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Effects of Some Common Weed Species on *Pinus radiata* Seedling Growth*

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몇 가지 雜草種이 라디아타소나무 幼苗生長에 미치는 影響*

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ABSTRACT

Second year results are presented from a trial designed to quantify the reduction in radiata pine (*Pinus radiata* D. Don) seedling growth caused by competition from a range of important weed species on a moist North Island site in New Zealand. Radiata pine seedlings(1/0) were grown on the weed free control and with either herbaceous broadleaves, grass, broom, pampas, buddleia, or gorse. Resource(nutrient and water) levels were varied by factorial +/− irrigation and fertilizer treatments. Radiata pine seedling volume growth 21 months after planting was greatest when it was grown on the weed free control or in association with gorse, and was least when grown with either buddleia or pampas. There was no evidence that the effects of the weeds on seedling growth were mediated by either competition for water or nutrients. Tall, fast-growing species that overtopped the seedlings (broom, buddleia, pampas) had the greatest effect on seedling growth and the magnitude of the effect was correlated with degree of overtopping. This implies that shading or competition for light is probably an important factor.

Key words : competition, nutrients, water, weeds

要 約

뉴질랜드 북섬의 다우지역에서 라디아타소나무 유묘생장이 일련의 주요 잡초종과의 경쟁으로 인하여 감소함을 計量化하기 위하여 계획된 실험의 2차년도 결과이다. 라디아타소나무 유묘(1/0)들을 각각 잡초제거구와 활엽성초본, 목초, broom, pampas, buddleia, gorse와 함께 생육시켰다. 양료와 수분공급은 각 요인에 관수와 시비, 무관수와 무시비로 다양화하였다. 식재 21개월 후 라디아타소나무 유묘의 재적생장량은 잡초제거구와 gorse와 함께 생육된 구에서 최대였고 buddleia나 pampas와 함께 생육된 곳에서는 최소였다. 유묘생장에 대한 잡초의 영향이 수분이나 양료 경쟁에 의해 조정된다는 증거가 없었다. 유묘를 능가하여 치솟는 키크고 빨리 자라는 종(broom, buddleia, pampas)들이 유묘생장에 가장 큰 영향력을 갖고 있고 그 영향력의 크기는 유묘 위에 뒤덮는 정도와 상관관계가 있었다. 이것은 피음 혹은 광경쟁이 아마도 중요한 인자임을 암시해 주고 있다.

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INTRODUCTION

Many studies have demonstrated that radiata pine(*Pinus radiata* D. Don) growth and survival are reduced by the presence of competing plant species(Balneaves, 1982, 1987 ; Balneaves and Christie, 1988 ; Balneaves and Henley, 1992 ; Balneaves and Mccord, 1990 ; Brunsden, 1980 ; Cellier and Stephens, 1980 ; Mason, 1992 ; Ray *et al.*, 1989 ; Richardson, 1993 ; Smethurst and Nambiar, 1989). Large growth benefits following removal of competing vegetation are apparent over a wide range of site types and with many different competitor species(Richardson, 1992). Because of this, intensive vegetation management practices with heavy emphasis on herbicide use, are typical in the establishment of radiata pine plantations in New Zealand.

Second year results are presented from a study designed to investigate the effect on radiata pine growth of some of the important New Zealand forest weed species. The purpose was to investigate the nature of the interaction between the seedlings and weeds on a site that is located in one of the largest forestry regions in New Zealand. With the increasing cost of weed control and the pressure against the use of herbicides, it is essential that competition removal operations are applied only to the degree required to give optimal gains, and are targeted against the most damaging species in terms of the impact on crop growth. Information from studies such as this will help to meet these objectives.

MATERIALS AND METHODS

Site

A trial site was selected adjacent to the New Zealand Forest Research Institute Rotorua nursery (latitude 38° S, longitude 176° E). Rotorua has a mean annual rainfall of 1,491mm, a mean annual temperature of 12.7℃, and an annual average raised pan evaporation of 1,186mm(NZMS, 1980). There is a deep, moderately fertile pumice soil at Rotorua(yellow-brown Ngakuru loam), which is well drained and has a high moisture holding capacity.

Experimental design

A complete factorial set of treatments was laid out in a split plot design. Treatment factors were weed type, +/− fertilizer, and +/− irrigation. There were six weed categories(Table 1) plus a weed free control(i.e. a 7×2×2 factorial). Experimental blocks were split into halves, one half being irrigated. Within each irrigated block, fertilizer and competition treatment combinations were completely randomised. Three replications were installed through time, one per year from 1990-1992.

Installation

Tree seedlings were planted in winter(July or August) at a spacing of 1×1m, giving 25 trees per plot(5×5m). Gorse, broom, buddleia, and pampas were established by planting seedlings at 0.5×0.5m spacing in the October following tree planting. At the same time, grass seed was scattered by hand, and herbaceous broadleaves were allowed to emerge and grow in the appropriate plots. Unwanted weeds were periodically killed using a combination of hoeing, hand weeding, spot applications of glyphosate, and the use of haloxyfop to remove grasses from the herbaceous broadleaf plots and clopyralid to remove broadleaves from the grass plots.

Irrigation and fertilizer

The goal of irrigation and fertilizer application was to ensure that moisture and nutrients were non-limiting on these respective treatments. An

Table 1. Weed species competing with radiata pine

Plant Species
Gorse (*Ulex europaeus* L.)
Broom (*Cytisus scoparius* L.)
Buddleia (*Buddleja davidii* Franchet)
Pampas (*Cortaderia selloana* (Schult) Asch. et Graeb.)
Grass : Yorkshire fog (*Holcus lanatus* L.) + Italian ryegrass(*Lolium multiflorum* Lam.)
Herbaceous broadleaves (volunteer species)

Table 2. Fertilizer regime

Timing	Treatment	Rate(kg/ha)
Pre-plant	15% potassic Magphos (0-8-8-6(S)-20(Ca)-5(Mg))	750
Pre-plant	IBDU (Isobutylidenediurea) (32%N)	500
Pre-plant	FTE 36 (trace elements)	20
At planting	Nitrophoska yellow (15-7-5-4(S)-2.4(Mg))	100
Summer (annually)	Nitrophoska blue (12-5-14-1.2(Mg)+TE)	120
Autumn (annually)	Nitrophoska blue (12-5-14-1.2(Mg)+TE)	120
Spring (year 2)	Nitrophoska yellow (15-7-5-4(S)-2.4(Mg))	100

Table 3. Formate of the analysis of variance undertaken on seedling growth data

Sources of variation	Degrees of freedom	Mean square error	F-test
Irrgation (I)	1	MSI	MSI/MSEa
Block (B)	2	MSR	MSR/MSEa
B * I	2	MSEa	
Weed type (W)	6	MSW	MSW/MSEb
Fertilizer (F)	1	MSF	MSF/MSEb
W * F	6	MSWF	MSWF/MSEb
W * I	6	MSWI	MSWI/MSEb
F * I	1	MSFI	MSFI/MSEb
W * F * I	6	MSWFI	MSWFI/MSEb
W * F * I * B	52	MSEb	
TOTAL	83		

automatic overhead irrigation system was installed and the trial was irrigated every night with an amount of water greater than the calculated maximum evaporation. In total, this amounted to approximately 1,000-1,100mm/yr in excess of annual rainfall. To try and achieve a non-limiting nutrient supply, an intensive fertilizer regime was designed(Table 2). All fertilizers were broadcast over the plots so that the nutrients were reasonably accessible to both the trees and the weeds.

Measurements

Using 9 seedlings in the centre of each plot, root collar diameter and tree seedling height were measured at the time of planting and repeated at regular intervals(at least quarterly). Weed height growth was also monitored on eight randomly selected plants. Results are presented using measurements taken at the beginning of the second winter, 21 months after planting.

Data analysis

Seedling growth data taken 21 months after planting were analysed using the standard ANOVA procedure for factorial treatments laid out in a split-plot randomised block design with three replications. The sources of variation and degrees of freedom are summarised in Table 3.

Dependent variables included height, root collar diameter, and seedling stem volume index calculated as $(\pi/4) \times \text{height} \times \text{diameter}^2$. A natural logarithm transformation was used to stabilise the variance where appropriate, and initial seedling size was tested as a covariate in the analysis of crop growth. Seedling height growth was compared to weed height growth to calculate relative height, where relative height=(weed height growth/tree height growth).

Therefore, in any given weed type treatment, if relative height is greater than 1 the weeds are taller than the seedlings. Conversely where relative height is less than 1 the weeds are shorter than the seedlings.

RESULTS

Seedling growth

Seedling stem "volume"(calculated as root collar $\text{diameter}^2 \times \text{height} \times \pi/4$) was significantly influenced by weed type($P<0.0001$). There was no effect of fertilizer application or irrigation, but there was a significant interaction between weed type and fertilizer application($P<0.0001$). Seedling growing in the weed free controls and those growing with gorse had the greatest stem volume, while those growing with buddleia or pampas had the smallest volume(63-64% volume reduction, respectively)(Fig. 1). Seedling growth of radiata pine growing with grasses, broom or herbaceous broadleaves was reduced to intermediate levels(28-37% volume reduction).

Diameter growth trends were similar to those for volume. There were also statistically significant differences in radiata pine height growth according to weed type($P=0.006$)(Fig. 2). Differences due to weed type were fairly small with only the seedlings growing with buddleia and herbaceous broadleaves being significantly smaller than the controls. Height growth was not a good indicator of the effect of competition when compared to seedling stem volume(or basal area)(Fig. 3). Seedling stem volume is calculated from measurements of height and diameter. Given the small changes in *P. radiata* height, the effect of treatments on seedling volume is largely due to changes in stem diameter. Mortality was not a significant factor.

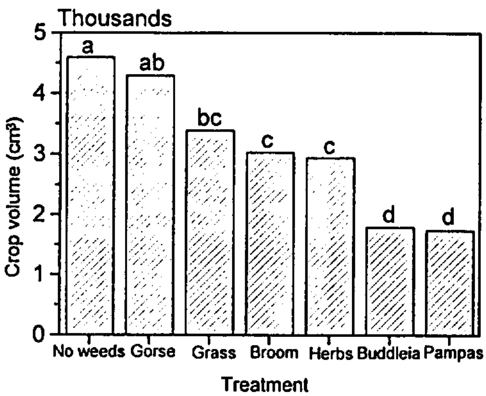

Fig. 1. Effect of weed type on radiata pine stem volume 21 months after planting. Bars in a graph with the same letter are not significantly different at the 5% level according to Fisher's Protected LSD test.

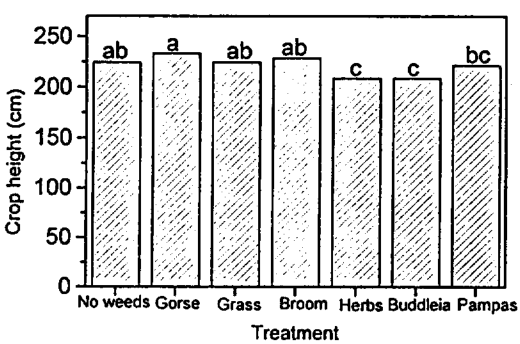

Fig. 2. Effect of weed type on radiata pine height growth. Bars in a graph with the same letter are not significantly different at the 5% level according to Fisher's Protected LSD test.

Weed growth trends

The trends in seedling stem volume growth continued to follow patterns observed during the

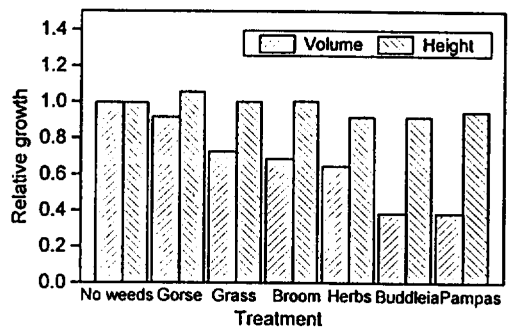

Fig. 3. Volume and height growth of radiata pine growing on weed own or with a variety of weed species, 21 months after planting at Rotorua.

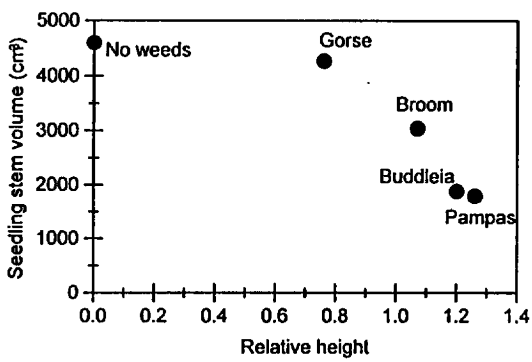

Fig. 4. Seedlings stem volume as a function of relative height, the ratio of weed height/ seedling height.

first year of growth(Richardson *et al.*, 1993). Fig. 4 shows the relationship between relative height and seedling stem volume for the tall-growing weed types and the control. Buddleia and pampas outgrew the seedlings(relative height greater than 1) and severely suppressed seedlings growth. Broom also showed tremendous height growth on some plots, and after 21 months it clearly has the capacity to overtop seedlings. However, the full effect of this weed has not been demonstrated in this trial because of a high degree of mortality on some plots, following infection by *Pleiochaeta setosa* (Kirchn.) Hughes. The negligible effect of gorse on radiata pine growth was almost certainly due to the slow growth of gorse(relative height less than 1).

Mechanisms of competition

Irrigation had no significant effect on seedling and weed growth, and there was no significant interaction between irrigation and competition treatment. This implies that water was not a growth-limiting factor on this site, and measurements of plant water stress and stomatal conductance supported this hypothesis(Richardson *et al.*, 1993). Even though measurements were taken during dry periods in mid-late summer, moisture stress was never particularly severe.

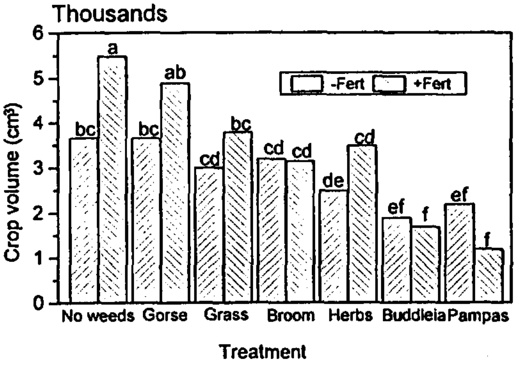

Fig. 5. The effect of fertilizer application and weed type on radiata pine stem volume growth, 21 months after planting. Bars in a graph with the same letter are not significantly different at the 5% level according to Fisher's Protected LSD test.

There was no significant main effect of the fertilizer treatment on stem volume growth($P=0.11$), but there was a significant interaction between fertilizer application and weed type($P=0.046$)(Fig. 5). Fertilizer significantly increased seedling growth on the weed-free plots, demonstrating that nutrient supply is limiting growth on this site. However, there were no other statistically significant differences between fertilized and unfertilized plots across the various weed type treatments. If the objective of the fertilizer treatment had been met(that is to ensure an unlimited supply of nutrients), the fact that the seedlings did not significantly respond positively to fertilizer addition implies that competition for nutrients by the weed species was not limiting growth. This hypothesis will be tested by foliar nutrient sampling in year 3.

DISCUSSION

Radiata pine seedling growth was reduced when it was grown in association with a range of competitors. In the first year after planting, herbaceous broadleaves had the greatest impact on radiata pine(Richardson *et al.*, 1993). However, as soon as the height of the tall-growing competitor species(broom, pampas, buddleia) reached approximately the same as that of the pines, seedling growth rates were rapidly reduced. Thus, these species had an increasingly severe effect on seedling growth. During the second year at Rotorua, both buddleia and pampas became more important than herbaceous broadleaves in terms of their effects on pine stem seedling volume. The potential effects of broom competition were probably underestimated in this study because of growth reductions and mortality resulting from infection by *Pinus setosa*. Gorse, grew relatively slowly and, probably because of this, had a minimal effect on crop growth.

It is known that stem diameter growth of radiata pine seedling is very sensitive to competitor induced water stress(Bloomsma and Hunter, 1990 ; Nambiar, 1984 ; Nambiar and Zed, 1980 ; Sands and Nambiar, 1984). In areas such as the Central North Island of New Zealand, where there is high, evenly distributed annual rainfall and the pumice soil has a high storage capacity, it might be expected that soil water deficits should not limit radiata pine growth in a typical year(Whitehead and Kelliher, 1991). However, it has been hypothesised that even in this situation, soil water deficits may develop near the soil surface resulting in stress to newly planted radiata pine seedlings with roots restricted to the upper soil layers(Richardson, 1993). Evidence from this trial does not support this hypothesis.

It is well known that interspecific competition can limit the ability of the crop to respond to otherwise favourable treatments, such as fertilizer application(Clinton and Mead, 1990 ; Flinn *et al.*, 1979 ; Flinn and Aeberli, 1982 ; Squire *et al.*, 1979 ; Waring, 1972 ; West, 1984 ; Woods, 1976). In these trials, the objective was to supply the fertilized plots with excess nutrients so that competition for nutrients was not a factor. Although there was no main effect of fertilizer application there was a significant interaction between competitor treatment and fertilizer. Fertilizer application to weed free plots gave a 48% volume increase, demonstrating that nutrient availability is limiting growth on this site.

The results suggest that the large growth effects of some weeds on seedling growth were mediated by a factor of factors other than competition for water and nutrients. Although direct measurements of light availability have not been presented, the relative height index calculated for the taller weed types(broom, buddleia, gorse, and pampas) is indicative of the degree of shading experienced by seedlings growing with the various weed types. A clear relationship between relative height and seedling growth was found (Fig. 4) where seedling stem volume rapidly decreased as relative height increased above about 0.8(that is when the weeds exceeded about 80% tree height). This strongly implies that the effect of the tall-growing weeds on seedling growth is mediated by competition for light. At age 2, the grass and herbaceous broadleaf weed types are clearly not competing with the seedlings for light. Although the effect of these weed types on seedling growth cannot be conclusively attributed to competition for light, observations made in year 1 clearly showed that for long periods the height of the grasses and herbaceous broadleaves exceeded that of the tree.

In summary, the growth trends observed during year one continued. Tall, fast-growing species that overtopped the trees(broom, buddleia, pampas) had the greatest effect on seedling growth implying that shading or competition for light is an important factor. As the degree of overtopping increased, tree size decreased. Significant growth losses were also attributable to grasses and herbaceous broadleaves. The mechanism of interaction for these weed types was not so clear, but water and nutrient availability was almost certainly not a factor. It is possible that shading of the trees by the grass and herbaceous broadleaves in year 1 may have been important. In the presence of weeds, there was no benefit from fertiliser application. Height growth was not as good an indicator of competition intensity as stem volume.

The results suggest that on moist, moderately fertile Central North Island sites weed control operations should be targeted to ensure that weeds do not overtop *P. radiata*. Tall, fast-growing species should be given a higher priority than herbaceous species(broadleaves or grasses) although growth benefits are also apparent from controlling herbaceous weed types.

REFERENCES

1. Balneaves, J.M. 1982. Grass control for radiata pine establishment on droughty sites. NZ J. For. 27 : 259-276.
2. Balneaves, J.M. 1987. Growth responses of radiata pine to area of herbaceous weed control. Proceedings of the 40th NZ Weed and Pest Control Conf. : 49-51.
3. Balneaves, J.M. and M. Christie. 1988. Longterm growth response of radiata pine to herbaceous weed control at establishment. NZ For. 33 : 24-25.
4. Balneaves, J.M. and D. Henley. 1992. Senven year growth response of radiata pine to

area of herbaceous seed control. Proceedings NZ Plant Prot. Soc. 45 : 262-263.

5. Balneaves, J.M. and A.R. Mccord. 1990. Gorse control : a trying experience at Ashley Forest. Proceedings of International Conference, Rotorua, New Zealand.
6. Bloomsma, D.B. and I.R. Hunter. 1990. Effects of water, nutrients and their interactions on tree growth, and plantation forest management practices in Australasia : A review. For. Ecol. and Man. 30 : 455-476.
7. Brunsden, G.J. 1980. Growth responses and stability of radiata pine chemical weed control and ripping in pumice pasture land. Proceedings 33rd New Zealand Weed and Pest Control Conference : 181-185.
8. Caldwell, T.M., E.I. Sucoff and R.K. Dixon. 1995. Grass interference limits resource availability and reduces growth of juvenile red pine in the field. New Forests 10(1) : 1-15.
9. Cellier, K.M. and C.G. Stephens. 1980. Effect of fertilizer and weed control on the early growth of *Pinus radiata* D. Don in Southern Australia. Aus. For. Res. 10 : 141-153.
10. Clinton, P.W. and D.J. Mead. 1990. Competition between pine and pasture : an agroforestry study. pp.145-154 in editors "Timber Production in land Management". AFDI Biennial Conference, 5-8 October. 1990. Bunbury, Western Australia. Dept. of Conser. and Land Management.
11. Flinn, D.W. and B.C. Aeberli. 1982. Establishment techniques for radiata pine on poorly drained soils deficient in phosphorus. Aus. For. 45 : 164-173.
12. Flinn, D.W., P. Hopmans, I. Moller and K. Tregonning. 1979. Response of radiata pine to fertilizers containing N and P applied at planting. Aus. For. 42 : 125-131.
13. Mason, E.G. 1992. Decision Support Systems for establishing radiata pine plantations in the Central North Island of New Zealand. Ph. D. thesis University of Canterbury, Christchurch.
14. Nambiar, E.K.S. 1984. Significance of first-order lateral-roots on the growth of young radiata pine under environmental stress. Aus. For. Res. 14 : 187-199.
15. Nambiar, E.K.S. and P.G. Zed. 1980. Influence of weeds on the water potential, nutrient content and growth of young radiata pine. Aus. For. Res. 10 : 279-288.
16. NZMS. 1981. Summaries of climatological observations to 1980. NZ Meteorological Service Miscellaneous Pulication 177.
17. Ray, J., N. Davenhill and A. Vanner. 1989. Cost-effective herbicides or Yorkshire fog control. Proceedings of the 42nd New Zealand Weed and Pest Control Conf. pp.124-126.
18. Richardson, B. 1992. The effects of weeds on tree growth. For. Res. Institute Bulletin 156.
19. Richardson, B. 1993. Vegetation management practices in Australia and New Zealand. Can J. of For. Res. 23 : 1989-2005.
20. Richardson, B., *et al.*, 1993. Interspecific competition between *Pinus radiata* and some common weed species first years results. NZ J. For. Sci. 23 : 179-193.
21. Sands, R. and E.K.S. Nambiar. 1984. Water relations of *Pinus radiata* in competition with weeds. Can. J. For. Res. 14 : 233-237.
22. Smethurst, P.J. and E.K.S. Nambiar. 1989. Role of weeds in the management of nitrogen in a young *Pinus radiata* plantion. New Forests 3 : 203-224.
23. Squire, R.O. 1977. Interacting effects of grass compitition, fertilizing and cultivation on the early growth of *Pinus radiata* D. Don. Aus. For. Res. 7 : 247-252.
24. Squire, R.O., D.W. Flinn and P.W. Farrell. 1979. Productivity of first and second rotation stands of radiata pine on sandy soils. I. Site factors affecting early growth. Aus. For. 42 : 226-235.
25. Waring, H.D. 1972. *Pinus radiata* and the nitrogen-phosphorus interaction. pp.144-161 in R. Boardman(Ed.), Proc. Australian Forest Tree Nutrition Conf., 6-17 September 1971, Canberra, Australia. Aus. For. and Timber Bureau, Canberra.

26. West, G.G. 1984. Establishment requirements of *Pinus radiata* cuttings and seedlings compared. NZ J. For. Sci. 14 : 41-52.
27. Whitehead, D. and F.M. Kelliher. 1991. Modeling the water balance of a small *Pinus radiata* catchment. Tree Physiology 19 : 18-34.
28. Woods, R.V. 1976. Early silviculture for upgrading productivity on marginal *Pinus radiata* sites in the south-eastern region of South Aust. Woods For. Dept., Adelaide, Bull., 24 : 90.