General paper

The potential of western red cedar (*Thuja plicata* D. Don) in Ireland

Karen Bothwell

Graduate of University College Dublin, B.Agr.Sc.(Forestry).[1]

Summary

Western red cedar (*Thuja plicata* D. Don) is a species with enormous potential in Ireland. It is highly suited to the island's mild wet climate and the heavy wet soils currently available for forestry development. The species is capable of high growth rates and productivity, and is noted for its high quality timber which possesses several unique wood properties. It is a shade tolerant species suitable for underplanting and for use in mixtures with other conifers, notably Sitka spruce (*Picea sitchensis* (Bong.) Carr.) and Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), and also as a nurse species in broadleaf plantations. While its growth rate does not compete with Sitka spruce on poorer site types, especially at higher elevations, western red cedar is capable of producing a high yield class crop on lower, more sheltered drumlin soils and on better quality lowland soils. While more detailed research is required, the favourable characteristics of western red cedar prompt its inclusion as a major species in future planting programmes, particularly in light of the current emphasis on diversification in Irish forestry.

Introduction

The Irish forest industry has become highly dependent on Sitka spruce (*Picea sitchensis* (Bong.) Carr.). The optimum management techniques required for growing this species are now well established. Over recent years, increased emphasis has been given to diversification and its role in maintaining ecological diversity and sustainability, and developing new markets. In light of this move towards diversification, as set out in the Government's strategic plan for forestry in Ireland (Anon., 1996), alternative fast growing conifer species need to be considered. It is within this context that this review was undertaken to study the potential of western red cedar (*Thuja plicata* D. Don) in Ireland.

Natural habitat

Western red cedar is a major species of the Pacific Northwest coast of America. Its range stretches from the coastal regions of southern Alaska (57°N) through the coastal regions of British Columbia, western Washington and Oregon to northern California. It extends inland as far as Idaho and Montana (Anon., 1965; Savill, 1991). It grows from sea level to an elevation of 1,500 m in coastal regions in Oregon, and is found between 600-2,100 m in the Rocky Mountains (Minore, 1990).

[1] Correspondence to the Department of Forest Sciences, Faculty of Forestry, University of British Columbia, Vancouver, BC, Canada.

Under favourable growing conditions, western red cedar can attain large proportions of 2.4 m in diameter and 60.0 m in height. The current record holding specimen measures 5.8 m in diameter and 54.3 m in height, and stands in "grotesque isolation, inland from Hoh River, Olympic Peninsula, Washington" (Kirk and Franklin, 1992). In its native rainforests, western red cedar can live up to 1,000 years, partly due to its tendency to produce an exceptionally broad base which resists toppling by wind.

Western red cedar is confined almost entirely to regions having high precipitation and atmospheric humidity (Sudworth, 1918, cited in Anon., 1965). In Puget Sound, Washington, the cool summers, mild winters and abundant rainfall create the most favourable growing conditions. In the area, annual precipitation rates range from 1,250-1,500 mm, reaching as high as 2,500 mm on higher ground (Anon., 1965).

In inland regions of the natural range, the climate is characterised by a short summer season with minimal precipitation. Thirty-five percent of the total annual precipitation of 750-1,200 mm falls as snow. Average annual temperatures range from 4.4-10.0°C. Western red cedar can withstand very low winter temperatures and is fairly resistant to late spring frosts (Savill, 1991).

Western red cedar is often found scattered among other conifers in moister parts of mixed forests, occasionally constituting up to 50% of the stand (Harlow *et al.*, 1996). It is occasionally found in pure stands, usually in low spots where the roots of other conifers would be unable to survive, or in disease-infected soils. The principal associated species in coastal areas are Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), Sitka spruce, nootka cypress (*Chamecyparis nootkatensis* (D. Don) Spach), firs (*Abies* spp.) and mountain hemlock (*T. mertensiana* (Bong.) Carr). It also grows with an assortment of broadleaf species, including red alder (*Alnus rubra* Bong.), Oregon maple (*Acer macrophyllum* Pursh) and western balsam poplar (*Populus trichocarpa* Hook.), especially in very wet areas in coastal regions. In the northern Rocky Mountains, common associates include western white pine (*Pinus monticola* Dougl. ex D. Don), western larch (*Larix occidentalis* Nutt.), lodgepole pine (*P. contorta* Dougl.), grand fir (*A. grandis* Lindl.), Engelmann spruce (*P. engelmannii* (Parry) Engelm.) and alpine fir (*A. lasiocarpa* (Hook.) Nutt.) (Anon., 1965).

History

Western red cedar was introduced into Britain in 1853, when John Veitch, an Exeter nurseryman, sent his colleague William Lobb to collect seed of the many rare and remarkable conifers reported to exist in Oregon and British Columbia (Anon., 1957). This late introduction is somewhat surprising, as western red cedar was first observed by the Malaspina expedition on the west side of Vancouver Island, British Columbia, in 1791 (Anon., 1957; Harlow *et al.*, 1996). A specimen was sent back to the botanist David Don who described it as early as 1794.

Probably the first occasion the species was used in forestry in Britain was at Benmore, Argyll, in 1876-77 (McBeath, 1914, cited in Anon., 1957). Until 1919, it had a limited use as a forest tree, being planted in small plots or as an edge tree to plantations of other species (Anon., 1957).

Inventory

After its purchase by the newly-formed Department of Agriculture in 1903, a series of stand plots was established in Avondale Estate, Co. Wicklow, to test the suitability of a

range of species for commercial planting in Ireland. An assessment of the suitability of some of the rarer species to Irish soil and climatic conditions was also intended. While many species failed, others, including western red cedar, proved promising. One acre of the species was planted in 1906 in a mixture, with 75% European larch (*L. decidua* Mill.) included as a nurse species. This high quality stand, which attained a yield class of 24, is regarded as a prime example of the potential of western red cedar in Ireland. Some of the older estates acquired by the Forestry Division, such as Vandeleur Estate, Co. Clare, and Rostrevor Forest, Co. Down, were also planted with western red cedar.

According to Coillte's 1995 inventory, 119.4 ha of western red cedar are under State ownership, with an average yield class of 18 m^3/ha/yr. Figure 1 shows the area of western red cedar planted each decade since its first planting in the 1850s. The largest cedar plantations are found in Hollyford, Co. Limerick, Swanlinbar in Co. Cavan, and Avonmore, Co. Wicklow. Coillte policy states its intention to plant at least 200 ha per annum from 1993 onwards, on fertile, low elevation, sheltered sites (Anon., 1990). The last inventory of private woodlands in 1973 estimated that 40.2 ha (11,910 m^3) of western red cedar were under private ownership, with a mean yield class of 15 m^3/ha/yr.

Western red cedar was the most widely used of all the minor conifer species planted in the UK (Aldhous and Low, 1974). Since 1950, over 5,000 ha of plantations have been established.

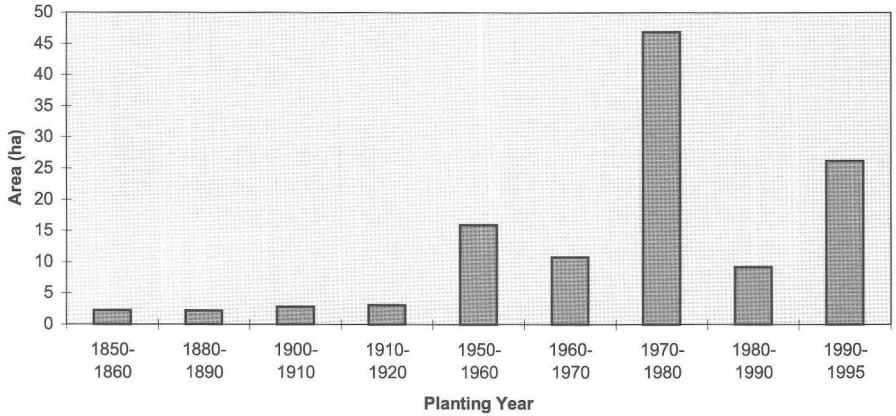

Figure 1. *Total area of western red cedar planted per decade since 1850 on State property in Ireland.*

Silvicultural characteristics

The most important silvicultural characteristic of western red cedar is its shade tolerance, with the species performing relatively better at lower light levels than Douglas fir and western hemlock (Carter and Klinka, 1992). Its low spatial crown requirements and shade tolerance contribute to high timber yields. Western red cedar is particularly suitable for use in mixtures with broadleaf species, as its narrow crown does not interfere with neighbouring trees (Savill, 1991). The late Ray Bourne devised a planting system comprising a larch matrix, into which groups of five broadleaves (e.g. oak (*Quercus* spp.)) are

planted in a diamond pattern, with four strong shade bearers, such as western red cedar, planted at the corners (Garfitt, 1995).

Western red cedar is useful for underplanting and was frequently planted under old oak coppice and European larch (Hiley, 1954). The species can play an important role in continuous cover forestry systems, as demonstrated by the high quality stems growing in the Bradford-Hutt plan (Timmis, 1994).

Van der Kamp (1988) describes western red cedar as being "remarkably free of serious diseases or insects". Formerly, it was a difficult species to propagate, due to the occurrence of *Didymascella thujina* in nurseries. This disease, however, can now be treated with fungicides (Savill, 1991). The species appears to be more susceptible than most conifers to *Heterobasidion annosum* and *Armillaria* spp.

Western red cedar is found on a range of site conditions, from slightly dry to wet, nutrient poor to nutrient rich, and acid to slightly alkaline (Anon., 1965). The species is favoured in ravines, gullies, flood plains, along river banks, swamps and bogs (Lavender *et al.*, 1990). It is seldom found on dry soils, although stunted growth is occasionally found on such sites (Harlow *et al.*, 1996).

Available data from the UK (Aldhous and Low, 1974) show western red cedar to be at its best on lowland sites, growing better than Sitka spruce and having a greater advantage over other species on imperfectly drained soils. Sitka spruce performed better above 275 m in England and Wales, and above 150 m in Scotland. Western red cedar grew faster than Douglas fir on most sites, and became increasingly more productive than Douglas fir on higher yielding sites. On the chalk downlands in the south of England, most conifers have been notably unsuccessful, many having been afflicted with lime-induced chlorosis after promising early growth (Wood and Nimmo, 1962). Western red cedar remains one of the few conifer species usable on such sites.

The species seems to be most productive on heavier lowland soils, especially gley soils and those with a slightly alkaline nature. Hence, it would be the ideal choice for afforestation along the drumlin belt in Counties Cavan, Monaghan and Limerick. The presence of western red cedar on the muskegs of North America led to attempts in Ireland and the UK to establish it on peat bog (Anon., 1957). These attempts were generally unsuccessful in comparison to Sitka spruce and lodgepole pine, although not on all peatlands. In the species trial at Trench 14, Clonsast Bog, Co. Offaly, western red cedar was the fourth most productive conifer, with a top height of 7.9 m and a yield class of 16 recorded at year 18 (Carey and Barry, 1975).

There have been relatively few published studies on the nutrition and fertilisation of western red cedar. It is said to be not as nutrient-demanding as its companion species Douglas fir, western hemlock and notably, Sitka spruce (Kimmins, 1987). The species is associated with ground vegetation indicating high nitrate availability, although it does occur on coastal salal (*Gaultheria shallon* Pursh.) dominated sites which are deficient in nitrogen and phosphorus. On northern Vancouver Island, British Columbia, the dominant forest type is old-growth cedar-hemlock. When these forests are harvested, the new plantations grow well initially, but enter check by year 6-8 due to low nitrogen and phosphorus availability, and competition from an ericaceous shrub salal (Prescott and Weetman, 1994). Sitka spruce and western hemlock experience severe growth check, whereas cedar appears to be less influenced by the nutritional problems, and is the dominant species being used in regeneration programmes on the island. Fertilisation with 200 kg N/ha and 50 kg P/ha or organic wastes is the most effective procedure for alleviating the problem (Prescott and Weetman, 1994). Western red cedar is not as responsive to fertilisation as

Sitka spruce or western hemlock on these sites. The above phenomenon is similar to the growth check experienced on *Calluna* heathlands and peatlands in Ireland and Britain.

In 1974, an experiment was established on the nutrient-deficient old red sandstone soils in Ballyhoura, Co. Cork (Horgan, pers. comm., 1997). These soils are very impoverished, being deficient in both nitrogen and phosphorus. In the past, the stripping of the top layer of peat by locals (a practice known as 'scrawing') removed the organic matter from the site. The soils have additional problems such as indurated layers and iron pans. A species trial involving seven different conifers (Douglas fir, grand fir, Leyland cypress (X *Cupressocyparis leylandii* (Jacks. & Dallim.)), noble fir (*A. procera* Rehd.), Sitka spruce, western hemlock and western red cedar) was initiated as part of the experiment. The trial received an application of phosphorus at planting and a second application at year 12. At year 19, many of the species had stunted growth and displayed serious signs of chlorosis. Western red cedar, however, showed the best height increment and the healthiest foliage, perhaps prompting its consideration for use on some of the poorer, nutrient deficient soils in Ireland.

Soils under individual western red cedar trees exhibit a higher pH than soils under hemlock trees in the same stands, a condition associated with the high calcium content of cedar foliage (Tarrant *et al.*, 1951). The high levels of calcium in its foliage and litter, relative to other conifer species, may be attributed to the ability of western red cedar to accumulate calcium in excess of its nutrient requirements and to therefore act as a 'calcium pump' to the site. The requirement for calcium is unclear and complex. Imper and Zobel (1983) found that, in southwest Oregon, the distribution of the species was related to the soil Ca:Mg ratio. For optimum growth, Krajina *et al.* (1982) describes western red cedar as requiring a nutrient-rich soil, with a well-balanced supply of both calcium and magnesium, and nitrogen present in the form of nitrate.

The magnitude of nutrient uptake and the relative importance of the different nutrients vary considerably between species. Broadleaves tend to have the greatest overall uptake, with calcium being the dominant element. Nitrogen dominates the annual uptake of most conifers, although some genera, such as *Thuja* and *Chamaecyparis*, have an uptake pattern more similar to broadleaves, requiring nutrients in the following order of preference: calcium; nitrogen; and phosphorus.

Forestry Commission research data for losses at planting show western red cedar to have one of the highest failure rates (Aldhous and Low, 1974). Survival and early growth is remarkably better under shelter than in the open. In Ireland, some foresters have noted problems when transplanting western red cedar. The reasons for this are uncertain but might be due to a number of factors such as poor quality nursery stock, poor handling and transportation, or exposure.

Growth is initially slower than Douglas fir and Sitka spruce on almost all sites (Aldhous and Low, 1974). The species is more productive than Norway spruce (*P. abies* (L.) Karst.) on lowland sites, but less so on intermediate upland sites. On the more exposed upland sites, especially in Scotland, it generally fails.

The planting of pure stands in the Pacific Northwest is not common. It is more often used in association with other species, with western red cedar being planted in wetter areas, areas of heavy brush or pockets with a history of root rot. Relatively little is known about the development of western red cedar in either pure or mixed stands. Pure even-aged stands on upland sites in western Washington can attain standing volumes comparable to pure Douglas fir by year 50. Such stand conditions also result in a narrow sapwood and very little taper or fluting. Pure stands minimise large branches and corresponding knot

development. Western red cedar grows much slower and with more tapered, fluted stems in mixed stands, as it readily becomes overtopped by other species.

Other establishment problems include browsing by large animals and rodents, and drought. Protection from rabbits, deer and other animals is often essential. Due to the lack of natural predators, introduced deer stocks on the Queen Charlotte Islands have reached high population densities, resulting in serious overbrowsing. Western red cedar has been seriously depleted on the islands, and in some areas has been eliminated as regeneration in mature forests and on cutovers (Lavender *et al.*, 1990).

Western red cedar has the ability to sustain a higher density of trees than Douglas fir or western hemlock at a given top or mean height (Minore, 1983). Open stands result in larger trees, but due to slow natural pruning, artificial pruning is required to ensure quality butt logs. Most western red cedar in Ireland has been planted at the conventional 2.0 m spacing. Wider spacing combined with pruning and frequent thinning to control form and to increase individual tree growth, should be considered, with the aim of producing larger diameter material on a shorter rotation.

In Britain, dominant height growth of western red cedar is generally slower than that of other species, but early height growth to year 20 is faster than that of Sitka spruce. At years 20 and 50, the cumulative volume produced is lower than that of Douglas fir and Sitka spruce and is similar to that of western hemlock (Aldhous and Low, 1974). By year 80, however, the situation is reversed, with western red cedar having a greater cumulative volume production. Stands tend to be uniform, with a relatively small range in height and girth (Aldhous and Low, 1974). The timing of first thinning in western red cedar stands is 5-8 years later than that in Sitka spruce or Douglas fir stands of the same age and yield class. Thinnings are similar in size to those for Sitka spruce at the same height, but this height is reached 5 or more years later (Table 1).

Table 1. *A comparison of stand parameters at year 20 (yield class 14) for western red cedar (WRC), Sitka spruce (SS), Douglas fir (DF) and Norway spruce (NS). From Hamilton and Christie (1971).*

Species	*Stems/ha*	*Mid diam. (cm)*	*BA (m^2/ha)*	*Mean volume/ thinned tree (m^3)*	*Age at 20 m height*	*MAI at 20 m (YC 14)*
WRC	1,073	24	49.3	0.28	50	13.1
SS	694	24	25.7	0.30	43	13.0
DF	626	23	25.7	0.25	34	11.7
NS	722	24	33.5	0.28	46	12.3

Syleptic growth usually occurs in seedlings for the first few years and sometimes in the juvenile phase, but some species maintain this form of free growth throughout their life cycle. While growth rates may not be as high as those for proleptic species, syleptic species can capitalise on favourable conditions late in the season. Western red cedar is one such species, enabling it to take advantage of Ireland's mild climate and long growing season.

Taper in western red cedar stems results from the shade tolerance status of the species. In mixed stands, lower limbs remain alive and active beneath the shade of neighbouring trees, and continue to contribute photosynthate downwards, resulting in lower stem expansion. To avoid tapered stems, this species should be grown in even-aged, pure stands at

narrow spacings or with species of similar shade tolerance. Even under these conditions, however, stems taper greatly up to 1.5 m above ground. Pruning may alleviate this problem, although some degree of buttressing may be inherent.

Fluting can occur in species with little lateral transportation of photosynthate in the phloem, a condition suggested in western red cedar by its straight grain and ease of splitting. Each limb 'supplies' the cambium directly beneath it, with the surrounding cambium fed by more vigorous limbs higher in the canopy. The suppression of an individual limb therefore results in the reduced growth and expansion of the corresponding area of the trunk. Combined with the poor lateral transport of photosynthate from adjacent areas of the stem, this gives rise to the development of an indentation or flute, which over years of growth can run from the suppressed limb down to the base of the tree. This flute will continue to deepen until the limb dies. After this point, the cambium beneath becomes reconnected to surrounding, more vigorous sources of photosynthate, and the flute is not increased. To avoid fluting, the same practices should be implemented as those for avoiding extreme taper. Fluting can also result from unusual rooting conditions, especially on excessively wet soils. In a UK study, fluting was more pronounced on hemlock, although it was also quite common in western red cedar stands (Aldhous and Low, 1974).

Forking was observed in 60% of all western red cedar plots (Aldhous and Low, 1974), becoming more prevalent with wider spacing, increasing exposure and diminishing vigour. Western red cedar is more likely to fork above breast height than at the base. Fluting and forking may be more prevalent in some seed sources (Savill, 1991). While choice of provenance may not be as important as for other Pacific Northwest conifers (Minore, 1990), origins from the north slopes of the Olympic Mountains in Washington and from Vancouver Island are recommended for planting in Britain and Ireland (Lines, 1987).

Large limbs and knots also occur where the lower limbs remain alive into the rotation. Individuals growing with their terminals in full sunlight maintain strong epinastic control, thereby maintaining a relatively conservative cone-shaped crown. If the tree becomes overtopped and is subsequently released, however, lateral branches seem to escape from the control of the terminal. Consequently, much of the increased growth is added to large branches in a spreading crown, and not to the stem wood.

Old lawn specimens of western red cedar can develop extraordinary characteristics. For example, lower limbs resting on the ground readily take root, springing up to surround the original tree with a grove of green buttresses (Johnson, 1973).

Wood properties

The sapwood of western red cedar, which is almost white in colour, is narrow, with a thickness of 2.5 cm over a wide range of diameters (Lassen and Okkonen, 1969, cited in Swan *et al.*, 1988). Thus, a high proportion of converted timber comprises heartwood, even in fairly young trees. The heartwood varies in colour when fresh, from a dark chocolate brown to a salmon pink colour to light straw. After drying, the wood assumes a uniform reddish-brown tone. After long exposure to the elements, however, this colour is lost and the wood becomes silver grey. It is straight grained, uniformly but coarsely textured and non-resinous, and has a fairly prominent growth-ring pattern. The wood also has a distinctive aroma.

Western red cedar is relatively light weight and soft. The average nominal specific gravity of old growth western red cedar is 0.31 and 0.33, based on green and oven-dried volumes respectively, and is similar to that of both Sitka and Norway spruce. The specific

gravity of short rotation, second growth material does not differ much from that of old growth material (Swan *et al.*, 1988).

The average density at 15% moisture content is 390 kg/m^3, a value which is much lower than that for other common conifer species grown in Ireland. The low wood density results in low strength, but confers excellent insulating properties to the wood. The thermal conductivity of western red cedar (0.73 at 12% moisture content) is one of the lowest for a commercially important species. A cross section 25 mm in thickness is equal in insulating effectiveness to 180 mm of brickwork or 300 mm of concrete.

Western red cedar timber splits easily. This property, combined with a straightness of grain, makes it ideal for products such as stakes, fencing and posts. The wood bonds well with a variety of adhesives. When dried and properly primed, it also takes paint and finishes extremely well. The screw and nail holding capacity is low, although this problem can be remedied by using special nails or by increasing the screw length. Its acidic properties cause corrosion of metals and black stain in the timber.

The species has the lowest volumetric shrinkage of any commercial softwood, and therefore possesses excellent stability for structural applications or for use in doors and windows. This is partly due to the low wood density and the low fibre saturation point of 18.5-23.0%.

Western red cedar is noted for its natural durability, a characteristic which is due to the very high extractive content of its heartwood. Extractive content is greatest in the most recently formed heartwood, with smaller amounts found in the sapwood. Extractives include compounds such as thujaplicins, thujic acid, methyl esters and lignins, mainly plicatic acid. Younger second growth trees have approximately half the thujaplicin content of their old growth counterparts (Nault, 1986, cited in Swan *et al.*, 1988). The thujaplicins are responsible for the fungitoxic nature of the extractives and thus the heartwood. These compounds are, however, soluble in water. As a result, western red cedar shingles and shakes used as roofing products in warm, damp climates, beneath hanging trees, or on roofs with low slopes, should be treated with some kind of preservative. Formerly, CCA (copper-chromium-arsenic) pressure treatment was favoured, but this method is now banned in some states in North America.

Western red cedar in thinner dimensions kiln-dries well, with little degrade. Thicker cross-sections may prove very difficult to dry, due to a tendency to hold patches of intense moisture. Care is therefore needed to avoid internal honeycombing and collapse. In British grown timber, such degrades are reported to occur in material grown on low or swampy ground. Collapse is also found to be associated with high extractive contents (Swan *et al.*, 1988). Splitting and checking are usually minimal and there is small movement in service.

The working properties of timber from Irish grown western red cedar are reasonably good. There are no reported problems in sawing logs using standard commercial machines and saws, although slabs from fluted butt logs are difficult to handle. Excessive taper leads to high conversion losses, necessitating the taper-sawing of logs.

During grading, timber tends to fall into the category of general structural use. Timber grown in Ireland and Britain contains many small knots which are often live. These knots tend to be distributed along the sawn timber, rather than grouped in regular whorls. It has been noted that small dead knots in boards from 20-30 year western red cedar were commonly rotten, leading to downgrading despite the surrounding timber being sound (Aldhous and Low, 1974).

Exceptionally high rates of dulling of cutting tools are observed with western red cedar, primarily due to the heartwood extractives. Cemented carbide-tipped saws (edger saws)

known to cut Douglas fir for 40 hours blunt in less than half this time when sawing cedar cants (Kirbach and Chow, 1976).

Utilisation

Relative to other conifers on a world-wide basis, western red cedar possesses wood properties matched by few species. A high demand exists for specialised uses based on the intrinsic properties of the wood, namely its superior dimensional stability, durability and insulating qualities. These properties will ensure its continued importance and will perhaps lead to an increased emphasis on the species in the world market.

The principal market for western red cedar in its native north-western America is the shingle and shake industry, which accounts for 25% of the total amount harvested each year in British Columbia and the United States. Raw material for this market must come from old growth trees of at least 200 years of age, to ensure an adequate thujaplicin content. Its durability, ease of working and lightness make it a premier wood for this purpose. Shingles have better insulating properties than most roof coverings, with less air percolating through a shingle roof than through a tiled counterpart. In North America, western red cedar shingles have a working lifespan of approximately 30 years, increasing to 50 years with pre-treatment. In California, cedar shingles are now illegal due to the high risk of fire (Heald, pers. comm., 1997).

Given its visual appeal, western red cedar has a major potential for use in high quality end uses such as veneers, joinery and panelling. Its dimensional stability, ease of working and durability make it ideal for use in fences, balconies, patios, coffins and other outdoor applications.

Normal uses in Britain and Ireland include interior and exterior joinery, interior fitting, furniture and structural purposes. It is also used for garden sheds and beehives. Its appearance, insulation properties and durability make it a popular timber for the construction of saunas, a large market for which exists, particularly in Scandinavia.

Due to the major advances in wood building and treatment techniques, recent years have seen a resurgence in interest in wood as a light, strong and economical material for hull construction in the boat building industry. The organic nature of wood has an aesthetic attraction which resin, glass, PVC foam, steel and aluminium simply do not possess. Wood, stabilised and strengthened using epoxy glues, is now used as the core material, unlike traditional techniques where hardwood planking of mahogany and teak was the sole element of the outer hull. Western red cedar is commonly used as a core material and a demand for these hulls is slowly being created (Glenn, 1997).

Many houses in the United States are constructed predominantly of western red cedar. The timber is fitted together using a tongue and groove method and does not require any further adhesives or nails. The timber offers excellent insulation properties and adds a high aesthetic quality to the building. Irish examples of construction with western red cedar include the wood technology building in the University of Limerick and the chalets in Killykeen Forest Park, Co. Cavan. It is envisaged that these, together with the newly constructed wooden Coillte head office in Newtownmountkennedy, Co. Wicklow, will stimulate an increased interest in wooden architecture over the coming years.

Western red cedar is not regarded as a prime pulpwood species, due to its dark coloured heartwood, high extractive content and stringy, fibrous bark, all of which create difficulties during the pulping process. The timber is, however, used in Kraft pulps, where its fibre morphology enables the manufacture of a dense, tight sheet with good opacity characteristics.

The rich colour, lacy sprays and sweet smell make the foliage of western red cedar suitable for use in greenery displays and flower arrangements. This foliage market could be supplied from pruned material. Another series of properties which may add further value are chemicals present in the tree, including leaf oils and heartwood extractives, all of which have yet to be commercially exploited.

Conclusion

In *The Forests of Ireland*, published by the Society of Irish Foresters (FitzPatrick, 1965), the following comment was made in relation to western red cedar: "little planting has been done in state plantations because of a fungus *Keithia thujina*, which causes leaf blight in the nursery. If this problem can be surmounted Thuja is a useful tree on limestone gravel and for underplanting".

Western red cedar should be promoted on two target site types: the heavier lowland soils; and soils with a slightly alkaline nature. Growth rates are extremely high on these wetter sites, with a yield class of 28 recorded on experimental plots in Britain (Aldhous and Low, 1974). Western red cedar is well capable of overcoming vegetative competition and also acts as a soil improver.

While the species will rarely be able to compete with Sitka spruce on a productivity basis, timber prices for western red cedar should be higher, given its rarer intrinsic wood properties. This suggests the need to grow western red cedar for a niche market. Such a market would undoubtedly require the highest quality. Sawmillers frequently complain of the large number of knots and buttressing, but these defects probably arise from poor stand management, with the species often present as a suppressed understorey component.

A major argument against the planting of western red cedar is the lack of an existing market for its timber. Without a supply of timber, however, such a market cannot develop. In order to break this vicious cycle, it will be necessary to plant on the basis of a market emerging as future production comes onstream. In the United States, western red cedar sawlog prices appear to be increasing faster than those for other species. Western red cedar attains a higher price due to its durability, favourable working properties and low radial shrinkage. Aesthetics are becoming a major price factor, and western red cedar, with its rich heartwood colour, ranks highly in this regard. Also, the supply of old-growth western red cedar is decreasing in its native habitat, due to increased environmental pressure which is limiting logging in old-growth coastal forests.

As a shade tolerant tree, western red cedar is ideal for use in mixtures with other species, both broadleaf and conifer. Many Douglas fir plantations throughout the country suffer from very large branching and poor stem form. Western red cedar could help to ameliorate these stands, both improving the quality of the Douglas fir and adding to the stand value itself. The species should also be considered as a nurse in broadleaf plantations to encourage single straight leaders, to provide wind and frost shelter, and to suppress side branching. Its shade bearing status and fast growth create a potential for use in continuous cover forest management systems undertaken in sensitive areas where clearfelling would be unacceptable on environmental and/or amenity grounds. Western red cedar can also be mixed with Sitka spruce, the most dominant species in Irish forestry.

Provenance trials should be established to attempt to secure quality planting stock with reduced fluting and buttressing and improved growth rates, although little is known about the behavioural differences attributable to provenance.

Diversity is an important word in forestry practice in Ireland today. Western red cedar has a major potential role to play in species diversification, particularly as better quality lowland becomes available for forestry. Western red cedar should be one of those at the top of the list of alternative species in Ireland.

ACKNOWLEDGEMENTS

I would like to express a special thanks to Robert Tottenham who gave me much encouragement in the writing of this paper. I would also like to thank Prof Jack Gardiner, Dr Michael Keane and Ted Horgan for their help. The original version of this paper was awarded the National University of Ireland Bursary in Agriculture, 1997.

REFERENCES

Aldhous, J.R. and Low, A.J. 1974. The Potential of Western Hemlock, Western Red Cedar, Grand Fir and Noble Fir in Britain. Forestry Commission Bulletin 49. HMSO, London. 105 pp.

Anon. 1957. Exotic Forest Trees in Great Britain. Forestry Commission Bulletin 30. HMSO, London.

Anon. 1965. Silvics of Forest Trees of the United States. Agricultural Handbook 271. USDA Forest Service. 762 pp.

Anon. 1990. Coillte Operations Manual. Coillte Teo., Leeson Lane, Dublin 2.

Anon. 1996. Growing for the Future: A Strategic Plan for the Development of the Forestry Sector in Ireland. Forest Service, Department of Agriculture, Food and Forestry. Government Publications Sales Office, Dublin. 98 pp.

Carey, M.L. and Barry, T.A. 1975. Coniferous growth and rooting patterns on machine sod-peat bog (cutover) and Trench 14, Clonsast. *Irish Forestry* 32:18-29.

Carter, R.E. and Klinka, K. 1992. Variation in shade tolerance of Douglas fir, western hemlock and western red cedar in coastal British Columbia. *Forest Ecology and Management* 55:87-105.

FitzPatrick, H.M. 1965. The Forests of Ireland. The Society of Irish Foresters. The Record Press Ltd., Bray, Co. Wicklow.

Garfitt, J.E. 1995. Natural Management of Woods - Continuous Cover Forestry. Research Studies Press Ltd. 152 pp.

Glenn, D. 1997. Building by numbers - The wood revolution. *Yachting World* February:36-42.

Hamilton, G.J. and Christie, J.M. 1971. Forest Management Tables. Forestry Commission Booklet 34. HMSO, London. 201 pp.

Harlow, W.M., Harrar, E.S., Hardin, J.W. and White, F.M. 1996. Textbook of Dendrology. 8th Edition. McGraw-Hill Inc. 534 pp.

Heald, R. 1997. Personal communication from Robert Heald, University of California, Berkeley, August 1997.

Hiley, W.E. 1954. Woodland Management. Faber and Faber, London. 463 pp.

Horgan, T. 1997. Personal communication from Ted Horgan, Coillte Teo., March 1997.

Imper, D.K. and Zobel, D.B. 1983. Soils and foliar nutrient analysis of *Chamaecyparis lawsoniana* and *Thuja plicata* in southwestern Oregon. *Can. J. For. Res.* 13:1219-1227.

Johnson, H. 1973. The International Book of Trees. Mitchell Beazley Ltd., London. 288 pp.

Kimmins, J.P. 1987. Forest Ecology. Collier Macmillan, London. 531 pp.

Kirbach, E. and Chow, S. 1976. Chemical wear of tungsten carbide cutting tools by western red cedar. *Forest Products Journal* March:44-48.

Kirk, R. and Franklin, J. 1992. The Olympic Rain Forest - An Ecological Web. University of Washington Press, Seattle and London. 128 pp.

Krajina, V.J., Klinka, K. and Worrall, J. 1982. Distribution and Ecological Characteristics of Trees

and Shrubs of British Columbia. University of British Columbia, Faculty of Forestry, Vancouver, BC. 131 pp.

Lavender, D.P., Parish, R., Johnson, C.M., Montgomery, G., Vyse, A., Willis, R.A. and Winston, D. 1990. Regenerating British Columbia's Forests. UBC Press, Vancouver. 372 pp.

Lines, R. 1987. Choice of Seed Origin for the Main Forest Species in Britain. Forestry Commission Bulletin 66. HMSO, London. 61 pp.

Minore, D. 1983. Western Red Cedar - A Literature Review. USDA Forest Service PNW Forest and Range Station, Portland, Oregon. Gen. Tech. Report, PNW 150. 70 pp.

Minore, D. 1990. *Thuja plicata* (D. Don). *In:* Silvics of North America. Volume 1. Conifers. USDA Forest Service. Agriculture Handbook 654.

Prescott, C.E. and Weetman, G.F. 1994. Salal Cedar Hemlock Integrated Research Program: A Synthesis. Faculty of Forestry, University of British Columbia, Vancouver, BC, Canada.

Savill, P.S. 1991. The Silviculture of Trees used in British Forestry. CAB International. 143 pp.

Swan, E.P., Kellogg, R.M. and Smyth, R.S. 1988. Properties of western red cedar. *In:* Western Red Cedar - Does It have a Future? Edited by Smith, N.J. Conference Proceedings. University of British Columbia, Faculty of Forestry. 13-14 July, 1987. 177 pp.

Tarrant, R.F., Issac, L.A. and Chandler, R.F. Jr. 1951. Observations in litterfall and foliage nutrient content of some Pacific Northwest tree species. *Journal of Forestry* 49(12):914-915.

Timmis, T. 1994. Bradford plan continuous cover forestry: Development, history and status quo. *Quarterly Journal of Forestry* 88(3):188-198.

Van der Kamp, B. 1988. Pests of western red cedar. *In:* Western Red Cedar - Does It have a Future? Edited by Smith, N.J. Conference Proceedings. University of British Columbia, Faculty of Forestry. 13-14 July, 1987. 177 pp.

Wood, R.F. and Nimmo, M. 1962. Chalk Downland Afforestation. Forestry Commission Bulletin 34. HMSO, London.