New Zealand Forest Site Management Cooperative

DEFINING THE OPTIMAL AREA AND DURATION OF WEED CONTROL AT TOKOITI FOREST - RESULTS AFTER THREE YEARS

By

A.L. VANNER, B. RICHARDSON and G. COKER

REPORT No. 96 JUNE 1998

DEFINING THE OPTIMAL AREA AND DURATION OF WEED CONTROL AT TOKOITI FOREST - RESULTS AFTER THREE YEARS

A. L. VANNER, B. RICHARDSON and G. W. R. COKER

Plant Protection Chemistry
NZ Forest Research Institute,
Private Bag, Rotorua

TABLE OF CONTENTS

DEFINING THE OPTIMAL AREA AND DURATION OF WEED CONTROL AT TOKOITI FOREST - RESULTS AFTER THREE YEARS

A. L. VANNER, B. RICHARDSON and G. W. R.. COKER

Plant Protection Chemistry
NZ Forest Research Institute,
Private Bag
Rotorua

ABSTRACT

Two trials were established on a pasture site in Tokoiti Forest, South Otago, to investigate the effect on the growth of *Pinus radiata* seedlings, of controlling competing vegetation for either one year or two years, and to determine the optimum size of the area of vegetation control around individual trees necessary to maximise tree growth. Growth measurements made in the third year after planting are presented, in trials designed to last for either 7 -10 years, or for the length of the rotation. Control of pasture grasses and weeds for 2 years after tree planting resulted in significantly higher productivity (measured in terms of tree basal area per plot) and tree growth, than when vegetation control was applied for only one year. The poorest rate of growth and lowest productivity occurred where no weed control was undertaken. Vegetation control in spots of either 1.5 or 2 metres diameter around the trees resulted in similar tree growth and productivity to trees growing in plots with total weed control. There is a suggestion that benefits in tree growth continue to accrue after weed control operations have ceased, but measurements need to be undertaken in future years to substantiate this. Multi leadering of seedlings resulting from browsing damage in the first two years by small animals was worst where total vegetation control was undertaken.

INTRODUCTION

In the establishment of forest plantations, it is accepted that weed control can have a beneficial effect on the growth and survival of the tree crop. Usually, the control of competing vegetation is achieved through the use of herbicides at some stage in the plantation establishment process.

Although weed control is usually undertaken in the first year of establishment, when small trees are most vulnerable to competing vegetation, there is a need to determine whether extending the duration of weed control for a second year or beyond can have a beneficial effect on wood production at the end of the rotation. This will be dependent on a number of site variables including the type of competing vegetation, environmental conditions and establishment practises.

Likewise, the area around the tree in which the competing vegetation is managed can be varied. Whilst the control of undesirable vegetation has often been achieved through providing total weed control by broadcast application of herbicides, spot application methods have now been widely adopted for reasons of economy, safety, and environmental considerations. It can be hypothesised that as the size of the weed free area around each tree is increased, tree growth will also increase because of reduced competition. This hypothesis needs to be tested, and the size of spot above which the gain in tree volume does not balance the additional treatment costs needs to be determined.

A number of trials have been established on different sites to provide data from which a model can be developed to predict the medium and long term effect of the area and duration of weed control on the growth of *Pinus radiata*. This will allow cost-benefit analysis to be undertaken so that optimum treatment regimes can be defined. As part of this series, two trials were established on a pasture site planted with *P. radiata* in Tokoiti Forest (City Forests Ltd.), South Otago. One trial has a planned duration of 7 - 10 years (Short Term trial) and the other will run throughout the rotation (Long Term trial). This report presents results three years after establishment, a year after most weed control operations ceased and where future differences in growth between treatments will be as a consequence of the influence of early weed control.

METHODS

Site

The trial is situated on rolling coastal land at Tokoiti Forest, to the east of Milton, South Otago. The soil type is a mixture of Taratu Hill soils (gravel) and Raurekau silt loams. Soil fertility is high, with a history of topdressing. Average annual rainfall is around 800 mm, with rainfall generally being higher in summer. Rarely, snow will fall on the site. Plots were established on the top of an exposed knoll and on southerly and south westerly slopes at an altitude of approximately 50 metres above sea level.

The predominant vegetation on the site is improved agricultural grasses with some thistles. Initially there were remnants of a forage brassica crop.

Establishment

The two trials were established in 1994. The Short-Term trial was designed to last for 7-10 years and the Long-Term trial for the duration of the rotation. Both trials were planted with one year old, bare rooted GF26, *Pinus radiata* seedlings in the winter of 1994.

Experimental design

Plots were laid out in a complete randomised block design with 5 replicates of each treatment. Plots in the Short-Term trial were 25x15 metres in size and were planted with 30 *P. radiata* seedlings at 4x3 metre spacings. The central 12 trees are used for assessment purposes. The Long-Term trial plots were 50x48 metres in size, planted with 208 seedlings at 4x3 metre spacing. The central 70 trees have been measured to date. In due course the number of trees in the measured area will be reduced to 27 trees following a final thinning to 325 stems/ha.

Treatments

Treatments in the Short-Term trial are a matrix of three areas of vegetation control around individual trees for two time periods (Table 1a). Two additional reference treatments were established, one with total vegetation control for the duration of the trial, and the other with no weed control. In the Long-Term trial, four treatments were established (Table 1b): these were 1 and 2 m spot diameters each maintained for two years; and two treatments of total weed control maintained for a rotation but with fertiliser applied to one of these. Fertiliser was applied in year 2, and will continue to be applied as and when necessary (as determined by analysis of the tree foliage) to maintain the fertility of the site at a level where nutrients are not growth limiting. Weed control was undertaken using herbicides to which *P. radiata* is tolerant (Table 2).

Table 1: Spot size treatments and duration of weed control

a. Short-Term Trial

DURATION OF CONTROL (Years)	SPOT DIAMETER (metres)	SPOT AREA (metres^2)
7 - 10	No Grass Control	No Grass Control
1	1	0.8
1	1.5	1.8
1	2	3.1
2	1	0.8
2	1.5	1.8
2	2	3.1
7 - 10	Total Weed Control	Total Weed Control

b. Long-Term Trial

DURATION OF CONTROL (Years)	SPOT DIAMETER (metres)	SPOT AREA (metres^2)
2	1	0.8
2	2	3.1
Rotation	Total Weed Control	Total Weed Control
Rotation*	Total Weed Control*	Total Weed Control*

* An application of fertiliser was made in year 2.

Table 2: Herbicide treatment rates and application times

Application Date	Treatment		
	One Years Weed Control	Two Years Weed Control	Permanent (Total) Weed Control
October 1994	terbuthylazine 7.5 kg/ha	terbuthylazine 7.5 kg/ha	terbuthylazine 7.5 kg/ha
	haloxyfop 0.4 kg/ha	haloxyfop 0.4 kg/ha	haloxyfop 0.4 kg/ha
	clopyralid 0.24 kg/ha	clopyralid 0.24 kg/ha	clopyralid 0.24 kg/ha
October 1995		terbuthylazine 3.9 kg/ha	terbuthylazine 3.9 kg/ha
		hexazinone 1.5 kg/ha	hexazinone 1.5 kg/ha
		clopyralid 0.04 kg/ha	clopyralid 0.04 kg/ha
February 1997			terbuthylazine 7.0 kg/ha
			hexazinone 1.73 kg/ha
			clopyralid 0.84 kg/ha

Treatment Application

Control of grasses and broadleaf weeds was achieved using applications of the herbicides clopyralid (Versatill), haloxyfop (Gallant), hexazinone (Velpar), and terbuthylazine (Gardoprim), herbicides to which *P. radiata* is tolerant (Table 2). The herbicides were applied in water in a total spray volume of 150 litres/ha. Herbicides were applied as spot applications using a knapsack sprayer fitted with a Solo Targetmaster, which delivers a measured quantity of spray through a Spraying Systems FL8 solid cone nozzle. The application details to achieve spots of the required size are shown in Table 3. Total weed control was achieved on the appropriate plots using knapsack sprayers fitted with a boom and flat fan nozzles.

Table 3: Spot Size Application Parameters

Spot Diameter (metres)	Nozzle Height* (cm)	Volume Applied/spot (mls)
1.0	30	12
1.5	65	27
2.0	95	48

* Height above the top of the vegetation.

On 20th October 1995 Calcined Magnesite was applied at a rate of 50 kg/ha to the total weed control fertilised treatment plots in the Long Term trial.

Assessments

Seedling heights and diameters were first measured in September 1994, following planting, and again every year for three years. Seedling survival and the number of trees in each plot forming multiple leaders, caused mainly through browsing by rabbits and hares, were also assessed. The maximum and minimum diameters of each spot were measured in the year following treatment with herbicides. An assessment was also made of the vegetation cover in each spot over the three year period following

establishment of the trial. Foliage samples were taken from the trees in February of 1996 and 1997 and analysis has shown that no further applications of fertiliser have been required to date to maintain nutrient balance. Assessment dates are shown in Table 4.

Table 4: Dates of trial operations

Date	Activity
20.7.94	Trees planted
19.9.94	Initial tree measurements
10.10.94	Short Term trial sprayed (Plots treated years 1 & 2 and for trial duration)
25.10.94	Long Term trial sprayed (Plots treated years 1 & 2 and for trial duration)
26.2.95	Weed cover & multi leaders assessed. Spot sizes measured. Grass & tree foliage sampled
21.8.95	Trees measured. Multi leaders, toppling & grass cover assessed
6.10.95-5.11.95	Spots resprayed (Plots treated in year 2 and for trial duration)
20.10.95	Fertiliser applied to Long Term fertilised plots
26.2.96	Weed cover & multi leaders assessed. Spot sizes measured. Grass & tree foliage sampled
19.8.96	Trees measured. Multi leaders, toppling & grass cover assessed
10.2.97	Weed cover assessed & spot sizes measured. Grass & foliage sampled
18.2.97	Total weed control plots sprayed
10.9.97	Trees measured.

Data for tree measurements, mortality and the frequency of multi leadering was subjected to analysis of variance and differences between treatments determined by Fisher's Protected Least Significant Difference test (P = 0.05).

RESULTS

Treatment means for the tree growth parameters measured three years after trial establishment are shown in Table 5. The tree basal areas and the tree volumes are calculated on a plot basis, thereby taking into account mortality in each treatment. The plot basal areas and volumes are much higher for the Long Term trial than the Short Term trial as 70 trees have been measured in the Long Term trial plots compared with 12 in the Short Term plots.

An assessment was made in February, nineteen months after the trees were planted, of the number of multi leadered seedlings present in each plot. Over the course of the trial, rabbit browsing had been observed, and the majority of multi leadering is as a result of the tops of the seedlings being eaten and subsequent development of lateral buds. The incidence of multi leadering is shown in Table 6.

Table 5: Tree mortality, and mean growth parameters for each treatment.

a. Short-Term Trial

Spot Diameter (Theoretical)	Duration (Years)	Mortality % (Trt Mean)	Tree Diameter (mm)	Tree Height (metres)	Plot Basal Area (cm^2)	Plot Volume (cm^3)
0	7 - 10	7.3 a	21.8 e	1.19 e	40.6 d	5783 d
1.0	1	4.3 b	46.3 d	1.70 d	114.3 d	20412 cd
1.0	2	1.0 c	61.9 bc	2.08 abc	319.3 bc	70171 ab
1.5	1	2.3 bc	56.5 c	1.97 c	248.0 c	54447 bc
1.5	2	3.3 bc	69.8 ab	2.13 abc	405.0 ab	91639 a
2.0	1	1.7 bc	57.0 c	2.02 bc	252.7 c	52720 bc
2.0	2	0.7 c	73.8 a	2.30 a	471.5 a	113909 a
Total	7 -10	3.3 bc	77.1 a	2.23 ab	440.1 ab	96151 a

b. Long-Term Trial

Spot Diameter (Theoretical)	Duration (Years)	Mortality % (Trt Mean)	Tree Diameter (mm)	Tree Height (metres)	Plot Basal Area (cm^2)	Plot Volume (cm^3)
Total	Rotation	11.4 a	74.0 ab	2.06 b	2769 a	589650 a
2.0	2	6.9 ab	69.6 b	2.25 a	2574 a	602460 a
1.0	2	2.6 b	61.0 c	2.03 b	2087 b	445279 b
Total*	Rotation	9.7 a	76.0 a	2.08 b	2954 a	634989 a

* fertiliser applied

Values in a column followed by a common letter do not differ significantly (P = 0.05)

Table 6: Percentage trees with multi leaders assessed in February of the second year.

Spot Diameter (Theoretical)	Duration (Years)	Short Term Trial	Long Term Trial
0	7 - 10	11.4 a	
1.0	1	15.8 a	
1.0	2	20.6 ab	17.2 a
1.5	1	23.0 ab	
1.5	2	29.8 ab	
2.0	1	12.4 a	
2.0	2	38.0 b	27.3 b
Total	7 -10	64.2 c	
Total	Rotation		69.8 c
Total/Fertilised	Rotation		74.2 c

Treatments joined by a common letter do not differ significantly (P = 0.05)

A single spring application of herbicide maintained excellent weed control throughout the season on this site. The percentage weed cover on individual plots following herbicide applications in 1994 and 1995, 4, 16 and, in the case of the treatments applied for 1 year, 28 months after treatment are shown in Table 7. Reinvading weed types recorded following herbicide application were mainly seedling grass and *Hydrocotyl* species, the latter being a small shallow rooted ground cover weed. Some seedling thistle, various species of Cudweed (*Gnaphalium* spp) and other small broadleaf species were also recorded, but not in any great numbers. In the spot treatments, grass regrowth from seed was most prevalent around the edge of the spots where seed had fallen from the surrounding untreated grass sward. The density of seedling grass decreased towards the centre of the spot.

Table 7: Weed cover on plots at February assessments over the first three years

a. Short Term trial

Spot Diameter (Theoretical)	Duration (Years)	% Weed Cover February 1995	% Weed Cover February 1996	% Weed Cover February 1997
0	7 - 10	100.0	100	96.6
1.0	1	6.0	56.4	69.7
1.0	2	4.7	0.9	11.3
1.5	1	10.5	72.0	44.5
1.5	2	5.3	1.1	48.4
2.0	1	8.0	63.7	76.7
2.0	2	5.5	1.1	35.7
Total	7 -10	0	2.9	43.8

b. Long Term trial

Spot Diameter (Theoretical)	Duration (Years)	% Weed Cover February 1995	% Weed Cover February 1996	% Weed Cover February 1997
Total	Rotation	0	4.9	28.9
2.0	2	13.4	6.9	47.8
1.0	2	7.2	12.6	30.3
Total*	Rotation	0	3.7	39.9

* Fertiliser applied

DISCUSSION

Seedling Mortality.

In the Short Term trial, mortality was highest (but less than 8%) where no weed control was applied (Table 5a, Figure 1a). While there were other small but significant differences in mortality between treatments, no clear pattern was observed.

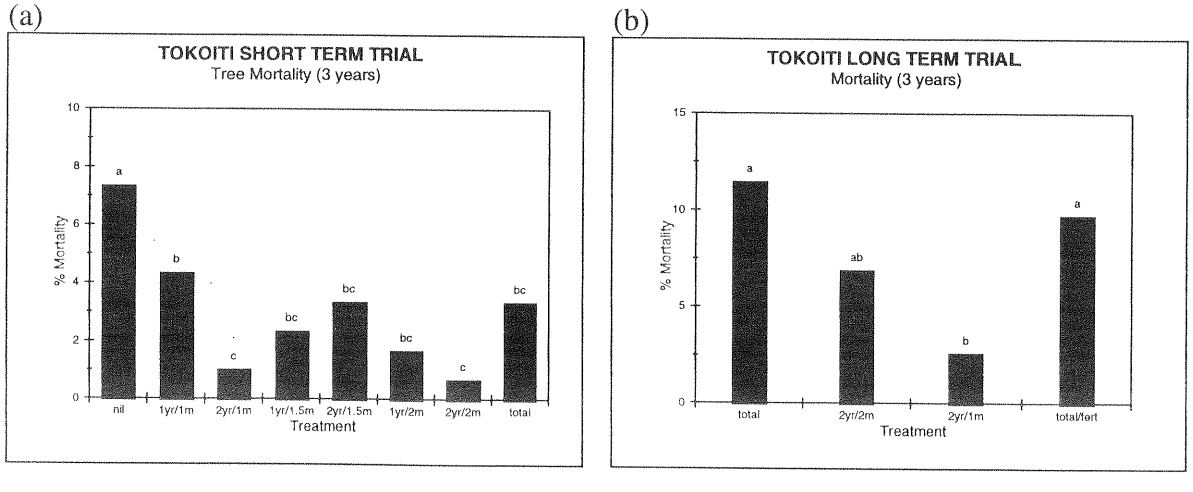

Figure 1: Effect of spot diameter and duration of weed control on seedling mortality. Bars topped by a common letter are not significantly different (P = 0.05)

In the Long Term trial, the highest mortality (about 12%) was recorded in the two total weed control treatments (Table 5b, Figure 1b) and the 2 m diameter spot maintained for two years. Lowest mortality occurred with the 2 m diameter spot maintained for one year.

Incidence of Multi-leadering

In both the Long Term and Short Term trials, there was significantly more multi-leadering (caused by hare and rabbit browsing) in the total weed control plots (Table 6). Overall, there was a weak correlation between the intensity of weed control and degree of browsing.

Stand Productivity

In comparing treatment effects on productivity comparisons were made on the basis of total tree basal area rather than volume index. This is because browsing damage will tend to have a lesser effect on diameter growth, and hence basal area, than height. Productivity values, on a plot basis, also account for differences in survival between treatments.

In the Short Term trial, the lowest productivity occurred with no weed control (Table 5a). This was not significantly different to where weed control was applied to an area of 1 metre diameter for 1 year (Figure 2a). For each spot diameter, the productivity was significantly higher where weed control was maintained for two years, compared with one year only (Figure 2a). The best spot treatment (2m diameter maintained for 2 years) was not significantly different to the total weed control treatment or the 1.5 m spot maintained for 2 years. Therefore, to maximise growth weed control should be maintained for a duration of two years. To maximise productivity with a minimum input of herbicide, it appears that an area of 1.5 metres diameter maintained weed free for two years would be optimal, even though slightly larger trees could probably be achieved with more weed control.

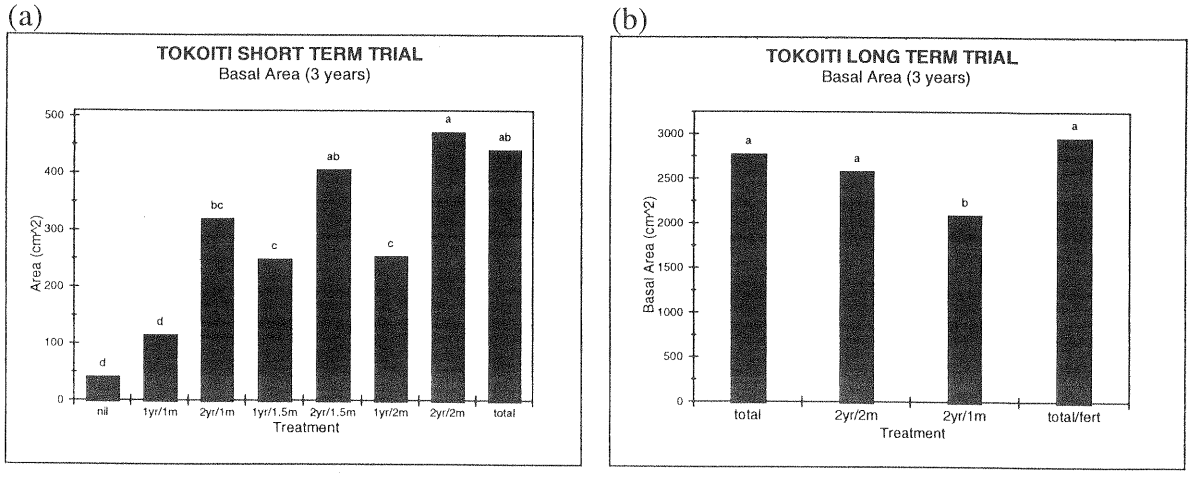

Figure 2: Effect of spot size and duration of weed control on plot productivity. Treatments joined by a common letter are not significantly different (P = 0.05)

In the Long Term trial, productivity was similar in both the total weed control treatments and where weed control was maintained in a 2 metre diameter spot for two years (Table 5b; Figure 2b). Where weed control was applied as a 1 m diameter spot, productivity was significantly reduced.

Tree Growth

To evaluate the effect of the area and duration of weed control on the growth of individual trees, an analysis was undertaken of the height and diameter data. As noted above, the trees were subjected to substantial browsing and as a result, more weight should be placed on the results of diameter growth.

Overall trends were similar to the basal area data with tree diameter growth in the Short Term trial significantly higher where weed control was applied for two years than for one (Figure 3a). There was no significant benefit from increasing the intensity of weed control beyond a 1.5 m diameter spot maintained for two years. Height growth also followed the same general trend (Table 5a).

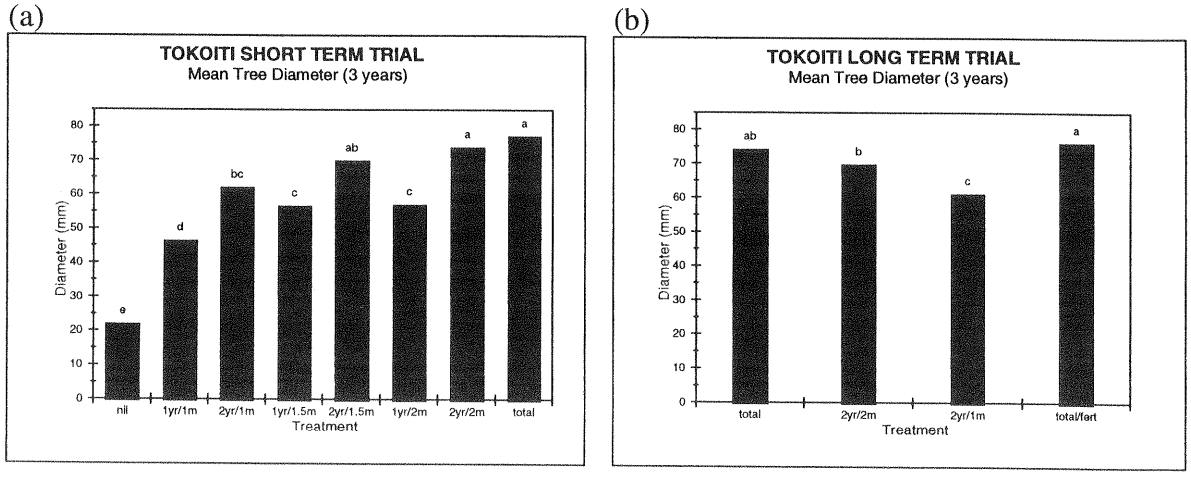

Figure 3: The effect of spot size and duration of weed control on tree size. Treatments joined by a common letter are not significantly different (P = 0.05)

In the Long Term trial differences in mean tree diameter were relatively small (Figure 3b), the smallest diameters being found in the 2 m diameter spot maintained for 1 year. The total weed control plus fertiliser treatment produced trees which were significantly larger than the 2 m diameter spot maintained for 2 years. Average tree height was significantly higher in the 2 metre spot treatment maintained for 2 years.

Overall, these results suggest that the application of fertiliser marginally increased tree growth, which is reflected in mean tree diameter, but that the browsing which was heavier in the total weed control areas (as indicated by a significant increase in multi-leadering) resulted in a lower measured tree height. It is generally accepted that rabbits tend to frequent areas where they can travel easily and thus would have been attracted to the trees on the total weed control plots.

To provide an overview of the growth and development over the first three years of the trial, mean tree diameter has been plotted over the first three years of the Short Term trial (Figure 4). There appears to be a trend towards a continuing divergence in

diameter over the third year, suggesting that the initial growth effects may continue through time. However, growth data needs to be collected for several more years before any definite conclusion can be drawn.

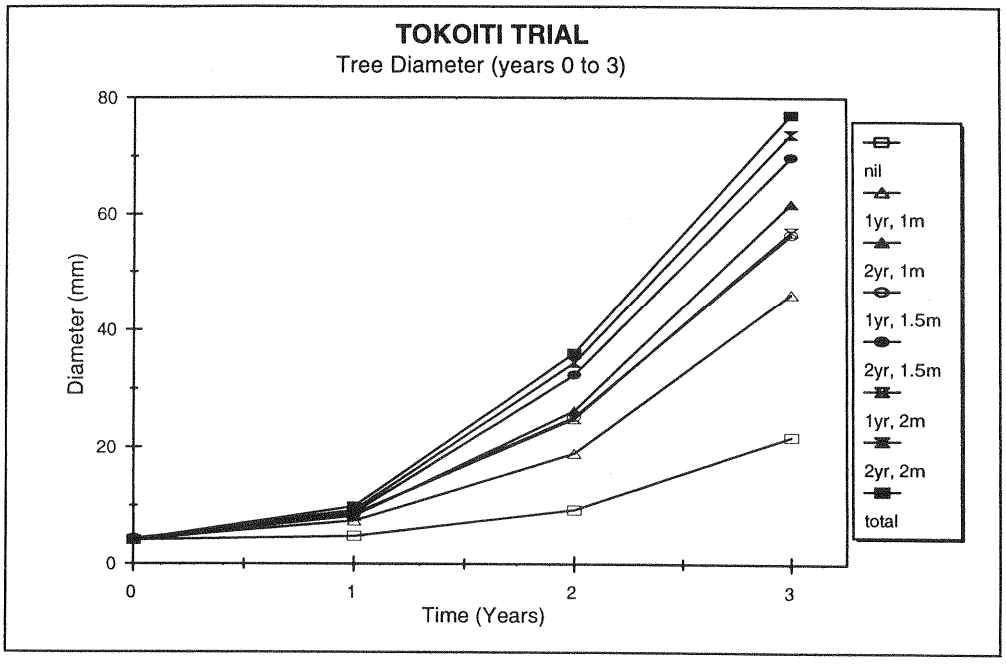

Figure 4: Effect of spot size and duration of weed control on the increase in mean tree diameter through time

CONCLUSIONS

Measurements of tree growth after three years on a fertile pasture site in South Otago showed:

- Weed control is essential to ensure maximum survival and growth of *Pinus radiata* seedlings planted in fertile pasture sites.
- Weed control for two seasons following planting results in higher stand productivity and greater tree growth than where weed control is applied in the year of planting only.
- Spot weed control around newly planted *Pinus radiata* seedlings results in similar tree growth to total vegetation control, providing spots are of a diameter of 1.5 metres or greater and maintained for at least two years.
- Where total weed control is undertaken, there is a significant increase in multi leadering in the first two years, as a result of browsing by small animals, compared with where spot weed control is undertaken.
- The effects of initial vegetation control may continue to be expressed and have a positive growth effect after herbicide applications have ceased, but measurements later in the life of the trial are required to confirm this.
- At this stage it appears that the most cost effective regime to maximise tree growth through weed control is to apply herbicides in spots 1.5 metres in diameter at the time of planting and again the following year.

ACKNOWLEDGMENTS

The authors wish to thank the NZ Site Management Cooperative and the Foundation for Research Science and Technology for the provision of funding for this trial and City Forests for the permission to use the site. We are particularly grateful for the support and assistance received from Phil Taylor and Mat Pannell and the staff of City Forests in carrying out the trial field work.