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Armillaria root disease of *Pinus radiata* in New Zealand (5)

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NOTE

ARMILLARIA ROOT DISEASE OF *PINUS RADIATA* IN NEW ZEALAND. 5: STAND ASSESSMENT USING AERIAL PHOTOGRAPHY

J. G. FIRTH and R. K. BROWNLIE

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

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ABSTRACT

A remote sensing method is being developed to improve the cost effectiveness of assessing incidence and distribution of Armillaria root disease in young *Pinus radiata* D. Don plantations.

Two multiple-tree row transects comprising 673 trees were located in a 4-year-old plantation of *P. radiata* (average height 3.5 m) and the health of the crown foliage on each tree was assessed according to a four-point colour classification. Root collars on all trees were examined for infection by *Armillaria* species as indicated by resinosis, and sometimes by characteristic mycelial fans, accompanied by rhizomorphs. The study trees were then located on high resolution, colour, stereo aerial photographs and the individual canopies were re-assessed using the same colour classification.

A total of 199 trees were identified as infected or colonised by *Armillaria* species (30% of all study trees). Of these, 131 bore healthy green crowns (66%) and 43 had died before attaining a height of 2 m (22%), and so they were not reliably detectable as diseased in colour photographs because of their green crowns or small image size. Of the other 25 diseased trees (13% of all diseased trees) which were taller than 2 m when assessed and either dead or with discoloured crowns, 24 (96%) were correctly classified on the 1:3,000 photographs and 19 (76%) on the 1:6,000 photographs. Most dead trees ≥2 m tall were easily recognised at both scales of photography.

The aerial photographs therefore enabled an accurate estimate of the incidence and spatial distribution of dying trees taller than 2 m that had Armillaria root disease. If a relationship can be established between such trees and the incidence of infection in a total stand, remote sensing is likely to prove a practical tool for assessing Armillaria root disease in *P. radiata* plantations.

Keywords: aerial photography; root pathogen; Armillaria root disease; *Pinus radiata*.

INTRODUCTION

Armillaria species are root pathogens found in many *Pinus radiata* plantations throughout much of New Zealand (MacKenzie 1987; Hood 1989; Hood & Sandberg 1993; Self *et al*.

1998). These fungi cause a disease which is prevalent in stands established on sites cleared of native forest. The disease also occurs in a number of second-rotation stands on non-native forest sites where infection was not previously detected during the first rotation (Gilmour 1954). In these stands, young trees infected with the pathogens are often killed, but many continue to survive and maintain green crowns (Shaw & Toes 1977).

Methods for managing the disease are being developed but in order to apply treatments in a cost-effective manner it will be necessary to identify and target stands where the total incidence of infected trees is high. This is not a straightforward procedure because the incidence of early mortality now tends to be low in many younger plantations, and much infection occurs in a "chronic" or "sub-lethal" form in which foliage symptoms are not always apparent.

The method currently available for assessing the level of stand infection by *Armillaria* species involves examining the root collars on a sample of trees for signs of resinosis accompanied by rhizomorphs (Self *et al*. 1998). This is a time-consuming technique and, as such, it may be difficult to justify on an operational basis. Current research is investigating an alternative approach that relies on the assumption that it may be possible to estimate total stand infection as a function of the incidence of visible tree mortality caused by Armillaria root disease (Hood & Kimberley 2002). While this research is incomplete, the technique appears to have sufficient potential to justify the investigation of cost-effective methods for quantifying dead and dying trees in diseased stands.

Costs may be reduced further if it proves possible to estimate Armillaria-induced mortality by means of remote-sensing technology. Recent technological advances in aerial camera designs, lenses, and films, and the availability of GPS-controlled navigation systems, suggested that such an approach might be feasible.

This paper describes the first phase of the research project (testing the concept, determining the specifications of the aerial photography, and evaluating the image resolution required) and the results obtained.

METHOD

The study was undertaken in a second-rotation, 4-year-old stand of *P. radiata* in Cpt 1351 (Stand 2.1) in Kaingaroa Forest, in which pruning and thinning had not yet been carried out. This site was selected because a preliminary field check had shown that several trees scattered throughout the stand were dead or dying due to Armillaria root disease (Fig. 1).

Aerial photographs were taken of the study site by NZ Aerial Mapping Ltd (Fig. 2). Diapositives* of the aerial photographs were examined stereoscopically by an experienced interpreter. Two multiple-tree row linear transects, approximately 400 m long, were placed across part of the stand to include some trees with discoloured foliage visible in the crowns. The health of every tree in each transect was assessed from the photographs according to the classification in Table 1 (*see also* Fig. 3).

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* Diapositives (i.e., transparencies) were used because they have a wider contrast range and higher resolution than prints.

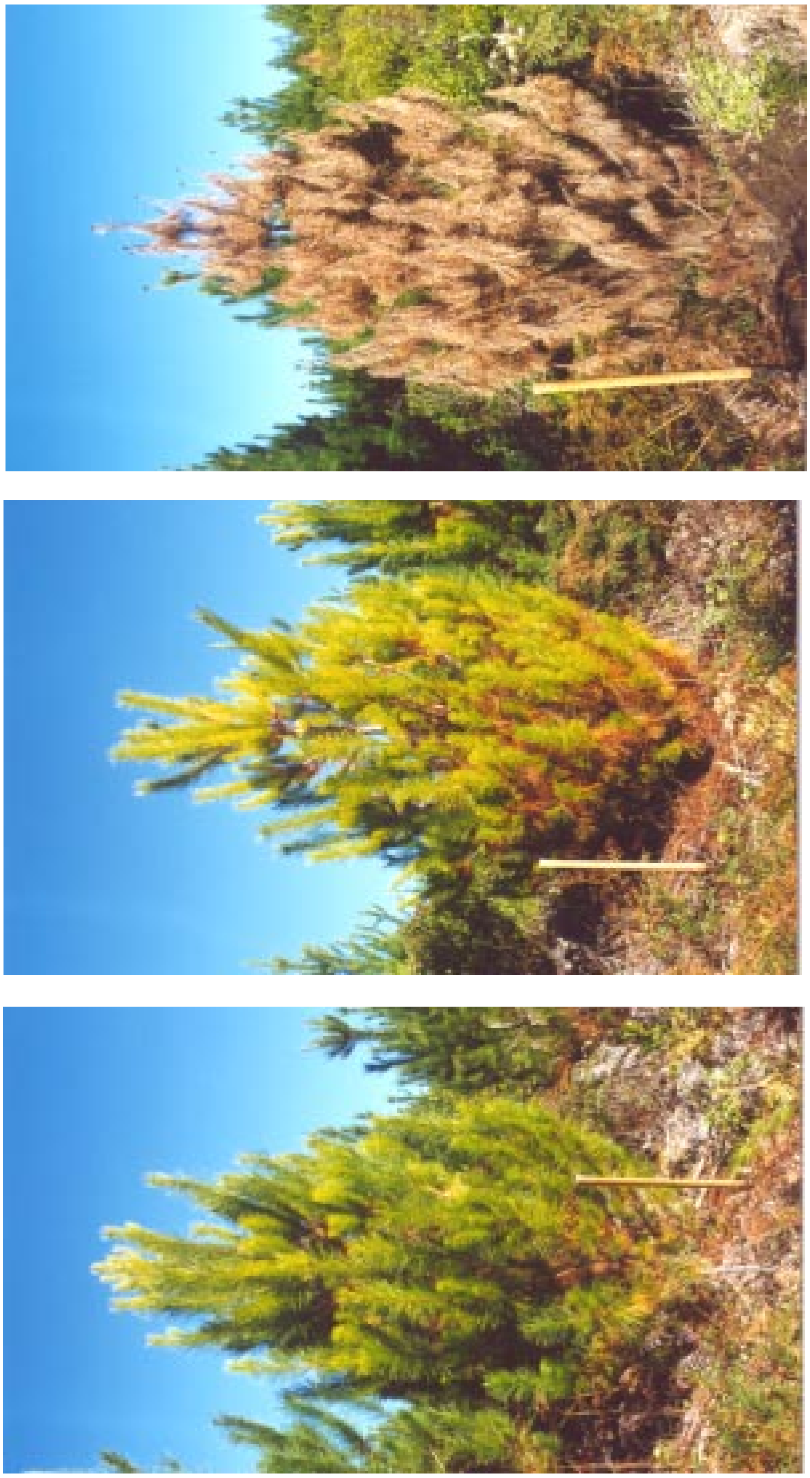
FIG. 1–Panoramic photograph of part of the study site, showing trees with symptoms of Armillaria root disease.

FIG. 2–Enlargement of part of an aerial photograph of the study site

Photography specifications:

Camera	RC30
Film	Kodak Aerographic colour film, Type 2444
FMC*	Active
Lens focal length	305 mm
Negative scales	1:3000, 1:6000, & 1: 10 000
Date taken	09/04/2001

* **F**orward **M**otion **C**ompensation eliminates the image blurring caused by the forward movement of the aircraft during film exposure. This feature becomes increasingly beneficial as the photo-scale increases.



Infection Class 1: pale green (healthy Class 0 trees to left and right)

Infection Class 2: yellow

Infection Class 3: brown

FIG. 3–Colour of the foliage of trees with Armillaria root disease

TABLE 1–A classification of the health of radiata pine.

Infection class	Foliage colour	Tree health status
0	Deep green	Healthy
1*	Pale green	Stressed
2*	Yellow	Dying
3*	Brown	Dead

* See examples in Fig. 3.

All trees were rated again for crown health in the field using the same scale, and the root collars were examined for evidence of infection by *Armillaria* species as indicated by resinosis accompanied by rhizomorphs and sometimes mycelial fanning, particularly in trees that had died. Trees with discoloured crown foliage were assigned to one of three height classes (<0.6 m, ≥0.6 to <2 m, ≥2 m).

RESULTS

The combination of the RC30 aerial camera, the Type 2444 film and FMC, provided high-resolution aerial photographs with excellent colour rendition. This facilitated the identification and classification of the trees on the 1:3000 and 1:6000 photographs. However, the images of the trees on the 1:10 000 photographs (~0.2 mm in diameter) were found to be too small to enable the colour of the tree's foliage to be assessed with reliability. The 1:10 000 scale photographs were, therefore, excluded from further consideration.

Altogether 673 trees were located in the field. The results of the assessment of these trees are shown in Table 2. Of those 673 trees, 199 (30%) were found to be infected by *Armillaria* species*, and 68 (10%) of these infected trees either had discoloured foliage or had died. Of

TABLE 2–Numbers of study trees by crown health, height, and infection with *Armillaria* species, as determined in the field and from two scales of aerial photography.

Visible health class	Field count		Photo-count	
	No. trees	Total trees infected with *Armillaria* species	Photo-scale 1:3,000	Photo-scale 1:6,000
0: Healthy (deep green)	595	131	595	597
1: Stressed (pale green)	6	5	7	2
2: Dying (yellow)	7	7	7	6
3: Dead (brown)				
(a) ≥ 2 m tall	13	13	12	11
(b) ≥ 0.6 to < 2 m tall	34	34	9	5
(c) < 0.6 m	18	9	0	0
Subtotal dead	65	56	21	16
TOTAL	673	199	630	621

* Because the trees assessed in the field were not selected randomly across the compartment, figures relating to the incidence of trees infected by *Armillaria* species should not be taken as representative of the compartment as a whole.

the other 25 diseased trees (13% of all diseased trees) which were taller than 2 m when assessed and either dead or with discoloured crowns, 24 (96%) were correctly classified on the 1:3,000 photographs and 19 (76%) on the 1:6,000 photographs. Most dead trees ≥2 m were easily recognised at both scales of photography but those <2 m could not be consistently identified at either scale because of their small image size.

The largest discrepancy between the field count and photo-counts was in the dead trees class (Table 2). Of the 65 dead trees identified in the field, only 21 (32%) and 16 (25%) were correctly identified on the 1:3,000 and 1:6,000 scale photography, respectively. However, when the dead trees were sub-classified according to their height classes (<0.6 m, ≥0.6 to <2 m, and ≥2 m), it was seen that most of the trees that were missed were the smaller ones, particularly those <600 mm. This is understandable when one considers that most of these trees had become smothered by weeds.

DISCUSSION

The results indicated that the largest photo-scale (1:3,000) was best suited for identifying crown colour categories on diseased trees in stands infested by *Armillaria* species. However, considering the trade-off between photo-scale, image resolution, and frame coverage, a more practical photo-scale would probably be ~1:4,000.

It was not always easy to identify the stressed (Class 1) trees either in the field or on the photographs. This was because their colour tended to vary with the viewing angle relative to the sun, as well as with the sun's brightness. In addition, variations between film emulsions and developing processes can result in subtle colour differences on the prints. These points need to be considered when assessing the proportion of pale green trees. However, this will not be a critical factor if the incidence of mortality can be used as an estimate of total incidence of infection (Hood & Kimberley 2002).

Although colour infra-red (CIR) film is the medium normally employed for assessing the health of vegetation, normal colour film was employed in this study for reasons of cost. CIR film would be expected to make stressed trees easier to identify.

CONCLUSIONS

It is possible to use aerial photographs to identify the incidence and spatial distribution of trees dead or dying as a result of Armillaria root disease in young pine plantations. For optimum results, an operational survey should be conducted when the trees have reached at least 2 m in height but before those with discoloured foliage have been thinned out. The resolution of the photographs must be as high as possible (FMC active) and to this end a photo-scale of approximately 1:4,000 is recommended.

An operational survey should include the field checking of a sample of trees to confirm that the symptoms observed are indeed due to Armillaria root disease.

The next phase of the research will be to determine whether the relationship between the visible and hidden rates of infection pertaining to this site are typical of others, to assess the cost-effectiveness of CIR for the photo-interpretation, and to develop a sampling strategy.

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