ROOT EGRESS IN LODGEPOLE PINE SEEDLINGS GROWN IN PEAT AND PLANTED IN SOIL

A.K. Helium'

Abstract.--Seedlings of lodgepole pine *(Pinus contorta* Dougl. var. Zatifolia Engelm.) were grown in 49 cm^3 containers filled with peat or soil and subsequently transplanted into 18 cm diameter pots filled with soils ranging in texture from sandy loam to clay loam. Watering intensity did not significantly influence the growth of transplanted seedlings. Seedlings reared in peat, and held for planting past their optimum size relative to container size, became progressively less able to adapt to soils with increasing clay content the longer they were held. When seedlings were reared in the same soil into which they were to be transplanted, clay content in the soil did not influence root egress at all.

Résumé.--Des semis de pin tordu latifolié *(Pinus contorta* Dougl. var. *latifolia* Engelm.) ont été cultivés dans des récipients de 49 cm^3 contenant de la tourbe ou différents types de sol, et ensuite transplantés dans des récipients de 18 cm de diamètre contenant des sols dont la classe de texture variait du loam sableux au loam argileux. L'intensité de l'arrosage après la transplantation n'a pas beaucoup influé sur la croissance des plants. Ceux qui avaient crû dans la tourbe et dont la transplantation avait été retardée une fois leur dimension optimale atteinte par rapport à la dimension du récipient ont eu d'autant plus de difficulté à s'adapter aux sols de plus en plus argileux que le retard avait été important. La teneur en argile n'a aucunement influé sur le développement des racines dans le cas des semis cultivés dans le même sol que celui dans lequel ils allaient être transplantés.

INTRODUCTION

The advantages of container-grown tree seedlings over bare-root stock are many and varied (Kinghorn 1970, Scarratt and Ketcheson 1974), and range from easier handling of stock and rearing, to more rapid nursery production, to less expensive field planting and higher survival. Techniques for rearing have been detailed at great length (Waldron 1972, Tinus et al. 1974, Kay 1975, Low 1975, Carlson 1979, Tinus and McDonald 1979).

Considerable attention has also been paid to growth of coniferous stock after outplanting although the results are contradictory with respect to growth advantages over bare-root stock (Arnott 1971, 1974, Gillgren 1972, Walker and Johnson 1974, Kormanik et al. 1976, Carlson and Nairn 1977, Hahn and Hutchison 1978, Segaran et al. 1978, Walker 1978).

Root development may be hampered by the container in which the seedling is grown in the nursery (Bergman and Hgggstriim 1976, Van Eerden and Kinghorn 1978). Not only may root form be restricted but this restriction may lead to unbalanced growth (Greene 1978) and to warnings of instability in sapling stands (Tinus 1978). The problem is especially severe for several members of the genus *Pinus* (Stone et al. 1963, Endean 1972, Van Eerden 1978).

It is not only the container, however, which may present problems; the potting medium is also important (Long 1932, Klett et

[1]Associate Professor, Department of Forest Science, University of Alberta, Edmonton, Alberta.

al. 1972, Helium 1975, Funk et al. 1980). Peat moss is the principal potting medium used in Canada and elsewhere.

The study reported here addresses the problem of planting seedlings of lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) that have been grown in peat moss in soils of different texture. The problem has received little attention, but may play a major role in determining seedling survival after outplanting. We know that peat has different hygroscopic properties than soil (Buckman and Brady 1960) and that this difference leads to moisture problems (Day and Cary 1974) when roots attempt to traverse the boundary between the peat and the soil.

The study attempts to answer three questions:

1. Does root growth outside the container, after simulated outplanting, vary in relation to available water as suggested by Endean and Hocking (1973)?

2. Does soil texture or soil manipulation (affecting bulk density) affect root egress as suggested by de Champes et al. (1975)?

3. Does the size of the seedling in relation to the volume of the container in which it is grown affect the seedling's growth when it is planted in soils of different soil texture?

METHODS

Three separate greenhouse studies were initiated, one each year from 1978 through 1980. All seedlings in the second and third year were grown in a greenhouse under a 16 hr day and at 20°C. In 1978 the seedlings were donated by North Canadian Forest Industries Ltd. This stock was considered overgrown for the size of the container used, and weighed nearly twice as much as was recommended for a 49 cm^3 rooting volume (Endean and Carlson 1975).

In 1978 and 1979 the seedlings were reared in peat moss and transplanted to flowerpots (18 cm diameter and 10 cm deep) filled with peat, sandy loam (Culp series), silt loam (Breton series), or clay loam (Maywood series) from the Edmonton areal. In 1980 the seedlings were both reared in Spencer-Lemaire Ferdinand containers (49 cm^3) and transplanted into the above three soils (transplanted into same flowerpots). Only in 1979 were the seedlings fertilized with a 10-52-10 fertilizer.

After transplanting, the seedlings were allowed to grow for 10 weeks at 20°C, with a 16 hr photoperiod, before harvesting.

Watering varied between years. In 1978 the transplanted seedlings were watered every 3 1/2, 7 or 14 days, in 1979 they were watered every 7, 14 or 21 days, and in 1980 they were watered every 14, 21 or 28 days.

A total of 75 seedlings were tested each year in 1978 and 1979, and 60 were tested in 1980. Each year, 15 of these seedlings were analyzed before transplanting, and the remaining seedlings were divided equally among the three watering levels and transplant media.

The seed sources for this study were: 1978--seedlot DG 63-3-6-74 from Grande Prairie, Alberta (1060 m above sea level and 54°30'N); 1979 and 1980--seedlot DB 8-4-5-77 from Blairmore, Alberta (1,500 m above sea level and 49°30'N).

The soils and peat were sieved through 6 mm mesh, sterilized (steam-sterilized at 82°C for 30 minutes), and watered daily for 14 days before transplanting to settle the material. Then cores of medium were removed from the centre of each pot to accommodate the 49 cm^3 seedling plug. The cores were removed using a hollow, rectangular dibble made of sheet metal. The bulk density of each of the mineral soils in the pots was measured after the 14 days of watering. A 70 cm^3 core was taken from the centre of each of three pots, in addition to those used in the transplant tests, 24 hr after the last watering when the soils were near field capacity.

At the time of final harvest the seedlings were carefully removed from the pots to ensure that roots were not damaged or cut off and that root egress from the plug form could be identified. Egressed roots were cut off in the laboratory so that the effects of rooting media could be compared.

Seedlings were oven dried at 105°C for 24 hr to determine dry weights.

The following measurements were made at time of transplanting and after the 10-week growing period: seedling height, maximum root length, shoot and root dry weights, root weight outside plug form, root-collar diam-

[2] The soils were tested by the Alberta Department of Agriculture and found to be adequately supplied with N and P and well supplied with K.

eter, shoot:root ratios (based on oven-dry weights).

Simple "F" and "t" tests were run and line formulae were calculated for salient data. Percent and ratio values were transformed to ARCSINE before analyses were run.

RESULTS

Seedling characteristics before transplanting are given in Table 1. Note that in 1978 seedlings were too large (by nearly 100%) for the 49 cm^3 container (Endean and Carlson 1975). The 1979 seedlings were too small (by about 30%) and those from 1980 were matched in size to the rooting volume of the container (300-500 mg total dry weight).

No correlation could be established between watering regime after transplanting and seedling growth (95% confidence level). Consequently, watering levels within soil types were considered as three replicates, each consisting of five seedlings, for the analyses in this study. This lack of watering effect on seedling growth must be related to the fact that the 18 cm flowerpots provided such a large reserve of water that infrequent additions of moisture were of no practical consequence. Watering periodicities from 3 1/2 to 28 days were all the same in their effect on growth.

Little or no height growth took place in the 10 weeks following transplanting although there was considerable root extension, some roots nearly doubling their maximum lengths (Table 2).

In contrast, both roots and shoots increased greatly in dry weight. The increases were greatest in the roots of the smaller plants. The 1979 stock increased its root weight an average of 686%, while the average-sized seedlings of 1980 increased their root weight by 397%. On the other hand, the overgrown stock of 1978 increased its root weight by only 272%. The effect was that the 1980 stock, matched to container size, had the heaviest roots (625 mg vs 607 mg and 259 mg averages for 1979 and 1978, respectively).

Shoot weight increases were much more modest, amounting to an average of 247% in the 1979 stock, 223% in 1980 and a mere 89% in 1978. In other words, the greatest increases were found in the smallest stock (at time of transplanting) and the smallest increases were found in the overgrown stock. Seedlings grown in sandy loam in 1980 also produced heavier roots than those grown in silt loam or clay loam (99% confidence level).

Similar trends were observed in root collar diameters and shoot:root ratios. Root collar diameters increased most in the smallest stock (at time of outplanting) and were similar for the large as well as average-sized stock (66 and 64%, respectively). Shoot:root ratios all decreased after transplanting by 35 to 55%. This decrease was a direct result of the large root weight increases over the test period.

When the weight of roots growing from the container (plug) form was analyzed separately from total root weight (Fig. 1) it was found that:

Table 1. Seedling characteristics, by test year, immediately prior to transplanting into 18 cm pots.

	Test year and growing medium				
	1978[a]	1979[b]	1980[c]		
	Peat	Peat	Sandy loam	Silt loam	Clay loam
Shoot (cm)	14.05	7.95	9.71	7.99	8.77
Max. root (cm)	16.24	12.87	11.98	11.69	14.16
Shoot dry weight (mg)	581.00	132.00	287.67	210.67	239.33
Root dry weight (mg)	223.00	65.19	84.67	95.33	93.33
Root-collar diameter (mm)	1.96	0.79	1.37	1.28	1.22
Shoot:root ratio	2.60	2.05	3.71	2.22	2.62

[a]Seedlings were approximately 150 days old at time of transplanting
[b]Seedlings were approximately 90 days old at time of transplanting
[c]Seedlings were approximately 180 days old at time of transplanting

Table 2. Changes in seedling characteristics over the 10-week transplanting test period.

	Test year and growing medium				
			1980		
	1978	1979	Sandy loam	Silt loam	Clay loam
Shoot (cm)	+ 13%	+ 9%	+ 7%	+ 18%	+ 15%
Max. root (cm)	+ 22%	+197%	+131%	+189%	+ 64%
Shoot, oven-dry basis (mg)	+ 89%	+247%	+180%	+233%	+257%
Root, oven-dry basis (mg)	+272%	+686%	+485%	+336%	+369%
Root-collar diameter (mm)	+ 66%	+157%	+ 52%	+ 62%	+ 78%
Shoot:root ratio	- 46%	- 55%	- 56%	- 24%	- 26%

a) oversized seedlings reared in peat (1978) showed a strong negative correlation (r^2 = 0.75) with increasing clay content of the surrounding transplant soil (Y = 75116.6 X) which was significant at the 99% confidence level (Y = weight of egressed root and X = percent clay in the transplant soil);

b) seedlings reared in peat and undersized for the container (1979) also showed a negative but much weaker correlation (r^2 = 0.32) between percent root egress and percent clay in the transplant soil (Y = 531-10.6 X) which was also significant at the 99% confidence level;

c) seedlings matched in size to their container and reared in the same soil in which they were to be transplanted showed no correlation (Y = 150.3 mg) between root egress and clay content of the transplant soil.

It is probable that the small amount of root egress for seedlings grown in soil (1980) is related to their slower overall growth in comparison with that of seedlings grown in peat.

Regardless of texture, the soils did not vary significantly in bulk density during the transplant period. Therefore, average values of 1.02, 1.08 and 0.94 for the sandy loam, silt loam and clay loam, respectively, suggest that root egress is probably not related to bulk density, at least not directly.

The weight of roots inside the container (plug) form increased over the 10-week transplant period. It doubled in the overgrown seedlings (1978), tripled in the average-sized stock (1980) and quadrupled in the small stock (1979). Texture differences among soils in the 1980 test had no significant effect on root weight inside the container (95% level). Since root egress decreases with increasing clay content of the soil after transplanting, it is essential that measurements of root growth be based on the percentage of egressed roots rather than on total root weight when soil effects on growth are evaluated.

CONCLUSIONS

The results of this study have clear implications for planting programs with containerized stock.

1. Watering frequencies ranging from every 3 1/2 days to every 28 days did not influence seedling growth in these studies. It appears that seedlings need no more water than that which was supplied every 28 days, provided that they do not suffer from competition with other plants and that conditions are similar to those of this study. The study lasted 70 days, or approximately 70% of what would constitute a normal growing season under many forest conditions in Alberta (Longley 1968). This modest use of water by the transplanted stock must be seen in relation to transplant shock, however slight it was in this study and in relation to the fact that stock did not flush and grow in height during the transplant period, something which happens commonly

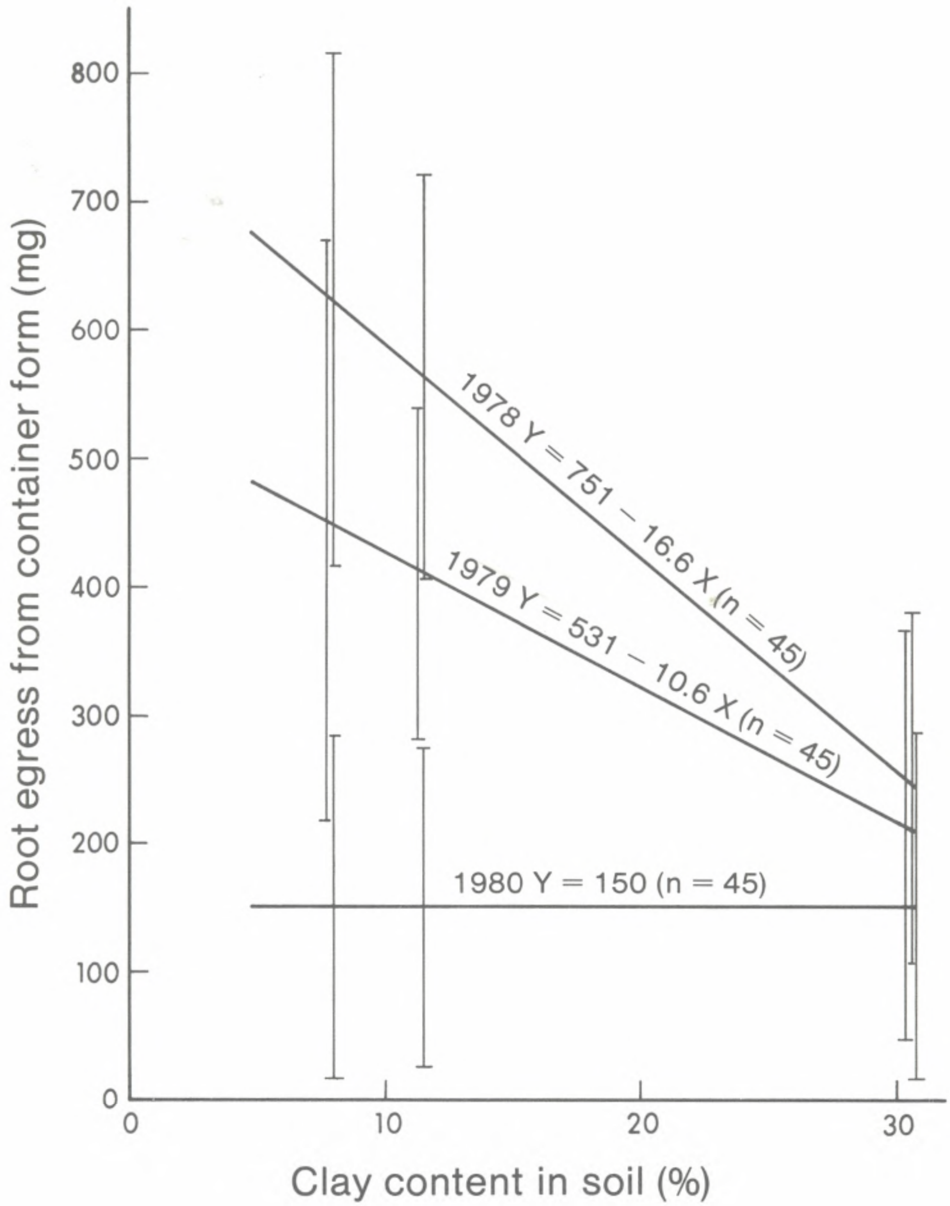

Figure 1. Relationships between root egress and clay content of surrounding soil.

in Alberta when cold stored or overwintered stock is outplanted.

2. The seedlings which were transplanted as peat plugs showed progressively less root egress as the clay content in the surrounding soil increased to a limit of 30% by weight. This agrees with findings by Dosskey and Ballard (1980) and Endean and Hocking (1973), and indirectly with the results of Lähde and Mutka (1975). The effect is interpreted as a response to moisture and texture discontinuities between the peat and soil but not to differences in bulk density.

3. Root-bound and large, overgrown seedlings reared in peat plugs (1978 stock) exhibited a much stronger negative response to transplanting in soil containing clay than did smaller seedlings. This suggests that root binding in lodgepole pine is potentially a serious hindrance to root egress, because egress decreases markedly as the surrounding soil increases in clay content. This points to a need for the use of very vigorous rather than large seedlings for reforestation. Holding container-grown seedlings in a nursery, or in the field, past the optimal time is therefore highly unde-

sirable and may in fact be the single most important factor giving rise to variability among seedlings in subsequent growth and establishment. The conclusion, by Endean and Carlson (1975), that large stock grows more than small stock after outplanting, given one container size for rearing, must be related to amount of rooting volumes matched to seedling size, as well as to seedling size itself. Growth is exponential in the early stages, larger seedlings growing more than smaller seedlings regardless of other factors. The plants in Endean and Hocking's experiment weighed no more than 450 mg at maximum and were therefore not pot-bound (Endean and Carlson 1975).

4. It takes much more time to grow a seedling to a given size in soil than in peat, even when rich agricultural soils are used. It is therefore questionable if it is economically or practically feasible to evade the problems of moisture and texture discontinuities that occur between the seedling plug and the surrounding soil by using soil rather than peat as a growing medium. Soil would also be much heavier than peat for the planters to carry.

5. Alternatives to growing seedlings in peat for outplanting in areas of heavy soils include direct seeding (Helium 1979) and/or extensive site preparation and soil working as suggested by de Champes et al. (1975). Good seedling establishment and growth require that the seedlings be spared severe shock in outplanting. One way to minimize the shock for container-grown seedlings could be to approximate the growing medium with the soil of the planting site, thereby increasing chances for survival and active growth.

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