REDUCING THE FREQUENCY OF SEEDLING MALFORMATIONS IN PINUS RADIATA NURSERIES BY THE APPLICATION OF INSECTICIDES

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ABSTRACT

The results of three trials undertaken in consecutive years in the Forest Research Institute Nursery, Rotorua, gave strong support to the hypothesis that **Thrips tabaci** Lindeman is the cause of needle crinkling and multileadering in **Pinus radiata** D. Don seedlings in forest nurseries. Fortnightly applications of an insecticide led to a reduction in the number of thrips present on the seedlings, and a reduction in the number of seedlings becoming multileadered. The lowest incidence of malformation occurred in beds of seedlings which had been sprayed at fortnightly intervals with 10 g deltamethrin in water using a spray volume of 100 *l*/ha.

Keywords: seedling malformation; multileadering; **Thrips tabaci**; **Pinus radiata**.

INTRODUCTION

In a survey of New Zealand forest nurseries growing *Pinus radiata,* it was found that only 50% to 60% of the seed sown produces what is considered to be a plantable seedling (A. R. D. Trewin, pers. comm.). Malformation of the seedlings, usually multileadering, was the most common reason for rejection, even though multileadering has no significant effect on the seedling when planted in the forest (Burdon & Bannister 1973). In some nurseries as much as 30% of the seed sown yields multileadered seedlings.

At the time this trial was initiated, the yield of genetically improved seed from seed orchards was not great enough to satisfy the sector's planting requirements with losses of this magnitude occurring in the nurseries.

The term "malformation" in this paper is used to cover a wide range of symptoms from the presence of a single primary needle which has either a single kink or several kinks along its length (a crinkled needle), to the loss of apical dominance in extreme cases, with the proliferation of lateral buds, leading to the production of a multileadered seedling.

The event which causes a needle to become kinked occurs before needle elongation and the effect becomes apparent only as the needle elongates out of the cluster of immature primary needles that constitute the apical tuft. When most of the primary needles in the terminal region become crinkled, they fail to elongate fully and become short, fat, and glaucous in appearance.

In nurseries where the incidence of crinkled needles was low the incidence of multileadering was also low, but where the incidence of needle crinkling was high so too was the incidence of multileadering.

The above symptoms were first described by R. D. Burdon (unpubl. data) who tried unsuccessfully to correct the condition by top-dressing the nursery beds with a fertiliser containing boron. In 1983, malformed seedlings from Eyreton Nursery in Canterbury were found to have *Thrips tabaci* present amongst the primary needles in the apical tuft (R. Zondag, unpubl. data). The same insect was thought to be associated with a similar nursery problem in Chile (R. D. Burdon, pers. comm.).

The association of this problem with the presence of thrips was further strengthened by a report from a nurseryman from Nelson. When Weedicide 18, a herbicidal oil, was used to control summer grass, malformed seedlings were uncommon but when nurseries changed to using water-based herbicides instead of the oil, seedling malformation appeared to become a problem. When the oil-based Weedicide 18, which has some insecticidal properties, was again used the number of malformed seedlings again decreased (E. Appleton, pers. comm.).

A series of trials was undertaken in three successive years to see whether spraying with insecticides would reduce the incidence of malformation, whether thrips could be found on the seedlings and if their numbers were affected by spraying, whether seedlings which showed signs of needle crinkling ultimately became multileadered, and to select the most effective insecticidal treatment.

METHODS

Location

All the trials were located in the FRI Nursery, Rotorua. The seed was precision sown in standard nursery beds, each containing eight drills. The beds were treated with fertiliser and herbicides and the seedlings sprayed with fungicides according to the normal prescription laid down for growing 1/0 *P. radiata* seedlings.

Plot Layout

In the first trial (1984–85) each treatment was applied to a single block comprising three adjacent beds 60 m long, using a standard tractor-mounted boom to apply the insecticides. Each block was separated from its neighbour by a buffer zone of two beds which were not sprayed with insecticide. In this trial 20 plots were located at random in each block. The size of each plot was such that the six central drills contained approximately 40 seedlings. As the seedlings were precision sown it was possible to identify individual seedlings within the plot over the period of the trial.

In the second trial (1985–86) the area (approx. 0.15 ha) was divided into two halves prior to sowing. One half was treated with phorate granules at a rate of 2.2 kg a.i./ha, whilst the other half was left untreated. As soon as the phorate treatment was complete, the seed was sown and the rotary-hoe of the bed former was used to incorporate the phorate. The treatment plots were laid out in a randomised block design with four replicates in the phorate-treated half of the area and four in the untreated half. The plots were 5 m long, each being separated along the bed by an unsprayed section of bed.

The beds which contained the plots were always separated from each other by two beds which contained no plots. The insecticide was applied using a specially designed plot sprayer mounted on a tractor.

In the third trial (1986–87) a randomised block design was used with each treatment replicated four times. The plots, which were again 5 m long, were sprayed using the equipment as in the previous year.

Spray Application

In the first trial the insecticide was applied in a total spray volume of 500 *l*/ha using a boom pressure of 275 kPa, a tractor speed of 1 m/s, and F3-80 flat fan nozzles (Delavan). The second and third trials were sprayed using a total spray volume of 100 *l*/ha, a boom pressure of 205 kPa, a tractor speed of 1 m/s, and 730077 flat fan nozzles (Spraying Systems Ltd).

Insecticide Treatments

All treatments were applied at fortnightly intervals starting when 50% of the crop was judged to have emerged and ceasing when the first undercut was made. Assessments ceased at the time of undercutting because this cultural practice can and frequently does change the positions of the seedlings within the bed making it difficult if not impossible to identify specific seedlings.

1984–85 Trial 1

(a) Control – no spray
(b) SunSpray oil 20 *l*/ha
(c) SunSpray oil 20 *l*/ha plus fenitrothion 0.6 kg a.i./ha

1985–86 Trial 2

All insecticide sprays contained Multifilm X-90 at a rate of 80 ml/100 *l* spray.

(a)	Carbaryl (Sevin WP)	750 g a.i./ha
(b)	Dimethoate (Rogor EC)	350 g a.i./ha
(c)	Chlorpyriphos (Lorsban WP)	800 g a.i./ha
(d)	Methamidophos (Tamaron SL)	900 g a.i./ha
(e)	Diazinon (Diazinon EC)	750 g a.i./ha
(f)	Deltamethrin (Decis EC)	12.5 g a.i./ha
(g)	Fenitrothion (Verthion EC)	600 g a.i./ha
(h)	Acephate (Orthene SP)	900 g a.i./ha
(i)	Control – no spray	

1986–87 Trial 3

(a)	Deltamethrin (Decis EC)	10 g a.i./ha
(b)	Deltamethrin (Decis EC)	10 g a.i./ha plus SunSpray oil 4 *l*/ha
(c)	Deltamethrin (Decis EC)	10 a.i./ha plus Multifilm X-90 80 ml/ha
(d)	Control – no spray	

Assessments

Trial 1

Seedling condition: The condition of each seedling in each of the assessment plots was recorded at weekly intervals using the following categories – dead, crinkled needles, apical abortion, multileadering, tortricid damage, or normal.

Thrip counts: Ten seedlings showing recent signs of needle crinkling were removed from each block, from areas not within an assessment plot, at fortnightly intervals starting when the seedlings were approximately 5 cm tall. In addition, 10 normal seedlings were removed from the unsprayed block. The seedlings were carefully dissected under a binocular microscope and the number of thrips counted.

Seedling quality: All the seedlings in the assessment plots were lifted in May 1985. The height of all the seedlings was measured, and whether the seedling was multileadered or not was recorded. A seedling was considered to be plantable if it had a single leader and was taller than two-thirds of the average height of the seedlings in that block.

Trial 2

Seedling quality: Fifty seedlings were lifted from each assessment plot and their height and whether they were multileadered or crinkled were recorded.

Trial 3

Seedling quality: The seedlings in the assessment plots were examined and classed as having or not having crinkled needles in February 1987. In May of the same year 250 seedlings were lifted from the middle six rows of each treatment plot, the height and root collar diameter were measured, and whether or not they were multileadered or crinkled was noted.

RESULTS

Trial 1

Of the 625 seedlings assessed in the unsprayed block, 563 or 90% of them showed signs of crinkled needles and of these 127 became multileadered at some stage (Table 1). Sixty-one seedlings were attacked by tortricid caterpillars, 23 of these seedlings also became multileadered and almost half of those also had crinkled needles. Although spraying the seedlings with oil or with oil plus fenitrothion only slightly reduced the number of seedlings with crinkled needles, the number subsequently becoming multileadered was approximately halved, the reduction being greatest in the block sprayed with the oil plus fenitrothion. Of the 299 seedlings which failed to show any sign of crinkled needles, only seven became multileadered. The number of thrips on the seed-

TABLE 1–Status of the seedlings in the 1984–85 trial. The numbers quoted indicate the condition of the seedling during the trial and not necessarily at the time of lifting.

Treatment	No. seedlings	No. with needle crinkle	No. multileadered after needle crinkle	No. with tortricid damage	No. multileadered after tortricid damage
Control	625	563	127	61	23*
Oil	622	552	65	55	6*
Oil + fenitrothion	582	415	63	7	1†

* 50% of these seedlings also showed signs of attack by thrips so are included both as multileadered after needle crinkle and also as after tortricid damage.

† This seedling was also attacked by thrips.

lings was relatively small (Table 2). The highest numbers were found on the unsprayed seedlings with crinkled needles. Spraying reduced the number of thrips found, the greatest reduction being in the seedlings sprayed with the oil plus fenitrothion. On one seedling, a thrip was seen rasping on a primary needle producing an oval wound. This needle was also observed to start bending around the point of the wound. It was noted that the damage was similar in shape to the scar on fully expanded kinked needles. Seedling condition at the time of lifting is summarised in Table 3. The highest number of culls was found in the unsprayed block, but of these only approximately 4% were culled because of lack of height, the rest were multileadered. In the block sprayed with oil alone the number of culls was reduced; again, approximately 4% were culled because of lack of height, the rest because of multileadering. The fewest culls were found in the block sprayed with oil plus fenitrothion, where again approximately 4% failed to satisfy the height criterion. The seedlings sprayed with oil alone or in combination with fenitrothion exhibited a yellow tinge which made them appear unhealthy, although this condition did not significantly affect height growth.

TABLE 2–Percentage of trees infested with thrips and their overall abundance 1984–85. The figures are based on 15 samples of 10 trees per group.

Treatment	Seedlings with thrips (%)	Average No. thrips per seedling
Control	53	1.2
Control no damage	27	0.38
Oil	42	0.57
Oil + fenitrothion	18	0.19

TABLE 3–Seedling quality at lifting 1984–85

Treatment	Height (cm)	Plantable (%)	Culls* (%)	Multileadered (%)
Control	34.9	73.5	26.4	22.8
Oil	29.2	82.6	17.4	13.7
Oil + fenitrothion	36.2	88.4	11.6	6.7

* Culls include seedlings which are multileadered and also those which do not meet the height requirement of being in excess of two-thirds the average height for that treatment.

Trial 2

Although the incidence of crinkled needles was low in this trial, spraying with deltamethrin resulted in the production of seedlings which were significantly taller than those from any other treatment (Table 4). Together with the low incidence of crinkled needles there was also a low incidence of multileadering. Although the numbers were too low to use statistical tests on, the lowest incidence of multileadering occurred in the deltamethrin treatment, the one with the tallest seedlings.

The incorporation of phorate did not reduce the incidence of needle crinkle or multileadering. The results from the phorate-treated and non-treated sections of the trial have been combined in Table 4. A slight, but not significant, decrease in height was seen in the area treated with phorate.

TABLE 4–The effect of insecticide spraying on seedling height and the frequency of multileadering 1985–86

Treatment		Height (cm)	Multileadered (%)
Dimethoate	350 g a.i./ha	21.5 a	2.6
Diazinon	750 g a.i./ha	21.7 a	3.1
Control	no spray	22.8 ab	4.3
Carbaryl	750 g a.i./ha	23.3 ab	2.3
Acephate	900 g a.i./ha	23.6 ab	3.0
Methamidophos	900 g a.i./ha	23.7 ab	1.1
Chlorpyriphos	800 g a.i./ha	23.7 ab	2.1
Fenitrothion	600 g a.i./ha	24.0 b	2.1
Deltamethrin	12.5 g a.i./ha	26.4 c	0.9

Heights bearing the same letter are not significantly different (p=0.05 Duncan's Multiple Range Test). The number of trees becoming multileadered was too small for statistical analysis.

Trial 3

In this trial the percentage of the unsprayed seedlings showing needle crinkling (Table 5) was similar to that in Trial 1. The final percentage becoming multileadered was also similar. Spraying with deltamethrin alone or in combination with oil or Multifilm significantly reduced both the percentage of seedlings becoming multileadered and the number with crinkled needles, and at the same time led to increased height growth. The greatest height growth occurred in the plots sprayed with deltamethrin alone.

TABLE 5–Seedling quality at lifting 1986–87. The result of fortnightly applications of deltamethrin with and without spray additives

Treatment	With crinkled needles (%)	Height (cm)	Multileadered (%)
Control	89.5 a	28.2 a	15.1 a
Deltamethrin	10.1 c	33.7 c	2.9 b
Deltamethrin + oil	18.0 b	32.4 b	2.3 b
Deltamethrin + X-90	12.8 c	31.6 b	2.4 b

Figures in the same column bearing the same letter are not significantly different (p = 0.05 Duncan's Multiple Range Test).

DISCUSSION

Although it has not been possible to prove conclusively that the malformations described in the introduction are caused by thrips, there is strong circumstantial evidence to point to their involvement.

Firstly, the type of damage that a thrip was observed to cause on a primary needle under the microscope is the same as that seen on expanded primary needles in the axis of a kink.

Secondly, in the first trial when there was a decrease in the number of thrips as a result of spraying, a reduction in the number of multileadered seedlings was also observed. In this trial, in the unsprayed block only one in every 43 of the seedlings

which showed no sign of needle crinkling (299 in all) became multileadered, whereas one in four of the seedlings showing needle crinkling (1530 in all) became multileadered. Thus, the chance of a seedling becoming multileadered is 10 times greater for a seedling with crinkled needles, a sign of thrip attack, than for a seedling with normal needles.

Thirdly, in the second trial when the incidence of needle crinkling was very low (so low, in fact, that at one time the authors considered abandoning the trial) the incidence of multileadering was also extremely low. In this trial, the rainfall during January was three times higher than that during the same month in either of the other two trials. The rainfall during the other months was similar in all trials. Thrip counts made during the first trial were always lower after periods of heavy rain. This observation could well explain why the incidence of multileadering is much greater in the drier South Island nurseries.

Phorate was incorporated pre-sowing in the hope that it would protect the seedlings when they first emerged prior to the first spray application. The results would suggest that no significant amount of damage occurred prior to the time of the first insecticide application.

It should be noted that thrips were found on unsprayed seedlings, which were showing no signs of needle crinkling, in Trial 1. Their presence does not negate the argument that thrips are responsible for causing needle crinkle because this condition is a historical record of their presence.

Multileadering can occur after attack by tortricid caterpillars but the damage on the seedling is quite distinct from the needle crinkling more commonly observed. Treatment with insecticides controlled the caterpillars completely but did not prevent the occurrence of needle crinkling or multileadering.

Seedling height was increased by spraying with deltamethrin. Even in the second trial, when the incidence of both needle crinkling and multileadering was low, fortnightly applications of deltamethrin significantly increased height growth. Whilst this is of no practical importance in Rotorua, the boost to growth could be important in nurseries where difficulty is experienced producing seedlings which are large enough to plant.

CONCLUSIONS

Fortnightly applications of deltamethrin at a rate of 10 g a.i./ha in the form of an emulsifiable concentrate will reduce the multileadering of *P. radiata* seedlings in forest nurseries when applied in a total spray volume of 100 *l*/ha using 730077 flat fan nozzles and a pressure of 205 kPa.

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REFERENCE

BURDON, R. D.; BANNISTER, M. H. 1973: The significance of forks and multileaders in nursery stock of **Pinus radiata**. **New Zealand Journal of Forestry 18(1)**: 133–40.