GROWTH EFFECTS OF LARGE GAPS IN *PINUS RADIATA* PLANTATIONS

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(Received for publication 16 January 1989; revision 22 August 1989)

ABSTRACT

Effects of circular gaps exceeding 100 m^2 in area, on height, diameter, form, and branch size of the gap-edge and non-edge trees in *Pinus radiata* D. Don plantations were examined at Myrtleford in Victoria, south-eastern Australia. There was little difference between the trees around gaps 6.1m in radius (area 117 m^2) and trees further inside the stand. For gaps 9.1 m or greater in radius (area >263 m^2), distance from the gap centre had no effect on tree height but, up to a distance of three trees from the gap edge, was negatively related to diameter and volume. Trees located on the sunnier side of gaps had greater diameter and volume than trees on the more shaded side. Edge trees had larger diameter, volume, and more branches with diameter above 2.5 cm than trees inside the stands.

The results indicate that for this site and for the particular local market, pruning of edge trees appears necessary to maintain log quality where the gap area approaches or exceeds 250 m^2.

Keywords: gap; edge tree; seedling replacement; *Pinus radiata*

INTRODUCTION

Mortality of planted seedlings is a recurrent problem in establishment of *Pinus radiata* plantations in Victoria, Australia. Severe (>25%) seedling mortality results in gaps in plantations and reduces potential for early commercial thinnings. In addition, average log quality may be lowered owing to a tendency for trees around gaps to develop thicker branches. Renewal planting is labour intensive and costly, and because of initial losses and slower growth, may contribute little to the final production of merchantable volume, so replacement of seedlings may be unnecessary. Chavasse *et al.* (1981) studied the problem of *P. radiata* seedling replacement and concluded that, for gap sizes up to 100 m^2, replanting is of little use, having no effect on the height and diameter at breast height (dbh) of the original crop and only a marginal effect on total branch area.

For outer rows of *P. radiata* stands, and where large gaps occur within a stand, the edge effect disappears two or three rows inwards from the stand boundary (van Laar 1978). Van der Sijde (1975) found that, in a comparison of trials in different-aged stands, tree diameter growth in the edge row was occasionally greater than that of the interior rows, but the row closest to the edge trees had similar growth to that of trees further into the stand. Edge trees are more exposed to wind forces, eventually develop larger basal diameter, and have wood with thicker cell walls than the trees which are prevented from swaying (Swanson 1975). Excessive limb development of some edge trees is also a disadvantage. Generally, in Victoria, it is conceded that replanting may be warranted where over-all losses are greater than 25% and grouped, and where the initial planting espacement is wider than 2.4 × 2.4 m.

The aim of this study was to examine the effects of gap sizes of over 100 m² on height, diameter, form, and branchiness of the edge and non-edge trees.

METHODS

The study was located at Running Creek Plantation, near Myrtleford, north-eastern Victoria. The area was selected in 1970 on the basis of uniformity of aspect, slope, drainage, and vegetation. Plots were established with the aid of local plans, aerial photographs, and detailed field reconnaissance. On each of three sites (replicates), four treatments, each represented by a circular gap of a specific size, were applied (Table 1).

TABLE 1–Plot and gap sizes used in the trial

Treatment	Plot		Gap	
	Dimensions (m)*	Area (m^2)	Radius (m)*	Area (m^2)
1	30.5 × 30.5	929	6.1	117
2	36.6 × 36.6	1338	9.1	263
3	45.7 × 45.7	2090	13.7	591
4	54.9 × 54.9	3010	18.3	1051

* The original measurements were in Imperial units. The sides of the plots were 100, 120, 150, and 180 feet long, and the corresponding gap radii were 20, 30, 45, and 60 feet.

Treatments were assigned at random and, because of the difficulty of fitting together various-sized square plots, the replicate outlines varied. Within each plot, the prescribed gap was located centrally, with the balance of the plot being planted with 1-year-old *P. radiata* seedlings at approximately 2.4 × 2.4 m espacement (Fig. 1). The actual gap area was a little larger than the prescribed circle, as most trees around the edge of the gap did not fall directly on the circumference. For each plot, windrow locations were mapped and slope, direction of magnetic north, and aspect were recorded.

Each tree was numbered and the following data were collected: diameter at breast height over bark (dbhob), form (straight, bent, or forked), diameter of the largest branch below 2 m above ground level, and volume (calculated using the tariff equation produced by the Victorian Department of Conservation, Forests and Lands for the region in which the trial took place).

An edge tree was defined as a tree whose branches contributed substantially to forming the gap boundary (*see* Fig. 1). The additional measurements recorded for edge trees were height, and diameter over bark (dob) of all branches less than 2 m above ground-level with dob greater than 2.5 cm (knots larger than 2.5 cm were regarded locally as making the logs unsuitable for veneer production). Measurements were taken from all edge trees facing gaps of 9.1 m radius or less, and from each alternate tree facing larger gaps.

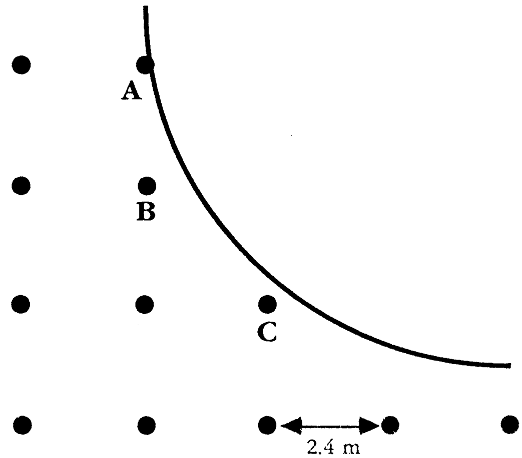

FIG. 1 — Gap boundary in relation to planted seedlings. At the time of measurement, tree B would be defined as an edge tree provided the branches of trees A and C did not virtually close the gap boundary.

Eight equidistant radii were established from the centre of each gap. The first radius followed planting row direction, and the subsequent seven were determined by the compass bearing. Along each radius, the first three trees were located and their height, distance from the gap centre, and dob of all branches (as defined for edge trees) were recorded.

Measurements were taken in 1981, about 3 to 4 years after canopy closure of the 11-year-old stands. A small number of trees found on former windrow sites were excluded from the analysis of the results, since such trees usually grow faster and are visually different from those on non-windrow sites.

The effect of sunlight on growth of edge trees was evaluated by dividing each gap into two equal parts by a line running north-east to south-west. The trees to the north or west of the line were defined to be in a "shaded" position and those to the south or east in a "sunny" position.

Analysis of variance was used to test the effects of treatments on growth of *P. radiata.* For factors with more than two levels, comparisons between pairs of means were made using the Student-Newman-Keuls procedure (Sokal & Rohlf 1969). The effect of treatments on the form of trees was analysed using log-linear models. For each gap size, data were pooled, and the relationships between tree growth parameters and distance from the gap centre were examined by fitting linear regression equations and testing their significance. In the reporting of results in the following section, the term "significant" means statistically significant at the 5% level.

RESULTS

The effects of the treatments on the various growth parameters, and the significance levels associated with the effects, are summarised in Table 2.

TABLE 2–Effects of site, gap size, tree location, and shading on tree height, dbhob, volume, and number of branches with dob >2.5 cm, of 11-year-old trees. The figures quoted are means. The letter *a* links means which are not significantly different at the 0.05 level, using the Student-Newman-Keuls procedure.

Parameter					p value in the ANOVA
	Site				
	1	2	3		
Height (m)	16.6	16.9	16.0		0.233
Diameter (cm)	19.4*a*	19.7*a*	18.7		0.037
Volume (m^3)	0.218	0.237	0.207		0.072
No. branches >2.5 cm dob	2.41*a*	3.58	2.54*a*		0.036
	Gap radius (m)				
	6.1	9.1	13.7	18.3	
Height (m)	16.5	16.2	17.0	16.4	0.561
Diameter (cm)	17.8	19.6*a*	20.2*a*	19.5*a*	0.003
Volume (m^3)	0.184	0.227*a*	0.245*a*	0.226*a*	0.012
No. branches >2.5 cm dob	1.59	2.76*a*	3.71*a*	3.32*a*	0.011
	Tree location				
	Edge		Non-edge		
Height (m)	16.5		16.6		0.665
Diameter (cm)	21.1		17.4		<0.001
Volume (m^3)	0.242		0.198		0.008
No. branches >2.5 cm dob	3.32		2.37		0.001
	Location within the gap				
	"Sunny" side		"Shaded" side		
Height (m)	16.7		16.2		0.323
Diameter (cm)	22.0		20.0		0.013
Volume (m^3)	0.263		0.224		0.044
No. branches >2.5 cm dob	3.53		3.11		0.418

Plot location did not have a significant effect on height or volume of the trees. However, the mean dbhob of trees on Site 3 was significantly less than on the other sites, and at Site 2 trees had significantly more branches >2.5 cm in diameter than on the other sites.

Gap size significantly influenced all the growth parameters measured except height. Where gap size was 6.1 m, trees had significantly smaller dbhob, less volume, and fewer large branches than the trees on plots with larger gap radii.

Height was not affected by tree location in relation to the gap. However, edge trees had significantly greater dbhob (3.7 cm on average), more volume (0.044 m^3 on average) and more large branches (on average, 0.95 within the recorded section of the bole) than the non-edge trees. In addition, edge trees on the "sunny" side of the gap had significantly greater dbhob (on average about 2 cm) and greater volume (on average 0.039 m^3) than the trees on the "shaded" side.

The effects of site, gap size, and tree location on the form of the trees (Table 3) were not significant at the 0.05 level. Although some of the differences between means appear substantial, there was considerable variation in straightness, malformation, and forking within the stands. The results certainly suggest that gap size is irrelevant to tree form.

TABLE 3–Effects of site, gap size, and tree location on the form of 11-year-old trees. The figures are means of the percentage of trees in each form category. The percentages do not sum to 100 because a small proportion of trees did not fit any of the categories. None of the effects are significant at p=0.05.

Form	Site			Gap radius (m)				Tree location	
	1	2	3	6.1	9.1	13.7	18.3	Edge	Non-edge
Straight	60.6	65.3	79.4	71.1	66.4	65.6	70.7	70.5	66.4
Bent	23.7	15.3	11.5	14.6	19.9	14.1	18.7	17.4	16.3
Forked	14.1	14.6	8.0	14.0	9.4	17.2	8.3	9.8	14.6

The relationships between the distance from the gap centre and tree growth parameters are shown in Table 4. It is evident that for the smallest gap (radius 6.1 m, area 117 m^2) height, dbhob, volume, and number of branches with dob >2.5 cm of the first three trees from the gap edge did not depend on the distance from the gap centre. Consequently, it is likely that gaps smaller than 100 m^2 have at most a marginal effect on these growth parameters.

TABLE 4–Regressions of height, diameter, volume, and number of branches with dob >2.5 cm (Y) on the distance from the gap centre (X)

Parameter	Gap radius (m)	Regression equation	r^2	p value
Height (m)	6.1	Y = –0.016X + 16.7	0.00	0.877
	9.1	Y = –0.051X + 16.8	0.00	0.727
	13.7	Y = –0.167X + 19.6	0.04	0.106
	18.3	Y = 0.090X + 14.7	0.01	0.267
Diameter (cm)	6.1	Y = –0.199X + 19.9	0.01	0.358
	9.1	Y = –0.889X + 30.6	0.10	0.001
	13.7	Y = –0.809X + 34.2	0.15	<0.001
	18.3	Y = –0.484X + 30.2	0.06	0.013
Volume (m^3)	6.1	Y = –0.0024X + 0.207	0.00	0.547
	9.1	Y = –0.0162X + 0.417	0.08	0.005
	13.7	Y = –0.0208X + 0.588	0.16	<0.001
	18.3	Y = –0.0098X + 0.426	0.05	0.029
No. branches >2.5 cm dob	6.1	Y = –0.028X + 1.9	0.00	0.739
	9.1	Y = –0.376X + 7.1	0.06	0.010
	13.7	Y = –0.186X + 6.8	0.02	0.223
	18.3	Y = –0.343X + 10.3	0.08	0.007

An assessment of larger gaps (radius 9.1, 13.7, and 18.3 m) found that both dbhob and volume were significantly related to the distance from the gap centre. Tree dbhob decreased by an average of about 0.5 cm to 0.9 cm per metre from the gap centre and tree volume decreased by an average of about 0.01 m^3 to 0.02 m^3 for every metre distant from the gap centre. The number of branches with dob > 2.5 cm also tended to decrease with increased distance from the gap centre.

DISCUSSION

The uniformity of height of the trees (16–17 m), irrespective of treatment, indicated that the study plots were established on a uniform area of land, expected to carry 27- to 30-m-high *P. radiata* at age 20. The results of this study apply only to sites with a similar tree growth potential.

The study supports the findings by Chavasse *et al.* (1981) that for gaps up to 6 m in radius (about 100 m^2) there is little need for renewal planting, as the remaining trees around such gaps will be similar in size to the trees within the stand. Gap radii of 9.1 m (area 263 m^2) or more result in edge trees with larger average diameter (dbhob), volume, and number of large branches than trees surrounding smaller gaps. This suggests that trees associated with larger gaps will develop larger and more numerous branches which, in the longer term, will reduce wood quality. It is recommended therefore, that in this particular area, gaps 9 m or more in radius should, if possible, be avoided. This could happen by improved site selection and preparation practices, better planting techniques, and the use of planting stock capable of survival in adverse conditions. Alternatively, edge trees and stands with very low stocking should be subjected to regular pruning.

Trends which were not significant in van der Sijde's (1975) study were found to be real in our trial. The relationship between tree dbhob and the distance from the gap centre was highly significant for all treatments in which gap radius was at least 9.1 m. Thus, when establishing research plots involving measurements of tree diameter, care should be taken that the plots do not abutt gaps larger than about 9 m in radius, or the validity of the results may be affected.

Trees on the "sunny" side of the gaps had larger diameter and greater volume than those on the "shaded" side. This suggests that, provided the trees remain wind stable, infrequent but heavy thinnings, allowing lateral light penetration into the crowns, would contribute to a better growth response and lower height:diameter ratio of the retained trees than that which could be expected after light and frequent thinning of the same stands. Achieving a relatively low height:diameter (slenderness) ratio (< 80) of retained trees is desirable in stands liable to damage by wind and snow (Cremer *et al.* 1983).

ACKNOWLEDGMENTS

Substantial contribution towards the study by Dr J.E. Opie, formerly Research Officer with the Forests Commission Victoria, who was actively involved in co-ordinating and planning the initial stages of the project, is gratefully ackowledged. Thanks are also due to Mr L.A. Stephens and Mr R.S. Beasley, Technical Assistants during the study, and to Mr A. Sumner, for their assistance in field work.

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