Potential Utilisation of Irish grown *Alnus glutinosa* and *Eucalyptus spp.*

By Dermot O'Donovan B. Comm.

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Department of Building and Civil Engineering

Thesis examining committee:

Thesis Supervisor
Dr Patrick Walsh, Department of Building and Civil Engineering, GMIT.

External Examiners
Dr Nuala Ní Fhlatharta, Head of the Forestry Development Department at Teagasc.
Mr John Fennessy, Research Programme Manager, Tree Improvement and Non-wood Forest Product, COFORD.

Declaration

I hereby declare that all the work presented in this thesis is my own except where duly acknowledged and that it has not been used to obtain a degree in this institute or elsewhere.

Signed: Date: 01 September 2008

Published work

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Foreword

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The research has evolved through the experiences of other researchers, namely

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Dedication

To my wife Laura, who supported the work of this thesis in ways that words simply cannot describe.

To my daughter, Féile, who interrupted the work of this thesis in her own adorable manner.

Finally, to my Dad, Adrian, who always encouraged me to try new things, whether or not he ever understood what it was I was doing.

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Abstract

Over the past century forestry cover in Ireland has risen from a low of 0.5% of total land area to approximately 10% today. This has been achieved through an afforestation policy which concentrated on exotic coniferous species for commercial planting. This imbalance in the forestry mix has resulted in Ireland having the lowest proportion of broadleaf forestry cover in the European Union. Broadleaves have a relatively longer rotation than coniferous species and require intensive management thus incurring greater costs in terms of the pursuit of quality timber. Ireland has thus become very dependent on imported hardwoods as a raw material for the manufacture of wooden products.

In recent years there has been extensive debate on the role of broadleaf species in Irish forestry. One of the results of this . has been a dramatic rise in the planting of certain species of broadleaf trees which are relatively easy to establish and develop. In order to fully exploit the commercial potential of such species, their range of end uses must be fully explored. This will enable those involved in forestry to see clearly the markets for their produce and thus achieve a maximum return on their investment.

This paper examines one such species. The timber produced from common alder (*Alnus glutinosa*) is used extensively in other European countries and around the world. In Ireland however, alder is not highly regarded in terms of its timber and there is minimal demand at present for Irish-grown common alder. This paper presents findings on the mechanical and physical properties of Irish-grown specimens of common alder, makes comparisons of those properties with similar species available on the European and Irish markets and explores its full utilisation potential. The results demonstrate that Irish grown common alder compares favourably with alder grown in other countries in terms of utilisation potential. The way in which alder is processed and used in other countries is also presented in an effort to broaden the analysis of its possible uses.

Commensurate with this analysis *Eucalyptus* spp. is introduced as a possible exotic species to be considered for Irish forestry. Extensively used in its native Australia, species of eucalypts have been planted in parts of Europe including Ireland and through trials have had some considerable success. This paper examines in particular its ability to produce quality timber and presents findings on its properties.

1 Introduction

A 2004 COFORD funded report, entitled Guide to Irish Hardwoods, concludes that:

"There are over 250 full-time businesses in Ireland that use homegrown hardwood" while *"Three users account for over 80% of the overall consumption."* Furthermore the report concludes that *"users who are presently consuming imported hardwoods would replace them with homegrown material if the latter was readily available, at good quality and at a competitive price"* (Xenopoulou 2004).

These findings are extremely pertinent to the future of the forestry sector in Ireland and particularly so to those involved in the production and supply of hardwood timber. The conclusions imply that hardwood timber derived from Irish-grown broadleaves does not compete on price or quality and that there are concerns and issues in relation to supply when compared with imported material. Furthermore the vast majority of Irish hardwoods are being utilised by a very small number of manufacturers.

Ireland has a climate very suitable for growing trees yet we have one of the lowest percentages of forest cover in Europe (Hickie 2002). In addition Ireland has a very low proportion of broadleaf forestry in comparison to other European countries while the market for hardwood timber is very much dependant on imported species at present.

1.1 Irish Forestry

There is also a large number of species of trees that are suited to the Irish climate. Trees are generally categorized into two groupings, i.e. broadleaf and coniferous trees. Anatomically broadleaf species are distinguishable by the presence of vessels in the microscopic structure of the wood. Coniferous wood on the other hand does not possess vessels but contain only two types of cells – transverse ray cells and longitudinal wood fibres (or tracheids). Broadleaf trees (or angiosperms) generally lose their leaves in the autumn and conifers are needle-bearing trees which retain their needles all year round. Often conifers are referred to as 'evergreens' and broadleaves as 'deciduous'. However there are examples of broadleaf trees which retain their foliage all year round also such as the Holm oak (*Quercus ilex*).

Trees are further classified into native and non-native trees, i.e. those that were established in Ireland prior to the arrival of humans and those that were not. Some trees are categorised as naturalised, i.e. trees that have been introduced so long ago that it could be argued that they have become naturalised. The beech tree (*Fagus sylvatica*) tends to fall into this category

The produce from trees and forestry is also complex. This can be grouped into ‘wood’ and ‘non-wood’ products. Non-wood products include amongst others fungi, lichens and foliage while wood products include everything from firewood to furniture grade timber. Generally the timber derived from coniferous trees is referred to as ‘softwood’ and that derived from broadleaves is referred to as ‘hardwood’. This is in reference to the fact that softwoods are generally less dense than hardwoods. The difference between these types of timber is actually to do with the fact that softwood tissue lacks the vessels found in hardwoods for transporting water. Hence some ‘softwood’ timber can actually be harder than ‘hardwood’ timber. Yew (*Taxus baccata*) is a good example, the timber of which is relatively dense while it is a coniferous tree.

1.2 Irish-grown timber

The market for timber produced in Ireland is dominated by that of coniferous trees. It has been the policy of state afforestation programmes since the beginning of the last century to concentrate on exotic species such as Sitka spruce (*Picea sitchensis*) and lodgepole pine (*Pinus contorta*). Most planting was initially done by the State. Due to the very low forest base in Ireland, grant systems were established to encourage private landowners, and the farming community, to invest in forestry.

In recent years there has been a greater emphasis placed on diversification and improved silvicultural methods to promote the development of broadleaf forestry (e.g. Mike Bulfin of Teagasc and the Native Woodland Scheme initiative) (Anon 2001). While the market in Ireland for the produce from coniferous plantations is relatively stable, the market for produce from broadleaves (i.e. hardwood timber) is, according to the findings of Xenopoulou (2004), much more volatile. There is also some reluctance among landowners to commit to growing broadleaf species for investment purposes due to the relatively higher establishment and greater management costs for those plantations as well as the longer rotation periods associated with broadleaf trees. In order to understand the context of the present forestry industry it is necessary to briefly review the history of forestry in Ireland.

1.3 Forestry Policy

Since the arrival of Normans to Ireland, during the turn of the first millennium, forests had been in decline. Similar to the experience of other developing countries the demands of intensive farming (both crop production and grazing) in Ireland led to the eradication of many previously forested areas. Ireland's colonial history also negatively impacted on the forest resource in the quest for building material and fuel so that by the time of the famine (circa 1840) Ireland's percentage of forest cover was somewhere in the region of 0.5%, most of which was to be found within private estates.

Figure 1: Common alder stand at JFK Arboretum

At the turn of the next century the Forest Service was given responsibility for the regulation of forestry and promotion of afforestation in Ireland. Research by the Forest Service resulted in Sitka spruce being selected as the most suitable species for commercial forestry and since the middle of the last century has been the most dominant species in plantations across the country.

Establishing forestry from such a low base level is a difficult and complex task. The state initially undertook the majority of forest establishment. Afforestation grants were then made available to those in the private sector wishing to plant trees. These grants differentiate between broadleaf and coniferous species as well as farmers and non-farmers. The grants and premiums are higher for broadleaves due to the higher initial cost of establishment and based on the fact that most broadleaves require better land to grow successfully compared to conifers (and so landowners are 'compensated' more for using this land for forestry). Broadleaves also take longer to mature and require more intensive management than conifers in order to produce quality timber. Broadleaves are also prone to the threat of browsing animals and attack by grey squirrels (Figure 5). The domestic market for broadleaves is also less developed than that for conifers so returns on investments are not as dependable and the risks associated with this type of forestry are greater.

The Afforestation (and later the Native Woodland Scheme) Grants encouraged private landowners to begin to plant trees commercially and during the late 1980s and 1990s private planting began to dominate the forestry industry. The grants continued to dictate the afforestation mix and the vast majority of planting was that of coniferous species, dominated still by Sitka spruce. The statistics in Table 1 provide an overview of the way in which forestry has developed over the past 10 years.

A number of important facts can be taken from these data at this stage:

- The rate of afforestation has declined since 1998 (and actually peaked in 1995 at 23,710ha (CSO 2006))
- The amount of current afforestation of State-owned lands is negligible (this is a result of a ruling in 2002 by the European Courts which dictated that the provision of grants to a semi-state organization was in contravention to European regulations, after which Coillte all but ceased their afforestation programme)
- Since 1998 broadleaf afforestation has risen as a percentage of total afforestation from approximately 16% to 30%
- Forest Service targets for forestry establishment as per the 1996 Strategic Plan (Anon 2006) have not been achieved

These data also raise a number of interesting points:

- Targets for afforestation of 25,000 ha per annum have fallen some way short of the plan from the year 2000 onwards.
- If the target of reaching forest cover of 17% by 2030 is therefore no longer realistic what impact will it have on the commercial viability and competitiveness of forests and forestry produce?
- Now that the state (under the governance of the Forest Service) is no longer actively involved in forest development what controls are in place to ensure the long-term success of this industry (as opposed to the medium term returns on investment of private landowners)?

- With 30% of planting being that of broadleaf species, what are the parameters for species selection?
- Where are broadleaf species deployed in terms of the forest mix? (If broadleaves are planted as marginal trees or if they are planted on marginal lands they are unlikely to reach their potential in terms of quality timber production)
- In terms of utilisation, what potential exists for Irish grown hardwood timber and what are the opportunities for developing this market?
- In terms of quality, what are the international standards that must be met in order for there to be a maximum return on the private sector and state investment?

1.3.1 The Influence of the grant system

Any financial grant system in any market will have an impact on decisions made by investors and entrants to that market. The fact that the grant system in use in Ireland is more favourable in relation to a medium-term return for the planting of short rotation species has had a significant impact on the development of the Irish timber industry. The supply of Irish-grown softwood (predominantly in terms of Sitka spruce round wood) into the market place has led to the establishment of a softwood processing industry and a number of large pulp-based panel production companies (e.g. OSB). This has also led to a relatively stable market for the produce from coniferous plantations and has secured the position of species with a high yield and fast rotation like Sitka spruce in the landscape of Irish forestry. The planting of Sitka spruce is deemed a relatively low risk strategy in commercial forestry in Ireland.

Table 1: Breakdown of afforestation in Ireland 1998 – 2006 (Forest Service, 2007)

	1998					2003					2006				
County	**Private (ha)**	**Public (ha)**	**Broadleaf (ha)**	**Coniferous (ha)**	**Total Afforestation (ha)**	**Private (ha)**	**Public (ha)**	**Broadleaf (ha)**	**Coniferous (ha)**	**Total Afforestation (ha)**	**Private (ha)**	**Public (ha)**	**Broadleaf (ha)**	**Coniferous (ha)**	**Total Afforestation (ha)**
Carlow	52.8	43.3	14.9	81.3	**96.1**	79.3	0.0	31.0	48.3	**79.3**	60.4	0.0	15.3	45.1	**60.4**
Cavan	228.1	190.9	90.0	329.0	**419.0**	220.5	0.0	58.0	162.5	**220.5**	217.1	0.0	41.7	175.4	**217.1**
Clare	676.7	204.4	144.2	736.9	**881.1**	587.7	2.4	79.0	508.7	**590.1**	693.6	0.0	222.6	471.1	**693.6**
Cork	1,038.6	358.7	272.6	1,124.6	**1,397.2**	962.8	15.1	300.0	662.8	**977.9**	1,441.0	0.0	507.9	933.1	**1,441.0**
Donegal	840.7	351.5	46.5	1,145.8	**1,192.2**	388.2	0.0	7.0	381.2	**388.2**	230.5	8.9	39.2	200.1	**239.4**
Dublin	63.0	0.0	57.0	6.0	**63.0**	19.1	0.0	19.0	0.1	**19.1**	0.0	0.0	0.0	0.0	**0.0**
Galway	458.4	309.6	28.0	740.0	**768.1**	382.3	69.5	62.0	320.3	**451.8**	355.9	16.3	131.2	241.0	**372.2**
Kerry	842.9	211.7	61.0	993.6	**1,054.6**	913.8	16.3	187.0	726.8	**930.1**	664.3	0.0	244.7	419.6	**664.3**
Kildare	249.7	0.0	136.9	112.7	**249.7**	133.5	0.0	62.0	71.5	**133.5**	84.2	0.0	46.4	37.8	**84.2**
Kilkenny	227.2	135.8	26.1	336.9	**363.0**	456.3	0.0	168.0	288.3	**456.3**	321.7	0.0	157.9	163.9	**321.7**
Laois	224.2	60.7	79.2	205.7	**284.9**	148.3	0.0	30.0	118.3	**148.3**	71.1	0.0	30.0	41.1	**71.1**
Leitrim	490.2	101.2	46.4	545.0	**591.4**	318.5	6.1	50.0	268.5	**324.6**	227.0	0.0	34.4	192.6	**227.0**
Limerick	289.2	199.4	50.8	437.7	**488.5**	807.5	0.0	151.0	656.5	**807.5**	521.3	0.0	145.6	375.7	**521.3**
Longford	144.2	106.0	12.3	237.9	**250.2**	212.0	0.0	50.0	162.0	**212.0**	254.5	0.0	61.3	193.2	**254.5**
Louth	77.9	21.0	7.5	91.5	**98.9**	7.5	0.0	6.0	1.5	**7.5**	20.4	0.0	10.2	10.2	**20.4**
Mayo	961.8	132.5	87.4	1,006.9	**1,094.3**	553.6	2.7	67.0	486.6	**556.3**	324.9	0.0	76.3	248.5	**324.9**
Meath	171.5	13.0	101.9	82.6	**184.5**	149.3	0.0	109.0	40.3	**149.3**	286.7	0.0	114.8	171.9	**286.7**
Monaghan	44.1	31.6	9.4	66.2	**75.6**	58.7	0.0	14.0	44.7	**58.7**	107.1	0.0	37.1	70.0	**107.1**
Offaly	295.9	0.0	143.4	152.5	**295.9**	385.7	0.0	106.0	279.7	**385.7**	218.0	0.0	68.8	149.2	**218.0**
Roscommon	263.8	96.4	67.7	292.5	**360.2**	451.2	10.6	31.0	420.2	**461.8**	322.4	0.0	42.5	279.9	**322.4**
Sligo	303.5	102.5	20.2	385.9	**406.1**	241.8	0.0	40.0	201.8	**241.8**	176.0	0.0	30.8	145.3	**176.0**
Tipperary	787.7	110.2	193.6	704.3	**897.9**	710.3	0.0	200.0	510.3	**710.3**	662.9	0.0	212.7	450.2	**662.9**
Waterford	308.9	24.0	58.2	274.7	**332.9**	230.9	0.0	32.0	198.9	**230.9**	307.8	0.0	95.6	212.2	**307.8**
Westmeath	370.3	77.5	153.3	294.4	**447.7**	209.2	0.0	111.0	98.2	**209.2**	155.4	0.0	55.3	100.1	**155.4**
Wexford	250.5	0.0	73.6	176.9	**250.5**	225.3	0.0	81.0	144.3	**225.3**	216.1	0.0	82.3	133.8	**216.1**
Wicklow	340.8	44.2	77.3	307.7	**385.0**	116.2	5.6	21.0	95.2	**121.8**	71.4	0.0	22.7	48.7	**71.4**
Total (ha)	**10,002.3**	**2,926.1**	**2,059.3**	**10,869.1**	**12,928.4**	**8,969.5**	**128.2**	**2,072.0**	**6,897.5**	**9,097.7**	**8,011.4**	**25.2**	**2,527.2**	**5,509.5**	**8,036.6**
%	**77.4**	**22.6**	**15.9**	**84.1**		**98.6**	**1.4**	**22.8**	**77.2**		**99.7**	**0.3**	**31.4**	**68.6**	

Tables 2 and 3 show how the afforestation financial incentive system of grants and premiums are structured. Indirectly the system favours species with short rotations. In Ireland, due to the demand for raw materials for the composite board industry (MDF, OSB etc.), this has lead to a relatively stable market for softwood timber in terms of demand and supply. Many hardwoods however take a longer time to mature for timber production. The grant system only pays premiums to landowners for the first 20 years. For many types of softwood this constitutes a significant proportion of their growing life. For many broadleaves (used for timber production) however, 20 years amounts to as little as 20% of their growth to maturity and leaves landowners for long periods without an income from their forests. While the grant system recognizes this by paying a higher grant and premium for broadleaf species it still leaves the land owner with a significant gap in their income from their land. This is particularly evident when the grants are used to establish new forests. Quality hardwood timber does however achieve significantly higher prices that that for softwoods but it is more time-consuming and expensive to convert and season. Broadleaf trees also require better quality land to grow successfully.

Table 2: Grant rates for afforestation (Forest Service 2007)

Maximum Grant levels.			
Grant/Premium Category (GPC)	1st Instalment Grant €/ha	2nd Instalment Grant €/ha	Total FEPS Grant €/ha
GPC 1 – Unenclosed	2,540.65	873.35	3,414.00
GPC 2 – Sitka Spruce/Lodgepole Pine	2,540.65	873.35	3414
GPC 3 – 20% Diverse Mix	2,699.60	873.4	3,573.00
GPC 4 – Diverse	2,984.52	942.48	3,927.00
GPC 5 – Broadleaf (except oak & beech)	3,999.67	1,199.90	5,199.57
GPC 6 – Oak	5,259.25	1,660.82	6,920.07
GPC 7 – Beech	5,738.87	1,865.13	7,604.00

Table 3: Premium rates for afforestation (Forest Service 2007)

Maximum Premium Levels.				
Grant/Premium Category (GPC)	Afforestation Premium (€/ha)			
	Farmer rate	Farmer rate	Farmer rate	Non-farmer rate
	<6ha	>=6ha	>=12ha	Per ha
GPC 1 – Unenclosed/All Species	240.94	240.94	240.94	197.12
GPC 2 – Enclosed/Sitka spruce/Lodgepole Pine	386.95	401.56	416.16	197.12
GPC 3 - Enclosed/20% Diverse Mix	449.74	464.35	478.94	197.12
GPC 4 - Enclosed/Diverse	478.94	493.55	508.15	197.12
GPC 5 - Enclosed/Broadleaf (other than Oak & Beech)	508.15	522.76	537.35	211.73
GPC 6 - Enclosed/Oak	544.65	559.26	573.86	211.73
GPC 7 - Enclosed/Beech	544.65	559.26	573.86	211.73

As a consequence of this the level of planting of broadleaves has been relatively low and the domestic market for the produce from broadleaf forests remains under-developed leaving this sector relatively undesirable for future entrants to the market. Figure 2 shows the possible influence of the grant system on broadleaf species selection with both ash and alder (both relatively short rotation species) making up over 50% of new planting since 1983 (Dunne 2005). While there is certainly a domestic market for ash in terms of the manufacture of hurleys, the same cannot be said of species such as alder..

Alder is certainly capable of producing quality timber in a relatively short rotation (40 to 50 years). However if alder is being chosen simply to fill wet pockets of land or for use on poor sites without proper emphasis on management and the application of best silviculture practice, this could further undermine the development of the broadleaf sector and leave alder with a poor reputation.

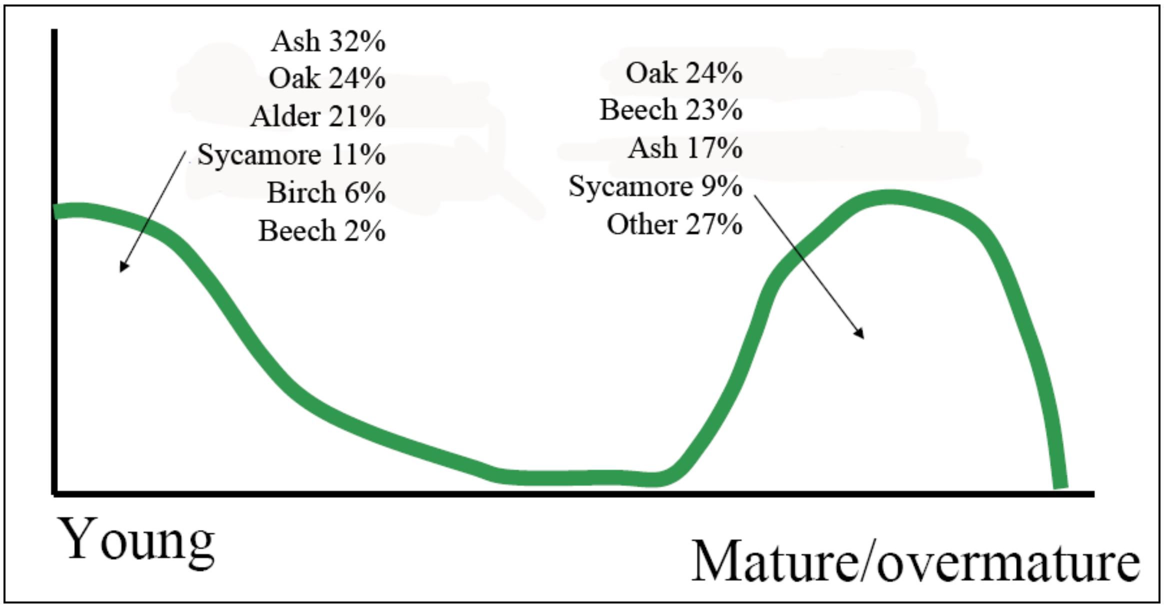


Figure 2: Breakdown of broadleaf forestry (Dunne 2005) ('Young' in this graph means up to 15 years old and 'mature' is more than 65 years old. The young portion of the graph equates to 48,000 hectares and the Mature/overmature to 39,000 hectares)

1.3.2 **Coniferous Forestry**

The predominant species of tree used in coniferous forestry in Ireland is Sitka spruce (*Picea sitchensis*). The Forest Service Information Sheet on Sitka spruce lists its uses as "*building timber, fencing material (stakes), pallet manufacture, Medium Density Fibreboard (MDF) and Oriental Strand Board.*". However Irish grown Sitka spruce does not cater for the high end joinery, carpentry or cabinet making sector due to the characteristic of knots which tend to shatter in drying (Magner 2005) and there are concerns as to the quality of Irish grown Sitka spruce for use as a building material (Lewis 2006). Much of the softwood for construction used in this country is imported from Scandinavia, Russia and other eastern and northern European countries where softwoods take up to 100 years to mature and have superior mechanical and physical properties and are consequently of a much higher quality.

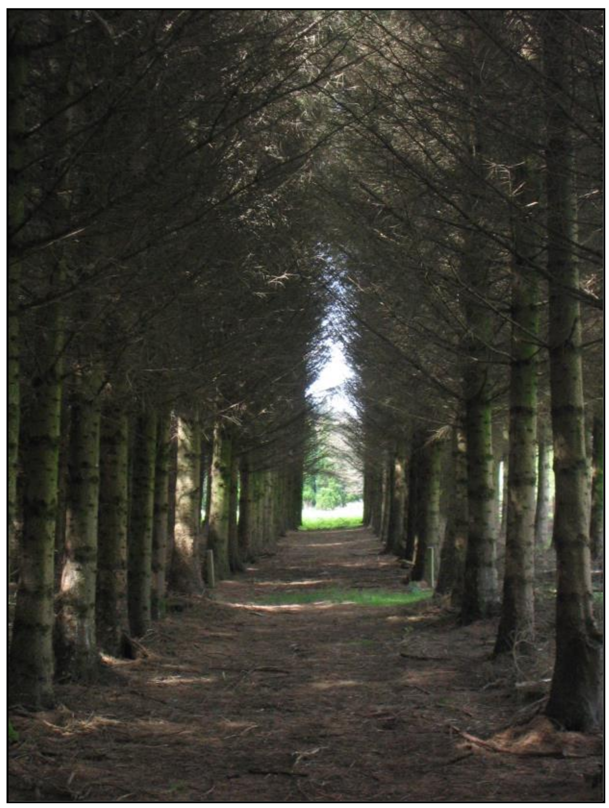


Figure 3: Sitka spruce forest in Co. Wexford

The recent reporting of the importation of round wood and pulpwood from Scotland by a panel production company in Ireland (IFCA 2006) has also created some uncertainty within the softwood forestry sector. The fact that the afforestation targets set out in the Strategic Plan (Anon 1996) have not been met may also undermine the competitiveness of Irish forestry produce from this sector in the future.

1.3.3 Broadleaf forestry

Figure 4: 12 year old ash stand in Co. Meath

Broadleaf species are relatively more expensive to establish and maintain than conifers due to longer rotation times and more intensive maintenance and management requirements (e.g. deer fences, tending). At many of the forestry conferences in Ireland attended by the author, broadleaves have been depicted as uneconomical and having a greater investment risk when compared with coniferous species (Phillips 2005). This perception is compounded by the fact that there is not an established market for the produce of thinned hardwood material and juvenile wood and so there is a certain unpredictability or risk associated with the returns on investments. The small size and dispersion of stands adds to those costs and reduces benefits from potential economies of scale. In previous years the lack of clear silvicultural guidelines for the management of broadleaves has also had a negative impact on their performance.

Despite the general perception that broadleaf commercial forestry is uneconomic there have been many proponents who argue that it is the structure of the grant system which negatively skews against broadleaf planting. A number of reports and papers have largely undermined the notion that hardwood timber production is uneconomic (Lewis 2006) while proponents of broadleaf forestry point to the importance of biodiversity and also to the potential economic benefits of hardwood timber and thinnings. Initiatives like the Native Woodland Scheme and the Millennium Forests project have been very successful in promoting native species. The sharp increase in energy and steel prices over the last number of years along with pressure to meet Kyoto targets has also increased the awareness and demand for timber and non-timber forest products. The fact that the market in Irish grown hardwood timber and non-timber products is under-developed means that there are many unknowns and much conjecture in the debate at present.

Figure 5: Grey squirrel damage in sycamore

In accordance with EU Biodiversity legislation, Ireland's Forest Service has established a planting target of 30% for broadleaves in 2003. This has slowly but gradually begun to impact on the landscape of our forests. This has resulted in the last two years in quite a dramatic increase in demand for broadleaf seeds and saplings from nurseries. The selection of suitable species to appropriate sites and the management regimes adopted thereafter will be critical to the success or otherwise of the hardwood industry in years to come.

Over the last decade there has been a relatively large increase in the planting of common alder (*Alnus glutinosa*) in Ireland. This species is one which is very easy to establish, survives on poor, damp soils and grows relatively fast compared to other broadleaves. However the demand for alder in Ireland is low and there have been many questions posed as to the reasons for its current selection. In addition there is uncertainty as to its usefulness as a source of quality timber.

There are also other exotic tree species which grow very well in Ireland and could be considered in the forestry 'mix'. There are over 600 species of Eucalypts in the world for example and many of them have very high growth rates. While not all are capable of surviving in the northern hemisphere, certain species have proven to be very capable of adapting to the Irish environment. Upon witnessing some of the impressive Irish grown specimens it is difficult to discount their potential.

1.3.4 **Hardwood Imports**

At present the demand for hardwood timber in this country far outweighs the native supply. The sales of Irish grown hardwoods in monetary terms in 1999 was approximately €3m (Xenopoulou 2004). The most recent data available at the time of writing for hardwood imports from the Central Statistics Office (CSO) is shown in Table 4. The materials in the table are those that have had at most two processes applied to them and do not include furniture products, doors or plywood. While the amount of imports has grown steadily since 1999, this gives some indication as to the percentage of hardwood timber that is imported in relation to that supplied by home grown timber industry. It is interesting to note also that of the €74m in sawnwood imported into Ireland in 2005 statistics from the United States Department of Agriculture show that almost €20m (US$23.348m) of these imports came from the USA (Table 5). The recent accession of 10 new member states to the European Union has also opened up a market for timber which is characterized by a low-cost high quality timber supply. This has lead to severe competition being experienced on the European market and price wars are not uncommon (USDA 2005, July 8).

Further analysis of the importation of timber as a raw material into Ireland shows that while the American market is an important one from Ireland's perspective the size of the overall market is substantially larger than this. Table 5 shows some of the most detailed data available on wood material imports for 2005. It is hard to understand how a country which is very suitable for growing trees is not capable of supplying its own market with quality homegrown material at a competitive price.

Table 4: Overall imports of timber into Ireland in 2005 (CSO 2007)

Description	CSO Code	€000	Tonnes	Notes
Charcoal	4402	910	880	
Fuelwood	4401	65	174	Fuel wood, in logs, in billets, in twigs, in faggots or in similar forms; wood in chips or particles; sawdust and wood waste and scrap, whether or not agglomerated in logs, briquettes, pellets or similar forms
Wood in the rough	4403	75,703	244,831	Roundwood, unsawn sections
Hoopwood	4404	484	827	Hoopwood; split poles; piles, pickets and stakes of wood, pointed but not sawn lengthwise; wooden sticks, roughly trimmed but not turned, bent or otherwise worked, suitable for the manufacture of walking sticks, umbrellas, tool handles or the like
Sawn Wood	4407	74,272	74,811	Wood sawn or chipped lengthwise, sliced or peeled, whether or not planed, sanded or end-jointed, of a thickness exceeding 6 mm
Moulded Wood	4409	42,166	28,193	Wood (including strips and friezes for parquet flooring, not assembled) continuously shaped (tongued, grooved, rebated, chamfered, V-jointed, beaded, moulded, rounded or the like) along any of its edges, ends or faces, whether or not planed
Veneers	4408	7,146	3,839	Sheets for veneering (including those obtained by slicing laminated wood), for plywood or for other similar laminated wood and other wood, sawn lengthwise, sliced or peeled, whether or not planed, sanded, spliced or end-jointed, of a thickness not more than 3mm
Total		**€200,746**	**353,555**	

Table 5: Imports of American Hardwoods to Ireland 2001 – 2005 (USDA 2005, July 8)

	Values in US$000				
Harwood Lumber	**2001**	**2002**	**2003**	**2004**	**2005**
White Oak	5,079	6,508	6,340	9,087	11,717
Ash	1,768	1,742	2,010	2,856	3,548
Other Temperate	1,577	2,549	2,147	1,670	1,652
Cherry	1,052	1,205	1,374	1,510	1,501
Walnut	92	343	592	852	1,478
Red Oak	2,128	2,218	1,733	1,575	1,386
Maple	1,593	1,538	1,370	1,090	1,080
Yellow poplar	221	327	278	692	750
Hickory	0	0	30	0	95
Western Red Alder	156	61	65	169	79
Birch	0	0	0	0	62
Tropical	0	10	0	0	0
Total (ha)	**13,666.0**	**16,501.0**	**15,939.0**	**19,501.0**	**23,348.0**

1.4 Objectives of this research

The objectives of this research are to examine the mechanical and physical properties of two species of trees which have been shown to perform well in the Irish climate. These species are common alder and eucalyptus. While both species produce wood that is categorized as ‘hardwood’ their timber is very different in both its physical appearance and strength properties. Through the verification of those properties the utilisation of timber products from those trees can be fully explored and demonstrated.

Specifically through this research it is intended to:

- identify standards pertinent to the production of quality timber
- explore the area of grading of timber in Ireland and overseas
- establish the following for the timber of each of these Irish-grown species:
    - static bending strength
    - cleavage strength
    - resistance to indentation
    - resistance to compression parallel to the grain
    - density
    - nominal specific gravity

- test panel products made from the available material in terms of its reaction to changes of relative humidity in its service environment.
- examine the way in which common alder is utilised overseas
- identify alternative uses for these materials

The materials and methods used in the research carried out on two species of trees are outlined at the end of this chapter.

1.5 Scope of this research

This research is confined to the two species of trees described above. Common alder is a native broadleaf and eucalyptus is a non-native or exotic broadleaf species which is also evergreen. The research, while including an overview of silviculture and other information specific to the growing of these trees, focuses on the properties of the species that determine their utilisation potential. This is done in accordance with BS 373: 1957. Commensurate with the testing of the specimens, examples of products that could be developed from the wood of each is also examined. While the testing is confined to Irish-grown trees, the author has also carried out research in other countries in order to examine new ways in which the material could be utilised. A furniture manufacturing region in Sweden and a kitchen cabinet door manufacturer in Italy are presented as case studies for the use of common alder overseas.

In addition, a number of products and applications suitable to these species will be examined and presented. The purpose of this is to explore the diverse range of uses that the species is able to support.

1.6 Materials and Methods

This section outlines the materials used for this research and the type of tests carried out on that same material.

1.6.1 **Testing of Irish Material**

To date the only testing carried out on Irish grown common alder was done at the former Forest Products Department of Enterprise Ireland (Xenopoulou 2004). These tests found values for bending strength and stiffness. The author is unaware of any testing of Irish-grown Eucalyptus samples for mechanical properties and there appears to have been little research done in terms of possible timber production in Ireland.

The tests outlined in Chapters 5 and 6 of this thesis are performed to ascertain the mechanical properties of Irish grown timber from these species in order for their potential uses to be based on verifiable data. The mechanical property tests described in these chapters were carried out in accordance with BS373:1957 *Methods of Testing Small Clear Specimens of Timber* (BS373) and the American Society for Testing and Materials (ASTM) D143. Commensurate with the testing of Irish grown common alder the author also tested Irish grown eucalyptus (*E. muellerana*) samples. Analysis of the cell structure of each species is also presented in these chapters.

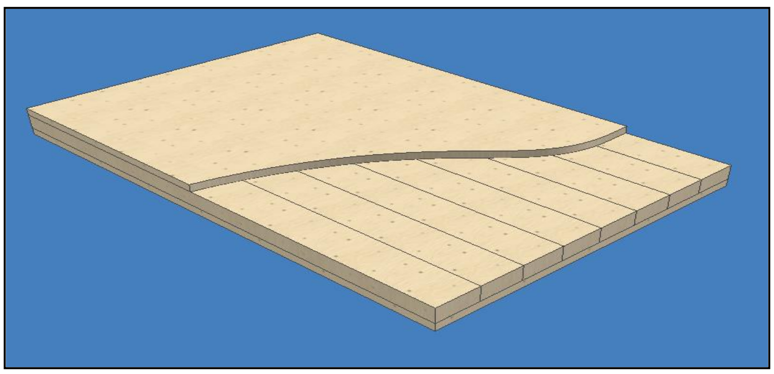


Figure 6: Design of blockboard construction

The author also carried out analysis on composite boards made from alder including a multi-ply and blockboard (Figure 6). These were tested visually for stability and distortion and measured for shrinkage and swelling under varying relative humidity conditions. These test panels were compared with samples of commercially available composite panel material.

1.6.2 Test Methodology

According to BS373 the appropriate cross sectional dimensions of the small clear samples of timber to be tested are 20mm by 20mm with the length varying according to the specific test in question. The material to be tested must be straight grained and free from defects and conditioned (65% relative humidity and 20^{o} Celsius). Due to the variability of wood as a material, the standard deviation of the results is also calculated and taken into account. To ensure the random selection of the samples to be tested, material should be taken from different boards and trees where possible.

1.6.3 Timber Sources

Due to time constraints for this project and the limited availability of mature alder for testing, material tested was sourced from one tree. This tree was converted and dried to a moisture content of 10-12% MC at Dundrum Sawmills. The tree was originally taken from area 4314 / SP 7000 in Slieve na mBann in Co. Tipperary. The tree was recorded at approximately 72 years old, measuring 19m in height and 48cm diameter at breast height (DBH). The material was in excellent condition and no problems arose in extracting samples from this specimen.

The eucalyptus samples were obtained from the Coillte estate in Glenealy Forest in Co. Wicklow. Two trees were selected that were approximately 70 years old. The species, identified through original planting maps and seed analysis were *E. muellerana* (yellow stringybark) and *E. viminalis* (manna gum). Both trees were through-sawn to plank form at Gleneally at a mill owned by Pat Staunton. One tree, *E. muellerana*, was immediately taken to University of Limerick for kiln drying using a schedule of 70Cº wet-bulb and 55ºC dry-bulb for a period of 4 weeks. The second tree (*E. viminalis*) was taken to GMIT Letterfrack for air drying and other analysis. The *E. viminalis* specimen was measured at approximately 37m in height and a DBH of 76cm while the *E. muellerana* specimen had a height of approximately 39m and a DBH of 78cm. The trees were converted into 2.4m boards of both 30mm and 50mm in thickness and widths averaging 300mm. Extensive degrade occurred during the conversion of these species and these are discussed further in Chapter 7.

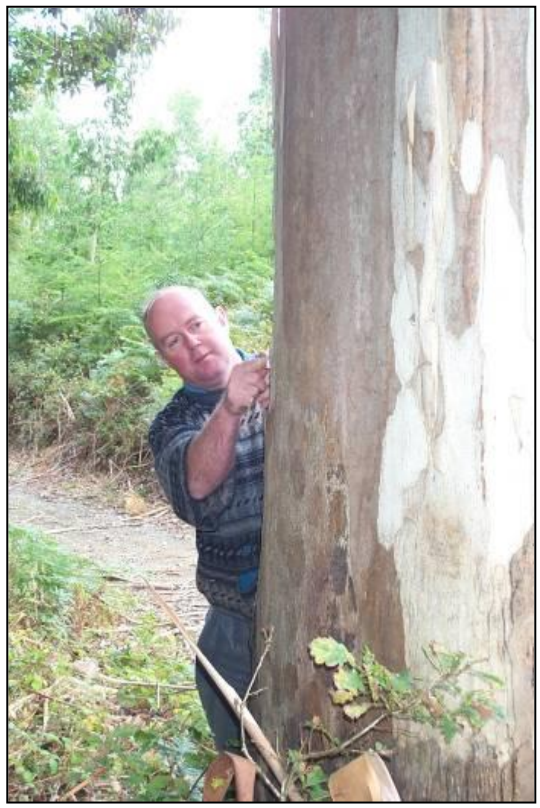


Figure 7: Test tree being marked for extraction at Glenealy Forest

1.6.4 **International Case Studies**

In Ireland there is little demand at present for common alder. The reasons for this are not entirely clear but it has certainly been overlooked as a material and this has resulted in the demand for Irish grown common alder to dissipate. However there has been a significant increase in the planting of alder over the past decade which will in the medium term give rise to renewed interest from a utilisation perspective. In order to explore the potential of common alder the author traveled to Sweden and to Italy to observe how alder is treated on the continent in terms of forestry, timber production and utilisation.

Sweden was chosen due to its long history of forestry and due to the diversity of uses to which alder is applied in that country. An organization called the Träcentrum (The Wood Centre) in Nässjo was visited during the period of this research and excursions which incorporated all elements of the process chain for the use of alder were undertaken.

Due Rose s.p.a. is a company situated in Pasionne de Pordenone, 40 kilometres north-east of Venice in Italy. This company is a leading manufacturer of kitchen cabinet doors. It supplies the Irish market through a distributor in County Carlow and one of the materials they use for their doors is alder. The author visited this company to explore the way in which alder is used in their production line and to investigate the demand for alder products from the Irish market.

2 Properties of Common Alder and Eucalyptus

2.1 Introduction

Common alder is a native species and has a prominent history in both Irish folklore and in terms of the history of forestry in Ireland. It is a very fast growing tree, suitable to a wide variety of soils and assuming a rotation of 40 years could perform well under the current afforestation or Native Woodland grant schemes (Little 2006). In the past number of years it has become the third most common broadleaf species of tree planted in Ireland (after ash and oak) with more than 3,000ha planted from 1998 to 2004 (Dunne 2005) while sales of alder plants from Irish nurseries have risen from 870,000 in 1998 to almost 5 million in 2005 (Table 6). At present however there is little or no market for the timber of native alder and concern has been expressed as to the reasons why such an explosion of demand for saplings has occurred.

Table 6: Sales of alder from nurseries in Ireland 2001 – 2005 (Compiled from pers comm)

Nursery	Figures in '000's			
	2001/02	2002/03	2003/04	2004/05
Coillte Nurseries	1,877	1,620	1,950	2,506
None So Hardy Nurseries	1,505	2,171	2,345	2,486
Total	**3,382**	**3,791**	**4,295**	**4,992**

Sales of Irish grown alder in 1999 were as little as 28m^3 with no expectation or potential for growth in its demand (Xenopoulou 2004). Indeed of 7 saw mills dealing in hardwoods in Ireland contacted by the author in July 2007 none of them stocked common alder. Interestingly though according to the trade data in Table 7 American red alder sales to Ireland from the USA in 2005 amounted to $79,000 and were as high as $169,000 the previous year (this drop off may have resulted from the decrease in manufacturing of kitchen cabinet doors in Ireland in the last two years). In fact the demand for American red alder (*Alnus rubra*) is also strong in other countries. In Spain for example approximately US$8m worth of red alder was imported from the USA in 2004 (up 93% since 2000). If it can be shown that common and red alder have similar properties and characteristics then there is evidence that a market may be viable for timber from common alder.

Table 7: Exports of American red alder to selected European countries (USDA 2005, July 8)

	Values in US$000				
Country	**2001**	**2002**	**2003**	**2004**	**2005**
Ireland	156	61	65	169	79
UK	560	314	416	403	265
Spain	4,120	5,282	6,525	7,751	7,970
Germany	7,991	1,739	1,969	6,875	11,400
Sweden	387	262	335	831	796
Italy	13,451	11,949	11,698	13,738	12,607
Total EU	**34,055**	**24,426**	**26,773**	**35,218**	**37,925**

Eucalyptus on the other hand is an exotic species native to Australia. It is an evergreen tree and its timber is classified as hardwood. There are more than 600 species recorded around the world (Jacobs 1981). A number of species of eucalypts have been grown under trial in Ireland as far back as the 1930's. The tree performs very well and grows particularly fast. It is primarily used for short fibre pulp but some species are also used for timber production, veneers and fencing posts. Although it is not listed as a qualifying species under the afforestation grant scheme it is difficult to overlook its potential. In trials in J.F.K. Arboretum in Co.Wexford a stand of *Eucalyptus nitens* planted in 1982 has reached heights of more than 31m and recorded a yield class of 30 (pers. comm. Chris Kelly).

Figure 8: 7 year old *Eucalyptus rubida* in Co. Wexford

In this chapter these species are examined in more detail. The information available on the growth characteristics and silvicultural methods of the trees and the mechanical and physical properties of their respective timber are summarised.

2.2 Alder and Eucalyptus - Historical

Mac Coitir (2003) quotes the seventh century king Mad Sweeney (Suibhne Geilt) from his poem *Laoi Shuibhne* (translated by J.G. O'Keefe)

A fhern, nidot naimhdidhe	O alder, thou art not hostile
Is alainn do lí.	Delightful is thy hue
Ní dat cuma sceó sceanbaidhi,	Thou art not rending and prickling
Ar an mbeirn a mbí.	In the gap wherein thou art

Common alder (alder) is of the genus *Alnus* and the family *Betulaceae* (which is the same family as birch). The Latin *glutinosa* refers to the stickiness of the crushed or young leaves. The name alder is believed to have originated from the old German *elo* or *elawer* meaning reddish brown (Fraser 2005). The Irish for alder is *fearnóg* and a number of towns in Ireland are believed to be named after it – Ferns, County Wexford, Ferney, County Fermannagh and Ballyfarnan, County Roscommon (Hickie 2002).

Most of the approximately 600 species of eucalypts are native to Australia and Tasmania where they are usually referred to as 'gum' trees. Since the 1950s there has been a huge increase in interest globally in the species for plantation purposes, and due to an excellent combination of specific gravity and volume production, they have become very important in the production of renewable fuelwood resources (Jacobs 1981). Eucalypts have also proven to be very adaptable to many environments and are to be found even on the wind-swept hills of Connemara! Their importance in forestry terms is evidenced by the amount of research carried out globally on eucalypts.

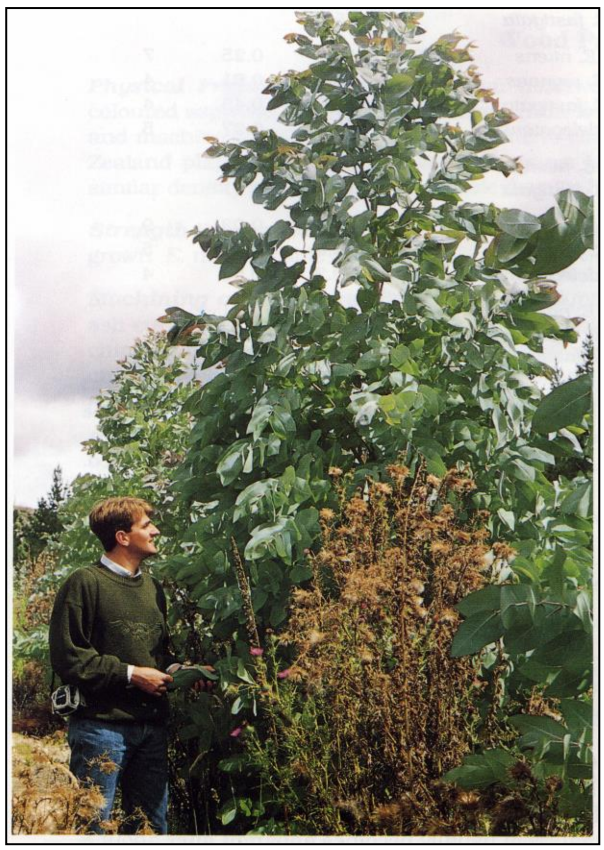


Figure 9: 15 month old *E. nitens* in New Zealand (Miller et al, 1992)

There are many similarities between groups of eucalypts and they are catagorised into sub-groups. One such group is the 'ash eucalypts'. These species have very similar properties and include such eucalypts as *E. regnans*, *E. deligatensis*, *E. fastigata*, *E. oblique*, *E. sieberi*, and *E. fraxinoides*. *E. nitens* is not an ash eucalypt but is often included with this group due to the fact that it has similar wood properties and also requires specialised sawing techniques.

2.2.1 **Irish Folklore and Mythology**

Alnus glutinosa is commonly known under a number of titles including common alder, European alder and black alder. In Britain the alder was also known as tag alder, winterberry, feverbush and owler. Alder was also known as 'Irish mahogany' due to its reddish brown colour (however this pseudonym did not necessarily originate in Ireland as it was also known as 'Scottish mahogany' and even 'Swedish mahogany'). In Irish folklore it was one was one of the "peasant trees", and according to Hickie (2002) was *"associated with spring fertility rights"*. In the old Irish law-text *Bretha Comaithchesa* there is a list of 28 trees and shrubs divided into 4 groups. The list and groups dictated the laws governing their use and also penalties faced by someone who cut down or damaged a tree without permission. Alder, associated with the Ogham letter *Fern* (MacCoitir 2003), was in the second group called the *aithig fhedo* (commoners of the wood) and at the time was used for the production of shields, masks and tent poles (Kelly 2004). Penalties for damaging or felling an alder ranged from a fine of one sheep for the cutting of a branch, a 'dairt' for fork cutting, one 'milch' cow for felling and the price of two and a half milch cows for the removal of a tree (MacCoitir 2003). In Irish mythology the first man was believed to have been made from alder whereas in Scandinavia the first woman was believed to have been fashioned from the trunk of the alder (Fraser 2005). In astrology alder people i.e. those born in the month of February are said to be like the Phoenix in that they regenerate themselves after each setback (Knowles 2006).

2.2.2 **Eucalyptus in Ireland**

Eucalypts were introduced in Ireland as far back as 1908 in Avondale, Co.Wicklow (Mooney 1960). Many initial plantings were experimental in nature and in some cases ornamental. Though there are concerns as to the frost-hardiness of some species many have thrived in the Irish climate in spite of Eldin's (1969) assertion that *"…all eucalypts… are frost tender, and none succeeds in northern North America, nor in Europe north of the Alps"*. Of particular importance are a number of plantations in the east of Ireland in the counties of Wicklow and Wexford.

Figure 10: Bark of *E. puciflora* in Fota Park Arboretum

In 1934 various species of eucalypts were planted in a six acre blocks in Glenealy Forest in Ballymanus, County Wicklow. These included species such as *E. Muelleri, E. radiata*, and *E.viminalis*. The elevation of this plot is 168m above sea level with a south-east aspect and on a medium to moderately exposed slope. The seed provenances for these Eucalypts were New South Wales, Victoria and Tasmania respectively and interestingly on this plot there were only ten recorded losses of *E. viminalis* due to frost (Mooney 1960). In fact Mooney goes further to assert that the figures recorded for eucalypts in Glenealy *"are sufficiently consistent to establish that exceptional volume production far above anything obtainable from the conifers usually grown here and probably comparable to, if not greater than, poplar, may be expected"*. Figures recorded in 1957 indeed reflect very positively on this conclusion as can be seen in Table 8. Of *E. Muelleri* Mooney (1960) notes that the trees are *"straight, of very fine form and finely branched and have a healthy well furnished live crown."*

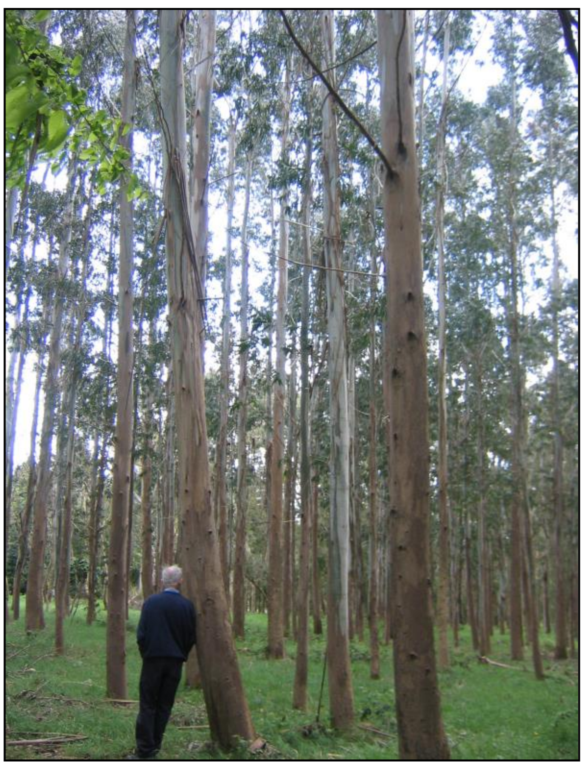


Figure 11: *E. nitens* in JFK Arboretum (planted 1982)

Table 8: 1957 Assessment of trees in Glenealy (Forest Service 1957)

Species	Year of Planting	Stems per acre	Mean Tree Total Height	Mean Tree B.H.Q.Q.	Volume per acre- cubic. Feet Hoppus	Actual No. of Trees per Plot
E. Muelleri*	1934	505	69'	8	6,124	62
E. radiata	1934	786	42'	6	2,822	28
E. viminalis	1934	-	-			Few scrub trees
(mountain type)						
E. dalrympleana	1934	501	57'	7	4,371	29
E. urnigera	1934	704	70'	7	6,507	80

* *E. Johnstoni* (Maiden) is now given as the accepted name for *E. Muelleri* (T.B. Moore, F.A.O. 1955)

These impressive figures are further backed up by the recordings of Mr. R. B. Walpole (Table 9) on some of the first plantings in Mount Usher in Co. Wicklow (Walpole 1959). Certain species on this site including *E. regnans* were recorded to have been killed by frost at -14ºC. Mooney (1960) also examined some of the end uses of eucalypt timber and some of the research carried out at the time on Irish grown eucalypts. These included satisfactory results for the production of hardboard from 23 year old *E. Muelleri* and the extraction of tannins for use in the leather processing industry. However, the over-riding results from this research appear to be the difficulty in felling and converting eucalypts due to end and longitudinal splitting. *Eucalyptus urnigera* was said have become *"distorted into extraordinary shapes, "collapse" being a prominent feature in all cuts"*. Eucalypt poles taken under controlled conditions from Ballymanus degraded considerably due to longitudinal splits (often occurring simultaneously to felling). Fibre board produced from eucalypts also had the effect of corroding the mill machinery while the process liquors were so acidic that they corroded the platens in the hydraulic press during the manufacture of hardboard. Despite this Mooney concludes that "*there is no other tree that will produce as much timber in so short a time under our conditions. The economic balance of this consideration deserves attention."*

Table 9: Recordings of notable trees (Walpole 1959)

Species	Year of Planting	Top Height	Girth at 4'3"
*E. subcrenulata**	1,949	47'	28"
E. viminalis	1,910	110'	119"
E. viminalis	1,910	95'	139"
E. deligatensis	1,910	92'	74"
E. gigantia	1,928	91'	103"
E. Muelleri	1,910	114'	99"
E. urnegra	1,910	89'	109"
E. coccifera	1910?	55'	
E. urnegra	1,910	89'	91"
E. Stuartiana	1,910	106'	128"
E. Stuartiana	1,910	106'	120"
E. Johnstoni	1,910	83'	61"
E. urnigera	1,910	103'	123"
E. amygdalina	1,948	33'	13"

*** *E. subcrenulata* now associated with *E. Muelleri***

There appears to have been little take-up on Mooney's call for more research although again in 1982 some eucalypts were planted for research purposes in John F. Kennedy Arboretum in New Ross, Co. Wexford. The species planted here was *E. nitens* (Figure 11) and it has demonstrated itself to be equally vigorous to those eucalypts planted in Glenealy. These trees were thinned at various stages, are given a yield class of 31 and have survived ground temperatures of -12ºC (Table 10).

Table 10: JFK Arboretum forest plot measurements for *E. nitens* (Kelly 1997)

Species	Origin	Year Planted	Spacing (m)	Estimated Yield Class	Top Height (m)	Standing Volume (m^3)	Thinnings ((m^3/ha)	Thinned	Total Production ((m^3/ha)
E. nitens	Anembe S.F. New South Wales Australia	1982	1.83	31	31.1	320.6	175.1	'92, '93, '97	495.8

2.2.3 Distribution and Site Conditions

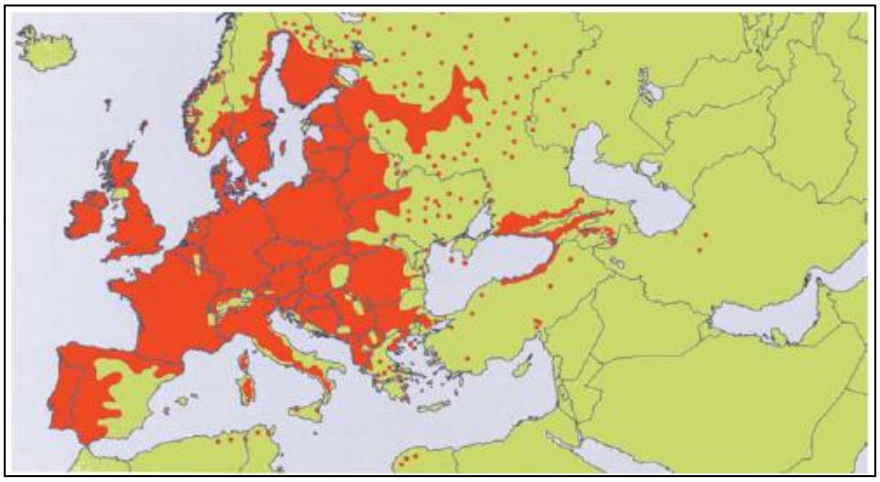


Figure 12: Distribution of common alder in Europe (Fennessy 2005)

Common alder is the only alder native to Ireland (Forest Service 2000) and has a natural habitat across most of Europe, Asia Minor and parts of northern Africa and are the dominant species in huge areas of natural woodland. However the densest distribution is in the lowlands of northern Germany, northern Poland, Russia and northwestern Ukraine (Anon 1990). Regarding its place in Irish forestry history, Hickie (2002) states that "*The areas that are good farmland today, like Cork and Limerick, were cloaked with elm, oak and alder"*.

Alder is capable of growing on a range of soil types but is particularly suited to wet to periodically saturated fertile, acidic soils (pH 4.0 – 7.5)(Forest Service 2000). It is also suitable to heavy textured soils where the threat of wind-throw may exist for other species. Alder prefers low land sites and is often found on riparian sites, near fresh water loughs, in marshes and on lakesides (sometimes partially submerged in water). It is therefore capable of surviving flooding conditions and is actually used (sometimes with grey willow) as a tidal woodland, in land reclamation and as a natural barrier to erosion. It also has the reputation of being drought resistant due to the ability of its roots to survive periods of anaerobic conditions (McVean 1953). Alder is also one of the main foods for a number of species of insects which in turn provide an important food source for fish (Savill 1991).

Alder roots have nitrogen fixing nodules with the capacity to fix atmospheric nitrogen that enables it to thrive on infertile soils (Hickie 2002). Alder is sometimes recommended as a nurse in forest establishment but due to its rapid growth and light-demanding nature, will quickly dominate most other species. It is very hardy to extremes of winter temperatures although Funk notes that "*it does not establish itself where the mean daily temperature is above freezing for less* *than six months of the year"*. It is also wind tolerant and moderately resistant to salt spray (Savill 1991).

For the purpose of the following sections and in order to be more specific in regards to a species of Eucalyptus, *Eucalyptus nitens* (common name is shinning gum) is the species considered. This species of eucalyptus has performed well in Ireland especially in the south and east and is regarded as one of the more suitable species for growing in this part of the world. It is also one of the species about which much research has been carried out in terms of timber production.

Eucalyptus nitens is native to south-east Australia and grows naturally between 30º23' and 38º 00'S in the coastal mountain ranges of eastern Victoria along the western edge of the Great Dividing Range and southern New south Wales (Maiden 1992). Its optimum altitude range is from 600m to 1600m above sea level. The climate there is cool to mild with mean annual rainfall of 750 to 1250mm and with a dry season of not more than 3 months. The mean temperatures range from 22ºC to 0ºC with some occasional snow (FAO 1981).

2.2.4 Species Identification

Alder is monoecious and develops male buds that are considerably longer than the female buds. It is during the opening of the purple buds (Figure 17) that the red sap of the alder becomes most apparent (MacCoitir 2003). Flowers are produced before leaves are fully out and the seeds produced have no wings but do have an air bladder which is believed to facilitate dispersal by water (McVean 1955), hence the alder's favoured habitat along rivers and wet lands. Catkins begin to appear during autumn (Figure 14), the bark is grey-brown (Figure 18) and its leaves are dark green and shiny, usually smooth and broadly ovate with maybe a slight notch at the apex (Figure 13).

Typically eucalypts have rounded juvenile leaves in opposite pairs that grasp the stem. The juvenile leaves are opposite and ovate to lanceolate and adult leaves alternate and lanceolate to falcate (Jacobs 1981). The solitary adult leaves (Figure 15) are found on distinct stalks and their shape depends upon the species of tree. Figures 20 and 21 demonstrate the distinct difference between juvenile and adult leaves of *E. rubida*. The leaves of eucalypts adjust themselves in order to turn their edge to the sun. This has the effect of minimizing the surface area exposed to the sun and thus reduces water loss during the hot summers in its native Australia (Eldin 1969).

Figure 13: Common alder leaves

Figure 14: Common alder catkins

Figure 15: Foliage of mature *E. nitens*

Figure 16: Flower and seed pods of *E. nitens*

In Australia they are commonly referred to as 'gum' trees and their aromatic leaves are the exclusive diet of the koala. *Eucalyptus nitens* is a member of the group of southern blue gums and is commonly known as shining gum in Australia. *Eucalyptus regnans* is in fact the tallest tree in Australia and is capable of attaining heights of more than 100 meters. The bark of *E nitens* is deciduous and leaves a smooth trunk which is light grey in color containing a mixture of cream, yellow and green hues. The tree is capable of attaining height increments of more than 2 meters per year for the first five to ten years (Miller et al. 1992).

Figure17: Common alder buds

Figure 18: Common alder bark

2.2.5 Species Growth

Alder has a relatively short life span and according to the Arboricultural Association's (1991) categorisation of tree species, can expect to have a life expectancy of between fifty and seventy years. This can be significantly reduced on poor sites. The growth of alder is very rapid in the first 15 to 20 years with increments of up to one meter a year during this time. Full development is attained in 30-40 years while full height is reached in 60 years (Fennessy 2005) up to a maximum of 20 meters. Trunk diameters can reach more than 100cm. An alder in Glaisin na Marbh in Co. Kerry however is recorded at 5.92m in girth and 12m in height (Ireland 2005). Maximum dimensions recorded by Mitchell (1978) in the United Kingdom were 65cm in diameter at breast height (DBH) and 22m in height. Alder is classified as yield class 6-16m³/ha by COFORD while the ITGA class it as 6-8m³/ha (Magner 2005) and this divergence seems to be a reflection of the soil types and site conditions in which it is established. In one case study Little calculates yield classes of 16 and 12 for two different plots and notes its ‘exceptionally fast growth rates” (Little 2006).

Eucalypts in general are fast growing, tall trees which demonstrate good site tolerance and are frost tolerant (ENSIS 2005). In its native Australia specimens of *E. nitens* have grown up to 90m in natural stands but more typically it grows up to 60m with its crown usually about one third of the tree height. Initial growth is particularly fast and increments of 2m per year are not uncommon. Juvenile foliage also encourages diameter growth. In J.F.K. Park in Wexford 23 year old specimen of *E. nitens* has exceeded 31m in height while trees in a 13 year old stand of *E. nitens* outside Gorey have been recorded at 26m in height and 24cm DBH (Figure 19).

Figure 19: Stand of E. nitens in Gorey

2.2.6 Silviculture

Fennessy (2005) outlines the suggested guidelines for alder plantations (Table 11). It is noted in this publication that thinning regimes, focusing on specimens with good growth potential, can result in diameter growth rates of up to 20% higher than in unmanaged stands. This paper also suggests that, in common with other broadleaves, a strategy "delaying thinning until a branch-free bole of 6-7m is achieved" be applied. Initial high density planting also encourages height rather than lateral branch growth and the figure of 3,300 should be taken as a minimum.

Table 11: Guidelines for common alder plantations (Fennessy 2005)

Top Height (m)	Stocking after treatment	Comment
0.5/0.8	3,300	Planted at 2.0 x 1.5
2/3	3,000	Formative Shaping
4/5	2,500	2nd Formative Shaping
7/8	2,100	Tending, removing wolves
9/11	1,000	Heavy crown thinning
12/13	700	Crown thinning of competing dominants
15/16	450	Select 150/200 final crop tree/ha
17/18	200	Further reduce to 100/120final crop trees

However Little (2006) has a slightly different approach and suggests a strategy of pruning and thinning to a final crop of approximately 250 stems (180 of which will be harvested and 70 left as standards to promote age diversification). This approach is in line with that of continuous cover forestry (CCF) silviculture He also notes that there is little need for mounding and that vegetation control is necessary only for the first 4 years. Assuming a 40 year rotation, trees with DBH of no less that 32cm would be harvested.

In Sweden the regime of tending is not considered necessary for alder as the lower branches tend to die off naturally (apart from the outermost stems on the plot). Thinning takes place every 8-10 years with the removal of approximately 30-35% at a time. This encourages the formation of a good canopy and allows for development of the lower stem. The optimum form for alder is considered to have approximately 50% green canopy and 50% clear stem. (pers. comm. Andreas Garden).

In New Zealand the target tree for sawnwood of *E. nitens* is at least 75cm DBH with a straight stem and well balanced crown. The first 5 to 6m of the stem should be free of branches with a lightly-branched upper stem. This is achieved using stocking densities of 1200 to 1800 stems per hectare with final thinning to 100 stems. One approach used is to encourage natural shedding of branches. In more recent years however pruning up to 6m in three stages combined with a regime of thinning up to year 12 (Maiden 1992). This approach is more in line with general broadleaf silvicultural guidelines in Ireland although the initial stocking levels are much lower. This however is compensated by the rapid growth of eucalypts. In order to promote initial establishment, the use of weed free zones up to one year of the canopy closing is practiced in Brazil (Leslie 2003). Eucalypts are however very sensitive to certain herbicides so care must be taken in their selection and application (Maiden 1992). In Australia forests typically follow a forty year rotation. Stocking densities for firewood and pulp would be up to twice as dense as that for sawnwood.

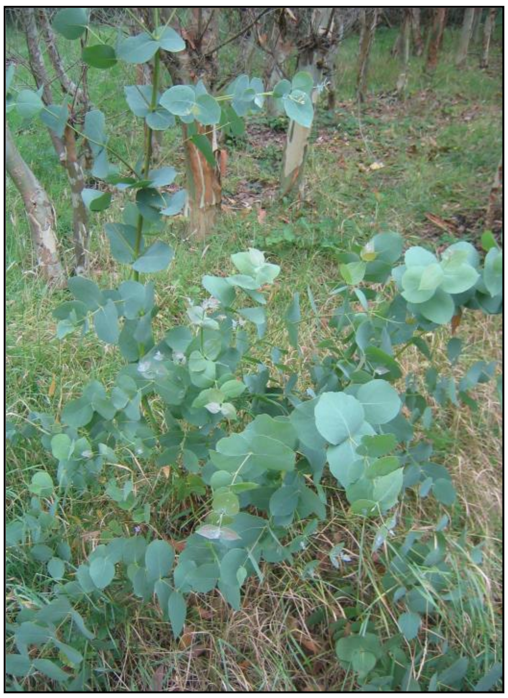


Figure 20: Young foliage of *E. rubida*

Figure 21: Mature foliage of *E. rubida*

2.2.7 **Threats**

Alder is not very susceptible to attack by grey squirrel (see figure 5) or grazing animals due to its high tannin content although Carey (2005) puts alder in the second class of 4 on his susceptibility scale. Alder does not appear to be as palatable to deer and other browsing animals as other hardwoods and Savill (1991) also notes that alders are notable among hardwoods in that they are not seriously attacked by rabbits and hares. There are some insects which affect living alder trees including *Hernichroa crocea* (striped alder sawfly), *Fenusa dohnii* (European alder leafminer), A*lticaambiens alni* (alder flea beetle) and *Prociphilis tesselatus* (wooly alder aphid) but none of these pose a serious threat.

At low altitude sites in New Zealand and Australia the Eucalypts are prone to attack by a number of insects and fungi. The most serious insect in this respect is the tortoise beetle *Paropsi scharybdis*. These beetles attack the adult leaves of Eucalypts leading to defoliation and stifling development. After a number of trials, *Enoggera nassaui* (pteromalid wasp) has been the most successful in the control of the beetle and its larvae. Eucalypts are also prone to attack by a number of other insects including *Strepsicrates macropetena* (leaf-rolling tortricid moth) and *Platypus apicalis* (pinhole borer) as well as some fungi e.g. *Mycosphaerella* spp. Eucalypts are also susceptible to browsing by deer (and possums in Australia) however grey squirrel do not appear to damage *E. nitens* in Britain.

2.2.8 **Phytophthora Disease**

Alder is prone to a lethal phytophthora disease caused by an unusual form of *Phytophthora cambivora* which is a well known pathogen of broadleaved trees but prior to its discovery had not been recorded on alder (FAIR-CT97-3615 2001). This disease was first detected in southern Britain in 1993. It results in the degeneration of alder leaves, root systems and lower stems and is detectable by the presence of bark lesions (Figure 22) or black rusty coloured ‘tarry spots’ from the collar upwards (Gibbs et al. 1999). It is also detectable by the presence of small and yellowish coloured leaves which have a tendency to fall prematurely. The disease can affect young woodland plantations but is most prevalent on riparian sites. Alder *Phytophthora* has resulted in die-back rates as high as 10% in places (Gibbs et al. 2003). Research carried out in Britain on alder plots over 8m wide along rivers has revealed a steady increase in its incidence and up to 2003 more than 15% of trees surveyed had died as a result of the disease (Hendry 2004). Hendry also notes that “*The microscopic spores of the alder Phytophthora (known as zoospores) are free-swimming in water and therefore probably disperse via river systems as well as in soil*.”

According to reports *Alnus glutinosa* appears to be most susceptible to the disease although it has also been detected in grey (*A. incana*) and Italian alder (*A. cordata*). Alder *Phytophthora* disease has been recorded in many countries around western and central Europe including Ireland and

Figure 22: Tarry exudations from a lesion on the stem of common alder (Gibbs et al. 2003)

attempts to isolate it have proven mixed to date. Testing for the disease has been already carried out at the Diagnostics Laboratory in GMIT (pers. comm. Patrick Walsh). Eradication of disease trees is not recommended in order to manage the disease due to the disturbance created by such activity. Research has revealed that different European provenances of common alder show little or no resistance to the disease. However coppicing has been put forward as one possible remedy especially where the root system can no longer support the main crown. (Gibbs et al. 2003). Proper surveillance of nurseries is important as a control and a planting regime that avoids sites liable to flooding and alongside riverbanks where the disease is prevalent are considered critical in its future control. The threat of the disease and its implications for the growth of alder in Ireland cannot be ignored.

2.3 Timber

The following section outlines the known physical and mechanical properties of the timber of common alder and eucalyptus.

2.3.1 Physical Properties

The Coillte Wood Products Guide (2006) states that "*Alder is a straight grained, fine textured timber which is pale when first cut but darkens to a reddish brown colour with some dark distinguishable rays visible*" as in Figure 26. The resultant dark lines in the timber of the alder give it an attractive character. The pinkish-brown heartwood and sapwood are virtually indistinguishable and the timber is lusterless although sound burrs can be highly figured (Funk 2005). In Sweden alder is host to the larvae of *Phytobia betulae* (bastfluga - which literally translates as the bark fly) which mine within the differentiating xylem tissue resulting in permanent brown tunnels in the wood (pers. comm. B. Parsson). This gives the timber an attractive grain pattern which is not dissimilar to the marks of rays (Figure 23)..

Figure 23: Common alder showing ripple grain and brown 'tunnels' of *P. betulae*

Figure 24: Section showing red hue on end grain of common alder

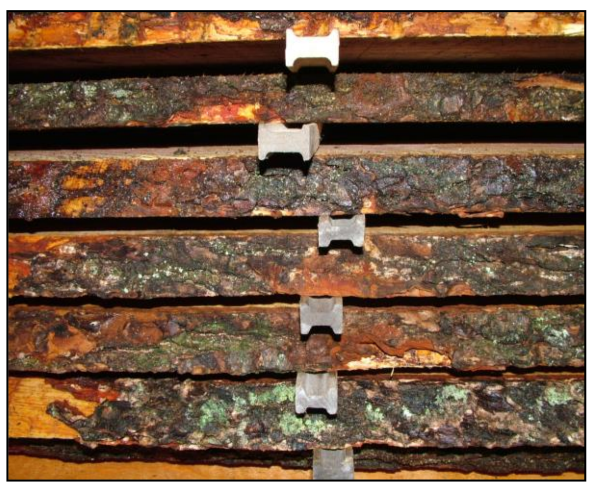


Figure 25: Common alder stacked in kiln

The kiln schedule for alder recommended by Pratt is PRL Schedule J (Fennessy 2005) . Simpson recommends a dry-kiln schedule using an initial dry bulb temperature of 60ºC and an initial wet bulb temperature of 67ºC. The wood dries very quickly and with little distortion and in many cases does not require air drying prior to mechanical drying. Pratt has classed alder as having a low checking tendency and Boddy (2005) comments that "*[alder] dries easily, fairly rapidly and well with negligible degrade and with little movement in service.*"

The timber is classed as having medium shrinkage rates of 4% radially and 6.5% tangentially (going from green to 12% MC) (www.genetrade.net) while movement in service is also classed as low to medium with a change in relative humidity from 60 to 90% resulting in movement of 2.78% and 1.5% in the tangential and radial planes respectively. An important factor from a utilization perspective is its stability both during the drying process and in service giving it a relatively high yield during conversion.

Figure 26: Common alder timber (Crown cut)

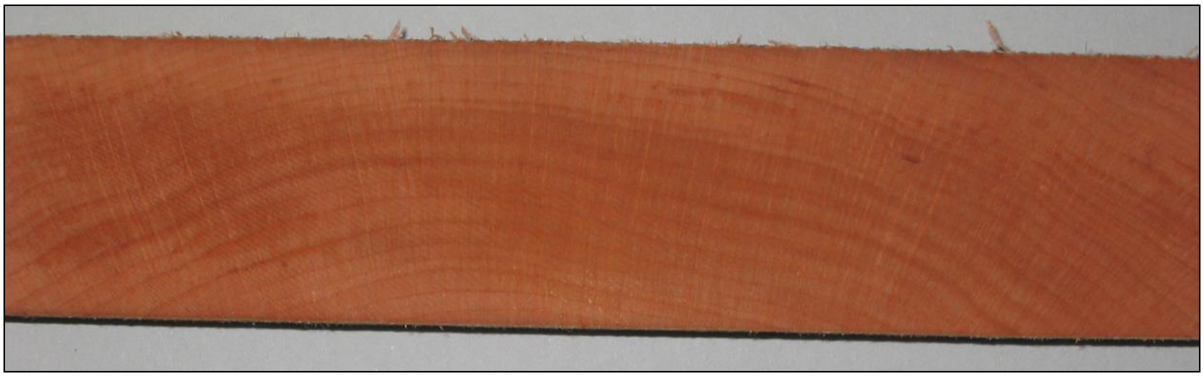


Figure 27: End grain section of common alder showing rays transversing the growth rings

The heartwood of *E. nitens* has a pale and sometimes golden brown colour while the sapwood is cream coloured and sometimes difficult to distinguish. The timber has a moderately coarse texture not dissimilar to oak (Miller et al. 1992). The grain is often interlocked. Timber of different eucalyptus species can be very different. The group of ash eucalypts, with which *E. nitens* is associated, are also commonly referred to as 'Tasmanian oak' due to the similarity of the characteristics of the timber to oak.

2.3.2 Mechanical Properties

Figure 28: 'A' graded planks of common alder awaiting kiln drying

There has been little testing done to date of the mechanical properties of Irish grown alder and most analysis is based on British and other European grown species (Table 12). Alder has a relatively low density (530kg/m³) and a specific gravity of 0.53 (Porter, 2004). With regards to density it is important to note that because of its diffuse porous cell structure the density of alder is not affected by its speed of growth. This is very important as alder in Ireland grows relatively quickly while its density remains unaffected.

Alder is not naturally durable, is prone to attack by the common furniture beetle and will perish if left untreated. In EN350-2 alder is given a durability rating of 5 ('*not durable')* and is noted as being susceptible to *Anobium punctatum* (common furniture beetle) and termites and also highly susceptible to *Hesperophanes cinereus* (longhorn beetle). Interestingly however, it is resistant to decay when fully submerged in water. Traditionally this made it very suitable for use in canal sluice gates and indeed much of 16th century Venice was built using alder piles and stilts (Fraser 2005). Its heartwood and sapwood are very receptive to penetration by preservatives (Xenopoulou 2004) and EN 350-2 rates it '*easy to treat*' indicating that the timber can be pressure treated without difficulty. It has a moderate bending classification and it is common to find checking on the ends of bends during the setting process. It has medium crushing strength and low bending strength and resistance to shock loads (Boddy 2005).

Table 12: Properties of Irish and British Grown Common Alder (Xenopoulou 2004)

Species	Modulus of Rupture	Modulus of Elasticity	Janka Indentation	Compression Parallel to Grain	Impact Strength	Shear Parallel to Grain
	N/mm^2	N/mm^2	N	N/mm^2	N/mm	N/mm
Common Alder (Ireland)	110	12800	-	-	-	-
Common Alder (UK)	80	8800	2900	41.0	0.64	12.0

One of the major limitations to using eucalypts for the production of timber or other wood based products is the difficulty of converting and drying it successfully. Many eucalypts develop internal longitudinal growth stresses that result in end-splitting both at felling stage and also during sawing as evidenced in Figure 29. This can lead to a certain amount of shatter and distortion in sawn wood thus significantly diminishing its yield (McKenzie 2003). In addition eucalypts display varying amounts of cell collapse (predominantly only in the wide early wood bands in cross section) and internal checking once the drying process begins. This collapse leads to a condition referred to as 'crumping' or severe cupping (Figure 30) (Haslett 1988).

Specialised sawing and drying techniques are employed for the successful conversion of eucalyptus. For *E. nitens* Maiden (1992) recommends sawing oversize into slabs which can be re-sawn at a later stage and the use of water spray during prolonged periods of storage in order to limit splitting. Quarter sawn timber carefully dried to 30% moisture content and further steam reconditioning (high humidity treatment at 100°C and 100% humidity) for 2 hours per 25mm thickness is regarded as best practice in New Zealand (Maiden 1992). Although the final drying

Figure 29: Example of rupture in *E. muellerana*

may still lead to the reopening of surface cracks (McKenzie 2003). However, even in quarter sawn flitches which were carefully dried, large number of cracks and collapse were found in *E.nitens* (Haslett 1992). Final kiln drying at temperatures up to 115°C is recommended and prior to removal from the kiln Haslett (1992) suggests a final high humidity treatment in order to reduce drying stress and variation in final moisture content.

A number of studies have been carried out to investigate the way in which the amount of collapse can be reduced or reversed in eucalypts. In New Zealand the wrapping and coating of the timber prior to kiln drying have been employed with some success (pers. comm. Patrick Walsh). A procedure using treatment in a steam chamber followed by a period of cooling and 'stabilising' produced good results in research carried out by Josó António Santos. This study also revealed some recuperation of distortion and a recovery of volume (Santos 2002). There are also positive results for the successful drying of eucalyptus using vacuum and press drying methods (Ressel 2003).

Due to the relatively high extractive content of eucalypts compared to other genera (Hillis 1978), Chafe (1987) investigated the effect of the removal of certain soluble extractives on collapse and volumetric shrinkage on 12 species of eucalypt. Although some correlation appeared to exist the results were not conclusive. Later research was focused on the effects of pre-steaming on *E. regnans* and again small but significant changes were observed on shrinkage and collapse (Chafe 1990). It is also worth noting that there is a considerable variation in the problems encountered during drying among the eucalypts. This is further influenced by the conditions under which the trees have grown. The strength properties of New Zealand and Australian-grown eucalypts are shown in Table 13.

Figure 30: Example of 'crumping' in *E. muellerana*

2.3.3 Working Properties

Alder is readily sawn and has a low cutting resistance. It has a mild blunting effect on tools and responds well to sharp thin cutting edges (www.genetrade.net). Due to its low density tooling must be kept sharp in order to avoid tearing of the grain, particularly for use on timber with non parallel grain patterns. Alder screws and nails satisfactorily although for upholstery frames, birch is preferred for its ability to hold staples. Alder is easy to glue, can be stained readily and polished to a very good finish (Porter 2004).

The main problems encountered in machining *E. nitens* are said to originate from the presence of interlocking grain. This may cause chipping and breakout when planing and turning. Due to the internal checking, and collapse of cells, cracks may appear on the surface. Also due to pronounced movement and after drying in Eucalypts generally, care must be taken to dry the timber carefully before gluing. Machining smaller sections where possible helps to reduce shrinkage and movement. The presence of tannins in the wood can also react with some glue types and may discolour the glue line. Boring, sanding, sawing and screwing are all possible without problems in *E. nitens*. The timber can be stained easily and takes a range of finishes including traditional oils and modern lacquers (Haslett 1988).

Table 13: Strength properties of the group of Ash eucalypts (Haslett 1988)

Species	Modulus of		Modulus of		Compression		Hardness (KN)	
	Green	12% MC	Green	12% MC	Green	12% MC	Green	12% MC
E. deligatensis								
New Zealand[1]	71.0	113.2	10.4	12.4	31.3	57.6	4.1	4.8
Australia[2]	63.0	110.0	11.0	15.0	33.0	60.0	4.0	4.9
E. fastigata								
New Zealand[1]	76.2	120.8	11.2	13.2	35.8	59.6	NA	4.2
Australia[2]	80.0	107.0	14.0	14.0	36.0	65.0	5.7	6.4
E. fraxinoides								
New Zealand	NA	119.0	NA	13.4	NA	59.2	NA	NA
Australia[2]	65.0	139.0	11.0	23.0	35.0	78.0	4.6	5.6
E. obliqua								
New Zealand[1]	72.0	113.7	9.9	14.1	31.9	55.5	4.1	5.2
Australia[2]	75.0	118.0	14.0	15.0	35.0	61.0	5.3	7.1
E. regnans								
New Zealand	NA	119.0	NA	13.4	NA	59.2	NA	6.3
Australia[2]	63.0	110.0	11.0	15.0	33.0	60.0	4.0	4.9
E. sieberi								
New Zealand[1]	65.0	120.6	9.9	14.2	32.4	69.1	4.3	6.3
Australia[2]	61.0	122.0	12.0	17.0	26.0	65.0	3.1	6.5
E. nitens								
New Zealand*	68.1	137.5	8.4	15.6	28.5	68.2	NA	NA
Australia[2]	62.0	99.0	10.0	13.0	31.0	58.0	4.8	5.8

* results from one high density tree only

[1] Bier,H. 1983: The strength properties of small clear specimens of New Zealand-grown timber . New Zealand Forest !

2 Bootle, K.R. 1986: Wood in Australia - Types, Properties and Uses. McGraw-Hill Book Company, London/Toronto/

2.4 Utilisation of alder

Alder has had a very interesting and varied utilization in Ireland. Mac Coitir (2003) makes many references to the '*red and fiery shields*' most likely made from alder and notes its association with blood and war due to its red sap. The Forest Service Information Sheet also lists its traditional uses as shields, wattles and hedging. Samuel Hayes in his book Practical Treatise on Trees (1794) comments that:

> *"Birch and alder of the smallest size will fell for the chairmakers' use; if larger, they are used for cart saddles, soals for pattens, and heels for women's shoes, the demand for which is often very considerable." (Hayes 1794)*

Medicinally alder bark was used to soothe swelling and inflammations of the throat, cure rheumatism suffered by peasants in the Alps and alder leaves were used to ease weary feet (www.controvercial.com, 2006). Young alder branches are easily worked and green branches were used to make whistles and panpipes. Alder was used to make containers to hold milk and the catkins and bark of the alder were said to be used to make a black dye (MacCoitir 2003). Alder was also traditionally used to produce high quality charcoal (due to a low level tar content) and gun powder due to its inherent ability to ignite very readily and easily (Fraser 2005). In parts of Europe it was used for cigar boxes due to its cedar-like appearance. In Ireland and Britain it was the favoured timber for cart wheels, spinning wheels and wooden heels. It was and still is widely used for clog manufacture in Scandinavia. Due to its durability under water it was used for bridges, boat jetties and canal gates and the ancient roman writer Virgil suggested that the first boats may have been made from alder (Fraser 2005).

Figure 31: Common alder for use in clog manufacture

Alder has of course been used for furniture in the past but in recent times has not been in high demand in Ireland for this purpose, perhaps due to a lack of supply. However it is used in kitchen cabinet doors, veneer and plywood production and for turning. Porter (2004) notes its use for broom handles, brush backs and the high demand in Japan for '*gnarled pieces*' for sculpture and carving. In America red alder *Alnus rubra* has more widespread appeal in furniture and wood products and is also used extensively in door manufacture often utilising lower grades and marketed as '*rustic alder knotty doors*' (Anon 2005). In Sweden furniture makers use alder as a substrate for veneer due to its inherent stability. It is also used for the backs and sides of drawers and for cladding of saunas (as alder is not a good conductor of heat) (Palm et al. 2005).

Young alder is suitable for coppicing and, using short rotation cycles, lends itself for fuel production, hardwood pulp and as a source of biomass (Funk 2005). It is not suitable however as a raw material for paper production due to the need for extensive bleaching. Funk (2005) notes that trials by deSouza Goncalves in 1980 in Alabama on six year old *A. glutinosa* produced more than six times as much volume per tree as sycamore of the same age. Alder has also been used for smoking meat and fish in central and northern Europe and on the east coast of America. In fact alder produces relatively high concentrations of active antioxidants during the smoking process which are important both in terms of preservation of foods and for dietary components (Kjallstrand and Petersson 2000). Alder also requires a relatively low temperature for the smoking process and has the added advantage of infusing foods with a natural red tinted dye. In America alder (and cedar) is traditionally used for 'baking planks'. These are boards upon which meat is placed in an oven and gives food a distinct 'smoke-like' flavour during cooking. They can be reused over and over again in ovens or can be used once-off for grilled food.

2.5 Utilisation of eucalyptus

Traditionally the first users of eucalyptus trees were the Aboriginal people of Australia. Burls of *E. camaldulensis* (*Peeal* to the Aboriginals) were used to make containers and medicinally to treat diahorrea while the leaves were used in aromatic steam baths. The inner bark of *E. obliqua (wangarra)* was used to make coarse string for bags and fishing nets. The oil from the leaves of *E. leucoxylon* (Tarrk) provided a treatment for colds and the nectar from its flowers was used for sweet drink. The wood of this species was also used for making weapons and tools (Victoria 2006).

2.5.1 **Pulp**

By 1974 the wood produced from eucalypt forests was mainly smallwood and its uses were predominantly for fuel and pulp (85%), poles and roundwood products (10%) with sawnwood making up the remaining yield (FAO 1981). Many countries around the world use species of eucalypts very successfully for the production of short-fibre (0.6 to 1.4mm) pulp. Australia, Brazil, Portugal and Spain use plantation eucalypts for pulp for their paper industries. However not all species are suitable for this purpose. The denser eucalypts which have relatively thick walled fibres are not recommended as they do not produce strong paper (FAO 1981). Ideally species with thin walls and wide diameters, as well as those with less colour in their cells are the most suitable for this purpose which include amongst others *E. delegatensis, E. globulus, E. grandis, E. regnans* and *E. viminalis*. However Maiden (1992) notes that "*in tear strength, bleaching and optical properties E. nitens pulp compares well with that of other eucalypts*".

2.5.2 **Biomass**

More and more land area is being devoted to biomass production around the world. Biomass produced from high density woods produces wood which has a relatively high calorific value per unit volume. Eucalypts fall into this category and thus have good potential for biomass production. Much of the initial research into the potential of eucalypts was carried out in New Zealand from 1970 onwards. Approximately 150 species have been introduced there, however, only a small number have been considered for production forestry including *E. nitens, E. fastigata, E. muellerana and E. globidea* (McConnochie and Borralho 1998). Studies on biomass equations using short rotation cycles were carried out in New Zealand on *Eucalyptus ovata, E. saligna, E. globulus, E. nitens* and *E. regnans.* (Senelwa 1997) and in Australia *E. nitens* has been examined for both below and above ground growth for biomass (Misra 1997).

In the United Kingdom a number of trials were established in southern counties. Purse and Richardson (2001) have conducted successful trials on eucalypts including *E. nitens* and *E. gunnii* despite some concern expressed over the frost hardiness of eucalypts in general. Bennet and Leslie (2003) however point out that several species including *E. gunii*, *E. niphophila* and *E. debeuzevillei* were suitably frost hardy to survive the winter of 1981/82, one of the most severe in Britain since meteorological records began. They argue that "e*ucalyptus should be considered as an energy crop for lowland Britain given its fast growth, high wood density relative to other biomass genera and the suitability of its wood for small scale heat and power installations and co-firing in electricity generating plants"* (Leslie 2003). Furthermore in milder locations (e.g. those around the coasts) where planting involves short rotations, *E. nitens* is considered the most productive of the eucalypts suitable for growth in Britain (Cundall 2006).

2.5.3 Veneer and Timber Production

Defect-free eucalypts are capable of producing decorative veneers by slicing but have proven difficult for peeling. Flitches are first preheated to approximately 75°C and the slicer bed and knife are kept as dry as possible in order to prevent tannin staining (Haslett 1988). Quarter sawn flitches appear to reduce or eliminate any collapse during drying and both the paler timber and those with dark red and brown shades are those most sought after (FAO 1981). Eucalyptus burr veneers are available from veneer merchants in the UK. Although the difficulties in drying eucalyptus are well documented, the timber is still utilised for a range of specialty uses including furniture, paneling, cabinet making and turnery. In Australia the ash eucalypts are referred to as 'Tasmanian oak' but are not as naturally durable as oak and are therefore not suited to outdoors use unless suitably treated. The treatment of Portuguese grown *E. Globulus* with waterborne CCA preservative for use as fencing posts proved adequate, especially for small and medium diameter specimens, by longitudinal penetration (Nunes and Reimao 1988)

There are a number of products made from eucalyptus already available to us here in Ireland. Lifestyle Furniture Ltd., based in Co. Laois have a range of solid wood and veneered Brazilian eucalyptus furniture with a 'tobacco' finish. This range is being well received at the top end of the furniture market (the fact that eucalyptus is a relatively new material in this part of the world may give it a slight competitive advantage in this respect).

2.5.4 Medicinal

Medicinal uses for eucalyptus are widely recognized in western society and eucalypt derivatives have been used in toothpaste and mouthwashes for many years. Eucalyptus oil, mainly derived from the foliage of *E. globulus*, has a number of medicinal properties including antiseptic qualities and it is believed that the oil of some species have anti-malarial activity (Anon 2004). The oils are very flammable (which makes eucalypt forest fires quite severe) and are used to alleviate asthma congestion, as a wound dressing and in massage oils to treat arthritic joints (Weleda 2006).

2.6 Commercial Potential

While Phillips (2005) has done a general analysis of the economic returns on broadleaves it is hard to rely on the data in light of its sharp rebuttal by Caroline Lewis (Lewis 2006). A case study by Little (2006) entitled *Realising Quality Timber from Ireland's Native Woodlands* is by far the most thorough and thus more reliable analysis found by the author (although it is particular to one individual site and it does assume that proper management is carried out). Little calculated that under a 40 year rotation an approximate return of just below 9% on investment was achievable for the alder stand in question under the Native Woodland Scheme (slightly less under the Afforestation Scheme). This provides credible evidence that the growth of alder in forestry can offer landowners a relatively secure return on their investment. There is of course an assumption that there is sufficient demand for alder timber in this country. Prime quality kiln dried (12% MC) alder retails in Ireland from €1,000 - €1,400 per cubic meter depending upon species, availability and thickness. It was not possible to obtain a price on eucalyptus sawnwood in Ireland.

2.7 Gap in Literature

The research and information identified in this chapter on both alder and eucalyptus has established a number of areas where there exists significant gaps in the available knowledge regarding these species. There has been little testing of Irish grown specimens in terms of mechanical properties. The lack of verifiable data relating to their mechanical properties limits the full utilisation potential of each. While both species have obvious advantages in terms of rotation and yield, a market must be available for their produce if they are to be considered viable in terms of Irish forestry crops. The fact that there is little or no supply of alder presently in Ireland indicates that there is also a knowledge vacuum in terms of market research and, to some extent, the commercial potential of alder. With regards to utilisation, there appears to be only a limited amount of information on the full utilisation potential of alder. This is particularly so in considering the small diameter sections that become available when thinning of plantations takes place. There has also been little or no effort to successfully convert and season Irish grown eucalyptus for timber production.

2.8 Conclusion

The purpose of this chapter has been to review all the information available to date on common alder and eucalyptus. One of the major difficulties with reviewing information on eucalyptus is the fact that there are so many species of eucalypts and thus the amount of source information is vast. The author has chosen to confine this review to a number of species, i.e. *E nitens, E.muellerana* and *E. viminalis*.

Alder has been available for centuries to Irish crafts people and manufacturers. It is now making a significant return in forestry in Ireland. It is this re-emergence that is causing many questions to be asked in relation to its role in forestry and timber production. Experience overseas suggests that alder is an important species and has a range of uses that may not have been considered in Ireland. In addition, the availability of large quantities of alder (both in terms of forest by-products and timber) could trigger the development of new indigenous industries that may use such species as a raw material.

The following chapters examine the experiences in other countries in terms of hardwood utilisation and consider some of the standards which must be adhered to in relation to hardwood production in Ireland. The latter chapters pertain to the testing carried out by the author on these species of eucalyptus and alder.

3 Alder - Overseas Experiences

3.1 Introduction

As part of the author's research into the utilisation potential of common alder he visited Sweden to experience the process chain for alder and other hardwoods. This research also involved a visit to a company in Italy that produces kitchen cabinet doors for the Irish market. These trips were funded under the COFORD Networking and Knowledge Transfer Supporting Initiative. The author's host in Sweden was Träcentrum (The Wood Centre) in Nässjo in the central southern part of the country. Träcentrum's director Susanne Johansson organised a number of excursions for the author which included a field trip to see some mature stands of alder, a visit to a saw mill specialising in alder and to a manufacturer of alder wood chips for the meat and fish smoking industries. The company visited in Italy was one of the leading European manufacturers of kitchen cabinet doors Due Rose s.p.a.

3.2 Sweden

This section gives an insight into the forestry industry and then examines the way in which common alder is grown and processed and the diverse ways in which it is utilised in Sweden.

3.2.1 Forestry in Sweden

Figure 32: Natural habitat of grey alder

Sweden is a country of some 450,000 square kilometres and stretches some 1,600 kilometres from the southern Baltic Sea to north of the Artic Circle. The climate is mild and temperate with annual precipitation varying from 1,500mm in the west to 300mm in the eastern areas. Sweden's forestry covers approximately 55% of the total land area, equivalent to some 23 million hectares. Most of the forests in Sweden form part of the Boreal coniferous belt. Conifers account for 85% of the forested area. The output from the timber industry in the last 20 years has increased by

30% to approximately 85 million cubic meters annually. The average forest holding in Sweden is 27 hectares and between 80 and 90% of forests are certified by either the Forest Stewardship Council (FSC) or Programme for the Endorsement of Forest Certitication (PEFC). PEFC tends to be used by smaller land owners while FSC is the preferred choice of the larger holdings as it has more international recognition.

Wood has historically been Sweden's greatest export industry and has traditionally been focused on the softwood sector. The main coniferous species grown in Sweden are Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*). The broadleaf mix comprises oak, ash, elm, alder (*A. glutinosa* and *A. incana*), birch (*B. pendula*), maple (*Acer platanoides*), willow (*Salix nigra*), aspen (*Populus tremula*), cherry (*Prunus serotina*), mountain ash (*Sorbus aucuparia*) and hornbeam (*Carpinus betulus*). Both Sweden and Norway were the first European countries to promote forest conservation laws in an effort to protect virgin forests, many of which had been exploited due to pressures on land use for agriculture. In the early 1900s a special Forestry Act stated that woodlands in Sweden would be operated in accordance with sustainable management principles (Anon.1).

Despite operating to very high standards of forest management however, in the 1960s and 1970s there was a policy of eradication of hardwoods in an effort to improve the performance of softwood plantations and to rid them of hardwood 'pests'. Biological diversity has now been re-enforced and a number of initiatives have begun to promote the use of Swedish grown hardwoods. Since then the hardwood sector has fought to regain a foothold in the market and has suffered from the damaged public image attributed to broadleaf species.

Figure 33: Naturally regenerated forest

The rate of growth of trees in Sweden is much slower than in Ireland especially for softwoods. Norway spruce typically follows a 60-70 year rotation while for Scots pine it's between 80 and 100 years (sometimes up to 120 years). Hardwoods also tend to take longer to mature - approximately 110 years for oak and 60 for birch and alder. The utilisation of Swedish hardwoods is not unlike the situation in Ireland. While the establishment of hardwood plantations has begun in earnest over the past 30 years, the dependence on imported hardwoods is as high as 85%. These are typically imported from Poland, Germany, USA and the Balkan states. There has been a marketing campaign in Sweden over the last number of years for Swedish people to support home grown agri-food produce, disappointingly, as was pointed out to the author, this was not extended to Swedish grown hardwood timbers (pers. comm. Andreas Graden).

3.2.2 **Grants**

There is a system of grants for the establishment of hardwood plantations which covers 80% of the costs of planting oak, ash, beech, cherry, elm, maple and lime. It does not cover the establishment of birch and alder or any softwood plantations and is in recognition of the extra costs involved in the establishment of broadleaf species. There are no premium payments similar to those available under the Irish afforestation scheme. Swedish forestry policy dictates that the main species chosen for forestry must have a yield that is at least 60% that of Norway spruce. Alder and birch forests in Sweden are predominantly naturally regenerated forests and, as the author discovered, are largely unmanaged which is why they are not covered by the grant system.

3.2.3 **Träcentrum (Wood Centre)**

Träcentrum was established in order to promote the utilisation, and examine the potential, of quality native hardwoods. Träcentrum encompasses a support body for the hardwood sector, a training college for students of furniture, joinery and related skills and a number of enterprise units. Some of the activities the organisation facilitate and co-ordinate are:

- industry related networking opportunities
- the provision of support for improving marketing and product development
- promotion of employee skills development
- developing new products
- investigating improved production methods

Figure 34: Träcentrum Director Susanne Johansson

All activities carried out at Träcentrum are conducted in close cooperation with companies, universities, authorities and other relevant stake holders. On the day of the author's arrival a furniture exhibition was opening to promote the use of native hardwoods at Träcentrum. The promotion of hardwoods is seen as key to the development of an effective hardwood industry. Träcentrum is not a government agency but is supported by industry. The area around Nässjo where it is situated has traditionally been the heart of the furniture industry in Sweden.

3.2.4 **Field Trip to Alder Stands**

Andreas Graden, a forestry consultant and researcher based in Länghem about 35km south of Ulricehman was the author's guide on this field trip. He works at the Rädde Foundation, a forestry research centre, which is a member of the Swedish Rural Economy and Agricultural Society. This society is entirely independent of all commercial and political interests and carries out research relating to farming, fishing, forestry and animal welfare. Rädde is the forestry section of this foundation.

Figure 35: Common alder at Rädde

<u>Site 1 – Rädde</u>

The research centre has a large number of research plots of mixed forestry including alder and birch, Norway spruce and oak as well as pure stands of alder, aspen, poplar, larch and lime. The common alder stand is 14 years (Figure 35). This has been managed well and demonstrates good form. The height is approximately 10 meters and average stem diameter of 10cm. According to Andreas there is little need for tending the alder as the lower branches tend to die off naturally (apart from the outermost stems on the plot). Thinning takes place every 8-10 years with the removal of approximately 30-35% at a time. This encourages the formation of a good canopy and allows for development of the lower stem. The optimum form for alder according to Andreas is to have approximately 50% green canopy and 50% clear stem.

<u>Site 2 – Holmryd</u>

The next plot we visited is more typical of the stands of alder in Sweden. This is a stand that has developed naturally on old pasture land and is approximately 40 years old (Figure 36). The site is located 150 metres above sea level and is predominantly comprised of alder with some birch and lime dispersed amongst it. There has been no thinning or tending. The alder have poor form and have relatively small diameter stems (up to 16cm) with the crown very high on most stems. The stand is a good example of what results when there is no thinning carried out. The fact that there is no support for funding the establishment of alder plantations means that many people neglect plots where alder is growing. One of the main problems associated with this is the lack of management that is carried out resulting in poor stem volumes and low quality form as was witnessed at Holmryd.

Figure 36: Andreas Graden at common alder and birch stand

Site 3 – Slätthult

The final stand visited was the most impressive. The site was approximately 350m above sea level with a stream running through the stand (Figure 37). This stand was 35 years old and thinning had been carried out at two stages. The standards here showed better form, improved crown formation and had larger diameters than the previous stand (up to 26cm). While deer used this area for grazing, there was no evidence of damage to the alder due to browsing. The difference between the two sites was very marked and clearly demonstrated the positive effect of thinning.

Into the hills surrounding Svöde we saw some more alder, this time grey alder (*A. incana*) which is also native to Sweden. Grey alder naturally generates at a higher altitude just below the pines and cluster along the river banks coming down the hills.

Figure 37: Andreas at stand of common alder at Slätthult

3.2.5 Sawmill

The mill the author visited was in Värnamo (about 30km south of Nässjo) and was typical of those in operation in Sweden. The manager Bengt Parsson, is a third generation owner/manager. This mill processes approximately 10,000m^3 of hardwoods annually, employs 6 people and is small in Swedish terms. Approximately 40% of its through-put is alder, the remainder being birch, oak and ash.

The alder is sourced locally (within a 60-100km radius) and is generally sold on to local markets. There are a couple of large companies that specialise in felling timber and Bengt Parsson negotiates a price directly with them. All the alder is at least 18cm in diameter (mostly more than 20cm). Alder generally takes 50 – 60 years to reach this size (assuming its coming from an unmanaged site). Depending upon the grade, the miller will pay between 300 and 600SEK (€31.5 - €63) per m^3 for alder. The measurement is taken with the bark on and is reduced by 0.6% to take account of this.

Surprisingly, this mill doesn't kiln dry timber. Timber that is air dried typically reaches a natural moisture content (MC) between 18 and 20%. Timber for furniture making for indoor use is kiln dried to between 8 and 10% MC.

Figure 38: Common alder awaiting processing at sawmill

The stability of alder does however reduce the need for extended periods of air drying. Alder also goes a deeper red colour when put directly into a kiln after conversion and some manufacturers prefer this. The conversion of the alder is through and through (or plain sawn) and generally left with waney edge. Grading is done by the miller and is specific to each individual mill. Bengt Parsson prefers it this way because he understands his customers' requirements.

3.2.6 Grading Alder

The lowest grades (C) and odd sizes are used for the manufacture of clogs. This is a local industry while the market for clogs is both national and international (mostly for export to the Danish market). The optimum MC for the manufacture of clogs is between 60 and 80%. The higher grades of alder (A and B) are sold to kitchen manufacturers and furniture companies. The selling price for this grade is approximately 4-5,000SEK (€421 – 526) per m3. While the selling prices are relatively low, alder is a very easy timber to process and is very stable once sawn. It also dries relatively quickly and thus is cheaper to transport. These prices are for timber that has only been sawn and not dried so any costs incurred with its handling and storage have been reduced.

Figure 39: Common alder air drying

Interestingly we came across a consignment of birch for an Irish customer. This was low quality birch and was to be used for the construction of frames for soft furnishings. Birch holds a nail and a staple better than alder and so is the preferred choice of furniture manufacturers. This appears to be one of the problems Bengt Parsson faces – trying to find markets for the medium to low quality alder. The demand for smaller logs (thinnings etc.) for firewood is relatively low and while the pulp industry uses alder it requires extensive bleaching due to the hue of the timber.

According to Mr. Parsson the demand for alder has dropped over the past couple of years. This is due in part to a drop in demand from the European markets especially Denmark. This could be either due to a general fall in the demand for alder or due to cheaper alder being available from eastern European markets. There is also the possibility that better quality alder (*Alnus rubra*) is being imported to Europe at a competitive price. Mr. Parsson also believed that alder was a much undervalued timber and felt that its potential was being undermined by imported hardwoods which were very competitively priced and better quality.

3.3 Alder Utilisation in Sweden

Alder has an established reputation in Sweden for use in furniture making and kitchens. During the authors visit to Sweden he visited several exhibitions where furniture made from alder was featured.

3.3.1 Furniture

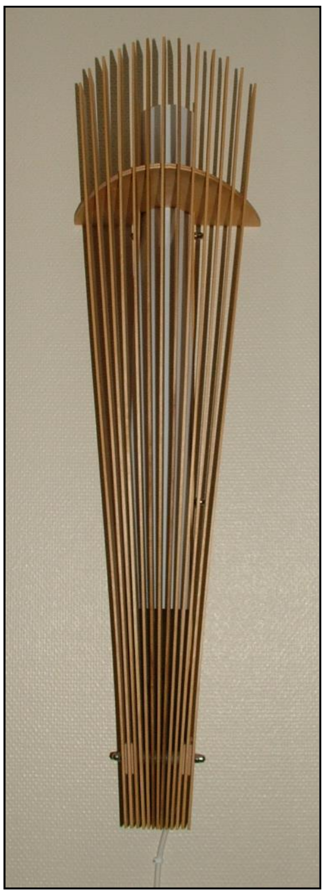


Figure 40: Fan light made from alder

KÄLLEMO, a leading international design house, had a very interesting exhibition of furniture. They have worked with designers such as Kandell, Mats Theselius, Jonas Bohlin and more recently developed a product (rubber chair) for production by Komplot Design which has won several prestigious international design awards. There was an array of materials employed in the furniture on display such as wood (including alder) steel, metal, glass, fabrics and rubber. One cabinet made in alder reveals some of properties that make alder attractive to use. The tall cabinet in Figure 41 has doors that have been treated with a petrol blue stain as alder takes a stain very well.

Figure 41: Tall storage unit with stained alder doors

Another piece on display is a fanned light (Figure 40). This makes use of small sections of alder. It is important to find products that can utilise the smaller sections of alder that will become available from thinning processes.

3.3.2 **Substrate for Veneers**

Figure 42: Alder used in cabinet doors

Due to its stability and relative low cost, alder has traditionally been used as a substrate for veneers. The alder substrate in this instance is usually made up of strips of alder glued together in the form of a type of blockboard. The stability of the alder allows for expensive decorative veneers to be applied to it with minimum amount of movement of the core material.

Bruno Mathsson, a world-renowned Swedish furniture maker and designer, used alder for many of his tables and desktops. Mathsson made no attempt to disguise the alder substrate as with the Mi 901 collapsible table (1935). He also used a birch veneer locally known as 'curly birch'. This species of birch is genetically modified and develops a burr-like grain pattern. They are processed only for veneer due to their high value and mostly exported to Germany (pers. comm. Bengt Ellis).

3.3.3 **Beehives**

Figure 43: Beehive walls with insulation

Lars Nyberg, a wood consultant based in Svöde is in the process of setting up a hardwood mill and kiln operation. He is also designing bee hives that are built by joining together insulated blocks of common alder (Figure 43). The alder is jointed into sections and machined to incorporate a core of polystyrene insulation. The blocks are then simply screwed and glued together to form the hive. This is something which could be quite relevant to the Irish market considering the growth in interest in beekeeping over the past number of years. The only issue would be the non-durability of alder and the type of finish to apply to the hives in order to overcome this.

3.3.4 Clogs

Figure 44: Alder Clogs (Kinsa State Hisorical Society)

Clogs have been a traditional shoe worn in Scandinavia and Holland for centuries. The material traditionally used for clog manufacture is common alder (they are also made from willow or poplar). The clogs are usually made entirely from wood (Figure 44) but may also have wooden soles and leather uppers. Wooden clogs are said to be very good for the wearer's feet and in Holland they have been officially passed as safety work wear. Clogs make good use of the lower grades of timber and smaller logs available from thinning regimes.

3.3.5 Woodchips for Smoking

Smoking fish and meat is popular in Sweden and in the rest of Scandinavia. The author visited a chip production outlet called Töreboda Filis AB situated 30km north of a Svödell. Töreboda Filis are one of the market leaders for the supply of wood chips and sawdust for smoking. Smoke conserves food, giving it a distinct taste and (sometimes) colour. The quality of smoked foods is as dependent upon the quality of the wood chips as it is on the quality of the food itself. Two species are generally used in Scandinavia – alder and beech. Alder is actually the fuel of choice because of its ability to colour the smoked produce quickly and uniformly. In addition, a lower smoking temperature can be used compared to using beech or oak. This reduces the amount of polycyclic hydrocarbons (PAH's), such as benzene, released during the smoking process (Kjallstrand and Petersson 2000).

Töreboda Filis select and sort only choice local alder for their chips. Medium alder logs cost approximately 300SEK per m^3 and are kept on site in log form for at least two summers before it is processed. The company carries about 5,000m^3 of alder logs in the yard all the time. The factory comprises a chipper, an oven and a grading line. Most of the machinery is custom made for the company. After the chipping, the chips are dried to a moisture content of 10%. The chips are then passed over a series of grates that sort them into 3 different sizes

(0-2mm, 2-4mm am 8mm). Finally the chips are bagged in 100 litre bags and sealed. The selling price for a 100 litre bag is 50SEK which would allow you to smoke between 400 and 500kg of food.

Töreboda Filis AB are the main producer of chips for the domestic market, while Denmark is their main export market. They produce somewhere in the region of 70,000 bags of chips annually and apart from the owner the company employs just one other person.

Figure 45: Alder stored in yard

Figure 46: Chipping and grading line

Figure 47: Chip filling station

Figure 48: Final product (size 0-2mm)

3.3.6 Firewood

Figure 49: Grey alder thinnings for fire wood

The method used to rate firewood is based on a standard relative to birch. Birch is given a 100% firewood rating, while oak is 120% and alder is 70%. Alder firewood costs approximately 100SEK (€10.5) per m^3 compared to 250SEK for birch. Chippings and other waste from mills can also be sold to the local councils for use as a source of energy (each town has a combined heat and power plant generating hot water for distribution via the water mains to peoples' homes).

3.4 Due Rose s.p.a. - Italy

In this section the use of alder in the production of kitchen cabinet doors for the Irish market is presented.

3.4.1 Introduction

Due Rose s.p.a. is situated in Pasionne de Pordenone 40 kilometres north-east of the famous city of Venice. Established in 1966, Due Rose produce kitchen cabinet doors and components in both solid and veneered form using a variety of substrates (MDF, chipboard and solid wood) and a large variety of timber species. Over the years the company has adapted its technologies and products to establish itself as one the European leaders in cabinet doors. Their products are sold in both Europe and America and in recent years they have entered the Irish market using Springhill Woodcrafts in Carlow as their Irish distributor. My interest in visiting this company was to examine the current trends in materials and to get a

Figure 50: Federica Contedardo in Due Rose showroom

better understanding of the primary factors affecting the demand for common alder. The production manager Georgio Sut and the purchasing manager’s personal assistant, Federica Contedardo, accompanied the author on a tour of the factory.

Due Rose achieved ISO 9001 in 2000 and the company is in the process of applying for certification. As of March 2006 their purchasing policy stated that only timber certified by FSC would be purchased. This, according to Federica, is being demanded by their customers. Despite the increased costs of certification Due Rose planned to have all their products certified by the end 2006. This is an important factor for Irish suppliers and reflects a wider trend in the wood products industries across Europe.

3.4.2 Production

Due Rose Spa produce approximately 500 units (cabinets) per day. The timber that is ordered is predominantly in component form. This means that it is either planed to its final thickness or left slightly oversize and finished in the factory while being machined for joints (Figure 51). Delivery of the raw materials in this form has significantly reduced the company’s waste but also increased the quality of material arriving on the factory floor because more thorough grading is now happening at source. The specification of grades is a critical factor in the success of the relationships Due Rose has with their suppliers.

Figure 51: Pre-cut alder for cabinet doors

Due Rose use predominantly European timbers. The availability of large stocks of quality timber from eastern European countries has made European timber much more competitive in recent years. Yugoslavian oak, Estonian birch, Romanian lime and Polish alder are typical of the materials used. Veneers to match theses species are also more readily available now which is very important to Due Rose as approximately 60% of their products use veneers to some degree. The company also uses American red alder, Canadian Maple and a variety of tropical hardwoods.

3.4.3 **Irish Market**

The Irish market accounts for approximately 5% of Due Rose's sales, while the UK market accounts for as much as 30%. The Irish market is growing however at a steady rate. Due Rose produce a range of components especially for both the Irish and UK markets in alder. Both European alder (*A. glutinosa*) and American red alder (*A. rubra*) are used in these products. The following are some significant points of interest with regard to the use of alder:

- Sales of alder components have dropped in recent years. This appears to be mainly due to the lack of availability of quality red alder from America. American red alder quality is superior to that of its European equivalent. This has pushed the price of red alder up significantly (up to €900 - €1000 per m^3) and makes it more expensive than top quality European oak (€800 per m^3) and European ash (€600 per m^3). This has resulted in a significant drop in the demand for alder from Due Rose. Approximately 5-6% of Irish orders at the time were for alder products. This has led Due Rose to search for cheaper sources of red alder and has meant that they now buy raw materials from China (this has been imported from the US by Chinese timber merchants and is sold on to the European market). The drop in supply, the increased carriage costs and the extra link in the supply chain have contributed to the increase in the final cost of the red alder.

Figure 52: Common alder door with cherry veneer

- Although European alder is available (approx €500 per m3 from Poland) the quality is poor in comparison to red alder due in part to poor silviculture (pers. comm. Georgio Sut).

- Alder is used in a variety of ways by the company:

1) Solid alder doors with an alder panel are available as a finished component. These are predominantly superior quality red alder. They are often finished with a stain that makes them appear similar to American cherry.

2) A solid alder frame is sometimes mixed with a veneered or solid cherry panel (Figure 54). In this instance the alder is always stained to match the colour of the cherry panel. This is again superior quality alder, but could be common or red alder.

3) Lower quality European alder is also used as a substrate for cherry veneer (Figure 52). Due to the stability of alder it is very suitable as a substrate for veneer (Lime is used also for this purpose). A stain is applied to the finished component to blend the colours of the two materials together. Both alder and lime take a stain very well which facilitates the blending of the colour of the solid wood and the veneer.

3.4.4 **Importance of Quality**

For all the species used in the factory there is an equivalent test board (Figure 53) which demonstrates the acceptable quality standards of the materials used. If there is a doubt regarding any aspect of quality of either a finished good or a component then this board can be referred to. This demonstrates the acceptable colour, grain patterns, natural defects (knots, sap etc.) and sap wood content. For alder the most common defects are small knots and pockets of sap. The marks left by the bark fly in alder are not considered a defect.

Figure 53: Common alder test boards

Despite the wide range of modern styles available, the majority of customers still prefer traditional styles. Shaker doors are of course very popular also. Oak is certainly one of the most popular materials and is the preferred choice by customers in Italy, England and Ireland. Maple and cherry are also popular in Ireland, while in the UK there is a large demand for birch products. Alder is not sought after in Italy.

Figure 54: Common alder frame with solid cherry panel

According to Mr. Sut, Irish customers are relatively fussy with regard to the appearance of the finished product. When Due Rose switched their production of cherry components from American cherry to European cherry there were many complaints initially from Irish customers who preferred the plain or American species. By contrast when it comes to oak both the Irish and the UK customers tend to prefer oak with a bit more character. Small knots are quite acceptable (and even preferred) by Irish and UK customers while the Italians will not accept any knots on oak and want only straight grained oak.

3.5 Conclusion

Sweden has a very well established forestry industry yet it relies heavily on imported hardwoods to cater for the current demand for hardwoods. Alder is put to many uses in Sweden even though it is not held in high regard as a timber product, especially when compared to oak or maple. However, those who use alder, and process it, do so because it is relatively cheap and is easily processed and machined (pers. comm. Susanne Johansson). The main issue with alder in Sweden is its quality, which is poor due to non-management of the alder forests. However the market does support the processing of alder and the diversity of its uses demonstrated the potential of the timber. Interestingly alder is also known as the ‘mahogany’ of the northern hemisphere.

Certainly there are larger economies of scale to be availed of in Sweden in terms of timber extraction and production in comparison to Ireland. Irish foresters must firstly concentrate on the domestic market in order to maximize their potential from local sectors. Local industries and manufacturers would need to be convinced that a continuous supply of quality stock is available if they are to consider using Irish grown alder. However, if good quality timber is available at a competitive price, then alder could be considered for use in the wood products industry here in Ireland.

The visit to Due Rose revealed some interesting facts about the market trends in Ireland. The use of European timbers appears to be increasing as more and more of the Balkan states open up their borders to EU states. Companies are embracing certification which should help to improve the quality of the timber in the market. The open nature of the timber market means that all the emerging east European countries are in direct competition with timber suppliers here in Ireland. The increase in the price of American red alder in recent years (pers. comm. Georgio Sut) has led to a drop in its demand and has created a potential opening for quality European grown common alder. The promotion of alder as a viable alternative to other imported timbers relies on a quality product being offered to the Irish market at a competitive price. The decline in furniture manufacturing in Ireland means that timber producers must take a close look at local industries and manufacturers in order to assess and analyse their requirements.

4 Grading and Standards

4.1 Introduction

One of the barriers preventing the Irish hardwood industry reaching its potential is the lack of standards in the grading of hardwoods. This has led to a lack of consumer confidence in the Irish grown timber market and has been compounded by the fact that the supply of quality hardwoods has all but dissipated. We are currently in the middle of a transition period in terms of the broadleaf resource. As of 2005 Ireland had approximately 48,000ha of broadleaves categorized as young and we have approximately 39,000ha categorized as mature and over-mature (Dunne 2005). This leaves a gap in the age profile of broadleaves (Figure 55) which will lead to a further reduction of supply over the coming years. Furthermore, the quality of the mature and over-mature category of broadleaves is questionable as they have not been managed to any particular silvicultural standards.

The adherence to high standards is crucial to the development of a viable hardwood timber industry. The end user has certain expectations of quality which must be addressed if Irish grown hardwoods are to cater for more than just the craft industry (Xenopoulou 2004). The standards explored and presented in this chapter refer to both standards of forest management but more pertinently to standards of grading and quality as offered to consumers of hardwoods in other countries.

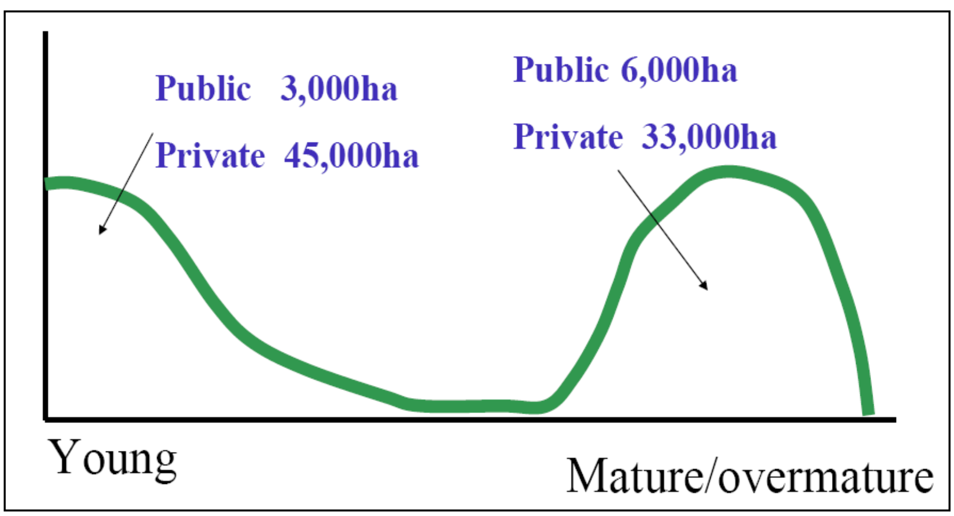


Figure 55: Breakdown of broadleaf stock in Ireland (Dunne 2005)

4.2 Grading Standards

This section outlines the different standards used for grading timber and the way in which structural and non-structural timber is governed by those standards.

4.2.1 **European Standards**

Standards regarding grading of wood for structural purposes are covered in a European context by European Norm (EN) 518:1995 *Structural timber – Grading – Requirements for visual strength grading standards* and EN 519:1995 *Structural timber – Grading – Requirements for machine strength graded timber and grading machines*. There is however a very clear line drawn between softwood and hardwood grading requirements.

4.2.2 **Standards for softwoods**

Standards pertaining to grading softwoods have been well developed over the last number of decades. International Standard (IS) I27 - *Specifications for stress grading softwood timber*, British Standard (BS) 4978 (Section 1 & 2) - *Softwood grades for structural use* and BS 5268 - *Structural use of Timber* all relate to grading of softwoods. These standards require that the timber is marked with the appropriate strength class, grading standard, company identification, the certifying body and design standards where necessary. While EN1313-2 covers the permissible deviations (at a moisture content of 20%) in the cutting and processing of timber for sale.

Softwoods are graded with the presumption that the entire length of the board is to be used as a complete unit. Therefore softwoods for structural use (e.g. roof trusses) are often graded by mechanical means. Hardwoods on the other hand tend to be used in smaller component parts and often in multiple ‘cutting units’ taken from a board and they are also used generally in much more diverse and often non-structural ways (e.g. veneers, panels etc.).

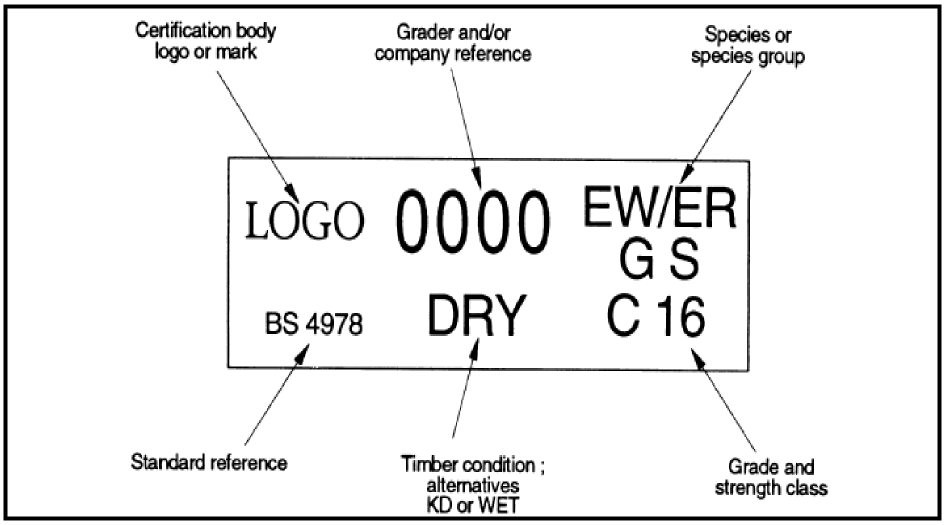


Figure 56: Marking for visual strength graded timber (EN518 1995)

4.2.3 Visual and Appearance Grading of Hardwoods

Hardwoods therefore tend to be graded by ‘visual’ means and also in terms of ‘appearance’. Appearance grading is in recognition of the diverse uses for which hardwoods are required some of which are non-structural. The standards for visual grading of structural hardwoods are governed by EN 518:1995. This standard sets out the requirements for grading classifications of all timber used for load-bearing structural purposes while recognising the “*diversity of grading rules*” in different countries. Its two main principles are for the separation of timber into clearly defined grades and for the rules of grading to be easily understood and capable of implementation (EN518 1995). This standard also sets specific guidelines for the limitations for the geometrical and strength-reducing characteristics of timber including knots, slope of grain, density and rate of growth, distortion, reaction wood and wane (Table 14).

However, concise grading rules have not been developed for hardwoods and, even though EN518 puts guidelines in place for the development of the visual grades for structural hardwoods, a plethora of national grading rules which differ greatly from country to country have evolved throughout Europe. This has led to a certain degree of ambiguity in the market place and consumers are very dependent on how their suppliers interpret and qualify their own grading procedures. From an international trading perspective, this undermines the ability to compare prices of goods and inhibits true competition in the marketplace. In Ireland there are no clear grading rules developed to date.

Table 14: Guidelines of maximum distortion figures as per EN518

Type	Max. permissible distortion corresponding to strength classes C18* and below	Max. permissible distortion corresponding to strength classes aboveC18*
Bow	20	10
Spring	12	8
Twist	2mm / 25mm width	1mm / 25mm width
Cup	No restrictions	No restrictions
* According to EN 338		

4.3 Grading American Hardwoods (USA)

In an attempt to find the best way to deal with the issue of grading it is necessary to look at best international practice. The National Hardwood Lumber Association (NHLA) in America has developed a rigorous set of guidelines for grading hardwoods. These rules are the result of stakeholder consultation with the aim of:

"… *providing the best available products, conservation of timber from which it is cut and in maintaining a lumber language of terms and specifications which permit a ready and understandable meeting of the minds among buyers and sellers wherever and for whatever use hardwoods are required.*" (NHLA 2003) (Pg. 4)

4.3.1 NHLA Rules

The reference to a common 'lumber language' is very important in this respect especially in the EU where so many different languages are spoken. The grading rules first develop a set of 'classes or grades' into which timber can be categorised. These grades are based on specific parameters which are set out in the following table (Table 15). It is important to note that these are the minimum standards required for each grade.

Furthermore the rules stipulate the wane allowances, permissible split sizes, average diameter of knots as well as limitations on warp and cup in each grade. There is also a stipulation that 90% of all widths in every grade shall be full width thus allowing for a small number of boards in a bale to be narrower or shorter boards. This is again based upon the principle of

Table 15: Summary of grading NHLA hardwood grading rules

Grade	Yield	Cutting Units	Minimum Dimension	Comment
FAS (First and Seconds)	1	7' x 3" or 5' x 4"	8' x 6"	Both faces FAS grade
FAS IF (FAS One Face Only)	1	7' x 3" or 5' x 4"	8' x 6"	Opposite face must be no worse than No.1 Common
Selects	1	7' x 3" or 5' x 4"	6' x 4"	Similar to
No.1 Common	1	3' x 3" or 2' x 4"	4' x 3"	Admitting only 5% of 3" boards, shorter length permitted that yield 92-100%
No. 2A & 2B Common	50-67%	2' x 3"	4' x 3"	No.2A requires clear cuttings, 2B requires sound cuttings
No.3A Common	0	2' x 3"	4' x 3"	Must yield 4.5 clear cuttings
N0.3B Common	0	36in2 (min 1.5in wide)	4' x 3"	No limit on number of cuttings

conservation of timber from which it is cut. The procedure with regard to other natural defects such as burls, streaks, stains, checks and sapwood to heartwood ratios are also governed within the rulebook. The document is very detailed and has a glossary of terms which acts to facilitate the user in the 'language of lumber' so that there is no ambiguity. This is supported by a more user friendly guide *The illustrated guide to American hardwood lumber grades* published by the American Hardwood Export council. This booklet is a simplified but thorough summary of the grading rules.

4.3.2 The Benefits of the Grading Process

Grading is carried out by highly trained individuals and on a visual basis. All boards are predominantly square edged and cut to specific lengths and widths so that the end user can specify dimensions to suit a particular job and can be confident in the calculation of yield, thus minimising waste. It is always recognised that wood is a natural product and does not always 'conform' to standards readily and therefore certain allowances are catered for within the rules. That said the benefits of such a concise grading standard are significant such as:

- providing a standard upon which purchasing decisions may be based
- affording the end user greater purchasing power
- enabling end users to compare like with like in terms of species
- promoting conservation and efficient use of lumber
- facilitating the specification of lumber for particular tasks

- enhancing quality of raw material available
- promoting best practice within the industry
- establishing a professional market environment for the trading of timber
- increasing consumer confidence in the product (wood)

4.4 Grading in the UK

Figure 57: Grader at John Boddy Timber Ltd.

In 1996 EN975-1 was published. This was the result of the hardwood industry seeking to develop a common grading document for both oak and beech. ‘Appearance’ grading is a different type of grading compared to that done visually. While visual grading is concerned with structural properties of timber, appearance grading is more to do with the non-structural or aesthetic properties of timber. Despite the publication of EN975-1, its adoption by suppliers was relatively limited in the UK mainly due to its limited application (Davies 2005) . However it did have the effect of instigating a UK Forestry Commission funded publication called ‘Making the Grade’.

4.4.1 *Making the Grade*

Published in 2005 this was the first serious attempt to address the issues of appearance grading of hardwoods in the UK. The guide set out in clear language the grades available, types of defects, measurement systems and special features of hardwoods which may or may not have an impact of the grade including knots, grain, colour etc. Importantly the guide also reocognised that the precise grading of hardwoods in the UK (and Ireland for that matter) would be impracticable and therefore allowed some form of individualisation of the application of grading rules within.

Examples of what to expect from each grade are clearly illustrated in this publication which removes much uncertainty from the buyer-seller transaction. Measurement in terms of quantifying volumes for sales purposes is also covered in this guide (based upon the now withdrawn BS 5450:1997– *Sizes of Hardwoods and Methods of Measurement* with clear illustrations and examples of how waney-edged boards are treated. The guide also contains a very good glossary of terms.

Making the grade is a very good discussion paper and follows the format of a booklet in the UK published by one of the UK’s more established international hardwood timber companies – John Boddy Timber Ltd. The customer guide published and updated periodically by this company is a very thorough guide to grading - and more importantly specifying - timber in the UK (Boddy 2005). The important aspect of both of these publications is that they give the buyer a clear and unambiguous document upon to which base purchasing decisions. This, in the long term, is essential to the survival and success of any market environment. While this could prove to be adaptable to the situation in Ireland it may be necessary to consider eliminating the use of terms such as ‘hoppus foot’ and using just a single measurement unit (i.e. cubic meters as opposed to cubic feet) as this makes it more compatible with mainland Europe and the system of softwood measurement and pricing.

4.5 Grading in Ireland

This section examines the grading rules and guidelines existing in Ireland and the problems associated with them.

4.5.1 Grading rules

Hardwood grading rules in Ireland are very disparate and have evolved from a number of different origins. Many mills grade their timber but more often than not these grading rules are ‘mill-based’ and will vary widely across the country. This in many ways reflects the quality of Irish-grown hardwoods available to processors. Generally, Irish grown hardwoods are available sporadically with supply and lead times often unpredictable. Quality is also extremely variable and reflects the unmanaged environment from which much hardwood is extracted in Ireland. Many small mills do not even attempt to grade and instead allow customers to select boards or bales that suit their requirements.

Figure 58: Typical problems of quality in over-mature species

A number of organisations have developed some formal customer-focused guidelines to grading and specifying. Dundrum Sawmills (owned by Coillte) in Tipperary is the largest hardwood mill in Ireland and they have created grades for some of the more popular species. Minimum lengths and widths are specified but terms such as ‘knots’, ‘splitting’, ‘prime’, ‘rustic’ are used extensively in describing appearance grades without any definitions or quantifications which enable customers to know exactly what they are ordering. Also the grading is very much species-specific which means that some species have more grades than others. While a lack of clear grading rules makes it difficult to trade competitively with imported hardwoods, the obvious lack of quality hardwoods makes the task even more difficult.

In recent years COFORD have attempted to address the deficiencies of the hardwoods market with their publication ‘*Hardwood Matters*’. This was a welcome approach to improve growers’ confidence and knowledge, increase the volume of hardwoods reaching the market and create links between growers, processors and service providers(COFORD 2005). Within this publication grading guides originally used within the Scottish hardwoods industry are adapted as a ‘guide to grading’ (Table 16). This has a positive impact in that it creates awareness among growers that the end use and ultimate market price is very dependant upon the quality of timber that they produce. However, whilst grading descriptors are necessary and welcome, this is a basic level of grading. The danger here is that private growers producing hardwoods may lack an understanding of the quality issues that impact on the value of their market produce. This also impacts negatively on consumer confidence in the product.

Table 16: COFORD's Guide to grading hardwoods (COFORD 2005)

Guide to Grading Hardwood		
First grade lengths of		
Oak, ash, sycamore, elm, cherry, yew, sweet chestnut	Are regarded as either	Veneer butts or planking butts
Oak and elm	Further graded into	Beam logs
Oak	Further graded into	Fencing quality
Cleak white beech	graded for	Furniture (mainly chair
Second lengths or poorer grades in		
Ash, sycamore, beech, lime, Norway maple	Used for: (also termed 2nd quality planking)	Upholstery Grade planking
All species noted above, which are of poor from and quality,and do not fall into the above grades are regarded as		Chockwood (or pitwood or mining timber)

4.6 Silviculture and Management Standards

While the rebuilding of Irish stocks of broadleaves continues the highest standards of management and production must be applied in order to compete both nationally and internationally. At the moment we are highly dependent upon foreign imports of hardwoods. Therefore it is against these imports that our hardwoods will be judged and if they are of lesser quality then either the market will not support this product or downward pressure will be exerted on the selling price to reflect its value. This is so for all stages of the product life cycle, i.e. from silviculture and thinning regimes to the finishing and disposal of wood based products.

4.6.1 **Forest Certification**

ISO14000 and the Code of Best Forest Practice are very much in harmony with forest certification policies. The principles of Sustainable Forest Management (SFM) are enshrined in these documents and forest certification has now become synonymous with sustainability.

Originally set up in order to promote and assist the survival of the rainforests and other tropical forests, certification is now a barometer of an organisation's commitment to sustainable forestry management principles. SFM can also be considered an important branding tool for all foresters and manufacturers in the current 'green' or 'eco' climate. Despite some degree of dissent amongst stakeholders, Forest Stewardship Council (FSC) is still the most widely recognized and internationally accepted certification scheme. This seems particularly so in Great Britain and Ireland. The profile of FSC in Ireland has risen in recent years (not always in a positive light) as a result of Coillte having received FSC certification. The fact that Medite Europe (manufacturers of medium density fibreboard) and other users of Coillte's forest products have also attained certification has contributed to this increased awareness and this reflects a wider trend across Europe to move to certified products.

Sustainability is also crucial in the future development of Irish forestry policy. This should by no means be considered a burden for Irish foresters. Perhaps the one area of concern is the cost of implementing high management standards such as ISO14000 and FSC certification. Considering that the average size of plantations is relatively small in this country (approx 9 hectares), we don't tend to achieve the economies of scale required to make implementation attractive or even practicable. However recent developments in group schemes may offer a viable way forward. In 2005 in Tipperary the first private sector group forest certification scheme (totaling approximately 360ha) attained FSC certification. This could lead to significant savings not just in terms of management costs but also in terms of thinning, extraction, and other production costs. Group certification schemes have seen growth in Ireland over the last number of years and access to FSC schemes has also been facilitated in this regard.

It is imperative that the benefits of forest certification are realised. More and more products on the market now carry certification logos and customers are becoming more and more aware of the impacts of manufacturing on the environment. This governs not only the implementation and compliance with environmental legislation, but the realisation of the benefits of value-added products. FSC principles demand consultation with local stakeholders, independent monitoring and most importantly a chain of custody allowing consumers to track a product from forest to shelf. Certification not only gives products and materials international recognition, but it allows for their entry into markets many of which now demand proof of sustainability. This branding of products opens up many markets with the added advantage of improved prices for timber, improvements to standards of management and enhanced corporate responsibility. This is also a form of product branding which may lead to other benefits such as improved quality, customer loyalty and market stability.

Figure 59: Bale of FSC certified Tulipwood

4.6.2 The Code of Best Forest Practice - Ireland

The Forest Service's publication - *Code of Best Forest Practice – Ireland* - encompasses all aspects of forestry, focusing on several key areas such as sustainable forest management (SFM) and compliance with all EU and Irish legislation. Other areas covered by this publication include:

- nursery practices
- species selection
- control of pests and diseases
- forest management and impacts (Forest 2000).

4.6.3 ISO14000

ISO14000 is an important standard also to consider. When implemented, this suite of standards help to ensure consistency in environmental management practice, the harmonisation of national environmental standards within an international framework, simplification of registrations and labeling and the implementation of guidelines for environmental management excellence. The main areas of IS14000 are:

- commitment and policy development,
- policy implementation,
- setting of objectives and reaching targets,
- performance evaluation and environmental auditing.

ISO 14000 is a standard of continuous improvement and in this respect is followed by a ‘review and improvement’ period which can contribute to continued positive development for the organisation involved. This can also facilitate the implementation of other standards as well as desired certification schemes for sustainable forest management.

4.6.4 **Alder Working Group**

The establishment of the Alder Working Group in 2004 involving amongst others representatives from COFORD, Teagasc, Coillte, the Forest Service and forestry consultants is a key development to the challenges that lie ahead. The remit of this working group according to John Fennessey of COFORD is:

“*to address the current supply and demand for seed and plants of the species and to develop suitable seed sources to meet projected increase in future demand on a sustainable basis*”(COFORD 2005)

Common alder has established itself as the third most planted tree in Ireland in recent years (ash and oak are the most common hardwoods planted). This increase in planting has happened commensurate with an increase in broadleaf afforestation targets and the establishment of more stringent biodiversity guidelines by the Forest Service. Whilst the ease of establishment of alder to many varied sites is unquestionable, issues such a seed provenance and supply, threats from disease and silvicultural guidelines must be addressed in order to produce the best quality of timber possible and to ensure the highest return on investments.

The Alder Working Group (of which the author is a member) has led to the establishment of a survey of alder sites in order to establish plus-trees for the development of a future seed orchard for native common alder (Figure 60). This survey has identified a number of mature alder stands which demonstrate the potential of alder on suitable sites and has also identified a number of very successful young plantations (10 years old). Since 2004, the group has identified seed sources which have added to the National Catalogue of Seed Stands (COFORD 2007). Through an alder breeding programme, co-ordinated by Dr. Elaine O'Connor of Teagasc, plus trees have been successfully grafted (Figure 61) and are to be planted as an alder clone bank. More plus-trees are being identified with the objective of eventually having more than 200 plus-trees forming a breeding population on a variety of sites around Ireland. Another phase of this research involves the establishment of plants grown from seeds of these trees and planting them out in one-parent progeny trials (COFORD 2007).

It is also recognised that much alder, to date, has been planted as an edge species or used as a fill for 'wet pockets' in sites that could not support any other species. As with all hardwoods, awareness of end uses and utilisation potential are vital for the establishment of a market for alder and the work of both these studies will be critical to the success of alder in the future.

4.7 Conclusion

Adherence to standards needs to be translated at the very early stages of hardwood planting with regard to management regimes and thinning and tending in order to be constantly striving for the highest standards achievable. Concise and consistent grading rules will assist in producing hardwood that can compete on the international stage. The development or adoption of a particular grading system is a crucial factor in determining the success of the hardwood sector of the Irish forestry industry. The awareness of grades and quality amongst forest owners, as well s the level of forest management, will ultimately dictate the end value of their produce. This information must be disseminated by all those in the supply and process chain for the benefit of all stakeholders. A lack of understanding of the requirements of the end user of forest products will have a devastating impact on consumer confidence of forest produce in Ireland.

Figure 60: 'Plus' trees identified in Killegar (Dr. Elaine O'Connor 2006)

Figure 61: Grafting of 'plus' tree root stock onto alder stem (Dr. Elaine O'Connor 2006)

5 Testing and Analysis

5.1 Introduction

This chapter outlines the tests carried out on alder and eucalyptus samples explained in Chapter 1. It explains in detail the type of tests, the equipment and jigs used, the sample sizes and the results sought for each test.

5.2 Tests

The tests chosen are those that are relevant to the uses of these materials for furniture, flooring, wooden handles, sports goods and other related applications as per BS373:1957.

5.2.1 **Sample Creation**

All the samples were randomly selected from the available material and machined according to the sizes specified in BS373. The number of samples for each test was restricted to 20 which allowed for nineteen degrees of freedom in the results and, assuming that the data is accurate, would provide results which could be considered adequately robust. In addition, this number was constrained by several other factors such as time, resources of raw material and funding available.

Each selected board and sample were then labelled appropriately to allow traceability from the board to the test specimen (Figures 62-63). They were also checked for defects and grain direction. This was particularly important in the case of the Eucalyptus as there was extensive cell collapse due to the enforced drying in the kiln. All samples tested were clear and straight grained and free of knots, cross grain, splits and checks as recommended in BS373.

Figure 62: Preparation of E. muellerana samples

Figure 63: Preparation of common alder samples

5.2.2 Test Site and Conditions

All testing was carried out in GMIT Letterfrack and in accordance with specifications of the standards BS373:1957 and ASTM D143. The tests were carried out on an Instron 3367 testing machine. The test parameters were inputted for each test including

- the direction of load
- specimen size
- specimen label
- cross-head rate of decent
- calculations required (e.g. load on specimen at maximum load)
- number of data points to be recorded during each test
- the limit settings (load limit of load cell),
- special limits for the test (e.g. travel distance of cross-head)

The temperature of the room and the relative humidity levels were also recorded during the test phase. The samples used for the compression test were tested for moisture content immediately after testing was carried out. The recording interval of each test was determined (i.e. how many points required to be recorded over the life of the test) and the Instron software recorded and graphed the relevant data. The data from the experiments was then exported from the Instron software into Microsoft Excel for further analysis and calculations.

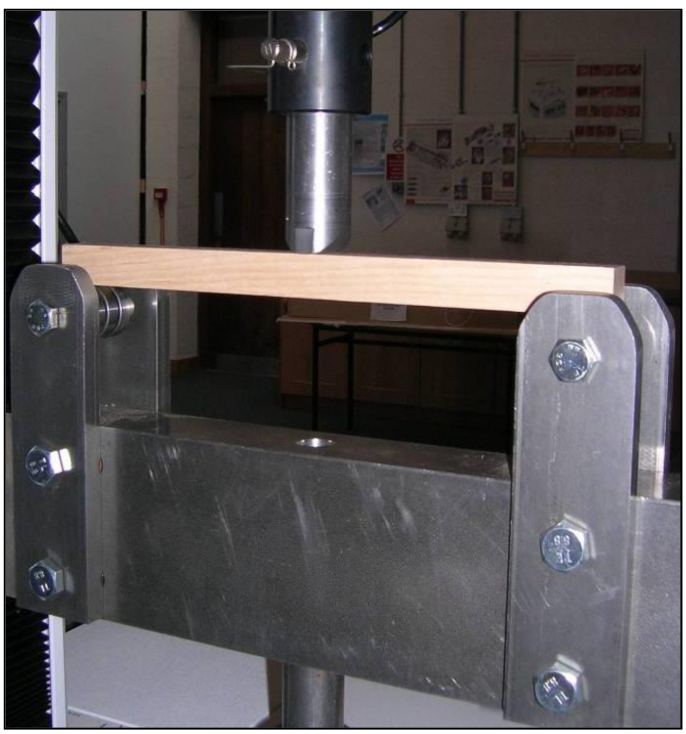


Figure 64: Jig for Static Bending Test

5.2.3 Static Bending test

According to BS373 this test requires a load to be applied to the centre of a sample, dimensioned 20 x 20 x 300mm, suspended between two points of support 280mm apart. The supports must enable the sample to follow the bending action without restraining its movement in any way (Figure 64). The loading head must have a radius of 30mm and be applied at 6.6mm/min. The test is run with the load head positioned approximately 0.5mmm above the midpoint of the sample and such that the load is applied parallel to the growth rings. The test is run until the sample fails, at which time it is stopped. The data recorded for this test is the maximum load applied, the deflection of the specimen and the load at limit of proportionality i.e. that point in the stress-strain diagram at which the curve deviates from the straight line (BS373)). The data is used to calculate, amongst others, the modulus of elasticity (MOE) and the modulus of rupture (MOR) for the species and both modulus tests are measured in netwons per millimetre squared (N/mm2).

The MOE (also referred to as 'Young's Modulus') is a measure of a timber's stiffness or resistance to bending. This value is very useful in calculating the deflection of a beam under a certain load. The MOR is the maximum bending strength of the specimen tested which is another measure of the wood's resistance to bending.

5.2.4 Janka Indentation Test

For this test the load required to force a hemispherical indenting tool of 11.28mm diameter to a depth of 5.65mm into the test piece is recorded (Figure 65). As per FPRB50 the samples used for this test were those that had already been used to conduct the static bending test. Care must be taken to avoid any defects such as cracks on the test pieces as a result of the previous test and the test piece may be supported so at to avoid splitting. The indentation is made on both the radial and tangential surfaces of the test pieces. The test is run until the indentation tool descends to 5.65mm and the maximum load applied is recorded. The average load applied is then calculated with the results expressed in newtons force (N).

Figure 65: Jig required for Janka Indentation Test

5.2.5 Cleavage test

Figure 66: Jig Required for Cleavage Test

This test requires that a test piece of the 'Monnin' type is used (Figure 67). This also requires a specialised jig to fit the test piece as illustrated in Figure 66. The load is then applied at a cross head speed of 2.54mm/min. This test is carried out separately for both radial and tangential surfaces for the species. The test is run until the piece fails and the maximum load applied is recorded. This is then used to calculate the strength per millimetre of width to resist splitting for the species which is expressed as force per unit width. This is calculated by dividing the maximum force recorded in newtons by the width of the specimen (N/mm width).

Figure 67: Monin-type test specimen

5.2.6 Compression Parallel to the Grain

Compression tests require that an even load be applied over the entire cross-section of a sample, dimensioned 60 x 20 x 20mm, which is placed vertically in the test jig (Figure 68). The load is lowered at a constant rate of 0.635mm per minute and the maximum load applied before failure is recorded. It is important that the sample ends are smooth and parallel and that the test plates are also parallel. It is also critical that the load is applied evenly across the cross-section. The resulting property is the maximum compression strength parallel to the grain and is attained by dividing the maximum load by the cross-sectional area of the sample (N/mm^2). The test is run until the load limit or the distance limit (set at 75% of the sample height) is surpassed.

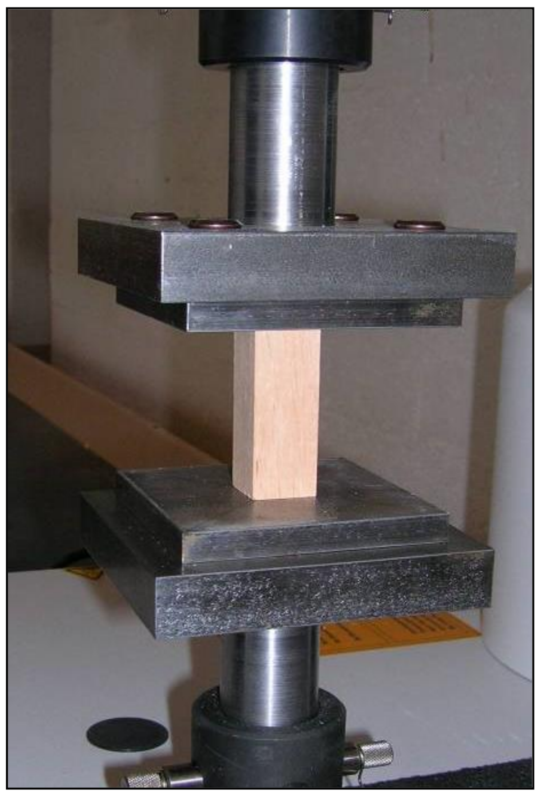


Figure 68: Jig Required for Compression Test

5.2.7 Moisture Content (MC) Determination

In accordance with BS373 a sample of the test pieces are required to have their moisture content calculated by the oven-dry method. This is done by initially weighing the pieces and then putting them into a preheated aerated oven set at 103 +/- 2^{o}C. At regular intervals the test pieces are weighed until there is no reduction in their weight (at which point they are deemed to have a 0% MC). The moisture content is calculated as a percentage of the dry weight of the wood using the following formula:

$$MC = \frac{W_1 - W_2}{W_2} X100$$

where W_1 is the original weight of the sample

and W_2 is the oven-dry weight

5.2.8 Density Determination

Density is a measure of the weight of the wood per unit volume and provides the user with a general indication of the strength of the wood. Woods with a high density shrink and swell more that those with low densities and generally present greater difficulties during seasoning. It is also used as a gauge to predict the hardness and machining properties of a species of timber. To determine the density first the volume and weight of each specimen is measured. In practice this is generally done either on oven-dried wood or on wood at 12% MC. The weight is then divided by the volume of the specimen to give its density expressed in kilograms per metre cubed (kg/m^3) (Desch 1996). This test was carried out using the relevant data from the compression test. As the weight of each specimen was recorded in the moisture content test, the data for their original weight along with their volume can be used to calculate its density. The results were recorded for each specimen, entered into an excel spreadsheet and the mean for each species calculated.

5.2.9 Specific Gravity Determination

The specific gravity calculations are based on data retrieved from the moisture content determination experiment. The weight at test and the oven dry weight are recorded and are divided by the volume at test in each case. These calculations yield the specific gravity and the nominal specific gravity respectively for the species.

5.2.10 **Microscopic Analysis**

The author carried out microscopic analysis of both *Alnus glutinosa and Eucalyptus muellerana*. Three samples of each species measuring 10 x 10x 20mm were prepared to enable a radial, tangential and cross sectional slide sample to be produced. The test pieces were first put in a solution of 80:20 water and ethanol. After a number of weeks the pieces were mounted on a Sledge microtome and, with the angle of the blade set to 15^{o}, slide samples of approximately 0.01mm were prepared (Figure 69).

Figure 69: Samples cut on microtome

Figure 70: Samples in solution of ethanol and dye

These samples were first put into an aqueous solution of saffron for 10 minutes. Then they were washed with water after which they underwent a four stage dewatering process using ethanol (10 minutes in each ethanol bath) (Figure 70). The samples were then transferred onto a slid upon which one drop of montant was applied. The cover glass was laid on top and the slide was placed in an oven to cure at 50^{o}C for two days. The excess montant was then washed off with ethanol and the slides were labelled.

5.2.11 **Panel products**

A range of panels were created using alder and tested in order to ascertain their stability in service. These types of panel products are in use in other countries and demonstrate the potential for alder for use in panel construction as well as for use as a substrate for more expensive veneers. The panels tested by the author included a multi-ply board, a block board and a ‘laminboard’. The controls used for these tests were samples of high grade birch plywood (which is constructed of 1.5mm veneers of birch throughout) and standard furniture grade plywood.

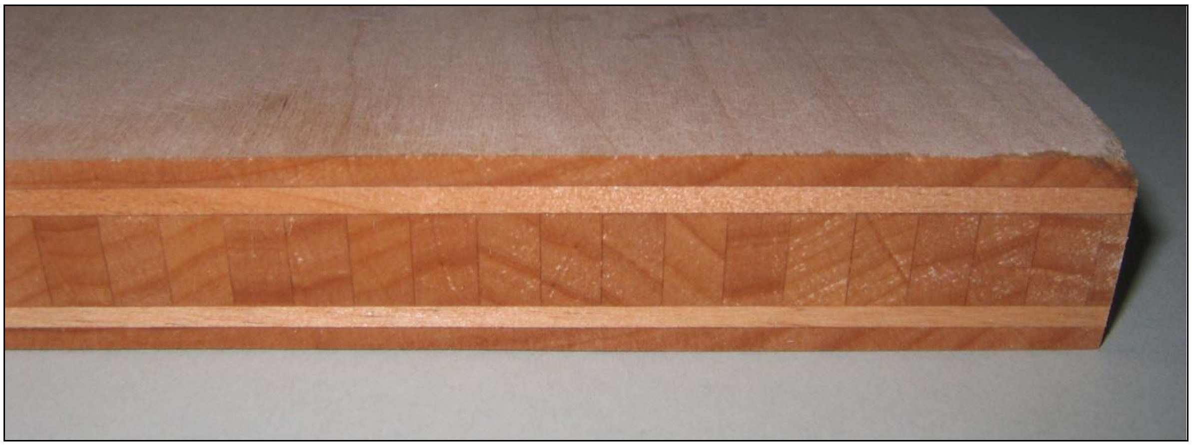


Figure 71: Laminboard sample

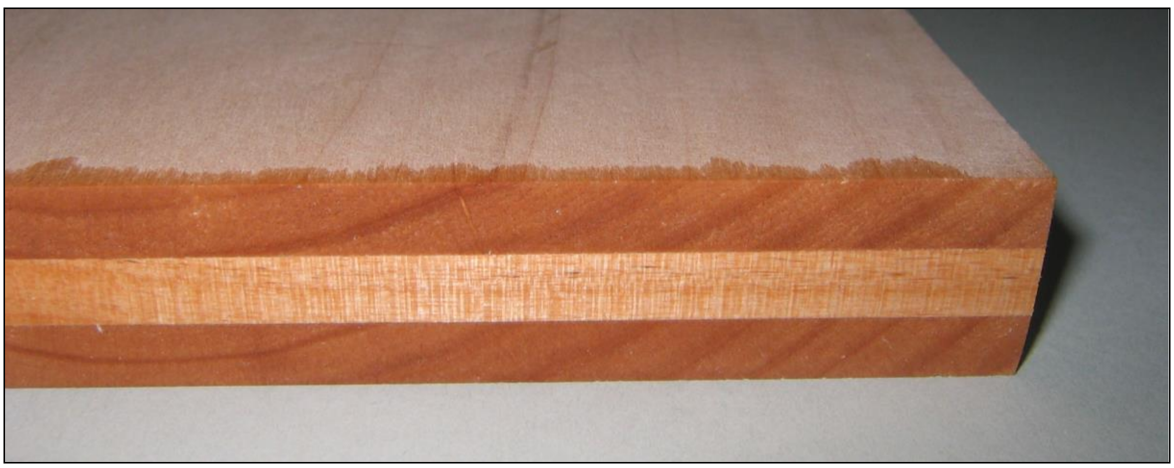


Figure 72: Multi-ply sample

Figure 73: Blockboard sample

The laminboard is constructed using 10 x 5mm sections glued to each other on the longest face (Figure 71). These are then covered with 2 layers of 3mm constructional alder veneer laid with alternate grain direction. The blockboard is constructed in a similar fashion except that the core comprises 25 x 10mm sections glued on the shortest face (Figure 73). The multi-ply is based upon standard plywood construction and uses three layers of 7mm alder layered upon each other in alternate grain direction (Figure 72).

The stability tests were carried out using a test chamber. The temperature in the chamber was kept constant and the relative humidity was reduced using the dehumidifier and increased using a salt and water solution. According to BS3718 - *Specification for Laboratory Humidity Ovens (non- injection type)* table salt (sodium chloride) in controlled conditions achieves a relative humidity of approx 75% at 20ºC and potassium chloride will achieve a relative humidity of approx 85% at 20ºC. BS3718 recommends the use of low salt as it contains more potassium then normal salt therefore should achieve a higher relative humidity. A layer of salt of approx 3mm deep was placed on a tray and damped with water to create a “slurry” as per BS3718 and placed at the bottom of the chamber. The condition of the boards, temperature and humidity levels were recorded prior to the tests being carried out. The boards were left in the chamber for just under two weeks to allow the conditions of the chamber to take effect.

The relative humidity was decreased to 30% and increased to 70% to reflect the typical conditions for house interiors and thus the service environment for such products. New board were placed in the chamber at the beginning of each test. The effects of the changing humidity were recorded on each product.

Figure 74: 'Slurry' of salt and water solution

6 Presentation of Results

6.1 Introduction

This chapter presents the findings of the tests carried out by the author as described in the previous chapter. The data collected were exported to Microsoft Excel and tested using the formulae in BS373 (Appendix 3). The results are related to tests carried out on small clear samples of Irish grown *Alnus glutinosa* and *Eucalyptus muellerana*. In order to evaluate the results relative to other woods, comparative values are given for test data available from EN338:2003 for other hardwoods commonly used and specified in Ireland.

Where there are blanks in the following tables, data were not available for the properties of these species.

6.1.1 Static Bending

This test provides data for calculating the MOE and the MOR for the species. Table 17 shows the test results for both species. From this table it is apparent that common alder has a moderate MOR and a low MOE value (82 and 8708N/mm^2 respectively) and thus has a moderate resistance to bending and low bending strength. In comparison to red alder the results are the opposite with red alder demonstrating a low MOR and moderate MOE. This would imply that common alder would be slightly better at holding loads relative to red alder. It could therefore act as a potential alternative to red alder in any load bearing applications. The results of this test mean common alder would be suitable for non-structural joinery and any type of furniture requiring moderate load resistance such as tables and other general furniture applications, kitchens cabinet doors and some general purpose joinery.

Table 17 also displays the results for the *E. Muellerana* samples. In contrast to the alder, it can be seen that this eucalyptus has a very high MOR and MOE value (152 and 16618N//mm^2 respectively). This indicates that that it is very resistant to any bending thus making it ideal as a structural wood for items like floor joists, glue-lams, rafters, stair strings, shelving and rails on tables and chairs.

Table 17: MOR and MOE Test Results for Alder and Eucalyptus

Species	MOR (N/mm2)	Species	MOE (N/mm2)
Eucalyptus muellerana	**152**	***Eucalyptus muellerana***	**16618**
Oak (Irish)	128	Oak (Irish)	14800
Birch (UK)	123	Birch (UK)	13300
Red Oak (UK)	123	Beech (UK)	12600
Beech (UK)	118	Ash (Irish)	12600
Ash (UK)	116	Red Oak (UK)	12500
Beech (Irish)	116	Ash (UK)	11900
Ash (Irish)	114	Beech (Irish)	11700
Walnut (American/Black)	110	Walnut (American/Black)	11600
Cherry (UK)	110	Birch (Irish)	11200
Wych Elm (UK)	105	Wych Elm (UK)	10600
Walnut (European)	100	Walnut (European)	10500
Sycamore (Irish)	99	Cherry (UK)	10200
Sycamore (UK)	99	European Oak (UK)	10100
European Oak (UK)	97	Red alder (U.S.)	9500
Common alder (Irish)	**82**	Sycamore (Irish)	9400
Common alder (UK)	80	Sycamore (UK)	9400
Spanish Chestnut (UK)	79	Spanish Chestnut (Irish)	9400
Birch (Irish)	78	Common alder (UK)	8800
Spanish Chestnut (Irish)	72	**Common alder (Irish)**	**8708**
Poplar (UK)	72	Poplar (UK)	8600
Red alder (U.S.)	68	Spanish Chestnut (UK)	8200
Elm (UK)	68	Elm (UK)	7000

6.1.2 **Janka Indentation Test**

The value determined from this test indicates the wood's resistance to indentation or its 'hardness'. This property is especially important for wood used in the manufacture of flooring boards, sports equipment, wooden mallets and bearing blocks. From Table 18 it can be seen that the eucalyptus has a hardness value of 6412N which is very high and similar in value to beech. This could also lend itself to use in chopping boards, bread boards and other kitchen utensils but should not be considered until further investigation is carried out.

On the other hand common alder has a low hardness value (slightly lower than that of red alder and also in this instance English-grown common alder). This result is important when considering common alder for applications that may involve heavy wear and tear or contact with other materials.

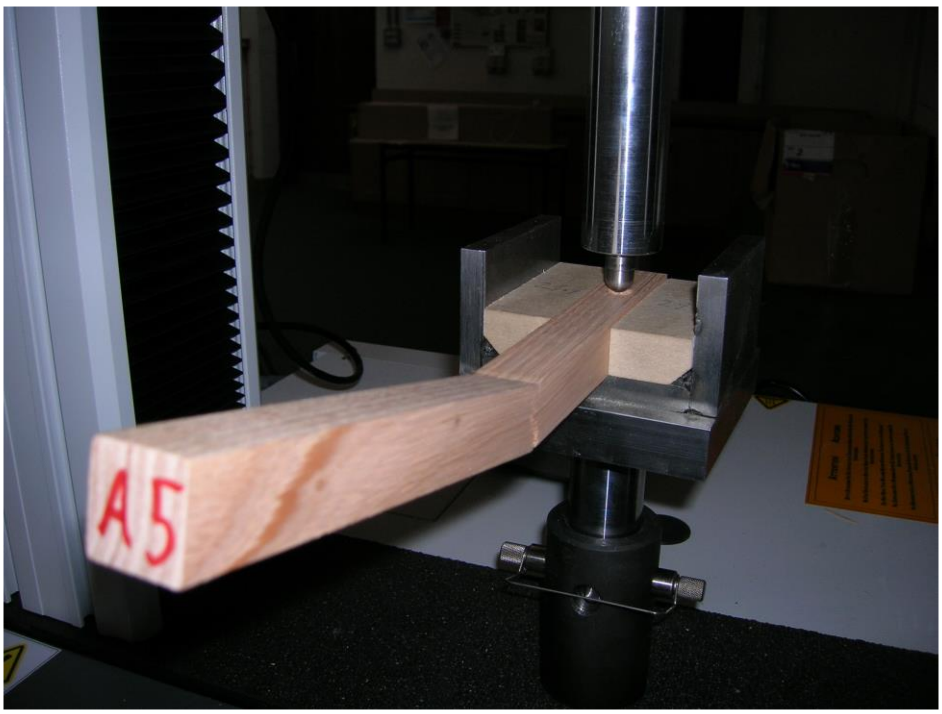


Figure 75: Eucalyptus sample undergoing hardness test
(Specimens previously used for static bending tests)

Table 18: Hardness Test Results for Alder and Eucalyptus

Species	Hardness (N)
Red Oak (UK)	7340
Eucalyptus muellerana	**6412**
Beech (UK)	6410
Ash (UK)	6140
Cherry (UK)	5780
Birch (UK)	5470
European Oak (UK)	5470
Sycamore (Irish)	4850
Sycamore (UK)	4850
Walnut (European)	4750
Wych Elm (UK)	4490
Elm (UK)	3650
Spanish Chestnut (UK)	3070
Common alder (UK)	2940
Walnut (American/Black)	2900
Red alder (U.S.)	2600
Poplar (UK)	2360
Common alder	**2277**
Ash (Irish)	-
Beech (Irish)	-
Birch (Irish)	-
Oak (Irish)	-
Spanish Chestnut (Irish)	-

6.1.3 Cleavage Test

The resultant values determined in this test are the resistance of the wood to cleavage in both the tangential and radial surfaces. Once again, as can be seen from Table 19, *E. muellerana* has a very high value of 23.93N/mm. Thus it is very resistant to cleaving which indicates very good mechanical properties such as nailing, screwing, bolting etc. and potential for use in general and structural joinery.

Figure 76: Cleavage test specimens

Common alder on the other hand is found to have relatively low cleavage strength of 11.68N/mm. This indicates that utilisation involving nailing or bolting would not be very suited to it as cleavage stresses would be created around the bolt and nail holes.

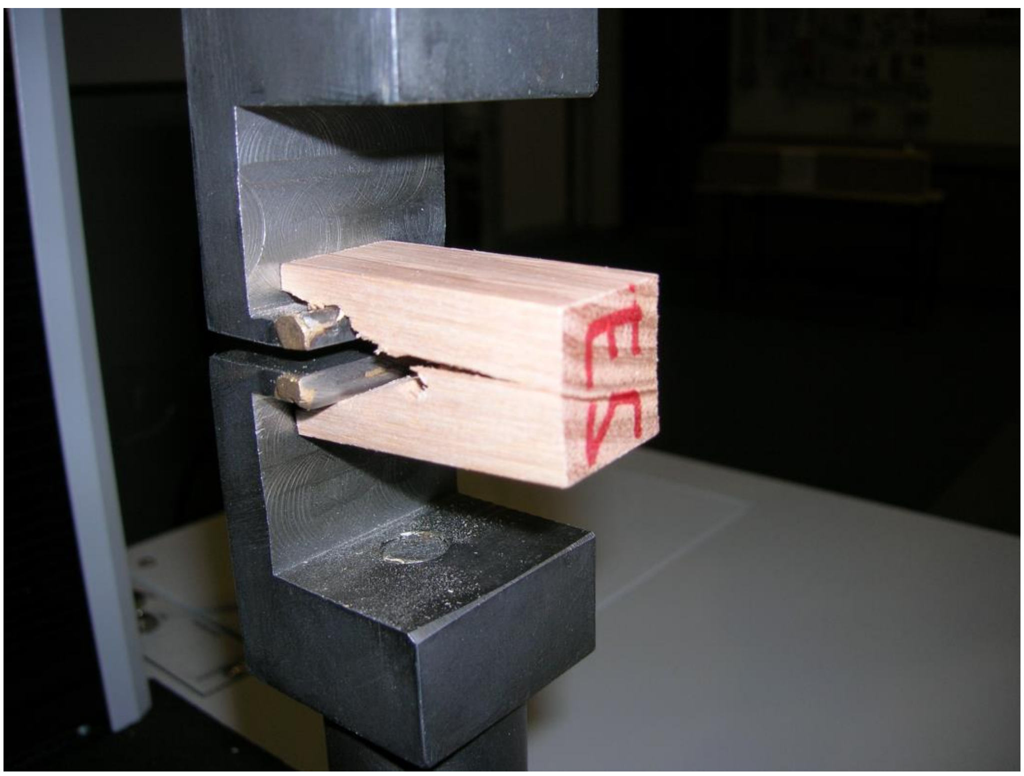


Figure 77: Eucalyptus sample undergoing cleavage test

Table 19: Cleavage Test Results for Alder and Eucalyptus

Species	**Cleavage (N/mm Width)**	
	Radial	**Tangential**
Eucalyptus muellerana	**25.76**	**23.93**
Wych Elm (UK)	20.5	24.5
Birch (UK)	19.3	20.8
Cherry (UK)	18.9	24.9
Beech (UK)	17.3	24.9
Sycamore (UK)	16.8	27.3
European Oak (UK)	14.5	20.1
Elm (UK)	14	16.8
Common alder (UK)	13.3	15.8
Spanish Chestnut (UK)	13.3	14.5
Common alder	**11.58**	**11.68**
Ash (Irish)	-	-
Ash (UK)	-	-
Beech (Irish)	-	-
Birch (Irish)	-	-
Oak (Irish)	-	-
Poplar (UK)	-	-
Red alder (U.S.	-	
Red Oak (UK)	-	-
Spanish Chestnut (Irish)	-	-
Sycamore (Irish)	-	-
Walnut (American/Black)	-	-
Walnut (European)	-	-

6.1.4 **Compression Parallel to the Grain**

Table 20 shows the results of the compression tests carried out on both species. It is worth noting that *E. muellerana*'s resistance to compression or 'strength' of 72.5N/mm^2 is considerably higher than any other hardwood in the group being considered. Due to this strength parallel to the grain uses involving resistance to high compressive forces may be considered such as chair legs, joinery work, structural beams and other load bearing vertical members.

It can also be seen from Table 20 that common alder has a relatively low resistance to compression of 38.9N/mm^2 but does have a very similar value to red alder. Due to this low value, common alder would not be recommended for use in vertical load bearing situations. Its main uses therefore lie in other areas where its weak compression strength is not a factor.

Figure 78: Compression test specimens

Table 20: Compression Test Results for Alder and Eucalyptus

Species	Compression (N/mm2)
Eucalyptus muellerana	**72.5**
Birch (UK)	59.9
Red Oak (UK)	57.4
Beech (UK)	56.3
Cherry (UK)	54.5
Walnut (American/Black)	54
Ash (UK)	53.3
European Oak (UK)	51.6
Wych Elm (UK)	49.2
Sycamore (UK)	48.2
Sycamore (Irish)	48
Spanish Chestnut (UK)	44.4
Common alder (UK)	41.1
Red alder (U.S.)	40.1
Common alder	**38.9**
Poplar (UK)	37
Elm (UK)	33.9
Ash (Irish)	-
Beech (Irish)	-
Birch (Irish)	-
Oak (Irish)	-
Spanish Chestnut (Irish)	-
Walnut (European)	-

6.1.5 Density

As would be expected from some of the difficulties encountered in successfully drying eucalyptus, tests have proven that it is extremely dense (Table 21). This has been calculated at 919 kg/m^3 for the samples tested. For common alder the opposite is true with a relatively low density of 472kg/m^3 calculated. Such a low density suggests relatively low strength also. However a low density also indicates ease of seasoning and drying and stability in service, which is the case for common alder.

Table 21: Density Test Results for Alder and Eucalyptus

Hardwood Name	Density
Eucalyptus muellerana	**919**
Beech (Irish)	715
Red Oak (UK)	705
Oak (Irish)	700
Ash (Irish)	690
Ash (UK)	689
Beech (UK)	689
European Oak (UK)	689
Birch (UK)	673
Walnut (American/Black)	630
Cherry (UK)	625
Walnut (European)	610
Wych Elm (UK)	609
Sycamore (Irish)	600
Birch (Irish)	570
Sycamore (UK)	561
Spanish Chestnut (Irish)	530
Common alder (UK)	513
Elm (UK)	513
Spanish Chestnut (UK)	513
Common alder	**472**
Red alder (U.S.)	449
Poplar (UK)	415

6.1.6 Nominal Specific Gravity

From Table 22 below it can be seen that *E. muellerana* has a high nominal specific gravity of 0.83 whereas common alder has a low value of 0.43. This would be expected due to the close relationship between specific gravity and density values.

Table 22: Specific Gravity Test Results for Alder and Eucalyptus

Species	Specific Gravity
Eucalyptus muellerana	**0.83**
Red Oak (UK)	0.64
Beech (UK)	0.62
European Oak (UK)	0.61
Ash (UK)	0.6
Birch (UK)	0.6
Cherry (UK)	0.56
Wych Elm (UK)	0.55
Sycamore (UK)	0.51
Elm (UK)	0.46
Spanish Chestnut (UK)	0.46
Common alder (UK)	0.45
Common alder	**0.43**
Red alder (U.S.)	0.43
Ash (Irish)	-
Beech (Irish)	-
Birch (Irish)	-
Oak (Irish)	-
Poplar (UK)	-
Spanish Chestnut (Irish)	-
Sycamore	-
Walnut (American/Black)	-
Walnut (European)	-

6.1.7 Moisture Content

The results obtained from the oven-dry moisture content determination test for each species is shown in Table 23. These values are recorded for the test specimens according to BS373. The values are lower than those specified in the standard due to difficulties controlling the test site for humidity and temperature. This is referred to later in section 6.3.

Table 23: Moisture Content (Oven-Dry) Test Results for Alder and Eucalyptus

Species	Average % Moisture Content
Common Alder	**9.43**
Eucayptus muellerana	**9.11**

6.1.8 Panel Products

The most stable of the panel products proved to be the blockboard which demonstrated no noticeable movement at all after conditioning in the test chamber. This compared very favourably with both the furniture grade ply and the birch ply. The results of these are shown in Table 24 and 25. Although there was movement, in the ply particularly, virtually no shrinkage or swelling occurred on any of the boards.

Table 24: Results of lowering the moisture content of the panels from 9 to 6%

Panel Type	Lowering Moisture Content							
	Before Test				After Test			
	1st MC	Length	Width	Thickness	Last MC	Length	Width	Thickness
Blockboard	9%	305	189	20.2	6%	305	189	20.2
Visual Description	Board is defect free and lies perfectly flat on a level surface.				Board is defect free and lies perfectly flat on a level surface.			
Laminboard	9%	305	189	20	6%	305	189	20
Visual Description	Board is defect free and lies perfectly flat on a level surface.				Board is defect free but has cupped by approx 1.5mm			
3 ply	9%	305	189	21.2	6%	305	188	21
Visual Description	Board is defect free and lies perfectly flat on a level surface.				Board is defect free but has warped approx 3mm at corner			
Birch Ply	9%	300	207	18	6%	300	207	18
Visual Description	Board is defect free and lies perfectly flat on a level surface.				Board is defect free and lies perfectly flat on a level surface.			
Standard Ply	9%	300	207	18	6%	300	207	18
Visual Description	Board is defect free and lies perfectly flat on a level surface.				Board is defect free and lies perfectly flat on a level surface.			

Table 25: Results of raising the moisture content of the panels from 9 to 13%

Panel Type	Raising Moisture Content							
	Before Test				After Test			
	1st MC	Length	Width	Thickness	Last MC	Length	Width	Thickness
Blockboard	9%	306	189	20.2	13%	306	189	20.2
Visual Description	Board is defect free and lies perfectly flat on a level surface.				Board has same splits on one side and lies perfectly flat on a level surface.			
Laminboard	9%	306	189	20	13%	306	189	20
Visual Description	Board is defect free and lies perfectly flat on a level surface.				Board is defect free and lies perfectly flat on a level surface.			
3 ply	9%	306	189	21.2	13%	306	189	21.2
Visual Description	Board is defect free and lies perfectly flat on a level surface.				Board is defect free but has a slight twist approx 1.5mm at corners			
Birch Ply	9%	300	207	18	13%	300	207	18
Visual Description	Board is defect free and lies perfectly flat on a level surface.				Board is defect free and lies perfectly flat on a level surface.			
Standard Ply	9%	300	207	18	13%	300	207	18
Visual Description	Board is defect free and lies perfectly flat on a level surface.				Board is defect free and lies perfectly flat on a level surface.			

6.1.9 **Microscopic analysis**

The following images and observations were made in relation to the microscopic analysis of *Alnus glutinosa* and *Eucalyptus muellerana*. Three samples of each species were analysed and photographed using a magnification of 200. The three sections are those that are typically used for anatomical analysis (CSIRO 1987):

- radial-longitudinal section – parallel to the longitudinal and corresponding to the radius (RLS)
- tangential-longitudinal section - parallel to the longitudinal and perpendicular to the radius (TLS)
- transverse(or cross)-section – perpendicular to the longitudinal axis of the stem (TS)

The following are some of the distinguishing features of Alnus glutinosa under microscopic analysis.

RLS – Figure 79

- Scolariform perforation plates (tangentially elongated bordered pits) (A) run across the width of the vessels forming a ladder-like appearance with more than 20 bars
- Rays are arranged in groups (B) of an average of 15 up to a maximum of 40 (can be aggregate or single in formation). The cells of rays are homogeneous. Medullary rays should be clearly visible without magnification in radial bands..

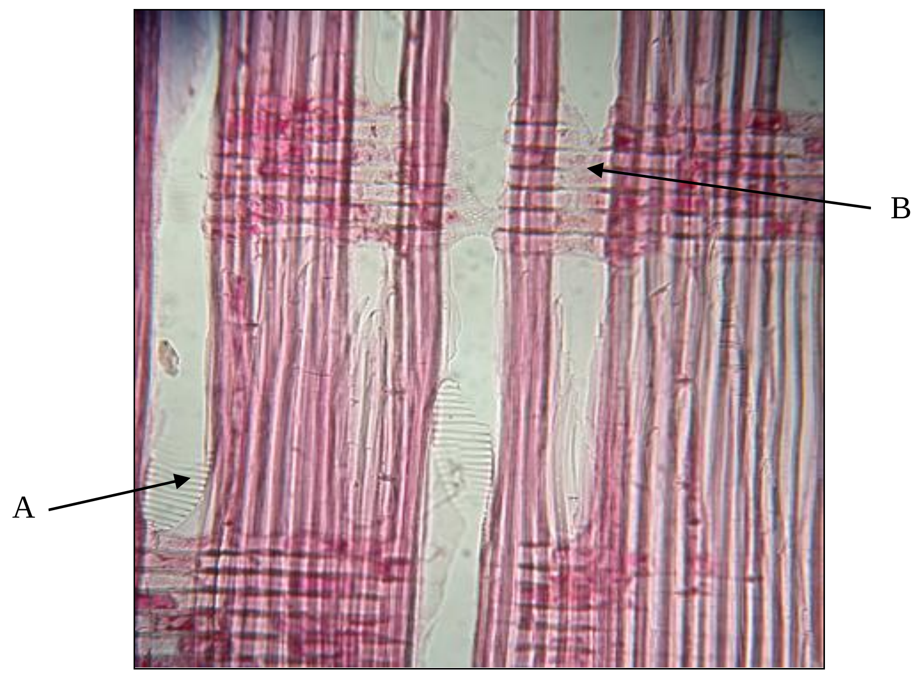


Figure 79: *Alnus glutinosa* RLS x 200

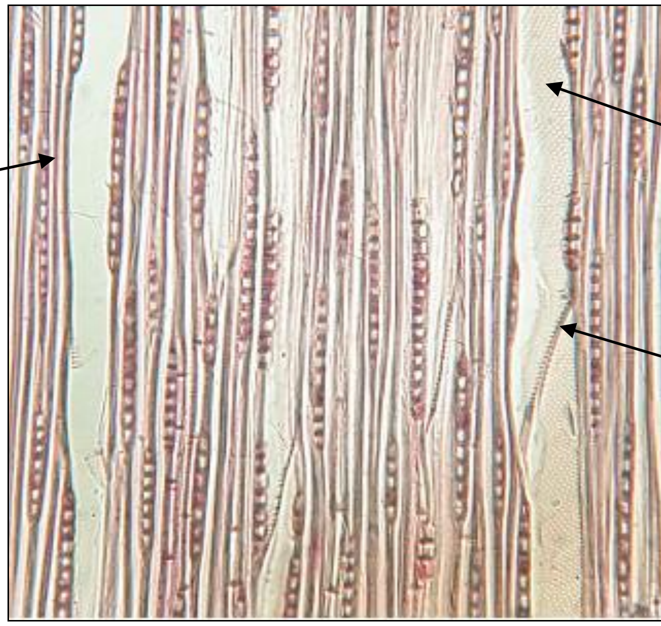


Figure 80: ***Alnus glutinosa*** **TLS x 200**

<u>TLS</u> – Figure 80

- Narrow rays, uniseriate and occasionally biseriate in formation (A)
- Spiral thickening absent
- Intervascular pitting predominantly alternate to opposite (B)
- Side view of scolariform perforation plates (C)

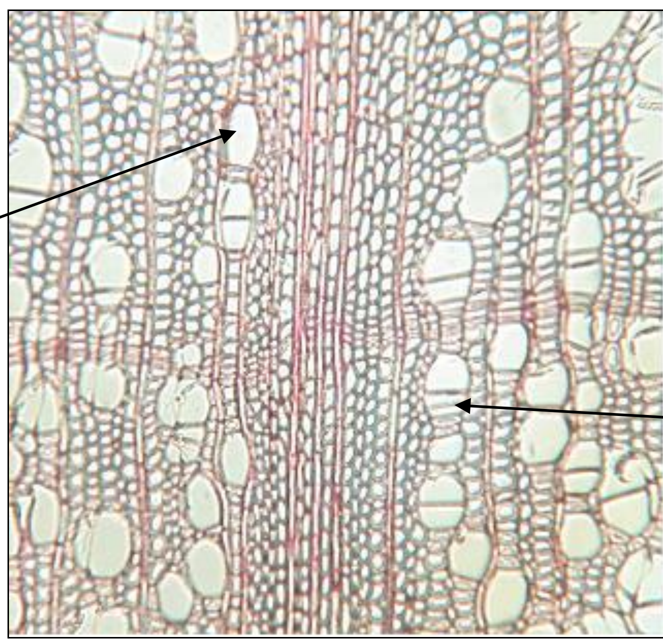


Figure 81: ***Alnus glutinosa*** **TS x 200**

TS – Figure 81

- Diffuse-porous arrangement of vessels which are elliptical or polygonal in cross-section (A)
- Pores are solitary and in radial multiples (B)
- Parenchyma are abundant in single strands or in small groups between fibres
- Growth ring boundaries are indistinct with fewer vessels present in latewood zone

The following are some of the distinguishing features of *Eucalyptus muellerana* under microscopic analysis.

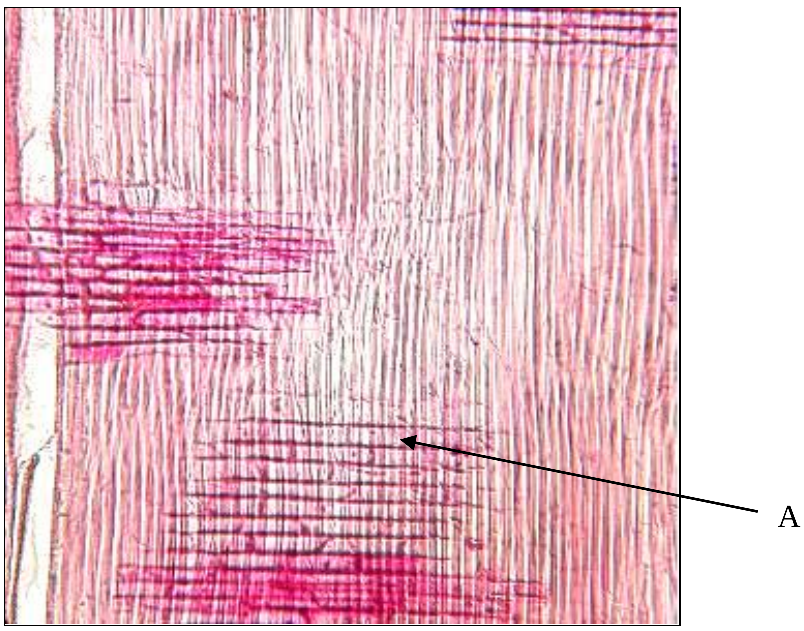


Figure 82: *Eucalyptus muellerana* RLS x 200

RLS (Figure 82)

- Homocellular rays (longer radially that axillary) (A)

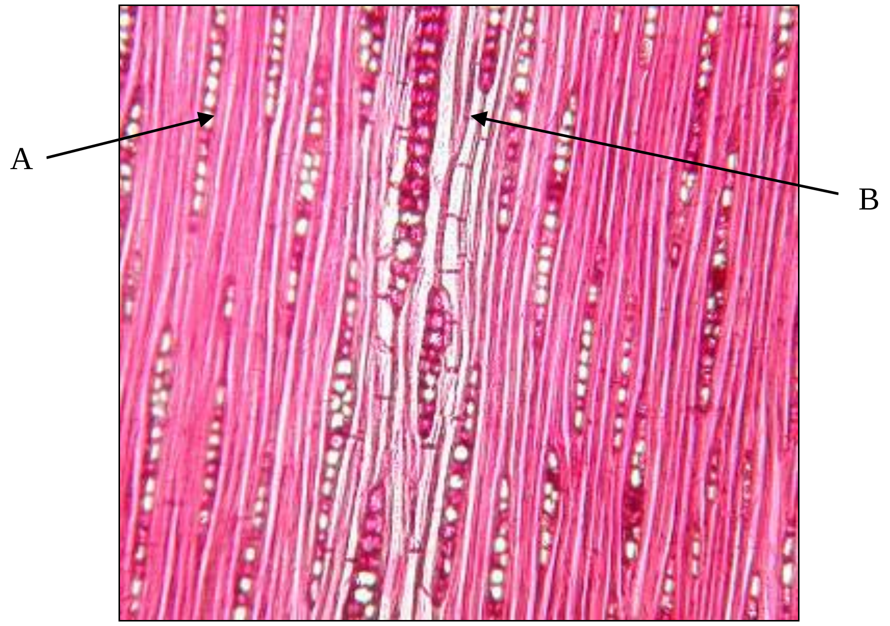


Figure 83: *Eucalyptus muellerana* TLS x 200

TLS – Figure 83

- Narrow rays, ranging from uniseriate to biseriate in formation 10-20 cells high(A)
- Absence of septate fibres
- Presence of paenchyma cells along vessel walls (C)

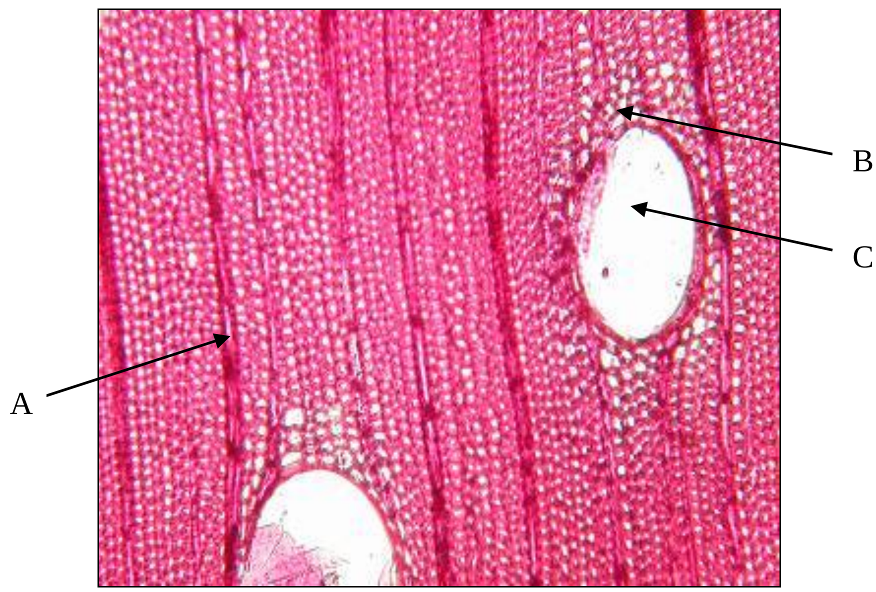


Figure 84: *Eucalyptus muellerana* TS x 200

TS – Figure 84

- Growth rings not very distinguishable
- Rays clearly visible (A)
- Parenchyma cells arranged in paratraheal and vasicentric formation (B)
- Predominantly solitary vessels (C)

One point of particular interest notable in these slides is the comparison between both transverse sections. The greater thickness of the cell walls of *E. Muellerana* in comparison to those of alder are indicative of the higher density and thus moisture content of those cell of that species. This is symptomatic of the distortion that occurs during the drying process of *E. Muellerana*.

It is important to note that while cross referencing *Alnus glutinosa* for analysis was facilitated by the extensive number of published references available, this was not the case with *Eucalyptus muellerana*. The author was not able to find references to this particular species although there were similarities with other species of Eucalypts including *E. Maidenii*, *E. Rubida* and *E. viminalis*. The observations were made using keys and references from Grosser (1977), Sachsse (1984), Hoodley (1990) and CSIRO (1987).

6.2 Summary of Results

Tables 26 and 27 are summaries of the test results presented in this chapter and the inferences drawn in terms of utilisation from those results.

Table 26: Summary of Test Results for Common Alder

Alnu glutinosa (Common alder)	Value	Units	Description of result	Utilisation based upon results
Modulus of Rupture	82	N/mm^2	Moderate maximum bending strength	General purpose furniture where member are supported such as table tops and kitchen cabinet doors
Modulus of Elasticity	8708	N/mm^2	Moderate in terms of stiffness	
Janka Indentation	2277	N	Poor resistance to indentation	Not recommended for uses which require abrasion or contact
Compression Parallel to Grain	38.9	N/mm^2	Relatively poor resistance to compression	Not recommended for load-bearing applications
Cleavage Radial	11.58	N/mm	Moderate resistance to splitting	satisfactory for nailing, screwing (pilot holes recommnended)
Cleavage Tangential	11.68	N/mm		
Density	472	Kg/m^3	Relatively low density and specific gravity	Low strength, but ease of seasoning, drying and transportation
Nominal Specific Gravity	0.43			

Table 27: Summary of Test Results for *E. muellerana*

E. Muellerana	Value	Units	Description of result	Utilisation based upon results
Modulus of Rupture	152	N/mm^2	Excellent maximum bending strength	Excellent structural timber for use in stairs strings, rail on tables, floor joists, flooring, internal joinery, doors
Modulus of Elasticity	16618	N/mm^2	Excellent in terms of stiffness	
Janka Indentation	6412	N	Extremely good interms of resitance to indentation	Flooring, sports goods, bearing blocks
Compression Parallel to Grain	72.5	N/mm^2	Resistance to compression extremely high Good load-bearing ability Very strong parallel to the grain	Legs of tables and chairs Load-bearing members of furniture Joinery
Cleavage Radial	25.76	N/mm	Very strong resistance to splitting	Good for nailing screwing and bolting
Cleavage Tangential	23.93	N/mm		
Density	919	Kg/m^3	High density and specific gravity	Very strong, more difficutly in drying
Nominal Specific Gravity	0.83			

6.3 Sources of Error

The main factor to be considered here was the fact that the moisture determination of the samples demonstrated an average percentage moisture content of the alder and eucalypt samples of 9.43 and 9.11% respectively. According to BS373 samples should be tested at 12% moisture content. In addition to this the humidity of the lab could not be controlled adequately so the average relative humidity was recorder at 58% as opposed to the required 65%.

While the samples of alder were in excellent condition the samples were extracted from a single tree. However as required they were taken randomly from different sections of that same tree. The eucalyptus was taken from random areas but was also sourced from the one tree. Due to the poor condition of the samples of eucalyptus clear specimens were more difficult to extract for testing purposes. However due to the large amount of timber available it was eventually possible to get a sufficient quantity of samples.

7 Discussion of Results

7.1 Introduction

This chapter examines the results of the various tests carried out during this research and explores some of the issues and questions that remain in relation to the subject matter of the thesis.

7.1.1 Test results for common alder

The results obtained for the test samples of common alder were satisfactory in a number of ways. Primarily they compare favourably to those of British grown common alder but more importantly they also compare well to properties of the American species red alder (*Alnus rubra*) as can be seen from Table 28. This clearly demonstrates one of the problems with the supply of Irish grown hardwoods in Ireland at present. Research has demonstrated that there is a demand domestically for American red alder yet there is effectively no market for Irish grown material. This is most likely due to a number of reasons including availability, price and quality.

The fact that alder grows faster here in Ireland than in many other countries should be a major advantage in terms of competition. The results show that due to the diffuse-porous nature of the wood tissue, the density and hence strength are not adversely affected by this fast growth rate. The continuing increase in the cost of energy will inevitably increase the cost of imported hardwoods as well as increase the demand for alternative fuels and materials compared to those produced through, and reliant upon, the petroleum industry. The volatile nature of the American dollar at present is currently making hardwoods from the USA extremely good value.

It should be noted here that there is a distinct difference in the values achieved for modulus of rupture and elasticity of the samples tested for this report compared to those achieved for the Forest Products Department of Enterprise Ireland (Table 28). The results of this report are more in line with those of the British-grown material. This difference could be due to the fact that both tests were carried out using a relatively small number of samples and are taken from one tree only.

Table 28: Results of Mechanical Properties of Irish-grown Common Alder compared with British and American (red) -grown alder

Species	Modulus of Rupture	Modulus of Elasticity	Janka Indentation	Compression Parallel to Grain	Cleavage Radial	Cleavage Tangential	Density	Nominal Specific Gravity
	(N/mm^2)	N/mm2	N	N/mm2	N/mm	N/mm	Kg/m3	
Common Alder (Irish) - this report	82	8708	2277	38.9	11.58	11.68	472	0.43
Common Alder (Irish) - EI	110	12800	-	-	-	-	-	-
Common Alder (UK)	80	8800	2940	41.1	13.30	15.80	513	0.45
Red Alder (U.S.)	68	9500	2622	40.1	-	-	449	0.43

7.1.2 Examples of Alder products

The following illustrations (Figure 85-88) demonstrate some more suitable applications of Irish-grown common alder based upon the testing carried out during this research. Figures 85 and 86 illustrate the use of the alder blockboard as a substrate for more decorative figured veneers. While alder is suitable material for paneling in its own right, this makes use of the stability of the alder as a substrate.

Figure 85: Alder blockboard with a burr yew veneer

Figure 86: An array of decorative burr veneers on alder blockboard substrate

The mirror in figures 87 and 88 illustrates an ideal use for alder. This application uses the full range of machining and working properties for which alder is suitable (planing, grooving, dowelling, sanding, finishing) and incorporates a relatively dark inlay of walnut to contrast with the orange-brown of the alder. This application for alder ensures that the relatively soft timber does not get too much wear and tear due to the nature of the product. In this respect it is crucial for those whose responsibility it is to specify timber to choose species whose properties are in accordance with the intended performance of the product in service.

Figure 87: Mirror frame in common alder with walnut inlay (made by Paul Leamy)

Figure 88: Detail of inlay and attractive alder grain pattern

7.1.3 **Test results for Eucalyptus**

The results for the *E. muellerana* samples were very interesting. It proved to have some of the highest values in terms of strength, compression, density and resistance to bending compared to all other species commonly used in this country. Due to the unusual nature of the reaction of the timber during conversion a more detailed analysis of the sample preparation is explained in the following section.

7.1.4 **Eucalyptus Samples Preparation**

In order for the reader to get a good impression of the issues with converting Eucalypts into usable timber the different stages of conversion are recorded in this section. The two eucalyptus trees were felled in February in Glenealy Woods. As soon as the trees hit the ground large splits and severe rupture developed from the pith as can be seen in Figures 91 and 92. These resulted from internal growth stresses which are consistent with reports and experiences from Australia and New Zealand. Once these had occurred they did not tend to degrade further during conversion. However the *E. muellerana* specimen degraded very badly in the kiln. After 3 weeks in the kiln the timber had become very distorted with severe cupping, bowing and cell collapse noted (Figure 95). It was however possible to recover small clear samples for test specimens from this batch. The author was offered the trees from Coillte and later identified them with the help of David Thompson from Coillte. This was done by finding the leaves and foliage of the original trees (Figures 93 and 94) and cross referencing them from the *Eucalypts for Planting* (FAO 1979) and original planting maps of the area in question.

The second batch of timber, *E. viminalis,* was cleaned and stacked using 20mm stickers and the ends covered in wax to prevent rapid evaporation (Figure 97). This batch was covered and left to dry for a period of at least 24 months before use. Some of this batch demonstrated much better form and splits did not tend to degrade. However cell collapse was also apparent after the first year.

The main problem with recovery from both eucalyptus samples was the cell collapse or checking. While the *E. muellerana* distorted (Figure 99(c)) and even demonstrated crumping (Figures 99(d) and (e)) this was most probably exaggerated due to the fact that it had not been air dried prior to drying in the kiln. This is apparent also on the surface of the boards and appears as cracks as in Figure 100(a). The batch of *E. viminalis* that was air dried displayed much better form but still demonstrated internal cell collapse (Figures 99(a) and (b)). Interestingly this was most apparent on the boards where the grain orientation was tangential to the surface as in Figure 99(a) and was noticeably less on those boards where the grain direction was radial to the surface as in Figure 99(b). The cell collapse on the boards of *E. viminalis* also occurred mostly on the earlywood rings. Literature from Australia does indicate that most of the damage and distortion occurs in the latter stages of drying (20 to 12% MC)

Figure 89: Standing Test Tree - *E. muellerana*

Figure 90: Cross-cutting of Main Stem

Figure 91: Stems Demonstrating Internal Stresses

Figure 92: Stem Demonstrating Severe Rupture

Figure 93: *E. muellerana* leaves and buds

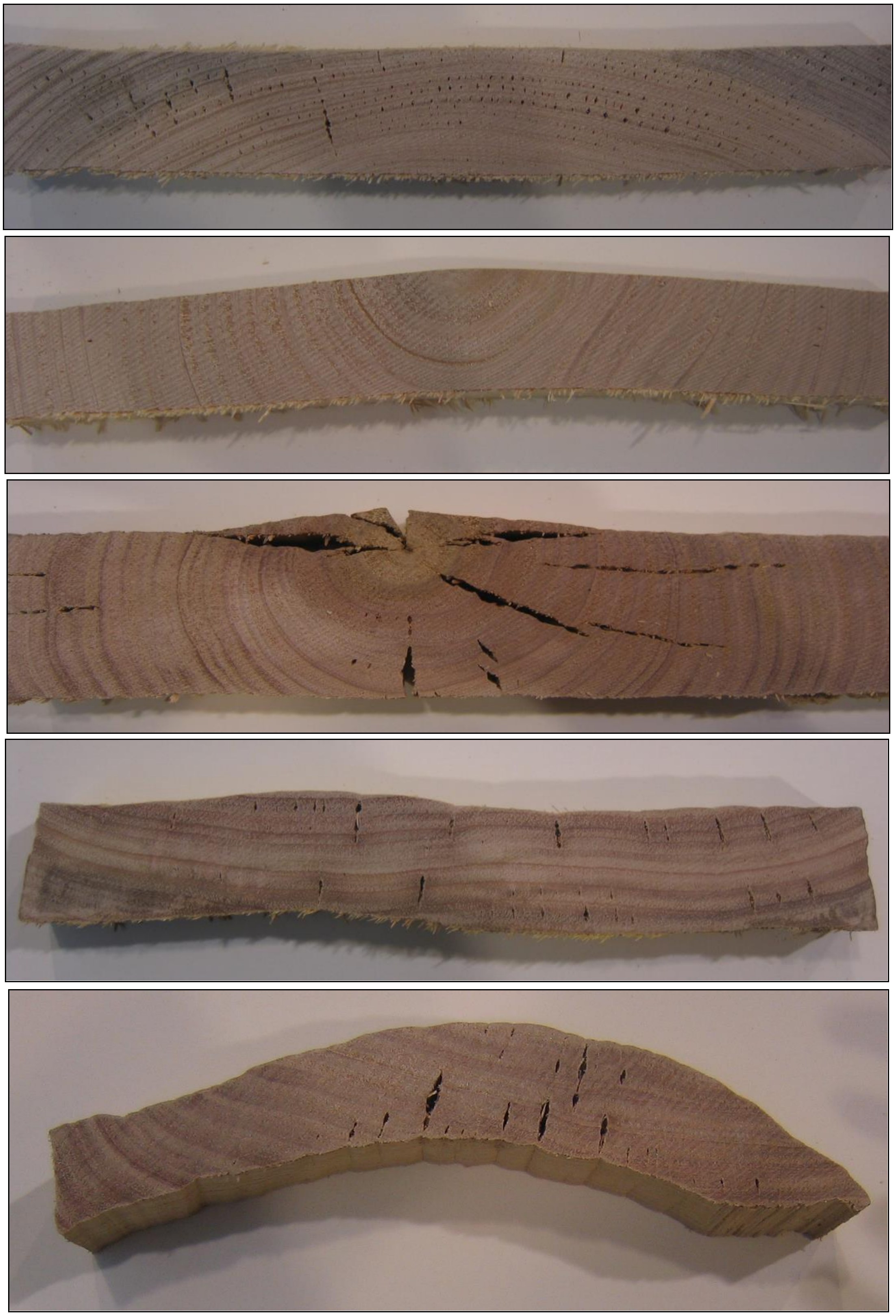
Figure 94: *E. viminalis* leaves and buds

Figure 95: *E. muellerana* post kiln drying

Figure 96: *E. viminalis* pre stacking in Letterfrack

Figure 97: Stacking of *E. viminalis*

Figure 98: Board showing degrade of *E. muellerana*



(a)

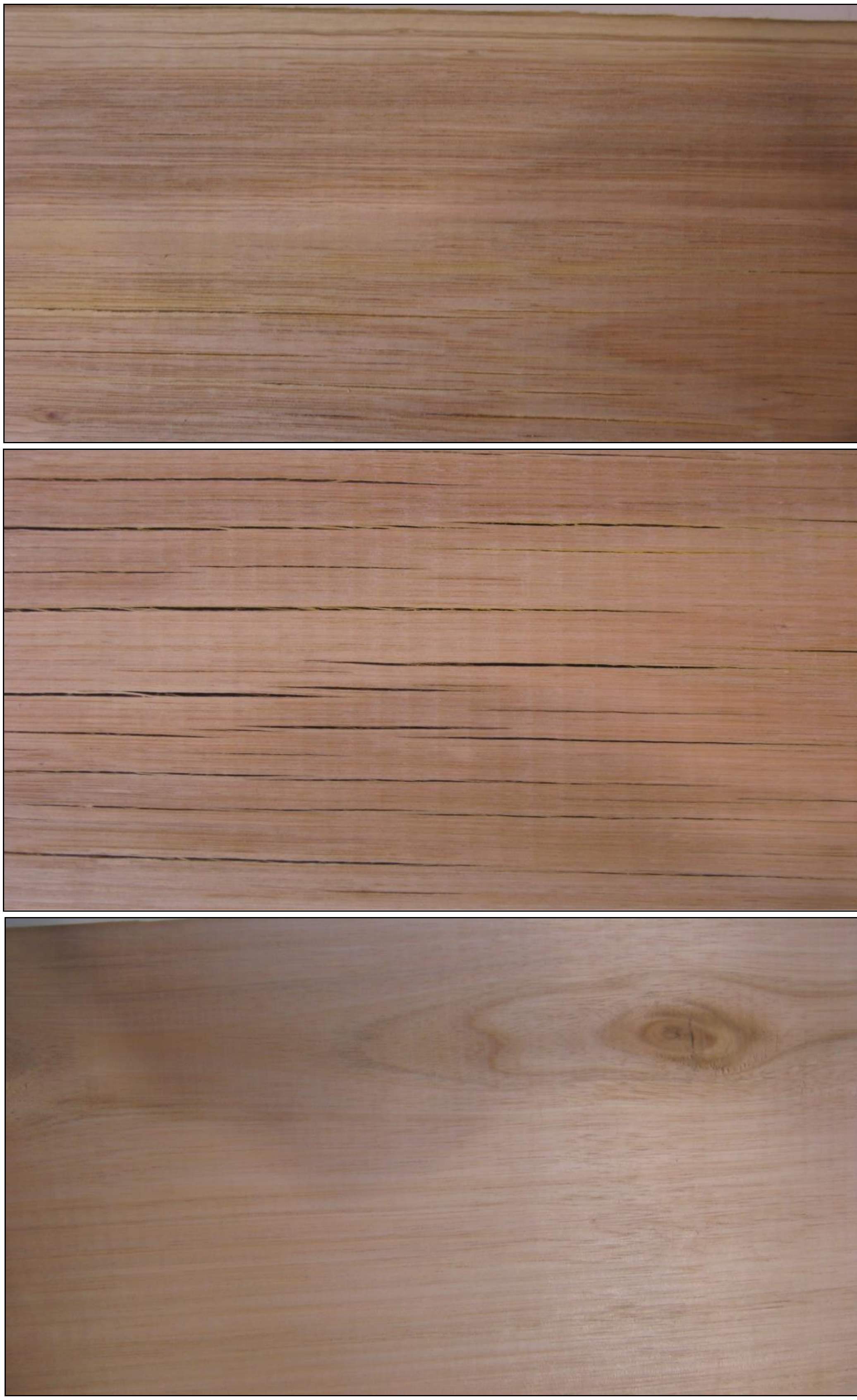
(b)

(c)

(d)

(e)

Figure 99: Cross sections of *E. muellerana* and *E. viminalis*



(a)

(b)

(c)

Figure 100: Tangential sections of *E. muellerana* and *E. viminalis*

The very attractive grain and colour of *E. muellerana* is visible from Figure 100 (a) and (b). Pinks, browns and yellows make up part of the spectrum of colours present. This and the figured grain make it easy to see why people go to the bother of converting eucalypts for timber. There is a marked difference in the *E. viminalis* timber as can be seen in Figure 100(c). This timber is pale yellow-pinkish colour and while testing was not carried out on this species it is noticeably less dense that that of *E. muellerana*. The timber of *E. viminalis* is said to be only moderately hard and not strong or durable (FAO 1981).

8 Conclusion

This thesis has presented findings for the utilisation of two broadleaf species which have proven to be very successful in terms of growth in the Irish climate. Their potential for timber production and utilisation are markedly different. This chapter presents the conclusions that may be inferred from the research contained within this thesis. It also identifies areas of further research that could be pursued in this field.

Irish forestry, in particular broadleaf forestry, is at a critical stage of development in Ireland at present. The standards of forestry management and timber production are gradually being developed as Ireland is starting from a particularly low base. Encouraging private forestry development is critical to the future expansion of this invaluable resource but more must be done in terms of awareness of the quality that end users require. Unlike other rotations of crops, many broadleaf forestry plantations will not be used by this current generation but are investments for the generations to come. This is difficult to promote as a ‘crop’ when returns are long term in nature, unpredictable and when there is genuine risk attached to the investment (frost damage, incorrect seed/site selection, grey squirrel damage etc.).

When markets open up and develop in Ireland for the full range of forest produce this will benefit all stakeholders. Short rotation crops used for biomass and biofuel will help to smooth the financial returns available to landowners. Localised firewood markets will also begin to develop in the future as the cost of oil continues to increase thus decreasing transport costs and increasing the competitiveness of such products. This will then have the effect of encouraging new entrants into the market, increasing production and thus allowing landowners attain greater economies of scale. The wider availability of hardwood timber from all stages of the forest lifecycle should also promote innovation and creativity in indigenous industries. The availability of a resource or raw material locally such as timber has proven to be very attractive to suppliers and customers in rural areas of Sweden. The use and exploitation of modern manufacturing technologies can be adopted by Irish companies to attain a competitive advantage on their European counterparts. However, the continuity of the supply of the raw material must be guaranteed in order to create confidence in the market place.

Adherence to standards must be kept to the forefront in all areas of production and development. For most broadleaf species the end goal will be the harvesting of the best trees or standards for timber production. In order to get the greatest return on their investment best practice must be adhered to at all stages. An understanding of timber and the aspects of quality that users of timber require is critical to the successful establishment and continuity of this market. The adoption of a standard set of grading rules would also be of benefit. This is also crucial in order to compete with imports.

Working in local communities, addressing local demand in terms of both private individuals, organizations and companies has already begun in earnest in terms of food production. This is the route that can also be explored by those involved in forestry produce. However unless a more serious effort is made to develop this sector there will always remain a level of uncertainty over the continuity of supply or forest produce from broadleaves. Common alder is a tree of huge potential and is just one of many native and naturalized broadleaves that is suitable for forestry in Ireland. A diverse approach to forest development and species selection has many benefits to both stakeholders and the environment. Examining the potential for all of these species is required for their full potential to be realized.

A pertinent factor in this regard is that while a 30% broadleaf planting target has now been attained by the Forest Service as recommended by both the EU and the Review of the Strategic Plan for forestry (Bacon 2006), there is a need to ensure that planting is taking place which reflects the long term perspective of the sector. The planting of broadleaves for shelter belts for coniferous trees or the filling of pockets of marginal land with broadleaves will not lead to the resultant quality hardwoods that are required and demanded by manufacturers in this country. There has also been a sense of apprehension at some of the conferences attended by the author that alder is being planted due to its ease of establishment rather than for its long-term potential. Hopefully this thesis will ease the minds of some of those involved in timber production.

8.1 Alder Utilisation

While the test results confirm that Irish grown material is similar to that of European grown alder and for the most part comparable with red alder, it does not however explain why alder is not used more extensively in this country both in terms of forestry and in timber products. There is little doubt that in relative terms alder is the ‘plain Jane’ of native Irish timbers. However it has so many advantages in terms of forestry and timber production it is difficult to argue against its potential. These advantages include:

- Short rotation species
- Naturally suited to wetlands
- Easy to establish
- Not very susceptible to damage by deer or grey squirrel
- Tending not as critical as with other species
- Easy to process
- Very stable timber
- Very light (for transportation)
- Growth rate of alder doesn't affect its density
- Dries fast (for timber and for firewood)

In terms of utilisation in timber products alder also proves to be extremely versatile. The variety of applications is expanded also by the author's research in other countries where alder has a broader utilisation. Alder's stability in service, its ease of staining and accepting a finish, its good machining properties and its plain texture make it suitable for many applications which are summarised in Table 29.

Table 29: Summary of Uses for Common Alder

Utilisation of Common Alder
Furniture components
Kitchen cabinet doors
Carcass construction
Mirror frames
Substrate for decorative veneers
Blockboard
Multi-plywood
Floors (as a substitute for pine/spruce)
Interior panelling
Childrens toys
Cladding for saunas
Veneer production
Wood chips for smoking
Baking boards
Firewood
Underwater construction work
Charcoal

8.1.1 Future Market Potential

One area of growth in Ireland initially will be the market for forest thinnings. These would be the sections from second and third phases of thinnings (10-15cm diameter). There are a number of companies that manufacture machinery for the production of blockboard panels using small sections similar to that tested by the author as outlined in Chapter 5. This makes ideal use of smaller sections of round wood and could be very suitable for the likes of alder and birch. This also is consistent with the stage of the lifecycle of forestry that Ireland is in at present (referred to in Chapter 1) with a large proportion of the forest estate between 10 and 25 year old. Other uses and applications of small diameter sections from thinnings need to be explored and developed.

8.2 Eucalyptus Utilisation

Figure 101: LifeStyle Furniture 'Amazon Range' of eucalyptus furniture

While there are many instances of and uses for eucalyptus around the world the author was not able to find any manufacturers using eucalyptus in the production of furniture or other wood products in Ireland. However a number of furniture companies and distributors have ranges of eucalyptus furniture. Lifestyle Furniture’s Amazon range for example comprises solid and veneered ‘tobacco stained’ eucalyptus furniture which is sold at the high end of the furniture market. Figure 101 above shows one of the bedroom ranges. The solid sections are constructed using small section of the timber glued together in order to restrict movement in service (Figure 102). Lidl® and Brown Thomas® now carry a number of ranges of eucalyptus outdoor furniture (although care must be taken when selecting a suitable eucalypt species for this purpose as some are not naturally durable). Highly decorative eucalyptus burr veneer is also used by bespoke furniture makers both in Ireland and Britain and is available from Capital Crispin Veneers in London.

Figure 102: Laminated solid section of eucalyptus with 'tobacco' stain (Courtesy of Lifestyle Furniture)

What is particularly interesting with regards to eucalyptus is that it grows so quickly and that its timber is so dense. Despite the fact that some species are not as frost hardy as others and despite the difficulties of processing and converting eucalypts in general, a number of species have proven to be quite adaptable to our climate.

There are however a number of factors which would restrict its potential (and that for most eucalypts) for timber production in Ireland. Firstly, there are few if any sawmills where speciality drying is practiced in this country. Secondly, serious investment of time and resources would need to be made available to develop techniques which would facilitate the successful drying of eucalypts such as is being investigated through research and development in Portugal and Spain and through the work of COST Action E15 – *Advances in the drying of wood* research organisation. Due to the relatively small scale of forestry in this country it is difficult to see this forthcoming. The fact that Eucalypts are not on the list of species for which afforestation grants apply also restricts this to some degree, even though it has not prevented a number of individuals and companies growing eucalypts around the country (mostly for foliage). The main application the author would see for this product is in the areas of pulp or biofuel and this is backed up by both research in Britain (Leslie 2003) and in Ireland (pers. comm. David Thompson). There are issues regarding natural regeneration which would of course need to be considered in this regard but its potential is unquestionable in this respect.

8.3 Further Research

While this thesis has focused on timber derived from mature trees from these species further research is necessary to investigate the properties of timber from younger samples also. This could be very interesting in terms of eucalyptus. If some of the issues around growth stresses could be reduced or controlled in younger trees then the potential of eucalypts for sawnwood could be immense. There are also potential applications in terms of biofuel and biomass which should be given further attention. Alder on the other hand has a wide variety of applications and perhaps requires some promotion in this country. Overseas markets however also need to be examined to see if there are exportation opportunities for Irish grown material. Potential uses for small diameter sections of alder, and other hardwoods, should be investigated in order to generate continuous income streams from forest holdings.

The role of the Forest Service in promoting native hardwoods is also something that could be further explored. While analysis and collection of data is on-going in terms of forest inventory, research into the potential utilisation of produce from broadleaf forestry must be carried out in advance of many of the species currently in plantations coming to maturity. The application of new technologies for use in the production of innovative products is vital if the broadleaf sector of forestry is to become a sustainable industry in Ireland.

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Appendix 1 - Test Data and Results

Bending Strength Test Data

Common Alder

Specimen label	Width (mm)	Depth (mm)	Stress at Yield (MPa)	Strain at Yield (mm/mm)	Modulus E (MPa) (N/mm2)	Load at Yield (kN)	D2 (MM)	Modulus R (MPa) (N/mm2)
SBT_AG_A1	20.00	20.00	76.44	0.014	7672.13	1.36	400.00	76.44
SBT_AG_A2	20.00	20.00	82.37	0.015	8853.08	1.46	400.00	82.37
SBT_AG_A3	20.00	20.00	80.82	0.012	8273.49	1.44	400.00	80.82
SBT_AG_A5	19.90	19.90	86.23	0.012	9147.65	1.51	396.01	86.23
SBT_AG_A6	19.90	19.90	76.62	0.012	8719.95	1.34	396.01	76.62
SBT_AG_A7	19.90	19.90	83.49	0.017	7857.26	1.46	396.01	83.49
SBT_AG_A8	19.90	19.90	82.05	0.012	8746.47	1.44	396.01	82.05
SBT_AG_A9	19.90	19.90	80.27	0.012	9248.01	1.41	396.01	80.27
SBT_AG_A10	19.90	19.90	74.52	0.009	9315.55	1.30	396.01	74.52
SBT_AG_A12	19.90	19.90	86.66	0.015	8111.85	1.52	396.01	86.65
SBT_AG_A13	19.90	19.80	87.90	0.013	8688.50	1.52	392.04	87.90
SBT_AG_A14	19.90	19.80	80.34	0.011	8821.04	1.39	392.04	80.34
SBT_AG_A15	19.90	19.90	83.24	0.013	8676.67	1.46	396.01	83.24
SBT_AG_A16	19.90	19.90	84.30	0.014	8428.46	1.48	396.01	84.30
SBT_AG_A17	19.90	19.80	78.61	0.010	9568.62	1.36	392.04	78.61
SBT_AG_A18	19.90	19.90	84.05	0.016	8042.58	1.47	396.01	84.05
SBT_AG_A20	19.90	19.90	75.63	0.012	8100.72	1.32	396.01	75.63
SBT_AG_A21	19.90	19.80	85.18	0.012	9555.49	1.48	392.04	85.18
SBT_AG_A22	19.90	19.80	94.38	0.013	9679.12	1.64	392.04	94.38
SBT_AG_A23	19.90	19.90	88.65	0.015	8645.52	1.55	396.01	88.65
				Average	**8707.61**		**Average**	**82.59**
				Std. Dev.	**586.13**		**Std. Dev.**	**4.94**

Bending Strength Test Data

Eucalyptus muellerana

Specimen label	Width (mm)	Depth (mm)	Stress at Yield (MPa)	Strain at Yield (mm/mm)	Modulus E (MPa)	Load at Yield (kN)	D2 (MM)	Modulus R (MPa)
SBT_EM_A1	19.80	19.90	143.14	0.014	15754.80	2.49	396.01	143.14
SBT_EM_A2	20.20	20.20	136.19	0.010	17048.40	2.49	408.04	136.19
SBT_EM_A3	19.90	19.90	154.43	0.014	17210.00	2.70	396.01	154.43
SBT_EM_A4	20.20	20.20	135.46	0.015	12760.50	2.48	408.04	135.46
SBT_EM_A5	20.10	20.20	108.09	0.009	13770.20	1.97	408.04	108.09
SBT_EM_A6	19.90	19.90	148.59	0.015	15738.30	2.60	396.01	148.59
SBT_EM_A7	19.90	19.90	168.66	0.015	18318.10	2.95	396.01	168.66
SBT_EM_A8	19.90	19.80	130.98	0.013	13909.20	2.27	392.04	130.98
SBT_EM_A9	19.80	19.80	148.42	0.011	17885.40	2.56	392.04	148.42
SBT_EM_A10	19.90	19.90	176.29	0.017	18350.10	3.09	396.01	176.28
SBT_EM_A11	19.90	19.90	156.05	0.016	16070.30	2.73	396.01	156.05
SBT_EM_A12	19.90	19.90	139.21	0.010	17538.50	2.44	396.01	139.21
SBT_EM_A13	19.80	19.90	155.68	0.016	16575.60	2.71	396.01	155.68
SBT_EM_A14	20.00	19.90	160.54	0.011	19392.90	2.83	396.01	160.54
SBT_EM_A15	19.80	19.90	175.43	0.014	17962.30	3.06	396.01	175.43
SBT_EM_A16	19.80	19.90	146.84	0.015	15476.80	2.56	396.01	146.84
SBT_EM_A17	19.80	19.90	136.96	0.015	13749.60	2.39	396.01	136.96
SBT_EM_A18	19.80	19.90	169.33	0.014	19196.70	2.95	396.01	169.33
SBT_EM_A19	19.80	19.90	177.28	0.014	19384.30	3.09	396.01	177.28
SBT_EM_A20	20.10	20.20	167.68	0.016	16272.90	3.06	408.04	167.68
				Average	**16618.25**		**Average**	**151.76**
				Std. Dev.	**1979.99**		**Std. Dev.**	**17.95**

Janka Hardness Test Data

Common Alder				*Eucalyptus muellerana*			
Specimen ID	**Width (mm)**	**Thickness (mm)**	**Load (N)**	**Specimen ID**	**Width (mm)**	**Thickness (mm)**	**Load (N)**
HT_AG_RL01	19.9	19.8	1956.63	HT_EM_RLA1	19.8	19.8	5960.25
HT_AG_TL01	19.9	19.8	2308.57	HT_EM_TLA1	19.8	19.8	4074
HT_AG_RL02	19.9	19.8	2325.96	HT_EM_RLA2	19.8	19.8	6187.33
HT_AG_TL02	19.9	19.8	2309	HT_EM_TLA2	19.8	19.8	6046.29
HT_AG_RL03	19.9	19.8	2278.8	HT_EM_RLA3	19.9	19.8	6998.54
HT_AG_TLA3	19.9	19.8	2213.8	HT_EM_TLA3	19.9	19.8	6980.62
HT_AG_RLA5	19.9	19.8	2354.84	HT_EM_RLA4	20.1	20.1	6120.4
HT_AG_TLA5	19.9	19.8	2487.66	HT_EM_TLA4	20.1	20.1	4803.22
HT_AG_RLA6	19.8	19.8	2165.92	HT_EM_RLA5	20.1	20.1	4328.44
HT_AG_TLA6	19.8	19.8	2190.72	HT_EM_TLA5	20.1	20.1	5502.44
HT_AG_RLA7	19.9	19.8	2370.18	HT_EM_RLA6	19.8	19.8	6062.65
HT_AG_TLA7	19.9	19.8	2108.26	HT_EM_TLA6	19.8	19.8	6199.68
HT_AG_RLA8	19.9	19.8	2436.51	HT_EM_RLA7	19.8	19.8	7251.38
HT_AG_TLA8	19.9	19.8	2047.26	HT_EM_TLA7	19.8	19.8	7187.69
HT_AG_RLA9	19.9	19.8	2131.56	HT_EM_RLA8	19.8	19.8	4873.38
HT_AG_TLA9	19.9	19.8	2223.66	HT_EM_TLA8	19.8	19.8	5149.71
HT_AG_RLA10	19.9	19.9	2586.89	HT_EM_RLA9	19.8	19.8	5473.46
HT_AG_TLA10	19.9	19.9	2192.42	HT_EM_TLA9	19.8	19.8	5259.47
HT_AG_RLA11	19.9	19.9	2389.25	HT_EM_RLA10	19.9	19.8	7198.91
HT_AG_TLA12	19.9	19.9	2315.13	HT_EM_TLA10	19.9	19.8	8098.47
HT_AG_RLA13	19.9	19.9	2199.28	HT_EM_RLA11	19.8	19.8	5989.45
HT_AG_TLA13	19.9	19.9	2688.06	HT_EM_TLA11	19.8	19.8	6361.07
HT_AG_RLA14	19.8	19.9	2099.74	HT_EM_RLA12	19.9	19.9	9697.99
HT_AG_TLA14	19.8	19.9	3051.31	HT_EM_TLA12	19.9	19.9	8836.18
HT_AG_RLA15	19.8	19.9	2135.03	HT_EM_RLA13	19.9	19.9	5509.21
HT_AG_TLA15	19.8	19.9	2498.56	HT_EM_TLA13	19.9	19.9	5934.05
HT_AG_RLA16	19.8	19.9	1910.32	HT_EM_RLA14	19.8	19.9	8067.17
HT_AG_TLA16	19.8	19.9	2436.01	HT_EM_TLA14	19.8	19.9	8374.65
HT_AG_RLA17	19.8	19.9	2094.23	HT_EM_RLA15	19.8	19.8	7392.17
HT_AG_TLA17	19.8	19.9	2009.3	HT_EM_TLA15	19.8	19.8	7597.17
HT_AG_RLA18	19.8	19.9	1955.82	HT_EM_RLA16	19.8	19.8	5143.51
HT_AG_TLA18	19.8	19.9	2205.81	HT_EM_TLA16	19.8	19.8	5275.95
HT_AG_RLA20	19.8	19.9	2237.36	HT_EM_RLA17	19.9	19.8	4558.53
HT_AG_TLA20	19.8	19.9	2108.58	HT_EM_TLA17	19.9	19.8	4912.85
HT_AG_RLA21	19.8	19.9	2785.66	HT_EM_RLA18	19.8	19.8	6405.48
HT_AG_TLA21	19.8	19.9	2119.56	HT_EM_TLA18	19.8	19.8	7141.19
HT_AG_RLA22	19.8	19.9	2692.77	HT_EM_RLA19	19.8	19.8	6959.08
HT_AG_TLA22	19.8	19.9	2114.62	HT_EM_TLA19	19.8	19.8	7116.88
HT_AG_RLA23	19.8	19.9	2120.51	HT_EM_RLA20	20.1	20.1	7419.92
HT_AG_TLA23	19.8	19.9	2221.61	HT_EM_TLA20	20.1	20.1	8032.07
		Average	**2276.93**			**Average**	**6412.02**
		Std. Dev.	**238.93**			**Std. Dev.**	**1299.68**

Cleavage (Radial) Test Data

Common Alder

Specimen ID	Width (mm)	Thickness (mm)	Load at Max.Load (N)	Splitting Resistance (N/mm
CT_AG_E01	19.8	19.9	165.12	8.34
CT_AG_E02	19.8	19.9	220.48	11.14
CT_AG_E03	19.8	19.9	239.23	12.08
CT_AG_E04	19.9	19.9	238.79	12.00
CT_AG_E05	19.8	19.9	234.64	11.85
CT_AG_E06	19.8	19.9	257.91	13.03
CT_AG_E07	19.8	19.9	263.05	13.29
CT_AG_E08	19.8	19.9	276.31	13.96
CT_AG_E09	19.8	19.9	185.79	9.38
CT_AG_E10	19.8	19.9	205.86	10.40
CT_AG_E12	19.8	19.9	210.59	10.64
CT_AG_E13	19.8	19.9	237.67	12.00
CT_AG_E14	19.8	19.9	237.01	11.97
CT_AG_E15	19.8	19.9	285.97	14.44
CT_AG_E16	19.8	19.9	268.54	13.56
CT_AG_E17	19.8	19.9	184.58	9.32
CT_AG_E18	19.8	19.9	210.12	10.61
CT_AG_E19	19.8	19.9	208.31	10.52
CT_AG_E20	19.8	19.9	215.63	10.89
CT_AG_E24	19.8	19.8	240.34	12.14

Average	**11.58**
Std. Dev	**1.61**

Cleavage (Tangential) Test Data

Common Alder

Specimen ID	Width (mm)	Thickness (mm)	Load at Max.Load (N)	Splitting Resistance (N/mm
CT2_AG_F01	19.8	19.8	217.86	11.00
CT2_AG_F02	19.8	19.8	247.58	12.50
CT2_AG_F03	19.9	19.8	218.49	10.98
CT2_AG_F05	19.9	19.8	243.12	12.22
CT2_AG_F06	19.9	19.8	220.47	11.08
CT2_AG_F07	19.9	19.8	223.88	11.25
CT2_AG_F08	19.8	19.8	229.03	11.57
CT2_AG_F09	19.9	19.8	251.54	12.64
CT2_AG_F10	19.9	19.8	298.53	15.00
CT2_AG_F12	19.9	19.8	224.51	11.28
CT2_AG_F13	19.9	19.8	201.34	10.12
CT2_AG_F14	19.9	19.8	223.47	11.23
CT2_AG_F15	19.9	19.8	195.19	9.81
CT2_AG_F16	19.9	19.8	205.63	10.33
CT2_AG_F17	19.8	19.8	243.86	12.32
CT2_AG_F18	19.9	19.8	242.84	12.20
CT2_AG_F19	19.9	19.8	239.36	12.03
CT2_AG_F20	19.9	19.8	202.98	10.20
CT2_AG_F21	19.9	19.9	234.28	11.77
CT2_AG_F22	19.8	19.9	277.31	14.01

Average	**11.68**
Std. Dev	**1.28**

Cleavage (Radial) Test Data

Eucalyptus muellerana

Specimen ID	Width (mm)	Thickness (mm)	Load at Max.Load (N)	Splitting Resistance (N/mm
CT_EM_E01	19.8	19.8	502.86	25.40
CT_EM_E02	20	20.1	508.13	25.41
CT_EM_E03	19.8	19.8	508.237	25.67
CT_EM_E04	19.8	19.8	638.328	32.24
CT_EM_E05	20	20.1	382.863	19.14
CT_EM_E06	19.8	19.8	542.63	27.41
CT_EM_E07	19.8	19.8	443.632	22.41
CT_EM_E08	19.8	19.8	492.367	24.87
CT_EM_E09	19.8	19.8	481.913	24.34
CT_EM_E10	19.8	19.8	511.803	25.85
CT_EM_E11	19.8	19.8	339.137	17.13
CT_EM_E12	19.8	19.8	508.53	25.68
CT_EM_E13	19.8	19.8	454.433	22.95
CT_EM_E14	19.8	19.8	596.589	30.13
CT_EM_E15	19.8	19.8	465.447	23.51
CT_EM_E16	19.8	19.8	507.694	25.64
CT_EM_E17	19.8	19.8	531.55	26.85
CT_EM_E18	19.8	19.8	604.85	30.55
CT_EM_E19	19.8	19.8	611.847	30.90
CT_EM_E20	19.9	20	579.451	29.12

Average	**25.76**
Std. Dev	**3.78**

Cleavage (Tangential) Test Data

Eucalyptus muellerana

Specimen ID	Width (mm)	Thickness (mm)	Load at Max.Load (N)	Splitting Resistance (N/mm
CT2_EM_F01	19.8	19.8	489.72	24.73
CT2_EM_F02	20	19.9	538.44	26.92
CT2_EM_F03	19.8	19.8	490.07	24.75
CT2_EM_F04	19.8	19.8	421.84	21.31
CT2_EM_F05	20	20	330.86	16.54
CT2_EM_F06	19.8	19.8	512.78	25.90
CT2_EM_F07	19.8	19.8	377.89	19.09
CT2_EM_F08	19.8	19.8	552.11	27.88
CT2_EM_F09	19.8	19.8	499.86	25.25
CT2_EM_F10	19.8	19.8	542.99	27.42
CT2_EM_F11	19.8	19.8	340.57	17.20
CT2_EM_F12	19.8	19.8	435.65	22.00
CT2_EM_F13	19.8	19.8	530.65	26.80
CT2_EM_F14	19.8	19.8	553.26	27.94
CT2_EM_F15	19.8	19.8	486.20	24.56
CT2_EM_F16	19.8	19.8	409.64	20.69
CT2_EM_F17	19.8	19.8	393.36	19.87
CT2_EM_F18	19.8	19.8	548.44	27.70
CT2_EM_F19	19.8	19.8	588.81	29.74
CT2_EM_F20	19.9	20	443.37	22.28

Average	**23.93**
Std. Dev	**3.84**

Compression Test Data

Common Alder

Specimen Label	Width (mm)	Thickness (mm)	Cross-sectional Area (mm2)	Load (N)	Maximum Compression Strength (N/mm2)
AG_B2	19.9	19.9	396.0	14720.00	37.17
AG_B3	19.9	19.9	396.0	17214.10	43.47
AG_B4	19.9	19.9	396.0	15246.40	38.50
AG_B5	19.9	19.9	396.0	16476.20	41.61
AG_B6	19.9	19.9	396.0	16868.10	42.60
AG_B7	19.9	19.9	396.0	14462.00	36.52
AG_B8	19.9	19.9	396.0	15763.40	39.81
AG_B9	19.9	19.9	396.0	13877.20	35.04
AG_B10	19.9	19.9	396.0	16750.00	42.30
AG_B12	19.9	19.9	396.0	13971.10	35.28
AG_B13	19.9	20.0	398.0	14997.30	37.68
AG_B14	19.9	20.0	398.0	16119.70	40.50
AG_B15	19.9	20.0	398.0	16156.90	40.60
AG_B16	19.9	20.0	398.0	13796.90	34.67
AG_B18	19.9	20.0	398.0	14968.20	37.61
AG_B19	20.0	20.0	400.0	14950.00	37.38
AG_B21	19.9	19.9	396.0	15487.70	39.11
AG_B22	20.0	19.9	398.0	15432.80	38.78
AG_B23	20.0	19.9	398.0	15912.00	39.98
AG_B24	20.0	19.9	398.0	15740.20	39.55

Average	**38.91**
Std. Dev.	**2.53**

Compression Test Data

Eucalyptus muellerana

Specimen Label	Width (mm)	Thickness (mm)	Cross-sectional Area (mm2)	Load (N)	Maximum Compression Strength (N/mm2)
EM_B1	19.8	19.9	394.02	29000.40	73.60
EM_B2	19.8	19.8	392.04	29000.20	73.97
EM_B3	19.8	19.9	394.02	29000.30	73.60
EM_B4	19.8	19.8	392.04	28546.30	72.81
EM_B5	19.8	19.9	394.02	27941.20	70.91
EM_B6	19.8	19.8	392.04	28035.30	71.51
EM_B7	19.9	20	398.00	29000.10	72.86
EM_B8	19.9	19.8	394.02	25781.30	65.43
EM_B9	19.9	19.9	396.01	27678.60	69.89
EM_B10	19.9	19.8	394.02	29000.60	73.60
EM_B11	19.9	20	398.00	29000.40	72.87
EM_B12	19.9	19.8	394.02	29000.40	73.60
EM_B13	19.9	19.9	396.01	29000.10	73.23
EM_B14	19.9	19.9	396.01	29000.10	73.23
EM_B15	19.8	19.9	394.02	29000.00	73.60
EM_B16	19.8	19.8	392.04	29000.00	73.97
EM_B17	19.9	19.9	396.01	27882.50	70.41
EM_B18	19.9	19.9	396.01	29000.40	73.23
EM_B19	19.9	19.9	396.01	29000.50	73.23
EM_B20	19.9	19.8	394.02	29000.00	73.60

Average	**72.46**
Std. Dev.	**2.04**

Density Test Data

Common Alder

Sample Label	Width (mm)	Thickness (mm)	Length (mm)	Volume (wet) (m^3)	Weight (wet) in KG	Density
AG_B2	19.9	19.9	60	0.0000237606	0.0115	483.99
AG_B3	19.9	19.9	60	0.0000237606	0.0115	483.99
AG_B4	19.9	19.9	60	0.0000237606	0.0110	462.95
AG_B5	19.9	19.9	60	0.0000237606	0.0115	483.99
AG_B6	19.9	19.9	60	0.0000237606	0.0115	483.99
AG_B7	19.9	19.9	60	0.0000237606	0.0110	462.95
AG_B8	19.9	19.9	60	0.0000237606	0.0110	462.95
AG_B9	19.9	19.9	60	0.0000237606	0.0110	462.95
AG_B10	19.9	19.9	60	0.0000237606	0.0115	483.99
AG_B12	19.9	19.9	60	0.0000237606	0.0110	462.95
AG_B13	19.9	20	60	0.0000238800	0.0120	502.51
AG_B14	19.9	20	60	0.0000238800	0.0120	502.51
AG_B15	19.9	20	60	0.0000238800	0.0115	481.57
AG_B16	19.9	20	60	0.0000238800	0.0110	460.64
AG_B18	19.9	20	60	0.0000238800	0.0110	460.64
AG_B19	20	20	60	0.0000240000	0.0110	458.33
AG_B21	19.9	19.9	60	0.0000237606	0.0110	462.95
AG_B22	20	19.9	60	0.0000238800	0.0110	460.64
AG_B23	20	19.9	60	0.0000238800	0.0110	460.64
AG_B24	20	19.9	60	0.0000238800	0.0110	460.64

Average	**472.29**
Std. Dev.	**14.50**

Density Test Data

Eucalyptus muellerana

Sample Label	Width (mm)	Thickness (mm)	Length (mm)	Volume (wet) (m^3)	Weight (wet) in KG	Density
EN_B1	19.8	19.9	60	0.0000236412	0.0210	888.28
EN_B2	19.8	19.8	60	0.0000235224	0.0235	999.05
EN_B3	19.8	19.9	60	0.0000236412	0.0235	994.03
EN_B4	19.8	19.8	60	0.0000235224	0.0215	914.02
EN_B5	19.8	19.9	60	0.0000236412	0.0205	867.13
EN_B6	19.8	19.8	60	0.0000235224	0.0225	956.54
EN_B7	19.9	20	60	0.0000238800	0.0220	921.27
EN_B8	19.9	19.8	60	0.0000236412	0.0210	888.28
EN_B9	19.9	19.9	60	0.0000237606	0.0210	883.82
EN_B10	19.9	19.8	60	0.0000236412	0.0230	972.88
EN_B11	19.9	20	60	0.0000238800	0.0205	858.46
EN_B12	19.9	19.8	60	0.0000236412	0.0250	1057.48
EN_B13	19.9	19.9	60	0.0000237606	0.0200	841.73
EN_B14	19.9	19.9	60	0.0000237606	0.0235	989.03
EN_B15	19.8	19.9	60	0.0000236412	0.0215	909.43
EN_B16	19.8	19.8	60	0.0000235224	0.0200	850.25
EN_B17	19.9	19.9	60	0.0000237606	0.0190	799.64
EN_B18	19.9	19.9	60	0.0000237606	0.0220	925.90
EN_B19	19.9	19.9	60	0.0000237606	0.0225	946.95
EN_B20	19.9	19.8	60	0.0000236412	0.0220	930.58

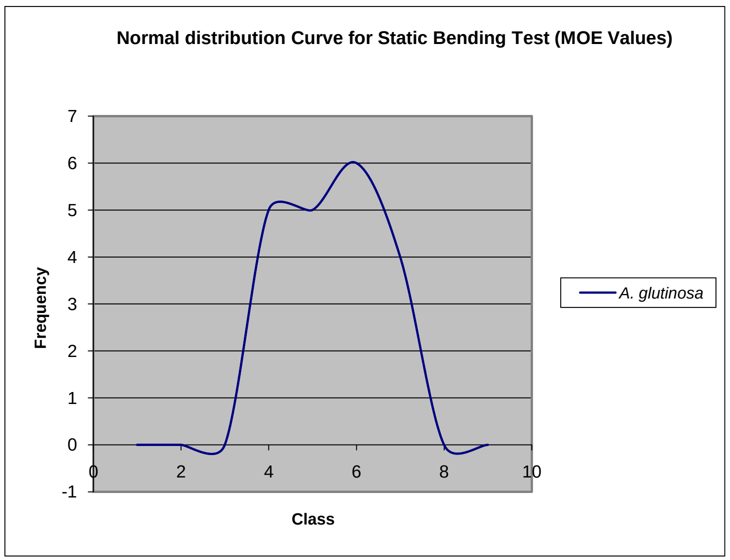
Average	919.74
Std. Dev.	63.21

Appendix 2 - Graphical Presentation of Test Data

Graphical presentation for MOE tests on common alder

Class	Range	Frequency
1	6070.02 - 6656.15	0
2	6656.16 - 7242.27	0
3	7242.28 - 7828.40	0
4	7828.41 - 8414.53	5
5	8414.54 - 9000.66	5
6	9000.67 - 9586.79	6
7	9586.80 - 10172.92	4
8	10172.93 - 10759.05	0
9	10759.06 - 11345.18	0

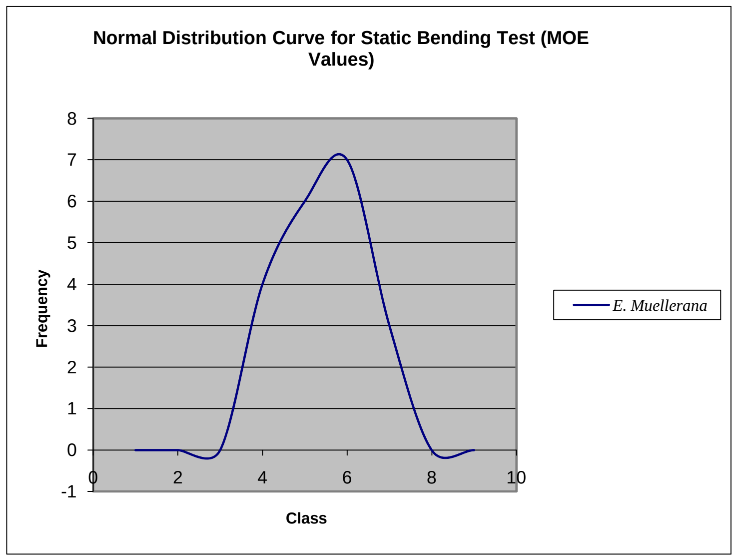
Results (N/mm^2)	
Mean	8707.61
Standard Deviation	586.13



Graphical presentation for MOE tests on *E. muellerana*

Class	Range	Frequency
1	7708.28 - 9688.27	0
2	9688.28 - 11668.26	0
3	11668.27 - 13648.25	0
4	13648.26 - 15628.24	4
5	15628.25 - 17608.23	6
6	17608.24 - 19588.22	7
7	19588.23 - 21568.21	3
8	21568.22 - 23548.20	0
9	23548.21 - 25528.19	0

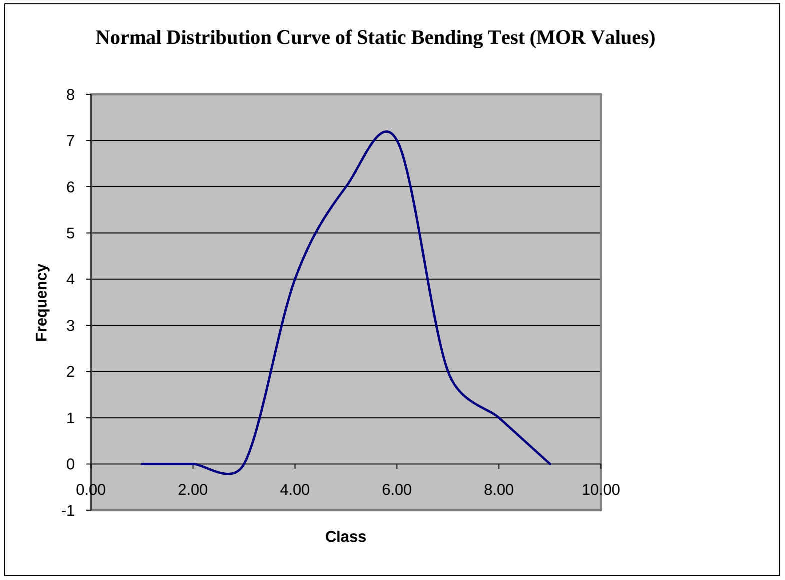
Results (N/mm^2)	
Mean	16618.25
Standard Deviation	1979.99



Graphical presentation for MOR tests on common alder

Class	Range	Frequency
1	60.36 - 65.29	0
2	65.30 - 70.23	0
3	70.24 - 75.17	0
4	75.18 - 80.11	4
5	80.12 - 85.05	6
6	85.06 - 89.99	7
7	90.00 - 94.92	2
8	94.93 - 99.86	1
9	99.87 - 104.80	0

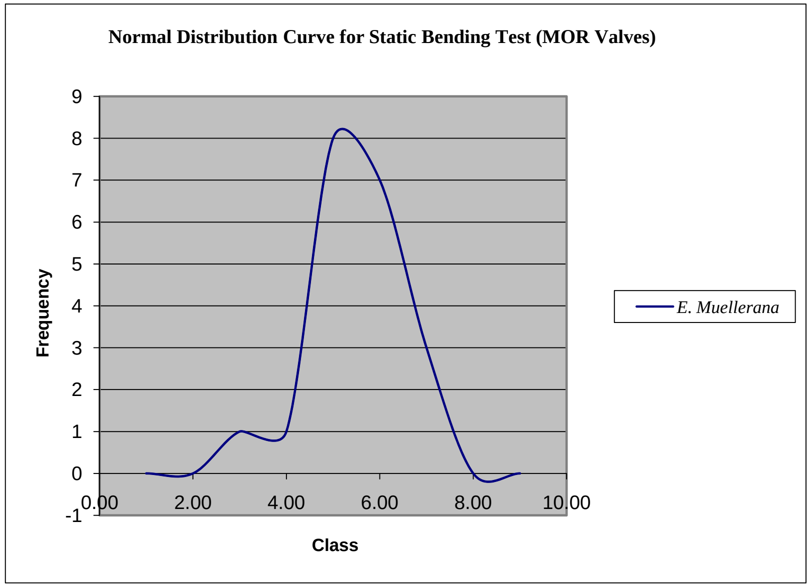
Results (N/mm^2)	
Mean	**82.59**
Standard Deviation	**4.94**



Graphical presentation for MOR tests on *E. muellerana*

Class	Range	Frequency
1	70.98 - 88.92	0
2	88.93 - 106.88	0
3	106.89 - 124.83	1
4	124.84 - 142.78	1
5	142.79 - 160.73	8
6	160.74 - 178.68	7
7	178.69 - 196.63	3
8	196.64 - 214.58	0
9	214.59 - 232.53	0

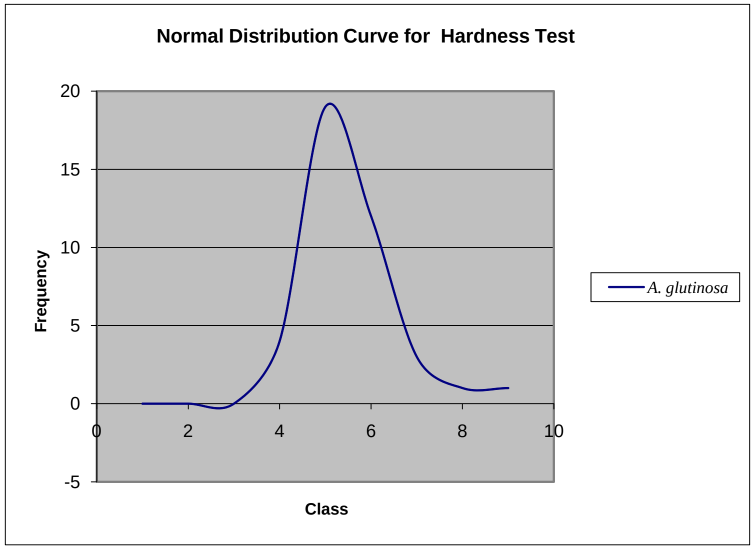
Results (N/mm^2)	
Mean	151.76
Standard Deviation	17.95



Graphical presentation for hardness tests on common alder

Class	Range	Frequency
1	1201.75 - 1440.67	0
2	1440.68 - 1679.60	0
3	1679.61 - 1918.53	0
4	1918.54 - 2157.45	4
5	2157.46 - 2396.38	19
6	2396.39 - 2635.31	12
7	2635.32 - 2874.24	3
8	2874.25 - 3113.17	1
9	3113.18 - 3352.10	1

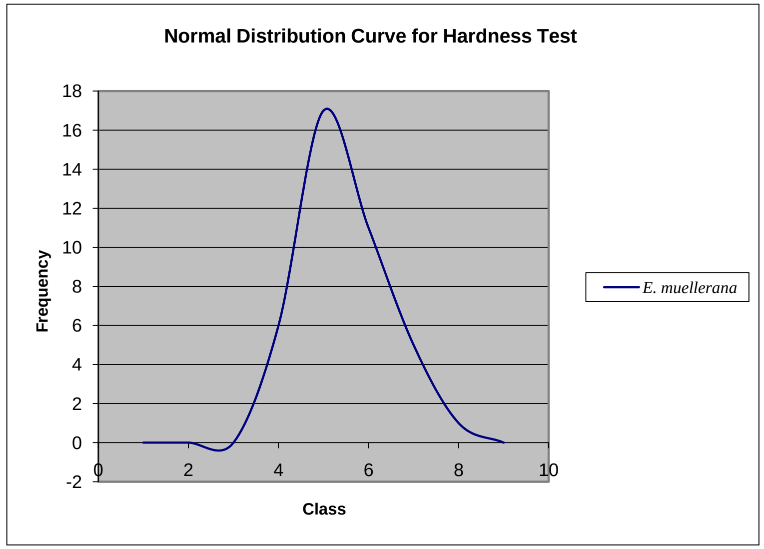
Results (N)	
Mean	2276.90
Standard Deviation	238.90



Graphical presentation for hardness tests on *E. muellerana*

Class	Range	Frequency
1	563.48 - 1863.15	0
2	1863.16 - 3162.82	0
3	3162.83 - 4462.50	0
4	4462.51 - 5762.17	6
5	5762.18 - 7061.85	17
6	7061.86 - 8361.53	11
7	8361.54 - 9661.20	5
8	9661.21 - 10960.88	1
9	10960.89 - 12260.56	0

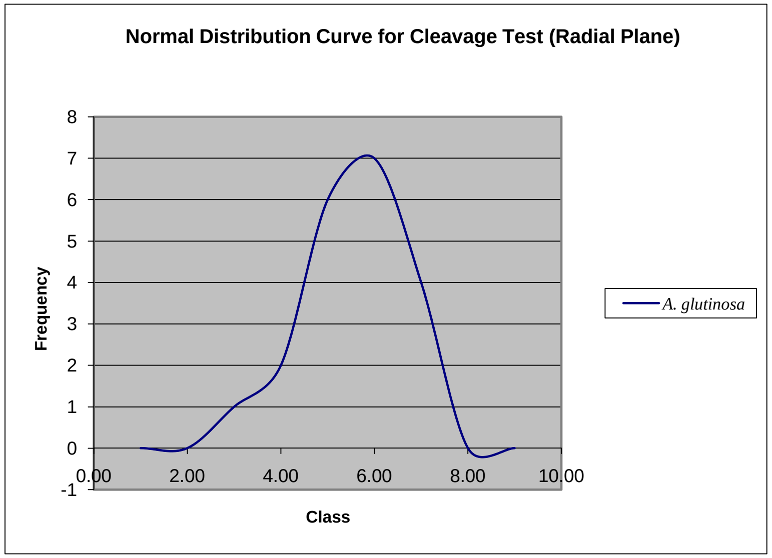
Results (N)	
Mean	6412.00
Standard Deviation	1299.70



Graphical presentation for cleavage (radial) tests on common alder

Class	Range	Frequency
1	4.32 - 5.93	0
2	5.94 - 7.54	0
3	7.55 - 9.15	1
4	9.16 - 10.76	2
5	10.77 - 12.37	6
6	12.38 - 13.99	7
7	14.00 - 15.60	4
8	15.61 - 17.21	0
9	17.22 - 18.82	0

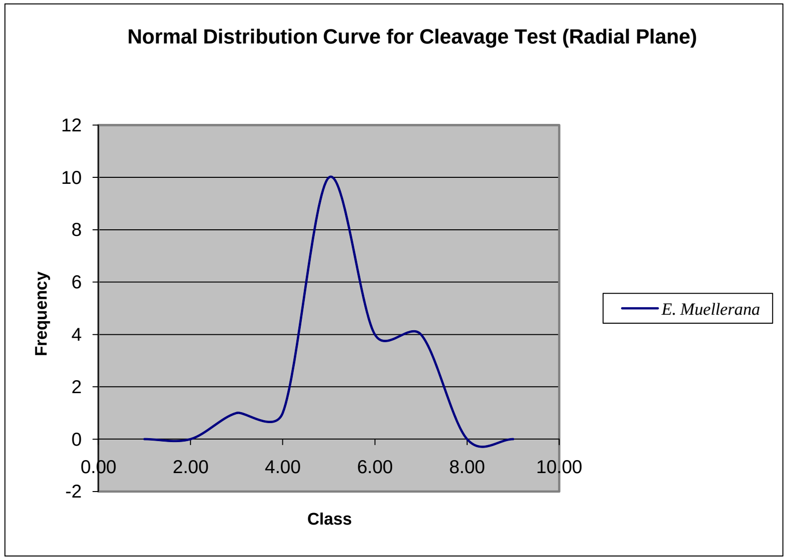
Results (N/mm Width)	
Mean	11.58
Standard Deviation	1.61



Graphical presentation for cleavage (radial) tests on *E. muellerana*

Class	Range	Frequency
1	8.76 - 12.53	0
2	12.54 - 16.30	0
3	16.31 - 20.08	1
4	20.09 - 23.86	1
5	23.87 - 27.64	10
6	27.65 - 31.42	4
7	31.43 - 35.19	4
8	35.20 - 38.97	0
9	38.98 - 42.75	0

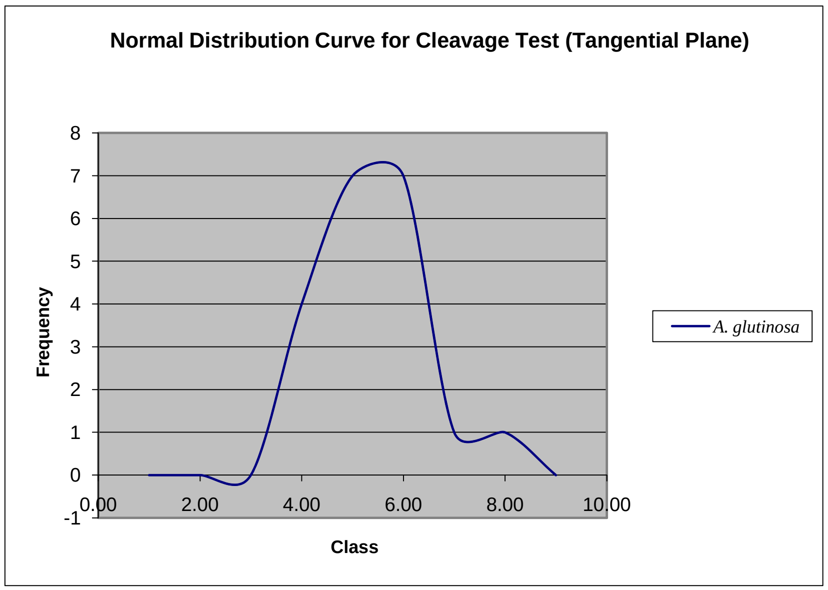
Results (N/mm Width)	
Mean	25.76
Standard Deviation	3.78



Graphical presentation for cleavage (tangential) tests on common alder

Class	Range	Frequency
1	5.93 - 7.20	0
2	7.21 - 8.48	0
3	8.49 - 9.75	0
4	9.76 - 11.03	4
5	11.04 - 12.31	7
6	12.32 - 13.58	7
7	13.59 - 14.86	1
8	14.87 - 16.13	1
9	16.14 - 17.41	0

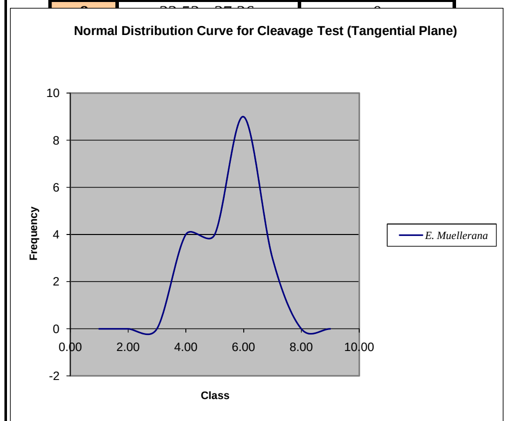
Results (N/mm Width)	
Mean	**11.68**
Standard Deviation	**1.28**



Graphical presentation for cleavage (tangential) tests on *E. muellerana*

Class	Range	Frequency
1	6.65 - 10.48	0
2	10.49 - 14.32	0
3	14.33 - 18.16	0
4	18.17 - 22.00	4
5	22.01 - 25.84	4
6	25.85 - 29.68	9
7	29.69 - 33.52	3
[illegible]	[illegible]	[illegible]

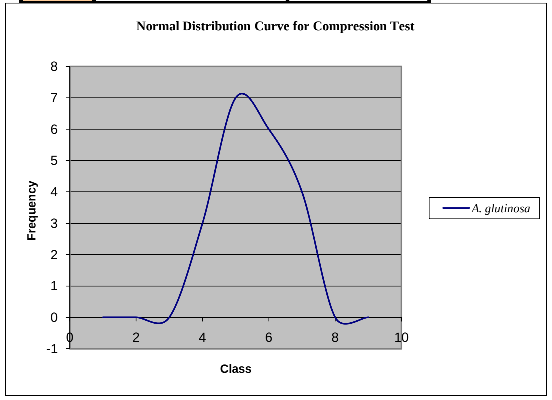
Results (N/mm Width)	
Mean	**23.93**
Standard Deviation	**3.84**



Graphical presentation for compression tests on common alder

Class	Range	Frequency
1	27.53 - 30.05	0
2	30.06 - 32.57	0
3	32.58 - 35.10	0
4	35.11 - 37.63	3
5	37.64 - 40.16	7
6	40.17 - 42.69	6
7	42.70 - 45.22	4
8	45.23 - 47.75	0

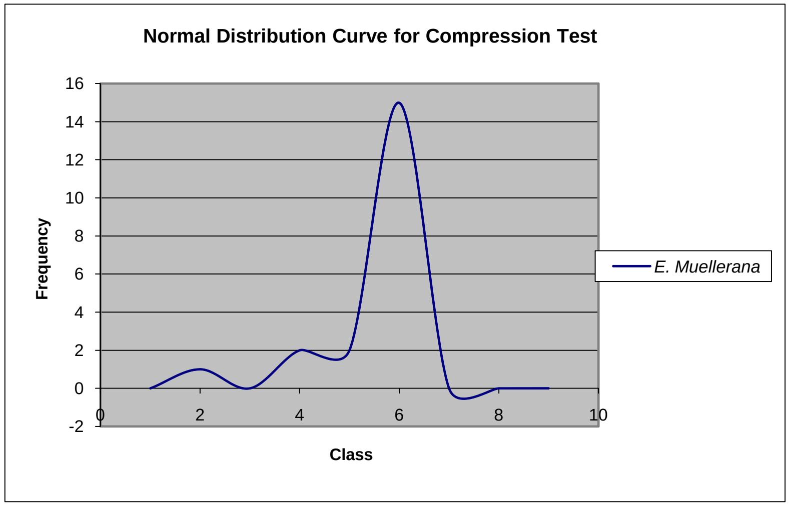
Results (N/mm^2)	
Mean	38.91
Standard Deviation	2.53



Graphical presentation for compression tests on *E. muellerana*

Class	Range	Frequency
1	63.30 - 65.33	0
2	65.34 - 67.36	1
3	67.37 - 69.40	0
4	69.41 - 71.43	2
5	71.44 - 73.47	2
6	73.48 - 75.50	15
7	75.51 - 77.54	0
8	77.55 - 79.57	0
9	79.58 - 81.61	0

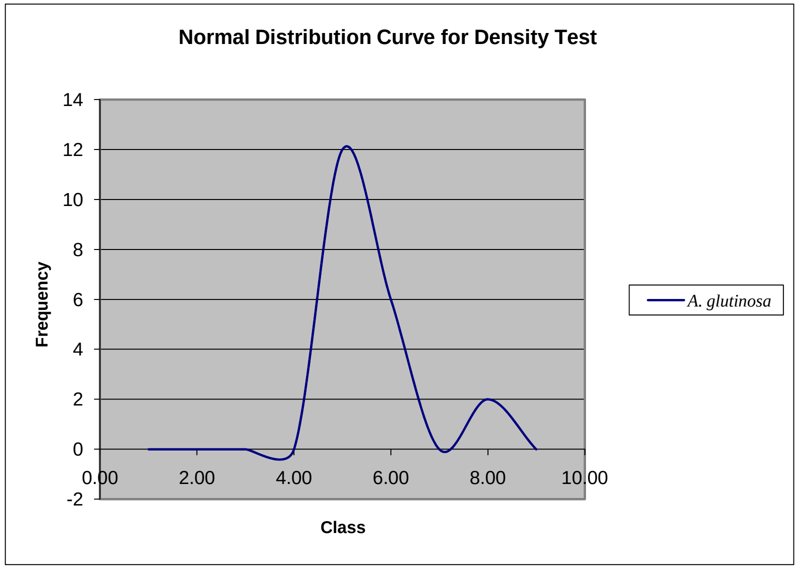
Results (N/mm^2)	
Mean	72.46
Standard Deviation	2.04



Graphical presentation for density tests on common alder

Class	Range	Frequency
1	407.04 - 421.53	0
2	421.54 - 436.03	0
3	436.04 -450.53	0
4	450.54 - 465.03	0
5	465.04 - 479.53	12
6	479.54 - 494.03	6
7	494.04 - 508.53	0
8	508.54 - 523.03	2
9	523.04 - 537.53	0

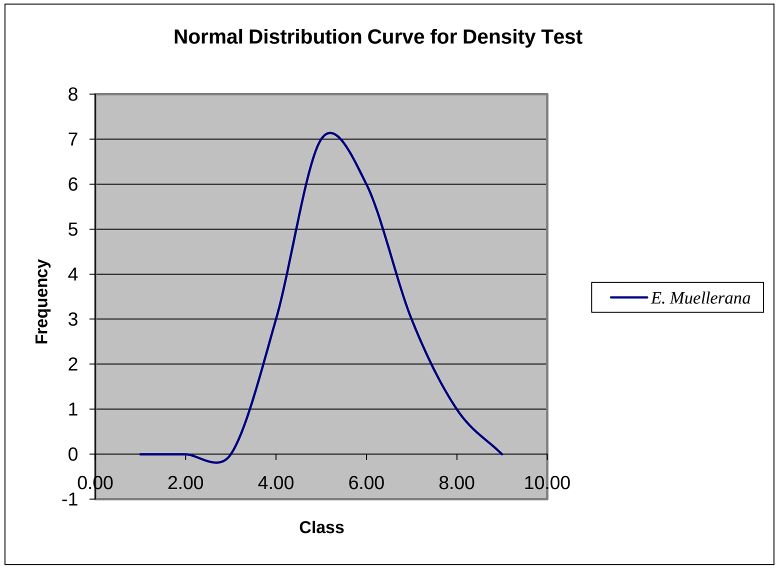
Results (Kg/m^3)	
Mean	**472.29**
Standard Deviation	**14.50**



Graphical presentation for density tests on *E. muellerana*

Class	Range	Frequency
1	635.27 - 698.48	0
2	698.49 - 761.69	0
3	761.70 - 824.90	0
4	824.91 - 888.12	3
5	888.13 - 951.33	7
6	951.34 - 1014.55	6
7	1014.56 - 1077.76	3
8	1077.77 - 1140.98	1
9	1140.99 - 1204.19	0

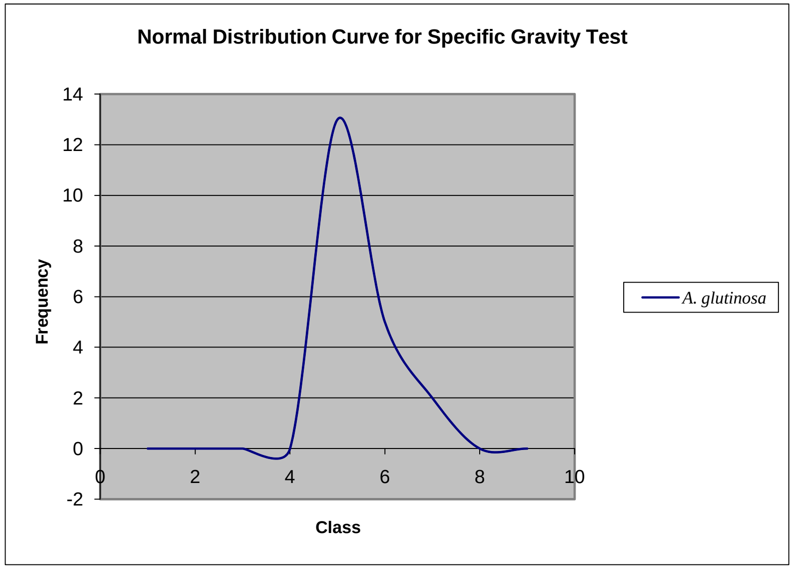
Results (Kg/m^3)	
Mean	**919.74**
Standard Deviation	**63.21**



Graphical presentation for specific gravity tests on common alder

Class	Range	Frequency
1	0.364 - 0.377	0
2	0.378 - 0.392	0
3	0.393 - 0.406	0
4	0.407 - 0.421	0
5	0.422 - 0.435	13
6	0.436 - 0.450	5
7	0.451 - 0.465	2
8	0.466 - .0479	0
9	0.480 - 0.494	0

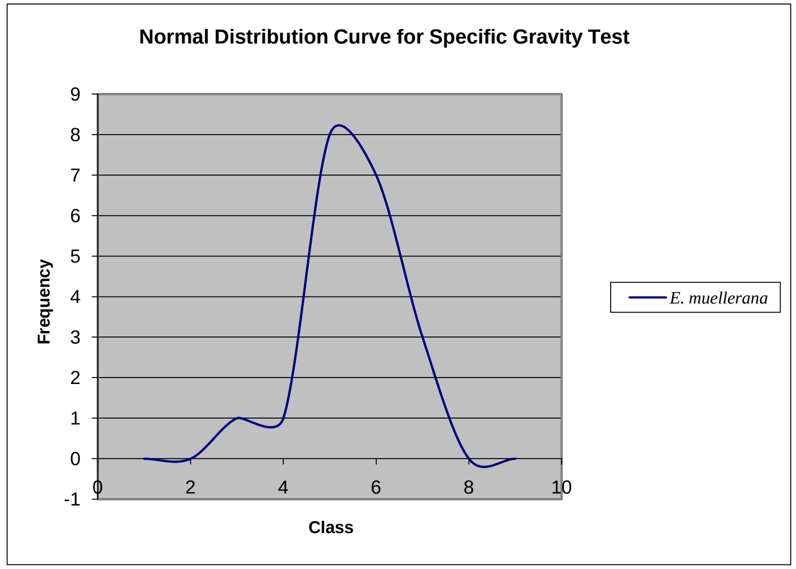
Results	
Mean	0.429
Standard Deviation	0.015



Graphical presentation for specific gravity tests on *E. muellerana*

Class	Range	Frequency
1	0.562 - 0.621	0
2	0.622 - 0.681	0
3	0.682 - 0.742	1
4	0.743 - 0.802	1
5	0.803 - 0.862	8
6	0.863 - 0.922	7
7	0.923 - 0.983	3
8	0.984 - 1.043	0
9	1.044 - 1.103	0

Results	
Mean	0.83
Standard Deviation	0.06



Appendix 3 – BS373:1957 – Formulae for calculation of results

Appendix A Formulae and methods of computing physical properties

Moisture content.

1) Data:

W_1 = Weight of sample at test in grammes.

W_0 = Oven-dry weight of sample in grammes.

2) Property to be computed:

Percentage – Moisture content

$$X = \frac{W_1 - W_0}{W_0} \upsilon 100$$

Specific gravity.

1) Data:

W_1 = Weight of sample at test in grammes.

W_0 = Weight of sample, oven-dry, in grammes.

V_1 = Volume of sample at test in cubic centimeters.

l = Length in inches.

b = Breadth in inches.

h = Height in inches.

2) Properties to be computed:

i) Specific gravity at test

$$S_1 = \frac{W_1}{V_1} \text{ or } \frac{W_1}{l \upsilon b \upsilon h \upsilon 16.39}$$

ii) Nominal specific gravity, oven-dry

$$S_0 = \frac{W_0}{V_1} \text{ or } \frac{S_1 \upsilon 100}{x + 100}$$

iii) Density at test and nominal density, oven-dry, in pounds per cubic foot obtained from i) and ii) by multiplication with 62.35 $(x + 100)/100$ where x is the percentage moisture content.

NOTE The weight of wood in a given volume changes with the shrinkage and swelling caused by changes in moisture and the term specific gravity as used in the testing of timber is indefinite unless the conditions under which it is determined are specified. The convention of using a "nominal" specific gravity, based on the volume of the test piece when tested and its weight when oven-dried, is observed.

Mechanical properties

Static bending.

1) Data:

i) Dimensions of test-piece:

b = Breadth in inches.[a]

h = Depth in inches.[a]

l = Gauge length in inches[a] (method b).

a = distance in inches[a] between point of application of load and support = 6 in. (method b).

L = span (method a) = 28 in. or 28 cm.

[a] Centimetre measurement may be used with appropriate conversion factors.

ii) Load-deflection curve from which are derived:

P = Maximum load in pounds.

P' = Load in pounds at limit of proportionality.[a]

Δ' = Deflection in inches at mid length at limit of proportionality.

A' = Area in square inches of load-deflection curve to limit of proportionality.

A = Area in square inches of load-deflection curve to maximum load.

A'' = Area in square inches of load-deflection curve when a deflection of 6 in. has been reached or the load after passing a maximum value has been reduced to 200 lb, whichever occurs first (method a: 2 in. standard). For method a: 2 cm standard, the limiting deflection is 6 cm and the limiting load one tenth of the maximum load.

C = Area constant in inch pounds, i.e. the energy represented by 1 sq. in. on the load-deflection diagram; it is equal to the load in pounds represented by 1 in. ordinate multiplied by the deflection in inches represented by 1 in. abscissa.

[a] The limit of proportionality shall be taken as that point in the stress-strain diagram at which the curve deviates from the straight line.

2) Properties to be computed:

		Method a (Figure 1a)	Method b (Figure 1b)
i)	Fibre stress in pounds per square inch at limit of proportionality (F.S. at L.P.)	$\frac{3P'L}{2bh^2}$	$\frac{3P'a}{bh^2}$
ii)	Equivalent 'fibre stress in pounds per square inch at maximum load (F.S. at M.L.)	$\frac{3PL}{2bh^2}$	$\frac{3Pa}{bh^2}$
iii)	Modulus of elasticity in pounds per square inch	$\frac{P'L^2}{4\Delta'bh^2}$	$\frac{3P'al^2}{4\Delta'bh^2}$
iv)	Horizontal shear stress in pounds per square inch on neutral plane at limit of proportionality (S. at L.P.)	$\frac{3P'}{4bh}$	At centre = O At ends = $\frac{3P'}{4bh}$
v)	Horizontal shear stress in pounds per square inch on neutral plane at maximum load. (S. at M.L.)	$\frac{3P}{4bh}$	At centre = O At ends = $\frac{3P}{4bh}$
vi)	Work in inch pounds per cubic inch to limit of proportionality. (Elastic resilience).	$\frac{CA'}{Lbh}$	$\frac{CA'}{lbh}$
vii)	Work in inch pounds per cubic inch to maximum load (Wk to M.L.)	$\frac{CA}{Lbh}$	Not computed
viii)	Total work in inch pounds per cubic inch. (Total Wk.)	$\frac{CA''}{Lbh}$	Not computed

Impact bending.

1) Data:

i) Dimensions of test piece:

b = Breadth in inches or cm

h = Depth in inches or cm

L = Span (28 in. or 24 cm).

ii) Weight of tup W = 50 lb. 2 in. standard

or = 3.3 lb 2 cm standard

iii) D = Height of drop in inches to produce complete failure or a deflection of 6 in. (2 in. standard) or 6 cm (2 cm standard).

Compression parallel to grain.

1) Data:

i) Dimensions of test piece:

A = Cross-sectional area in square inches.

L = Gauge length in inches between extensometer points.

The maximum values of L shall be 6 in. for the test piece 8 in. long, and 4 cm for the test piece 6 cm long.

ii) Load-compression curves from which are derived:

P' = Load in pounds at limit of proportionality.

P = Maximum crushing load in pounds.

Δ' = Deformation in inches at limit of proportionality.

2) Properties to be computed:

i) Compressive stress at limit of proportionality (C.S. at L.P.)

$= \frac{P'}{A}$ lb εsq. in.

ii) Compressive stress at maximum load (C.S. at M.L.)

$= \frac{P}{A}$ lb εsq. in.

iii) Modulus of elasticity (E).

$= \frac{P'L}{\Delta'A}$ lb εsq. in.

Compression perpendicular to grain

1) Data:

i) Dimensions of test piece:

A = Area of cross-section normal to direction of load in square inches.

ii) Direction of load, either radial or tangential.

iii) Load-compression curve from which is derived

P' = Load at limit of proportionality.

P'' = Load at 0.1 in. compression.

P = Maximum load if reached at a compression less than 0.1 in.

2) Properties to be computed:

i) Compressive stress at limit of proportionality (C.S. at L.P.).

$= \frac{P'}{A}$ lb εsq. in.

ii) Compressive stress at compression of 0.1 in. (strain = 0.05) (C.S.)

$= \frac{P''}{A}$ lb εsq. in.

iii) Crushing strength at maximum load (C.S. at M.L.).

$= \frac{P}{A}$ lb εsq. in.

The direction of loading, either radial or tangential, must be stated.

Shear parallel to grain.

1) Data:

i) bh = Area in shear in square inches.

ii) Surface of shear failure, radial or tangential.

iii) P = Maximum load in pounds causing shear.

2) Property to be computed:

Apparent average shearing stress (A.A.S.S.).

$= \frac{P}{bh}$ lb εsq. in.(radial or tangential)

Cleavage test.

1) Data:

i) b = Breadth of test piece in inches.

ii) Plane of cleavage, either radial or tangential.

iii) P = Maximum load in pounds causing cleavage.

2) Property to be computed:

Strength per inch of width to resist splitting, i.e. cleavage

$= \frac{P}{b}$ pounds per inch width (radial or tangential)

Tension parallel to grain.

1) Data:

i) A = Minimum area of cross-section of test length.

L = Gauge length in inches between extensometer points.

ii) Load-extension curve from which are derived:

P' = Load in pounds at limit of proportionality.

P = Maximum load in pounds.

Δ' = Extension in inches at limit of proportionality.

2) Properties to be computed:

i) Tensile stress at limit of proportionality (T.S. at L.P.).

$= \frac{P'}{A}$ lb εsq. in.

ii) Tensile stress at maximum load (T.S. at M.L.).

iii) Modulus of elasticity (E)

$= \frac{P'L}{\Delta A'}$ lb εsq. in.

Tension perpendicular to grain.

1) Data:

i) A = Area of cross-section of test length in square inches.

ii) Direction of applied tensile load, either radial or tangential.

iii) P = Maximum load.

2) Property to be computed:

Tensile strength, radial [T.S. (R)] or tangential [T.S. (T)].

$= \frac{P}{A}$

Appendix 4 - COFORD Alder Working Group

COFORD

NATIONAL COUNCIL FOR FOREST RESEARCH & DEVELOPMENT

Forestry and Wood Update

DECEMBER 2004 - Volume 4 Number 12

CONTENTS

COFORD
Arena House
Arena Road
Sandyford
Dublin 18
Ireland

Tel: +353 - 1 - 2130725
Fax: +353 - 1 - 2130611
Email: info@coford.ie
Web: www.coford.ie

100 years of Irish Forestry

NDP NATIONAL DEVELOPMENT PLAN

COFORD's activities are funded by the Irish Government under the National Development Plan, 2000-2006.

Alder Working Group

Alder is a scheduled species for grant aid under the current forestry schemes. As it is one of the native broadleaf species, there has been a major increase in demand for the species over the past number of years. The Forestry Scheme Manual suggests the use of native material as first choice, but plants from many parts of Europe are finding their way into our forests. Some of these sources may be of unsuitable or dubious origin. For instance, some roadside planting of alder in recent times has been very susceptible to dieback.

Alder is considered easy to establish and is unattractive to deer and grey squirrel. As the push for more broadleaves intensifies with the proposed increase from 20% to 30% by 2006, alder is likely to feature prominently and seed supply is likely to become even more problematic. As stated, much of the reproductive material used is of foreign, mainly UK and European, origin. In some way this defeats the objective of increased use of native species and, in any event, Irish material is much more adapted to our growing conditions.

To address these and other issues, COFORD established a working group earlier this year. The most recent meeting of the group took place in Carrick-on-Shannon and was followed by visits to a number of alder stands in the vicinity.

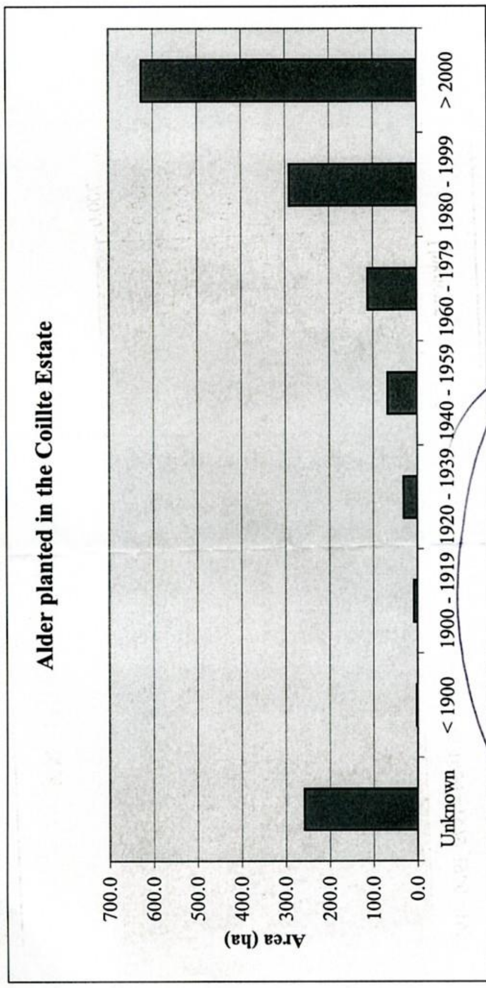
If you require further information on any aspect of the species or have information on a good stand or individual trees please visit the COFORD web site where you can download information on alder survey that is underway (www.coford.ie/AlderSurvey.pdf), or contact John Fennessy at 01-2130725, email: john.fennessy@coford.ie.

Appendix 5 - Members of the Alder Working Group

Name	Address	Organisation
Mr Noel Kiernan,	**Cartron, Drumlish Co Longford**	**Forestry Consultant**
Mr Dermot O'Donovan	**GMIT Letterfrack Co Galway**	**Lecturer**
Mr Pat Doody	**Ballintemple Ardattin Co Carlow**	**Coillte**
Mr Bernard Carey	**Ballinahinch, Boydyke Co Clare**	**Mid Western Forestry Services**
Mr Liam Kelly	**Bellview Dublin Road Mullingar Co Westmeath**	**Teagasc**
Mr Senan Kelly	**Government Buildings Cranmore Road Sligo**	**Forest Service**
Dr Elaine O'Connor	**Kinsealy Research Centre Malahide Road Dublin 17**	**Teagasc**
Mr Derek Felton	**Woodstock Seed Violet Bungalow Shankill Co Dublin**	**Forestry Consultant**
John Fennessy	**Arena House Arena Road Sandyford Dublin 18**	**COFORD**

Appendix 6 - Alder data from Coillte

Unknown	< 1900	1900 - 1919	1920 - 1939	1940 - 1959	1960 - 1979	1980 - 1999	> 2000
257.8	2.2	8.4	31.2	66.6	111.8	290.1	625.6



John Goss
01-6472300

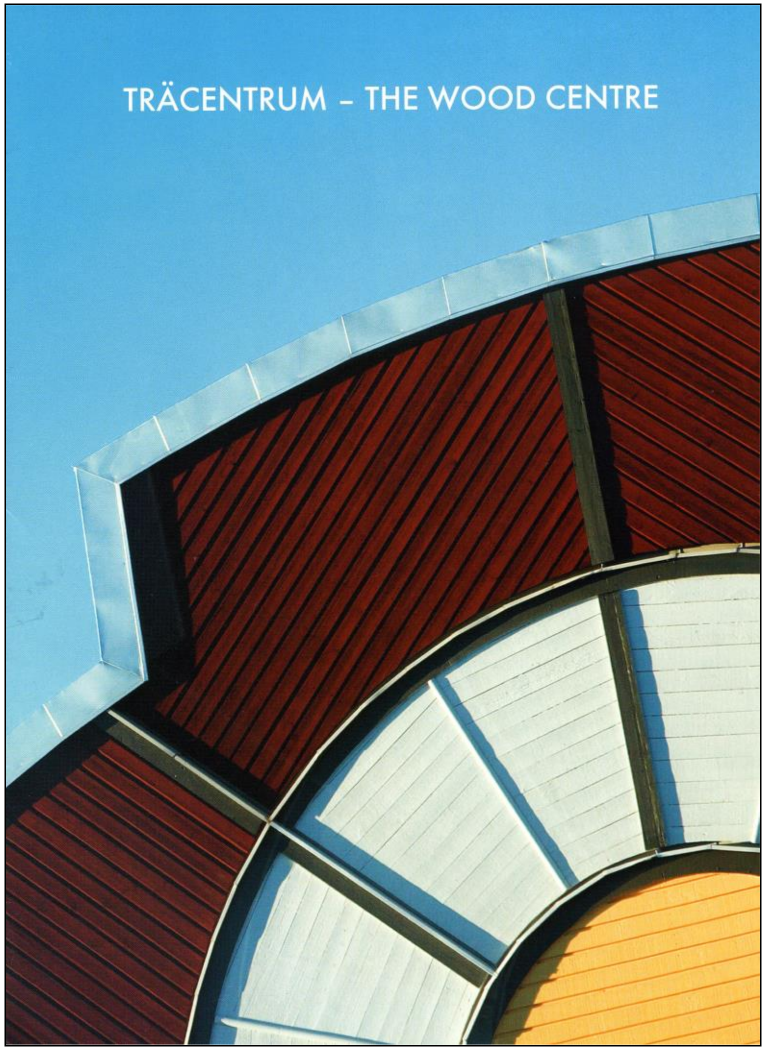
Dermot O'Donovan
GMIT
Letterfrack
Co Galway,

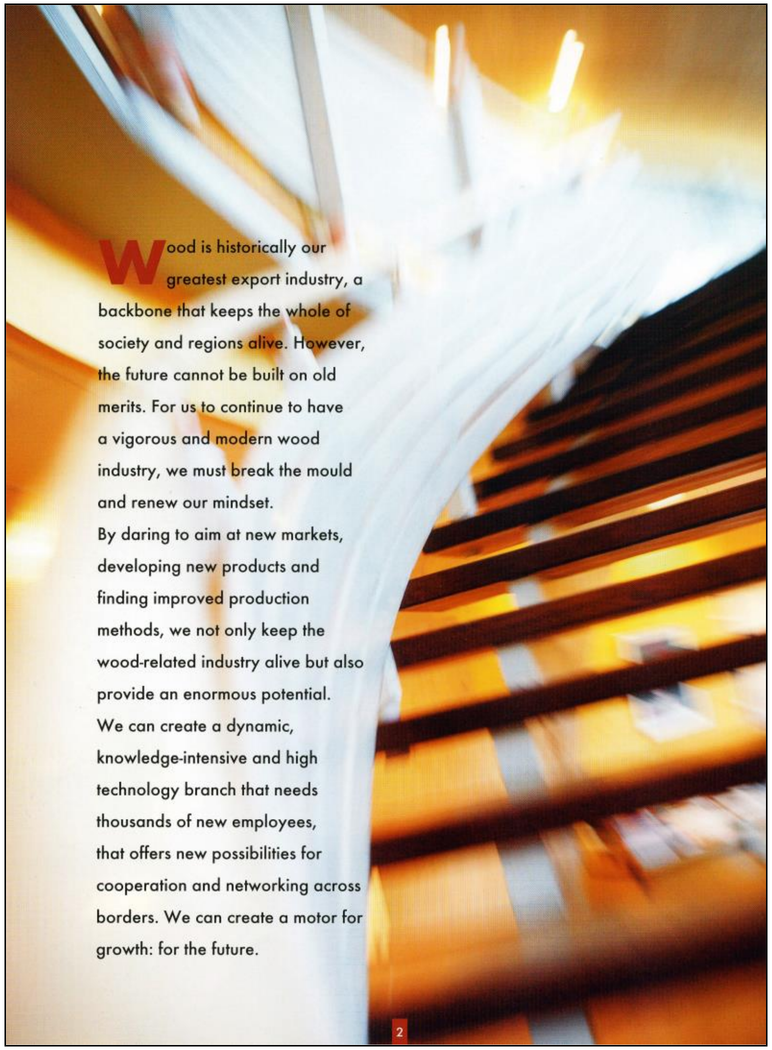
Dermot,

This is the best I could do on the Alder figures. Hope its what you need. Many thanks.

S.McGuinness

Appendix 7 - Träcentrum (Wood Centre), Nässjo, Sweden





Wood is historically our greatest export industry, a backbone that keeps the whole of society and regions alive. However, the future cannot be built on old merits. For us to continue to have a vigorous and modern wood industry, we must break the mould and renew our mindset.

By daring to aim at new markets, developing new products and finding improved production methods, we not only keep the wood-related industry alive but also provide an enormous potential. We can create a dynamic, knowledge-intensive and high technology branch that needs thousands of new employees, that offers new possibilities for cooperation and networking across borders. We can create a motor for growth: for the future.

2

Wood has many different areas of use, for example, as the basic material for a kitchen worktop or furnishing items in a boat.

A DAY AT TRÄCENTRUM – THE WOOD CENTRE

The day has hardly begun when Bengt goes in through the Träcentrum entrance. Bengt is the MD of a company that delivers furnishing items in wood, primarily to the furnishing and boat industries. The company recently initiated cooperation with Träcentrum, with the objective of increasing sales by means of improved **marketing and product development.**

Through Träcentrum Business Link, Bengt has gained valuable contacts with three other companies and together they deliver furnishings to a large conference establishment in Norrköping. Today Bengt is going to meet a project manager to get information about an exhibition that is soon being run at Träcentrum. For Bengt, the exhibition is an important event. Träcentrum´s extensive network contains many potential customers and there are also possibilities of meeting colleagues in the branch.

Helena and Lasse go through the corridor to the Träcentrum workshop, past light and pleasant rooms filled with students. The vocational college and the university college Höglandet is running at full speed with practical and theoretical subjects. In the daytime Helena and Lasse work as machine operators and shall for three days improve their knowledge of CNC technology. In cooperation with Träcentrum, their companies has produced a development plan where **company-adapted competence development** for the staff is an important piece in the jigsaw puzzle. The first part of the training is carried out at Träcentrum and then continues at the company ▸▸▸

PROJECT ACTIVITIES

All projects that are conducted at Träcentrum have a common aim to, in a concrete way, strengthen and develop the business activities – products and production within the wood-related industry. Our project activities have produced very good results and new projects are started on a regular basis. Some examples are:

- Benchmarking
- Business-promoting networks
- Hardwood – new material, new markets
- Träcentrum Business Link
- Technology development service
- Method development for knowledge transfer

THE RIGHT KNOWLEDGE IN THE RIGHT WAY

New knowledge makes people and companies grow. Träcentrum produces company-adapted training within focal areas – business development, product and production development, tailored in close relation to companies' operations and requirements. Time and place is decided by the customers. The training can be utilized by several companies at the same time, or is conducted for a specific customer. Training examples:

- Practical sales training
- CNC technology
- Surface treatment
- Development of working environment
- Material theory, Wood
- 3D CAD

3

UNIQUE TRAINING WITH UNIQUE RESULTS

More than 350 people study at Träcentrum within upper secondary education training, qualified vocational training and independent university college courses. Throughout their entire training period the students have very close relationships with companies throughout the whole of Sweden, for example, through projects with firm links with reality as well as long practical periods. This close cooperation contributes to the fact that over 80% of the students have work after their completed studies.

CONFERENCE, KICK-OFF, EXHIBITION AND MEETING

Träcentrum is an experienced arranger of conferences, kick-off's, seminars, exhibitions, parties, concerts, customer lunches and other meetings for companies and private people. For further information, please refer to our conference brochure.

COOPERATION AND NETWORKS

Cooperation is the basis for all activities at Träcentrum. Everything we do is conducted in close cooperation with companies, branch institutes, university colleges, authorities and interest organizations. Träcentrum brings competence together and promotes a purposeful and long-term development of the wood-related industry. In addition, Träcentrum is included in several networks and for this reason can offer companies an important springboard towards new markets, customers and knowledge. We also contribute to increased networking within the wood-related industry.

THE INSPIRATIONAL ENVIRONMENT IS WELL APPRECIATED

▸▸▸ Out in the Centre hall breakfast coffee is being served to 50 hungry participants who will soon take their seats for the first session of a seminar on the working environment. Johanna takes the opportunity to admire the view through one of the glass walls. She is responsible for training at a national industrial company and regularly uses Träcentrum´s facilities for **training programs.** The inspirational environment is generally well appreciated by everyone who takes part and thanks to Nässjö's good traffic connections it is easy to assemble people from several regions.

When Bengt comes back down, there is a buzz of activity with students and other visitors in the Centre hall. He pauses and looks at some of the products that are exhibited. There are staircases, sofas and completely new innovations in wood combined with other material. Bengt moves on to check out the sizes of the stands and other details prior to the **exhibition.** On the way he chats with a couple of industry colleagues. They are here to get information about business-promoting networks, where smaller **suppliers cooperate** to expand in the market.

Several networks have been started through Träcentrum. It operates as a coordinator in the network and assists, for example, in finding new market channels and linking external resources. ▸▸▸

At Träcentrum there are the facilities for many different types of conferences, meetings and lectures. Whether it involves two or two hundred people, a fine experience awaits here.

4

Trăcentrum is a natural meeting place. Cooperation and networks are important elements in the activities.

5

PRODUCT DEVELOPMENT

Träcentrum is a pattern and reference facility. Our training halls and workshops contain modern equipment for, e.g, CNC & CAD technology, surface treatment, etc. Here it is possible for companies, students and other interested parties to test different methods for the development of products. The result in the long run will be increased competitiveness and profitability.

A NEUTRAL PARTNER

Träcentrum is a neutral partner – a resource that takes over when a company's own resources are no longer sufficient. Development is vital and we create concrete projects firmly established in existing requirements, primarily within business development, product development and production. We are a speaking partner who helps companies to realize ideas, to find new markets and cooperation partners, to improve production and increase profitability. At the same time, we can assume the role of innovator and break new ground where opportunities exist. We are generalists who cooperate with specialists and with the help of a large contact network we can link together resources and competence to bring lasting results.

HERE CAN COMPANIES DEVELOP

▶▶▶ Helena and Lasse, who have just left their machines for a while, pass the library. Together with one of the trainers they sit down to discuss which improvements and **development possibilities** that CNC technology can contribute to their company. Both of them look forward to applying their new knowledge to their production. They also discuss the possibility of participating in more company-adapted training at Träcentrum, for example, within production techniques.

As the training day runs to an end Johanna goes through the list of those interested in the evening's activities. Several participants come forward and express their positive opinions on the day. On the way out Johanna waves to the conference hostess who is busy preparing an evening lecture on the development possibilities of hardwood. Hardwood is one of the areas where Träcentrum is associated with **special competence** and the lecture will deal with the development possibilities of the material and how it can be used by consumers and producers.

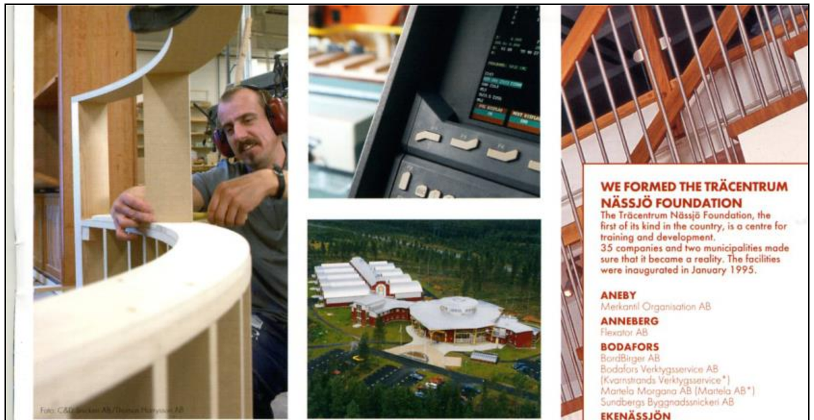
At the same time as the day visitors are on their way home, the evening guests begin to arrive. Among these are around 190 people who will visit the Regional Forestry Board's forestry evening. There is still full activity in the training halls since many students have chosen to stay for a few extra hours of study. At Träcentrum one day is hardly over before the next one begins. ■

YCC, Conceptual Car by Volvo. Wooden details from Svensson & Linnér.

6

New technology, design and untraditional product development are deciding factors in the modern wood industry.

Satellite from [illegible] Produktion AB



BE A PART OF TRÄCENTRUM –THE WOOD CENTRE

The Träcentrum Nässjö Foundation was formed in 1991 and, in addition to the original 37 founders, now engages a large number of companies from the whole of Sweden. Cooperation is the core of all the operations and our cooperation partners can be found at all levels of society, from trade and industry, to universities and authorities. With us you can participate in concrete development projects, in specially adapted and regular training or use the unique facilities for conferences and meetings. Irrespective of what you choose, you will be an active part of a continually growing centre for development and training. Our objective is naturally that even more companies shall gain concrete commercial benefits from Träcentrum and with your help we can develop even more. You are very welcome to visit Träcentrum!

For further information about our operations, please contact us or visit our homepage: www.tracentrum.se

WE FORMED THE TRÄCENTRUM NÄSSJÖ FOUNDATION

The Träcentrum Nässjö Foundation, the first of its kind in the country, is a centre for training and development.
35 companies and two municipalities made sure that it became a reality. The facilities were inaugurated in January 1995.

ANEBY
Merkantil Organisation AB

ANNEBERG
Flexator AB

BODAFORS
BordBirger AB
Bodafors Verktygsservice AB (Kvarnstrands Verktygsservice*)
Martela Morgana AB (Martela AB*)
Sundbergs Byggnadssnickeri AB

EKENÄSSJÖN
Ekenäs Träindustri AB

EKSJÖ
Eksjö Kommun

FORSERUM
Ceos Gross AB (CEOS industriprodukter*)

HJÄLTEVAD
Becker Acroma KB

HUSKVARNA
Karl Andersson & Söner AB
SYSteam Datakonsult AB (SYSteam AB*)

JÖNKÖPING
Ejderstedt & Fröding AB
Stora Byggprodukter AB (Vest-Wood AB*)

LUND
K-konsult Syd (Creacon HKAB*)

MALMBÄCK
Bodafors Trä AB
Br. Wigells Stolfabrik AB
Malmbäcks Intarsia AB
Malmbäcksverken AB

MJÖLBY
Högberg & Hultner i Mjölby AB

NÄSSJÖ
AB Sigfrid Stenberg
Törnbloms Display AB (ITAB Inredningar i Nässjö*)
J. Olof A. Hermansson
Lagerstedt & Berg Stafettpinnen AB (Lagerstedt & Berg AB*)
Laminatgrossisten i Nässjö AB (LG Collection AB*)
Nässjö Kommun
Rolf Burman AB
Rol Webo AB (ROL Inredningar AB*)
Samhall Högland AB (Samhall Brahe AB*)
Star Byggprodukter
Söderbergs Möbler AB
Br. Eriksson Trävaruaffär AB (Trä-Xet AB*)

RÖRVIK
Rörvikshus AB (Rörvikshus Sweden AB*)
Svensson & Linnér

SANDSJÖFORS
Sandsjöfors Modulbyggen AB (Moelven Byggmodul Sandsjöfors*)
Jobo Trä AB (Rörvik Timber Höglandet AB*)

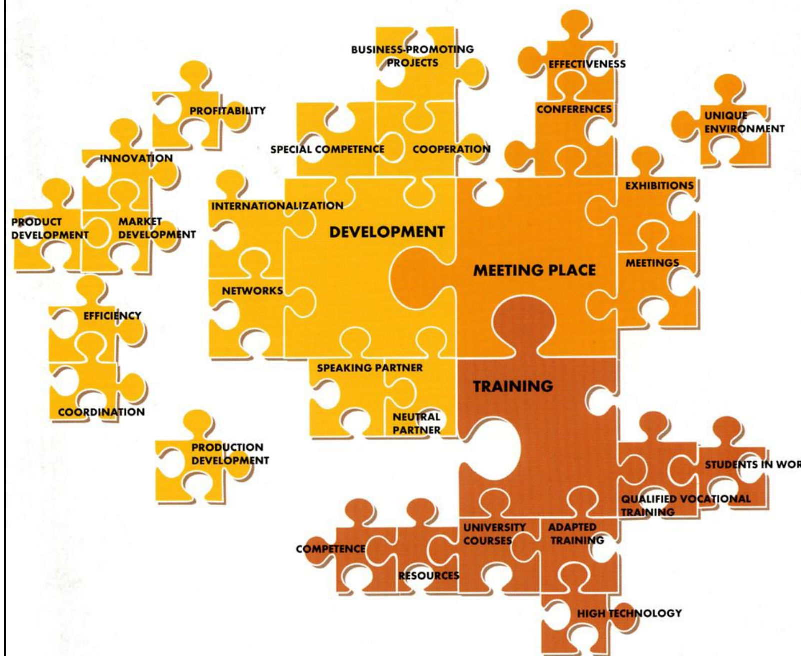
VRIGSTAD
CJ Möbler AB

* Present company name

7

THIS IS TRÄCENTRUM – THE WOOD CENTRE

The task of Träcentrum is to be a natural partner for the wood-related industry. By means of concrete projects, training and development efforts. By gathering knowledge and spreading it further, by finding new channels of cooperation and interfaces between trade and industry, the general public and other interested parties. By being a speaking partner, an innovator and a neutral partner. By being a natural meeting place.
In this way the profitability and strength of the wood-related industry will increase.



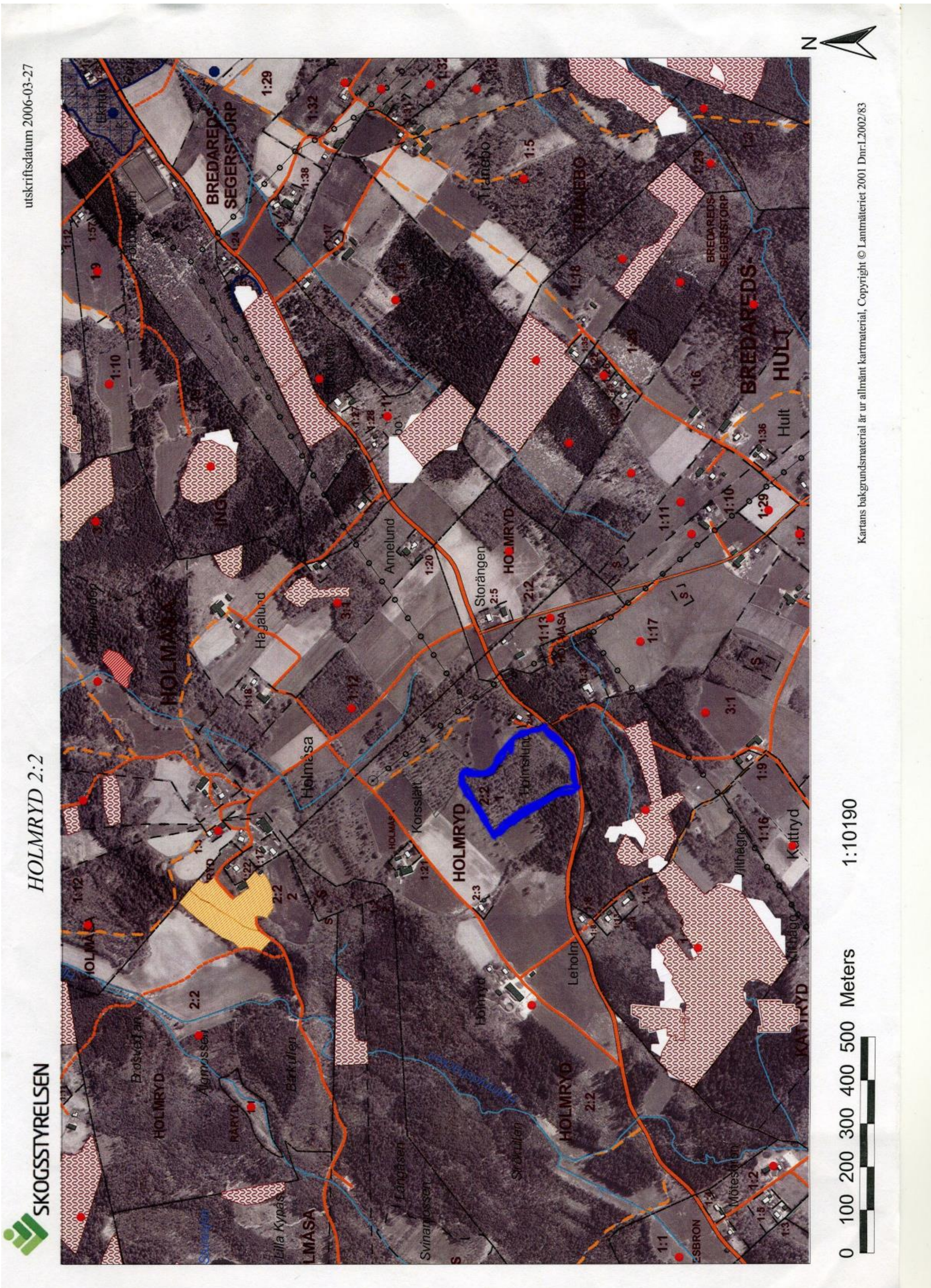
TRÄCENTRUM NÄSSJÖ

Mål 2 Södra

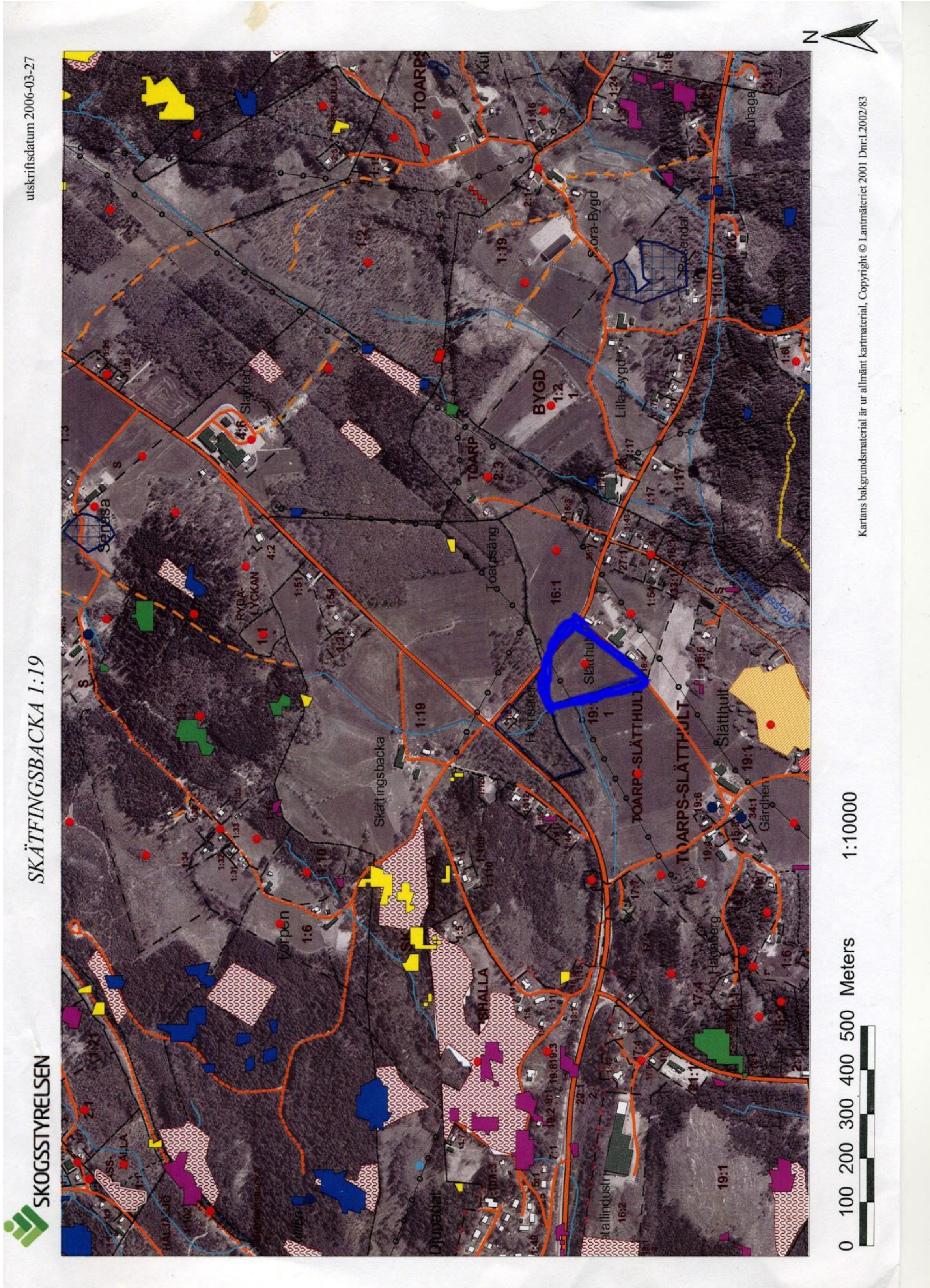
Projektet delfinansieras av EUROPEISKA UNIONEN
EG:s strukturfonder

Telephone: 0046 (0) 380-55 43 00. E-mail: info@tracentrum.se **www.tracentrum.se**

Appendix 8 - Site map for field trip in Sweden (Holmryd)



Appendix 9 - Site map for field trip in Sweden (Slätthult)



Appendix 10 - Due Rose s.p.a. , Pasiano di Pordenone, Italy

Due Rose s.p.a.
antine e componenti per mobili

SINCE 1966 DUE ROSE s.p.a., HAS PRODUCED COMPONENTS BOTH IN SOLID WOOD AND VENEERED ON A VARIETY OF SUPPORTING MATERIALS.

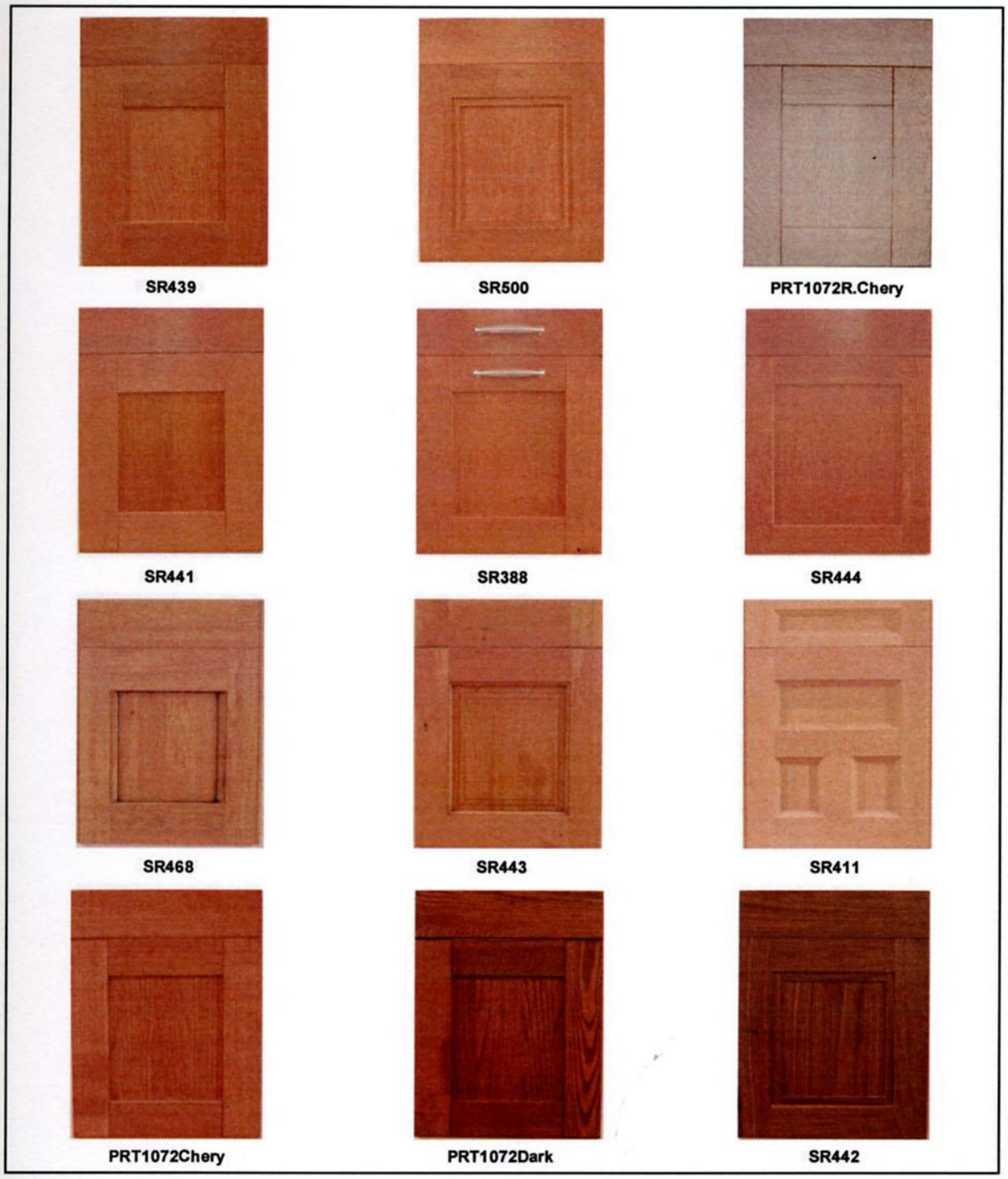
The company, certified **UNI EN ISO 9001 ed 2000**, adopts the latest technologies in order to manufacture products of the highest quality at competitive prices, focusing on the beauty of the wood and paying close attention to man's relationship with Nature and the need to safeguard the environment.
This sensivity to aesthetic and technical aspects is demonstrated by the careful and scrupulous way in which the numerous woods are crafted, in their constant availability and the uniformity of their characteristics.
The technical and aesthetic qualities of the solid wood are further enhanced by a wide range of finishes, all designed to protect the wood and to highlight its grain and colour; the wood is not covered or modified, but its attractive appearance is enhanced.
All the products in the range – doors, glazed doors, drawers and accessories in solid wood – are subjected to stingent test procedures (resistance to light, atmospheric agents, chemical products etc.) carried out at the **Catas** test institute; every element produced is subjected to constant quality control throughout the production process and protected by special packaging until it reaches the user.
The manufacture of these elements requires a high level of professional expertise and the most modern production equipment.
The beautiful appearance and technical characteristic of the raw material, together with rapid execution, precision, compliance with standards and, where requested, production o small batches and special or made-to-measure elements, all combine to create products with significant added value.
Customer service is one of Due Rose's strongest points; those who understand wood and the various phases of the production process, will realize that this extensive technical experience makes it possible to create products whose characteristics are unique.
It is for this reason that Due Rose provides all its customers with the best possible technical assistance service, including a process of **co-design** for product definition: from the initial consultancy service to the development of the product, from the technical feasibility study to the evaluation of the correct ratio between the desired product and its cost. **Every aspect of this service is designed to meet the specific requirements of the customer**.

Due Rose S.p.A.

Via San Martino, 2 - 33087 Pasiano di Pordenone tel. +39 0434 4227 fax +39 0434 422980 www.duerose.it – info@duerose.it

Jan - 06

Due Rose s.p.a.
antine e componenti per mobili



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