PARTIAL DEFOLIATION AND WOOD PROPERTIES OF 5-YEAR-OLD *PINUS RADIATA*

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ABSTRACT

The effects of removing foliage of specific ages in 5-year-old trees of **Pinus radiata** D. Don (a) in spring, and (b) at different times during the growing season, were measured in terms of the response through the following 2 years in ring width, percentage latewood, wood density, and tracheid length.

Removal of 1-year-old needles was nearly as severe a treatment as defoliation of the current year's needles, both of which resulted in a very significant reduction in diameter growth, accompanied by an increase in wood density and tracheid length at breast height. The timing of the treatments during the growing season had no detectable effect on density or tracheid length in the wood samples examined.

INTRODUCTION

The annual growth of trees involves both longitudinal and radial extension of the stem, branch and root axes through the division of meristematic zones. Cell formation in the vascular cambium is closely regulated by the physiological activity of the tree crown, particularly by the production of growth substances and translocatable assimilates (Larson, 1969). Normally, mature conifers carry more foliage than is necessary to sustain growth, and large losses can be tolerated before death occurs. Pruning of live branches is a very widespread forestry practice and substantial removals do not necessarily affect tree vigour (Luckhoff, 1949). As a general guideline, 30% has often been quoted as the amount by which the crown can be reduced without undue effect on height growth or volume production (Mar : Møller, 1960). For several years after tree pruning, the annual rings often exhibit an increase in percentage of latewood and in wood density (Gerischer and de Villiers, 1963; Fielding, 1968; Cown, 1973).

Forest crops are often subject to defoliation by insects, diseases, fire, and adverse weather conditions, and the effects on growth may be quite different from that observed after a pruning operation. Many defoliating agents preferentially remove needles of specific ages throughout portions of the crown (Kozlowski, 1971).

In studies involving defoliation, partial masking of crowns, and $^{14}CO_2$ labelling, it has been shown that the contribution of foliage to stem growth depends on the age and location of the needles concerned (Larson, 1964; Gordon and Larson, 1968; Rangnekar *et al.*, 1969; Zimmerman and Brown, 1971). Thus different types of defoliation might be expected to have different effects on tree growth.

A recent paper by Rook and Whyte (1976) described height growth and volume increment responses in 5-year-old *Pinus radiata* D. Don trees which had undergone a number of defoliation treatments. Needles of specific ages had been systematically removed from the crowns and tree growth monitored over the next 2 years. Partial defoliations did not result in mortality but all treatments caused a reduction in vigour, the most severe with removal of current year's foliage, the least severe with removal of 3- to 4-year-old foliage.

EXPERIMENT 1 (SPRING DEFOLIATION)

Materials and Methods

After termination of the experiment described by Rook and Whyte (1976), 5-cm thick discs were obtained from the stems in some of the treatments and used for analyses of the intrinsic wood properties. Of the nine treatments applied in early September 1966, four were studied:—

1 Control — no defoliation;
2 Removal of current year's needles;
3 Removal of 1-year-old needles;
4 Removal of 2- and 3-year-old needles.

The trees were harvested in 1968 after completion of seasonal radial growth, and butt and breast-height discs were removed from three to five stems per treatment. Measurements on the samples included (a) ring width, (b) percentage latewood, (c) wood density, and (d) tracheid length.

The sanded surfaces of the dried discs were used for radial increment and latewood assessments along four equally spaced radii for each of the rings 1965-66 to 1967-68. Latewood width was determined by the blunt probe method (Harris, 1965) and expressed as a percentage of the total ring. Small wood blocks (10 mm tangentially and longitudinally) were removed from each of the growth layers along the shortest radius, to avoid any possible compression wood, and used for density determination by the method of maximum moisture content (Smith, 1954). Whole-ring samples were macerated in a mixture of 1 : 1 glacial acetic acid and hydrogen peroxide, and 50 complete tracheids were measured according to the scheme devised by Harris (1966).

Results

The results for both butt and breast height discs have been reported in detail elsewhere (Cown, 1971), and responses of the two stem levels were so similar that only a summary of the breast height ones will be given here (Fig. 1). Results are expressed as percentages of the control tree values.

In the first year the three defoliation treatments all showed a decrease in growth of up to 25%, but in the second year specific treatment effects were more distinct. Treatment 2 (removal of current needles in 1966) was the most severe, with radial growth in 1967-68 only about 20% of the control; treatment 3 showed a loss of about 45% and treatment 4 (removal of 2- and 3-year-old needles) about 20%. These results agree closely with the basal area data given by Rook and Whyte (1976).

In the year after treatment the growth reductions were not associated with significant changes in the proportions of earlywood and latewood, but in the succeeding year

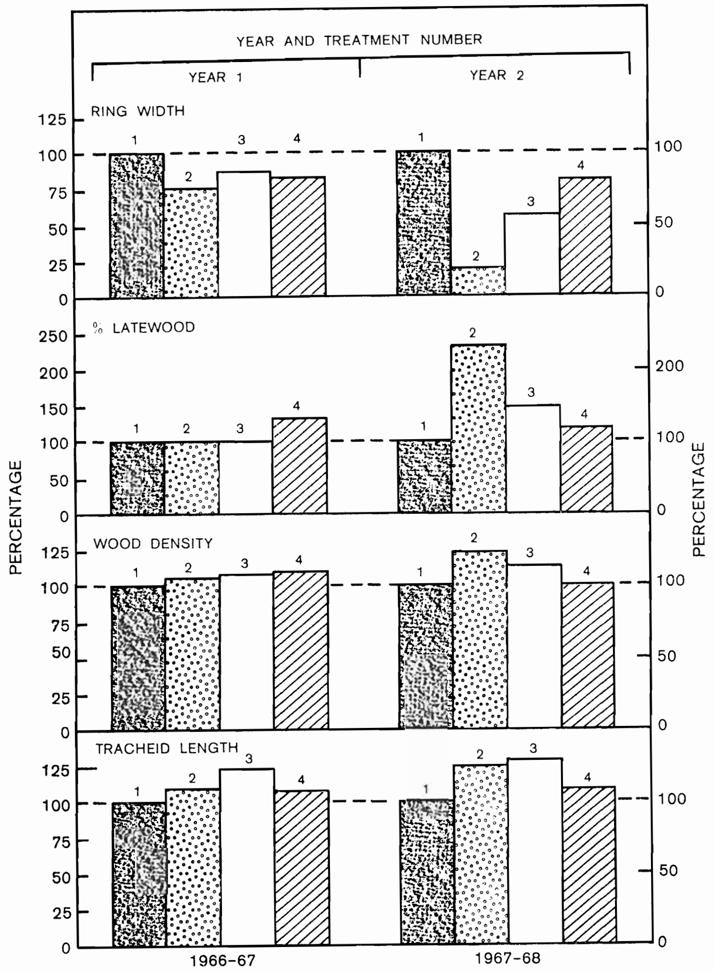

FIG. 1—Effects of defoliation treatments on selected wood properties (expressed as a percentage of the control tree values).

earlywood production in the most severe treatments (2 and 3) was affected to a much greater degree than latewood. These effects are seen in the percentage latewood and the wood density results where it is apparent that reduced growth and higher latewood percentage are associated with increased density. Treatment 2 showed a breast-height density 22% greater than the control for the 1967-68 growth period, an increase much in excess of that normally reported as a response to silvicultural treatment (Cown, 1974).

The tracheid length data showed that stems in treatments 2 and 3 tended to produce successively longer cells relative to the controls throughout the observation period. The greatest change seemed to occur when the 1-year-old needles were missing, i.e., in treatment 3 during 1966-67 and treatment 2 during 1967-68.

In general, the responses in the butt discs were similar to those in the breast height samples but of lower magnitude.

EXPERIMENT 2 (DEFOLIATION DURING THE GROWING SEASON)

Materials and Methods

The effect of timing of defoliation was examined in a further series of eight treatments:

Treatment Class	Defoliation date
Control — no defoliation	
A — removal of current year's needles and continued removal of all new needles	(1) September 1966
	(2) December 1966
	(3) March 1967
	(4) June 1967
B — removal of 1-year-old and older needles	(2) December 1966
	(3) March 1967
	(4) June 1967

Butt discs only were available from these treatments, and these were treated in a manner identical to that employed in Experiment 1. However, since the defoliations took place during 1966-67 and were not repeated in 1967-68, the results reflect the influence of a single treatment only in the period 1966-68.

Results

All treatment means were again calculated as percentages of the control tree values in each year, and thus allowance was made for the rapidly changing wood properties in successive rings near the pith. Table 1 is a summary of a more complete analysis given elsewhere (Cown, 1972).

As expected, trees defoliated early in the growing season exhibited a greater growth depression than those stripped later. Little difference was apparent between the March and June treatments, which showed an 11-15% reduction in ring width for 1966-67. In year 2 (1967-68) the A series (current year's needles removed in 1966-67) showed a very much greater decrease in radial growth than the B series.

TABLE 1—Treatment responses as a percentage of the control tree values

Wood Property	Treatment class	1966-67 Defoliation date Sept (1)	Dec (2)	Mar (3)	June (4)	1967-68 (1)	(2)	(3)	(4)
Ring width	A	54	68	86	87	16	22	20	15
	B	51*	75	85	89	68*	93	80	91
% Latewood	A	107	114	56	94	348	227	406	395
	B	150*	100	100	84	105*	135	112	84
Wood density	A	94	95	91	93	110	113	114	107
	B	101*	95	98	97	103*	97	100	99
Tracheid length	A	102	101	99	100	105	102	101	100
	B	105*	95	108	97	112*	94	107	99

* Removal of 1-year-old needles only (from Experiment 1 butt discs)

For the other wood properties measured, the timing of treatments had surprisingly little effect during the year of defoliation, and in fact no consistent trend was apparent. As in Experiment 1, the greatest responses to treatments occurred in the second year, and again loss of new needles was shown to have a drastic effect on radial growth and a greater influence on wood density. Such treatments produced very narrow growth rings with density an average of 11% higher than the controls. Tracheid length remained little affected in these butt discs but it is likely (based on Experiment 1) that a somewhat greater response would be observed at breast height.

DISCUSSION AND CONCLUSIONS

Before discussing the implications of the results, several limitations of the experiments should be pointed out.

It is very likely that the normal patterns of assimilate distribution within the crowns would have been disrupted by artificial defoliation and the remaining needles compelled to compensate for the deficits. Thus the observations on the role of different ages of foliage, while indicating the possible effects of pathogenic defoliations, may not reflect their contributions to growth in a complete crown. The physical removal of portions of the crowns could also have had a wounding effect resulting in a disruption in the balance of growth substances and abnormal cambial activity. Tree age imposes a limitation on extrapolation to older crops since the young material used had disproportionately large amounts of the younger foliage classes (Rook and Whyte, 1976).

It is clear from the results that all of the spring defoliation treatments resulted in significant reductions in diameter growth in the following 2 years. Only the removal of the current year's and 1-year-old foliage had a significant effect on height increment (Rook and Whyte, *op. cit.*). With the wood characteristics discussed above, removal of the 2- and 3-year-old needles had the least effect, but even this resulted in a 15-20% reduction in growth and smaller changes in density and tracheid length.

Previous studies have shown that photosynthetic efficiency increases to a peak at new needle maturity then decreases with age (Craighead, 1940; Linzon, 1958; O'Neil, 1962; Larson, 1964). The immediate effect of removing the current foliage in spring (Treatment 2) would be to make a greater amount of assimilate available for cambial growth, but later in the season the deficit of foliage would result in less growth than in the control trees. In the year after defoliation, most available food in the early part of the growing season might be used to support the production of new needles rather than earlywood cells, and this could account for the large increase in latewood percentage in the 1967-68 ring. Such an alteration in percentage latewood was also noted by Polge and Garros (1971) for 9 years after defoliations of 10-year-old *Pinus pinaster* Ait.

The effect of removing 1-year-old needles is probably a predominantly nutritional one since they normally contribute most to the development of the current year's needles (Rangnekar *et al., op. cit.*). This would place a greater demand for assimilates on the older needles which normally tend to export photosynthates basipetally, so that new needle development would take place at the expense of radial growth. With a large reduction in the total amount of assimilates produced, it may not be possible for the trees to lay down adequate food reserves for the next year's growth. Thus in the second year after defoliation the trees would have to survive initially with reduced or absent carbohydrate reserves to contribute to new needle maturation. This could explain the lack of obvious signs of recovery in radial growth in the treatment 3 trees in 1967-68.

The 2- and 3-year-old needles would tend to contribute more to stem growth than to new needle development and their removal would be expected to result in a decrease in radial increment at least in the first year after treatment. This is shown in Fig. 1 but it is surprising that there is no indication of a corresponding increase in 1967-68 when the trees had a more complete complement of foliage. Thus it would seem that some other effect is being carried through and preventing the trees from recovering according to their full potential, e.g., the wounding mentioned earlier.

The increases in tracheid length observed after defoliation may be interpreted broadly as a result of both the reduction in growth rate and the increase in latewood percentage. These factors have been shown to influence cell length in young radiata pine (Cown, 1973; 1975).

The results of Experiment 2 confirmed that defoliation at the beginning of the growing season is the most severe treatment. With sudden and complete removal of specific ages of needles, the timing of defoliation would have a critical effect on the amount and type of wood produced if the treatments were to be a periodic event, e.g., annually. Since the experimental treatments were applied once, the long-term effects of repeated defoliations can only be guessed.

The most significant type of natural defoliation currently prevalent in New Zealand forests is that caused by infection with the fungus *Dothistroma pini* Hulbary. In contrast to the sudden removal of specific ages of needles as carried out in the experiments reported here, the disease causes needles to be shed progressively from the base of the crown upwards over a period of months. Moreover, photosynthetic efficiency may decrease gradually and, in such attacks, trees can be left with only a portion of the new foliage to support their life processes. Deaths as a direct result of the disease have not been reported in New Zealand but substantial growth reductions are known to occur (Gilmour and Noorderhaven, 1973).

On the basis of results presented here, increment loss in stands subjected to defoliation might be expected to be accompanied by an increase in wood density and tracheid length of up to 25% for the annual rings concerned.

During the period of *D. pini* susceptibility of *P. radiata* (up to 15 years of age) much of the wood produced will be low-density, short-fibred corewood (Cown, 1974). To this extent the effects of defoliation can be expected to reduce corewood formation and slightly improve its poor wood properties. However, these "gains" will not compensate for the loss of increment and the longer rotation required to reach a merchantable size. In species such as *P. nigra* Arn. and *P. ponderosa* Laws which show lifelong susceptibility to *D. pini,* repeated attacks throughout the period when outerwood is being formed reduce production during the period when increment and wood properties are optimal.

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