- *Various Eucalyptus species have been planted in Ireland over the last 100 years with varying degrees of success. The problem in deciding which species to plant involves both selecting the best species in terms of survival and productivity as well as one that has a commercial end-use.*
- *The timber properties of Irish grown Eucalyptus in the past have proven to have problems, but with the current increased interest in biomass for fibre and energy production Eucalyptus species may now have a commercially viable end use.*
- *The species that have been most successful under Irish conditions include:*
  - *E. nitens,*
  - *E. globulus,*
  - *E. delagatensis,*
  - *Eucalyptus muelleri (E. johnstonii),*
  - *E. urnigera.*
- *Recommendations regarding establishment, species options and possible yields are presented.*

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Eucalyptus as a potential biomass species for Ireland

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Introduction and background

The first report of *Eucalyptus* planting in Ireland was of *Eucalyptus globulus* at Garron tower in Antrim in 1857. Elwes and Henry (1912) in their survey of tree species in the British Isles reported that prior to 1908 the *Eucalyptus* species that had been successful included *E. globulus, E. pauciflora, E. viminalis, E. coccifera, E. gunnii, E. muelleri* (also known as *E. johnstonii*) and *E. urnigera.*

In 1908 A.C. Forbes, working on the establishment of plots at Avondale, imported seed from Tasmania of *Eucalyptus muelleri, E. urnigera, E. coccifera* and *E. gunnii* (later identified as *E. ovata* and later renamed as *E. viminalis*). Some of these trees became the source of seed used to establish trials at Ballymanus and other locations around the country. Forbes (1933) concluded that, of all the *Eucalyptus* species tested to date, *Eucalyptus urnigera*, *E. viminalis, E. muelleri* and *E. gigantea* (name later changed to *E. delagatensis*) were the most promising. In the same year Fitzpatrick (1933) listed a total of 13 *Eucalyptus* species that had survived and grown well in Ireland up to that date.

Between 1925 and 1961 a series of plots of various *Eucalyptus* species were planted around the country, many of which survive to this day. Perhaps the most well known are a series of trial plots planted in 1934/35 to 1937 at Ballymanus, in Glenealy Forest in Co Wicklow. The 1934 plots (old compartment number 6, now felled) included *Eucalyptus muelleri, E. radiata, E. viminalis, E. dalrympleana* and *E. urnigera* (Table 1).

In 1935 a second series of plots (old compartment number 11, still standing) were planted that included *E. muelleri, E. johnstonii, E. amygdalina, E. gigantea* (*delagatensis*) and *E. viminalis* (both coastal and mountain sources) (Figure 1). The importance of seed source was only recognised later during the cold winter of 1939/40 when *E. viminalis* and *E. amygdalina* were completely destroyed by frost. Details on the performance of species in these plots are presented in Table 2.

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Table 1. Survival, heights and DBH of the 1934 *Eucalyptus* plots planted at Glenealy, Co Wicklow, at 150 m elevation on a moderately exposed old oak woodland site about 10 km from the sea. Original planting was a 50:50 mixture with Japanese larch planted at a 1.4 x 1.4 m spacing. All seed originated from tress growing at Avondale.

Species	11 Yr Surv. (%)	11 Yr H (m)	21 Yr Ht (m)	24 Yr ht (m)	29 Yr Ht (m)	11 Yr DBH (cm)	21 Yr DBH (cm)	24 Yr DBH (cm)	47 Yr DBH (cm)
E. johnstonii	100	9.5	17.2	18.7	24.0	8.9	16.5	19.0	33.9
E. radiata	94	4.8	15.7	12.9	14.9	6.3	12.7	13.3	23.0
E. urnigera	100	5.8	16.9	21.5	20.8	6.3	14.6	16.5	29.2
E. viminalis	35	7.4	14.8	--	18.1	7.0	--	--	26.6
E. dalrympleana	100	4.9	14.8	17.5	20.0	7.0	15.2	17.8	27.3

Figure 1. The 1935 *Eucalyptus* plots at Ballymanus property in Glenealy Forest, Co Wicklow, after 74 growing seasons with a top height of over 30 m.

Table 2. Survival, height and DBH of the 1935 *Eucalyptus* plots planted at Glenealy (same location as that of Table 1 but planted pure at a 1.8 x 1.8 m spacing). *E. viminalis* (mountain and coastal) as well as *E. johnstonii, E. amygdalina* and *E. delagatensis* were from New Zealand, *E. johnstonii* and *E. urnigera* from trees growing at Avondale.

Species	10 Yr Sur (%)	10 Yr Ht (m)	20 Yr Ht (m)	23 Yr Ht (m)	28 Yr Ht (m)	36 Yr Ht (m)	10Y D (cm)	20Y D (cm)	23 Y D (cm)	46 Y D (cm)	65 Y D (cm)
E. viminalis (mountain)	74	3.7	12	13	17	21	2.5	14.6	10.8	19.9	26.2
E. viminalis (coastal)	0	--	--	--	11	--	--	--	--	20	--
E. urnigera	96	4.8	16	18	18	29	3.8	14.6	12	21.5	--
E. johnstonii	98	7.7	18	22	23	29	7	12	13.3	18.5	32.3
E. viminalis (coastal)	1.6	5.5	11	--	11	--	5.1	12.7	--	31.7	--
E. johnstonii	98	7.8	18	21	22	29	7	12.1	15.2	26.4	29.5
E. viminalis (mountain)	--	3.7	12	15	17	--	2.5	14.6	14.6	18.1	--
E. johnstonii	91	4.9	12	19	22	30	2.5	14.6	17.1	31	--
E. amygdalina	18	3.7	13	14	16	--	5.7	17.1	14	31.4	--
E. delagatensis	100	4.9	14	16	18	31	5.1	14.6	15.2	24.9	41.5

In 1937 a series of plots consisting of *E. muelleri, E. urnigera* and *E. viminalis* was planted, the results of which are not significantly different from the 1934 and 1935 plots and the results are not presented here. A summary of the performance of all these species was discussed in detail by Mooney (1960).

Selecting the 'best' species of *Eucalyptus* has been and continues to be the main question regarding this species. Hanan (1965) observed "*The problem has resolved itself into the finding of a species which is frost-hardy and likely to give high yields in our climate, while at the same time being of definite commercial interest*." While the question of hardiness and yields has been partly answered, the question remains as to whether these yields are sufficient for commercial-scale production and utilisation in this country.

Attempts to utilise several Irish grown *Eucalyptus* species for sawn timber, board manufacture, pit props and transmission poles did not provide very promising results (Mooney 1960 and Hanan 1965). Problems with splitting and cracking of the stem presented major problems for the use of these species as sawn timber. Perhaps as a result of the rather poor utilisation results, essentially no further work was done with *Eucalyptus* between 1962 and 1992.

An exception was with the establishment of the John F. Kennedy (JFK) Arboretum in Wexford, where a large collection of *Eucalyptus* species was planted from the early 1970s both in the arboretum and in forest plots. Here a plot of *E. nitens*, planted in 1982, has performed particularly well (Table 3).

In the 1970s, as a result of the international oil embargo, interest in biomass developed and *Eucalyptus* was considered as a possible forest biomass species. McCarthy (1979) reported that on two out of four test sites in the country *E. johnstonii* yielded the highest dry matter production of any forest species tested. The two sites where *Eucalyptus* did well were on a podzol at 290 m elevation and on a raised bog at 100 m elevation.

The conclusion from the limited number of plots established prior to 1992 suggested that *E. urnigera, E. johnstonii* and *E. nitens* were the most successful and productive species on a range of sites around the country.

With the establishment of Coillte Teoranta in 1989, a general review of policies for the selection of species and forest management practices was carried out. Because of the rapid growth rate and good stem form in many *Eucalyptus* species, it was decided to explore some of the more frost-hardy species that had potential commercial value on suitable sites. *E. gigantea* (now *E. delagatensis*) and

Table 3. Top height (m) of the 1982 forest plot JFK Arboretum, 1.8 x 1.8 m spacing, 0.13 ha, elevation 97 to 100 m, SE aspect. *Eucalyptus nitens* (Anembo SF, NSW.) This plot is located in one of the warmest parts and driest of the country.

	4 Year	9 Year	11 Year	14 Year	18 Year	23 Year
Top height (m)	2.8	15.7	19.1	22.2	25.5	31.1

E. nitens were selected as the most promising species. A new series of operational trials was established in 1992 and 1993 with the plan to distribute plants to all regions within Coillte to test the inland and northern climatic limits of the species. However, site availability was limited and not always the most suitable sites were planted. Plants were imported from the UK and the 1992 planting series was limited to *E. delagatensis* and *E. gunnii* because no *E. nitens* was available; however, *E. delagatensis* and *E. nitens* were planted in 1993. Containerised plants 15 to 90 cm tall were used in 1992, but in 1993 some larger bare-root plants were used (Neilan 1995). The results of these series of trials are presented in Tables 4 and 5 and shown in Figure 2.

It must be stressed that the original objective of all of these plots was to identify *Eucalyptus* species that could be used for the production of timber (sawn timber, pit props, transmission poles, etc.) and for this reason stem form and timber properties were considered important selection criteria. Of the species tested in the 1992/93 plots *Eucalyptus nitens* and *E. delagatensis* appeared to be the most promising. *E. gunnii* is noted for its cold hardiness and has performed well. Its poor stem form tended to rule it out as a suitable timber species, but it could have a role as an energy or fibre species.

Figure 2. *Eucalyptus nitens* planted at the Red Bog property, Coolgreany Forest, in Co Wexford after 15 growing seasons (see Table 5).

Table 4. Survival, top heights and DBH of the 1992 *Eucalyptus* plots planted in a range of sites across the country. Spacing 2 x 2 m.

Forest	Species	Survival (%)		Top Height (m)		Average DBH (cm)		Max. DBH
		2 yr	9 yr	9 yr	14 yr	9 yr	14 yr	14 yr
Bree, Co Wexford	*E. delagatensis*	90	80	13.0	17.5	14	23	28
Bree, Co Wexford	*E. gunnii*	90	75	11.0	21.0	11	18	23
Macroom, Co Cork	*E. gunnii*	80	60	13.0	19.5	11	17	22
Drimaleague, Co Cork	*E. gunnii*	80	50	11.0	21.0	10	18	31

Table 5. Survival, top heights and DBH of the 1993 *Eucalyptus* plots planted in a range of site around the country. Spacing 2 x 2 m.

Forest	Species	Survival (%)		Top Height (m)		Average DBH (cm)		Max. DBH
		1 yr	8 yr	8 yr	13 yr	8 yr	13 yr	13 yr
Coolgreaney, Co Wexford	*E. nitens*	60	60	11.0	21.5	12	26	34
Cappoquin, Co Waterford	*E. nitens*	100	90	13.0	22.5	13	26	32
Hollyford, Co Tipperary	*E. nitens*	90	70	13	17.0	10	16	31
Lough Talt, Co Silgo	*E. nitens*	90	0[1]	12.0	--	13	--	--
Ballynoe, Co Cork	*E. nitens*	80	60	14.0	20.0	13	24	31

[1] Killed by -14°C frost in December 2000.

With increasing demands for fibre as well as increasing energy costs, interest in biomass has developed in recent years (Purse and Richardson 2001). This has created a new niche for *Eucalyptus*, possibly including some of the species tested in the earlier plots that had not produced quality timber.

Regarding growing biomass for energy production, it is important to appreciate that the calorific value of wood is approximately proportional to the basic density of wood (dry weight/unit volume). Although the conifers tend to have a slightly higher calorific value than most broadleaves, there are exceptions, including some species of *Eucalyptus*. It is important to identify species that combine a high basic density with a good growth rate on a short rotation for optimal biomass for energy production.

Although past attempts to produce sawn timber from Irish grown *Eucalyptus* has not been very successful, some of the other species of *Eucalyptus* may have the potential to do so; however, young, fast-grown logs tend to split and crack. Potential timber producing species include *E. nitens* and *E. delagatensis*, but neither of these species has been tested for its ability to produce sawn timber under Irish conditions.

Results

The results from the first *Eucalyptus* trial in Glenealy, planted in 1934 (Table 1), show the early rapid growth of two species after 11 years (*E. johnstonii* and *E. viminalis*) with slower initial growth but catching up in three other species (*E. radiata, E. urnigera* and *E. dalrympleana*). A similar pattern was seen in the results from the 1935 trial (Table 2) where *E. johnstonii* showed rapid early growth and by year 20 *E. urnigera* had caught up. By year 24 the *E. urnigera* had surpassed the *E. johnstonii* in both height and diameter. It is important to note that although these results are from small, unreplicated plots in one location, some of these species (e.g. *E. johnstonii* and *E. urnigera*) have done well on a number of sites in Ireland. Although the timber produced by these species presents problems for short rotation biomass for either energy or fibre rotations *E. johnstonii* and perhaps *E. urnigera* could play a role, provided a suitable seed source is available.

The results for a single, unreplicated forest plot of *E. nitens* at JFK Arboretum (Table 3) showed that after a slow start, by year 9 the trees were growing at an average of 1.7 m/year which only began to decline by year 18, well past the rotation age for both energy and fibre.

The 1992 series of plots (Table 4) showed that by year 9 the *E. delagatensis* and the *E. gunnii* were both growing, on average, more than 1 m per year. Nevertheless, variations in location and site conditions can be seen on the performance of *E. nitens* and *E. gunnii* in Tables 4 and 5.

The results of the *E. nitens* plots planted in 1993 (Table 4) showed that on all sites this species was growing over 1.3 m per year, on average, and had reached a height of 11 to 14 m after 8 growing seasons. This highlights the potential of this species as a short rotation energy or fibre species.

It is important to note that at one trial of *E. nitens*, planted in Lough Talt Forest near Tubbercurry in Co Sligo along the banks of the River Moy, trees 10 m tall were completely killed by a very unusual cold period during December 2000 when air temperatures fell to -14°C. This highlights the need for proper species and provenance as well as site selection, especially considering low areas where cold air can collect (e.g. in a valley along the banks of a river).

Conclusions

Although Forbes (1933) provided a short-list of the *Eucalyptus* species that showed the most promise, their use remained at a very low level for the next 70 years mainly due to the lack of a clear end product use for the material. While some of the early Ballymanus trial plots remain quite impressive, **it is the 1992/93 plots that are the most convincing**.

In 1960 Mooney observed "*The poplars may possibly challenge the eucalypts in growth, but poplars must usually be given the most favourable site conditions whereas a eucalypt will grow well over a wide range of conditions which include dry shallow mineral soils types in exposed conditions.*" He continued "*Its proven ability to withstand wind and its exceptional fast growth should recommend it as a shelter belt tree over a wide range of mineral soils, excluding heavy wet soils and peaty sites*."

Recommendations

In order to promote the wider use of *Eucalyptus* in this country the following are a series of points to consider when

planting *Eucalyptus* as well as some information on the species options that are available.

SITE SELECTION: *Eucalyptus* species vary greatly in their cold hardiness, thus species selection is mainly determined by the lowest temperatures at the site. Frost hollows, large cold air drainage areas and colder sites in general should be avoided unless cold tolerant species are planted (see species descriptions later). The main danger is an unseasonable frost in any location as well as an unexpected frost in a mild location. Depending on the species planted, most of this country should be capable of growing *Eucalyptus*. On very exposed or wet sites, wind throw should also be considered.

SOIL TYPES: *Eucalyptus* do best on fertile, free draining lowland soils. Some species may be suitable for planting on alkaline soils. Drainage is essential for most species.

SITE PREPARATION: Sub-soiling or ripping (at 30 to 45 cm) will improve establishment. Planting in the rip lines is recommended.

PLANTING STOCK: Containerised plants (20 to 30 cm plants in 100 cc containers) are to be preferred. It is important that plants have a good shoot:root ratio, and smaller plants tend to have a better shoot:root ratio. Avoid pot bound plants and plants with root spiralling. They should be planted on the flat. Spring planting is to be preferred because it allows for good establishment before the first frost. Late summer planting should be possible (if done early enough), but this requires further testing before it can be recommended. Autumn planting is used in reliably mild climates if temperatures during the winter/early spring are sufficient to allow root growth during this period, but this could be risky in Ireland. Filling-in is generally not practical for short rotation *Eucalyptus*.

VEGETATION CONTROL: Weed control is critical for good survival and growth up until the time they close canopy (first 2 years).

NUTRITION: Most *Eucalyptus* species will respond to N, P and K fertiliser, but there is no experience relating to Irish conditions.

SPACING: Spacing depends mainly on the fertility of the site and the end product. On poorer sites wider spacings can be used. In general spacing should be 2 x 2 m for biomass production but can be wider (up to 3 x 3 m) if timber production is the objective.

ROTATION LENGTHS: Should be 8 to 12 years or longer, depending on the species growth rate and the end product use.

ANIMAL AND INSECT DAMAGE: *Eucalyptus* species are generally not seriously damaged by rabbits or deer (*E. gunnii* is an exception) or pine weevils, unless local populations are high and there is nothing else for them to eat. Grey squirrels do not appear to attack *Eucalyptus*. The introduction of insect pests from the native range of these species could have an effect on productivity.

COPPICING: Most *Eucalyptus* species coppice, but there are exceptions, specifically *E. nitens* and some provenances of *E. delagatensis*. While the ability to coppice offers the potential to avoid replanting, this may not be the main criterion in species selection.

Species recommendations

The following are comments about the main species that should be considered for planting in Ireland either for energy or fibre.

***E. nitens* (Shining Gum)** is an important species for fibre production in other parts of the world, especially Chile. Very good for early rapid growth, volume production and cold hardiness. Has done well in Irish trials on a limited number of sites. Good for sites with a lower risk of cold temperatures (hardy to -12°C). Does well on a wide range of moderately fertile soil types. Has timber production potential (but fast growth can cause wood stability problems) and for fibre production. Wood density is low for this eucalypt so it may not be the best species for energy production. One of the species of *Eucalyptus* that does not coppice well. Not readily browsed by most livestock.

***E. globulus* (Blue Gum)** is a very important species for the pulp and paper industry elsewhere. It has done well in a limited number of Irish coastal locations. There are also several subspecies that are worth further testing. Good potential pulp wood species for temperate areas. Not as cold hardy as *E. nitens.* (hardy to -6°C). Easy to establish, rapid growth, good stem form, is wind firm, unpalatable to livestock and coppices well. Grows on a wide range of soils, but avoid shallow soils and soils with free carbonate. Good

fibre or fuel species. Wood suffers from growth stresses which reduce its use as a timber species. Coppice rotation lengths of 10 to 12 years should be possible. The 2006 Society of Irish Forestry study tour of Galicia, Spain, visited a Finsa MDF plant that uses *Eucalyptus globulus* in the production of MDF. The coastal climate of Galicia is similar to Ireland with typical summer temperatures of 20 to 25°C and winter temperatures of -6°C. If MDF can be produced from *E. globulus* in Galicia, there is no reason why it could not be produced in Ireland.

E. dalrylempleana **(Mountain Gum)** is a species with good height growth (slower growing than *E. nitens*), but less diameter growth than *E. nitens*. Very limited results in Irish trials. Not a very exacting species regarding soil type, but not suited to dry soils. Said to grow on alkaline as well as acidic and neutral soils. Good stem form, self prunes and coppices well. Very useful species where resistance to cold is required (hardy to at least -13°C). Wood is white to pale pink, straight grain, moderate strength, hardness and durability, high wood density. Not a widely used species.

E. delagatensis **(Alpine Ash)** provides good cold tolerance (hardy to -12 or -14°C). Not a fast grower. Limited experience in Irish trials. Grows well on most well drained, deep soils. Avoid calcareous and dry soils. Low wood density may make it more useful as a fibre than as an energy species.

E. gunnii **(Cider Gum)** has been widely planted in Ireland mainly as an ornamental species. Provides very good cold tolerance but has only moderate vigour and a variable stem form. Has shown good growth rates in recent Irish trials trials and may be useful for biomass production. Coppices well. One of the most palatable species. Moderate wood density.

E. urnigera **(Urn Gum)** is not planted commercially and is mainly used as an ornamental species. Good for colder sites (hardy to -15°C) , but productivity less than other species. Good stem form. Has done well in Irish trials on a range of sites. No information on wood properties. May be useful as an energy or fibre species.

E. johnstonii **(also known as** ***E. muellerana*****)** Past identification of these species in Irish trials is confused. Not a commercially used species. Has done well in older Irish trials. Does best on deep clay loams in valleys and sheltered sites. Hardy to -4 to -7°C. Can be damaged by prolonged dry periods. Has rapid early growth. Recommended for use in farm woodlots in mild coastal areas for the production of posts and poles. May have a role as an energy or fibre species.

E. viminalis **(Manna Gum)** has done well in Ireland on a range of sites. Grows on a wide range of soils from impoverished sandy podzols to alkaline soils. It is hardy to -10°C, which varies with the provenance; however, 'frost cracks' have been observed in Ireland with this species. Easy to establish, has rapid early growth and coppices well. Timber quality is poor because it has a tendency to warp, twist and collapse. The main use would be for fibre or energy.

Yields

There is very limited information available on the yields that can be expected from *Eucalyptus* in either Ireland or the UK. Commercial plantations of *E. nitens* in Chile and Tasmania normally have a MAI (Mean Annual Increment) of more than 25 m^3/ha/yr at age 10 but can be as high as 35. A MAI of 25 is roughly equivalent to about 10 oven dry tonnes of matter per hectare per year. A series of *Eucalyptus* species planted at Thetford forest in the UK in 1981 produced MAIs of 13.5 to 18.4 m^3/ha/yr (Bennett and Leslie 2003). These trials were on dry sandy soil in eastern England, which would be very different from the sites where *Eucalyptus* would be planted in this country. There is no reason why an MAI of 20 to 25 or even greater could not be achieved in good sites in this country with good silvicultural management.

Perhaps the evidence for this belief can be seen in Figure 3 and Table 6 where the side-by-side performance of Sitka spruce (*Picea sitchensis*) and *E. nitens* of the same age can be compared.

Table 6. Top height and DBH after 13 growing season of side-by-side plots of *Eucalyptus nitens* and *Picea sitchensis* planted near Cappoquin, Co Waterford in 1993 as shown in Figure 3.

Species	Top height (m)	DBH (cm)
Picea sitchensis	11.5	11
Eucalyptus nitens	22.5	26

Figure 3. Plots of Sitka spruce (*Picea sitchensis*) and *Eucalyptus nitens* planted side by side at the same time in Cappoquin forest, Co Waterford, after 14 growing seasons (see Tables 5 and 6).

A word of caution

Some of the species in the older trials have shown that *E. johnstonii* and *E. urnigera,* as well as the more recently tested species of *E. nitens, E. delagatensis* and *E. gunnii* have demonstrated that they can produce biomass at substantial rates under Irish growing conditions. However, these results should be treated with some caution. The limits where *Eucalyptus* can be successfully grown have not been established. Both species and site selection are critical. If anything, these results should be taken as an indication that *Eucalyptus* has the potential to produce biomass and possibly sawn timber in this country, but the precise details of where and how to do this remain to be determined.

Acknowledgements

Much of the work on *Eucalyptus* since its first planting by A.C. Forbes can in one way or another be attributed to the enthusiasm and influence of the late O.V. Mooney who maintained an interest in this species throughout his working career and even into his retirement. Dr Michael Carey also has to be recognised for having the conviction to establish the 1992/1993 series of trials. Without their interest in the species much of the information presented in this report would not have been possible. Appreciation is also due to Dr John Purse of PrimaBio Ltd. (www.primabio.co.uk) for his continued advice about *Eucalyptus* in general and his useful comments on a draft of this note.

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