Chemical thinning of radiata pine

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Abstract

New Zealand trials using metsulfuron (Escort) and glyphosate (Roundup) for chemical thinning of radiata pine have shown little indication that chainsaws are likely to be replaced as a method of thinning-to-waste. New chemicals, or new formulations of the same chemicals, could reverse this conclusion. In the meantime, chemical thinning-to-waste may have application in very limited situations, including regeneration or wilding control.

Keywords: EZJECT, chemical thinning, poison thinning, thinning, glyphosate, metsulfuron, *Pinus radiata*.

Introduction

In New Zealand, it is standard practice to thin trees to waste with a chainsaw. Chemical thinning was researched extensively in the 1950s and 1960s, using the chemicals then available (ammate, sodium arsenite), but was widely rejected as a tool (Beveridge and Hedderwick 1962; Hedderwick 1966; Tustin 1969; James *et al.* 1970; numerous and various FRI unpublished work). In some other regions of the world (e.g. Queensland, United States) herbicides are still often used to reduce stockings to prescribed levels and to remove undesirable tree species. Methods of chemical application include:

- "hack and squirt" with a modified hatchet and vaccinator gun;
- the Sylvaxe Hypo-Hatchet, a custom-designed tool that uses the same principle as above;
- the FIC (Forestry Injection Company) hammer and plug system;
- the motorized drill and injection system;
- the Jim-Gem tree injector;
- the Monsanto EZJECT lance (Figure 1). This may have largely superseded other methods, as is discussed later.

Using the EZJECT lance

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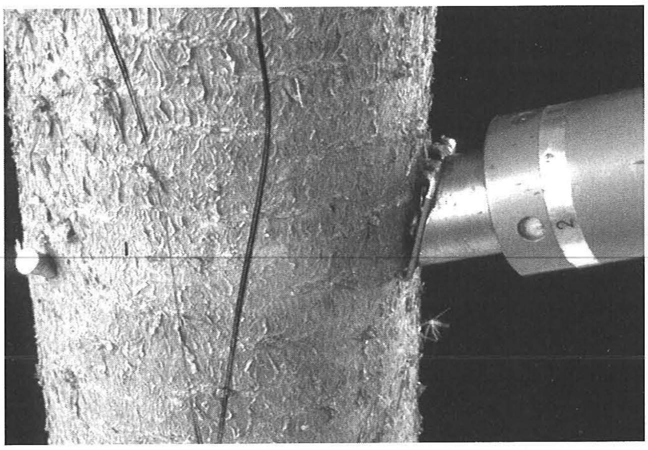


Stem showing Roundup capsules injected into cambium

Some chemicals that have been used or proposed include:

- Sodium arsenite
- Ammonium sulphamate (Ammate)
- Sodium chlorate
- Hexazinone (Velpar)
- Imazapyr (Arsenal)
- Chlorsulfuron (Glean)
- Metsulfuron (Escort)
- Glyphosate (Roundup, Trounce)
- Triclopyr (Grazon)
- 2,4 D
- Picloram amine + triclopyr (Tordon)

There are several reasons for wishing to find an alternative to chainsaws. Chemical thinning has the potential to reduce chainsaw accidents, as well as eliminate noise and strain injuries. It may be cheaper, as unskilled operators can be employed, and there are no chainsaw purchase or maintenance costs. It is not yet known whether there are savings in man-hours per hectare. It may be more effective at killing trees in situations where stony ground prevents cutting below the lowest green branches. Dead standing trees, rather than felled trees, may enable the remaining crop to stabilise against wind after a thinning operation. The absence of slash may reduce the hindrance for subsequent silviculture or understorey grazing, and may have implications (positive or negative) for fire risk.

Although the potential benefits of chemical thinning appear compelling, there are several major drawbacks. The first is that it is not usually 100% effective. While a 95% kill rate may be sufficient for silvicultural purposes, an incomplete kill may be unacceptable for aesthetic reasons. Trees in various stages of death do not give the impression of a healthy forest. Indeed, even the presence of dead standing trees may generate a strong negative reaction from the general public, or by shareholders of a forest company. Delayed death is problematical, in that it may be hard for operators to see where they have just been, and even harder for quality control personnel to identify treated areas. With conventional thinning to waste, crop trees respond rapidly to the increased light, moisture and nutrients, but this effect could be muted with death that occurs over a prolonged period.

Two criticisms of chemical thinning that are often raised by foresters are "flashback", or translocation of chemical via root-grafting to non-target trees, and safety hazards from dead spars. As will be discussed, these are probably not an issue with modern chemicals and silvicultural regimes.

A final drawback, which may be of great importance, is the build-up of pathogenic organisms on poisoned trees. With chainsaw thinning, cull trees die and decay quickly. Saprophytes quickly occupy the wood. Trees which die slowly may become colonised by parasites, which can then spread to adjacent healthy crop trees. Van der Pas (1981) noted that *Armillaria* root-rot was disproportionately present in second-rotation stands that had been poison-thinned during the first rotation. (The large size and slow death of the poison-thinned trees may be relevant, and may contrast to current practice).

An examination of this early literature showed four major reasons for the dissatisfaction that culminated in the general abandonment of chemical thinning:

- some of the poisons used (eg. arsenic) were toxic to people as well as to trees;
- the chemicals were sometimes ineffective, or ineffective within an acceptable time frame;
- the standing spars persisted for years, posing a safety hazard. (Possibly because the chemicals used also acted as wood preservatives, and because the timing of waste-thinning in earlier trials was substantially later than currently practised);
- the poison often killed, or impaired the growth of, crop trees through root-grafting;
- as the effects of poison thinning were not immediate, the operation was hard to supervise.

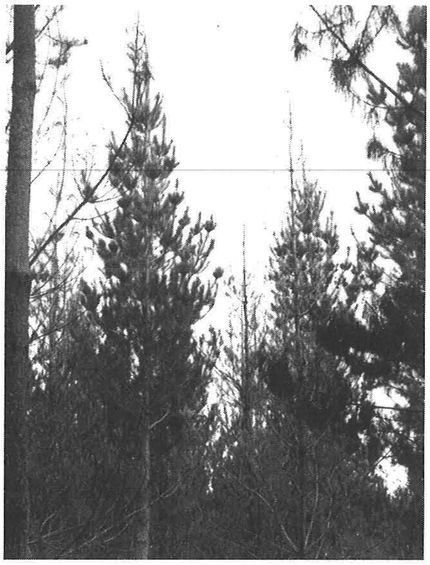
Background to recent trials in New Zealand

a) The Tasman trial at Tauhara

Following Cyclone Bola in 1988, Tasman Forestry requested the NZ Forest Research Institute (FRI) to investigate ways of reducing windthrow following delayed thinning. Downturns in pulpwood demand periodically resulted in stands that had been scheduled for production thinning being thinned to waste. FRI suggested that, if it were possible to kill the trees but leave them standing, the remaining trees would have time to stabilise against wind.

FRI was contracted to install a trial to assess different methods of thinning. The four treatments (unreplicated) were: chainsaw thinning control; poison thinning with metsulfuron herbicide (using "hack & squirt" at 0.13 g active ingredient per notch, notch centres 15 cm apart horizontally); ring-barking with a modified chainsaw head; and "strap-thinning" using 1 cm cold rolled steel strapping. This trial was established in September 1990 at Tauhara Compartment 1/1, near the Tasman headquarters. The trees were 9 years old, had been selectively pruned, and averaged 20.4 cm dbh (Figure 3).

The only effective non-chainsaw treatment was the poison thinning, which attained 100% mortality within three months, with no apparent adverse effects to the crop. The decay of the spars (mean DBH 19.3 cm, PMH 15.5 m) was monitored subsequently. After 4 years, 65% of dead trees had collapsed, and this figure increased to 100% after 7 years. Even in the earlier years, the spars could not be considered a serious safety hazard in view of their small size. Any "hangups" on neighbouring trees was restricted to the outer parts of branches of crop trees and in any case did not persist.



The Tauhara trial, one year after treatment. Crop element is unaffected by herbicide and resistant to windthrow

b) The Forestry Corporation trial at Kaingaroa

Encouraged by the success of the Tasman trial, a contract was negotiated with the Forestry Corporation of NZ to establish a 5 ha trial in Kaingaroa in October 1993 with a number of dosage-related treatments. All treatments involved metsulfuron using "hack & squirt". In the main trial (Compartment 429) trees averaged 13.5 cm DBH and 7.0 m MCH. In the step-out treatment (Compartment 945) trees averaged 21.8 cm DBH and 21.9 m MCH. Table 1 provides further detail. The main results are given in Table 2.

TABLE 1
Kaingaroa chemical thinning trial: Treatment details

Treatment	Compartment	Number of Replicates	Concentration of Escort (g l^{-1}) (1 ml per notch)	Number of notches
1	429	4	0	None (chainsaw control)
2	429	4	30	Every 15 cm circumference
3	429	2	30	One only
4	429	2	15	Every 15 cm circumference
5	429	2	15	One only
6	945	1	30	Every 15 cm circumference
7	429	1	30	Every 15 cm circumference but above lowest green whorl
8	429	1	30	Every 15 cm circumference but applied in Autumn

After the first year the trial was abandoned and a second "follow up dose" was applied to most plots in order to tidy the site (given the ugly appearance of so many dead and dying trees). The mortalities for years 2 and 3.5 should not therefore be assumed to be the likely result of a single application. Treatments 7 and 8 received only the initial dose, as did two of the four plots in treatment 2. The mortality in these latter two plots averaged 86.7% and 90.0% after 2 and 3.5 years respectively.

TABLE 2
Kaingaroa chemical thinning trial: Results

Treatment	After one year. Percentage morbidity	After 2 years. Percentage mortality	After 3.5 years. Percentage mortality
1	100.0	100.0	100.0
2	74.2 a	90.0	95.0
3	32.2 bc	85.0	93.3
4	41.0 b	90.0	96.7
5	11.7 c	71.7	85.0
6	86.7	n/a	85.0
7	25.0	43.3	63.3
8	0.0	26.7	56.7

Where: Statistically indistinguishable numbers share the same subsequent letters (part of column 2 only)
"Morbidity" describes trees that are dead, that have only a few green needles remaining, or that have lost over half their green crown, show no signs of new growth and are likely to die.
"Mortality" describes trees that are totally dead, with no sign of life.

The mortality figures may seem to indicate a somewhat satisfactory result, but the 10% survivors constitute a conspicuous eyesore. Trees often have branches that appear perfectly healthy, and are gradually erecting themselves to become a new stem. If several branches remain, the result is a "stag's head". In a tightly stocked stand, however, most of the surviving poisoned trees are likely to be suppressed before harvest because their height has been severely compromised.

New work

The Eyrewell trial: Background

In the United States, earlier methods of chemical thinning have been replaced by the EZJECT lance, according to Weyerhauser and Monsanto (the manufacturers of the lance). The EZJECT system uses an aluminium rod that is loaded with 400 brass cartridge cases (.22 calibre) filled with glyphosate gel. The user stabs the base of the tree (no great force is necessary) and one or a number of the cases are inserted around the circumference to penetrate to the cambium. The glyphosate then leaches out slowly.

TABLE 3
Eyrewell chemical thinning trial
Treatment details

Treatment number	Capsules per tree	Orientation of capsules relative to eachother	Number of 20-tree plots with this treatment
1	None	n/a	2
2	1	n/a	1
3	2	Horizontal	1
4	2	Vertical	1
5	3	Horizontal	2
6	3	Vertical	2
7	4	Horizontal	1
8	4	Vertical	1
9	5	Horizontal	2
10	5	Vertical	1
11	5	Horizontal, above lowest whorl	1

The Eyrewell trial, one month after treatment, showing a distinct, but patchy response. Crop trees were unaffected.

With Public Good Science funding, and a 2 ha site at Eyrewell Forest (Compartment 2) provided by Carter-Holt-Harvey, the EZJECT system was tested for waste-thinning of radiata pine. The stand had a mean DBH of 7.9 cm and a MCH of 6.1 m. Treatments involved different numbers of capsules per tree (1 to 5 capsules), horizontal or vertical application (horizontal is where the capsules are distributed evenly around the circumference, and vertical is where they are one above the other), and application above and below the lowest green whorl. The trial was established in November 1995 and data were collected for the following two years. Table 3 gives details of the treatments.

The Eyrewell Trial: Results

Although all trees treated showed effects of glyphosate after only one month (dead leaders) (Figure 4), it was six months before the first tree was totally dead. After two years, trees were still dying. The overall mortality even after two years was disappointing, and substantially lower than that obtained with metsulfuron at Kaingaroa. Results are given in Table 4.

TABLE 4
Eyrewell EZJECT trial
Percentage morbidity and mortality after 2 years

Number of capsules	Percentage morbidity	Percentage mortality
1	20.0	6.7
2	30.0	6.7
3	53.3	3.3
4	56.7	13.3
5	80.0	31.7

where: "Morbidity" describes trees that are dead, that have only a few green needles remaining, or that have lost over half their green crown, show no signs of new growth and are likely to die.
"Mortality" describes trees that are totally dead, with no sign of life.

More detailed ANOVA analysis on the Eyrewell trial confirmed the manufacturer's recommendation that it was more effective to administer the doses around the circumference horizontally than in one position vertically (P=0.02), but that it appeared to make no difference whether the capsules were applied above or below the lowest whorl. Smaller, or least vigorous, trees were disproportionately affected by the chemical (P=0.0001), and were easily killed. This may indicate that the technology has potential for control of regeneration or wilding trees.

A rough indication of the degree of mortality or morbidity (ie very unthrifty trees) can be gauged from regression equations based on the trial (Table 5).

TABLE 5
Regression predictors of percentage morbidity and mortality after 2 years

Orientation of capsules	Percentage morbidity	Percentage mortality
Vertical	11.9 * b	1.1 * b
Horizontal	18.4 * b	6.5 * b

where b = dosage rate (number of EZJECT capsules)

There was no evidence of any "flashback" in that chainsaw thinned crop trees grew no faster in basal area or height than crop trees in chemical-thinned plots. Crop trees in chemically thinned plots grew the same regardless of the dosage of chemical that had been applied to their culled neighbours. Moreover, there were instances where two trees were planted in the same hole, or a tree forked at a low height above the ground. When only one of these stems was treated, the other appeared to be unaffected.

Although the majority of chemically treated trees did not completely die, even after 2 years, neither did they demonstrate good growth. Only 6% of treated trees showed any basal area increment in their second year. This indicates that, in a normal forest situation, they are very likely to be suppressed by untreated trees. The main purpose of thinning¾to provide unimpeded growth to a small selected component of the stand ¾appears to have been achieved.

Discussion

The Kaingaroa trial demonstrated that chemical thinning using metsulfuron and "hack & squirt" was not likely to be favoured by managers as an alternative to chainsaw thinning. The EZJECT system showed early promise but can be considered even less satisfactory. The main limitations to this technology are:

- difficulty of identifying treated trees immediately after herbicide application;
- the delay between treatment and final death is typically several years;
- inadequate mortality rates, even after several years;
- dead, dying and distorted trees are a prominent eyesore.

Other criticisms of chemical thinning were raised in the trials during the 1960s, but these have been found invalid with the herbicides currently in use. There is no evidence of "flashback", or translocation of chemical to non-target trees. Dead spars are not a safety hazard, and in comparison to the known safety hazard of chainsaws this is a trivial objection. The accumulation of pathogens, such as *Armillaria,* may not be a problem if mortality is relatively quick and/or if trees are thinned when they are small.

Where to now?

Following these trials, it is difficult to believe that there is a major place for chemical thinning of radiata pine in New Zealand with either metsulfuron or glyphosate as an alternative to thinning-to-waste with a chainsaw. Before making this conclusion, however, it may be worthwhile to examine one more possibility: the combination of both glyphosate and metsulfuron (36:1 ratio) may provide synergistic effects (Murray Lane, pers. comm.). Trounce plus metsulfuron is in widespread use for weed control. High concentrations of both chemicals can be applied in granular form using plugs placed in holes made by a specialised hammer ("Thor's hammer"). This is quick and easy to use, and¾having fewer parts, especially moving parts¾is less likely to encounter operational problems than the EZJECT lance.

Chemical thinning, as demonstrated in the trials described here, may have practical application in minor situations where:

- small-scale growers do not possess a chainsaw or do not know how to use one safely;
- terrain is too steep or unstable for safe chainsaw use;
- wind risk following thinning is a major concern;
- the species being removed is particularly sensitive to the herbicides used.

The potential of chemical thinning for the removal of very small trees (0.5-2.0 m high) should not be overlooked, as glyphosate appears to be disproportionately effective for such small trees (Bergerud 1988). These trees are problematic in two instances:

- regeneration of inferior tree species or inferior genetic stock among planted pines. This is a particular problem on the drier parts of both islands, where seeding rates tend to be higher.
- wilding tree spread.

Removal of wildings or regeneration by mechanical means is not always easy. In rocky terrain, it is difficult to sever a tree sufficiently close to the ground to kill the lowest branches or needles. In these cases, it is possible that chemical thinning could achieve higher mortality rates than slashers or chainsaws. In the case of wilding control in areas with a high conservation value, operators tend to include volunteers who do not have adequate chainsaw skills. In the case of regeneration in plantation forests, chemical thinning offers the possibility of low-cost control.

A final point to emphasise is that the effectiveness of chemical thinning depends on the nature of the herbicide. The New Zealand trials were installed in the belief that the new generation of herbicides made the findings of thirty years ago obsolete. This has proved not to be the case. Nevertheless, new herbicides may be developed that are far more efficacious than those currently existing, and if that occurs the idea of chemical thinning as a major substitute for chainsaw thinning may need to be revisited.

Acknowledgments

The authors are grateful to Fletcher Challenge Forests and Carter Holt Harvey for provision of the sites, and to Myles Carter, John Penman, Dave Henley and John Poynter for doing most of the field work.

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