OPERATIONAL CONTROL OF *DOTHISTROMA* NEEDLE
BLIGHT IN *RADIATA* PINE PLANTATIONS IN
NEW ZEALAND 1966 - 73

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Summary

An epidemic build-up of *Dothistroma* needle blight of pines in New Zealand has been controlled by a large scale fungicide aerial spray programme totalling more than 147 000 spray hectares during 1966-73. The organisation and application methods developed from research are outlined. Using a criterion of 25% defoliation before sprays were applied, control has been remarkable over this 7-year period and has surpassed that predicted from research trials. Copper-based fungicides at 2.24 kg copper (metallic equivalent) in 56 litres water/ha, applied once in November or December, have proved so successful that only 10.6% of 13 560 ha sprayed in one large plantation have required a second spray during these 7 years.

INTRODUCTION

Dothistroma pini, which causes a fungal disease of pine needles, is native to North America, Europe, and probably Japan. It also occurs (presumably introduced) in parts of Africa and South America.

The fungus attacks and kills pine needles, causing them to fall prematurely. The immediate effect of this reduction in photosynthetic leaf tissue is a gradual decline in vigour, which under some extreme circumstances may eventually cause the death of the whole tree.

This disease was found in New Zealand in 1964. When or how it had been introduced is not clear. It was first found in the central North Island, and it is mainly in this region that it has developed to epidemic proportions. Some commercial species of pine are more susceptible than others to this disease (Bassett, 1972). Of those grown in this country, Corsican pine (*Pinus nigra* Arnold laricio) and ponderosa pine (*P. ponderosa* Laws) are particularly susceptible, while lodgepole pine (*P. contorta* Dougl.) is more resistant. Radiata pine (*P. radiata* D. Don), the main commercial species, is highly susceptible as a young tree but is generally relatively resistant from the age of 15 years.

By 1966 it was estimated (Gilmour, 1967) that out of a total of 40 000 ha of infected pine plantations in New Zealand some 11 000 ha were severely infected.

Fungous Diseases of Trees and Vines

INITIAL TRIALS AND RECOMMENDATIONS

Gibson (1965: *et al.*, 1966) in Kenya showed that copper fungicides were effective against *Dothistroma pini*. Based on this finding, a comprehensive range of aerial spray trials has been conducted since 1965 by the Forest Research Institute, Rotorua (Gilmour and Noorderhaven, 1971; 1973).

The first schedule shown to be effective was cuprous oxide at the rate of 2.24 kg Cu metallic equivalent (m.e.) wettable powder (WP) in 56 litres water/ha, applied twice each growing season, once in December and again in February. This schedule was used in the first large scale operation in 1966-67, when about 12 000 ha of infected young radiata pine were sprayed. Since then, modifications to the schedule have been developed. These are shown in Table 1, with the estimated cost/ha/annum of each schedule for that part of the rotation when spraying may be required.

TABLE 1: RECOMMENDED SPRAY SCHEDULES 1966-73

Year	Cuprous oxide or Copper oxychloride kg Cu m.e.*/ha	No. of Applications Per year	Estimated Frequency of Applications	Approx. Cost‡ \$/ha/ann.
1966	2.24	2	annual	13.54
1967	2.24	2	biennial	6.77
1968	2.24	1	annual	6.77
1969	either 1.12 or 2.4	1	biennial	2.30
		1	triennial	2.25
1970 }				
1971 }	2.4	1	triennial	2.25
1972 }				
1973	2.4	1	?	?

*m.e. = metallic equivalent.

‡Cost based on average price of fungicide and aerial application 1966-72.

The 1.12 kg Cu/ha schedule recommended in 1969 has so far been applied to only about 2000 ha in 1969-70. Since this time, the dosage of 2.24 kg Cu/ha in 56 litres water/ha has been applied in November or December, whenever the defoliation level reaches 25% or more of the unsuppressed tree crown throughout a stand.

The above recommended spray schedules were costed for comparison using the average prices between 1966-72. The actual cost of controlling the disease over the life of one crop of radiata pine remains unknown. It will probably depend on the interaction of unpredictable factors, e.g., fluctuations in costs of fungicide and application, and the effect of weather on disease development. In addition, the spray criteria and dosage which are found necessary to prevent loss of growth are likely to be changed over the years. Thus, it is difficult to predict the frequency or cost of spraying from an analysis of the effectiveness and cost of the spray programme over the past 7 years. The analysis is, however, worth recording as an indication of the effectiveness of the spray programme so far.

Fungous Diseases of Trees and Vines

Table 2 shows that of the 13 560 ha of radiata pine sprayed in Kaingaroa State Forest only 10.6% of the area has required more than one initial treatment over the 7-year period. Furthermore, the time interval between sprays was 4 or 5 years for about 70% of the area resprayed. This indicates that probably only one or two spray applications may be necessary to control *Dothistroma pini* in each crop of radiata pine, instead of the three or four which had been predicted previously from research trial results.

TABLE 2: ANALYSIS OF RESPRAYED AREAS — RADIATA PINE
KAINGAROA STATE FOREST 1966-73

Interval between sprays (yr)	Area (ha)	As % of total area sprayed*	As % of total area resprayed
1	218	1.60	15.1
2	133	0.98	9.2
3	74	0.55	5.2
4	210	1.55	14.6
5	806	5.94	55.9
Totals	1441	10.62	100.0

* = Total area sprayed 13 560 ha 1966-71/72.

NOTE: Most of these resprayed areas have only received two sprays while 81 ha or 0.6% of the total area sprayed have received three applications with a 2-year interval between each application.

A spray schedule to control the disease on Corsican and ponderosa pines is still under investigation.

NATIONAL SPRAY PROGRAMME

Administrative organisation

In 1966, the forest owners decided on a national aerial spray programme to control *Dothistroma pini*. The decision was based on the recommendation of the Forest Research Institute. A "Dothistroma Action Committee" was formed, with representation from private forest owners and the N.Z. Forest Service (Management and Research Divisions), under a N.Z. Forest Service chairman. Its functions are to co-ordinate planning, including:

1. The organising of the letting of contracts for bulk purchase of copper fungicide and the aerial application;
2. Quality control of the whole spray programme.

Aerial spraying equipment and method

Before the spray operation, all aircraft are calibrated for effective swath width, spray pattern, and application rate. The spray equipment usually used is a boom and nozzle rig, mounted behind and below the trailing edge of the wing. Micronair rotary atomisers have also been used. The main aircraft used are S-2D Snobs or Cessna 188 Agwagons

Fungous Diseases of Trees and Vines

which fly at 176 or 193 km/h respectively, at a height of 5 to 10 m above tree top height. Other aircraft which have been used are Fletchers Fu 24/950 (400 hp), Pawnees, Airtrucks, Pipers, and Hughes and Bell helicopters.

To achieve minimum drift and maximum spray deposition, the following meteorological criteria have been used as a guide for the ground controllers. Spraying is usually unsatisfactory when:

1. Wind speed exceeds 8 km/h;
2. Temperature exceeds 20°C;
3. Relative humidity is less than 45%.

Spraying is, however, continued beyond these limits, providing spray recoveries are satisfactory.

These criteria are currently under critical investigation by scientists of the New Zealand Institute of Agricultural Engineering, in co-operation with the Forest Research Institute, forest owners, and the aircraft industry.

Disease appraisal

The annual application of copper fungicide is based on a standardised disease rating of the tree crown. A radiata pine stand is scheduled for spraying when the normal green crown of the majority of the trees is at least 25% infected. Assessment is based on a standardised series of colour photographs of diseased trees, showing infection rating from 0 to 100%. The rating for Corsican and ponderosa pines is currently under investigation.

All infected plantations are inspected from the air in July each year. When necessary, ground surveys are made to confirm the aerial disease rating. This annual disease intensity survey, along with a detection survey, is mainly conducted by a specially trained team of Forest Biology Observers from the Forest Research Institute, who are assisted by field foresters. This service is available to all forest owners (Bassett, 1972), and has been used widely.

Aerial spraying — Quality control

From the results of these surveys the area to be sprayed is determined by the forest manager. After collating the national spray returns, the Dothistroma Action Committee then organises the contracts for both the fungicide and the aerial application.

For some years a New Zealand formulated cuprous oxide WP has been used. In the 1972-73 programme, however, an imported copper oxychloride WP was applied because it was a superior formulation, less costly, and had been shown to be as effective as cuprous oxide (Gilmour and Noorderhaven, 1973).

All copper-based fungicides used in these operations must comply with a stringent specification:

Formulation WP complete with sticker and spreading agents.
Copper content 50 ± 2% Cu m.e.

Suspensibility 80% by Geigy Standard Method No. 23. The fungicide must also retain this suspensibility when subjected to the C.I.P.A.C. accelerated storage test, No. M.T. 46.1.1 (Raw, 1970).

Fungous Diseases of Trees and Vines

Particle size (a) Passing 300 BS sieve 99.9%; (b) 5 microns, or less 90%; (c) 3 microns, or less 70%.

Field control is the responsibility of an airstrip controller and a spray-area ground controller. Two spray-area ground controllers are required for each aircraft, but one airstrip controller can organise up to four aircraft.

The airstrip controller supervises the mixing of the fungicide and is also responsible for briefing the pilot and staging of aircraft to the ground controller, with whom he must be in radio communication.

Before spraying commences, aerial photographs of each compartment* to be sprayed are marked, using a template (Appendix I). The pilot uses this photograph to locate and inspect the compartments, and to orientate himself with flight patterns. During spray operations, he makes this inspection on his last "empty" return flight from the previously sprayed compartment.

On the reverse of the aerial photograph are recorded:

1. Compartment no. and area;
2. Compartment area to be sprayed;
3. Total quantity of spray mixture required;
4. Load volume and number (adjusted in practice so that flight lines start and finish on a compartment edge);
5. Number of flight lines per area and per load.

Once spraying has been completed the pilot returns the aerial photograph to the airstrip controller.

The ground controller is responsible for monitoring weather conditions by means of meteorological instruments and checking on the effectiveness of the spray pattern falling within the designated spray area. This is achieved by laying out in the open (along roads and tracks) at least one line of paper spray traps at 15 m intervals across each compartment and at right angles to the line of flight. The spray patterns obtained are checked against a minimum acceptable standard spray pattern (Appendix II) which has a mean recovery dosage rate of *ca.* 0.3 kg Cu m.e./ha. If the spray deposit is below the acceptable minimum over 30 m or more (two consecutive traps) this area is resprayed immediately and the extra flying cost is borne by the aircraft operator. Because of the expertise of the pilots, however, respraying is seldom necessary. Immediately after spraying all spray traps are recovered, marked and numbered, and later sent to the Forest Research Institute for analysis.

Spray recoveries

In both trial and operational applications, the total copper recoveries on ground traps have been measured in terms of kg/ha and stain droplet size. In trial work at 1.5 to 3 km/h wind speed, and at a flying height of 1.3 m and 10 m, the spray patterns for single swaths have been characterised in detail for the boom and nozzle rig. The spray distribution pattern was decidedly skewed for the 10 m elevation, but from 1.3 m there was a reasonably normal distribution pattern. Multiple trial swaths

*A manageable subdivision of a forest into areas usually > 100 ha, generally delineated by roads, fire breaks, or topographical features.

Fungous Diseases of Trees and Vines

patterns have given recoveries of up to 1.7 ± 0.17 kg Cu/ha or about 70% recovery. In the 1970/71 operational spraying programme recoveries from boom and nozzle sprayers were lower: the Cessna 188 Agwagons gave a mean recovery rate of 0.96 ± 0.06 kg Cu/ha while Aero Commander Snow aircraft gave a mean recovery rate of 0.74 ± 0.07 kg Cu/ha at the 95% confidence level. These estimates, which were obtained from an analysis of 17,500 ground traps, were only about 30-40% of the nominal copper dosage (2.24 kg Cu/ha).

Micronair rotary atomisers were used between 1966-1968 in some areas and gave comparable total copper recoveries in operational work although the droplet spectrum was narrower and finer than the medium-fine, wide droplet spectrum of the boom and nozzle rig. However, because of heavy wear on the ball valves by the abrasive cuprous oxide formulation, this equipment was abandoned in 1969.

Spraying programme

Table 3 lists the annual spray areas (area x number of applications) by tree species for the period December 1966 to February 1973.

TABLE 3: ANNUAL SPRAY AREA BY TREE SPECIES
DECEMBER 1966 — FEBRUARY 1973

Year	<i>radiata pine</i>	Species	All species
		<i>ponderosa pine & Corsican pine</i>	
	ha	ha	ha
1966/67	29 583	2 875	32 458
1967/68	18 885	2 864	21 749
1968/69	10 727	—	10 727
1969/70	11 582	—	11 582
1970/71	9 692	—	9 692
1971/72	31 044	912	31 956
1972/73	17 061	11 789	28 850
Total	128 574	18 440	147 014

Aircraft logistics

In most of the annual spray programmes, 12-15 aircraft operated by two large companies were used to be reasonably sure of completing the programme in the 6-week period from 1 November. One of the most efficient programmes was in 1972 when most of the spraying was completed in the first 19 days of November.

This 19-day programme used four aircraft (three S-2D Snows and one Fletcher Fu 24/950 (400 hp) and sprayed almost 6000 ha of pine in Kaingaroa State Forest. Analysis of the programme showed that:

1. Aircraft utilised 47 out of the possible maximum of 76 aircraft days (no. calendar days x no. of aircraft hired);
2. Mean area sprayed/aircraft/ flying day = 126 ha;
3. Mean hours flown/aircraft/working day = 2.4 h;

Fungous Diseases of Trees and Vines

4. Mean area flown/flying hour = 52 ha.

It is usual under New Zealand flying conditions to allow about 2200 ha/aircraft over the whole 6-week period. The above programme was therefore better than estimated.

Frequency and cost of spray application

Current research and field operational trends indicate that, with radiata pine, one spray of copper fungicide at the rate of 2.4 kg Cu m.e. in 56 litres of water/ha gives effective control for at least 3 to 4 years. However, large areas of new plantings are proposed up till the turn of the century, and so increasing areas of control spraying are envisaged.

In 1970 the cost of control was estimated (New Zealand Forest Service, 1970; Sutton, pers. comm.) after assuming a compound interest rate of 7%, only four fungicide applications per rotation, and a fungicidal application dosage rate of 2.24 kg Cu m.e. in 56 litres water/ha applied in November or December. The estimated cost of one application in 1969-70, which included only the cost of aerial application and fungicide, was \$7.17/ha. Relating this to wood production and conversion factors, it was shown that the additional compounded cost in growing trees on a short rotation (26 year) sawlog regime was equivalent to about 38c/m³ (9c/100 bd ft) sawn output, or a little more than 1% of the average ruling wholesale price. For trees grown on a pulpwood regime (22 year rotation) the compounded cost of spraying was equivalent to about 17.5c/m³ (0.5c/ft³), or about 60c/tonne of newsprint which was about 0.4% of the average ruling f.o.b. price for newsprint at that time.

So far, the cost of controlling this disease by aerial spraying with copper fungicides is likely to have been less than half these values.

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APPENDIX I

(A/C = aircraft)

APPENDIX II

DOTHISTROMA CONTROL — ACCEPTABLE MINIMUM SPRAY PATTERN

Spray equipment — Aerial mounted boom and nozzle rig.

Fungicide — Cuprous oxide, 50% Cu metallic equivalent (m.e.) wettable powder.

Nominal dosage — 2.24 kg Cu m.e. in 56 litres/ha.

Minimum dosage — 0.3 kg Cu m.e./ha.