The Importance of Lodgepole Pine in Irish Forestry[1]

J. O'DRISCOLL

Forest and Wildlife Service,
Sidmonton Place, Bray, Co. Wicklow.

CLASSIFICATION

The genus Pinus, of which *Pinus contorta* is a member, is one of the most widely distributed genera in the northern hemisphere. It contains over 90 species extending from the polar region to the tropics. It is the only northern hemisphere genus which occurs naturally south of the equator (Wright 1962). Within this very large genus, *Pinus contorta* belongs to the subgenus Pinus or hard pines and within this subgenus to the subsection contortae. Allied to it within this subsection, are *Pinus divericata* (banksiana), *P. virginiana* and *P. clausa,* all of which are native to North America. Two of these species are found in eastern North America and the other two in western North America (Critchfield and Little 1966).

PALEOHISTORY

The earliest recorded presence of *Pinus contorta* on the North American continent was 26 million years ago during the Miocene period. It did not become widely distributed until the Pleistocene period, 1.5 million years ago, when records indicate that it may have extended 100-400km further north than its present day range. During the Wisconsin ice age much of the northern distribution of the species was wiped out. As the ice sheet did not extend further south than northern Washington the species widespread distribution in western United States was not greatly affected. This southern refugium may have been the base from which it reoccupied its present northern range. Fossil records show that the species was the first to colonise the glaciated terrain in both the Fraser River lowlands and in the Rocky Mountains following the retreat of the ice sheet. It has not however, been conslusively shown that the southern refugia were the only ones from which the species

1 Presented at "Symposium on Lodgepole Pine", Pomeroy, Co. Tyrone, April, 1979.

IRISH FORESTRY, 1980 Vol. 37, No. 1: 7-22

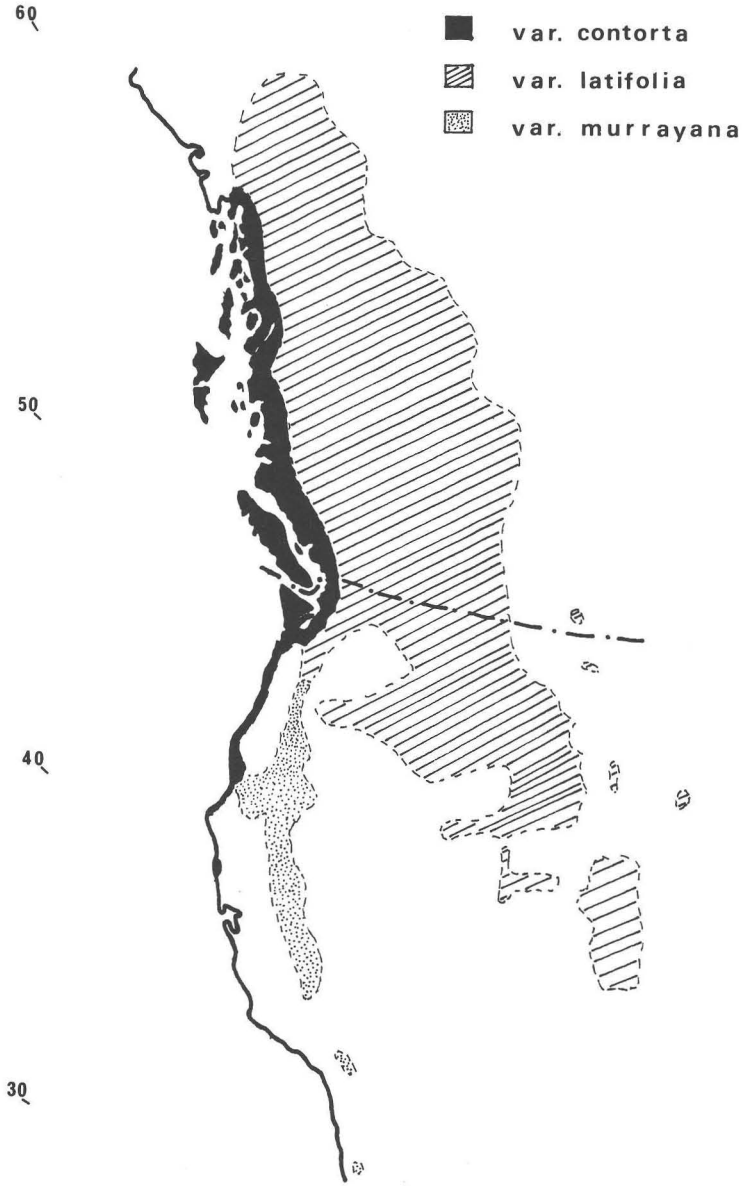

Fig. 1 — Approximate geographical distribution of the three subspecies of *Pinus contorta*.

could have re-colonised those recently available sites. Other suggested refugia include (1) unglaciated parts of the Yukon (2) ice free areas east of the Canadian Rocky Mountains and (3) the north Pacific coast. Strong contra agruments exist to show that these refugia did not exist. (Critchfield 1978).

DISTRIBUTION

Whatever the origin, the present day distribution of the species is extremely large covering a very wide ecological amplitude, both climatic and edaphic. It is found growing from southeastern Alaska and interior Yukon in the north to Baja, California in the south and east as far as the Black Hills of South Dakota. Its north — south distribution covers 33° of latitude while east — west it covers 33° of longitude (Fig. 1). Of all the pine species it has the greatest elevational range, from sea level along the Pacific North West coast to 3900m in the Sierra Nevada Mountains (Fowells 1969). The interaction between the species and the wide variety of climatic and edaphic conditions on which it occurs has resulted in the species being classified into three distinct groups (1) *Pinus contorta var. contorta* found mainly along the Pacific coast mountains of British Columbia and California. (2) *Pinus contorta var. latifolia* covering the Intermountain region and Rocky Mountain systems from central Yukon to eastern Oregon and southern Colorado and (3) *Pinus contorta var. Murrayana* found mainly on the Cascade and Sierra Nevada Mountains in Oregon and California. (Critchfield 1957).

Throughout its coastal distribution it is found mainly on very poor site types which are unfavourable for the growth of possible competitors. To the north the site types are mainly bog and muskegs while further south in Washington and Oregon they are cliff faces and sand dunes. Immediately inland from the coast the species is found on serpentine soils on San Juan islands and in western Washington and on nutrient poor glacial drift areas in the Puget Sound. Climatic conditions throughout this part of the distribution are typically cool and moist with a narrow range of temperatures (Critchfield 1978). Because of the poor nature of the soils the number of associated species is very limited. On the bog ecosystems lodgepole pine can be associated with poorly growing western hemlock, red cedar and yellow cedar (Valentine et al 1978). On the sand dune sites it is mainly pure but where soil nutrient level is somewhat higher it is found in association with Sitka spruce and red alder (Franklin and Dyrness 1973). Growth and form throughout the coastal distribution is poor with maximum development taking place in the southern part of this distribution. This section of the species can be broadly classified as a coloniser after fire or other disturbance.

Most of the commercial stands of the species occur within the var. latifolia group and are found on well drained calcareous tills having a silty loam or clay loam texture. Climatic conditions in this region are characterised by hot dry summers with low rainfall and cold winters with heavy snowfall. Growing season is short with frosts occurring every month. The species occurs mainly in pure stands in this portion of its distribution. The wide expanse of pure stands in this part of the overall distribution is attributed to the species' ability to aggressively colonise fire ravaged sites.

Tree form is generally good. Growth is characterised by a high density of stems per unit area and individual trees having low volumes. Due to the high number of stems growing on any site overall stand volume is high. A stand in British Columbia for example at 80 years yielded 430m^3/hectare (Fowells 1965).

Extensive pure areas are also found within the var. Murrayana distribution of the species on pumice and volcanic ash soils. The climate in this region is characterised by low summer rainfall, wide diurnal temperature fluctuations and a relatively short growing season. Much of the precipitation occurs as snow. Stands are generally pure in this region, though in some more fertile areas ponderosa pine is also present. The predominance of the lodgepole pine is thought to be due to its ability to withstand frost on the better drained depressions, while on the poorly drained areas ponderosa pine is not able to compete (Franklin and Dyrness 1973). The stands are climax ones rather than successional as occurs in other parts of the species distribution. Growth form is generally straight and slow. On exceptional site, yields of 550m^3/hectare have been recorded with a stocking of 1960 stems/hectare (Fowells 1965).

Discovery

The species was reported to have been seen by Lewis and Clarke in 1805 on their voyage of exploration but was not recorded scientifically until 1825 by David Douglas. He recorded its presence at the mouth of the Columbia River at Cape Disappointment, Washington (Kent 1900). Its name is attributed to David Douglas as a result of observing the curious form of dead trees of the species on pumice soils near Klamath Lake, Oregon, the branches of which curved downwards and inwards (Veitch 1881). However it was not until 1885 that it was first introduced to Great Britain. The inland form var. Murrayana though not discovered until 1852, reached Britain one year ahead of the coastal form var contorta, in 1854 (Elwes and Henry 1910).

Species in Ireland

The first known record of its introduction to Ireland was in 1884 when a number of specimen trees were planted at Cong, Co. Galway (Forbes 1928). The next recorded planting was at Avondale in 1916 when the then Director of Forestry Mr. A. C. Forbes compared a provenance of var. contorta to a provenance of var. Murrayana in an attempt to ascertain which "species" or provenance was the most suitable for Irish conditions. When reported on in 1928 the growth of the coastal provenance was fifty percent taller than the inland provenance (Forbes 1928). These differences were probably instrumental in influencing the Director of Forestry to choose coastal provenances in preference to the interior provenances as is borne out by the seed purchase patterns of that time (Guillebaud 1933, Mooney 1966).

Pattern of Seed Imports

The first commercial importation of seed was made in 1911 when 0.2lbs of var. Murrayana was obtained from Rafn of Copenhagen. This was followed by a further 0.43lbs, in 1915, of the same origin. It was not until 1923, when State afforestation was undertaken on a large scale, that larger quantities were obtained from Manning Seed Company. In all probability these earlier collections were of coastal origin though no record exists to prove unequivocally that they were. In the intervening years up to 1977 11,485lbs of seed were imported. The pattern of the origins in the twenties was predominantly coastal. In the thirties, though imports were predominantly coastal, there was a definite swing towards inland provenances mainly from the var. latifolia distribution. At the end of this period the Lulu island provenance made its first appearance. A further increase in the amount of inland and Lulu island seed occurred in the forties with a correspondent drop in the poundage of coastal origins. It was in this decade that the first home collected seed was used. The really major swing away from coastal origins occurred in the fifties when Lulu island became the main source of supply. Inland origins were also used during this period but unlike earlier importations they were mainly from the var. Murrayana distribution. In the early sixties it was realised that the full volume production potential of the species was not being achieved by most of the origins used in the fifties. As a result there was a dramatic drop in the importation of seed of both inland and Lulu island origins with a correspondent increase in the quantity of seed of coastal origin. This trend was further accentuated by an increased use of home collected seed of known coastal origin (Fig. 2).

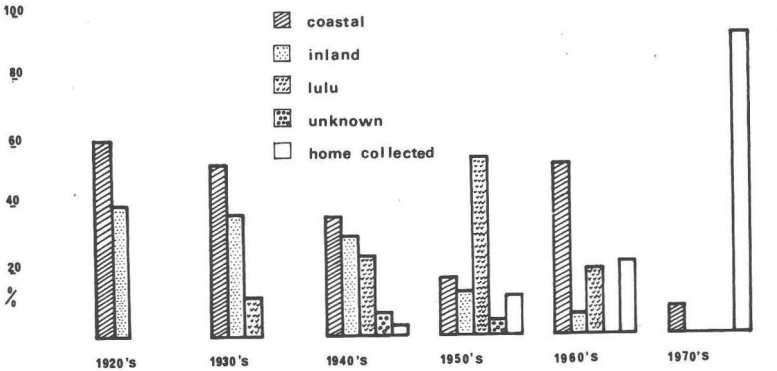

Fig. 2 — Seed Purchase Pattern 1920-1977

Pattern of Planting

Where records are available, the early pattern of planting places lodgepole pine as the fifth most important species after Sitka spruce, Scots pine, Norway spruce and European larch. During this period in the early thirties the percentage of lodgepole pine planted ranged from 6 to 15%. No figures are available for the forties. In the early fifties, however, it became the most widely used species when its use ranged from 26 to 40%. This expansion of its use corresponded with the increased afforestation programme in the west of the country. Its position as dominant species lasted three years and from then until 1977 it has always ranked second to Sitka spruce. This pattern is reflected in its reduced use in the sixties. It nevertheless remained high ranging from 22 to 31%. In the early part of the seventies it dropped to its lowest level for twenty years at 21%. However as the decade progressed it was returned to a high level of 35% of plants used (Anon 1933-1977, Anon 1976-1977) (Fig. 3).

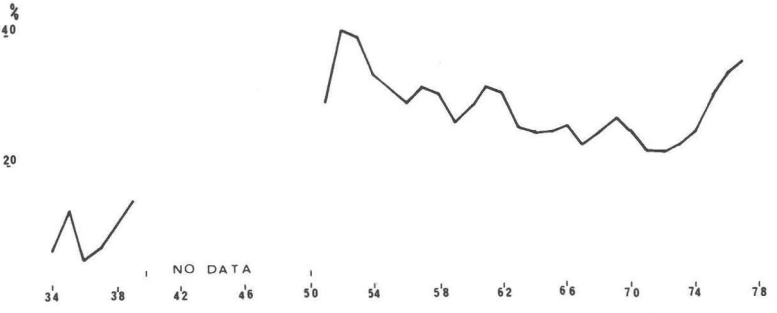

Fig. 3 — Percentage of Lodgepole pine Planted 1933-1977

PRODUCTIVITY

No readily available data exists for the total area of productive forest of lodgepole pine in the State at the present time. The earlier inventory of 1968 covered planting between 1923 and 1958, and recorded an area of 18,700 hectares (O'Flanagan 1973). The recently completed 1975 inventory covered plantings between 1959 and 1968, the data of which are at present being processed. A small area in private woodlands has also been recorded (Gallagher and Purcell 1976). The bulk of the area in the earlier inventory was planted pure with only 11% being in mixture. Classified under broad provenance headings, 8,400 hectares, representing 45% of the total area in state forests in 1968 was of coastal origin. The Lulu island group represented 37% with an area of 6,900 hectares, while the inland group with 18% of the area had 3,400 hectares. The productivity differences between these broad groups was quite large. The most productive, as might be expected, was the coastal group with a range of productivity from yield class 6 to 16 and an average value of 12. The bulk of the area within this group, 72% was present in yield classes 11 and 16. The range of yield classes for the Lulu island group was from 2 to 12 with an average value of 6. However the bulk of the area, 59% was present in yield classes 6 to 8. The third broad group, that of the inland provenances also had a productive range of yield class 2 to 12 with an average value of 6. As with the Lulu group 67% of the productive area of the inland group fell within the confines of yield classes 6 to 8 (Fig. 4). The values for the coastal lodgepole are likely to be revised upwards as a result of findings in the recent (1975) Inventory (Clinch 1977).

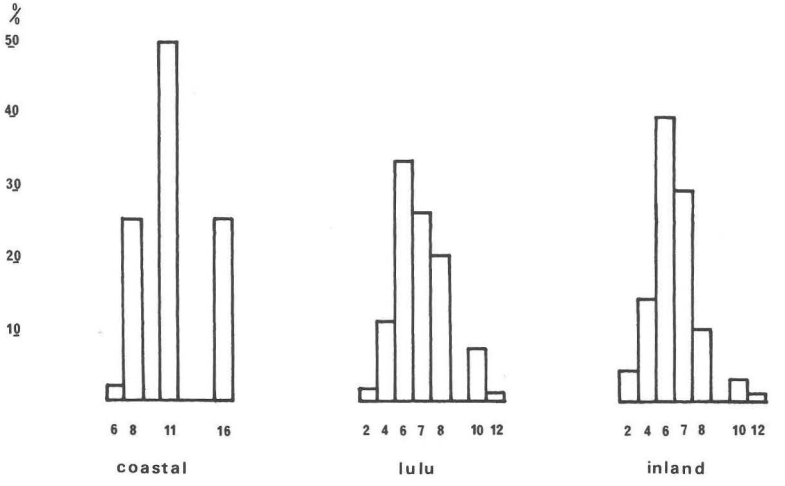

Fig. 4 — Percentage Area by Yield Class 1968 Inventory.

Of the total recorded productive area planted up to the end of 1958, 55% was with less productive provenances. Taking the average values for each group there is a shortfall of four yield classes between these less productive areas and what might have been had coastal provenances been used. (Hamilton et al 1974; Anon 1976). This over a 40 year rotation has resulted in a loss of production of $373m^3$/hectare equivalent to £9, 300 assuming sawlog prices for final crop.

RESEARCH

In the late 1950s and early 1960s it was observed that the seed lots imported during the early part of the fifties as coastal origin, were not as productive as had been hoped. This prompted a survey of older stands which revealed that the most productive areas were of coastal origin, probably Washington (Mooney 1957), but exact location details were not available. In an attempt to verify the origins of these older stands a ten provenance experiment was laid down in 1962 using seed supplied by a commercial seed merchant. The provenances comprised six reputedly coastal origins, two interior British Columbian origins and two interior Oregon origins. The experiment was outplanted on seven sites in 1965. At the end of three years in the field the pattern of growth, which the experiment was to follow, had been established. On all sites the coastal provenances, reputed to be from Washington and Oregon, were the most vigorous. The coastal British Columbian provenances were grouped second while all the interior provenances were third (O'Driscoll 1972). Of major importance even at this stage was the unreliability of commercial seeds lots for provenance work. One seed lot within the experiment was replicated by year. Differences both in growth and morphology rapidly emerged, indicating the inaccuracy of the stated origin. All of the British Columbian coast group bore markedly Lulu island type characteristics. At the end of nine years the ranking had not altered, the coastal Washington and Oregon provenances being still the most vigorous. When extrapolated on yield class graphs the overall average production for 7 sites was coastal type yield class 14, Lulu island type 8 and inland type 6 (Table 1).

Recognising the limitations of the first series of experiments, a second was laid down in 1965 with 16 provenances using, where possible, source authenticated lots. These comprised nine coastal origins, four inland origins, two home collected ones and one second generation New Zealand origin. Both the home collected and New Zealand origins were included for comparison purposes. At the end of the nursery stage the south coastal provenances were the most vigorous, followed by the north coastal type and poorest of

all were the interior provenances (O'Driscoll 1972). In 1967 the experiment was transferred to seven sites. At the end of nine years the group ranking was still the same as it had been at the end of the nursery stage (Fig. 5). When the average for all sites is taken, a yield class value of 16 was found for the south coastal group, 10 for the north coastal group and 6 for the interior group. If only the most productive site is taken the yield class value for the south coastal group is raised to 18 and to 12 for both north coastal and inland groups (Table 2). At age 45 this difference would amount to 280m^3/ha. In monetary terms given current prices this would amount to £7,000 for sawlog or £840 for pulp.

Table 1 — Growth of Series I Provenance Experiment

Provenance	Classification	9 yr old hts(m)	Y.C. extrapolated
Olney 1961, O.	south coastal	4.0	14
Lincoln, O.	south coastal	3.9	14
Long Beach, W.	south coastal	3.8	12
Olney 1960, O.	north coastal	2.8	8
Lot 6857, B.C.	north coastal	2.8	8
Vancouver, B.C.	north coastal	2.8	8
Penticton, B.C.	var. latifolia	2.2	8
Quesnel, B.C.	var. latifolia	2.1	6
Chester, C.	var. Murrayana	1.8	6
Lot 6000, C.	var. Murrayana	1.7	6

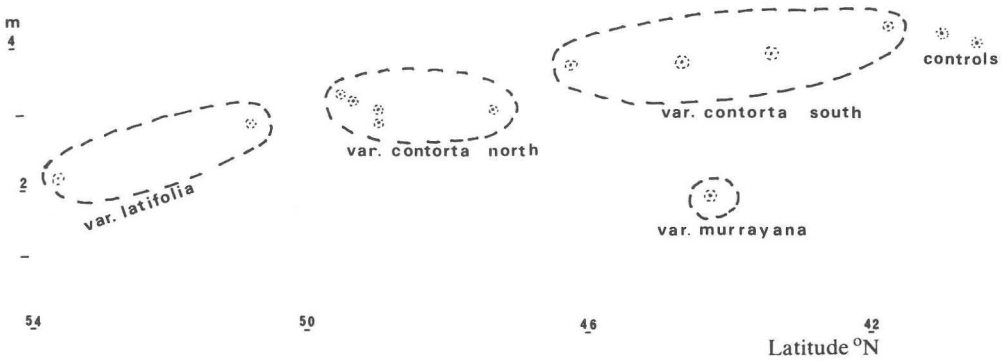

Fig. 5 — LP Series II Height at 9 years (1976)

Table 2 — Growth of Series II Provenance Experiment

Provenance	Classification	Ht. at 9 yrs. (m)	Yield Class Av. of 4 sites	Best site
Crescent City, C.	south coastal	4.3	16	18
Ballynoe	south coastal	4.1	14	16
North Bend, O	south coastal	3.9	14	16
Long Beach, W	south coastal	3.8	12	16
Newport, O	south coastal	3.8	12	14
Qualicum, B.C.	north coastal	3.3	10	12
Mendocino, C.	south coastal	3.2	10	12
Sechelt, B.C.	north coastal	3.2	10	12
Cowichan, B.C.	north coastal	3.1	10	12
Hoodsport, W.	north coastal	3.1	10	12
Forth Mt.	north coastal	2.9	10	12
Salmon Arm, B.C.	var. latifolia	2.9	10	12
Fort St. James, B.C.	var. latifolia	2.1	6	8
Sisters, O	var. Murrayana	1.9	6	8
Montana	var. latifolia	1.6	6	8

The third and last series to be laid down was that of the IUFRO collection comprising 58 provenances plus two home collected lots. This series was outplanted in 1971 on five sites. Due to the large number of provenances represented in the experiment it was not possible to have them all on each site. This problem was overcome by grouping the provenances into regions and ensuring that each region was represented on each site. At the end of 6 years there was a decrease in height growth with increasing latitude among the coastal provenances followed by the Washington, Vancouver Island, mainland B.C; Queen Charlotte Islands Alaskan and interior provenances in descending order of vigour (Table 3, Fig. 6). It is not possible at this age to put a meaningful yield class value on the different provenance groupings.

From a general observation of these three series of experiments it has been possible to divide the coastal distribution of the species into two broad sub groups, a south coastal type typified by a dense heavy crown and a north coastal type typified by Lulu island type characteristics. The former extends south from southern Washington along the coast. The latter extends south into the Puget Sound

Table 3 Most vigorous provenances within each group.

Series III Provenance Experiment

Group	Provenance	Av. ht.at 6 years
South Oregon	Carter Lake	2.9m
Washington	Long Beach	2.3m
Vancouver Is.	Lund	2.0m
Mainland B.C.	Garibaldi	1.8m
Q.C.I.	Mayer Lake	1.5m
Alaska	Petersburg	1.3m
N. Inland	Champion Lake	1.4m
S. Inland	Trout Lake	1.2m

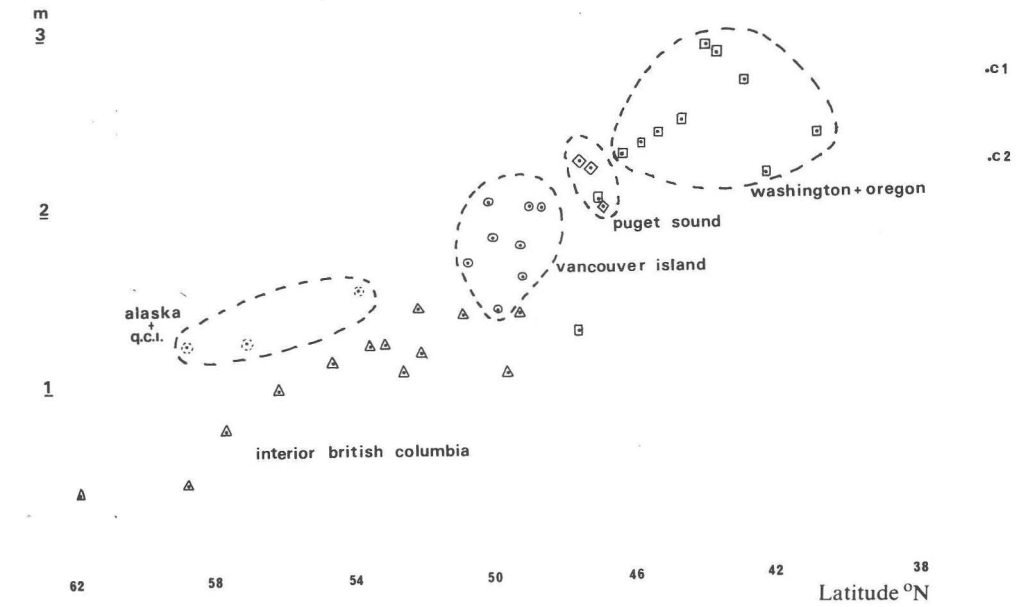

Fig. 6 LP Series IV IUFRO Height at 6 years (1977)

region and north along the coastal of Vancouver Island and mainland British Columbia. In all experiments to date the most vigorous provenances have always come from the southern end of the species distribution while the north coastal group has ranked intermediate between the south coastal and inland groups. This pattern of growth corresponds very well with those of the earlier plantings.

The most vigorous provenances which yielded the large timber were from the southern sub group of the coastal distribution though in all probability not as far south as the most vigorous in the IUFRO experiment. The form and growth of the Rainier type, planted in the 30's, corresponds reasonably well with that of the southern arm of the north coastal sub group. Both have the characteristics of slower growth, upswept branches and generally less vigorous appearance. The inland provenances both in the earlier plantings and in the experiments clearly show lack of vigour, the poorer the site the worse it is.

One somewhat disturbing feature however of the south coastal provenances planted in the last ten to fifteen years has been the high incidence of basal sweep. When assessed within the 1967 provenance experiment, differences between provenances in percentage stems affected and length of stem affected were statistically significant. It was however also evident that basal sweep was present in all provenances but the degree of its expression varied with the provenance. In the south coastal group percentage stems affected ranged from 64 to 79%, with the north coastal group it was from 33 to 47% while for the inland group it was from 18 to 39%. The corresponding length of stem affected ranged from 0.7 to 0.9m for south coastal group, 0.5 to 0.7m for the north coastal group and 0.4 to 0.7 for the inland group (Table 4).

The extent of the incidence of basal sweep has caused many to cast doubt on the usefulness of the south coastal group of provenances for Irish forest conditions. Assuming saw log prices the actual loss in revenue on the final crop of the south coastal group with the most severe basal sweep would amount to £700 in a £10,000 return per ha. at 45 years. Returns for box wood and pulp would be proportionally less and may even be negligible in the case of pulp. For the north coastal and inland groups the loss in revenue due to basal sweep would be £600 in £7,600 for saw log material.

Nevertheless it has been suggested that the use of slower growing inland or north coastal provenance would overcome this problem. However if older south coastal plantings are observed it is seen that basal sweep is not such a serious problem. It can be speculated that this was due to the site type and methods of planting used. It would appear that with the increase of plantings on ploughed ground and on more exposed sites, there has been a marked increase in the frequency of basal sweep. This is in agreement with experience in

Table 4 Extent of Basal Sweep in Series II Experiment at 12 years.

Provenance	Classification	% Stems affected	Length of Stem affected
Crescent City, C.	south coastal	79.5	0.8m
Ballynoe, Irl.	south coastal	77.5	0.9m
Newport, O.	south coastal	74.8	0.8m
Long Beach, W.	south coastal	72.5	0.8m
North Bend, O.	south coastal	71.7	0.8m
Kaingaroa, NZ.	south coastal	71.6	0.9m
Mendocino, C.	south coastal	63.9	0.7m
Cowichan, BC.	north coastal	47.3	0.6m
Hoodsport, W.	north coastal	46.9	0.7m
Qualicum, BC.	north coastal	46.8	0.7m
Sechelt, BC.	north coastal	43.4	0.7m
Sisters, O.	var. Murrayana	41.7	0.5m
Salmon Arm, BC.	var. latifolia	39.2	0.7m
Forth Mt. Irl.	north coastal	32.9	0.5m
Fort St. James, BC.	var. latifolia	23.3	0.4m
Montana	var. latifolia	18.2	0.4m

Britain (Lines 1972) where it was most severe on exposed and poorly drained soils. The main disadvantage of the inland or north coastal provenances is their slow growth even on the most productive sites. In addition it is open to speculation whether the returns on supposedly better material would compensate sufficiently for the extended rotation. This problem may be better solved by greater attention to planting stock and to methods of establishment and site selection.

UTILISATION

The timber quality of home grown timber has been shown to be excellent. In a test carried out in the early sixties at Princes Risborough, lodgepole pine was shown to saw and season very well and in fact was superior to Sitka spruce in both these characteristics. It was generally denser than Sitka spruce which implies that it has superior strength qualities. Spiral grain was found to be of very little

importance, in comparison with spruces, where it can be a major problem. In one sample the percentage of compression wood was high occurring on the side opposite to that of the prevailing wind. The species' permeabilility was poor making it difficult to treat with timber preservatives (Anon 1965).

These tests were carried out on trees from basically the same provenance group. A study in Britain between a Washington coast provenance and an interior British Columbia provenance from Prince George showed that there was a significant difference between provenances in all characteristics measured. The tests applied particularly to pulp properties as no sawing tests were carried out. In the coastal provenance density was 20% greater than that of the interior provenance, Compression wood was also much higher. Pulp yield was greater in the south coastal provenance. Because of greater tracheid length in the Prince George provenance both breaking length and burst factor of the interior provenance was superior. It was also found that vigour had no effect on the density (Henderson and Petty 1972).

Experience with the marketing of home grown timber has shown that it makes excellent panelling and high quality furniture. Much of the present output from state forests is being used for pulp and pallet wood. Where large timber is available it is converted to panelling and can commend a premium of £20 per m^3 standing. Unfortunately due to the small area of older coastal provenances there is not a lot of this type of material available.

FUTURE

Experience to date in Irish forestry has shown that the most productive provenances are from the species south coastal distribution. Of recent years some disquiet has arisen with regard to the degree of basal sweep recorded in younger stands. Suggestions have been made that an inland or a north coastal provenance should be used to overcome this problem. However, no hasty decisions should be taken as it must be remembered that the site types at present being planted are more extreme than earlier ones. Were these to be planted with slower growing provenances they might fail completely or require such a fertiliser input as to make the entire operation uneconomic. Their longer rotation period required to get them to sawlog category would also throw some doubt on their economic value. To be an economic proposition they would need to be planted on site types normally planted with Sitka spruce. A further suggested alternative is interprovenance hybrids. These have been shown to grow straight and vigorously in Great Britain (Faulkner et al. 1977). There, however, remains the one problem of producing sufficient reproductive material, be it seed or cuttings,

to make it a viable proposition. This problem may of course be overcome in the future. A more immediate and possibly a more rewarding remedy would be to attempt to reduce some of the possible contributing factors to basal sweep in the coastal provenances. This would involve examining all the methods and techniques of establishing crops of this provenance, treating the species in its own right and evolving a silviculture suited to it as distinct from spruce management. The influence of stand treatment such as pruning and recent machine grading tests are encouraging in this respect. (Gallagher 1975, Phillips 1978). In this way the vast potential of these provenances for growth and yield would be utilised to the full.

REFERENCES

Anon
1933, 1977 Report of the Minister for Lands on Forestry, Dublin, Ireland.

Anon
1965 Properties of home grown Pinus contorta. Research Record No. 2 Forest and Wildlife Service, Dublin, Ireland (Unpublished).

Anon
1975 Provisional Yield Tables for Lodgepole pine. Research Communication No. 16. Forest and Wildlife Service, Dublin, Ireland (Unpublished).

Anon
1976, 1977 Report of the Minister for Fisheries and Forestry on Forestry and Wildlife Service, Dublin, Ireland.

Clinch, P.
1977 Growth patterns in young conifer crops; effect of second manuring. Research Communication No. 18. Forest and Wildlife Service, Dublin, Ireland (Unpublished).

Critchfield, W. B.
1957 Geographic variation in *Pinus contorta*. Maria Moors Cabat Foundation. Publication No. 3 Harvard University Press.

Critchfield, W. B.
1978 The distribution, genetics and silvics of lodgepole pine. Proceedings Joint IUFRO Provenance Working Group Meeting, Vancouver British Columbia (in press).

Critchfield, W. B. and Little, E. L.
1976 Geographic distribution of pines of the world. USDA Forest Service Misel. Publication 991, Washington.

Elwes, H. J. and Henry A. H.
1910 Trees of Great Britain and Ireland. Vol. 15, pp 1134-1139.

Faulkner, R., Fletchner, A. M.,
Johnstone, R. C. B. and Forrest, G. I.
1977 Genetics, Forest Research, Forestry Commission, London.

Forbes, A. C.
1928 Pinus contorta or P. murrayana. Gardiners Chronicle, March 31st 1928. pp 232-283.
Fowells, H. A.
1965 Silvics of forest trees of United States. USDA Forest Service Agricultural Handbook 271, Washington.
Franklin, J. F. Dyrness, C. T.
1973 Natural vegetation of Oregon and Washington. USDA Forest Service, General Tecnical Report PNW — 8 Portland, Oregon.
Gallagher, G.
1975 Effects of green pruning in conifer crops. Research Communication No. 14, Forest and Wildlife Service, Dublin.
Gallagher, G. J. and Purcell, T. J.
1976 An inventory of Private Woodlands. Seminar for the Private Sector, Dun Laoghaire, (Unpublished).
Gullebaud, W. H.
1933 Report on certain plantations of *Pinus contorta* in the Irish Free State (Unpublished).
Hamilton G. J. and Christie J. M.
1971 Forest management tables (metric). Forestry Commission Booklet No. 34 Forestry Commission London.
Henderson, J. and Petty, J. A.
1972 A comparison of coastal and interior provenances of lodgepole pine *Pinus contorta Dougl. ex Loud.* Forestry, Vol. 45, pp. 49-57.
Kent
1900 Veitchs Manual of the Conferae.
Lines, R., and Booth, T. C.
1972 Investigations of Basal Sweep of lodgepole and Shore pines in Great Britain. Forestry, 45, pp. 59-66.
Mooney, O. V.
1957 *Pinus contorta* in Irish forestry. Proceedings of British Association for the Advancement of Science, Dublin.
Mooney, O. V.
1966 Experiences with *Pinus contorta* in the Republic of Ireland. Proceedings 6th World Forestry Congress Madrid. pp. 1568-1576.
O'Driscoll, J.
1972 Provenance, Forest Research Review 1964-70, pp. 32-41. Forestry Division Dublin Ireland.
O'Flanagan, L.
Inventory of Woodlands of the Forest and Wildlife Service. Forest and Wildlife Service, Dublin, Ireland.
Phillips, H.
1978 Effects of spacing, thinning and pruning on wood quality (Internal report of Forest and Wildlife Service, Dublin, (Unpublished).
Valentine, K. W. G., Sproat, P. N.,
Baker, T. E. and Levkulich, L. M.
1978 Soil landscapes of British Columbia, Ministry of the Environment Victoria, British Columbia.
Veich
1881 A Manual of the Conferae.
Wright, J.
1962 Genetics of Forest Tree Improvement F.A.O. Rome.