INFECTION OF WOUNDS IN EUCALYPTUS DELEGATENSIS

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ABSTRACT

Colonisation of pruning wounds made by the removal of small (< 25 mm) and large (> 25 mm) branches leaving three different stub lengths (0, 15, and 30 cm), in spring, summer, autumn, and winter, was studied in a 4-year-old stand of **Eucalyptus delegatensis** R.T. Baker in Kaingaroa State Forest. Isolations were made from all pruned branch stubs. Of the 288 trees examined, 46% had visible rot and a further 29% showed discoloration of the sapwood indicating an early stage of decay. In most of these trees, the rot-inducing fungi had gained entry through branches which had died through suppression. Of the experimentally pruned branches, the largest proportion with rot were those flush-pruned in spring and summer (eight and five respectively out of 24); only one of the autumn flush-pruned and none of the winter flush-pruned branches had rot. At the end of 12 months, 27.4% of the isolates from experimentally pruned branch stubs were of fungi capable of causing decay. The most common rot fungus isolated was **Stereum purpureum** (Pers. ex Fr.) Fr., which formed 12.4% of the total number of isolates. The incidence of decay fungi isolated from pruning wounds declined with season, in the order spring, summer, autumn, winter. The influence of stub length and branch diameter on the incidence of decay fungi varied from species to species. Infection of pruning wounds by decay fungi cannot be entirely avoided by silvicultural means but its incidence can be reduced by pruning in winter.

INTRODUCTION

In 1976, a considerable amount of sap rot was detected during thinning operations in unthrifty 7-year-old *Eucalyptus delegatensis* trees in Mangatu State Forest (unpubl. data, available on request). These trees had been pruned in 1973 and again in 1975 and the fungi responsible for causing the rot (mainly *Stereum purpureum* (Pers. ex Fr.) Fr. = *Chondrostereum purpureum* (Pers. ex Fr.) Pouzar) had entered through the pruning wounds. As pruning of live branches to improve tree form and timber quality is likely to become a common silvicultural practice for eucalypts in New Zealand, a survey of pruned stands was undertaken (mainly in the central North Island) to determine the extent of this type of damage. The survey showed that rot associated with pruning wounds was present in all the stands sampled and that, in addition to *E. delegatensis,* the following species were also affected: *E. botryoides* Sm., *E. fastigata* Deane et Maiden, *E. macarthurii* Deane et Maiden, *E. pyrocarpa* L. Johnson et D. Blaxell, *E. regnans* F. Muell., and *E. viminalis* Labill. (A. Zandvoort, pers. comm.).

It seemed clear that if pruning of eucalypts was to be continued, some way had to be found to avoid or reduce the infection of pruning wounds by decay-causing organisms. This paper reports the results of a field trial done to determine the extent and cause of infections in pruning wounds made at different times of the year to see whether control through silvicultural manipulations is possible. Results of a trial on chemical control will be reported later.

MATERIAL AND METHODS

The trial was sited in a 4-year-old stand of *Eucalyptus delegatensis* (planted in 1972) in Kaingaroa State Forest (Cpt 1060). Combinations of the following factors were investigated:

(1) Pruning time: Pruning done in (a) spring (mid-October), (b) summer (mid-January), (c) autumn (mid-April), (d) winter (mid-July).

(2) Branch diameter: (a) small (< 25 mm), (b) large (> 25 mm).

(3) Stub length: (a) 0 (flush-pruned), (b) 15 cm, (c) 30 cm.

(4) Sampling time: (a) 3 months after pruning, (b) 12 months after pruning.

A randomised block design was used, with four contiguous blocks and three replicates of each factor combination per block. Within a block trees were marked as if a thinning was to be carried out and the factor combinations were assigned randomly to the trees marked for "thinning". One tree was assigned for each factor combination with the exception of branch diameter; the same tree was used for the combination of both small and large branch diameter factors with a given stub length, the branches being marked with different coloured fluorescent paint at the base before pruning was done. There were 72 pruned trees per block (four pruning times × one branch diameter × three stub lengths × two sampling times × three replicates); 36 of these were sampled 3 months after pruning (nine per pruning time) and 36 were sampled 12 months after pruning. Jacksaws were used for the pruning. The diameter of each branch stub left after pruning, the height of the pruned branches above ground level, and the diameter at breast height (d.b.h.) of each tree were recorded. The first pruning was done in mid-October 1976 and the last sampling was done in mid-July 1978.

The trees to be sampled were cut at ground level and sawn into billets. If there was visible rot associated with an experimentally pruned branch, the vertical extension of the rot above and below the wound was measured but no attempt was made to calculate the volume of wood affected. Presence of rot associated with dead branches or with any injuries to the stem was noted but its extent was not measured. Discoloration of the wood indicating an early stage of decay was also noted.

Sections of trunks (20–40 cm long, depending on the size of the branch stub) containing the experimentally pruned branches were brought back to the laboratory. They were split vertically along the branch stub, small (1 × 1 mm) chips of wood were taken aseptically from (a) near the distal end of the branch stub, (b) halfway along the stub, (c) where the branch entered the stem, and (d) at the junction of the branch pith and the stem pith, and placed on 3% malt agar. Where the branches were flush-pruned, chips could be taken only from positons (c) and (d). Many fungal cultures

isolated were of non-sporulating hymenomycetes and these were identified by their cultural and biochemical characteristics, following Stalpers (1978) and Käärik (1965).

There were 48 different factor combinations (three stub lengths × two branch diameters × four pruning times × two sampling times). Of these, 32 included a 15- or 30-cm stub length and provided four sampling positions per factor combination giving a total of 128 sampling positions. The remaining 16 had a 0 cm stub length with only two sampling positions, giving 32 sampling positions. Thus there were 160 sampling postions in all and, as all factor combinations were repeated 12 times (three replicates × four blocks), a total of 1920 isolations were attempted, from 576 (48 × 12) pruning wounds.

RESULTS

Incidence of Rot

Of the 288 trees examined, 132 (46%) had visible rot and a further 83 (29%) had discoloured sapwood. Isolation results indicated that discoloration was an early stage of decay. In most of these trees, the rot-inducing fungi had gained entry through dead branch stubs (Table 1). Eight percent of the trees had visible rot associated with experimentally pruned branches (Table 2). Of these, two-thirds had been sampled 12 months after pruning and the others 3 months after pruning. The largest proportion of all the experimentally pruned branches with rot were those flush-pruned in spring and summer (eight and five respectively out of 24); only one of the branches flush-pruned in autumn and none of those flush-pruned in winter had visible rot. When stub length is considered, 15% of the flush-pruned branches showed rot; the corresponding figures for the 15- and 30-cm stubs were 7% and 3% (Table 2).

TABLE 1—Source of visible rot in experimental trees
(n=288)

Source	Percentage of trees
Experimentally pruned branches	8
Dead branches	15
Wounds on stem	2
Unable to be determined whether from experimentally pruned or dead branch	21
Source not determined: wood discoloured	29

Isolation of Micro-organisms

Of the 1920 isolation chips, 703 (37%) were colonised by organisms capable of growth on the isolation medium (Table 3). Further details of the organisms grouped together in this Table are given in Table 4.

TABLE 2—Occurrence of visible rot in trees whose branches were pruned in different seasons and to different stub lengths (3- and 12-month assessments combined)

Season	Stub length (cm)			Total	Total pruned	Percentage
	0	15	30			
Spring	8	2	1	11	72	15
Summer	5	4	0	9	72	12
Autumn	1	1	2	4	72	5
Winter	0	0	0	0	72	0
Total	14	7	3			
Total pruned	96	96	96			
Percentage	15	7	3			

The data were analysed as follows: a multi-way frequency table was constructed using the attributes major groups of fungi isolated ((a) white- and brown-rot fungi other than *S. purpureum,* (b) *S. purpureum,* (c) Ascomycetes and Fungi Imperfecti), season, and stub length. The resulting counts were analysed as a log-linear model with dummy variables corresponding to each of the frequency table's defining attributes as explanatory variables. Both main effects (e.g., the effects of season of pruning on groups of fungi isolated) and interaction effects (e.g., that between season and stub length on groups of fungi isolated) were tested. The effects of branch diameter, tree diameter, and height of pruned branches above ground on groups of fungi isolated were also tested. For the 3-month assessment there were no significant effects of any of the variables on the incidence of white- and brown-rot fungi or of *S. purpureum.* These results are therefore not presented.

In the assessment made 12 months after pruning (Table 5), the winter pruning treatment yielded significantly less isolates of white- and brown-rot fungi and *S. purpureum* than pruning in any other season. The incidence of white- and brown-rot fungi increased significantly as the height of the pruning wound above ground increased and their incidence was significantly lower with 30-cm branch stubs.

Interpretation of the coefficients is made difficult by the log frequency scale and wide variability of standard errors but the relative magnitude of the coefficients and their sign do indicate trends. All three groups of fungi isolated from the pruning wounds declined in frequency with season in the order spring, summer, autumn, winter. The incidence of *S. purpureum* and Ascomycetes and Fungi Imperfecti was greatest with 15-cm stubs and lowest with 0-cm stubs; the incidence of white- and brown-rot fungi followed a different progression, being lowest with 30-cm stubs and highest with 0-cm stubs. White- and brown-rot fungi and Ascomycetes and Fungi Imperfecti appear to decrease with increasing tree d.b.h. and branch stub diameter; for *S. purpureum* the pattern is reversed.

TABLE 3—Numbers of isolates from pruning wounds (there were 160 isolation positions with 12 chips from each position)

Organism	Season	Sampled after (months)	Stub length (cm) 0 — Branch diameter (mm) <25 — Sampling position c	0 — <25 — d	0 — >25 — c	0 — >25 — d	Stub length (cm) 15 — Branch diameter (mm) <25 — Sampling position a	15 — <25 — b	15 — <25 — c	15 — <25 — d	15 — >25 — a	15 — >25 — b	15 — >25 — c	15 — >25 — d	Stub length (cm) 30 — Branch diameter (mm) <25 — Sampling position a	30 — <25 — b	30 — <25 — c	30 — <25 — d	30 — >25 — a	30 — >25 — b	30 — >25 — c	30 — >25 — d	Total
Bacteria	Spring	3	1	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1	—	—	—	3
		12	—	2	2	—	1	—	—	—	3	—	—	—	6	1	—	—	2	1	—	—	18
	Summer	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
		12	5	—	2	—	5	1	—	—	5	—	—	—	5	—	—	2	2	—	—	—	27
	Autumn	3	5	—	6	—	9	5	1	1	6	3	—	—	6	1	—	—	7	1	—	1	51
		12	1	3	3	1	4	1	—	1	4	2	1	2	3	1	—	—	3	—	1	—	32
	Winter	3	9	2	8	—	10	1	1	1	7	—	—	—	7	2	—	—	7	3	—	—	58
		12	3	—	5	—	4	—	—	2	4	—	1	3	5	—	—	2	9	1	—	1	40
White- and brown-rot fungi	Spring	3	—	—	1	1	—	1	—	—	1	—	3	—	—	1	—	—	—	—	1	1	10
		12	—	2	1	3	1	4	3	—	2	3	2	2	1	—	1	—	1	1	—	—	27
	Summer	2	—	—	3	—	1	1	—	1	—	—	3	1	—	—	—	—	1	—	—	—	11
		12	1	—	4	3	—	—	—	—	6	3	2	—	1	—	2	—	4	1	—	—	27
	Autumn	3	1	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	3
		12	1	—	2	3	—	—	—	—	—	1	—	—	1	—	1	1	1	1	1	1	14
	Winter	3	—	2	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	5
		12	—	—	1	1	—	1	1	—	1	1	—	—	1	—	—	—	1	—	—	—	8

Stereum purpureum	Spring	3	1	1	—	—	1	2	—	—	1	1	—	—	—	1	—	—	—	1	1	1	11
		12	—	2	1	1	—	2	1	—	—	2	—	—	—	4	1	1	—	5	2	1	23
	Summer	3	—	1	—	—	—	2	2	—	—	1	2	—	—	1	1	—	—	—	—	—	10
		12	—	1	—	4	1	3	2	1	—	5	2	1	—	1	—	—	—	4	3	—	28
	Autumn	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
		12	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	2	4	—	—	8
	Winter	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
		12	—	—	—	—	—	—	1	1	—	1	1	—	—	—	—	—	—	1	1	—	6
Ascomycetes, Sphaeropsidales, Melanconiales	Spring	3	3	—	2	—	3	—	—	—	3	—	—	—	1	—	—	—	2	—	—	—	14
		12	3	—	1	2	5	5	4	—	2	3	1	—	1	3	5	—	2	1	—	—	38
	Summer	3	1	—	3	—	2	4	—	—	4	1	—	—	2	—	1	—	3	1	—	—	22
		12	4	1	2	—	1	2	2	—	—	1	2	1	4	4	—	—	1	2	—	—	27
	Autumn	3	—	—	2	—	1	—	—	—	1	—	1	—	—	—	—	—	1	—	—	—	6
		12	2	—	1	—	—	2	4	1	—	5	1	—	1	5	1	—	—	2	2	—	27
	Winter	3	—	—	—	1	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	3
		12	2	—	1	—	1	2	4	—	1	3	1	—	1	1	4	—	—	—	—	—	21
Moniliales	Spring	3	—	—	2	—	—	—	2	1	4	—	—	—	4	1	1	1	5	—	—	—	21
		12	4	2	6	—	3	1	—	—	4	1	—	—	3	1	—	—	4	1	—	—	30
	Summer	3	2	—	1	—	2	—	—	—	1	1	—	—	3	—	—	—	4	—	1	—	15
		12	2	—	—	1	2	—	—	—	1	1	—	1	2	1	1	—	2	—	—	—	14
	Autumn	3	—	—	2	—	—	—	—	—	1	—	—	—	—	1	—	—	1	1	—	—	6
		12	3	—	2	1	1	2	1	—	2	—	—	—	1	—	4	—	—	—	—	—	17
	Winter	3	1	1	—	1	—	—	—	2	—	1	—	—	1	—	—	—	2	—	—	1	10
		12	2	—	—	2	2	—	1	—	—	—	—	1	1	—	—	—	—	1	1	—	11

Total 703

TABLE 4—Genera and frequency of isolation of organisms isolated from pruning wounds

Group of organisms	Genus	Frequency (%)	Total No. of isolates
Bacteria	Not determined	32.5	229
White- and brown-rot fungi (other than **Stereum purpureum**)	**Peniophora**	2.0	
	Aleurodiscus	0.9	
	Stereum	0.9	
	Fomes	0.8	
	Corticium	0.5	
	Phenerochaete	0.5	
	Poria	0.5	
	Polyporus	0.4	
	Unidentified	8.5	105
Stereum purpureum		12.4	87
Ascomycetes, Sphaeropsidales, Melanconiales	**Chaetomium**	0.2	
	Cytospora	17.1	
	Phoma	2.7	
	Pestalotia	1.8	
	Coniothyrium	0.5	
	Diplodia	0.2	158
Moniliales	**Penicillium**	4.7	
	Cephalosporium	2.6	
	Fusarium	2.5	
	Trichoderma	2.1	
	Cladosporium	1.8	
	Epicoccum	1.3	
	Stemphylium	1.1	
	Aureobasidium	0.8	
	Gliocladium	0.5	
	Cylindrocarpon	0.2	124
		100.0	703

DISCUSSION

At the end of 12 months after pruning, isolations showed that 27.4% of the isolates from the experimentally pruned branch stubs were those of fungi capable of causing decay (Table 4). The most common single species capable of causing decay was *S. purpureum,* which formed 12.4% of the total number of isolates. *Stereum purpureum* is likely to be the most damaging of the decay fungi isolated as it causes a progressive dieback in a very large number of host species (Peace 1962).

The finding that infection of branch stubs by decay fungi and partcularly by *S. purpureum* was less in autumn and winter than in spring and summer is the reverse of the observations by Dye (1967) who noted that peach and nectarine trees pruned in summer were less likely to become infected by *S. purpureum.* Dye (1974) reported that *S. purpureum* spores were shed in all seasons of the year and that lack of inoculum

TABLE 5—Estimates of effects of season, stub length, branch diameter, tree diameter, and height of pruned branch above ground on the major groups of fungi isolated

Effect	Major groups of fungi isolated		
	(a) White- and brown-rot fungi other than **S. purpureum** **v.** none	(b) **S. purpureum** **v.** none	(c) Ascomycetes and Fungi Imperfecti **v.** none
Season:			
summer **v.** spring	-0.16	0.06	-0.06
autumn **v.** spring	-0.81	-0.91	-0.39
winter **v.** spring	-2.17***	-1.64**	-0.87*
Stub length:			
15 cm **v.** 0 cm	-0.24	1.15	0.91*
30 cm **v.** 0 cm	-1.39*	0.85	0.18
Branch diameter	-0.072	0.028	-0.016
Tree diameter	-0.0005	0.0038	-0.0054
Stub height	0.22*	-0.051	0.073

* Indicates statistically significant $p \leq 0.05$
** Indicates statistically significant $p \leq 0.01$
*** Indicates statistically significant $p \leq 0.001$

could not be the reason for the low infection he found. Beever (1970) found that nitrogen and carbohydrate levels in xylem sap of peach were highest in late winter and early spring and lowest in summer and he has suggested that the seasonal variation in infection of pruning wounds in stonefruit is due to the differential ability of xylem sap to support growth of *S. purpureum*. There is no information on the levels of nitrogen and carbohydrate in xylem sap of eucalypts; it is possible that as, unlike stonefruit trees, eucalypts are not deciduous, there are no marked seasonal differences in their xylem sap nutrients.

The influence of stub length on the incidence of decay fungi was not clear-cut. The white- and brown rot fungi were isolated most frequently from flush-pruned branch stubs whereas the incidence of *S. purpureum* was least in the flush-pruned stubs. As it is more important to lessen the incidence of *S. purpureum* rather than the other white- and brown-rot fungi, and as leaving branch stubs after pruning may lead to the formation of knotty cores, flush-pruning seems to be the more desirable course. The influence of stub diameter was not statistically significant, although there was a trend toward greater incidence of *S. purpureum* with increasing branch diameter. It would appear that in this study, pruning large branches did not markedly increase the risk of wound infection by decay fungi.

It is clear that infection by decay fungi of dead branch stubs or of wounds caused by artificial pruning cannot be entirely avoided by silvicultural means, although the

proportion of artificial pruning wounds which become infected can be reduced by flush-pruning in winter. The best way to eliminate infection of pruned branches might be to treat the wounds with a protectant which prevents entry of decay organisms. A trial to test several protectants is at present being done and if a suitable one is found it may be advisable to reduce the incidence of suppressed dead branches by planting the trees at a wide spacing so as to reduce deaths of branches through suppression, and to plan for the timely pruning (and treating) of all unwanted branches.

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