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Effect of grit grade and grit source on the germination, early morphology and health of Sitka spruce (*Picea sitchensis* (Bong.) Carr.)

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Abstract
The impact of grit grade and source on the seed germination, early morphology and health of Sitka spruce (*Picea sitchensis* (Bong.) Carr.) germinants and on soil pH was investigated in a greenhouse trial. Seed germination, germinant morphology and health were best in the coarse (2.0-6.0 mm) grits, and grit source had no effect. Germination percentage, germinant size and number of healthy germinants were lowest in the fine (0.2-2.0 mm) grits, and there was significant variation among grit sources. The pH of the soil was increased in three grit sources within this grade, and in one by nearly two pH units. Results for the mixed (0.2-6.0 mm) grits were closer to those obtained for the coarse grits for all variables except soil pH, but grit source effects were significant. The pH values for this grade were almost identical to those obtained for the fine grits.

Key words: Seed cover, grit, germination, pH, Sitka spruce

Introduction
It is generally accepted that seed of most tree species covered with fine grit or coarse sand germinate quicker and give higher yields than if nursery soil alone is used. Grit is the preferred seed cover material used in Irish nurseries. A grit having a particle size of 3.0-5.0 mm is recommended by the Forestry Commission (Mason, 1994). In addition, grits should be free from silt and lime. The silt portion may 'cake' and reduce germination, while the lime may increase the pH of the soil. Furthermore, the colour of the grit has an effect on germination and growth, with light coloured grits giving the best results. In one British study using Sitka spruce (*Picea sitchensis* (Bong.) Carr.), a very coarse (>6.0 mm), dark grey grit yielded 274 seedlings/m^2 of 2.5 cm height, compared with 821 seedlings/m^2 of 4.6 cm height for a coarse (or medium), white grit (2.0-6.0 mm) (*Ibid.*). The colour of the grit affects the temperature of the covering material, and severe damage to new germinants may occur during warm sunny days if black or dark grey coloured grits are used (Petrie and Mackay, 1948).

A wide variety of grit types are used in Irish nurseries, largely depending on local availability. It has long been suspected, however, that the quality and type of grits used contribute to the variable germination of seeds and early growth rates of seedlings in some Irish nurseries. There is little information (and none published) on the effects of grit quality and type on seed germination and early seedling growth in Ireland. It is worth noting that although the overall pH of the soil may be influenced only slightly by the use of grit, the pH of the soil in the germination zone may be affected more. There is no information on the possible effects of grits used in Ireland on soil pH. To this end, the influence of grit grade (fine, coarse or mixed) of six different grit types or sources (used operationally in three nurseries in 1993) on the germination and early growth of Sitka spruce was investigated in a greenhouse trial. The effects of grit grade and source on the pH of the soil in the germination zone was also studied. The effect of grit colour on germination was, however, not investigated.

Materials and methods

Grit source and description

Six grits, used at three different Coillte nurseries in 1993, were used in this study (nurseries A, B and C[1]). The particle size distribution of the ungraded grits varied considerably (Table 1). Grits from nursery A (A1) and nursery B (B1) had higher proportions (60%) of large (>2.0 mm) material compared with those from other sources (40-50%). A physical description of the grits is given in Table 2.

Table 1. *Percentage particle size distribution in the six different grits. (The grits from the three nurseries are denoted by an arbitrary letter (A, B and C), followed by an arbitrary number for each of the two grits per nursery.)*

Class	*Particle size mm*	*Grit Source* A1	A2	B1	B2	C1	C2
Gravel	>2.0	59.95	39.56	61.00	41.33	49.88	49.12
Sand							
Coarse	0.5-2.0	39.46	55.31	37.61	53.08	47.61	46.86
Medium/fine	0.05-0.5	0.50	5.07	1.33	5.51	2.32	3.95
Silt/clay	<0.05	0.09	0.06	0.06	0.08	0.09	0.07
pH		7.80	8.20	7.30	7.30	8.50	7.80

Note: Particle size categories are those used by Teagasc (the Agriculture and Food Development Authority).

Table 2. *Physical description of the six different grits.*

Grit	*Description*
A1	White coloured granite schist
A2	Dark grey/black coloured granite
B1	Grey coloured granite
B2	Dark red/purple coloured sandstone
C1	Pink/light red coloured granite
C2	Cream coloured quartzite

[1] To preserve anonymity, the nurseries are referred to only by use of an arbitrary first letter followed by an arbitrary 1 or 2 for each of the two grits per nursery.

Grit treatments

To determine the effects of grit source and grade on various response variables, each of the six grits (sources) was separated into three particle size categories by passing the ungraded material through a series of sieves/screens of mesh sizes 0.2, 2.0 and 6.0 mm. Fine (0.2-2.0 mm), coarse (2.0-6.0 mm) and mixed grade (0.2-6.0 mm) grits were created from each grit type. Most of the silt/clay (<0.2 mm) fraction was removed from all grades. The mixed grade was almost identical to the ungraded grit except for this factor. This process yielded a total of 18 different grit treatments (6 grit sources x 3 grades).

A 5 g random sample was taken from each of the 18 different grit treatments for pH (H_2O) determinations, using standard procedures (Anon., 1974). Each grit sample was placed in a beaker containing 12.5 ml of deionised water, agitated for 10 minutes, and then allowed to stand for 48 hours. Five pH readings were taken of each sample solution using a standard pH meter (Radiometer PHM 84). The solution was agitated before each reading. The pH readings for each grit sample and among sample grades from the same grit source varied little. The mean pH of the mixed grades were 7.3 (B1, B2), 7.8 (A1, C2), 8.2 (A2) and 8.5 (C1) (Table 1).

Experiments

Germination and early growth

In early June 1993, stratified Sitka spruce seed (registration code 94R91) of Washington provenance were sown in plant pots containing soil from the Coillte nursery at Ballintemple, Co. Carlow. The soil was a sandy loam of pH 5.5, having an organic matter content of 8-12% and sand, silt and clay fractions of 66%, 19% and 15% respectively. The pots were sown with 25 seeds and placed in a glasshouse unit at Thornfield, UCD, receiving water at 2-day intervals. The seeds were covered with 0.5 cm of grit from one of the 18 grit treatments, while the controls were covered with 0.5 cm of soil. Each grit treatment was represented by five single pot replications. The germination test was laid out as a randomised block (five) design, each block containing one replication of each of the 18 grit treatments and 6 controls (equivalent to the number of grit sources).

The number of germinating seeds per pot was recorded at 2-day intervals over 21 days. Germination was defined by plumule emergence as it was difficult to judge when radicle emergence took place without disturbing the grit surface and seeds.

As the soil would dry quickly in the pots at this time of the year in a greenhouse and in order to improve relative humidity levels, small polytunnels covered with shade cloth (50% reduction over ambient) were placed over the pots. The temperature in the tunnels was within 20-30°C and relative humidity was >90% at all times.

At the end of the germination period, the shoot and root lengths of five healthy germinants from each pot were measured. For this purpose, every fifth germinant was systematically removed, beginning at one point in each pot (sometimes requiring more than one sweep). Following measurement, each germinant was carefully washed to remove grit, soil and other residue and oven dried at 65°C for 24 hours, after which dry weights were determined.

The stage of development and disease status of each of the remaining germinants per pot were assessed a few days later. The stage of development of each germinant was scored as follows: (i) emerged from seed but seed cap present; (ii) cotyledons fully developed; (iii) primary needle initiation beginning; and (iv) visible new shoot elongation underway. The presence of damping off fungi (*Pytium* spp.) or *Rhizoctonia solani* was noted, and the actual level of damage per plant was subjectively scored (healthy, unhealthy or very unhealthy).

Soil pH

A parallel experiment, identical in design to the germination experiment, was initiated to investigate the effect of grit on soil pH. In this experiment, however, no seeds were sown in the pots and the soil within each pot was separated into three layers. The layers were introduced to facilitate sampling and to prevent the intimate mixing of grit and soil. Furthermore, it was felt that the germinating seeds might disturb the upper layer. The layers were demarcated using six pieces of a permeable inert nylon gauze per pot. The top layer was located near the grit surface (2 cm depth), the middle layer approximately 7 cm from the grit surface and the third near the bottom of the pot. The pots were watered in the same way as those in the germination experiment. After 21 days (as in the germination test), the layers were removed from the pots, sieved and oven dried. The pH (H_2O) of each soil sample was determined. Five 5 g samples were arbitrarily taken from each layer, mixed in 10 ml of deionised water, agitated for 1 minute and then allowed to stand for 10 minutes. Each pH reading was taken after the suspension had been agitated again for another 1 minute.

Data analysis and presentation

Most data were analysed following an ANOVA for a balanced randomised block design, followed by a least significance difference test to determine which means were significantly different. For each variable, the following analyses were carried out: (i) effects of replication and grit source across all grades; (ii) the effects of replication, grit source and grit grade; and (iii) the effects of replication and grit grades within each grit source. The pH data were similarly analysed, except that the effect of layer was considered an additional factor (repeated measures design). The data were also analysed separately for each layer. The pH data were transformed to antilogarithms for analysis. The stage of development and condition data were analysed using chi-squared tests.

Results

Germination

Grit source and grit grade had a highly significant effect on final seed germination ($p \leq 0.001$). The effect of grit grade was largest, with the fine grits having the lowest germination (Figure 1). There was no significant difference in germination rates among grit sources within the coarse grade, with close to 80% of the seeds germinating. In contrast, there were substantial differences among sources within the fine grits. Seed germination was highest in grit A1 and lowest in grit C1 within the fine grits. Germination values for the mixed grits were closer to those of the coarse grits, but the values were more variable. This trend mainly reflected the proportion of fine grit in the mixed grit (Table 1), with grits having the highest proportions tending to have the lowest germination.

Morphology and condition

Grit grade had a highly significant effect on height, root length and dry weight (all $p \leq 0.01$) after 21 days in the glasshouse (Figure 2). Germinants from the fine grits had a smaller shoot length and a lower mass than those from other grades. Root length, however, was longer in germinants from the fine grits. Grit source had no significant effect on germinant morphology.

A high proportion of germinants from the mixed (90%) and coarse (87%) grits were undergoing shoot growth after 21 days, significantly greater ($p \leq 0.001$) than the proportion of those from the fine grit (76%) (Figure 3). Grit source had no significant effect on these values.

Diseased (mostly due to damping off fungi) and/or unhealthy germinants were significantly more frequent in the fine (14%) than in the mixed (8%) or coarse (4%) grits (Figure 3). Grit source had no significant effect.

Soil pH

The effect of grits on soil pH was most pronounced for the layer nearest the seeds. Data are presented for this layer only (Figure 4), although the trend was generally consistent across each layer.

The pH of the pots containing soil only (control) was increased by approximately 0.5 pH units, presumably as a result of the influence of the near neutral tap water. The pH of the control pots is indicated as a horizontal line in Figure 4.

The pH of the soil just beneath the seeds was increased in some mixed and fine grits of some sources, but not in the coarse grits of any source, compared with the control (soil only) (Figure 4). There was an increase of nearly 2 pH units in the mixed and fine grits of C1, but the effect was smaller in A2 (approximately 0.5 pH units). The fine grit of B1 increased pH by a similar amount to that of A2, but the effect was not reflected in the mixed grit of this source. This is presumably due to the fact that the proportion of fine grit was only 40% in B1, compared with 60% in A2.

Discussion

The results of this study clearly show that grit grade had a large impact on seed germination and the early growth and health of Sitka spruce germinants. The results also show that some of the grit types or sources (all used in Coillte nurseries in 1993) may not be suitable for covering Sitka spruce seeds.

Seed germination, stage of development and germinant morphology were best when the coarse (2.0-6.0 mm) grits were used. Grit source had no significant effect on this outcome. Soil pH also was not significantly influenced by this grit type. These results underline the value of using relatively large diameter grits to cover Sitka spruce seeds in Irish nurseries. It is likely that other species would equally benefit from using these grits (cf. Faulkner, 1953; Mason, 1994). Very large diameter grits (>6.0 mm) are not recommended for covering seeds (Mason, 1994), but the effects of using such grits were not investigated here.

In contrast, the fine grits had the most negative effect on germination, morphology, stage of development and health. There were significant differences among grit sources for the fine grits, perhaps due in part to the highly significant effect on soil pH for this grade.

The results for all variables in using the mixed grits were closer to those obtained using the coarse than the fine grits. Unlike the coarse grits, however, there was considerable variation among sources in germination, ranging from approximately 62% in C2 to 89% in A1. Soil pH was increased significantly in two of these grits, perhaps contributing to the reduction in germination. Nevertheless, evidence from this trial suggests that the proportion of

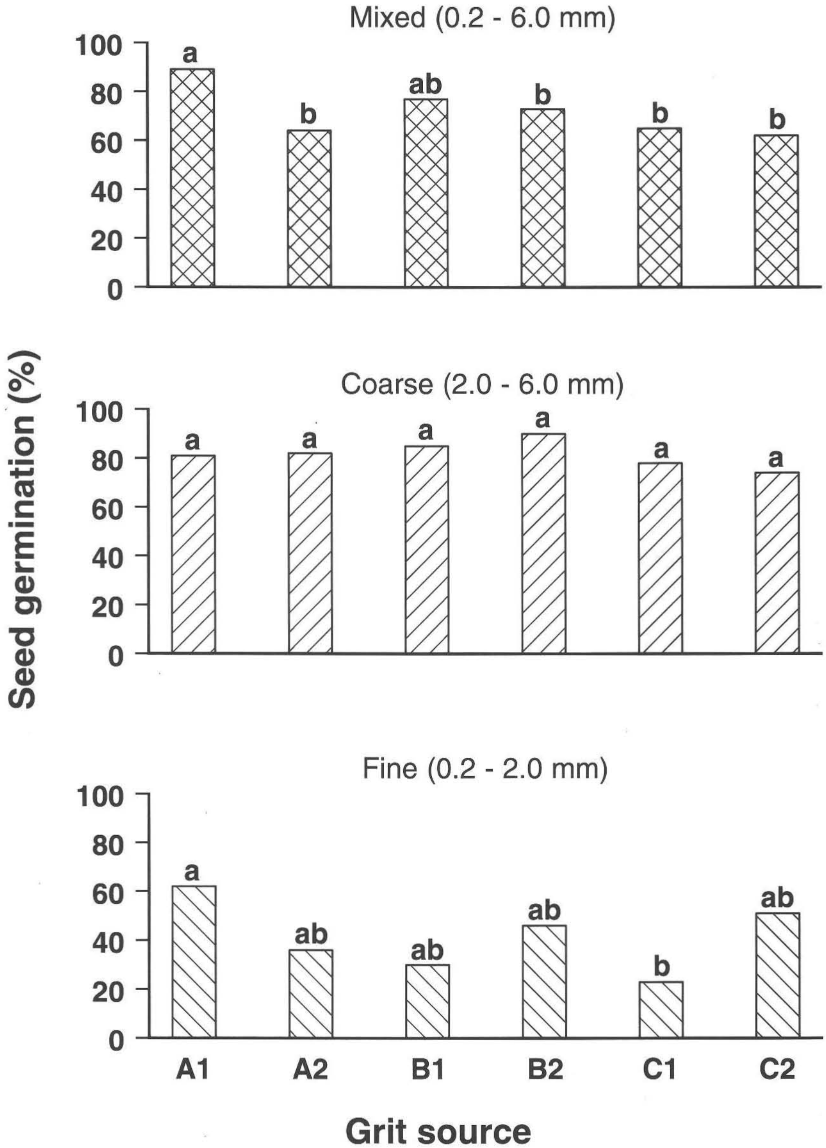

Figure 1. *The effect of grit grade within each of six different grit sources on the germination of Sitka spruce seeds in a greenhouse trial after 21 days. Values having the same letter within each grade are not significantly different at* $p \leq 0.05$*. The grits from the three nurseries are denoted by an arbitrary letter (A, B and C), followed by an arbitrary number for each of the two grits per nursery.*

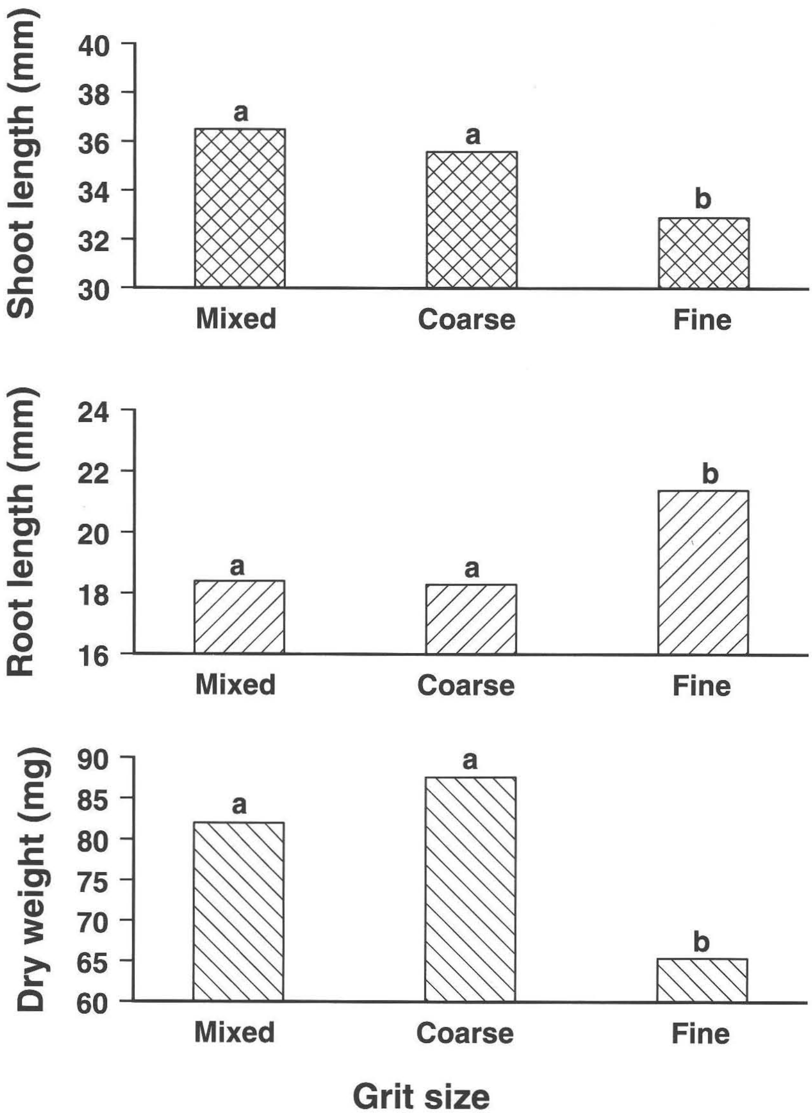

Figure 2. *The effect of grit grade averaged across all grit sources on the morphology of Sitka spruce seeds in a greenhouse trial after 21 days. Values having the same letter are not significantly different at $p \leq 0.05$. Grit source was not significant.*

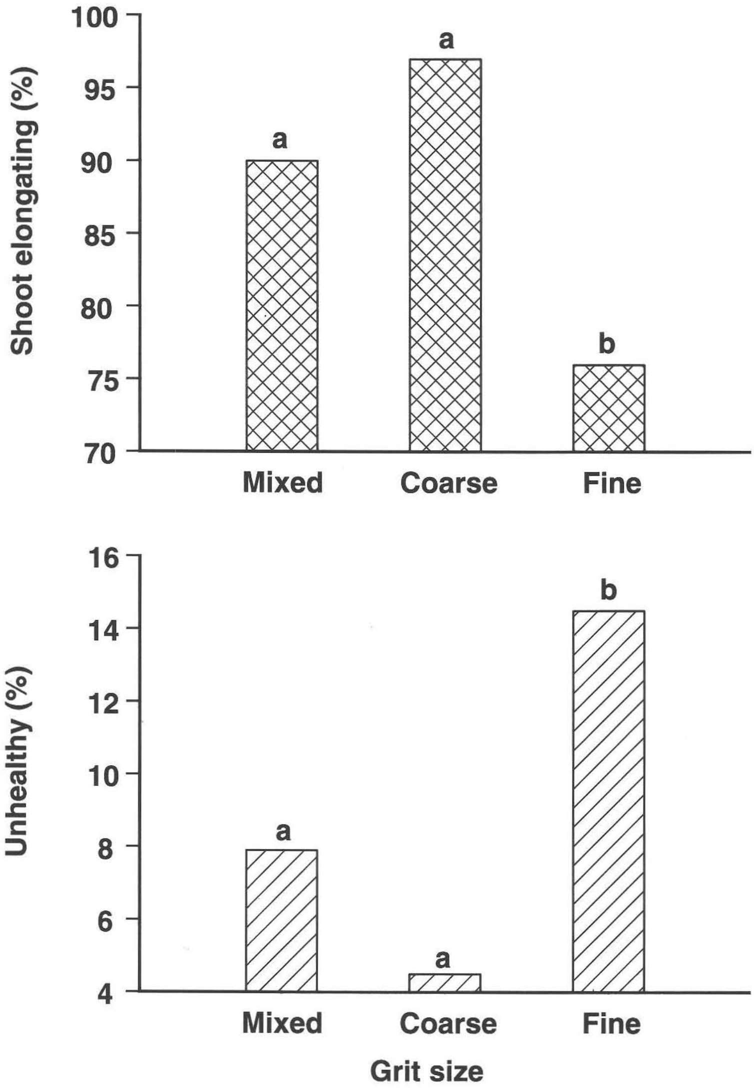

Figure 3. *The effect of grit grade averaged across all grit sources on the stage of development and health of Sitka spruce seeds in a greenhouse trial after 21 days. Values having the same letter are not significantly different at* $p \leq 0.05$ *for each variable. Grit source was not significant.*

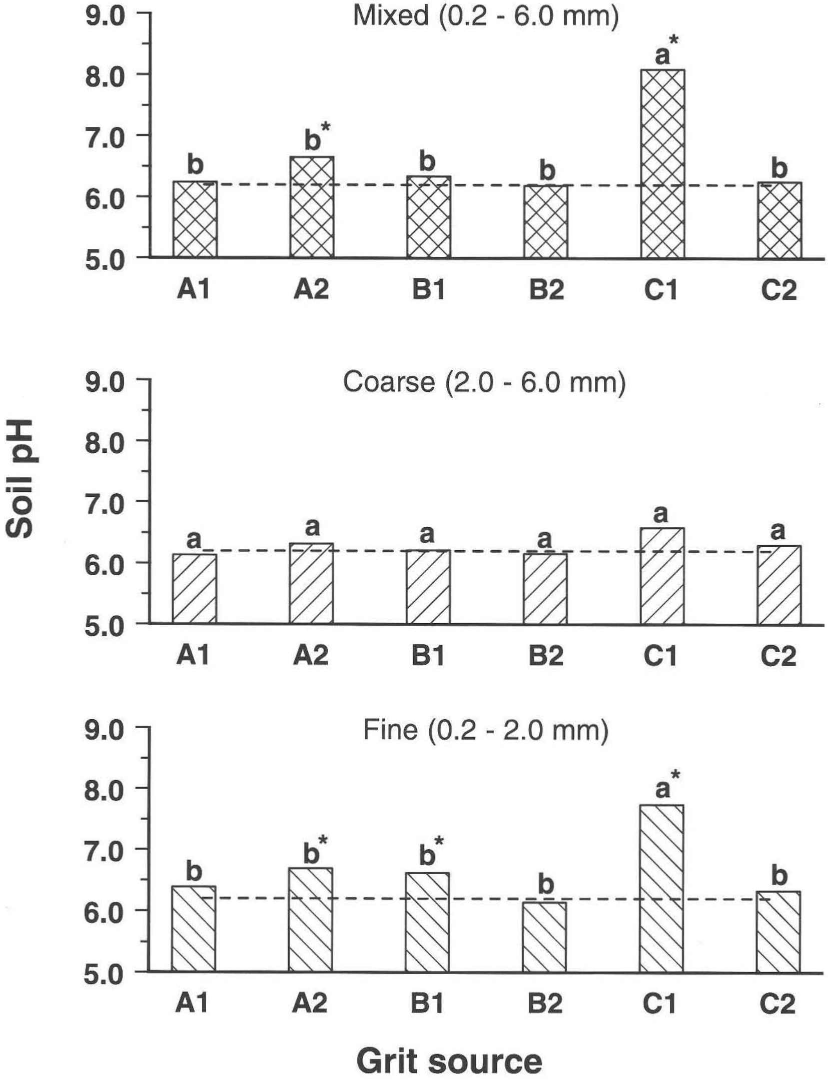

Figure 4. *The effect of grit grade within each of six different grit sources on the pH of the soil in a greenhouse trial after 21 days. Values having the same letter within each grade are not significantly different at* $p \leq 0.05$. *The dashed horizontal line refers to the pH of the control (soil only). Values indicated (*) are significantly different from the control. The grits from the three nurseries are denoted by an arbitrary letter (A, B and C), followed by an arbitrary number for each of the two grits per nursery.*

fine grits in the mixed grit also had a large impact on most variables. Grits having a low proportion of fine grits performed best, giving results similar to the coarse grit of that type. The mixed grits were almost identical to ungraded grits, except that the very small material was also removed (mostly very fine sand and silt comprising approximately 1-1.5% of the total).

Other workers have found that grits having a high proportion of particles in the 3.0-5.0 mm range gave the highest yield of Sitka spruce seedlings, compared with fine or coarse grade material (Mason, 1994). Hallet (1982), working in eastern Canada, suggests that grits predominantly in the 1.0-4.0 mm size category (60-80% in the 1.0-2.0 mm and 15-40% in the 2.0 mm range, with few fines) should be used for covering seeds of spruce or pine (*Pinus* spp.) when grown in containers. Other conifer species may have similar requirements to Sitka spruce, although there is evidence that some small-seeded species (e.g. *Thuja plicata* D. Don and *Chamaecyparis lawsoniana* (Murr.) Parlatore) may germinate better using coarse sand rather than grit (Gordon and Wakeman, 1979). There is little other information on the effects of grit grade on the germination and growth of conifers.

This study also provided evidence that some grits being used in Irish nurseries increase soil pH. In addition to the possible direct effect on germination, an increase in pH will have a detrimental effect on the nursery soil in the long term, perhaps contributing to the development of nutrition problems (Mason, 1994). The presence of free lime is undesirable and can be detected using vinegar or dilute hydrochloric acid, with the grit fizzing if it contains too much lime (*Ibid.*). The actual level of free lime in the grits studied was, however, not determined analytically. Three of the six grits used in this study increased soil pH, and the effect for one grit was dramatic, increasing it by nearly 2 units. However, as this experiment was carried out in a controlled greenhouse environment using local tap water (near neutral pH), it is difficult to extrapolate from these results to the nursery. In addition, the results presented here were for pH effects in the germination zone only, and the effect was less pronounced in deeper layers. Nevertheless, two points are worth noting. First, it is likely that soil pH is perhaps affected more in the nursery as the grits remain in the soil for a much longer period than was examined in this study. Second, even if average soil pH is only slightly influenced by the grit, it is likely that the impact on soil pH in the germination layer (Figure 4) is much more marked, perhaps contributing to a reduction in seed germination (Figure 1).

Recommendations

1. Only grits containing a high proportion ($\geq$60%) of coarse (2.0-6.0 mm) material should be used to cover Sitka spruce seeds.
2. The content of free lime in the grits should be low. The grit should pass the test described above (after Mason, 1994).

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