FROST DAMAGE, SURVIVAL, AND GROWTH OF PINUS RADIATA, P. MURICATA, AND P. CONTORTA SEEDLINGS ON A FROST FLAT

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ABSTRACT

Three cultivation treatments (ripping only, discing and ripping, and ripping and bedding) were tested on a frost-prone site in Otago. Incidence of frost damage and tree survival and growth were compared for **Pinus radiata** D. Don, **P. muricata** D. Don, and **P. contorta** Loudon. Frost damage to **P. radiata** and **P. muricata** was severe on uncultivated plots but was significantly reduced on the intensely cultivated plots; rip/bed sites gave the best results. Survival of these species followed similar trends. **Pinus contorta** was relatively unaffected. **Pinus radiata** 1½/0 stock did not grow well on the uncultivated plots, and growth responded markedly to ripping. More intensive cultivation did not yield additional growth. Growth of **P. muricata** and **P. contorta** did not improve significantly with soil cultivation.

Keywords: frost damage; survival; growth; cultivation; **Pinus radiata**; **Pinus muricata**; **Pinus contorta**.

INTRODUCTION

Effects of site cultivation on establishment of *P. radiata, P. muricata,* and *P. contorta* on an extensive frost-flat were studied in Mahinerangi Forest, near Dunedin (45°50′30″S and 169°56′30″E). The experimental area had been part of a sheep station until 1945, and the vegetation was predominantly native tussock (Hetherington & Balneaves 1973). In 1946 the Dunedin City Corporation planted the area in *P. radiata,* but a combination of fire in 1947 and severe summer frosts destroyed much of the plantings. Only a few trees survived, mostly on the higher ground where cold air drainage was good.

After being logged in 1973, the area was more intensively roaded and then burnt in September 1973. In February 1974 the site was ripped to a depth of 60 cm with a winged ripper and then planted with 1/0 *P. radiata* seedlings the following August. The new plantings were released from tussock regrowth and other herbaceous vegetation by a proprietary mixture of terbuthylazine and terbumeton. After extensive frost damage to the seedlings the area was blanked in 1975 with 1½/0 *P. radiata* seedlings. Subsequent frosts in the spring/early summer of 1975–76 killed many trees, and it was decided the whole area should be replanted.

On the basis of recommendations by Menzies & Chavasse (1982), various site cultivation options were tested and the performance of *P. radiata* stock from three different nurseries was evaluated to determine the influence of cultivation treatments on establishment and early tree growth.

METHODS

The area was burnt in September 1976. A 3-ha block on the frost flat was pegged out into twelve 30 × 50-m plots. In February 1977 four treatments were replicated three times in a randomised block design: (1) no cultivation, (2) rip only, with a winged ripper to a depth of 60 cm, (3) multiple disc and rip, and (4) rip and bed using the "Egmont" bedding plough.

Pinus radiata seed from Amberley seed orchard ("Southland" bulk collection) was distributed to the FRI nursery at Rangiora (North Canterbury), Fords Nursery at Maheno (North Otago), and Edendale Nursery (Southland) to be raised as $1\frac{1}{2}/0$ planting stock. An additional lot of 1/0 planting stock was raised at Edendale Nursery. For comparison, 2/0 *P. contorta* (ex Cpt 20 Seed Stand, Eyrewell Forest) and 2/0 *P. muricata* (blue strain, ex Ashley Forest Seed Stand) was raised at the FRI Nursery, Rangiora.

All stock was lifted, packaged, and transported to the planting site on the same day, stored in a shed overnight, and planted the following day (22 August 1977). Double rows of each tree stock type/species were planted, giving a total of 50 trees/type in each replicate. Spades and the "positive-pull-up" technique were used for planting (Trewin & Cullen 1985). Planting was done on a random basis to avoid any bias caused by individual planting technique.

Hexazinone was sprayed at 1.8 kg/ha in a blanket application by helicopter to control herbaceous vegetation after planting. Herbicide was applied each spring (late October) in 1977, 1978, and 1979 to maintain weed-free ground during the establishment phase.

Tree heights were measured each year until 1982, then again in 1986. Basal diameter (10 cm above ground level) was measured annually until 1979, and stem diameter at 1.4 m (dbh) was measured in 1982 and 1986.

Daily temperature records from the meteorological station (No. 159891) located in the same general area as the trial were used to establish frost frequency. Severity of frost damage (Menzies & Chavasse 1982) was recorded at each assessment and again after two particularly severe frost periods in April 1979 and October–November 1980.

Survival, frost damage, and diameter and height growth were tested by analysis of variance. Means were compared at the 95% probability level by Duncan's Multiple Range test.

RESULTS AND DISCUSSION

Frosts were recorded every month, except December 1981, for the 5 years after planting (Table 1). *Pinus contorta* showed no frost damage, and all seedlings of the other species had some degree of frost damage within 12 months of planting. Moderate to severe frost damage affected many trees after a series of frosts from June through to September 1978 (Table 2). Further damage to seedlings occurred in April 1979

after a hard frost (Table 1). However, moderate to severe frost damage affected more trees after frosts in spring/early summer (October–November) in 1980. The severity of these frosts was outside the range acceptable for *P. radiata* (Menzies & Holden 1981).

Fewer trees planted on the more intensive cultivation treatments experienced moderate to severe damage and, in general, damage was significantly less in the rip/bed treatment than in the others (Table 2). The 1/0 *P. radiata* stock was damaged more severely than the $1\frac{1}{2}/0$ stock in all the site cultivation treatments.

TABLE 1–Lowest monthly minimum grass temperature (°C) and number of frost days/month (in parentheses)

Month	1977 min temp.	1978 min temp.	1979 min temp.	1980 min temp.	1981 min temp.	1982 min temp.
Jan		–1.4 (1)	–1.6 (2)	–1.8 (2)	–0.5 (0)	–1.7 (1)
Feb		–1.9 (3)	–1.0 (1)	–3.0 (4)	–1.8 (3)	–2.7 (2)
Mar		–2.5 (4)	–2.2 (3)	–1.0 (2)	–3.8 (2)	–3.2 (7)
Apr		–5.1 (8)	–9.8 (7)	–2.9 (7)	–2.5 (5)	–5.5 (13)
May		–7.6 (14)	–7.0 (14)	–3.5 (10)	–8.9 (18)	–7.0 (12)
Jun		–11.0 (21)	–8.6 (18)	–10.5 (17)	–7.5 (16)	–7.5 (19)
Jul	–8.2 (22)	–8.4 (25)	–8.4 (21)	–8.4 (20)	–6.0 (18)	–9.8 (24)
Aug	–9.0 (21)	–9.6 (24)	–8.8 (22)	–10.4 (15)	–8.0 (20)	–8.0 (23)
Sep	–8.1 (17)	–11.0 (20)	–7.8 (21)	–5.5 (14)	–9.8 (10)	–6.2 (19)
Oct	–5.2 (11)	–4.9 (12)	–5.0 (9)	–8.1 (11)	–3.0 (12)	–5.2 (13)
Nov	–4.1 (7)	–4.3 (9)	–2.7 (6)	–7.5 (12)	–2.2 (3)	–4.0 (7)
Dec	–2.3 (3)	–1.0 (1)	–4.1 (3)	–1.9 (4)	+1.5 (0)	–4.4 (6)

TABLE 2–Percentage of trees damaged (mod-severe*) by frost

Site preparation	*Pinus radiata* $1\frac{1}{2}/0$						*Pinus radiata* 1/0		*Pinus muricata*		*Pinus contorta*	
	FRI		Fords		Edendale		Edendale		FRI		FRI	
	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980
No cult.	60a	66a	52a	66a	58a	60a	63a	86a	59a	66a	0a	18a
Rip only	50b	51b	40b	58b	50b	55ab	44b	69b	42b	48b	0a	16ab
Disc/rip	43c	50b	39b	48c	49b	51ab	42b	50c	37b	50b	0a	16ab
Rip/bed	36d	42c	18c	24d	35c	48b	41b	45c	22c	38c	0a	11b

* Menzies & Chavasse (1982) classification greater than 50% of the foliage dead with dead terminal bud.
Note: Numbers with the same letter within the vertical columns do not differ significantly ($p>0.05$)

Before the frosts in 1979 seedling survival was high, except for the 1/0 *P. radiata* (Table 3). However, by winter 1981 survival of *P. radiata* had decreased for all treatments, particularly for the uncultivated treatment. Survival of *P. muricata* had also decreased, but *P. contorta* remained unaffected. Survival of *P. radiata* increased significantly for the more-intense site cultivation treatments.

Major road alignments and the building of a 10-m-high road-fill only 400 m downstream from the trial in February 1979 may have contributed to the severity of frosts and resulting damage. Planting sites should provide for drainage of cold air to

TABLE 3–Percentage seedling survival for 1979 and 1981

Site preparation	*Pinus radiata* 1½/0						*Pinus radiata* 1/0		*Pinus muricata*		*Pinus contorta*	
	FRI		Fords		Edendale		Edendale		FRI		FRI	
	1979	1981	1979	1981	1979	1981	1979	1981	1979	1981	1979	1981
No cult.	91a	78a	86a	60a	88a	67a	69a	30a	91a	84a	100a	100a
Rip only	91a	80a	91a	67a	97b	80b	74ab	62b	96ab	91ab	100a	96a
Disc/rip	92ab	84ab	99b	81b	99b	85b	79bc	72c	99b	93b	100a	96a
Rip/bed	98b	91b	98b	96c	100b	98c	83c	77c	100b	97b	100a	100a

Note: Numbers with the same letter within the vertical columns do not differ significantly (p>0.05)

lower areas. Earth fills may block such drainage and should be avoided where planting sites are subject to frost (Rosenberg 1974; Menzies & Chavasse 1982).

Differences in height growth for the different treatments were significant 2 years after planting, with the rip/bed giving best initial growth. However, by age 5 (1982) the growth differences between the three cultivation treatments were not significant. Trees in the no cultivation treatment were still significantly shorter than those in the other treatments. This relationship was still evident at age 9 (Table 4). Similar trends were apparent for diameter growth.

TABLE 4–Final height and diameter (1986) of tree stocks in different cultivation treatments

Site preparation	*Pinus radiata* 1½/0			*Pinus radiata* 1/0	*Pinus muricata*	*Pinus contorta*
	FRI	Fords	Edendale	Edendale	FRI	FRI
A. Height growth (m)						
No cult.	5.41a	4.19a	5.19a	3.45a	5.26a	5.31a
Rip only	5.97b	5.57b	5.78b	4.52b	5.28a	5.39a
Disc/rip	6.03b	5.59b	5.87b	5.41c	5.43ab	5.57a
Rip/bed	6.04b	5.77b	5.89b	5.83d	5.87b	5.78a
B. Diameter growth (cm)						
No cult.	11.7a	9.3a	10.9a	5.0a	10.8a	9.5a
Rip only	14.0b	12.8b	13.1b	8.8b	11.1a	9.8ab
Disc/rip	15.0b	12.4b	13.8b	10.6c	11.2a	10.3ab
Rip/bed	15.0b	14.1c	14.1b	14.4d	11.4a	10.8b

Note: Numbers with the same letter within the vertical columns do not differ significantly (p>0.05)

Between age 2 and age 5, *P. contorta* grew faster in height than either *P. radiata* or *P. muricata,* but by age 9 the 1½/0 *P. radiata* and 2/0 *P. muricata* had equalled or surpassed it. The 1/0 *P. radiata* performed poorly compared with the 1½/0 stock (Table 4). By age 9, the mean diameter of the 1½/0 *P. radiata* stock was significantly greater ($p \leq 0.05$) than that of *P. muricata* or *P. contorta* and these in turn had significantly larger diameters than the 1/0 *P. radiata.* Although 1/0 *P. radiata* generally performed less well than the other material, its growth was equal to 1½/0 *P. radiata* when planted on the rip/bed treatments.

CONCLUSIONS

Cultivation improved survival of all *P. radiata* stock. Frost damage was least severe on the rip/bed option and subsequent survival was improved. Spring frosts (October–November) were more damaging to *P. radiata* than early autumn frosts.

Pinus muricata and *P. contorta* did not grow as fast as *P. radiata* and intensive cultivation (rip/bed) did not greatly improve growth beyond that in the uncultivated treatment. Growth of $1\frac{1}{2}/0$ *P. radiata* was enhanced by ripping, but further intensive cultivation (disc/rip and rip/bed) did not further improve height and diameter growth on this site. One-year-old *P. radiata* seedlings grew as well as the $1\frac{1}{2}/0$ *P. radiata* when planted on the rip/bed treatment.

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