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Use of exponential nitrogen loading in the nursery to promote nutrient uptake and quality of pedunculate oak seedlings

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Current policy in Ireland calls for increased quality and quantity of broadleaved seedling plantings. Simultaneously, concerns regarding environmental compliance necessitate development of nursery production methods that minimise negative impacts. Exponential fertilisation has potential for producing high quality seedlings through nutrient loading, while simultaneously minimising nitrogen losses during culture. The optimal rate of fertiliser applied exponentially has been determined for various broadleaved species in the US and this approach has been operationally implemented in practice. However, effective exponential fertiliser prescriptions have not yet been established in Ireland. Seedlings produced via an exponential loading system are better able to thrive upon outplanting compared to non-loaded seedlings since they are able to utilise stored nutrient reserves.

With financial support from COFORD and two US agencies (National Science Foundation (NSF) and the Fred M. van Eck Foundation) a project was undertaken on pedunculate oak (Quercus robur L.) seedlings to investigate the impacts of a wide range (0.10-1.0 g N seedling^{-1} yr^{-1}) of exponential fertilisation rates on:

- *seedling morphology and yield,*
- *soil and tissue nutrient dynamics.*

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Background

Conventional fertilisation regimes of many forest nurseries involve supplying seedlings with periodic applications of a constant rate of fertiliser addition throughout the growing season. Exponential fertilisation (whereby fertiliser rates are incrementally increased in relative proportion to seedling size) has been shown to improve fertiliser nitrogen uptake efficiency for of both conifer and oak species in NorthAmerica and minimise nutrient leaching and environmental contamination (Dumroese et al. 2005). Using this method, smaller (younger) seedlings receive less fertiliser while demand is low and larger (older) seedlings are fertilised at higher rates (Figure 1) in accordance with increasing ability to use nutrients. It is also possible to induce luxury nutrient uptake with this fertilisation

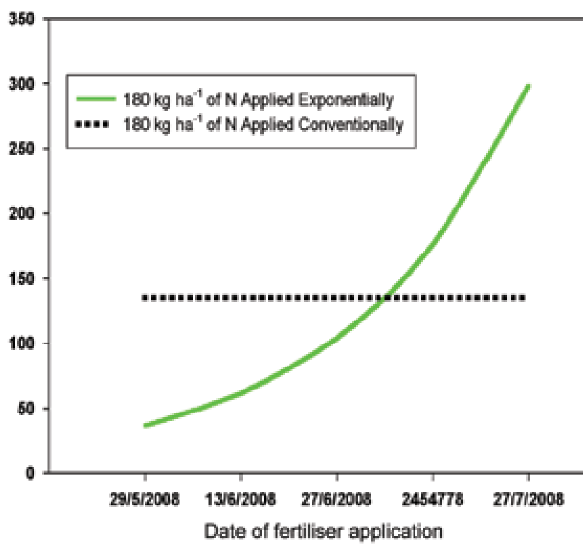

Figure 1. Comparison of the standard rate of 180 kg ha^{-1} N seedling^{-1} applied conventionally (dotted line) with same rate applied exponentially (green line). The approach for the other exponential N treatments (see Table 1) was identical to that shown for the 180 kg ha^{-1} exponential treatment, except the amount applied on each date differed. Note lines illustrate amount of fertiliser applied and not total N added.

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method through application of relatively high fertiliser rates later in the season (i.e. nutrient loading), which often results in production of seedlings that are nutritionally superior to those grown under conventional methods (Birge et al. 2006) and generally show improved field establishment success (McAlister and Timmer 1998; Salifu et al. 2009).

Irish nurseries have difficulty competing against 1-year imports of planting stock, since the cool climate has traditionally dictated 2-0 production of oak seedlings (Long 2006, O'Reilly et al. 2005). Several studies conducted at Irish bareroot nurseries as part of the QUALIBROAD project indicate that it may be possible to grow broadleaved seedlings, including pedunculate oak (*Quercus robur* L.), to target size (i.e. > 45 cm shoot height and >6 mm root collar diameter) within one season by using a combination of seed storage/pre-treatments and specialised seedling cultural practices (i.e. use of cloches, higher fertilisation rates, autumn sowing, etc.; O'Reilly et al. 2005, 2009). Thus, further refinements to bareroot production systems through improvements of cultural techniques such as fertilisation could warrant 1-0 broadleaved seedling production in Ireland while minimising environmental impacts. The effects of exponential fertilisation treatments on the morphology, yield of target sized plants, and N tissue content of pedunculate oak seedlings and soil N loss are reported in this note. The results showed that exponential fertilisation has potential to aid in production of target sized pedunculate oak stock in a single season in Irish nurseries.

Project methodology

The seedlings used in this study were grown at Coillte's Ballintemple Nursery, Co Carlow. Following germination in the spring of 2008 (sown autumn 2007), seedlings within the test plots were thinned to a uniform density of 100 seedlings m^{-2}. Seedlings were grown under standard operational conditions, except for the fertiliser (Sulfa CAN™; calcium sulphate ammonium nitrate containing 27% N) treatment, which was applied at approximately 2-week intervals from 29 May to 25 July (Figure 1). Treatments consisted of a standard rate of 0.18 g nitrogen (N) $seedling^{-1}$ (amount normally applied in year two of 2+0 production cycle), a control treatment (no fertiliser), and four exponentially (E) fertilised treatments (0.10 E, 0.18 E, 0.5 E, and 1.0 E g N $seedling^{-1}$) where applications were determined via exponential functions as described by Timmer and Aidelbaum (1996). Height and root collar diameter data (RCD) were collected prior to fertilisation and 12 weeks after final fertilisation. Because of the high morphological variability in oak seedlings due to variable timing of germination, height and RCD effects were compared using relative growth increases (i.e. final morphology compared to initial morphology). Other seedlings were lifted to determine dry weight and nutrient content of shoot and root tissues prior to and following fertilisation. Soil sampling was conducted prior to fertilisation, every two weeks following fertilisation, and on 21 October 2008 to perform plant nutrient analysis and estimate N losses.

Findings and management implications

Seedlings that received the 0.5 E (i.e. 1,880 kg ha^{-1} fertiliser) rate had a superior combination of morphology and nutrition compared to all other treatments. The 0.5 E treatment had the greatest relative RCD increase (Figure 2) and 10 fold dry weight increases. The percentage of seedlings reaching heights above 30 cm was highest in the 0.5 E plots (Table 1). Although final height and RCD values were similar across the fertiliser treatments (Table 1), the 0.5 E treated seedlings had root, shoot, and seedling N contents that were greater (Figure 3) than those in the standard fertilised treatment (0.18 S). Weather data collected at the nearby Met Éireann station at Oak Park nearby showed that summer

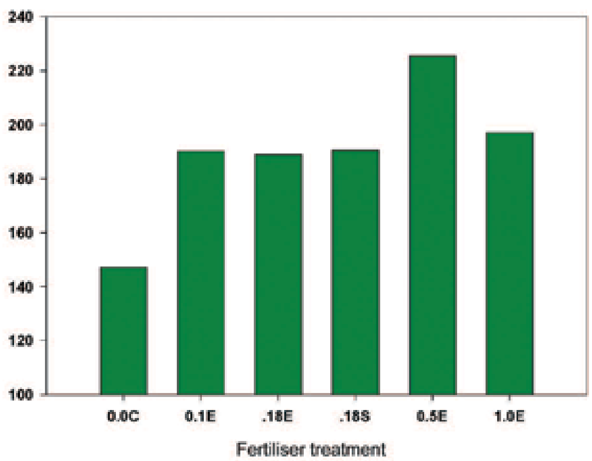

Figure 2. Mean root collar diameter (RCD) increase (%) across treatments calculated as ((RCD Final-RCD Initial)/RCD Initial) × 100.

Table 1. Mean root collar diameter (RCD), height, and percentage of seedlings reaching heights ≥ 30, 40, and 45 cm on 21 October 2008.

Treatment	RCD (mm)	Height (cm)	Percentage meeting target		
			≥30 cm	≥40 cm	≥45 cm
Control	5.1	21.2	7.5	0	0
0.10 E	5.5	26.8	35.9	2.6	0
0.18 E	5.6	27.6	35	7.5	2.5
0.18 S	5.8	29.7	37.5	10	5
0.5 E	6.2	29.9	50	12.5	5
1.0 E	5.9	30.4	47.5	15	15

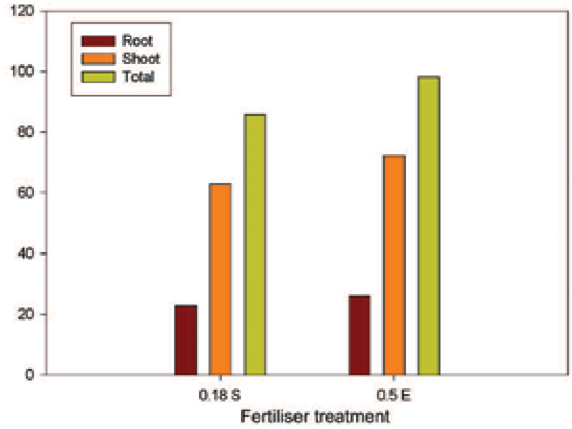

Figure 3. Comparison of root (red), shoot (orange), and seedling (green) end of season nitrogen content between the standard (0.18 S) and optimal (0.5 E) exponential treatment.

Figure 4. Plot showing seedlings that were fertilised with 0.5 g N seedling^{-1}. Some plants reached the target of 45 cm height by the end of one growing season (see Table 1).

precipitation totals were over double those of 1961-1990 averages. Thus, these values were obtained during an extremely wet season, so it is likely that there would have been a better outcome if rainfall levels had been closer to normal.

Nonetheless, the results indicate that it may be possible to produce 1-0 bareroot seedlings meeting target specifications in Ireland (Figure 4) if further manipulations to seedling culture are implemented; however, potential environmental degradation via N leaching must also be considered.

An assessment of nitrogen losses in this study found substantial losses at increasing fertiliser rates (data on file); however, these losses may be attributed to the extremely high precipitation levels in 2008. A subsequent study conducted on another seedling crop during 2009 (which was also exceptionally wet) further substantiated the claim that the 0.5 E rate was the optimal treatment. However, the results from the 2009 study (data not shown) showed that increasing the number of fertiliser applications (i.e. 7 versus 5) and extending the duration of fertilisation into August increased the yield of seedlings meeting target dimensions.

Since the results of both experiments were so promising, Coillte plans to carry out a larger pilot-scale study in 2010 at Ballintemple using the 0.5 E treatment. In addition, the impact of exponential fertilisation treatments on field performance potential is being investigated in an ongoing study at UCD.

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