ESTABLISHMENT TRIALS ON FROST-PRONE SITES

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ABSTRACT

Trials were established in three successive years at Kaingaroa and Karioi Forests in the central North Island to evaluate problems in re-establishing cutovers and planting new areas where frost damage was a problem. The stock types used were radiata pine seedlings and cuttings, and lodgepole and muricata pine seedlings.

Radiata pine seedlings gave the best results overall, with higher survival and growth rates than other stock types.

Site cultivation improved the survival of all stock types, and exposure of mineral soil and keeping the site free of weeds raised the minimum temperature at ground level by up to 4°C.

The best time for planting frost sites was autumn or spring. The worst time was early winter, when seedlings came from a relatively frost-free environment in the nursery to temperatures of around —11°C at the field sites.

The frost tolerance of radiata pine seedlings ranged from —6°C in the summer, to —14°C in the winter.

INTRODUCTION

There are few regions in New Zealand where frosts do not occur in autumn, winter, and spring, or even in the summer at higher altitudes (Kidson, 1932; Jackson, 1974). As new land available for exotic afforestation becomes scarcer, forests are being established on sites where the frequency and severity of frosts are high. The history of establishing these sites at Kaingaroa Forest in the central North Island is discussed by Washbourn (1978). Radiata pine (*Pinus radiata* D. Don) is New Zealand's major exotic species, and establishment in Kaingaroa Forest at altitudes above 540 m was successful where the slope of the ground was three degrees or more, allowing air drainage, but failure often occurred on flatter country. Lodgepole pine (*Pinus contorta* Douglas) and Corsican pine (*Pinus nigra* ssp. *laricio*

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TABLE 1: EFFECT OF NURSERY STOCK, PLANTING TIME, AND SITE PREPARATION ON THE SURVIVAL AND GROWTH OF RADIATA PINE SEEDLINGS ON A HARD FROST SITE

Site Preparation	Time of Planting	Nursery	Age of Stock	Grade of Stock	Survival after 3 yr (%)		Height Increment after 3 yr (cm)		Total Height after 3 yr (cm)		Total Height after 6 yr (cm)	
					*Top**	*Bottom**	*Top*	*Bottom*	*Top*	*Bottom*	*Top*	*Bottom*
Burnt and ploughed	May	Kaingaroa	1/0	1st	71	43	107	84	124	99	500	430
				2nd	46	26	96	72	109	84	390	260
			1½/0	1st	70	53	107	84	127	102	450	350
				2nd	56	41	100	83	113	98	390	350
			2/0	1st	54	44	99	74	139	114	450	340
				2nd	32	10	76	60	107	91	390	290
Burnt and ploughed	July	FRI	1½/0	1st	76	63	106	93	136	123	510	440
				2nd	71	40	99	77	132	102	440	360
			2/0	ordinary	74	83	141	125	184	158	490	480
Not burnt but ploughed				hard	97	95	146	134	191	182	NA	NA
				hard	93	90	109	87	147	125	NA	NA

* Furrow position.

(Poiret) Maire) could be established, but the growth rate is slower than with radiata pine, and the use of Corsican pine ceased in 1967 after *Dothistroma pini* needle blight became a problem. Also, both species can be damaged by unseasonal frosts, during their time of flushing.

An earlier trial established in 1967 at Kaingaroa (R452) on a previously unplanted, frosty area studied the effects on survival and growth of radiata pine seedling of:

(a) Burning the present vegetation, followed by ploughing.

(b) Planting on top of the furrow slice or in the furrow.

(c) Different size, age, and quality of planting stock.

The results from some of the treatments are shown in Table 1. Survival and growth were consistently better from trees planted on the top of the furrow, although the temperature on the top of the furrow was only 0.7°C warmer than on the bottom. The difference is more probably related to allowing the trees to grow above the frost level faster, as there is improved survival with taller trees:

% Trees Healthy after 2 years but Dead after 3 years

Height class at 2 years (cm)	25	26-50	51-75	76-100	100+
Planted top of furrow	60	21	5	2	0
Bottom	57	25	8	4	0

Kaingaroa first-grade stock (selected on the basis of size and form) outperformed second-grade stock. Similarly, FRI first-grade stock was superior. The FRI stock was graded on the basis of sturdiness (height/diameter ratio), with first-grade stock having a ratio of 70 or less, plus a good fibrous root system, and grade 2 stock having a ratio of 71-85.

The initial size of stock did not appear critical in this trial, as the Kaingaroa 1/0 stock outperformed the $1\frac{1}{2}$/0 and 2/0 stock. Stock well conditioned by undercutting, wrenching, and lateral root pruning (FRI 2/0 hard stock) also performed better than less intensively conditioned seedlings (FRI 2/0 ordinary stock)

Planting in July gave better results than planting in May. However, since there were different tree stocks at the two times of planting, it was not possible to tell if the differences in survival were due to the planting stock quality or the time of planting.

A series of trials were therefore designed to study:

(a) If radiata pine could be established on these sites.

(b) Whether seedlings or cuttings would be more frost hardy.

(c) How the growth and survival of radiata pine seedlings and cuttings compared with lodgepole and muricata pine (*Pinus muricata* D. Don) seedlings.

(d) If site preparation helped survival.

(e) What is the best time of the year to plant these areas.

METHODS

(a) *Establishment of Cutover Sites* (R967, W218)

Plots were established for three consecutive years at Kaingaroa and Karioi Forests in the central North Island starting in 1970. Half of each trial was cultivated by windrowing, and each half divided into three block replicates. Treatments were randomly allocated to plots of three rows of ten trees within each block replicate. The treatments were 1½/0 radiata pine seedlings, routine seedlot from Kaingaroa Forest; 1½/0 radiata pine seedlings, seed orchard selection (A1 from Wellington Conservancy); 0/1 radiata pine cuttings from four-year-old parents randomly selected at the northern boundary, Kaingaroa Forest; 0/1 radiata pine cuttings from nine-year-old parents, selected as for the four-year-old parent cuttings; 2/0 lodgepole pine seedlings, green-strain seed from Wellington Conservancy; and in the last two years, 1½/0 muricata pine seedlings, blue-strain seed from Ashley Forest the first year, and Kaingaroa Forest the second year. The cuttings were selected and raised by the Genetics and Tree Improvement Section at FRI. One hundred and eighty cuttings with at least 10 clones and 3 ramets per clone were planted each year at each site for each age of parent trees. The ramets were randomly allocated to the block replicates.

The trees were planted at 1 m × 1 m spacing, using spades, in late August each year at each site.

Height growth, tree health, and survival were followed for the next two or three years, depending on the level of frost damage.

Air temperatures on the cultivated halves of the trials were measured with a thermohygrograph and maximum and minimum thermometers housed in a Stephenson screen at 60 cm above the ground level, and a minimum thermometer at 5 cm above the ground level.

(b) *Establishment of Previously Unplanted Frost Flats* (R968)

A site dominated by silver tussock (*Poa laevis* R. Br) and monoao (*Dracophyllum subulatum*) was selected in Compartment 889 at Kaingaroa Forest. A third of the area was established in consecutive years, starting in 1970. The layout was the same as for the trials on cutover sites, with three block replicates cultivated by double discing, and the other three left untreated. The cultivated halves were kept weed-free by using hoes for the duration of the trial. The trial was established identically to the cutover site trial.

Besides measuring air temperatures on the cultivated sites as at the cutover site, minimum temperatures were measured on both the cultivated and uncultivated subplots at 5, 20, 40, 60, 80, 100 and 120 cm above ground level.

(c) *Time of Planting* (R952)

Trials were established in two consecutive years (1971-72) in Compartment 889 at Kaingaroa Forest on a previously unplanted "hard" site, cultivated by double discing. $1\frac{1}{2}/0$ radiata pine seedlings were raised at the FRI nursery, and 216 seedlings were planted each month in six randomly allocated blocks.

Height growth, tree health, and survival were followed for the next three years.

Air temperatures were measured as at the cutover trial sites.

RESULTS AND DISCUSSION

(a) *Cutover Sites* (R967, W218)

Frost damage was not a problem at the Kaingaroa and Karioi Forest sites for the first two years of planting, although sites at progressively higher elevations were selected each year. In the first year's planting, survival after two years exceeded 90%, except for the seed orchard radiata pine seedlings, which had poor root systems with few fibrous roots or mycorrhizae, and a survival of less than 40% at Karioi and less than 60% at Kaingaroa Forest.

Frost levels for the second year of planting did not exceed —3.5°C in the summer, and —8.3°C in the winter at both sites. Survival of the radiata and lodgepole pine seedlings exceeded 90% at both sites, but the survival of the radiata pine cuttings, especially the nine-year-old parent cuttings, and the muricata pine seedlings was lower. There was serious possum damage to the radiata pine cuttings and muricata pine seedlings, and this limited the numbers of trees available for height and survival analysis.

The trials for the third year of planting were at 665 m above sea level at Kaingaroa Forest, and at 880 m above sea level at Karioi Forest. Some frost damage occurred at both of these sites, and so the results from these sites will be given in more detail than for the previous years of planting.

The survivals after two years were similar to the previous year's planting; survival of the radiata and lodgepole pine seedlings exceeded 90% and the survival of the muricata pine seedlings and the four-year-old parent and nine-year-old parent radiata pine cuttings were 75, 71 and 61%, respectively, at Kaingaroa Forest, and 96, 79 and 61%, respectively, at Karioi Forest. Cultivation improved survival by 19% at Kaingaroa and 13% at Karioi Forest (both significant at the 5% significance level, using arc-sine transformed survival data).

Height growth data were also similar to the previous years, and these are shown in Fig. 1. At Kaingaroa Forest, the radiata pine seedlings were significantly taller after two years, although the four-year-parent cuttings and lodgepole pine seedlings had a similar growth increment. The muricata seedlings and nine-

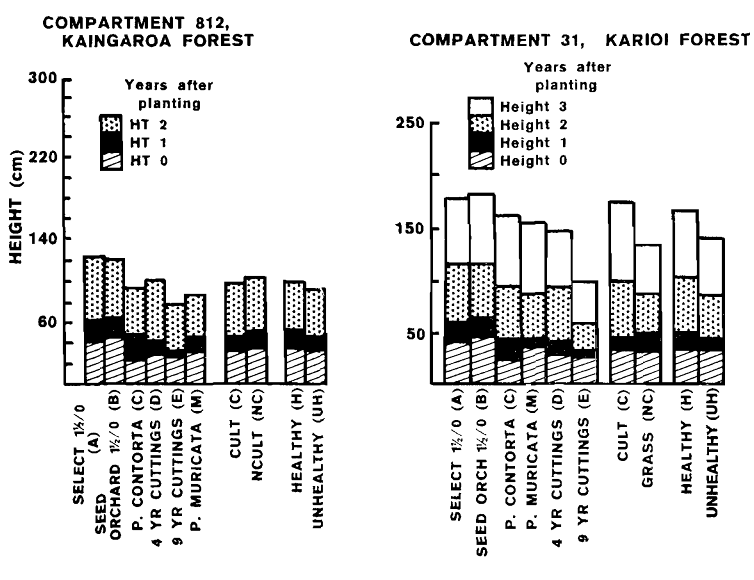

FIG. 1: *Height growth on the cutover sites at Kaingaroa and Karioi Forests.*

year-parent cuttings were significantly shorter, and grew significantly less. The results were the same at Karioi Forest, except the cuttings had significantly worse growth than all the seedlings. Cultivation significantly improved growth at both sites.

The lodgepole pine seedlings and the cuttings were smaller than the other treatments at the time of planting, and they did not catch up to the radiata pine seedlings even after two or three years. Thus the variation in the initial size of the treatments makes it difficult to get comparisons between them.

There was more frost damage at these sites planted in 1972 than in the previous years' plantings. The minimum temperatures at 5 cm above ground level are given in Table 2. Frosts occurred every month during the first year, ranging from —4.5°C in the summer to —10.1°C at Karioi and —8.6°C at Kaingaroa Forest in the winter.

TABLE 2: MINIMUM TEMPERATURES AT 5 cm ABOVE GROUND ON THE CULTIVATED HALVES OF THE CUTOVER SITES AT KAINGAROA AND KARIOI FORESTS, PLANTED 1972

	Minimum Temperature (°C)				
	Karioi Forest		*Kaingaroa Forest*		
Year	*0*	*1*	*0*	*1*	*2*
Month:					
Jan.		— 3.0		—2.6	— 6.1
Feb.		— 2.2		—2.3	0.6
Mar.		— 0.7		—4.6	— 7.9
Apr.		— 5.1		—6.0	— 6.0
May		—10.1		—8.6	— 8.7
Jun.		— 7.2		—7*	—13.2
Jul.		—11.1		—8*	— 9.2
Aug.		— 8.0		—8.6	— 7.8
Sep.	—4.5	— 6.8		—6.4	— 8.9
Oct.	—2.5	— 6.3		—6.5	— 6.6
Nov.	—2.5	— 2.9	—4.2	—4.6	— 4.9
Dec.	—4.5	— 3.8	—3.3	—3.6	— 0.5

*Estimated from screen temperature.

At Karioi Forest, more severe frost damage occurred in the grassed area, but the damage was not severe enough to justify blanking. Only a small proportion of the trees had severe enough frost damage to cause loss of increment. At Kaingaroa Forest, the frosts were more severe in the second winter, with frosts down to —13.2°C, when the trees were averaging 120 cm in height. The level of damage to the trees is given in Fig. 2.

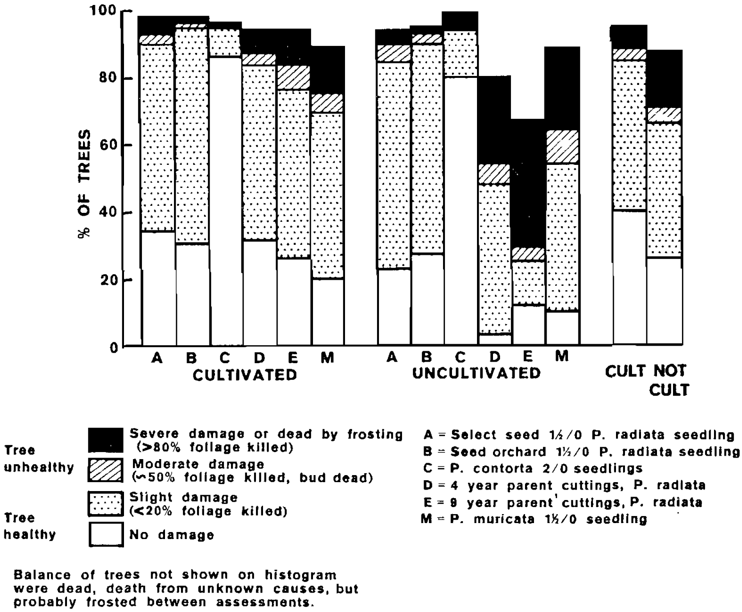

FIG. 2: *Frost damage during the first two years after planting at Compartment 812, Kaingaroa Forest.*

While trees are not badly retarded by slight frost damage, once they are moderately damaged with the leader killed, recovery is rare and they are often killed by consecutive frosts. Damage was worse on the uncultivated site, particularly with the cuttings and muricata pine which were frosted in the first year. Lodgepole pine generally lost only a few lateral buds. In spite of the frosts, enough radiata pine seedlings have survived to give a satisfactory crop.

Thus the important results from the trials were:

(a) Radiata pine seedlings had the best overall growth rate and survival. The growth and survival of radiata pine cuttings and muricata pine seedlings was inferior to that of radiata or lodgepole pine seedlings.

(b) Cultivation of cutovers by windrowing resulted in higher survivals and less frost damage in all types of planting stock.

(c) Once trees have been damaged with about 50% of their foliage killed and/or the terminal bud killed, height growth is significantly decreased, and often the trees succumb to subsequent frosts.

(d) Over 90% of the radiata pine seedlings studied came through two years of frosts with only slight damage when summer frosts were down to —6.1°C and winter frosts were as low as —13.2°C. However, since only a third of the seedlings came through with no frost damage, the above temperatures are probably close to the limit of radiata pine frost tolerance in those seasons.

(b) *Kaingaroa Forest Frost Flats* (R968)

The results for the three years of planting were similar, and so only the results from the second year are given. Insufficient trees survived to allow height growth analysis, and so only the survival and frost damage data are given. The percentages surviving with no or slight frost damage are given in Table 3 for each assessment.

Lodgepole pine was virtually undamaged throughout the trial period. The radiata pine seedlings suffered some damage in the spring after planting, but recovered over the summer. The nine-year-parent cuttings had poor root systems, and did not establish well, and some died the first summer. The first serious frost damage occurred on the uncultivated site in late summer and autumn (see Table 3), and in autumn on the cultivated site. By the end of the first winter (July, year 1), the percentage of healthy trees was around 80% for both seedling types and the four-year-parent cuttings on the cultivated site, but under 60% on the uncultivated site. After the spring frosts (November, year 1), the percentage of healthy trees of all but the four-year-parent cuttings halved, so that on the cultivated site the percentake of healthy trees was 43% for select seedlings and 33% for seed orchard seedlings, and 65% for the four-year-parent cuttings. The percentage of healthy trees for all the radiata pine treatments was under 20 on the uncultivated site. There was little further change in the number of healthy seedlings until after the second winter, but the four-year-parent cuttings were frosted during this time so that the percentage of healthy trees fell from 65 to 37% by June, year 2, on the cultivated site. The remaining radiata pine trees on the uncultivated site were killed by the end of the second winter. Further deaths occurred during the next two years on the cultivated site, so that the final percentage of healthy trees four years after planting were 10% for both seedlings and four-year-parent cuttings.

TABLE 3: PERCENTAGE OF HEALTHY TREES (WITH NO OR SLIGHT FROST DAMAGE), AT COMPARTMENT 889, KAINGAROA FOREST

Assessment Time	*Year*	*Site: Cultivated*					*Unculativated*				
		Treatment:									
		A	*B*	*C*	*D*	*E*	*A*	*B*	*C*	*D*	*E*
Aug.	0	100	100	100	100	100	99	100	100	100	100
Sep.	0	94	100	100	100	98	75	100	100	100	96
Nov.	0	100	100	100	100	100	97	100	100	99	100
Dec.	0	100	100	100	100	88	96	99	100	99	72
Feb.	1	100	100	100	96	84	72	86	99	70	38
May	1	89	94	100	92	76	63	85	99	72	37
Jul.	1	80	78	100	85	62	34	59	100	45	11
Nov.	1	43	33	100	65	30	7	17	100	13	2
Jan.	2	39	37	99	52	53	3	13	99	13	1
Jun.	2	38	40	99	37	21	2	0	99	0	0
Apr.	3	24	12	97	22	12	0	0	100	0	0
Jul.	3	21	15	100	16	8	0	0	100	0	0
Nov.	3	19	9	100	24	6	0	0	100	0	0
Jul.	4	12	8	100	10	1	0	0	100	0	0

A are 1½/0 select seed seedlings, radiata pine
B are 1½/0 seed orchard seed seedlings, radiata pine
C are 2/0 lodgepole pine seedlings
D are 0/1 cuttings from four-year-old parents
E are 0/1 cuttings from nine-year-old parents

TABLE 4: PERCENTAGE OF HEALTHY CUTTINGS FROM FOUR-YEAR-PARENT CLONES (WITH NO OR SLIGHT FROST DAMAGE), SECOND YEAR OF PLANTING

*Clone**	*Cultivated*				*Uncultivated*			
Month	*Jul.*	*Jun.*	*Jul.*	*Jul.*	*Feb.*	*Jul.*	*Nov.*	*Jun.*
Year	*1*	*2*	*3*	*4*	*1*	*1*	*1*	*2*
937	100	63	50	50	89	67	33	0
939	100	56	44	33	100	50	13	0
943	100	67	33	33	75	63	0	0
942	86	43	29	14	89	67	33	0
945	88	38	25	13	67	56	33	0
938	86	29	0	0	57	43	29	0
946	100	33	0	11	89	67	0	0
944	75	25	13	13	56	33	0	0
941	33	11	11	11	63	0	0	0
940	100	20	0	0	63	13	0	0

*Clone numbers designated by FRI Genetics and Tree Improvement Section. The parents were randomly selected from a four-year-old plantation at Kaingaroa Forest.

There was a difference in survival between clones, and the survival data for four-year-parent cuttings are given in Table 4. Clones 937, 939, and 943 were the best, and 940 and 941 the worst.

Temperature data were collected from October of the second year of planting, and the temperature 5 cm above the ground for both the cultivated and uncultivated sites are shown in Fig. 3. Frosts occurred every month of the year, with the most severe frosts occurring towards the end of winter. The thermometer site was moved to the next year of planting in May. The minimum temperature was consistently higher on the cultivated site, and the difference was up to 4°C.

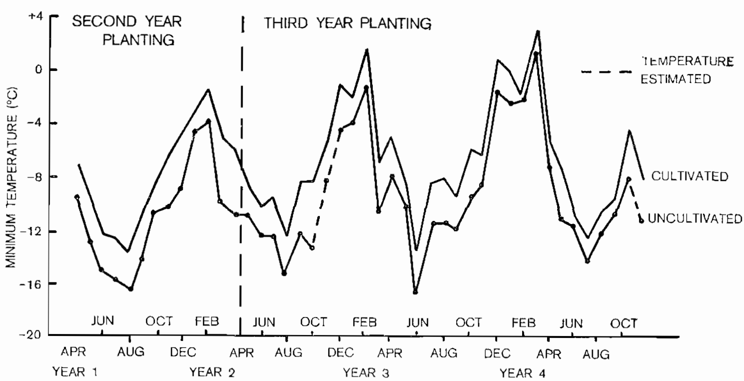

FIG. 3: *Minimum temperature 5 cm above cultivated soil and tussock-monoao areas, Compartment 889, Kaingaroa Forest.*

Temperature profiles above ground are shown in Fig. 4. On cultivated ground, there was not much change in temperature with increasing height above ground, but, on the uncultivated ground, the minimum temperature occurred at 20 cm above ground, and there was a rise in temperature with increasing height.

The most striking result from this trial was the effect of cultivation, both in terms of survival of the trees, and the effect on minimum temperatures. In all three years of planting, there was some damage in the spring following planting, but the trees recovered over the summer. The first serious damage occurred in the autumn after planting, especially on the uncultivated site, when minimum temperatures were below —9°C in April and —13°C in May. Winter temperatures of below —17°C killed the remaining trees on the uncultivated site.

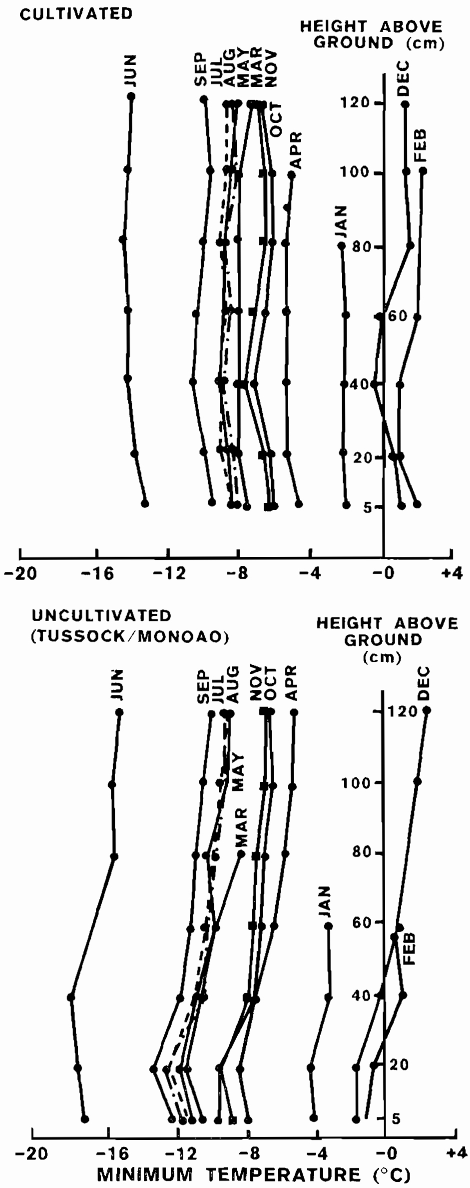

FIG. 4: *Temperature profile for year 3, Compartment 889, Kaingaroa Forest.*

On the cultivated sites, damage was recorded in autumn, winter, and spring frosts, but particularly the autumn/early winter, and late winter/spring frosts. Temperatures for these critical months were about —7°C for March and April, —8 to —9°C for May, —12 to —14°C for August, —9 to —11°C for September, and —8°C for October. A few seedlings and cuttings survived undamaged, and these temperatures would be the limit expected of radiata pine. The range of frost tolerance shown by both seedlings and cuttings gives some hope for selection of frost-tolerant trees. Some clones also survived better than others, suggesting the possibility for selection of frost-tolerant clones.

Two other important factors came out of this trial. First, it is apparent that excellent tree quality from the nursery is essential for establishing hard sites. The poor performance of seed orchard seedlings from the 1970 planting replication owing to poor mycorrhizal development in the nursery, and of the nine-year-parent cuttings owing to poor root development, stress the need for well-conditioned, vigorous stock from the nursery.

Secondly, frost damage occurred over a period of at least three years after planting, with most damage the year after planting, stressing the need for weed control to minimise frost damage, either by weedicides or further cultivation. The trees will not be safe from frosts until they grow above the frost level. Any setback from frost damage delays this growth and prolongs the danger period. As can be seen from the temperature profile (Fig. 4), there was no lessening of frost level up to 120 cm above ground at this trial. The exact danger height will depend on topography and air drainage patterns, but on large flat areas, experience has indicated that at least two years and even three years of growth is necessary before trees can be considered established and above frost levels.

(c) *Time of Planting* (R952)

The results from the two years of planting were similar, and so only the results from the second year of planting are given.

As with the first planting, few trees survived three years without some frost damage, and so each tree was classed healthy if it was over 180 cm tall after three years and unhealthy if below this height. On this basis 67% of the survivors were healthy. Heights ranged from 40 to 360 cm.

The same trends in survival as the first planting were apparent (Fig. 5). The worst months were May, November, and December, and the best months January to March, and June to September.

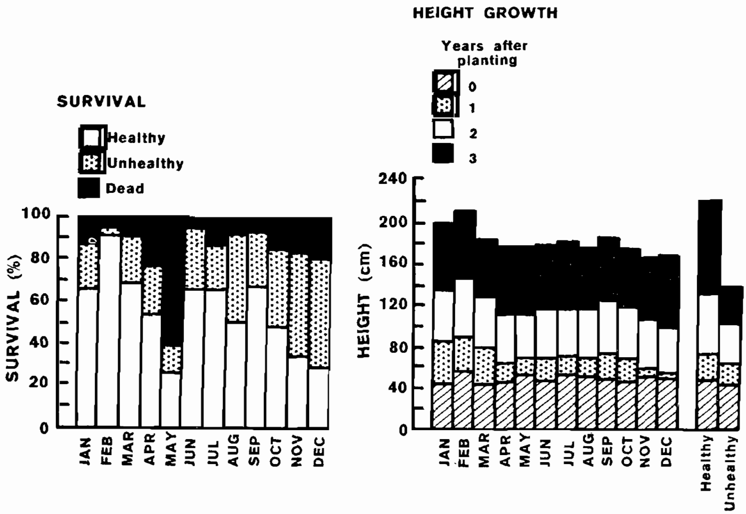

FIG. 5: *Height and survival data for time-of-planting trial, Compartment 889, Kaingaroa Forest.*

Overall, survival was higher than the previous year, with only April, May, November, and December plantings falling below 85% (Fig. 5).

The height data (Fig. 5) show the advantage of late summer-autumn planting, with subsequent higher increment in the first year. The next best increments were from spring and winter planting, except for May.

The temperature data are given in Table 5.

TABLE 5: MINIMUM TEMPERATURES AT 5 cm ABOVE GROUND AT THE TIME-OF-PLANTING TRIAL, COMPARTMENT 889, KAINGAROA FOREST

Month	*Minimum Temperature (°C)* 1972	1973
Jan.	— 4.5	— 2.2
Feb.	— 1.7	— 0.6
Mar.	— 2.5	— 9.0
Apr.	— 7.4	— 8.5
May	—11.3	—11.0
Jun.	—13.7	—13.8
Jul.	—12.9	—16.1
Aug.	—14.1	—10.5
Sep.	— 9.7	—11.4
Oct.	— 7.8	—11.6
Nov.	— 3.2	— 4.8
Dec.	— 3.6	— 3.8

Frosts occurred every month of the year from 1971 to 1973. In 1972 frosts became more severe in April, and with another sharp jump in severity during May to —11.3°C. The most severe frosts were in August (—14.1°C). Frost severity then rapidly lowered during September and October, reaching the summer levels by November. In 1973 there were three severe frosts in March, all around —9°C, and the winter frosts were worse than in 1972, reaching a low of —16.1°C in July, and with frosts of —11.6°C in October (spring). Again, the summer levels came by November.

Main interest in this trial was in the height growth and survival patterns. The May plantings failed in both years. They were frosted within two months of planting. As can be seen from Table 5, the frost levels in May and June were severe, with frosts lower than —11°C. The seedlings came from FRI nursery at Rotorua, where frosts for the last 10 years have not been lower than —7.4°C in May. Seedlings would still be hardening off in early winter, and the sharp drop to —11°C frost on transplanting was too great. Overall, survival was best in either autumn or late winter/spring — *i.e.*, February, March, August, and September. Seedlings planted by March had time to harden off naturally by the time the severe winter frosts started, and by late winter the seedlings were fully hardened in the nursery, and the worst winter frosts were over. However, the —9°C frosts in March 1973 severely damaged seedlings, and unseasonal frosts are still a problem. The autumn-planted trees established before winter, and therefore had the best growth rate.

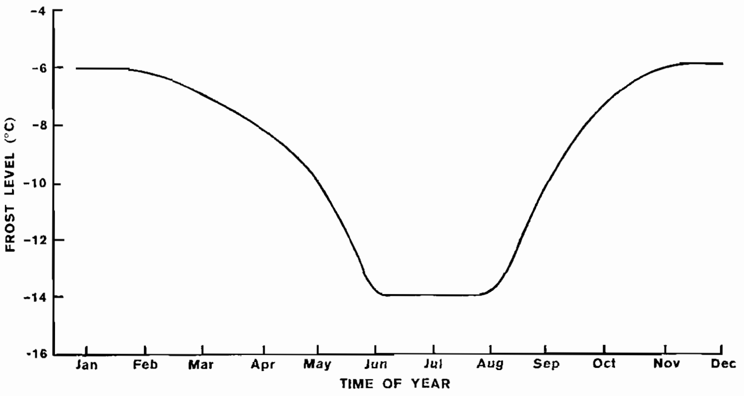

FIG. 6: *Radiata pine frost tolerance as deduced from field trials.*

Assuming a minimum acceptable survival of 80%, it is possible to derive an approximate seasonal frost tolerance of radiata pine seedlings from the trials, and this is shown in Fig. 6. The frost tolerance ranges from —6°C in the summer to —14°C in the winter. These figures agree closely with those of Washbourn (1978). The frost tolerance of lodgepole pine is greater than this, since none were seriously damaged in the trials, and the frost tolerance of muricata pine is less, particularly outside the main winter dormant period.

CONCLUSIONS

Radiata pine seedlings survived better and grew faster than cuttings on cutover sites, although this superiority was exaggerated somewhat by the larger initial size of the seedlings. There were differences in frost tolerance between different clones of cuttings from four-year-old parents. Lodgepole pine did not grow as tall as radiata pine, although it was hardly affected by any frosts. Muricata pine gave variable growth rates and survivals, was severely damaged by possums, and proved more prone to unseasonal frosts than radiata pine.

Cultivation improved survival on all sites, and on the hardest site, minimum temperatures were raised by up to 4°C by cultivation and maintaining a weed-free site and exposed black soil. This increase in minimum ground temperature can be enough to make the difference between success and failure of the planting.

The best times for planting frost sites were autumn and spring (February, March, August, and September). The best growth came from planting in autumn. The worst time for planting was early winter (May), when the seedlings came from a lower elevation nursery with few frosts, to —11°C frosts on hard sites.

The frost tolerance of radiata pine ranged from approximately —6°C in the summer to —14°C in the winter.

Recommended Establishment Regime for Radiata Pine

Complete cultivation should be carried out in late summer or autumn preceding planting, by mounding, bedding or discing, which exposes the soil and removes vegetation. The site must be kept weed-free for at least two years after planting by the use of weedicides or by further cultivation. If windrowing or roading is done in the area, care must be taken not to impede air drainage by creating obstacles across slopes. Planting should not be done before late winter or early spring. The planting programme should be planned so that the hardest sites are planted last. Radiata pine reaches peak frost tolerance at the end of winter, and May is the worst time for planting. Only large, vigorous well-conditioned stock should be used.

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