INTENSIVE SITE-PREPARATION TO CONTROL ARMILLARIA ROOT DISEASE IN SECOND-ROTATION *PINUS RADIATA*

MARK SELF and MARTIN MacKENZIE

New Zealand Forest Research Institute,
Private Bag 3020, Rotorua, New Zealand

(Received for publication 20 April 1994; revision 1 December 1994)

ABSTRACT

Stump removal and windrowing were used as a site-preparation technique to control infection by *Armillaria* spp. in two second-rotation *Pinus radiata* D. Don stands. Significant reductions in mortality due to *Armillaria* spp. from 10% to <1%, and from 22% to 5% at 5 years from planting were achieved. Parasitic sub-lethal infection at age 8 years in the same stands was reduced from 85% to 10% and 67% to 31%. Economic analysis predicted returns of $2761 to $8826 (mean $6249) for a cost of $3623 (at 8% interest rate).

Keywords: site preparation; *Armillaria novae-zelandiae*; *Armillaria limonea*.

INTRODUCTION

Mortality attributable to root disease caused by *A. novae-zelandiae* (Stevenson) Herink and *A. limonea* (Stevenson) Boesewinkel is a major pathological problem when pines are being established on land where the indigenous forest has been removed (Birch 1937; MacKenzie & Shaw 1977; Shaw & Calderon 1977; Roth *et. al.* 1979). Losses of up to 50% by age 5 years have been recorded on such sites (Beveridge *et. al.* 1973). Hood's (1989) review of *Armillaria* spp. in New Zealand emphasised that the fungi occur much more widely than just on converted indigenous forest sites. An apparent build-up of *Armillaria* spp. in second-rotation pine plantations gives us cause to consider the status of the disease, and to consider measures available to control it.

In Kaingaroa Forest, little or no parasitic attack by *Armillaria* spp. was reported by Gilmour (1954) during the first rotation; he also observed that saprophytic *Armillaria* spp. were becoming noticeable in first-rotation pines on formerly non-wooded sites. Second-rotation stands in Kaingaroa Forest were surveyed again by MacKenzie & Self (1988) and H. Essenberg (unpubl.), who both recorded much higher levels of infection by *Armillaria* spp. than those found in first-rotation stands by Gilmour. Stands surveyed by the authors which had been selected on the basis of a known history of infection by *Armillaria* spp. had incidences of sub-lethal infection levels of up to 94%. Randomly selected stands had parasitic infection levels ranging from 0 to 42% with a mean of 15% (MacKenzie & Self

1988), and 0 to 62% with a mean of 18% (Essenberg unpubl.). Hood & Sandberg (1993) found 24% chronic infection in a 6-year-old second-rotation *P.radiata* plantation in Kaingaroa Forest.

This build-up of *Armillaria* spp. in second-rotation pine stands reveals a gap in knowledge of the disease epidemiology. We have little understanding of which factors are contributing to this build-up and what we can do to minimise its impact. It becomes necessary to know if infection by *Armillaria* spp. can be economically controlled in second-rotation pine plantations.

Mechanical clearing, uprooting of trees, windrowing, and burning are widely recognised as site-preparation techniques for controlling root pathogens (Shaw & Calderon 1977; Roth *et. al.* 1980). Van der Pas (1981) showed that mechanical removal of residual root material and other debris from indigenous cutover sites reduced mortality attributable to *Armillaria* spp. by more than 30% compared with sites which were only chainsaw felled and burnt. Van der Pas & Hood (1984) showed that stump removal and windrowing of indigenous cutover sites reduced mortality due to *Armillaria* spp. from 22% to 2% at 4 years after planting.The same method of disease control could be appropriate in second-rotation pine stands.

THE TRIAL SITE

In Karioi Forest, poison thinning of first-rotation stands has created a serious establishment and post-establishment problem with infection of second-rotation pines by *Armillaria* spp. (van der Pas 1981). This situation has provided a unique opportunity for further study of control methods which may be required in the future if infection by *Armillaria* spp. in other plantation forests continues to increase.

This trial was designed to test the effectiveness of stump removal and windrowing as a means of controlling attack by *Armillaria* spp. in second-rotation pine plantations after crops with high levels of infection. The trial compared mortality until age 5 years and chronic infection at age 7 years where, prior to planting, stumps were removed and the areas windrowed and burnt with areas which were only windrowed and burnt .

METHODS

Compartments 28 and 29 at Karioi Forest were selected for study; they were planted in 1930 with *P. ponderosa* P. Lawson et Lawson which was poison thinned with arsenic (As_2O_3) (25% in water) during 1954-57, and these compartments were typical of much of the first crop. After logging in 1983 the two compartments were divided into two halves, and each of the resulting trial areas occupied an area of approximately 6 ha. Stumps were removed from one-half of each and piled into windrows using a D8 tractor and solid blade. Remaining areas were kept as controls in which the stumps were left intact while surface debris was windrowed. All areas were burnt after windrowing.

After planting at 2300 stems/ha in 1984, twelve rectangular plots were established, each of 10 rows × 20 trees (200 trees). Three plots were randomly located within each of two treatments in both compartments. Mortality attributed to *Armillaria* spp. or to other causes was recorded from establishment at approximately 6-month intervals until age 5 years. Differences in sub-lethal infection levels at age 8 were obtained by assessing five randomly located 20-tree transects in each treatment for each compartment (400 trees total). Counts were made of presence or absence of root collar girdling by *Armillaria* spp. which was identified by root collar resin bleeding and the presence of rhizomorphs or mycelial fans (as described by Shaw & Toes 1977). Confidence intervals for mortality curves and sublethal infection levels were constructed from standard errors of plot and transect means.

Economic Analysis

To produce a cost/benefit analysis which forest growers could use in decision making, figures from MacKenzie's (1987) growth loss study were used to calculate potential gains if the levels of control achieved in this trial were reproduced.

RESULTS

Stump removal dramatically reduced mortality attributable to *Armillaria* spp. and subsequent levels of sub-lethal infection (Table 1). An overall reduction from 16.2% to 2.3% mortality at 5 years was achieved. Individual 200-tree plots had mortality levels ranging from 0 to 8% in the stumped areas compared with 10% to 26% in the unstumped controls. Incidences of sub-lethal infection were reduced from 16% to 2% in Cpt 28 and from 76% to 20.5% in Cpt 29. Much residual infection was traceable back to roots and debris from the first crop which remained after the stump removal treatment. Another source of infection was the windrows themselves; trees within 4 m of the windrows were more likely to die than trees further away.

TABLE 1–Incidences of lethal and sub-lethal infection by *Armillaria* spp. with and without stump removal, on two site types, showing control achieved by stump removal.

	Compartment 28 *			Compartment 29		
	–95%	Mean infection (%)	+95%	–95%	Mean infection (%)	+95%
Sub-lethal						
Unstumped	81.5	85.0	88.5	61.5	67.0	72.5
Stumped	3.0	10.0	17.0	12.5	31.0	49.5
Effectiveness of control	96	88	81	80	54	32
Lethal						
Unstumped	9.8	10.3	10.9	18	22	26
Stumped	0	0.2	0.3	1.4	4.5	7.5
Effectiveness of control	100	98	97	92	80	71

* Compartment 29 was less sheltered, and also appeared to have more debris left behind after the stump-removal operations.

Economic Analysis

While these results show the benefits of intensive site-preparation, the capital outlay required is considerable. Selwyn Plantation Board Ltd is one of the few forest growers presently practising stump removal and windrowing. Their costs (1990) are \$420/ha excluding GST. Since this must be compounded over the length of a rotation, careful cost benefit analyses must be made by foresters prior to embarking on site preparation. The cost of stumping at $420/ha, compounded over a 28-year rotation at 4, 8, and 12%/annum comes to $1259, $3623, and $10,031. Average returns from this investment are of the order of $6000/ha.

If the reductions in disease shown in Table 1 could be achieved in a stand equivalent in terms of growth and *Armillaria* spp. infection to the 28-year sawlog regime used by MacKenzie (1987), then the calculated gains would be between 20.3 and 71.6 m^3/ha (Table 2). When these gains are multiplied by a standardised log price of $136/$m^3$ (assuming a logmix of 30% pruned logs, 40% sawlogs, and 30% pulp; yielding $200, $130, and $80/$m^3$ respectively) the potential gain equates to $2761–$9738/ha.

MacKenzie (1987) predicted volume losses due to both lethal and sub-lethal infection by *Armillaria* spp. of between 31.5 and 72 m^3/ha in a stand managed under a wide spacing sawlog regime which at age 10 had a sub-lethal infection level of 60%. Losses comprised 26–61 m^3/ha and 5.5–11 m^3/ha for lethal and sub-lethal components, respectively. Shaw & Calderon (1977) calculated volume losses of 144 m^3/ha (29%) due to attack by *Armillaria* spp. on a 26-year sawlog regime on an indigenous cutover site. They estimated the increased growing cost due to the impact of the root disease at 37%. For this analysis MacKenzie's more conservative figures have been used.

TABLE 2–Predicted yield gains based upon MacKenzie's (1987) figures.

	Compartment 28 *			Compartment 29		
	–95%	Mean	+95%	–95%	Mean	+95%
Sub-lethal						
Potential volume loss (m^3/ha)	5.5	8.3	11.0	5.5	8.3	11.0
Level of control (%)	81.0	88.0	96.0	32.0	54.0	80.0
Volume gain (m^3/ha)	4.5	7.3	10.6	1.8	4.5	8.8
Lethal						
Potential volume loss (m^3/ha)	26.0	43.5	61.0	26.0	43.5	61.0
Level of control (%)	97.0	98.0	100.0	71.0	80.0	92.0
Volume gain (m^3/ha)	25.2	42.6	61.0	18.5	34.8	56.1
Total volume gain (m^3/ha)	29.7	49.9	71.6	20.3	39.3	64.9
Financial return ($)†	4039	6786	9738	2761	5345	8826

* Compartment 29 was less sheltered, and also appeared to have more debris left behind after the stump-removal operations.

† Using a stumpage of $136/$m^3$ (assuming a logmix of 30% pruned logs, 40% sawlogs, and 30% pulp; fetching $200, $130, and $80/$m^3$, respectively).

DISCUSSION

The mortality reduction figures in this study (from 10.3% to 0.2% in Cpt 28 and from 22% to 4.5% in Cpt 29) agree with those of van der Pas & Hood (1984) who showed that the same method of site preparation on native cutover sites reduced mortality 4 years after planting from 22% to 2%. The survey of sub-lethal infection showed that the benefits of control continue beyond the establishment phase.

The source of differences between the two trial sites in gains achieved remains open to conjecture; it could be that removal of stumps was less effective in Cpt 29, or the difference may reflect the slightly more exposed location of that compartment.

In addition to high mortality levels in early years of stand development, losses continue after initial crop tree selection. (MacKenzie 1987; Shaw & Toes 1977). A survey in Kaingaroa Forest (MacKenzie & Self 1988) showed a build-up of *Armillaria* spp. in second-rotation stands. If this were to continue then perhaps the problems experienced in second-rotation pines after crops that have been poison thinned could occur in many other areas in third-rotation crops. Crops after production-thinned stands or stands severely affected by *Dothistroma pini* Hulbary in particular could be considered high risk areas. Ground disturbance, fresh stumps, and damage to remaining trees during production thinning may stimulate *Armillaria* spp. Standosz & Patton (1987) reported a build-up of *Armillaria* spp. in stands of *Populus tremuloides* L. after repeated short rotations. This supports observations of increasing *Armillaria* spp. populations in New Zealand plantations, and the possibility of increases in future if steps are not taken to control the disease.

CONCLUSIONS

Intensive site-preparation is an option worthy of consideration when *P. radiata* is to be established on sites following crops with high levels of infection by *Armillaria* spp. Though the cost of stumping is high, the benefits include increased survival during the first 5 years, reduction in parasitic infection with lower growth losses and risk of windthrow later in the rotation, and flow-on benefits of lower inoculum levels at establishment of the following rotation. The economic value of these benefits makes it an option worth considering on sites where infection by *Armillaria* spp. is likely to cause problems.

REFERENCES

BEVERIDGE, A.E.; KLOMP, B.K.; KNOWLES, R.L. 1973: Grazing in young plantations of radiata pine established after clearing logged and reverted indigenous forest. *New Zealand Journal of Forestry 18(1)*: 152–6.

BIRCH, T.T.C. 1937: *Armillaria mellea* (Vahl) Quel. in relation to New Zealand forests. Presented at the Australian and New Zealand Association for the Advancement of Science, Auckland, January 1937.

GILMOUR, J.W. 1954: *Armillaria mellea* (Vahl) Sac. in New Zealand. Part 1: In stands of *Pinus radiata* D. Don in Kaingaroa State Forest. *New Zealand Forest Service, Forest Research Institute, Forest Research Notes 1*: 1–40.

HOOD, I.A. 1989: Armillaria root disease in New Zealand forests. *New Zealand Journal of Forestry Science 19(2/3)*: 180–98.

HOOD, I.A.; SANDBERG, C.J. 1993: Armillaria—A hidden disease of *Pinus radiata*. *New Zealand Forestry 38(2)*: 29–32.

MacKENZIE, M. 1987: Infection changes and volume loss in a 19-year-old *Pinus radiata* stand affected by Armillaria root rot. *New Zealand Journal of Forestry Science 17*: 100–8.

MacKENZIE, M.; SELF, N.M. 1988: *Armillaria* in some New Zealand pine stands. Pp.82–7 *in* van der Kamp, B.J. (Comp.) Proceedings of the 36th annual Western International Forest Disease Work Conference, 19–23 September, Park City, UT.

MacKENZIE, M.; SHAW, C.G. 1977: Spatial relationships between Armillaria root rot of *Pinus radiata* seedlings and the stumps of indigenous trees. *New Zealand Journal of Forestry Science 7*: 374–83.

van der PAS, J.B. 1981: Impact and control of Armillaria root rot in New Zealand pine plantations. Pp.69–77 *in* "Root and Butt Rots in Scots Pine Stands". IUFRO working party S.2.06.-01, Polish Academy of Sciences, Poznan.

van der PAS, J.B.; HOOD, I.A. 1984: The effect of site preparation on the incidence of Armillaria root rot in *Pinus radiata* four years after conversion from indigenous forests in Omataroa Forest, New Zealand. Pp.387–97 *in* " Proceedings of the Sixth International Conference on Root and Butt Rots of Forest Trees", CSIRO, Melbourne.

ROTH, L.F.; ROLPH, L.; COOLEY, S. 1980: Identifying infected ponderosa stumps to reduce costs of controlling Armillaria root rot. *Journal of Forestry 78*: 145–51.

ROTH, L.F.; SHAW, C.G. III; MacKENZIE, M.; CROCKETT, F.H. 1979: Early patterns of Armillaria root rot in New Zealand pine plantations converted from indigenous forest: An alternative interpretation. *New Zealand Journal of Forestry Science 9(3)*: 316–63.

SHAW, C.G. III; CALDERON, S. 1977: Impact of Armillaria root rot in plantations of *Pinus radiata* established on sites converted from indigenous forest. *New Zealand Journal of Forestry Science 7(3)*: 359–77.

SHAW, C.G. III; TOES, E.H.A. 1977: Impact of Dothistroma needle blight and Armillaria root rot on diameter growth of *Pinus radiata*. *Phytopathology 67*: 1319–23.

STANDOSZ, G.R.; PATTON, R.F. 1987: Armillaria root rot in aspen stands after repeated short rotations. *Canadian Journal of Forest Research 17*: 1001–5.