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EXECUTIVE SUMMARY

This report describes two studies that aimed to determine appropriate initial stocking levels for plantations of improved radiata pine. Although conservative initial/final stocking ratios (of 6:1 or greater) have been used for unimproved radiata in the past, evidence of increased proportions of "acceptable stems" from genetically-improved breeds provides a strong case for reducing initial stocking levels.

Results from these studies at Rotoehu and Kaingaroa Forests demonstrated that initial/final stocking ratios of 3:1 or less should be adequate when using trees of the growth and form breed (i.e. "850" and "268" clonal series), but that trees of the long-internode breed should be planted at more conservative stocking ratios.

Genetic improvement ("genetic gain") in growth rate of the growth and form breed over "climbing select" seedlots was large (approximately 20% in volume growth). By comparison, growth rate improvement through silvicultural selection of the crop element was relatively less important.

Lower initial stocking levels will lead to large savings in establishment and tending costs. For some regimes, it should be possible to eliminate a waste thinning operation. Genetic improvement in "acceptable stems" should also improve the profitability of production thinning regimes.

Although all current silvicultural regimes will be favoured by these genetic gains, full realisation of gains will require the adoption of less conservative stocking ratios.

INTRODUCTION

Until recent years conservative initial stocking to final stocking ratios, in the order of 6:1, have been adhered to over most of the country. However improvement in the fields of site preparation, nursery practice, tree handling and planting, fertilizers, weed control, and most importantly genetically improved radiata pine breeds has led to a strong case for reducing initial stocking levels and subsequently the number of stems tended before final crop selection. This paper aims to demonstrate the effects of genetic improvement in both "% acceptable stems" and growth rate on planting and thinning practices and proposes reduced initial stocking levels to achieve lower growing costs.

Up to the early 1970's stands of radiata pine were established using either natural regeneration or various collections of unimproved seed. The "850" series or "first orchard" seed introduced in the early 1970's was the result of matings among 14-25 clones representing intensively selected plus-trees, identified in plantations in the early 1950's. However, because open-pollinated seed orchards require a minimum number of tree genotypes to avoid inbreeding, only a few of the poorer parent trees identified by progeny testing could be removed from the seed orchard. A similar plus-tree selection was undertaken in the late 1960's, but this time with sufficient numbers to allow progeny testing and subsequent selection of the best trees as seed orchard parents. Seedlots from these orchards are known as "second orchard" and the clones are of the "268" series. A long internode breed, the "870" series, is the result of a plus-tree selection carried out in 1970 for the purpose of increasing the proportion of clearcuttings grades of sawn timber.

A national network of tree improvement trials has demonstrated potential genetic gains in growth rate and form through use of the improved breeds, and in particular with large gains in the frequency of "acceptable stems" at the time of silvicultural tending. From a series of trials planted at 10 locations in 1978 the "850" orchard seedlot had an average of 69% acceptable stems compared with 56% for an unimproved seedlot. Similar trials planted in 1979-1980 comprising "268" and "long internode" seedlots show gains of up to 30% in "% acceptable stems" for the "268" series but limited gains for the "long internode" breed (C. Shelbourne, unpublished data).

Results from two more intensive studies are now available allowing an examination of the advantages and disadvantages of reducing initial stockings for improved breeds. The following questions were addressed:

- What are the genetic gains in growth rate and "% acceptable stems" of improved breeds compared with unimproved breeds grown under similar silvicultural regimes?

- Is silvicultural selection also important in the improvement of the stand in terms of "% acceptable stems" and growth rate?

- Can significant cost reductions be achieved by planting and subsequently tending fewer trees of the improved breeds without compromising crop quality or growth rate?

- What other implications are there for future planting and tending practices?

METHODS

Description of Trials

A trial was established at Rotoehu Forest in 1970 to assess the influence of tree breeding and stocking rate on tree crop quality for a clearwood regime. A range of initial stockings was planted using open-pollinated Gwavas seed orchard stock (of "850" series parentage). Treatments included two plots each of 250, 500, 750, 1000, 1250 and 1500 stems/ha for seed orchard stock and of 1500 stems/ha using routine climbing select stock. All crop trees were pruned to height 6 m. The final crop stocking in all cases was 250 stems/ha, implying initial stocking to final stocking ratios of 1:1, 2:1, 3:1, 4:1, 5:1 and 6:1.

In addition to this trial, step-outs of one replicate each were established in Lake Taupo, Waimihia, Matea and Whangapoua Forests with initial stockings of 750 stems/ha using seed orchard stock.

Compartment 1218 in Kaingaroa Forest is the site of a trial established in 1979 as part of a nationwide series of trials to measure the genetic improvement gained by using seed orchard seed.

The clonal series chosen for comparison in this study were the "268" series and the "870" long-internode series. Clones from both series were control pollinated to produce seedlots simulating the product of open pollinated seed orchards. A third seedlot used in the trial was of Kaingaroa climbing select seedling stock.

Details of the silviculture and trial design for both the Rotoehu trial and the Compartment 1218 trial are given in Table 1.

Assessments

The Rotoehu trial was assessed at age 7 by James (1979) in terms of the composition of the final crop by tree type and the mean diameter for each initial stocking treatment.

Inglis (unpub. data) also assessed the final crop by four preferred tree types in the Matea, Waimihia, and Lake Taupo step-outs. These four preferred tree types included defect-free dominants, dominants with minor stem deviation, defect-free co-dominants, and co-dominants with minor stem deviation. The proportion of trees of these four preferred types approximates the "% acceptable stems" classification used in the Cpt 1218 trial.

This paper will discuss various growth traits (volume, basal area and height) in addition to the "% acceptable stems" for treatments in the Rotoehu trial and its step-outs.

In November 1984 a pre- and post-thinning assessment was carried out in the Kaingaroa Compartment 1218 trial to determine crop height, diameter and "% acceptable stems" (J. King, unpub. results). Similar variables were assessed in June 1986 after marking for the second thinning was completed (M. Carson, unpub. results). In both cases the effect of silvicultural selection on crop yield and quality were quantified in terms of the above variables, and comparisons made between seedlots. Graphs were drawn of mean basal area per hectare upon age so that treatments could be compared.

TABLE 1 - Silviculture and Trial Design

Trial	Operation	Age (years)	Pruning lift (m)	Stocking before thinning (stems/ha)	Stocking after thinning (stems/ha)	Trial Design
Rotoehu Initial	Prune and thin	5.0	0-2	1500, 1250, 1000, 750, 500, 250	750, 500, 250	Complete randomised design
Crop Stocking Trial (planted 1970)	Prune and thin	6.5	2-4	750, 500, 250	500, 250	54 crop trees per 0.2 ha rectangular plot 2 replications per treatment (7 treatments)
	Prune and thin	7.2	4-6	500, 250	250	
Kaingaroa CPT 1218 Genetic Gains Trial (planted 1979)	Prune	5.5	0-2			Randomised complete block design
	Thin	6.5		1111	640	15 crop trees per 0.05 ha circular plot
	Prune*		2-4			
	Thin*			640	300	5 replications per treatment (4 treatments)

* Operations yet to be carried out

A statistical package (SAS) available on the VAX computer was used to do much of the data analysis for the Compartment 1218 trial. This included ANOVA (analysis of variance) testing terms for replications, seedlots and replication x seedlot interaction. The Waller-Duncan multiple comparison test was used to test differences between seedlots, replications and their interactions.

A graph was drawn of basal area on age in the Rotoehu trial to demonstrate the effects of initial stocking (and seedlot in the case of the 1500 stems/ha treatment). Conclusions are drawn on the acceptability and growth of stems resulting from silvicultural selection.

An ANOVA was carried out, through use of the SAS package, to test for differences between initial stockings, replications and stocking x replication interactions on the 1986 data only.

An exercise was carried out to demonstrate the differences in tending costs between regimes of high initial stockings and those with low initial stockings (as described in Table 2). From these figures it was possible to compare discounted costs for each regime. The six examples given were chosen as being typical of both clearwood and structural regimes that might be used around the country. A discount rate of 6% was used as this was the Forest Service standard at the time of writing.

TABLE 2 - Comparison of growing costs for alternative silvicultural regimes

Regime	Number of stems/ha				Cost of Operations					
	Planted	After 1st prune and thin (vs followers)	After 2nd prune and thin (vs followers)	After 3rd prune and thin	Planting	T_1	P_1	P_2	T_2	P_3
Clearwood Regimes										
1	1100	600	400 (200)	200	159	101	345	284	116	162
2	800	600 (200)	200	200	129	132	345	142	-	162
3	600	600	200	200	114	88	345	142	-	162
Structural Regimes										
4	1700	600 (1100)	370 (thin only)		212	266	345	-	-	-
5	1000	600 (400)	370 (thin only)		146	126	345	-	-	-
Smallwood/Clearwood or Structural Regime										
6	600	600	250 (thin only)		114	-	345	-	No cost	-

Note: The costs used in this exercise are based on those given in "Costs of Establishing and Managing Radiata Pine Plantations (A Guide to the Small woodlot Industry)", a "Trees and Timber" bulletin, by J. Lewis, and are valid as at October 1985. The costs are estimates covering the whole country.

RESULTS AND DISCUSSION

1. Gains in % Acceptable Stems

Rotoehu Trial

Figure 1 shows the relationship between initial stocking and preferred[1] trees as a percentage of the final crop, including three step outs at 750 stems/ha. The 250 stems/ha was the worst performed treatment reflecting possible exposure effects plus the absence of additional trees to compensate for death and malformation among those planted. By doubling the stocking to 500 stems/ha at planting a three-fold increase in preferred tree rate was observed.

The seed orchard stock planted at 1500 stems/ha gave the highest percentage of preferred trees over the trial as a whole. However, at 1250 stems/ha there is only a 1% drop and at 1000 stems/ha the reduction is only 8%. As James (1979) points out, even this 8% difference is unlikely to be large enough to negate the costs involved in raising stocking levels by 50%.

The climbing select seedlot, although planted at 1500 stems/ha, was inferior to the seed orchard seedlot at all levels of initial stocking except 250 stems/ha. At 1500 stems/ha the difference was 33% (90% as opposed to 57%) underlining the superiority in tree form of the seed orchard material.

All three step outs with results shown in Figure 1 were, like the Rotoehu trial, planted in pumice soil and grown under normal forest management, although the Matea site suffered high early mortality. The step outs plus the Rotoehu 750 stems/ha treatment all had preferred tree percentages of between 62% and 72%, a small range considering that the site indices varied from 26 m (Matea) to 36 m (Lake Taupo).

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1 the term "preferred trees" used here refers to the % of the <u>final crop</u> which is of the four best tree types as described in the "Methods" section of this report.

In reality, achievement of a 100% stocking of preferred trees is very unlikely due to the incidence of groupings of poor trees (meaning that some must be chosen in the selection process) and because errors are made during the selection process. The results in Figure 1 indicate that a realistic maximum for % preferred stems is probably about 85%-90%.

On this basis, the 500 stems/ha treatment in the Rotoehu trial may be considered adequate by most forest managers, since it will yield about 170-180 acceptable trees from a 250 stems/ha final crop, compared to only 140-150 trees of climbing select origin planted at a stocking three times as large. Alternatively, if managers wish to improve their stands beyond the level that has been 'acceptable; for unimproved stands in the past (perhaps to improve the quality of a production thinning crop) then initial stockings of up to 1000 stems/ha might be appropriate for "850" series seed orchard stock. At very low initial stockings (250 stems/ha at Rotoehu, for example) tree form can be expected to suffer serious problems on most sites, despite the mitigating effects of genetic improvement. This will be a constraint to recognise when using improved breeds in agroforestry stands.

Kaingaroa Compartment 1218 Trial

(i) First Assessment

The first assessment of the Kaingaroa trial was carried out in November 1984 (at age 5) when it was assessed for % acceptability before and after the first thinning (from 1111 to 600 stems/ha).

From Table 3 it can be seen that silvicutural selection followed by thinning improved % acceptable stems in all cases. The Kaingaroa Climbing select seedlot and the "870" series seedlot were improved more than the "268" series seedlot. However, the latter seedlot had considerably higher numbers of acceptable stems before thinning to the extent that they were close to the post-thinning values of the KCS seedlot and the "870" series seedlot (i.e. there was a difference between the two groups of "one thinning" in terms of % acceptable stems).

TABLE 3 - The effect of 1st thinning on % acceptable stems - Compartment 1218 Trial

Seedlot	% Acceptable Stems		
	Before 1st thinning	After 1st thinning	Increase due to thinning
KCS[1]	50.3b[2]	72.4	22.1
"268"	66.6a	85.3	18.7
"870"	49.1b	71.5	22.4

1 KCS = Kaingaroa climbing select
2 Treatment means followed by a different letter are significantly different (P=0.05)

The calculations presented in Table 4 indicate the implications that these proportions of % acceptable stems might have for initial stocking strategies.

TABLE 4 - Acceptable stems comparison planting 1111 stems/ha and using KCS as a base

Seedlot	% acceptable stems	No. acceptable stems/ha if plant 1111	Number of trees to plant if climbing select seedlot is assumed to give "enough" acceptable stems
KCS[1]	50.3	559	1111
"268"	66.6	740	839
"870"	49.1	546	1138

1 Kaingaroa climbing select seedlot

For an initial stocking of 1111 stems/ha, Table 4 gives the corresponding number of acceptable stems/ha which could be expected for each seedlot - approximately 550 for both the KCS and the long internode seedlots, compared with 740 for the "268" seedlot. This means that at the time of first thinning there will be, for example, an extra 200 or so more acceptable stems/ha to choose from for the "268" series seedlot than for the KCS seedlot.

Table 4 also gives equivalent initial stockings for the seed orchard seedlots under the assumption that 1111 stems/ha is enough to ensure an adequate final crop stocking using the KCS seedlot. In the case of the "268" seedlot, a reduction of almost 300 stems/ha is possible without prejudicing the number of acceptable stems available for final selection. A small increase is necessary for the long internode "870" series seedlot.

TABLE 5 - Initial stocking requirements allowing for X% environmentally-induced mortality

Seedlot	% acceptable stems	To achieve 600 stems/ha requires initial stockings of	Allowing for "other causes" of mortality of X% e.g. frost, weeds, etc			
			5%	10%	20%	30%
KCS	50.3	1193	1256	1326	1491	1704
"268"	66.6	901	948	1001	1126	1287
"870"	49.1	1222	1286	1358	1528	1746

Table 5 gives the initial stocking requirements for all seedlots if 600 acceptable stems/ha are required as a post-thinning stocking. The KCS seedlot initial stocking is close to the 1111 stems/ha actually planted in the trial, while it would appear that the long internode seedlot was (if anything) slightly "under-planted". The "268" breed was "over-planted" by some 200 stems/ha.

The stocking rates necessary to allow for a 5, 10, 20 or 30% mortality rate are also given in Table 5. This mortality could be caused by environmental factors on hard sites, such as frost, weeds, disease and insect attack. At 5% mortality both the KCS and the long internode seedlots need a planting rate corresponding to the "268" seedlot with a 30% mortality rate.

(ii) Second Assessment

The second assessment was carried out in 1986 (age 7) at the time of the scheduled second thinning down to 300 stems/ha.

Figure 2 demonstrates the silvicultural effect of thinning on % acceptable stems for both thinnings.

Although in terms of increases in % acceptable stems from thinning, both the KCS and "870" seedlots were similar to the "268" breed, they started at a much lower level and they lost considerably more acceptable stems between the first and second thinning. This loss is such that after the second thinning the level of % acceptable stems did not recover to what it was after the first thinning. The "268" seedlot on the other hand shows a gain in post second thinning acceptable stems over post-first thinning rates.

TABLE 6 - The effect of second thinning on % acceptable stems - Compartment 1218 trial

Seedlot	% Acceptable Stems			
	Before 2nd thinning	After 2nd thinning	Increase due to thinning	Loss between 1st and 2nd thinning
KCS	39b[1]	66b	27	33
"870"	45b	63b	18	27
"268"	71a	96a	25	14

1 Treatment means followed by a different letter are significantly different ($P = 0.05$)

Table 6 quantifies what is seen in Figure 2. It can be seen that the "ceiling" of % acceptable stems evident in the Rotoehu trial (of approximately 90% for "850" series material planted at 1500 stems/ha) has been exceeded by the improved "268" seedlot (96%). This may reflect greater uniformity of this seedlot in addition to an increased average frequency of acceptable stems.

For forest managers, these results imply that "to-waste" thinning of the improved multinodal breed is much less necessary for improving overall crop acceptability, but also that a silvicultural thinning can be more effective if carried out. This may lead to greater use of regimes that combine relatively low initial stockings (e.g. 400-600 stems/ha) with production thinning(s) - either with or without some pruning of the butt log.

2. Gains in Growth Rate

(a) Rotoehu Trial

Figure 3 shows the effect of initial stocking on basal area/ha in the Rotoehu trial. At age 16 the data can be split into two groups - one consisting of the 1500, 1250, 750 and 500 stems/ha treatments; and the other of the 1000 and 250 stems/ha treatments of seed orchard origin plus the 1500 stems/ha treatment of the climbing select seedlot. The 1000 stems/ha treatment appears to be the ringer in these results. It would be reasonable to expect the basal area/ha at this stocking to be between the values for 750 and 1250 stems/ha i.e. approximately 36 m^2/ha. Instead, it is some 4 m^2/ha below this value - lower than for both the 250 stems/ha and the 1500 stems/ha climbing select treatments.

However, plots within each treatment may be being affected by factors other than the treatments alone. An obvious site effect can be observed in the trial, and can be understood from inspection of basal areas by plot in Figure 4. Plots 10, 11, 12, 14, 15 and 16 were observed to be on a superior site to plots 2, 3, 4, 5, 6 and 7 with plot 1 in an intermediate position. Plots 8 and 13 are also in intermediate positions (although their poor growth rate may be due in part to their unimproved genetic origin).

The two plots of 1000 stems/ha are both located in the poorer of the two areas while both 1500 stems/ha plots are in the better area. This goes some way toward explaining the poor basal area growth of the 1000 stems/ha treatment, as well as suggesting that the estimates for the 1500 stems/ha treatment may be somewhat inflated.

Returning to Figure 3, it would appear that the growth performance of both the 750 and 500 stems/ha treatments has not been prejudiced by their lower selection ratios and they have maintained basal area growth rates comparable to the 1500 and 1250 stems/ha treatments.

The 250 stems/ha treatment has performed less well for basal area/ha not because of poorer individual tree growth rates but because of the mortality which has occurred within these plots (i.e. plot stockings of 45 and 48 trees, versus 50 trees in plots of other treatment levels).

Despite the confounding effect of microsite variation within the trial the relatively poor performance of the climbing select seedlot must be evidence for genetic gain in growth rate compared to the treatments planted with seed orchard seed. For similar initial stockings (of 1500 stems/ha) the seed orchard seedlot had 15.6% more basal area/ha than the climbing select seedlot at age 16. In addition, these seed orchard trees had a 1.6 m height advantage (Table 7). All other initial stocking treatments except the 1000 stems/ha treatment had in excess of 10% superiority in basal area growth over the climbing select seedlot. Compared to earlier results reported for the trial (James, 1979 and Figure 3) the seed orchard seedlot appears to have increased its growth advantage over the climbing select seedlot for the period following the cessation of silvicultural tending.

TABLE 7 - Mean tree heights at age 16 at initial stocking of 1500 stems/ha - Rotoehu

Climbing select 1500 sph		Seed Orchard 1500 sph	
Plot 8	Plot 13	Plot 10	Plot 11
28.4	28.4	30.1	30.0

The effects of thinning on basal area growth are illustrated in Figure 5. Rankings for basal area growth of all thinned treatments were not affected by either thinning, although differences between treatments were decreased somewhat. These results suggest that varying silvicultural selection ratios have not played an important part in improving basal area growth, while initial differences in microsite quality have persisted during and after the silvicultural selection phase.

(b) Compartment 1218 Trial

Results of the first assessment of the genetic gains trial illustrate the effects of silvicultural selection on the growth rate of seedlots of different genetic selection history (Table 8). In contrast to the marked differences by seedlot in improvement principally for tree form (expressed as "acceptable stems"), silviculturally selected differences in growth rate per tree were relatively low, and similar between seedlots (with a range of 7-10% increase). On the other hand, genetic differences in growth rate were already quite large - the "268" series seedlot had a margin of 22% superiority over climbing select before thinning, and 23% after thinning.

TABLE 8 - Increase in mean tree volume due to first thinning

Seedlot	Mean tree volume (dm^3/tree)			% Increment
	Before thinning	After thinning	Increment	
KCS	32.9b[1]	35.7b	2.8	9
"268"	40.1a	44.0a	3.9	10
"870"	33.7b	36.1b	2.4	7

1 Treatment means followed by a different letter are significantly different.

For the assessment at the time of second thinning, the % increments in tree volume from silvicultural selection were similar to those for the first thinning, although actual increments were three to four times as large (Table 9). The difference between the "268" series and climbing select seedlots was over 14% before thinning and almost 16% after thinning, indicating that large genetic differences in growth rate were being maintained by age 7. Conversely, the long-internode seedlot ("870" series) lost its small (1%) advantage in volume at age 5 over the climbing select seedlot, and was 5% behind the climbing select seedlot after the second thinning.

TABLE 9 - Increase in mean tree volume due to second thinning

Seedlot	Mean tree volume (dm^3/tree)			% Increment
	Before thinning	After thinning	Increment	
KCS	93.8b[1]	103.3	9.5	10
"268"	107.3a	119.3	12.0	11
"870"	87.7b	98.3	10.6	12

1 Treatment means followed by a different letter are significantly different.

In support of the Rotoehu trial results, the evidence from the Cpt 1218 trial seems to indicate a large genetic improvement in growth rate (of "850" series and "268" series seedlots, respectively) and a moderate improvement due to silvicultural selection.

3. Financial Analysis

Table 10 gives a cost comparison between three clearwood regimes two structural regimes and a smallwood/structural regime. Lowering the initial stocking alone by 200 sph without changing the number of thinnings does not have a marked effect in reducing costs, as can be seen in the difference between regime 2 and 3 (7% reduction in present net cost). However, if a thinning is dropped in conjunction with the lower initial stocking the effect on PNC is greatly enhanced - a 27% cost saving can be achieved in the clearwood schedule (regime 1 compared with regime 3). Removal of one thinning may, however, have an adverse affect on the % acceptable stems as the final crop must be decided upon at the only thinning to be done - at age 7 in this example.

Regimes 4 and 5 give a comparison of costs for a structural regime when a large (700 sph) drop in initial stocking is introduced. In this case a reduction from 1700 sph to 1000 sph produces a cost recovery of 33%, without altering the number of operations.

TABLE 10 - Present net costs for alternative clearwood and structural regimes

Operation	Year of operation[1]	Actual cost ($/ha)	Compounded cost ($/ha)	Discounted cost @ 6% (= present net cost) ($/ha)
Regime[2] 1 (1100-200 spha)				
Planting	1	159	862	
Thin 1	6	101	409	
Thin 2	8.5	116	431	
Prune 1	6	345	1397	
Prune 2	7	284	1085	
Prune 3	8.5	162	601	
			4785	348
Regime 2 (800-200 spha)				
Planting	1	129	699	
Thin 1	7	132	504	
Prune 1	6	345	1397	
Prune 2	7	142	542	
Prune 3	8.5	162	601	
			3743	272
Regime 3 (600-200 spha)				
Planting	1	114	618	
Thin 1	7	88	336	
Prune 1	6	345	1397	
Prune 2	7	142	542	
Prune 3	8.5	162	601	
			3494	254
Regime 4 (1700-370 spha)				
Planting	1	212	1149	
Prune 1	6	345	1397	
Thin 1	8	266	959	
			3505	255

TABLE 10 - (contd)

Operation	Year of operation	Actual cost ($/ha)	Compounded cost ($/ha)	Discounted cost @ 6% (= present net cost) ($/ha)
Regime 5 (1000-370 spha)				
Planting	1	146	791	
Prune 1	6	345	1397	
Thin 1	8	126	454	

			2642	192
Regime 6 (600-250 spha)				
Planting	1	114	618	
Prune 1	6	345	1397	
Thin 1	10-15	nil	-	

			2015	146

1. Rotation length is assumed to be 30 years.

2. Regimes 1-3 are clearwood regimes, and 4-5 are structural regimes. Regime 6 can have a smallwood/clearwood or smallwood/structure use.

3. Cost of production thinning assumed to be offset by revenue from sale of smallwood.

In regime 6, initial stocking is low enough to allow a single production thinning to be carried out at about mid-rotation age. It represents a wide range of possible regimes combining an early smallwood yield with either structural or clearwood objectives for the final crop component. If smallwood markets are available, and market prices are sufficient to offset thinning costs, then some variant of regime 6 could be a very attractive low-cost option. Results reported here for the "850" and "268" series of the improved general - purpose breed indicate that the low initial stocking/production thinning combination could be used in most forests in New Zealand and still provide timber yields equal to (or better than) those achieved from unimproved stock.

CONCLUSIONS

(a) Genetic Gain

These results add to the wealth of accumulating evidence for gains in growth rate and tree form from genetically - improved radiata pine. These gains may be large relative to unimproved stock, but they will always be difficult to quantify because of the inherent variability in unimproved stock (arising from their differing genetic origins, and the employment of differing methods of seed collection). Clearly, however, the "850" series orchard stock can yield much higher frequencies of "preferred stems" for a final crop than can unimproved stock, and "268" series stock should yield significant further gains. Growth rate gains can also be expected leading to higher merchantable yields and/or reduced rotation ages.

The poor results for the long-internode breed in the Kaingaroa trial need not rule out this seedlot for future use. Fertile pumice sites produce a strong expression of variation in stem sweep and tendency to forking in radiata pine; long-internode trees are more susceptible to stem form problems than are multinodal trees (Carson, 1987). On less fertile southern Kaingaroa sites and sheltered sites in Nelson and Southland, the long-internode breed suffers much less stem malformation and expresses worthwhile gains in growth rate (J. King, pers. comm.). However, the use of present long-internode stock at low initial stockings (e.g. in agroforestry stands) would not be supported by our results.

(b) Silvicultural selection versus genetic selection

Silvicultural selection can have a marked influence in improving the frequency of preferred stems for both unimproved and improved tree stock. Selection in stands of improved stock may be more effective in the long term than in unimproved stands, since selected trees are more likely to maintain their good form after thinning.

Silvicultural selection can produce an immediate increase in the average height and diameter of trees in a stand. In addition, the distribution of stand heights and diameters may be truncated by the removal of runts. However, the long-term effect of selection on growth rate may not be large (as indicated in the Rotoehu trial by the lack of divergence of basal area treatment means for differing initial stockings for years after selective thinning). This contrasts with the effect of genetic gains in growth rate, which begin to emerge in the first few years after planting, and may increase up to mid-rotation age (and possibly beyond).

(c) Cost savings by reducing initial stocking levels

One major and immediate advantage of planting trees of the general-purpose breed (i.e. of "850" and "268" clonal series origin) is the opportunity they offer to reduce planting and tending costs (as indicated in this study) by reducing initial planting stockings and subsequent stockings after pruning and thinning operations. Establishment costs will also be reduced in many situations (for example, through reduced spot-spraying, V-blading, etc.).

Additional cost savings can also result since fewer trees need be pruned to attain an acceptable final crop. Although our analyses required 600 stems to have a first pruning lift for a clearwood regime of finally 200 stems/ha, there is no good justification for adhering to this constraint. Results from the Kaingaroa trial showed that the "268" series trees maintained higher levels of acceptable stems between thinnings; this suggests that managers can have greater confidence in the early pruning selection, which can be reflected in lower numbers of trees pruned (and therefore lower pruning costs).

Establishment of improved breeds at low initial stockings can reduce (or remove) the need to carry out thinning-to-waste operations, and may make production thinning more profitable (or at least, less costly) through improved merchantability of the "cull" crop and improved stand access.

The sum of these cost savings, which are all incurred during the early phase of the forest rotation, may be of greater advantage to the forest grower than would be indicated by simple discounted cash flow analysis. As has been shown by the recent review of NZ Forest Service silvicultural regimes (Knowles and Whiteside, pers. comm.), such cost savings can lead to substantial reductions in capital requirements and individual forest overheads. These cost savings are also more 'certain' in their value than are end-of-rotation revenues from log sales, since they depend on known, short-term conditions, versus the recognised risk and uncertainty associated with log market prices 30 years and more in the future.

Recommendations for future forest management practice

1. Forest managers should use the improved radiata breed that best complies with end-product objectives of their organisation, while accepting the existence of "trade-offs" in relative advantages of each breed, and the need to modify their management practises to suit the breed(s) they choose.

2. Use of unimproved radiata pine tree stock should be phased out as soon as possible in favour of "850" series and (preferably) "268" series seed orchard stock (and similar clonal series derived from the "268" series).

3. Initial stocking levels of as low as 500 stems/ha should be considered for most future use of the general-purpose radiata breed. Choice of a low initial stocking should, however, imply a commitment to good management practice throughout the establishment and tending phase.

4. Initial stocking levels for the existing long-internode breed should not be reduced below the 800 stems/ha level.

5. Forest managers should consider reducing their nominal requirements for acceptable stems after a first thinning when using improved stock of the general-purpose breed.

6. Future regime evaluation exercises should examine the opportunities that may arise through wide-spread use of improved breeds planted at low initial stockings, particularly relating to 'to-waste' versus production thinning practices.

ACKNOWLEDGEMENTS

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REFERENCES

CARSON, M.J. 1987: The importance of internode length in Pinus radiata breeding, as determined using SILMOD. FRI Bulletin No. 115 (In Press).

JAMES, R.N. 1979: The influence of tree breeding and stocking rate on tree crop quality. NZ Journal of Forestry, 24(2) : pp 230-240.

Figure 1.

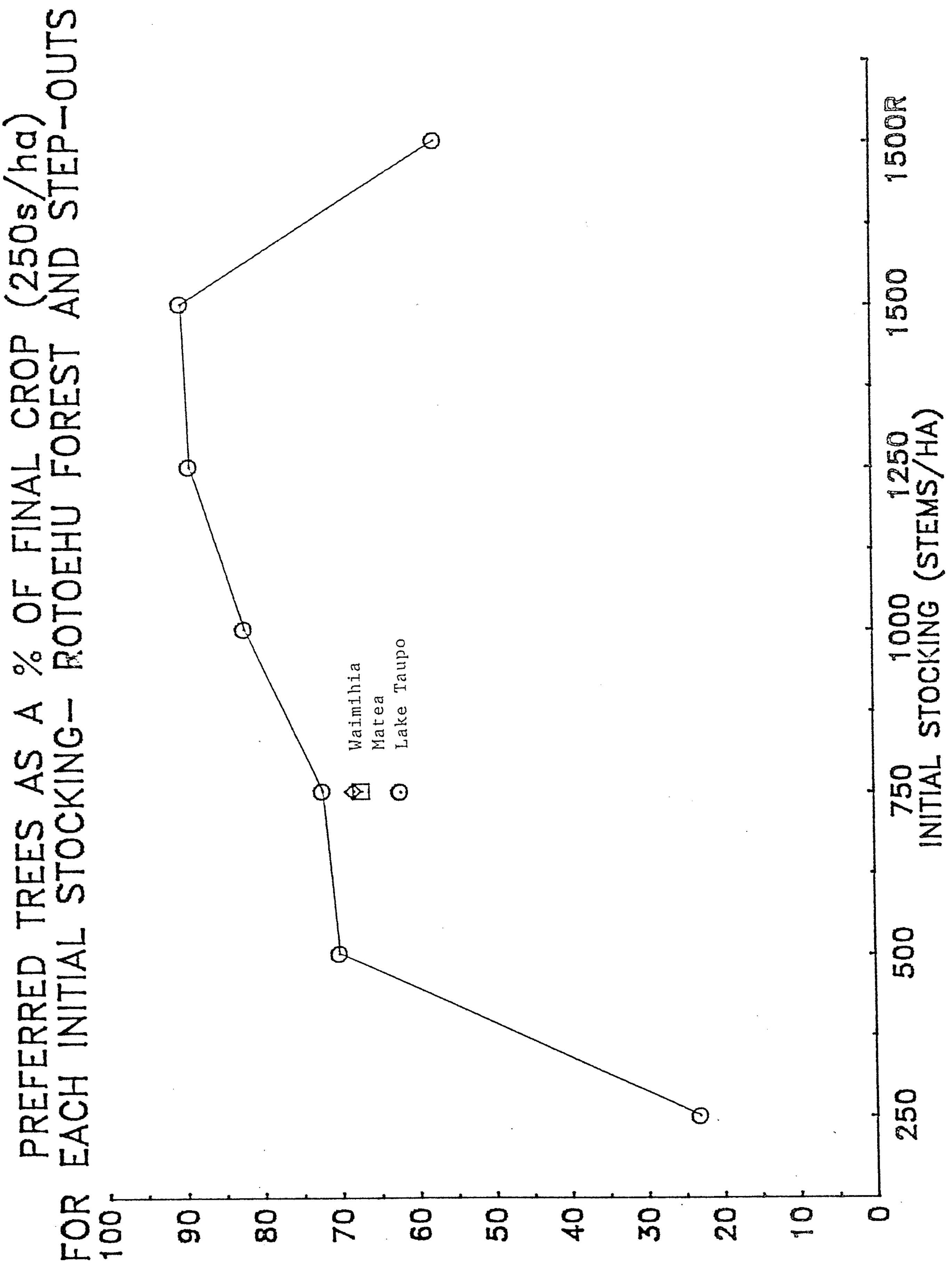


Figure 1

Figure 2.

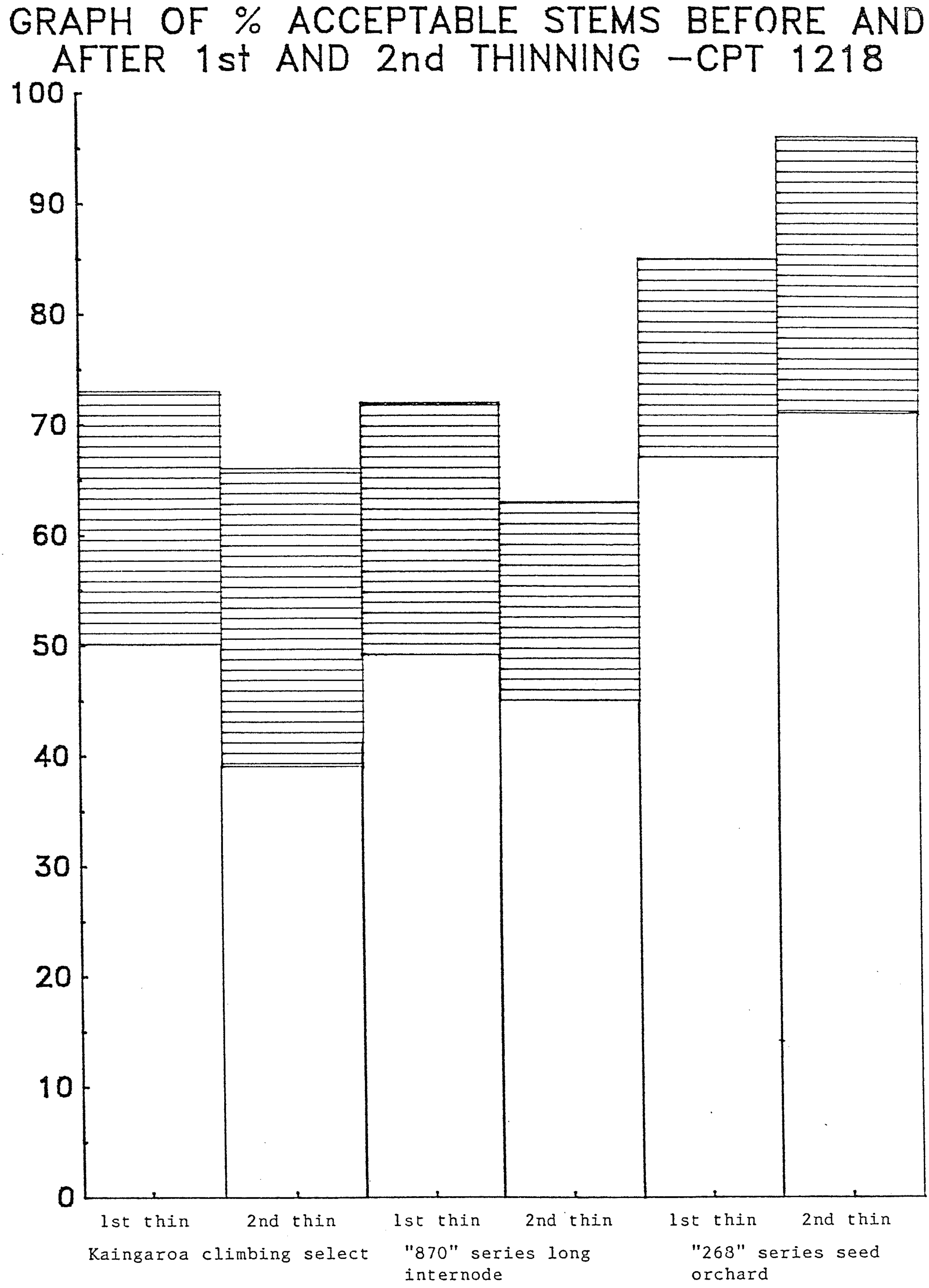

GRAPH OF % ACCEPTABLE STEMS BEFORE AND AFTER 1st AND 2nd THINNING -CPT 1218
100
90
80
70
60
50
40
30
20
10
0
1st thin
2nd thin
1st thin
2nd thin
1st thin
2nd thin
Kaingaroa climbing select
"870" series long internode
"268" series seed orchard

Figure 3.

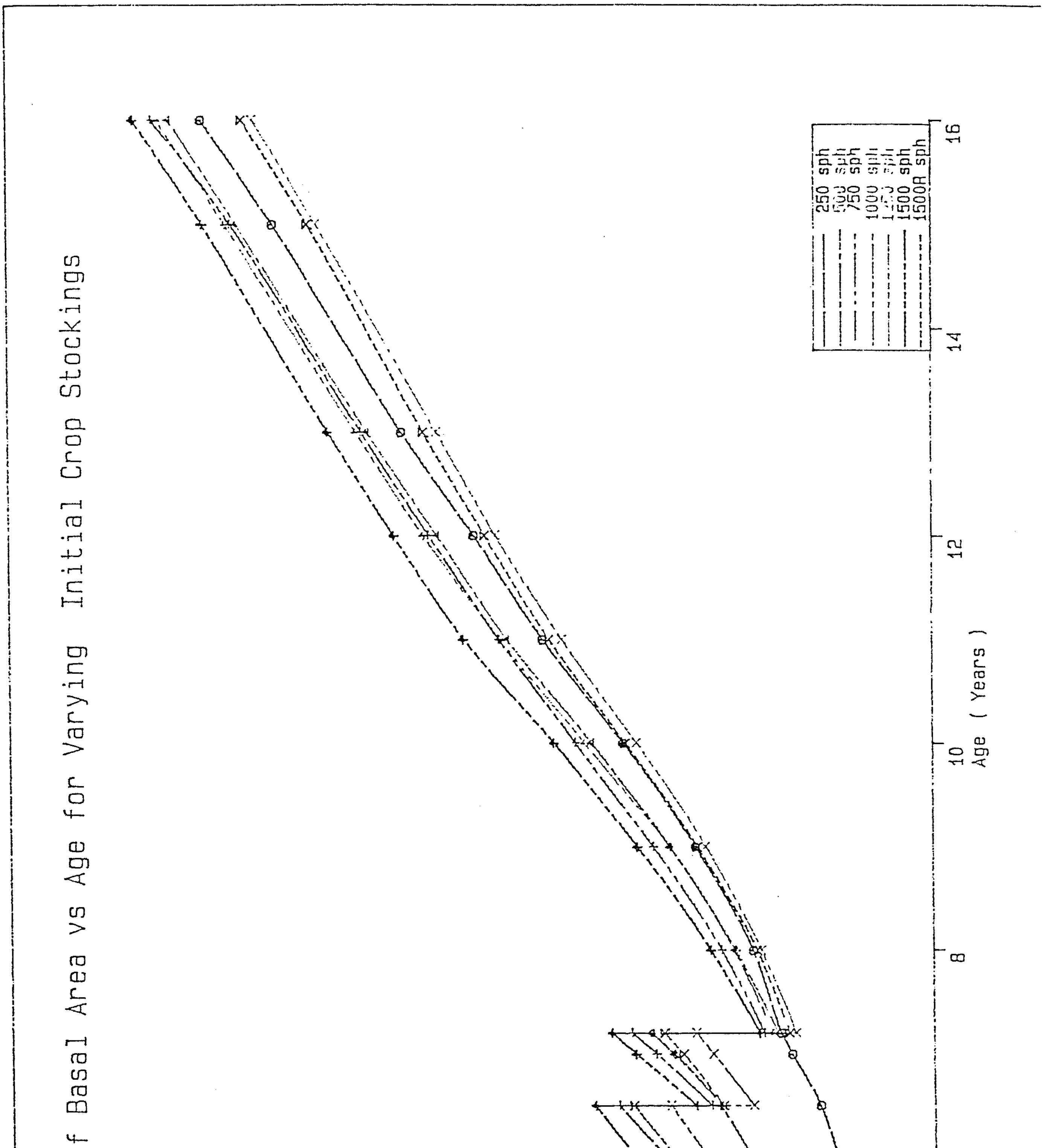
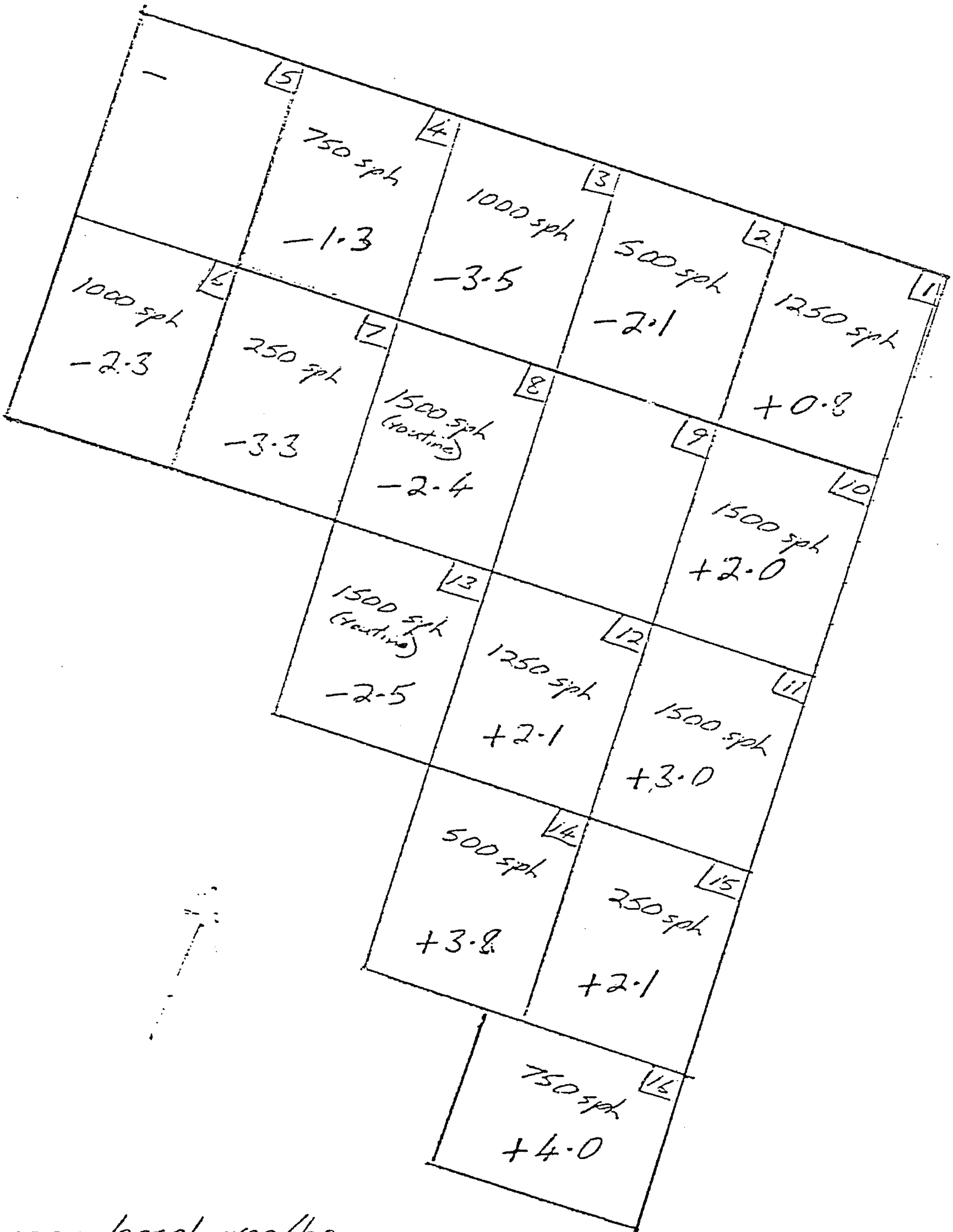

Graph of Basal Area vs Age for Varying Initial Crop Stockings
Basal Area (m^2/ha)
Age (Years)
0
5
10
15
20
25
30
35
40
6
8
10
12
14
16
250 sph
750 sph
1500 sph
1500R sph

Figure 4 - Map of Rotoehu trial showing initial stocking treatments and deviations from age 16 basal area mean



Overall mean basal area/ha at age 16 = 34·2 m²/ha - figures indicated in plots represent deviations from the overall mean basal area.

FIGURE 5 GRAPH OF BASAL AREA RESPONSE TO FIRST AND SECOND THINNING - ROTOEHU TRIAL