Organisations), an international provenance experiment in Sitka spruce was established which consisted of seed from 67 different locations, from the entire natural range of the species. This allowed for a more detailed examination of the influence of provenance than was previously possible. This trial was established in 1975 on 9 sites, covering most of the typical Sitka spruce planting sites in the country (Pfeifer 1993).

An internal Forest and Wildlife Service report, based on the results of the 1960 Killarney (after 24 growing seasons) and the 1975 IUFRO trials (after 9 growing seasons), highlighted the benefits of planting Washington and Oregon over QCI origins (Pfeifer 1983). It concluded: "Provenance trials have shown that growth differences between the QCI and Washington coast origins are in the region of 12 to 14% over all sites sampled in the trials. Therefore even if seed from managed QCI seed stands were available, its growth potential would still fall short of an imported Washington provenance. If we continue to collect seed from home collected stands of QCI origin, then we will perpetuate the planting of a less productive provenance."

As a result of the report, a Forest and Wildlife Service committee was formed in 1984 to discuss the question further. It decided that an overall national planting policy of 50:50 QCI: Washington would be the most prudent action. This decision was based on arguments that:

1. more southerly provenances "...might give rise to problems of too rapid growth, poor wood quality, lammas growth, stability and dangers of autumn frost damage".
2. the IUFRO provenance experiment was too young to make any firm recommendations;
3. early growth rates of the more southerly provenances might not be maintained throughout the lifespan of the crop;
4. the Forestry Commission at that time recommended QCI for use in the United Kingdom.

In the 20 years since the original decision, the 50:50 QCI:Washington national policy has been remarkably upheld. In 1993 the Sitka spruce planting programme in Coillte consisted of 56% QCI, 36% Washington and 8% Oregon origins. However, a survey carried out of 1997/1998 private sector planting showed that 79% of the plants were QCI 20%, Washington and 1% Oregon origin.

The purpose of this paper is to question the widespread use of QCI origins in light of more recent data (Pfeifer 1993, Thompson and Pfeifer 1995) and to argue that to optimise the productivity of Sitka spruce in this country it is time to increase the planting of Washington and Oregon origins and reduce the use of QCI origins.

Results from research trials, field investigations and observation of Sitka spruce origins, and change to Forestry Commission policy

As stated, since the 1984 decision to adopt a 50:50 QCI:Washington policy, new research relevant to the selection of Sitka spruce origins has become available. In addition, there has been a change to Forestry Commission policy. The material presented below follows the sequence of the four issues that were the basis for the 1984 decision.

Growth pattern, commercial wood yield and economic return from Sitka spruce origins

1960 Forestry Commission Sitka spruce trial at Killarney

This trial consisting of 10 commercially collected seed lots and one seed lot from Denmark was organised by the Forestry Commission in 1960. It was replicated at 14 sites across Great Britain, together with one at Tomies Wood, close to Killarney in Co Kerry. The Killarney site was selected as frost-free, fertile and sheltered, to

***Table 1**. Growth of 11 Sitka spruce provenances at Killarney up to 37 growing seasons.*

	Number of growing seasons									
	0	*3*	*6*	*9*	*14*	*32*	*37*	*14*	*32*	*37*
Provenance and location code[1]	*Mean height (m)*							*Diameter breast height (cm)*		
Cordova (AK)	*0.12*	*0.49*	*1.32*	*2.14*	*6.07*	*18.7*	*22.1*	*10.0*	*19.0*	*26.7*
Sitka (AK)	*0.18*	*0.57*	*1.44*	*2.15*	*5.97*	*19.1*	*22.2*	*9.5*	*22.2*	*24.6*
Terrace (BC)	*0.20*	*0.62*	*1.54*	*2.46*	*6.69*	*19.9*	*23.1*	*11.2*	*25.8*	*30.3*
Skidegate (QCI)	*0.23*	*0.75*	*.83*	*3.05*	*7.98*	*20.1*	*22.9*	*11.7*	*24.6*	*28.8*
San Juan (VI)	*0.24*	*0.74*	*1.93*	*3.32*	*8.01*	*16.6*	*23.5*	*11.5*	*24.6*	*32.5*
Sooke (VI)	*0.27*	*0.92*	*2.30*	*4.14*	*9.19*	*22.1*	*25.3*	*11.8*	*25.1*	*32.4*
Forks (WA)	*0.25*	*0.90*	*2.19*	*4.14*	*9.13*	*20.7*	*23.2*	*12.2*	*24.5*	*32.3*
Hoquiam (WA)	*0.23*	*0.81*	*2.15*	*3.94*	*9.06*	*20.5*	*22.7*	*12.3*	*25.1*	*32.8*
Jewell (OR)	*0.23*	*0.76*	*1.97*	*3.50*	*8.94*	*21.2*	*24.3*	*12.1*	*26.3*	*32.8*
North Bend (OR)	*0.23*	*0.92*	*1.97*	*3.32*	*8.27*	*21.7*	*24.9*	*11.4*	*26.6*	*33.3*
Jutland (DK)	*0.17*	*0.98*	*2.53*	*4.61*	*10.3*	*20.0*	*27.5*	*13.5*	*27.2*	*34.1*

[1] Location codes: (AK) Alaska, (BC) British Columbia, (QCI) Queen Charlotte Islands, (VI) Vancouver Island, (WA) Washington, (OR) Oregon and (DK) Denmark.

provide an optimal site for the different provenances, in comparison with some of the harsher sites planted in the UK. Results from the Killarney trial are presented in Table 1.

The results show a trend of increased height and diameter growth when moving from north (Alaska) to south (Oregon). The most productive provenances are the more southerly, especially Vancouver Island (Sooke), Washington (Forks) and Oregon (Jewell and North Bend). It is also interesting to note that the material from Jutland, which originated from a Washington seed source, was the top performer. Selection in the nursery and in plantations in Denmark may have contributed to its increased adaptedness to European climatic conditions.

The results also demonstrate that the initial fast growth rate of the more southerly sources does not decline with age (up to 37 growing seasons), which was one of the original concerns about their proposed more widespread use.

One criticism made of the results from the Killarney trial was that they represented only one site, which was specifically selected for the absence of frost. These criticisms were taken into account when the IUFRO trial was established. Nevertheless, Killarney provided a first look at the performance of different seed sources of Sitka spruce, which, at the time of writing, is still quite impressive.

1975 IUFRO Sitka spruce provenance trials

In 1975 a series of nine Sitka spruce provenance trials, representing 67 different seed origins or provenances was established in Ireland (Pfeifer 1993). Sites were specifically selected to represent typical sites were Sitka would be grown. These have been measured after 9 (Pfeifer 1993) and 19 growing seasons (Thompson and Pfeifer 1995). Site descriptions of the five are presented in Table 2.

Results of growth assessments in the five trials at the end of 22 growing seasons are presented in Table 3.

These results show the same trend as the Killarney trial, with increased volume production in the Washington and Oregon origins compared to QCI. It is also important to note that this trend was consistent over all five trials, which were located on a wide range of site types and different climatic conditions across the country.

Table 2. *Site descriptions of Sitka spruce IUFRO provenance trials.*

Trial	*Elevation*	*Rainfall*	*Soil type*	*Date of last spring frost*
	m	*mm yr^{-1}*		
Killygordon, Co Donegal	*185*	*1600-2000*	*peaty gley*	*May 1*
Belturbet, Co Cavan	*90*	*1000-1200*	*gley*	*May 1*
Rossmore, Co Waterford	*240*	*1000-1200*	*gley*	*May 15*
Comeragh, Co Waterford	*90*	*1000-1200*	*gley*	*April 15*
Kenmare, Co Kerry	*25*	*1600-2000*	*brown earth*	*March 15*

Table 3. Relationship between seed origin, height and volume growth in Sitka spruce IUFRO provenance trials after 22 growing seasons.

Origin	*Site*				
	Killygordon	*Belturbet*	*Rossmore*	*Comeragh*	*Kenmare*
	Mean height (yield class) M (m^3 ha^{-1} yr^{-1})				
QCI	*12.0 (18)*	*15.0 (22)*	*13.0 (20)*	*14.5 (22)*	*15.0 (22)*
N. WA	*12.5 (20)*	*15.5 (24)*	*13.5 (20)*	*16.0 (24)*	*17.0 (24+)*
S. WA	*12.5 (20)*	*16.5 (24)*	*14.5 (22)*	*18.5 (24+)*	*17.5 (24+)*
N. OR	*12.0 (18)*	*16.0 (24)*	*14.5 (22)*	*not tested*	*18.0 (24+)*
S. OR	*12.5 (20)*	*not tested*	*14.5 (22)*	*17.5 (24+)*	*17.0 (24+)*

***Table 4**. Average growth, associated volume assortments and standing value of five Sitka spruce IUFRO provenance trials.*

Origin	*Mean top height*	*Mean DBH*	*Yield Class*	*Standing volume*	*LSL/SSL[1]/pulp*	*1996 standing value*
	m	*cm*	*m^3 ha^{-1} yr^{-1}*	*m^3 ha^{-1}*		*£ ha^{-1}*
QCI	*13.9*	*19.1*	*22*	*315.7*	*27/44/29*	*6246*
N. WA	*14.9*	*20.7*	*24*	*389.6*	*38/40/22*	*8843*
S. WA	*15.9*	*21.4*	*24+*	*430.0*	*40/41/19*	*10180*
N. OR	*15.1*	*20.6*	*24*	*399.6*	*37/43/20*	*9110*
S. OR	*15.4*	*20.9*	*24*	*434.4*	*33/45/22*	*9456*

[1]LSL large sawlog, SSL small sawlog

Further assessments of standing volume were made and the percentage of large sawlog, small sawlog and pulp was estimated for each trial. The standing value (1996 prices) of the crop (after 22 growing seasons) was then calculated (Table 4).

Differences in the value of the standing crop (Table 4) were mainly due to differences in the percentage of large sawlog; total standing volume had a smaller influence (the greatest volume production was in the southern Oregon material). The high value of the southern Washington stands was due to their having the highest percentage of standing volume (40%), in the most valuable large sawlog category.

Although it might be expected that QCI material was the best suited to Irish conditions, due to its latitude of origin (53°N) and similar climatic conditions to here, the results of both the Killarney and the IUFRO provenance trials did not support this hypothesis. The reason is more than likely due to the warming effect of the Gulf Stream on the Irish climate. The result is a climate that is more similar to southern Washington and northern Oregon, a shift of about 7 degrees south (to about 46°N). Provenance trial results from other Pacific Northwest conifer species such as Douglas fir (*Pseudotsuga menziesii*) show a very similar pattern. Thus, using latitude alone to select provenances is not always as reliable a predictor of success as might be expected.

Wood quality

Fast growth results in increased volumes, but usually at the expense of wood quality. The main criterion used to determine wood quality is density, mainly because it is relatively easy to measure, and because it is closely correlated with strength properties.

The effect of provenance on wood density in Irish stands was reported by Murphy and Pfeifer (1991). Their study showed that wood density decreased slightly as seed sources moved from north (Alaska) to south (Oregon) and growth rate increased (Table 5). However, the decrease in density between QCI and Washington was only 5%. Whether this would result in a significant decrease in wood strength has not been established. Perhaps a more important observation in their study was that site conditions and management regime resulted in a greater variation in wood density than the influence of provenance (Murphy and Pfeifer 1991).

Wood density is only one of several factors involved in determining wood strength. It is particularly relevant in clearwood, but branching and knots have a greater influence on timber strength. Measurements of the size and number of branches in different Sitka spruce provenances (Murphy and Pfeifer 1991) have shown that southern provenances have both fewer and smaller diameter, branches than northern provenances per unit length of stem (Table 6). This occurs because the faster growth of the southern provenances results in branch whorls that are further

Table 5*. The relationship between north-south origin and wood density of Sitka spruce.*

Origin	***Mean wood density*** ***$g\ cc^{-1}$***
Alaska	*0.425*
British Columbia	*0.415*
QCI	*0.401*
Vancouver Island	*0.387*
Washington	*0.382*
Oregon	*0.397*

Table 6. The relationship between north-south origin and branching in Sitka spruce.

Origin	***Mean branch/stem diameter ratio***	***Mean number of branches/stem internode length***
Alaska	*0.22*	*0.27*
British Columbia	*0.21*	*0.25*
QCI	*0.19*	*0.21*
Vancouver Island	*0.19*	*0.21*
Washington	*0.19*	*0.20*
Oregon	*0.19*	*0.17*

apart along the stem, and earlier canopy closure which suppresses the diameter growth of lower branches.

These results show that for southern origins the size and number of branches decreases, with a corresponding decrease in knot size and frequency. This is likely to offset any reductions in strength properties due to a slightly lower wood density.

Treacy et al. (2000) examined wood density, microfibril angle, modulus of elasticity and modulus of rupture in Sitka spruce (QCI, Washington, Oregon and California origins) from a single experimental location in Ireland. They found the QCI material had the highest wood density, but also observed very large differences from tree to tree. The Washington material had the highest modulus of rupture, which indicates higher strength properties in this source. There were no significant differences ($p \leq 0.5$) in either the modulus of elasticity or microfibril angle between the four sources tested. These results also indicate that wood strength properties in the more southerly Washington and Oregon sources are comparable to QCI material.

Lee et al. (1999) compared both forest production and sawmill conversion of material from a 44-year-old Sitka spruce provenance trial in north Wales that included QCI and several Washington sources. The Washington sources produced higher sawlog volume, a larger proportion of 5 m length logs, no decrease in the proportion of sawn timber that satisfied the SC3 standard, and only a slight reduction in the proportion of SC4 construction timber, as compared to the QCI material. The report concluded that "Selection of either of these two origins (Washington-Hoh River or Columbia River) should give an increase in value to the forest manager relative to unimproved QCI material without any loss in overall strength for the construction timber market".

All these studies indicate that concerns that a significant decrease in timber strength will result from more widespread use of southern Sitka spruce origins are unjustified.

Leader breakage

It is logical to expect that leader breakage will be greater in faster growing origins where leaders may not be fully lignified before winter storms occur. However, observations in field trials and plantations do not support this because:

1. most leader breakage occurs during summer months (mainly July), before leaders of both fast or slow growing origins have begun to lignify,
2. leader breakage has not been found to be correlated with specific origins, but depends more on the site and degree of exposure.

Fears about increased incidence of leader breakage in Washington and Oregon sources are therefore not supported by field observations.

Lammas growth

Lammas growth is a second flush that occurs in late summer, after main shoot extension has finished. There is evidence to suggest that it is higher in southern or more vigorous provenances, but this does not seem to have had any significant effect on the frost hardiness or stem form of these origins.

Therefore concerns about a significantly increased incidence of lammas growth in Washington and Oregon sources are not justified.

Stability

Increased shoot growth could result in reduced root growth and thus reduce the stability of faster growing Washington and Oregon sources. However, there is no evidence to suggest that there is such a relationship. Studies on root:shoot ratios of different sources of Sitka spruce have not shown significant differences between sources (Cannell and Willett 1976). Stability of Sitka spruce is determined more by soil type, elevation, slope, site preparation and thinning regime than by seed source (Ni Dhubháin et al. 2001).

Concerns about reduced stability in Sitka spruce origins from Washington and Oregon compared to those from QCI are not valid.

Frost susceptibility

One of the largest fears of increasing the use of Washington and Oregon origins is that they are at a greater risk of frost damage than QCI. This may indeed be true in the nursery bed, where, as prolonged shoot growth is encouraged. QCI origins will tend to suffer less autumn frost damage because they become dormant earlier (late September to early October) than Washington or Oregon sources (late October to early November). However, once trees are established on the planting site, autumn frost causes little damage to Sitka spruce in Ireland. In fact Cannell et al. (1985) showed that early autumn frost was less frequent (once in every 8 to 10 years) than late spring frost (once every 3 to 5 years) in Scottish upland plantations.

Therefore, late spring frosts present much more of a threat. During the first 4 to 5 years after planting, once the air temperature falls below –5°C, newly flushed shoots can be damaged, leading to retarded growth, forking and, in severe cases, mortality. Damage typically occurs to shoots from ground level up to about 2 m,

Table 7. *Date of bud break by origin in the Killarney Sitka spruce provenance trial, over a period of two years.*

Origin and location code[1]	***1971 Bud break***	***1971 Days since first bud break (April 26)***	***1972 Bud break***	***1972 Days since first bud break (May 2)***
Cordova (AK)	*May 4*	*8*	*May 9*	*7*
Sitka (AK)	*May 2*	*6*	*May 7*	*5*
Terrace (BC)	*April 26*	*0*	*May 2*	*0*
Skidgate (QCI)	*April 26*	*0*	*May 2*	*0*
San Juan (VI)	*April 28*	*2*	*May 3*	*1*
Sooke (VI)	*April 29*	*3*	*May 2*	*0*
Forks (WA)	*May 3*	*7*	*May 8*	*6*
Hoquiam (WA)	*May 3*	*7*	*May 6*	*4*
Jewell (OR)	*May 1*	*5*	*May 5*	*3*
North Bend (OR)	*May 5*	*9*	*May 11*	*9*

[1] Location codes as Table 1.

Table 8. *Date of bud break at the end of the first growing season (1975) of 3-year-old plants in the IUFRO Sitka spruce provenance trial, averaged over three sites (Aughrim, Belturbet and Kenmare).*

Origin and location code[1]	***Bud break***	***Days since first bud break (May 9)***
Duck Creek (AK)	*May 14*	*5*
Ward Lake (AK)	*May 16*	*7*
Usk Ferry (BC)	*May 14*	*5*
Inverness (BC)	*May 13*	*4*
Link Road (QCI)	*May 13*	*4*
Holberg (VI)	*May 12*	*3*
Big Qualicum (VI)	*May12*	*3*
Forks (WA)	*May 13*	*4*
Hoquiam (WA)	*May 13*	*4*
Necanicum (OR)	*May 9*	*0*

[1] Location codes as Table 1.

although in frost pockets damage can occur above 2 m. As soon as trees have grown out of the danger zone they are usually free of frost damage, and because Washington origins grow faster, they generally outgrow frost risk earlier than slower growing origins.

In species such as Douglas fir and Norway spruce, which cover a wide range of diverse environments in their native range, it is possible to select seed sources that have large differences (up to 30 to 60 days) in the date of bud break, which can provide protection against late spring frost damage. However, because Sitka spruce is native to a long, low-lying, narrow strip along the Pacific coast, differences between origins in the date of bud break are not very large (Lines and Mitchell 1965, Kraus and Lines 1976). This is illustrated by flushing assessments carried out in the 1960 Killarney provenance trial (Table 7), and in a sample of provenances from the 1975 IUFRO trial (Table 8).

Although there were differences in both the date of bud break and the order in which the origins flushed from year to year and from trial to trial, this may be partly explained by year-to-year weather differences (different dates that origins became dormant, different origin chilling requirements, temperatures during the winter and how early spring arrived) that affect bud break. In addition, the Killarney results were from trees that had been in the field for 12 or 13 growing seasons, while the IUFRO trees had been in the field only one growing season. Nevertheless, the overall trends in both sets of results were similar: the most northerly origins (Alaska) flushed latest. However, these origins are too slow-growing to have a role in commercial forestry (Table 1), and only those from QCI and southwards are realistic options.

In both trials the date of bud break varied little between QCI, Washington or Oregon origins (2 to 9 days in the Killarney trial and 4 to 5 days in the IUFRO material). When the 2 to 9 day difference in bud break between origins of Sitka spruce is compared to the 30 to 60 day difference that occurs between origins of Norway spruce, it is clear that the use of different provenances of Sitka spruce to reduce the occurrence of late spring frost damage is not an effective option.

Thus, the commonly held belief that QCI origins provide protection against late spring frost is not supported by the facts.

In the absence of the option to use different Sitka spruce origins to protect against late spring frost damage, it becomes necessary to identify sites with a greater likelihood of late spring frost damage. Some attempt at this has been made in Scotland (Cannell, 1984). In Ireland some approximate frost likelihood maps have been produced which attempt to identify the average date of the last spring frost in different parts of the country (Figure 1). Despite their lack of precision they show that the likelihood of a late spring frost after 15 May is quite low.

Exposure tolerance

Because QCI material originates from exposed islands off the coast of British Columbia, it has developed the reputation of providing greater protection against exposure than other origins. In a study in Denmark on an exposed North Sea site, Alaskan Sitka was the most tolerant of exposure and there was little if any difference

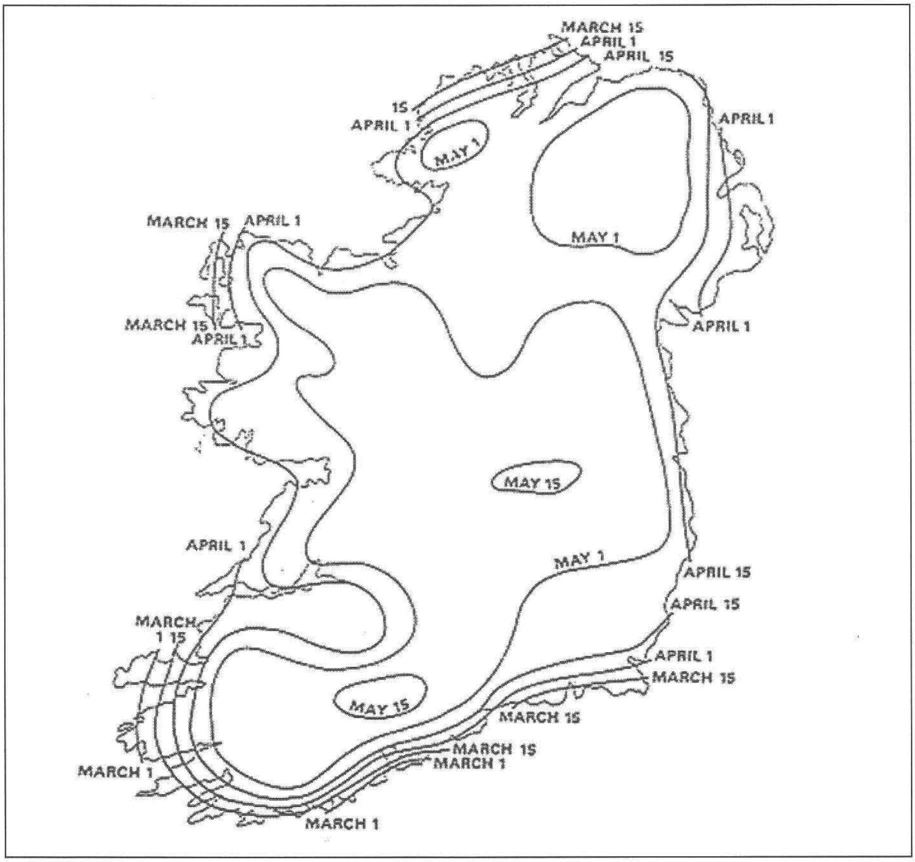

Figure 1. Average last date of spring frost in Ireland (Collins and Cummins 1996).

between QCI and Washington in their ability to tolerate exposure (Nielsen 2005). Thus, the belief that QCI provides greater tolerance to exposure is not supported by the facts.

Cold hardiness

Laboratory freezing tests have shown that both Washington and QCI material ultimately reach about the same degree of cold hardiness, although because QCI sources become dormant earlier than Washington, QCI material will reach a greater degree of cold hardiness earlier than Washington (O'Reilly 2005). However, this time difference between provenances is unlikely to provide any significant protection against early severe cold temperatures.

Forestry Commission policy

The original recommendation of the Forestry Commission to plant only QCI material on all sites has since been modified to include the use of Washington and Oregon material on low elevation sites in Wales, Cornwall and southern England (Lines and Samuel 1993), where climatic conditions are more similar to Ireland than to Scotland. More recently, an Ecological Site Classification system has been developed in the UK (Pyatt et al. 2001) to identify specific climatic zones, soil nutrient regimes and soil moisture regimes matched to a range of species. Specific origins of Sitka (Alaska, QCI, Washington and Oregon) have been recommended for sites with certain accumulated temperatures (degree days above +5°C) based on the accumulated temperatures experienced by these origins in the natural species range. For locations with an accumulated temperature (AT) of less than 1,400, QCI should be planted; for sites with an AT greater than 1,800 Oregon should be planted and for sites with an AT of more than 1,400 but less than 1,800 Washington should be planted. Applying these AT limits to Ireland (Figure 2) it is clear that Oregon should be planted in a coastal strip from the southeast, along the south coast to the southern

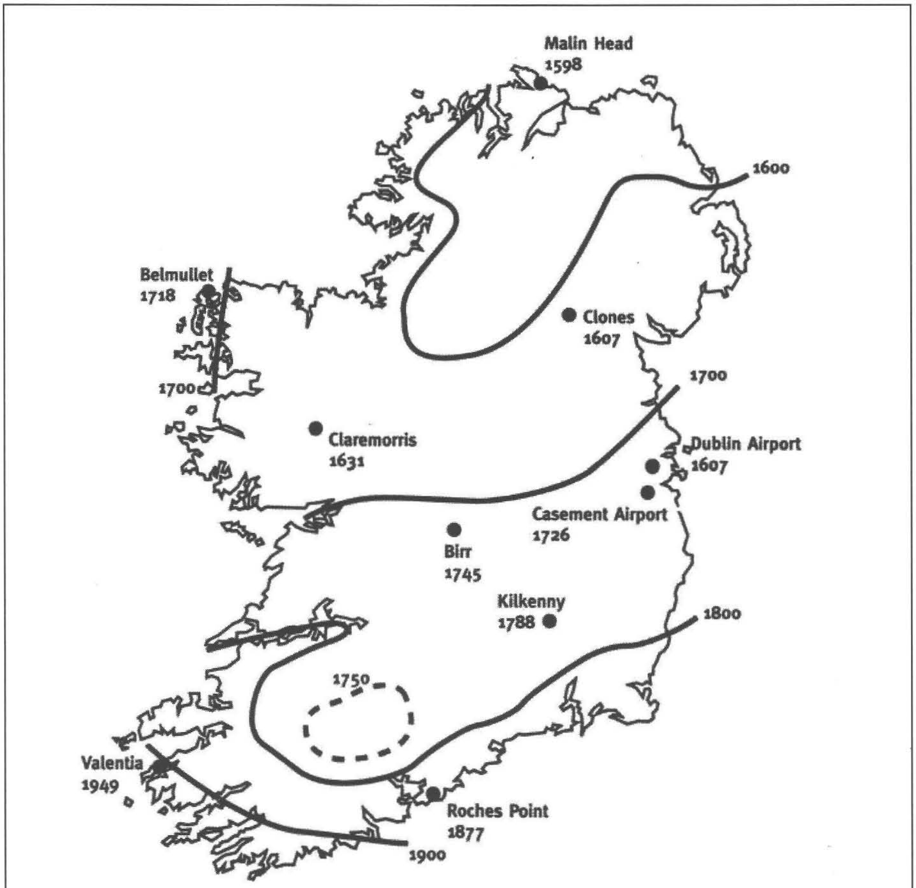

Figure 2. *Accumulated temperature or degree days (days above 5 OC) in Ireland (from Collins and Cummins 1996).*

shore of the Shannon Estuary (south of the 1,800 degree day line in Figure 2). Following the premise that QCI should be planted in areas with less than 1,400 AT, it would appear that there is no need to plant QCI anywhere in Ireland. Thus, Washington can safely be planted on all Sitka sites in Ireland not planted with Oregon.

Conclusions

The original arguments against the increased use of Washington and Oregon origins of Sitka spruce included concerns about too rapid growth, poor wood quality, lammas growth, stability, autumn frost damage, initial rapid growth that would not be maintained and the Forestry Commission recommendation to use QCI origins. As has been demonstrated in this paper, none of these arguments stand up to scrutiny and provide no compelling reason why QCI should be used to the extent it is. The conclusion is that Washington and Oregon origins of Sitka spruce should be planted for commercial purposes in this country.

The belief that QCI provides protection against late spring frost or that it can tolerate poorer or more exposed sites than Washington has no basis in fact. It is an unjustified fear of failure with Washington or Oregon sources that is perhaps the main reason for the widespread planting QCI.

However, the reduction in the planting of QCI will be a gradual process as stocks in nurseries gradually reflect the change in planting patterns. It will not happen overnight.

By planting more Washington and Oregon origins the productivity of the forest estate will be increased. For example, the current average Sitka spruce yield class of 16 in Coillte forests could be increased to almost 18, if more Washington and Oregon material were planted.

The 1984 decision to plant nationally plant a 50:50 ratio of QCI and Washington/Oregon sources was a safe, conservative approach, especially with only early provenance performance information available at that time, but now, in light of additional evidence, it is time for growers to change to Washington/Oregon origins. Thus, based on the arguments put forward above, there is no reason why so much QCI material should be planted in this country. Currently, Coillte planting comprises 64% Washington/Oregon: 36% QCI origins, but it is moving towards an 85% Washington/Oregon to a 15% QCI target. The QCI percentage could fall even lower in time. However, the continued planting of very large amounts QCI by the private sector - up to 80% - continues. This is based more on a false sense of security than on the results of scientific experiments. The widespread use of QCI origins results in at least a full Yield Class (2 m^3 ha^{-1} yr^{-1}) loss in roundwood production, with little or no benefit.

Sitka spruce provenance recommendations

Oregon provenance should be planted along the south coast (south of the 1,800 AT line in Figure 2). Elsewhere, Washington provenance should be planted where Sitka spruce is the chosen species.

QCI provenance - as discussed in this paper there are no good reasons to plant QCI in Ireland. In areas where QCI has been planted in the past, Washington will grow and produce a more productive crop. Even in areas of midland bog, because QCI provides no protection against late spring frost, Washington will survive, be more productive and will outgrow the risk of frost damage faster than QCI.

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