GROWTH AND WOOD PROPERTIES OF *PINUS RADIATA* IN RELATION TO APPLIED ETHYLENE

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ABSTRACT

Ethylene in the form of Ethrel was applied as a band to boles of **Pinus radiata**. A large, localised diameter growth response occurred which was linearly related to the logarithm of the concentration applied. The growth response was due to increased cell division. The water-soluble extractive content, the basic density, amount of ray tissue and tracheid wall thickness were increased. Tracheid length and wood strength were decreased. Volumetric shrinkage and lignin content were not influenced.

INTRODUCTION

The application of exogenous ethylene to tree boles has been shown to increase radial increment at the point of application (Neel, 1971; Brown and Leopold, 1973). Because bending has been shown to increase endogenous ethylene levels (Leopold *et al.,* 1972; Robitaille and Leopold, 1974), it has been suggested that ethylene may play a key role in the determination of tree form.

Although evidence in crop plants such as peas suggests that ethylene promotes radial expansion through cell swelling (Abeles, 1973), there is evidence that the cambial response of trees to ethylene may involve cell division instead (Robitaille and Leopold, 1974). However, detailed anatomical and chemical analyses of wood treated with ethylene are not available.

This paper presents data describing some effects of applied ethylene on the wood of *Pinus radiata* D.Don.

METHODS

In November 1976, a solution of 2% Ethrel (48% 2-chloroethylphosphonic acid) was applied at 1.4 m to boles of 12 four-year-old *Pinus radiata* growing in the University of Canterbury botanical gardens. The solution was applied by wrapping a 4-cm cotton-wool band saturated in the Ethrel solution around the bole and covering it with polythene film. Upon encountering physiological pH levels, Ethrel breaks down releasing ethylene, phosphonate and chloride ion (Warner and Leopold, 1969). The correspondence between the external concentration of Ethrel and the internal ethylene concentration was not determined. The solution was renewed at approximately three-week intervals. Controls consisted of trees with water saturated bands applied in a similar fashion.

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In 1977, a series of 36 seven-year-old *P. radiata* at Eyrewell Forest were treated in a similar manner except six solution concentrations of Ethrel were used; control, 0.01, 0.05, 0.1, 0.5 and 1.0%. On an additional three trees with exceptionally long branch-free internodes, a series of three bands of 1% Ethrel were applied at approximately 20-cm intervals within the one node.

Diameters were measured before treatment and after one year of growth both at the point of treatment and at a mid-internodal point adjacent to the treated internode. In the 4-year-old trees, height growth was also measured. In the 4-year-old trees, Ethrel applications were discontinued during the second growing season to observe if any carry-over effects occurred. Two-year diameter increments were measured on these trees.

Four of the 4-year-old trees were felled in 1978 and discs cut from the stems above, at, and below the point of treatment. For each disc located at the point of Ethrel application, two blocks were taken from opposite sides of the treated year's annual ring, fixed, embedded in wax, sectioned at 20 μm, stained with safranin and counter-stained with fast green. This was necessary because the wood properties had been strongly affected by the Ethrel making the wood rather soft and difficult to section. Control slides were prepared by sampling the disc cut from the internode below the treated disc in a similar manner.

Cell number counts were made along 20 radial files located so as to sample evenly the entire ring width. The number of tracheids along 100 eyepiece units in a radial direction were counted. In addition, the number of ray crossings in each of the twenty fields was counted and twenty radial cell wall thicknesses were measured in each field.

Acid-insoluble ('Klason') lignin was determined for treated and untreated wood (Tappi, 1974) from each tree and a very rough estimate of water soluble extractives (mainly tannins) made on two trees by evaporating to dryness the water extraction stage in the preparation of extractive-free wood (Tappi, 1975). Five sample blocks from treated and untreated material from each 4-year-old tree were used to determine wood density (unextracted) and volumetric shrinkage.

RESULTS

Growth in diameter at the point of application was expressed as a ratio of the growth at the untreated node above for each tree in order to account for differences in tree vigour. A highly significant positive correlation ($r = 0.95$) was found between the logarithm of the applied Ethrel concentration and this ratio (Table 1).

Height increment was measured only in the 4-year-old trees and was found to be slightly reduced by the Ethrel application (79.5 cm for controls against 66.3 cm for Ethrel treated trees), the difference being significant at the 7% level.

The radial growth response involved both increased xylem as well as phloem increments. Bark thickness appeared to increase roughly in the same proportion as wood increment but measurements of bark thickness were not fine enough to make an exact comparison. In the 4-year-old trees, xylem increments were increased about 1.6 times over the controls whereas bark growth was roughly twice the control. Radial cell counts showed similar radial tracheid diameters in both treated and untreated wood (87.7 μm for treated against 88.7 μm for untreated). Ray crossings per field were significantly increased by the Ethrel treatment (6.96 ± .28 *v.* 4.48 ± .11). Radial cell wall thicknesses were significantly increased in the Ethrel treated wood, 5.59 ± .10 μm *v.* 5.11 ± .15 μm ($p = .02$).

TABLE 1—Effect of ethrel concentration on radial increment

Concentration	Diam. Increment at Application Point	Diam. Increment above Application Point
	mm	mm
Control: Eyrewell Forest	15.2	16.0
.01%	16.8	17.3
.05%	15.0	15.4
.1%	18.8	16.5
.5%	21.5	18.0
1.0%	26.5	20.3
Control: Botanic Gardens	18.5	17.3
2%	29.5	16.8

TABLE 2—Percentage acid-insoluble lignin in ethrel and control discs

Tree Number	Ethrel (2%)	No Ethrel Disc Below	No Ethrel Disc Above	Average
1-E	26.9	26.8	27.0	26.9
1-F	23.9	27.7	26.7	27.2
2-F	27.4	24.2	25.5	24.9
3-F	27.1	26.7	22.9	24.8
Average	26.3			25.9

The lignin analysis showed that both treated and untreated wood had similar acid insoluble lignin contents on average (Table 2). Treated wood averaged 26.32% lignin, while untreated wood averaged 25.92%. The difference was not significant. During the preparation of wood for lignin analysis, it became evident that there were large differences in wood colour due to water soluble extractives in the treated wood. The Ethrel-treated wood had a reddish-brown colour and the hot water extracts from this wood were a deep reddish-brown as opposed to a light straw or clear colour from untreated wood. Untreated wood was estimated to contain 0.9% water soluble extractives as opposed to 3% for treated wood. Tannin inclusions were also evident in the microscopic analysis.

Wood density (unextracted) for treated wood averaged 383 $kg.m^{-3}$ and only 355 $kg.m^{-3}$ in the controls, significant at $p = .05$. An examination of macerated tissue from one tree indicated tracheid lengths of treated wood were only about 75% the length of those in untreated wood from the same tree (1375 ± 21 μm *v.* 1840 ± 21 μm).

DISCUSSION

The results clearly show that ethylene-induced swelling in *P. radiata* boles results from an increased rate of cell division rather than cell swelling, which supports the findings of Robitaille and Leopold (1974). McMahon (1975) has suggested that wood rays could be the sensitive organs in responding to bending stress. It is of interest therefore, that ethylene has stimulated the differentiation of wood rays although whether such a response results from endogenous ethylene needs to be demonstrated.

Wilson and Archer (1977) suggest that it is unlikely that ethylene is related to the formation of compression wood. The present study has shown however, that ethylene has induced several changes in the wood of *P. radiata* which are similar to compression wood, in particular the red-brown colour, the increased density and growth rate. In this regard, *Pinus elliottii* (Peters and Roberts, 1977) and *P. resinosa* (Wolter, 1977) both had increased total extractives following treatment with Ethrel. Other similarities involved are: the less well-ordered radial files of cells which give the tracheids a more rounded contour, the slightly thicker cell walls in the Ethrel-treated wood and the lower strength. However, lignin content was not shown to be increased by ethylene application as would be expected in the case of compression wood formation. On the other hand, Shain and Hillis (1973) suggested that ethylene levels are higher at the transition zone between sapwood and heartwood so that the ethylene effect noted may partially involve induction of heartwood.

From the growth of treated rings in the 4-year-old trees during the year following treatment, it did not appear that any sort of damage had occurred to the cambial tissue and wood formed appeared to be the same colour as the control wood. Rates of growth in the subsequent year were very similar also to the controls.

The ethylene effect does not appear in this case to involve interference with the polar auxin transport system. Trees treated with three bands within one internode all showed equal growth stimulation at each point of application, which suggests a purely localised effect. The known interactions between auxin and ethylene (Abeles, 1973) suggest further investigation of these aspects is warranted.

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