The response of Oak (Q*uercus robur)*, Ash (*Fraxinus excelsior*), Lenga *(Nothofagus pumilio) and* Maidenhair (*Ginkgo biloba*) to the Root Production Method (RPM)

Introduction

Globally there is a strong interest in rapidly producing trees, which will generate positive economic, ecological and environmental benefits at both local and national levels. Currently farm systems need alternative products involving multifunctional land uses to increase the returns on investment and diversify income. Growing quality timber and non-traditional forest products such as leaves bark, fruits nuts, seeds, biodiversity and wildlife value, medicinal and carbon storage possibly combined with either livestock or crops are means to do so (Olave et al, 2001)

Oak (*Quercus robur*), Ash (*Fraxinus excelsior*), Lenga (*Nothofagus pumilio*) and Madeinhair (*Ginkgo biloba*) are potentially useful tree species which can be integrated into agroforestry systems (Olave et al, 2001; Olave and McAdam, 2003). However there are environmental, biological and anthropogenic factors that limit their establishment and their early growth can be slow.

The Root Production Method (RPM) is an innovative technique developed by a forest nursery in Missouri, United States, which may create taller and hardier trees. This method combines bottomless containerisation on raised open benches, seed selection, seed handling and air as a means of root pruning among others (Olave and McAdam, 2003; Grossman et al, 2003). The RPM technique has been shown to induce flowering and seeding in a shorter time by accelerated root growth (Grossman et al, 2003). Additionally the same authors indicate that the benefits of the RPM process are extended to the outplanted trees.

In 2000 a research programme commenced in Northern Ireland on this technique to investigate whether the species above would develop and or flower faster if grown according to RPM. In addition, the influence of different morphological characteristics for planting and post-management that result in good quality plants for agroforestry characteristics of high economic return such as growth rates, stem form and flowering were evaluated.

Materials and methods

Plant material

Seed of oak, ash, lenga and maidenhair of similar origin were graded and sized before using in the investigation. In 2000 the oak and ash seedlings were grown in a glasshouse at Greenmount College Northern Ireland, while in 2001 lenga and maidenhair were grown in a greenhouse at NIHPBS, Loughgall Co Armagh, Northern Ireland. The seedlings were grown in accordance with normal cultivation procedures for the commercial production of containerised RPM plants. i.e., seeds were placed in bottomless trays at 150 seeds per tray filled with 70% peat, 30% pine bark plus fertiliser, fungicide, herbicide and a wetting agent and placed on open benches for air pruning of roots. After approximately 3 months the medium was also inoculated with mycorrhizae spores. Subsequently when the shoots of ash, lenga and maidenhair were approximately 20 cm tall and oak plants had completed the first flush, the robust seedlings were transplanted into milk cartons and the rest discarded. The seedlings in trays and milk cartons were kept at a minimum day and night temperature of 16° C and a relative humidity of 60% - 80% until the second flush of oak was completed. Prior to transplanting into 7.5 litre growing containers, seedlings were hardened off in the open for 2 days. Thereafter the plants were transferred outdoors to an irrigated nursery area, where they were kept until planting in winter. One year after sowing, planting stock of different sizes were planted out in the field.

Study site

Plants were planted out in a clay soil field at two sites in Northern Ireland. Prior land use for these plots were an apple orchard and grass production field. Ash, lenga and maidenhair plants were planted at Ballywalter, Co. Down and oak plants at Loughgall Co Armagh. The average annual precipitation is 72.35 mm and 71.1 mm respectively, but rain is common throughout the year. The average summer temperature is 14.5ºC for Loughgall and 14.1ºC for Ballywalter while the winter average is 5.19ºC and 5.6ºC respectively. The average annual temperature is 9.6 in Loughgall and 9.4 in Ballywalter.

On January 24, 2001, January 2002, February 2002 and January 2003, respectively, 200 oak, 60 each of ash, lenga and maidenhair plants were planted into the field. The experimental design was four blocks of 50 oak and 16 each of ash, lenga and maidenhair plants respectively grown by the RPM technique. The field gradient for oak plant was 7% on average while for ash and lenga it was only 1%.

No fertiliser was applied. Blocks were mechanically weeded when competition grew taller than 5 cm. Herbicide was also applied periodically. Gramoxone for oak and Kerb granules for ash, lenga and maidenhair.

Assessments

Survival, height and basal diameter were measured at the end of each growing season following outplanting. Form was also evaluated for all species in 2004. This latter was scored in 5 categories where 1= very good quality, 2= good quality, 3= moderate quality 4= Poor quality and 5= very poor quality (Figure 1). Phenological development of each tree was systematically observed throughout the whole period in the field in order to establish flowering and seed production.

The results were analysed for significant differences between large, medium and small size plant classes (Table 2). Twelve oak and 5 ash, lenga and maidenhair plants of each planting stock size in each block were analysed.

Table 1. Initial seedling height and basal diameter of 4 ranges species before outplanting

Species	Small		Medium		Large		
	Height (cm)	Diameter (mm)	Height (cm)	Diameter (mm)	Height (cm)	Diameter (mm)	Spacing (m)
Oak (*Quercus robur*)	45.9	6	67.5	6.9	92.7	8.2	4 x 1.5
Ash (*Fraxinus excelsior*)	48.1	10.5	68.8	12.1	79.3	13.2	1.5 x 1.5
Lenga (*Nothofagus pumilio*)	52.2	4.7	67.2	5.5	78.6	5.4	1 x 1
Maidenhair (*Gingko biloba*)	50	6.8	*	*	*	*	1.5x 1

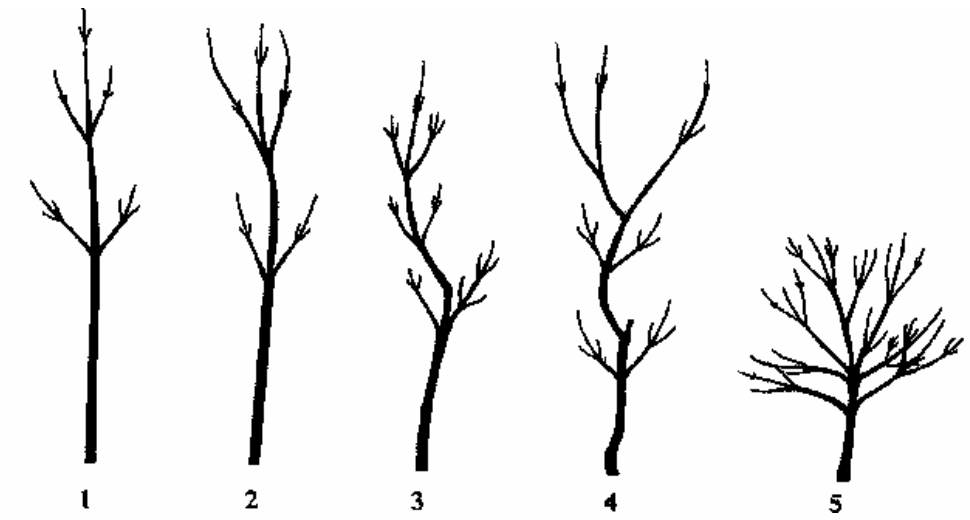

Figure 1. A visual guide of quality categories

Table 2. Stratification of trees by size class used for all species in the study.

Size	Rate size
Large	>75 cm height. RPM criteria based on Forrest Keeling Forest Nursery
Medium	60 to 74 cm height
Small	> 59 cm height

Results

Survival

Field results from research trials in Northern Ireland have shown that oak and ash plants have better survival rates (99.5%) than lenga (60%) and maidenhair (40%) plants produced under RPM protocol. After 3 growing seasons oak and ash showed exceptionally good survival on both sites.

Planting stock of different sizes did not influence survival at 12-month for oak and ash and it was constant from then onwards. However it did influence survival at 24 and 12 months for lenga and maidenhair respectively. lenga as well as maidenhair below 50 cm height had lower survival, compared to those above 50 cm tall.

Size and growth

Provided that the plants grown under the RPM process are healthy and vigorous, early growth rates are the first indicator of the plantation success (DARDNI, 2002). Practically, height growth is most important in plantations grown from RPM trees because of competing vegetation, improved growth, survival and precocious flowering. RPM plants which are able to keep ahead of vegetation during the first few years after outplanting are more likely to become firmly established and flower in a shorter time than plant grown by means of other methods (DARDNI, 2002).

For oak, initial planting stock sizes had a significant effect on height growth during the first year (Figure 2). However for the next two growing seasons planting stock size had no significant differences. Although height growth was excellent, with annual average growth rate of 73, 24 and 34 cm., clearly initial planting stock sizes did not influence the final height over three-year period. Large and medium ash planting stock had faster growth rates for the first two years than the 3rd year. However small plants catch up with them by the third growing season and after 3 growing seasons there was no significant treatment effect (Figures 2 and 3).

Lenga performed differently to the other species. Although the height growth rates followed a pattern somewhat similar to oak and ash i.e. large and medium plants grew faster than smaller plants during the firsts two seasons, the smaller plants had caught up with them by the end of the third growing season.

For lenga, increments in height growth over two growing seasons in the field were not as good as for oak and ash (Figure 3).

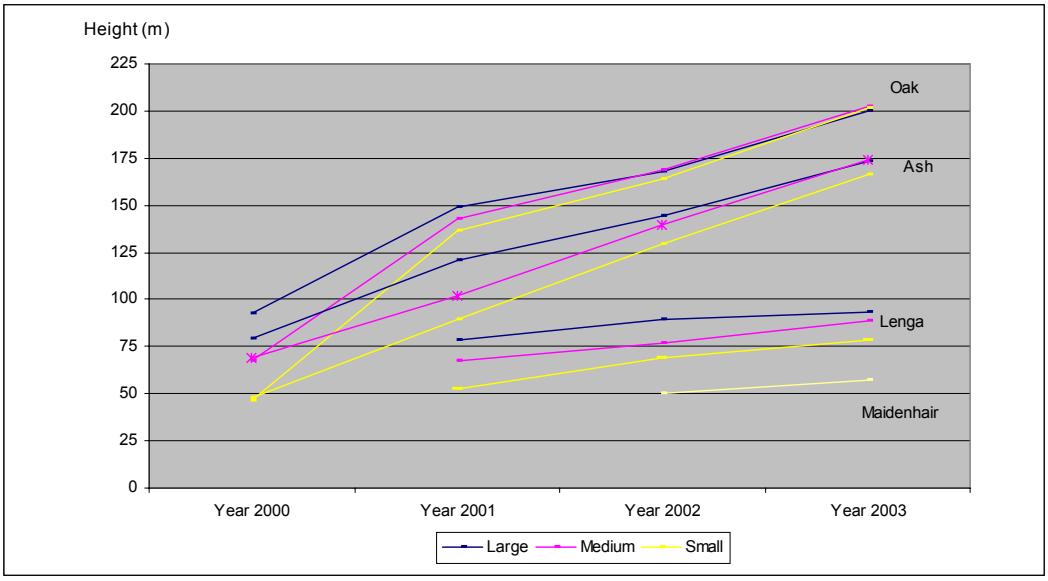

Figure 2. Summary of the response of height of oak, ash, lenga and maidenhair to stock plant size classes over three years in Northern Ireland.

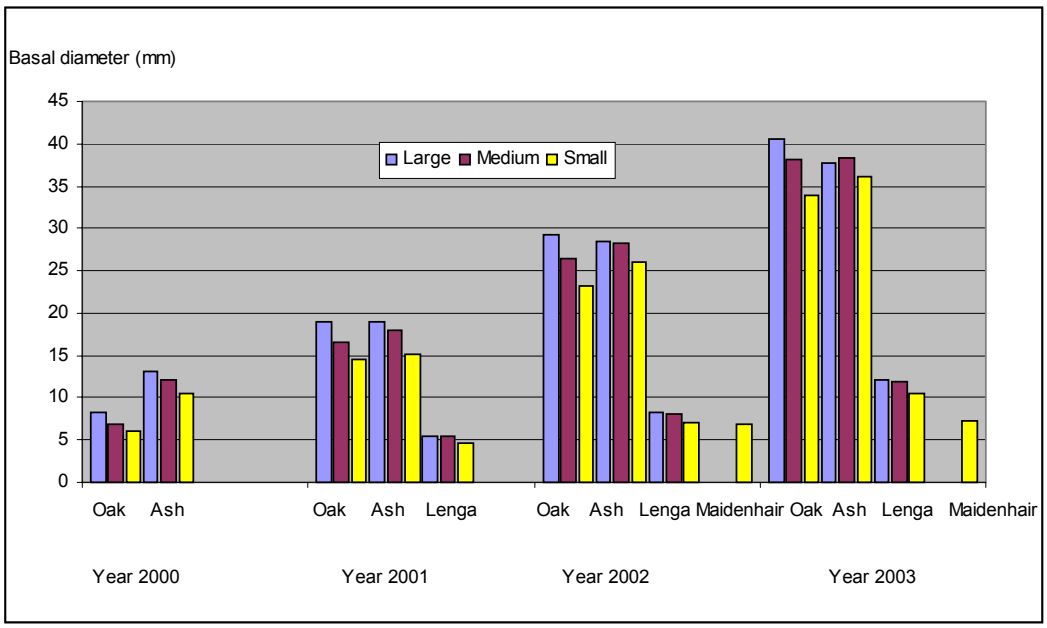

Figure 3. Summary of the response of basal diameter of oak, ash, lenga and maidenhair to stock plant size classes over three years in Northern Ireland.

It is important to notice that for maidenhair plants during the propagation process it was not possible to obtain plants falling within large and medium planting stock classes. i.e. all plants were small (Figure 2 and 3). Thus this process produced just small plants averaging 50 cm in height and 6.8 mm in diameter. Both these parameters probably affected their survival in the field, and though maidenhair plants reached a satisfactory height in the greenhouse they did not grow well into the field.

Form

While Tables 3, 4 and 5 indicate a general trend for oak and ash, there was considerable variation between these and lenga. This is shown by giving the number of trees in each category combined between tree different sizes of planting stock after 3 growing seasons for oak and ash and two growing seasons for lenga.

About 50% of trees fell within categories 2 and 3. However, although the remaining 50% were concentrated within categories 1, 4 and 5, there were more trees of better form within category 1. Nevertheless planting stock size had no significant effect on tree category.

For ash, whereas the number of trees categorised was smaller than for oak, the results have indicated similar pattern for the stem quality. However small trees may produce more tree of intermediate stem quality than taller. It was surprising that there were no trees falling into category 5 and few within category 4, which would confirm that ash has better apical dominance (Evans, 1984) than oak trees.

Although it is too early to make judgements about the stem quality of lenga, early indications are that it is producing a good and straight stem. This is important considering that this specie when planted in open field trends to lose its natural tree architecture in the early years (Olave, unpublished data).

Table 3. Effect of oak planting stock size on number of trees within each category.

Planting stock size	Category 1 N° trees	Category 2 N° trees	Category 3 N° trees	Category 4 N° trees	Category 5 N° trees
Large	9	19	15	3	2
Medium	7	19	14	4	4
Small	11	20	10	4	3

Table 4. Effect of ash planting stock size on number of trees within each category.

Planting stock size	Category 1 N° trees	Category 2 N° trees	Category 3 N° trees	Category 4 N° trees	Category 5 N° trees
Large	2	5	4	1	0
Medium	2	6	3	1	0
Small	2	2	13	2	0

Table 5. Effect of lenga planting stock size on number of trees within each category.

Planting stock size	Category 1 N° trees	Category 2 N° trees	Category 3 N° trees	Category 3 N° trees	Category 3 N° trees
Large	5	5	0	0	0
Medium	4	5	1	0	0
Small	7	2	1	0	0

Flowering

Although the RPM process is based on root pruning and fertilisation, both of which aid the stimulation of flowering (Chalupka and Cecich, 1997). There is an indication that this technique has given good results for other species (Grossman et al, 2003). In this case the production of trees by the RPM process was ineffective in the stimulation of either male or female flowering in all species. During spring 2004, male and female oak flowers were found. This may just be an isolated event and does not mean that there will be a heavy flowering during the next growing season.

Discussion

Growth rates and survival

Plants raised by the RPM technique invariably grew faster and produced taller plants than other tree seedling production methods (Olave, unpublished data) although morphological differences were rarely significant. Additionally, while use of the RPM technique has had an obvious effect on the early growth of oak and ash, the influence of planting stock size was not discernible.

Ash trees grown by the RPM process were only slightly superior to those grown by conventional techniques (Culleton et al, 1998). Oak and lenga grew much faster and taller (Olave, unpublished data) using RPM than by conventional methods. However the maidenhair plants performed better in the greenhouse than in the field.

The relationship between planting stock sizes and height tended to stabilise after three growing seasons; however early differences in height may be related as much to differences in initial size at planting as to genetic factors (Olave, unpublished data). Given this and the observation that planting stock size had no influence on further growth rates, it may be concluded that all the planting stock size categories employed in the study were successful in adapting plants to the environment in Northern Ireland.

The results indicate that, in both oak and ash, the benefits of the RPM technique, in terms of increased survival and early growth, were outgrown by the end of the second growing season. Beyond this, height, stem diameter and probably stem quality conditions were stabilised in relation to stock type size. Thus, if RPM planting stock is to match or improve on the performance impact of other tree production techniques on a given site, plants must be large enough to achieve this status within a few years from planting.

Survival of oak and ash was very over during almost all the period (>99.5). Survival of lenga and maidenhair plants was significantly lower. The stem quality of lenga and maidenhair could not be evaluated for two reasons, a lack of growth and poor available information on the early stages. Nevertheless the lenga plants grown by the RPM process might perform better than those raised using other tree seedling production methods during their initial propagation in the greenhouse (Olave, unpublished data).

Form

Oak saplings showed better form overall than ash by the beginning of the third year after planting, but branching and bigger crowns could increase management costs and reduce financial returns (Bulfin and Badford, 2000). It is likely that treatments which may stimulate flowering or fast growth in young trees (such as root pruning and or fertilisation) could affect subsequent performance and increase the loss of leading

shoots (Chalupka and Cecich, 1997). This may be because so much of the early energy is put to height growth at the expense of root development. From these results it too early to conclude whether or not the RPM technique may help in improving the stem quality of oak, ask and lenga. The latter, though, showed better form than normal; this may have been because trees in this trial were in a more sheltered position than normally found in the wild. A clearer assessment can be made once the lenga trees have grown out of the tubes.

Flowering

Longman (1987) states that the most promising treatment for hastening the change from the juvenile to the mature phase is to grow plants as fast as possible to a certain minimum size, and then place them in flower inducing conditions. Flowering in these species is complex, and may take a long period even applying other propagation techniques such as vegetative propagation. Some species produce purely male, female or hermaphrodite flowers while others have a mixture of flower types and some have flowers of a transitional form (Emhart et al, 1999; Savill, 1991).

Additionally, flowering may vary markedly between the species itself and individuals within the species. In the case of oak, ash, lenga and maidenhair, studies suggest that flowering may occur as early as about 40, 25, 25 and 30 years in natural environments respectively (Emhart et al, 1999; Savill 1991). However the induction of flowering by artificial means such as air pruning and fertilisation, during the early years has been successfully proven in several other species, mainly conifers (Chalupka and Cecich, 1997) but it could also involve a decrease in other traits such as form.

None of the trees in this trial produced either flowers or seeds or vestiges of these during the first three years in the field. However Grossman et al (2003) found that in RPM swamp white oak (*Quercus bicolor*) plants, the probability of producing a viable acorn is significantly related to initial basal diameter and height of plants at >12.7 mm and 1.5 m respectively. Hence this would suggest that with the morphological characteristics shown by oak and ash plants in this study, flowering could have occurred. However because of higher temperatures in the US and different stress condition that plants were subjected, to a hastening of precocious flowering could have occurred. Therefore in the present study, it would not be unreasonable to expect that the average RPM plants may require an additional one to two years to produce flower and seed in northern Ireland comparable to those planted in the United States. However the advantage of a possible shortened juvenile period in RPM plantations must be weighted against the advantages of other tree seedling production methods, these include reduced propagation and planting costs. The problem of branching and tree form, which appears to be more severe in RPM trees, should also be borne in mind.

Conclusion and recommendations

Planting stock size of 75 cm is one of a number factors which constitute a RPM prescription before outplanting (DARDNI, 2002). The preliminary results of this study indicate that there is no need for grades of height and basal diameter to match site conditions - those plants below 75 cm tall can perform as well than those above 75 cm tall. Hence their growth response must be conditioned by other factors. The degree and method of site preparation, rate of competition, time of planting, planting methods, soil fertility, root mass, local environmental conditions and genetic factors may all substantially modify the response of planting stock size on a given site. Therefore the interaction of all these factors must be taken into consideration when specifications for RPM planting stock are being defined.

Nevertheless this lack of a clear effect of planting stock sizes on the early growth of the plants used in this study (3 years for oak and ash and 2 and 1 years for lenga and gingko) is no justification for relaxing standards of RPM planting stock quality. The current grade of oak and ash planting stock are considered adequate for the Northern Ireland situation. It has been shown repeatedly which rate of survival and flowering precocity is related to those features of the plant that determines its morphological size (Landis et al, 1998; Chalupka and Cecich, 1997). Therefore it may be best to use medium and large plants. It is clear from the results of the studies described that propagation of oak and ash by the RPM process is feasible. Lenga requires a supportive propagation system to maximise rooting, whilst gingko appears to be less tolerant of environmental conditions in the field.

For the environmental conditions found in Northern Ireland overall percentage success for field performance of oak, ash and lenga has been encouraging and there seem to be

no serious technical constraints to commercial production of containerised plants of these species using the RPM technique.

However it must be stressed to exploit the benefits of the RPM technique, attention must be paid to the seed selection, provenance, seed handling and other genetic features. The species tested must be evaluated in long term field trials in order to select the few which prove outstanding.

This study is important as a contribution to the development of RPM technique and should be looked upon as an affirmation of the concept of air root pruning and controlled release fertilisation as workable tree seedling production alternatives.

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