What is the best lodgepole pine seed origin for Ireland? Results of 30 years of provenance research

David Thompson[1], Michael Lally[2] and Alistair Pfeifer[3]

Abstract

Because of its large natural range, lodgepole pine (*Pinus contorta*) provides a wide range of provenances for use on a range of sites. Unfortunately no one provenance of lodgepole pine combines good stemwood production with acceptable stem form. For this reason compromises must be accepted. South Coastal types provide rapid volume production with poor stem form, while North Coastal types provide good stem form with reduced volume production. Natural hybrids between coastal and interior provenances from the lower Skeena River in British Columbia and artificial interprovenance hybrids between South Coastal and Skeena River sources combine good stem form with acceptable wood production rates. Both are available in commercial quantities either from registered seed stands (lower Skeena River material) or seed orchards (interprovenance hybrids). Provenance recommendations for specific site types and end uses are provided.

Keywords: Lodgepole pine, *Pinus contorta*, provenance, interprovenance hybrids.

Introduction

Lodgepole pine (*Pinus contorta*) is an important species in Irish forestry. It currently occupies about 70,000 ha, about 21%, of the Coillte (Irish Forestry Board) estate. However, its planting has decreased dramatically over the past decades, from over 40% of the total planting programme in the 1950s to just 3% by the late 1990s. Nevertheless, it will continue to be an important species, because on some sites it remains the best species option.

Following its introduction to Ireland (see below), and from its performance in plantations and trials it was found that the South Coastal group of provenances (from the coast of southern Washington and northern Oregon) grew more vigorously in trials than the better formed, but slower growing, North Coastal origins (from British Columbia and Puget Sound). Consequently the South Coastal group became the preferred selection.

However, as experience was gained and crops reached merchantable size it quickly became apparent that while South Coastal types were highly productive, its lack of stem straightness considerably reduced the volume of higher value assortments that could be obtained. Unfortunately there is a strong genetic negative correlation in lodgepole pine between growth rate and poor stem form. No one provenance combines a good growth rate with an acceptable stem form, so compromises need to be made. For this reason it is opportune to consider the origins of the lodgepole pine we grow in this country.

1 Coillte Research and Environment, Kilmacurra Park, Kilbride, Co Wicklow, Ireland (david.thompson@coillte.ie).

2 Coillte Forest, Newtownmountkennedy, Co Wicklow, Ireland (michael.lally@coillte.ie).

3 Coillte Research and Environment, Newtownmountkennedy, Co Wicklow, Ireland (alistair.pfeifer@coillte.ie).

The purpose of this review is to summarise seed origin research carried out with lodgepole pine over the last 30 years in Ireland and to make recommendations on the best origins for current use.

Natural distribution and site requirements

Lodgepole pine is one of about 100 species of pines worldwide, and one of 19 found in North America.

It has the largest natural distribution range of all North American pines (Figure 1) extending in latitude from south-eastern Alaska (64° N), along the Pacific coast, through British Columbia, Washington and Oregon and south as far as Baja California in Mexico (31° N). From the Pacific coast it extends eastwards as far as South Dakota. The full range covers approximately 26 million ha. Its elevation range extends from sea level to 3,900 m.

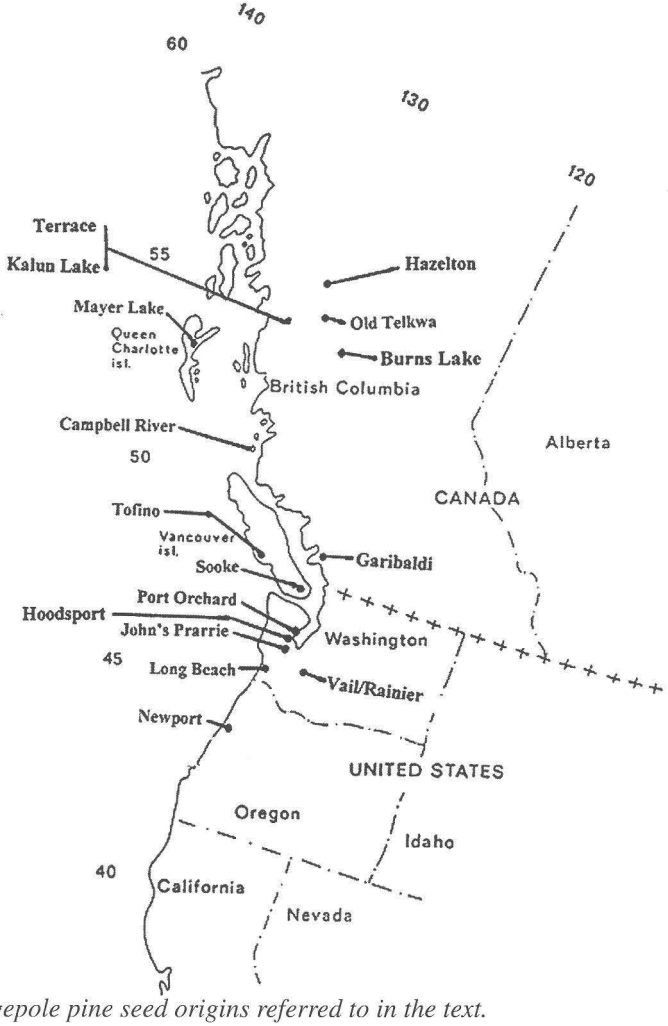

Figure 1. *Lodgepole pine seed origins referred to in the text.*

Rainfall ranges from 280 to 4,100 mm year^{-1} over its distribution. In response to these distributional and site influences lodgepole pine has developed local varieties adapted to a wide range of climatic conditions.

Lodgepole pine is a pioneer species which has relatively undemanding soil requirements, provided there is an adequate supply of phosphorus in the soil. It grows on a wide range of soil and site types including deep acid peats, upland heaths and hard boulder tills.

Historical background, introduction to Ireland and performance

Lodgepole pine was first reported by the Lewis and Clark expedition to the northwestern US in 1805 but was not scientifically described until 1825 by David Douglas. It was introduced to Britain about 1855 and was first planted in Ireland about 1884 at Ashford Castle, Cong, Co Mayo (Fitzpatrick 1966). Following the establishment of a state forestry programme in 1904 it was planted mainly to provide shelter for other species, or as a pioneer on the poorest sites, in the expectation that it would improve conditions for more demanding species in the second rotation.

The first large-scale planting took place at Ballyhoura Forest in Co Cork from 1918. Because the species showed the potential to produce pulpwood and perhaps commercial timber its role changed over time from a pioneer species to a commercial species in its own right. Mooney (1957) expressed the optimism of the time when he wrote "...if home grown *Pinus contorta* can be proved a tree of average utility value both as a timber and a pulpwood – and that can be put to the test in the immediate future- then the Irish forester can do something really big for the economy of this country, because these ground types which so far over the centuries have proved hard and unrelenting to men and agriculture will be theirs for the taking."

As a result of the cultivation practices (open furrow ploughing) and the seed sources used in the 1950s, problems with basal sweep and instability arose and became apparent from the late 1960s. Because no satisfactory silvicultural solution was found to these problems, serious doubts about the ability of the species to produce sawn timber were raised. Its use began to decline dramatically from the early to mid 1980s However today with increasing demands on timber production, especially on nutrient poor, exposed sites and the fact that lodgepole pine can serve as a nutritional nurse species on sites where supplemental fertilisation is no longer possible, the species may experience a revival in Irish forestry.

Seed origin, provenance trials and tree breeding

Provenance variation is apparent to greater degree in lodgepole pine than in any other commonly planted coniferous species in Ireland. Variation occurs not only in appearance, but also in growth rate and habit, stem form, ability to withstand exposure, fertility requirements, ability to suppress competing vegetation and cone characteristics (Lines 1996). Differences between coastal and interior origins are the most obvious

As early as 1916, A.C. Forbes, Director of Forestry, established the first provenance trial in Ireland at Avondale which compared coastal and interior sources. After ten growing seasons coastal provenances were 50% taller than interior sources (O'Driscoll 1980). In 1957 a survey of plantations of lodgepole pine concluded that Washington coastal origins were the most suited to Irish conditions. From the 1960s the poor performance of inland and Lulu island provenances was clear to all with the result that the fast growing South Coastal type was increasingly used, and by the early 1970s almost to the exclusion of all others.

Coastal lodgepole pine can be divided into South Coastal (SC) and North Coastal (NC) types (see definitions in the Introduction). South coastal types devote most of their resources to above ground biomass (stemwood, branches and needles) at the expense of root development (Table 1). Trees typically develop a large canopy (sail-area) on a poorly anchored stem. The stem becomes bent at the base (basal sweep) which contributes to later instability. Site factors such as soil type and moisture content, exposure and cultivation method are also important.

The faster growth of SC types adversely affects stem form (Table 1). On the other hand NC types devote more resources to below ground biomass (roots) which leads to good stability, but at the expense of stemwood production (Table 1). This results in a productivity reduction of at least one yield class (2 $m^3 ha^{-1} year^{-1}$).

Table 1. *Average growth rate, branching habit, root/shoot ratio and stability of SC and NC lodgepole pine types.*

Type	*Average growth rate*[1]	*Branch length*[2]	*Branch diameter*[2]	*Root/shoot ratio*[3]	*Damage by wind*[3]
	$m^3 ha^{-1} yr^{-1}$	*cm*	*mm*		*%*
SC	11	127	20.6	0.38	26
NC	9	87	16.6	0.66	8

1. Coillte inventory data, assessed as yield class
2. Pfeifer (1993)
3. Lines (1980)

As discussed above, it was apparent from a very early stage that coastal provenances of lodgepole pine grew best under Irish conditions. In spite of this realisation there was a lack of appreciation of the precise importance of provenance which resulted in the importation of some seed origins in the 1950s that led to very poor crops. In order to address this situation the first formal lodgepole pine provenance trial was established in 1962. This compared ten provenances and was followed by trials in 1966 and 1967 comprising 14 and 16 provenances, respectively. These trials did not, however, include a full range of sources. It was only in the early 1970s, following a comprehensive lodgepole pine seed collection covering the western part of the species range, made under the auspices of the International Union of Forrest Research Organisations (IUFRO), that a thorough investigation of the influence of provenance began. Of 143 provenances collected, 58 were considered the most promising for Ireland. These were used to establish a series of provenance trials, planted in 1972, at widely separated locations in Ireland.

As well as addressing the form of lodgepole pine from the provenance perspective work also began in the 1960s on plus tree selection and tree improvement. One of the first steps was the selection and testing of plus trees from superior Irish stands. Four seed orchards were established, comprising mainly South Coastal selections. It is ironic that, despite lodgepole pine having the most advanced tree improvement of any species in Ireland, very little of this material is used today.

In the early 1970s a programme was begun to develop a hybrid to combine the vigorous growth of the SC material with the good stem form of the NC sources. Interprovenance hybrids were produced and several trials were established around Ireland.

Results

Provenance trials

The results from a selection of provenances in the IUFRO trials grown at three locations are presented in Table 2. Petersburg, Mayer Lake and Garibaldi are typical NC origins with relatively slow growth rates and poor volume production but with good stem form. Long Beach and Newport are typical SC origins with good growth rate and high volume production but with poor stem form. As one moves from northern to southern origins growth increases but stem form deteriorates. Material from Sooke, Port Orchard and John's Prairie appears to be the best compromise between growth rate and stem form.

Table 2. *Growth and stem form (1= poor to 4= good) of a selection of lodgepole pine provenances after 25 growing seasons, averaged over three IUFRO trial locations (Lough Ennel 03/72, Co Westmeath, Crossmolina 01/72, Co Mayo and Kilworth 05/72, Co Cork).*

Provenance and location	*DBH*	*Top height*	*Basal area*	*Commercial wood volume (7 cm top diameter)*	*Yield class*	*Form*
	cm	*m*	$m^2 ha^{-1}$	$m^3 ha^{-1}$	$m^3 ha^{-1} yr^{-1}$	
Petersburg (A)	13.8	10.5	35.07	151	8	3.3
Old Telkwa (BC)	13.3	11.0	28.27	129	10	3.0
Mayer Lake (QCI)	16.1	11.5	40.83	200	10	3.2
Campbell R. (BC)	14.0	11.0	32.24	149	10	3.3
Garibaldi (BC)	16.4	12.0	41.77	215	10	3.0
Tofino (VI)	15.7	12.0	38.64	192	10	3.2
Sooke (VI)	17.4	12.0	46.33	240	10	3.1
Port Orchard (W)	18.2	12.0	49,56	258	10	3.0
John's Prairie (W)	17.5	12.5	45,27	243	10	2.9
Vail (W)	17.6	12.0	50.45	261	10	2.9
Long Beach (W)	19.7	13.5	51.65	309	12	2.5
Newport (O)	19.9	13.5	54.97	305	12	2.5

Locations: (A) Alaska, (BC) British Columbia, (QCI) Queen Charlotte Islands, (VI) Vancouver Island, (W) Washington and (O) Oregon.

The financial value of the standing crop in the different provenances was estimated for the Lough Ennell trial (Table 3). Although none of the provenances contained sawlog-sized material, the results show the effect of provenance on standing value even at an early age. In spite of greater volume production (Long Beach and Newport origins) the increase in pulpwood is at the expense of more valuable pallet wood. Thus the provenances that produced the greatest volume did not produce the most valuable crops. Similar to the results from the three sites combined (Table 2) the standing value suggests that provenances from the Puget Sound area of northern Washington (John's Prairie and Port Orchard) and southern Vancouver Island (Sooke) are a compromise between volume production and stem form.

Table 3. *Value of the standing crop after 25 growing season of a selection of lodgepole pine provenances at Lough Ennell 03/72, Co Westmeath.*

Provenance and location[1]	*Commercial wood volume (7 cm top diameter)* $m^3 ha^{-1}$	Pallet $m^3 ha^{-1}$	*Stake* $m^3 ha^{-1}$	*Pulp* $m^3 ha^{-1}$	*Value*[2] € ha^{-1}
John's Prairie (W)	308	135	41	132	3064
Port Orchard (W)	307	113	50	144	2830
Sooke (VI)	281	126	20	135	2617
Long Beach (W)	364	123	–	241	2339
Mayer Lake (QCI)	225	69	70	86	2303
Newport (O)	350	119	-	231	2261
Vail (W)	309	74	35	200	1953
Garibaldi (BC)	281	59	50	172	1888
Tofino (VI)	198	40	83	75	1859
Campbell River (BC)	161	8	96	57	1580
Old Telkwa (BC)	152	18	25	109	754

1. Locations as in Table 1.
2. Prices for top diameter assortments: pallet €17.78 m^{-3}, stake €14.60 $m^{-3}$and pulp €0.63 m^{-3} (prices date from 1996 and have not been adjusted for inflation). Typical top diameters of the three assortments are: pallet 14-19, stake 11-13 and pulp 7-10 cm.

Unfortunately most of the stands that provided material for the IUFRO trials no longer exist in the wild and commercial quantities of seed from sources such as John's Prairie, Port Orchard and Sooke are not available. Therefore, alternative sources of seed need to be found.

Natural hybrids

Although no one provenance combines good volume production with good stem form and while the Puget Sound origins appear to provide a compromise, seed is simply not available. Some NC origins from the Skeena and Fraser River Valleys of British Columbia do combine the good stem form of interior sources with the good volume production of coastal sources, as result of natural hybridisation (Lines 1996).

Work by the Forestry Commission in Scotland has identified several sources of NC lodgepole pine (from the lower Skeena River valley in British Columbia) with superior stem form. This material is intermediate between the more vigorous coastal material and the slower growing, but better stem form interior origins. Unfortunately only a limited number of trials including this material have been established in Ireland. One was planted near Roundwood in Co Wicklow in 1969, with three more planted in 1982-83. Results from these trials are presented in Tables 4 and 5 respectively.

Table 4. *Growth and stem form (1= poor to 4= good) and extent of basal sweep in lodgepole pine provenances at the Roundwood 05/69, Co Wicklow trial, assessed after 29 growing seasons.*

Provenance and location[1]	*DBH* cm	*Top height* m	*Yield class* $m^3 ha^{-1} yr^{-1}$	*Form*	Basal sweep *% stems*
Terrace- Kalun Lake (SK)	18	12.7	10	2.68	0
Terrace- Naas Valley (SK)	19	13.0	10	2.59	7
Hazelton (BC)	18	12.8	10	2.17	15
Rainier (W)	19	13.5	12	2.17	54
Hoodsport (W)	18	13.5	12	2.41	46

1. Locations: (SK) Skeena River Valley, (BC) British Columbia and (W) Washington.

Table 5. *Growth and stem form (1= poor, 4= good) and extent of basal sweep in lodgepole pine provenances at the Castleisland 07/82 Co Kerry, Doolough 08/82 Co Mayo and Bangor Erris 04/83 Co Mayo trials (all on blanket peat soil), assessed after 14 or 15 growing seasons.*

Provenance and location[1]	*DBH* cm	*Top height* m	*Yield class* $m^3 ha^{-1} yr^{-1}$	*Form*	*Basal sweep % stems*
Terrace-Kalun Lake (SK)	8.6	4.3	8	2.7	6
Hazelton (SK)	8.2	4.4	8	2.0	37
Rainier (W)	8.7	5.6	10	1.6	81
Hoodsport (W)	8.2	3.8	6	1.7	64

1. Locations as in Table 4.

The Terrace-Kalun Lake, Terrace-Naas Valley and Hazelton represent the Skeena River material that is intermediate between the costal and interior provenances. Rainier material is the origin that is closest to a typical SC type. Hoodsport is a Washington SC origin, but it is from a sheltered location, which did well at the Roundwood site, but not on the more exposed sites presented in Table 5. About one yield class (2 $m^3 ha^{-1} yr^{-1}$) separated the Skeena River hybrids from the Rainier material, but Skeena River had better stem form and less basal sweep. This better form and stem quality will increase its value compared with the Rainier material.

The Forestry Commission has recognised the value of these sources and has established seed stands incorporating them. Because of the reduced planting of lodgepole pine in the UK this material is available for commercial use in this country.

Interprovenance hybrids

As has been shown, the strong genetic inverse correlation in lodgepole pine between growth rate and poor stem form in lodgepole pine, referred to in the Introduction cannot be

overcome simply by provenance selection. The natural hybrids from Terrace- Kalun Lake, Terrace- Naas Valley and Hazelton offer one option, while artificial hybrids are another. These artificial "interprovenance" hybrids combine the good stem form of the NC types with the high volume production of the SC types (Table 6).

Table 6. *Diameter growth, stem form (1= poor to 4= good), extent of basal sweep and stem forking in lodgepole pine interprovenance hybrids and the parental provenances at the Ossory 03/83 Co Offaly and Glenamoy 50/83 Co Mayo trials, assessed after 14 growing seasons.*

Provenance and location[1]	*DBH*	*Form*	*Basal sweep*	*Forking*
			% stems	*%*
	cm			
Naas Valley (SK)	9.05	3.17	19	24
SC X Naas Valley (HYB)	12.54	2.54	38	47
Kalun Lake (SK)	10.01	2.99	21	21
SC X Kalun lake (HYB)	13.20	3.04	29	22
Hazelton (SK)	10.09	3.05	29	32
SC X Hazelton (HYB)	12.65	2.85	42	40
Hoodsport (SC)	11.06	2.54	46	29
SC X Hoodsport (HYB)	13.48	2.60	55	37
Rainier (SC)	11.30	2.36	45	44
Long Beach (SC)	13.80	1.76	82	62

1. Locations and hybrids (SK) Skeena River, (HYB) interprovenance hybrid. (SC) South Coastal and SC X is an interprovenance hybrid between a SC source and a named provenance.

In most cases the diameter growth of the interprovenance hybrid was superior to that of the original NC provenance, but with a slight reduction in stem form and an increase in both the incidence of basal sweep and forking (Table 6). Of the crosses examined the SC X Kalun Lake appears to be one of the best compromises, with good diameter growth combined with a small loss of stem form and a minimal increase in basal sweep and forking.

The results suggest that interprovenance hybrids offer the best compromise between wood production and stem quality. They also provide a more vigorous option than the natural hybrids (Tables 4 and 5).

The Forestry Commission established a series of seed orchards in the 1980s designed to produce seed of interprovenance hybrids on a commercial scale. Three seed orchards were established using a SC source crossed with a Skeena River (Terrace and Burns Lake) source. Specific crosses were made between 75 Skeena River trees and 75 SC Washington trees, with each family represented by 25 trees. In addition, plants of the same crosses were planted on three sites. The families with the poorest height growth and stem form were rogued from the seed orchards. The best 20 to 30 families remain in the orchard to cross and produce seed.

Conclusions

The main problem with using lodgepole pine as a plantation species is that no one single seed source combines good wood volume production with acceptable stem form. Results from the IUFRO trials have identified several provenances that do provide a compromise, but these stands no longer exist or cannot provide commercial quantities of seed. Mayer Lake from the Queen Charlotte Islands is one origin known to tolerate exposure well, but its productivity is one yield class less than SC types (Table 2). Tofino, from the west side of Vancouver Island, also has good volume production with a good stem form, if grown on more sheltered sites. Material from the lower Skeena River valley in British Columbia (Terrace, Kalun Lake and Hazelton) provides natural hybrids combining the good volume production of coastal sources with the better stem form of interior sources, but has a lower yield class than SC sources. This material is available from seed stands established by the Forestry Commission in the UK.

Similarly, interprovenance hybrid crosses between SC and NC origins is another option. This material is available from rogued seed orchards established by the Forestry Commission and provides the best genetic material currently available for lodgepole pine.

Recommendations

As a result of over 30 years of provenance research the following seed source recommendations can be made for lodgepole pine (Table 7).

Table 7: *Recommended seed sources of lodgepole pine for Irish sites.*

Crop and site type	*Recommended seed source*
In mixture with Sitka spruce	Alaskan (if available), NC (Including QCI and Vancouver Island) origins
Pure lodgepole pine plantations, on exposed, infertile sites	QCI, Vancouver Island or interprovenance hybrids
Pure lodgepole pine plantations, on less exposed, mineral soils	Interprovenance hybrids, lower Skeena River (Terrace, Kalun Lake Burns Lake and Hazelton) and Irish SC seed orchard material

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