THE SIGNIFICANCE OF PLANTING HEIGHT AS AN INDICATOR OF SUBSEQUENT SEEDLING GROWTH

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ABSTRACT

During a series of nursery trials, it was observed that, within any one treatment, height growth of seedlings appeared to be similar, irrespective of their initial height at planting. The measurements obtained from those trials are reported in detail. While growth of seedlings was markedly affected by age and by planting site, these factors had litle effect on the relative growth of seedlings in relation to their initial height. For radiata pine there was little effect of initial height on subsequent height growth during the first two years after planting and limited data for Douglas fir seedlings gave similar results.

It is concluded that, in evaluating the quality of seedlings grown at uniform spacings in the nursery, height alone gives no indication of the ability of a seedling to grow away rapidly after outplanting in the forest. Thus, in general, culling on the basis of height alone is of little value; root collar diameter is undoubtedly a better measure of seedling quality.

INTRODUCTION

Forest Research Institute (FRI) Symposium 9 in June 1967 (Chavasse and Weston, 1969) was largely concerned with seedling quality. In the questionnaire circulated prior to the symposium, forestry organisations were asked to report their specifications for plantable tree stocks. Almost without exception the sole criterion was that the plant must be a certain height, although in some answers there were such qualifying remarks as "a good balanced tree" or "some fibrous root development". During the symposium both nurserymen and forest managers confirmed this view, although there was some agreement that specifications must be related to site conditions. No one present was able to give a clear specification for a "good" tree and, as E. H. Bunn suggested in his opening remarks, there was a "tendency to judge stock in the nursery rather than by how it survives on the planting site".

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This stricture does not apply to nursery stock research, which consists largely of evaluating the effects of various treatments (conditioning, nursery spacing, handling, storage, packaging) by planting the seedlings and observing survival, growth, and health over 1 to 3 years. Until recently growth has been assessed almost entirely in terms of shoot extension, largely because this is the simplest parameter to measure, and also because analysis of height growth can provide meaningful results. Nevertheless, it is not possible to describe a "good" seedling simply in terms of its height, either absolutely or in relation to a particular crop. The quality of a seedling, and its ability to survive and grow well after planting in the forest, clearly depend on a number of factors. Similarly, the size of a seedling in relation to its neighbours will depend on several factors, such as differences in seed size, rate of germination, depth of sowing, physiological condition, and (to some extent) genetic make-up (*e.g.*, Sweet and Wareing, 1966).

Within any particular crop of seedlings there is usually a wide range of sizes. For example, Smith and Walters (1965) found heights of 3/0 Douglas fir seedlings to range from 7.5 to 80 cm. Ranges of heights in radiata pine and Douglas fir seedling crops in New Zealand can be observed in Figs. 1 to 6. The forest manager's interest in this lies in whether the shorter trees are able to perform as well as the taller in any given site conditions. But the matter is also important in research. G. B. Sweet (pers. comm.) states: "A point at issue to tree breeders who want to select for growth rate at as young an age as possible is — if total height at a young age has a high component of planting height in it (and if planting height does not result only from genes for high growth rate) then how does the tree breeder cope with this effect in his early progeny trial assessments?" Sweet and Wells (1974) reported, for example, an experiment where major differences in size between seedlings, grafts, and rooted cuttings 5 years after planting related to the initial sizes of the planting stock, rather than to differences in relative growth rates. Larger trees retained their lead over smaller.

The need to minimise the effect of uncontrolled factors has been recognised in research for some time, for it is now well documented that the quality of a seedling depends (among other things) on the space it occupies in the nursery, the conditioning regime to which it has been subjected, and the handling it receives after lifting (*e.g.*, Chavasse and Balneaves, 1971; van Dorsser and Rook, 1972; Menzies *et al.*, 1974; Chavasse and Bowles, 1975; Balneaves and McCord, 1976). Moreover, the quality of a seedling can be recognised by its "sturdiness" — the height:diameter (Ht/D) ratio, or simply

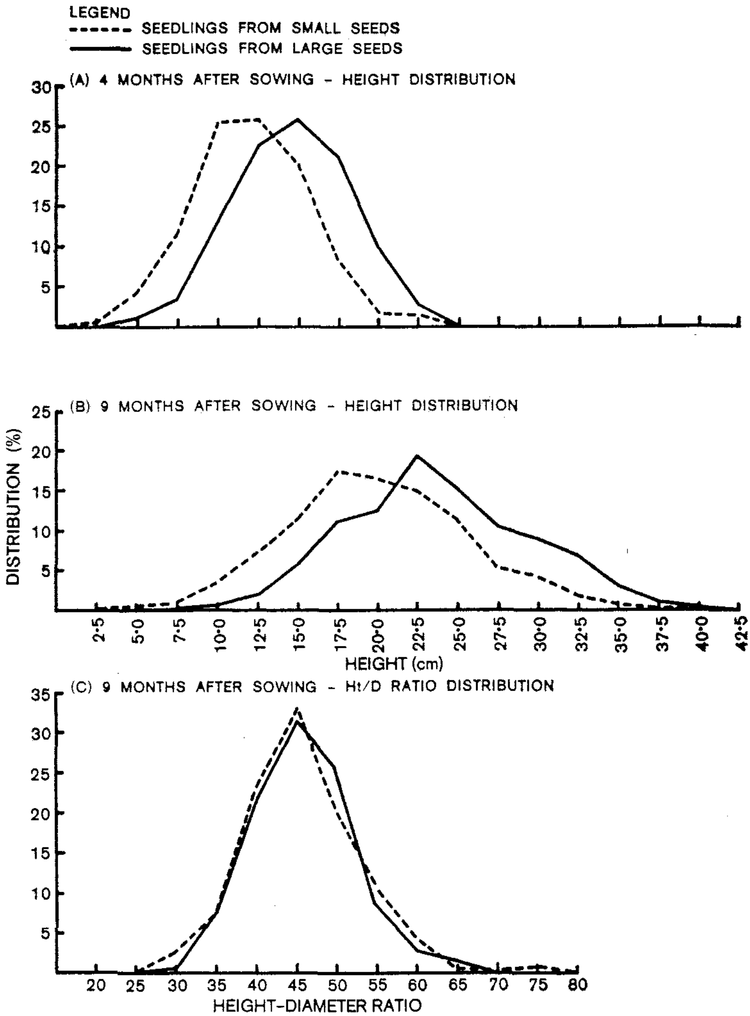

FIG. 1: *Distribution of height and Ht/D classes of precision-sown radiata pine seedlings.*

the root collar diameter (Prior, 1969; Anstey, 1971). After Symposium 9, G. W. Hedderwick (unpubl.) studied the effect of seed weight on the subsequent size of seedlings (Fig. 1). Seed from a typical radiata pine seedlot was divided into two fractions: large (35-45 mg) and smallest (10-20 mg).* Seed

*The 35-45 mg fraction represented about 30% of this seedlot: the 10-20 mg fraction only 5%.

was stratified and the two fractions were then sown in adjoining drills at a spacing of 6.3 cm within drills with 15 cm between drills, and at an even depth of 6 mm. It will be observed that, although the seedlings produced from the large seed fraction are some 5 cm ahead of those from small seeds at 9 months, the range of heights is almost identical in both fractions at 4 and 9 months after sowing. Similarly (Fig. 1c) the ranges of Ht/D ratios are identical for all practical purposes in each fraction. (The small number of very small trees was due to a compacted track running across the bed.) Therefore, while sorting seed by weight can shift average size one way or the other, in a manner positively correlated with seed size, it had no apparent effect on the range of seedling heights even where seeds were meticulously sown at even spacing and depth.

From various establishment trials, studied during 1969 to 1976, it was possible to obtain data on growth (within any treatment) related to initial height, in order to ascertain whether initial height is of any significance in subsequent seedling behaviour. The information in this paper was obtained in this way as a "spin-off" from experiments with a number of different treatments and objectives.

FINDINGS

Radiata Pine 1/0

A preliminary study involved trees planted after periods of storage at FRI nursery (Chavasse and Balneaves, 1971). There were eight storage treatments and a total of 6600 seedlings. Apart from lifting date and storage time, nursery treatment was identical for all lots. Height growth was measured for 1 year from date of planting. Within storage treatments, trends for height growth in relation to initial height were very constant, so results were pooled (Table 1). Although final height

TABLE 1: HEIGHT GROWTH OF 1/0 RADIATA PINE IN RELATION TO INITIAL HEIGHT

Initial Height Class (cm)	*Height Growth 1st Year (cm)*	*Final Height (cm)*
7.5	40.0	47.5
10.0	40.0	50.0
12.5	40.4	52.9
15.0	39.4	54.4
17.5	39.4	56.9
20.0	39.4	59.4
22.5	38.4	60.9
25.0	38.4	63.4
27.5 and above	38.4	65.9

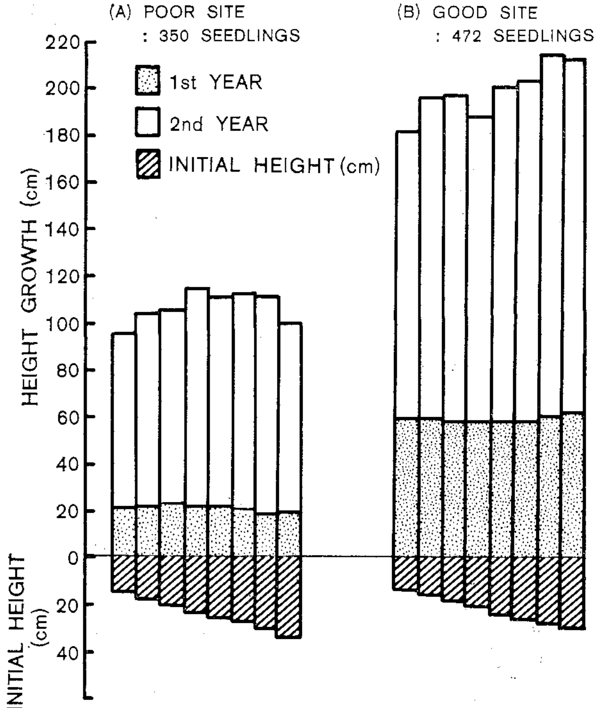

FIG. 2: *Height growth of 1/0 radiata pine over 2 years.*

was still positively correlated with initial height, height growth clearly was not.

Two further trials, planted in 1969 for testing the effects of herbicides, were studied in 1971. One was on a rather poor, dry, exposed site, and the other on a fairly rich, sheltered site. Results are shown in Fig. 2. On the poor site the shorter seedlings made slightly more height growth in the first year than the taller seedlings, yet in the second year the height growth of the taller seedlings was superior. On the good site there was no significant difference betwen height growth of tallest and shorter seedlings in the first year. In the second year, again, the tallest seedlings grew more than the shorter, with a fairly well-defined trend throughout the size range.

In summer 1972-3 a large trial was commenced in order to determine the effect of seedling size and nursery spacing on the quality of 1/0 radiata pine seedlings. Seedling size was varied by sowing at intervals throughout the spring and early summer, and prescribed heights for planting were 10, 15, 20, 25 and 30 cm. Both nursery spacing (which ranged from 1.25

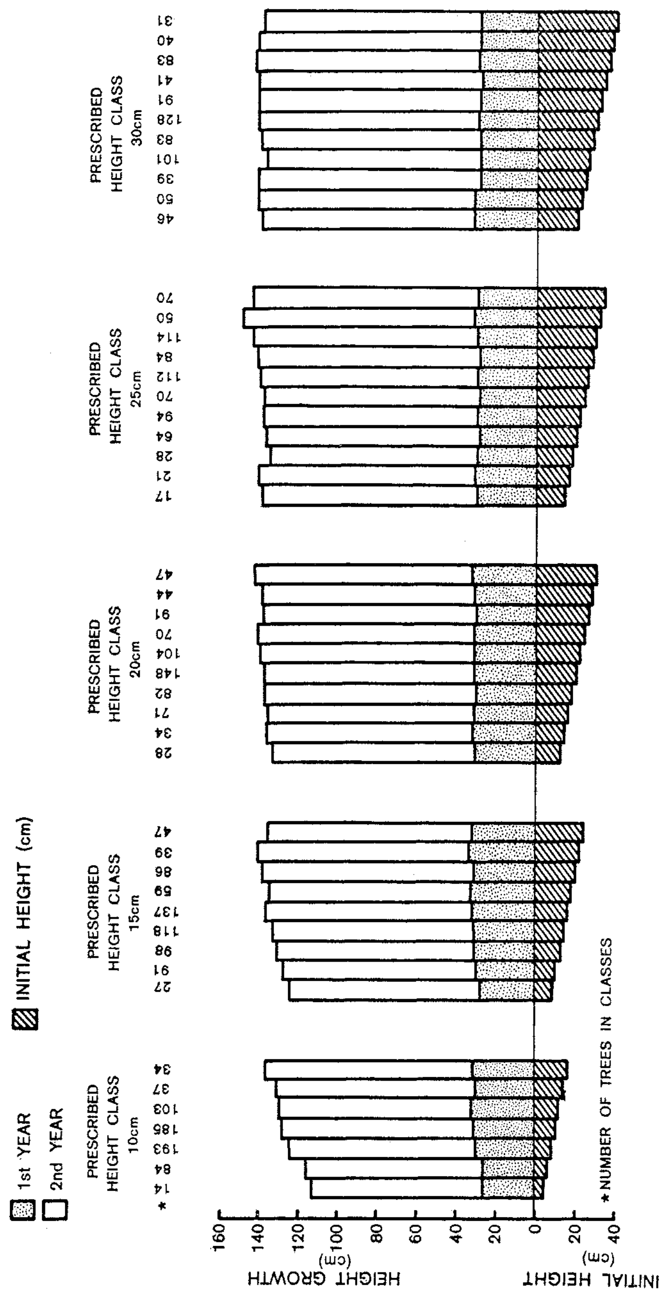

FIG. 3: *Height growth for 1/0 radiata pine over 2 years: good site.*

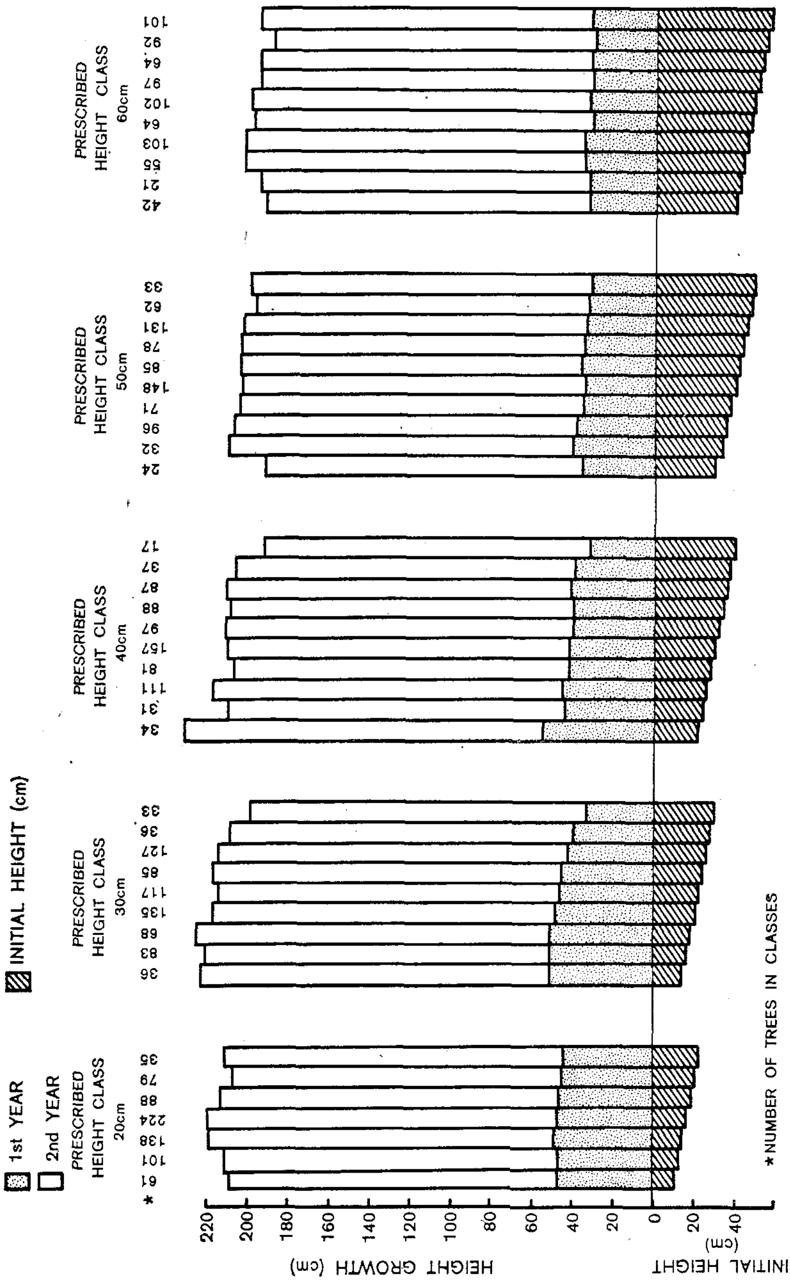

FIG. 4: *Height growth of 1½/0 radiata pine seedlings over 2 years: good site.*

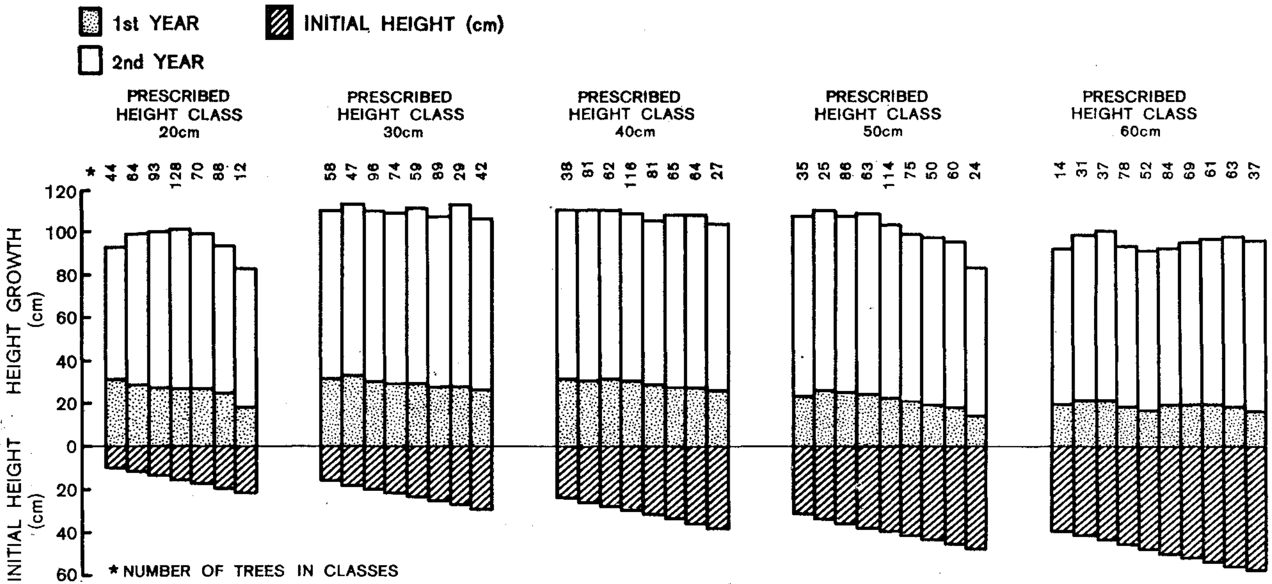

FIG. 5: *Height growth of 1½/0 radiata pine seedlings over 2 years: frost flat site.*

to 5 cm) and height class affected subsequent height growth when the seedlings were planted on a favourable site at the FRI nursery (Chavasse and Bowles, 1975). The effect of initial height on subsequent height growth within treatments is illustrated in Fig. 3. It should be emphasised that in this trial no culling was done.

In the 10-cm prescribed height class (*i.e.*, the last sown) initial heights ranged from 4 to 16 cm. In the first year there was a slight increase in height growth with increasing initial height, the shortest seedlings growing 26 cm, and the tallest 31 cm. In the second year the height growth of the taller seedlings was substantially better than that of the shortest.

In the 15-, 20-, and 25-cm prescribed height classes there was no detectable difference in height growth in relation to any initial height in the first year, but in the second year the taller trees grew slightly better than the shorter. In the 30-cm prescribed height class the height growth of the shorter trees was slightly better than that of the taller in the first year. In the second year the taller trees grew slightly more than the shorter.

A comparison of height growth *between* the five prescribed classes is shown in Table 2. It will be seen that mean height growth in the first year was very similar for all prescribed classes, with no clear trend. Height growth in the second year, however, shows a marked trend; the taller the prescribed class, the better the growth.

Radiata Pine 1½/0

A similar trial, to evaluate survival and growth in relation to size and quality of seedlings, was established in 1973 with 1½/0 radiata pine — half on a good site at FRI nursery and half on a frost flat in Kaingaroa Forest. (Chavasse and Bowles

TABLE 2: MEAN HEIGHT GROWTH FOR PRESCRIBED HEIGHT CLASSES
(1/0 radiata pine)

Prescribed Height Class (cm)	*Mean Initial Height (cm)*	*Height Growth*			*Final Height (cm)*
		1st Year (cm)	*2nd Year (cm)*	*Total (cm)*	
10	9.1	29.9	95.9	125.8	134.9
15	15.0	31.5	102.9	134.4	149.4
20	20.9	30.8	107.8	139.6	160.5
25	25.4	29.8	111.1	140.9	166.3
30	29.2	29.3	111.6	140.9	170.1

(1976) have reported on the FRI nursery site trial.) The prescribed heights for planting were 20, 30, 40, 50, and 60 cm. Results on both sites, in terms of height growth, are illustrated in Figs. 4 and 5.

For the seedlings planted at FRI (Fig. 4) the trend in height growth in the first year is consistent; within the prescribed height classes the shorter trees grew rather more than the taller, although this is least pronounced in the 20- and 60-cm prescribed height classes. In the second year, overall, there was no significant difference in height growth between the shorter and taller seedlings.

It was suspected that the effect of initial height on subsequent height growth would be affected by frost, and thus much more apparent on the frost flat than in FRI nursery. Temperatures throughout the trial period were, however, above normal, and the patterns of growth in relation to initial height within prescribed height classes matched those at FRI nursery (Fig. 5): that is, in the first year the shorter trees put on rather more height than the taller, while in the second year there was no significant difference between them.

A comparison of height growth *between* the prescribed classes (for both sites) is shown in Table 3. It will be seen that on both sites the height growth of the 30-cm prescribed height class is superior to that of all other classes. Apart from the growth of the 20-cm prescribed class, the taller the prescribed class, the poorer the height growth over the subse-

TABLE 3: MEAN HEIGHT GROWTH FOR PRESCRIBED HEIGHT CLASSES
(1½/0 radiata pine)

Prescribed Height Class (cm)	*Mean Initial Height (cm)*	*Height Growth* 1st Year (cm)	2nd Year (cm)	*Total (cm)*	*Final Height (cm)*
GOOD SITE (Fig. 4)					
20	15.5	47.0	164.5	211.5	227.0
30	21.8	49.5	170.3	219.8	241.6
40	30.6	42.1	169.1	211.2	241.8
50	41.5	34.6	168.2	202.8	244.3
60	50.5	31.3	164.8	196.1	246.6
FROST FLAT SITE (Fig. 5)					
20	15.2	26.6	71.0	97.6	112.8
30	22.0	29.0	80.4	109.4	131.4
40	30.1	27.0	81.3	108.3	138.4
50	39.5	21.9	79.7	101.6	141.1
60	49.6	18.3	75.2	93.5	143.1

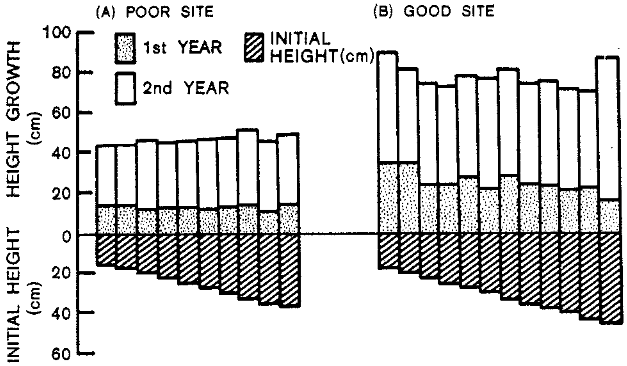

FIG. 6: *Height growth of 2/0 Douglas fir seedlings over 2 years.*

quent two years. The differences between the growth trend of 1½/0 radiata pine in the second year, when compared with the 1/0 stock (Table 2), is worthy of note. Also noteworthy are the rather small differences in the final heights of the prescribed classes (apart from the 20-cm class), particularly on the good site.

Douglas Fir 2/0

Only limited studies have been carried out with this species. The trees were planted for herbicide trials on the same sites as those to which Fig. 2 refers. On the poor site, 366 seedlings were measured; on the good site only 240. Results are shown in Fig. 6. On the poor site, height growth in the first year was independent of initial height, but in the second year the tallest trees made slightly more height increment than the shortest. On the good site, best height growth was shown by the shortest trees; in the second year there was no significant difference in height growth, irrespective of initial height.

CONCLUSION

The figures presented show rather clearly the gross effect of site on similar populations of trees — *e.g.*, good and poor sites are shown in Figs. 2 and 6, and by comparison between Figs. 4 and 5. On the other hand, these site differences do not seem to have affected the behaviour of seedlings in relation to height within treatment classes. Within any one treatment, and generally between treatments, the height of a seedling in the nursery did not in itself give any indication of its likely height growth in the first year after planting in the field. It should be noted, however, that none of the trials included spindly suppressed seedlings that might be obtained by normal irregular nursery sowing. These were eliminated by culling or precision sowing and thus the results do not mean that culling of spindly seedlings is unnecessary. However, in the precision-sown trials (Figs. 3, 4, and 5), where no culling was undertaken but where trees had been allotted uniform growing space in the nursery, the field results should reflect the inherent growth capacity of each tree, in relation to the site on which it was planted. In other words, height growth should provide some reflection of the genetic make-up of the individual seedling.

There were slight differences between age classes. In the smallest 1/0 prescribed height class (Fig. 3, 10-cm class) which had had a very short growing period in the nursery, the taller seedlings showed superior height growth in the first year, and even greater superiority in the second. No other prescribed height classes of the 1/0 stock showed such differences in growth in the first year, although taller seedlings did grow rather more than shorter ones in the second year. The pattern in the 1½/0 stock was slightly different. In the smallest prescribed height class there was no detectable difference between shortest and tallest seedlings in the first year, while in the second the growth of the tallest seedlings was superior to that of the shortest; this refers to the good site only. In all other cases, on both the good and the poor site, height growth of shorter seedlings was slightly superior to that of taller seedlings in the first year. In the second year, height growth appeared to be unrelated to initial height.

Owing to small samples, results for Douglas fir are only tentative, but the pattern was similar: shorter trees tended to grow more than taller ones in the first year. In the second year there was no apparent difference on the good site, but the taller trees showed superior height growth on the poor site. This tends to reinforce the findings of Smith and Walters (1965) who studied 3/0 Douglas fir seedlings, with initial heights from 7.5 to 80 cm. They found that height growth in the first year showed no relationship to initial height, yet, in the second year after planting, height growth "was highly significantly associated with seedling size".

In all these trials there is a common tendency for a weak positive effect of initial height to influence height growth in the second year after planting. This is in line with Smith and Walters' (1965) findings, and also those of Burdon and Sweet (1976). In studying means of overcoming non-genetic effects in clonal and progeny trials, they found that height growth of rooted cuttings within clones of radiata pine was only very weakly correlated with initial heights (coefficient = 0.1) during the first 2 years after planting out. In the second 2 years the correlation coefficient improved to 0.2. It may be that a period of 2 to 4 years is too short a time for full evaluation of the effect of initial height on subsequent performance of trees.

Other things being equal, the tallest trees at time of planting are likely to be the tallest trees at the end of the first year of growth in the forest. In some cases, height at planting may be an important criterion — for example, where trees are to be planted deeper than usual (as on sand dunes) or where greater initial height keeps seedlings above weed growth. On many sites, however, height growth in the first year after planting is likely to be of critical importance for the forest manager. These studies indicate that, within any one seedling population, there is little to be gained by culling on the basis of height alone; if seedling quality is defined as the ability to survive outplanting and to grow away rapidly, then height by itself gives no indication of quality within any one treatment class. As implied earlier, root collar diameter is undoubtedly a better measure (Prior, 1969; Anstey, 1971; Menzies *et al.*, 1974; Balneaves and McCord, 1976), and it has been clearly shown by these authors to be related to the space occupied by the seedling in the nursery bed.

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