Herbicides for removal of natural regeneration of radiata pine in second-rotation plantations

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Summary

Results are reported from a study carried out between 1979 and 1983 near Myrtleford in north-eastern Victoria, of the effectiveness of herbicides in controlling (killing or severely stunting) unwanted natural regeneration of radiata pine (*Pinus radiata* D.Don) after clearfelling of mature stands.

Effective control of individual stems resulted when the foliage was sprayed to drip-off point in spring with any of the following chemicals: amitrole plus ammonium thiocyanate at 17.5 g and 15.4 g respectively, dicamba at 12.6 g and dicamba derivative at 22.7 g, fosamine ammonium at 60.0 g, glyphosate at 18.0 g, and paraquat at 2.4 g a.i. each in 1.0 L water carrier. Higher concentrations of the same chemicals were also effective when applied at other times of the year.

For the control of thickets (1–2 m tall) of naturally regenerating radiata pine, fosamine ammonium applied as Krenite at 125 L ha^{-1} plus 1000 L ha^{-1} water carrier, produced the best result. Dicamba at 25 kg ha^{-1} and amitrole plus ammonium thiocyanate at 35 and 28 kg a.i. ha^{-1} were less effective. Being a contact herbicide, fosamine ammonium failed to control smaller trees shielded in the thickets by adjacent stems. Thus this chemical must be applied when the trees are small and the canopy is still open.

At present, the high cost of fosamine ammonium at effective rates (*c.* $1860 ha^{-1}), limits its usefulness in the control of radiata pine thickets. Further work is therefore necessary to increase its effectiveness and thereby reduce the cost of treatment.

Introduction

In Victorian plantations, dense natural regeneration of radiata pine (*Pinus radiata* D.Don) often develops after the parent stands have been clearfelled, unless the resultant debris is removed by a uniformly intense slash burn. Many stands are now re-established by planting genetically improved seedlings and the presence of dense natural regeneration may hinder the successful establishment of the new crop. In north-eastern Victoria alone, over 100 ha of radiata pine plantations clearfelled since 1979 have been recolonized by dense natural regeneration. Control (killing or severely stunting) of such regeneration has been attempted by both mechanical and chemical (Flinn and Minko 1982) methods, but only with limited success.

This study was established to investigate further the efficacy of seven commercially available herbicides and one, coded, experimental herbicide for controlling unwanted thickets of natural regeneration within young radiata pine plantations on steep slopes in north-eastern Victoria.

Methods

The study was carried out between 1979 and 1983 in the Ovens Plantation near Myrtleford, in north-eastern Victoria. A number of 46 to 55-year-old stands of radiata pine were clearfelled and, after removal of debris by fires, replanted during the following winter. The fire was of low intensity. After 2–4 years, self-sown trees of radiata pine (natural regeneration) had become established among the planted trees in thickets of 24–98 thousand ha^{-1}. Subsequently both types of trees were included in the experiments.

The first of two experiments tested the efficacy of several chemicals (Table 1) in controlling single, 1–2 m tall self-sown pines. The chemicals were applied, diluted in water at rates given in Table 4, by means of a pressure knapsack sprayer with a flat fan nozzle (pressure 310 kPa), to drip-off point. Each treatment was applied to 10 healthy, randomly selected trees and the treatments were repeated in spring (September 1979), summer (February 1980) and winter (May 1980) on fresh sets of 10 trees selected in the same way. All treated trees were re-examined 1 year after treatment (September 1980, February and May 1981 respectively) and the level of control achieved (percentage loss of foliage and mortality) was recorded.

The second experiment used those chemicals considered most promising in the first experiment and tested their effectiveness in controlling pine thickets of a similar age and height to those treated in the first experiment. These chemicals were: dicamba, fosamine ammonium and amitrole plus ammonium thiocyanate.

The remaining five chemicals (Table 1), though effective, were considered to be too toxic to wildlife, too expensive or too little was known about them (the manufacturers' label provided insufficient information to enable their safety to be assessed).

In experiment 2, the chemicals (Table 2) were applied in February, June and October 1982 to 10-m^2 plots of dense natural regeneration (Table 3).

The experimental design was a 4 × 4 Latin square with untreated surrounds

Table 1 Details of chemicals tested for the control of natural regeneration in a radiata pine plantation near Myrtleford, Victoria (1979 and 1983)

Product[A]	Active chemical	Active ingredient in undiluted product (g L^{-1})	Toxicity[B] (LD$_{50}$ rate) (mg kg^{-1})
Banvel 200	dicamba (amine)	200	2100
Brominil	bromoxynil	200	250
Gramoxone	paraquat	200	100
Krenite	fosamine ammonium	480	24000
Ronstar	oxadiazon	250	800
Roundup	glyphosate	360	4320
Velsicol 4092	dicamba (derivative)	360	1028
Weedazol TL	amitrole plus	250	1100
	ammonium thiocyanate	220	800

[A] Trade names are used for the convenience of the reader. Such use does not constitute an endorsement of any product to the exclusion of others that may be equally suitable.

[B] After Hodogaya Chemical Co. Ltd, Tokyo, 1978. ('Short Review of Herbicides', 247 pp.).

Table 2 Details of chemicals applied in experiment 2 to dense thickets of radiata pine natural regeneration (30 000–120 000 stems ha^{-1}) in a plantation near Myrtleford, Victoria

Product	Chemical	Volume of product added to 1 L water[A] and applied to each 10-m^2 plot (mL)	(g a.i.)
Weedazol TL	amitrole plus	140	35.0
	ammonium thiocyanate		30.8
Banvel 200	dicamba	125	25.0
Krenite	fosamine ammonium	125	60.0
water	water only (control)	0	–

[A] 1 mL surfactant Plus 50 added.

Table 3 Density and heights of radiata pine thickets at the beginning of experiment 2

Chemical	Application time 1982 (month)	Mean[A] no. trees per 10-m^2 plot	Mean[A] height of 10 tallest trees on each 10-m^2 plot (cm)
amitrole plus	February	77	126
ammonium thiocyanate	June	82	110
	October	79	135
dicamba	February	79	116
	June	76	136
	October	67	127
fosamine ammonium	February	65	112
	June	80	163
	October	73	126
water only (control)	February	72	142
	June	98	144
	October	69	129
l.s.d.[B] ($P < 0.05$)	February	24	28
	June	27	37
	October	22	44

[A] Mean of four replications.
[B] Least significant difference.

1 m wide for each individual plot. Before treatment, all trees in each plot were counted and the 10 tallest were tagged and measured for height (Table 3).

When treated in February and June the trees were in the hard-bud stage and, by October, had reached the lateral-extension stage. Chemicals were applied, diluted in water, at the rates shown in Table 2.

The same sprayer, spray nozzle and nozzle pressure were used as in the first experiment. Each treatment was applied in clear, calm and dry weather. One year after treatment (February, June and October 1983 respectively) surviving trees were counted and the tagged trees re-measured. Occurrence of dead-topping (loss of leading shoot) causing malformation of the main stem was also recorded.

Treatment differences were tested by analysis of variance using both percentage and arc-sine transformed data.

Results

In the first experiment, assessments made 1 year after application showed that any chemical applied in spring caused either equal or greater defoliation and, subsequently, either equal or greater mortality than when applied in summer or winter (Table 4). Furthermore, the chemicals were generally more effective at higher than lower concentrations. With the exception of oxadiazon, which at the rate applied produced variable results, all chemicals were effective (causing 100% mortality) in controlling radiata pine seedlings when applied in spring. Dicamba, paraquat, amitrole plus ammonium thiocyanate, and glyphosate were also effective when applied in summer and winter, whereas the two higher rates of fosamine ammonium performed efficiently in spring and summer though not in winter. Overall, the results indicated that, with the possible exception of oxadiazon, any of the chemicals tested will give effective control of single (1–2 m tall) natural regeneration trees, if applied to the foliage until drip-off point at the appropriate season and concentration.

In experiment 2 (Table 5) the effects of amitrole plus ammonium thiocyanate were more variable than those in experiment 1. This was possibly due to the lesser quantity of spray applied to each individual tree, as well as to the mutual protection (shielding) of seedlings in thickets against spray contact. Apparently, these two factors increased the sensitivity of the test. In both experiments use of arc-sine transformation in the analysis of field data has not changed the significance levels of the results.

Irrespective of the time of application or the stage of the terminal bud development of the trees, amitrole plus ammonium thiocyanate applied at 140 L ha^{-1} product caused no mortality and little dead-topping. The only effects observed were severe, yet temporary, chlorosis of the foliage and a slight, yet significant ($P < 0.05$), loss of height increment. This treatment was the least effective of the three herbicides tested.

Dicamba applied at 25 kg ha^{-1} appeared to be of limited use in controlling dense patches of natural regeneration. Although it temporarily arrested height growth, it was only partially effective in reducing tree numbers whether applied in February or June, during the dormant stage of the apical bud, or in spring (October), during bud extension.

Although relatively slow acting, fosamine ammonium at 60.0 kg ha^{-1} produced consistently and significantly ($P < 0.05$) better results than the other two chemicals. It achieved high mortality and, like dicamba, because of the severity of the induced dead-topping, it also caused negative increment in the

Table 4 Loss of foliage and mortality of radiata pine regeneration 1 year after the application of chemical spray treatments (experiment 1)

Product	Volume of product added to 1 L water (ml)	Level of control 12 months after application[A] loss of foliage (%)			Mortality (%)		
		Application date					
		spring (Sept. 79)	summer (Feb. 80)	winter (May 80)	spring (Sept. 79)	summer (Feb. 80)	winter (May 80)
Banvel 200	250	100	100	100	100	100	100
	125	100	100	100	100	100	100
	63	100	100	84	100	100	80
Brominil	40	n.t.[B]	90	66	n.t.	20	20
Grammoxone	25	100	88	100	100	60	100
	12	100	n.t.	100	100	n.t.	100
Krenite	250	100	100	92	100	100	20
	125	100	100	n.t.	100	100	n.t.
	63	100	80	n.t.	100	80	n.t.
Ronstar	20	71	n.t.	25	0	n.t.	0
	10	0	100	2	0	100	0
Roundup	200	100	n.t.	100	100	n.t.	100
	100	100	n.t.	100	100	n.t.	100
	50	100	n.t.	100	100	n.t.	100
Velsicol 4092	250	100	n.t.	n.t.	100	n.t.	n.t.
	125	100	n.t.	n.t.	100	n.t.	n.t.
	63	100	n.t.	n.t.	100	n.t.	n.t.
Weedazol TL	100	100	100	100	100	100	100
	280	100	100	100	100	100	100
	140	100	100	100	100	100	100
	70	100	98	99	100	60	80
	35	n.t.	95	n.t.	n.t.	40	n.t.

[A] Mean measurement of 10 trees.
[B] n.t., chemical not tested.

few surviving trees (Table 5). However, the chemical failed to control the natural regeneration completely, allowing trees to survive largely unaffected within thickets, where there is mutual protection (shielding). Also, the price of this chemical at \$14.88 L^{-1} (1983) is relatively high compared with that of amitrole plus ammonium thiocyanate or dicamba (\$7.76 L^{-1} and \$4.47 L^{-1} of product respectively).

Discussion and conclusion

The results show that it is possible to control (kill) single trees of natural regeneration of radiata pine by spraying at the appropriate time with the appropriate quantity of either amitrole plus ammonium thiocyanate, dicamba, fosamine ammonium, glyphosate or paraquat.

Fosamine ammonium has more potential than either amitrole plus ammonium thiocyanate or dicamba for the control of dense, 1-2 m tall, thickets of radiata pine. It has lower

Table 5 Effects of chemicals on mortality, dead-topping and height increment of natural regeneration of radiata pine at the completion of experiment 2

Chemical	Measurement time 1983 (month)	Mortality[A] of trees 10-m² plot %	Level of control (10 tallest trees 10-m² plot)		
			Mortality[A] %	Dead-topping[A] %	Height increment[A] %
amitrole plus	Feb.	0	0	0	26
ammonium	June	1	0	8	19
thiocyanate	Oct.	0	0	0	23
dicamba	Feb.	6	10	23	8
	June	14	25	15	7
	Oct.	13	23	47	4
fosamine	Feb.	66	60	28	-4
ammonium	June	84	86	11	-1
	Oct.	64	78	13	-2
water only	Feb.	0	0	0	43
(control)	June	0	0	0	34
	Oct.	0	3	0	39
l.s.d.[B]	Feb.	3	23	20	14
($P < 0.05$)	June	2	19	15	5
	Oct.	12	24	7	8

[A] Mean of four replications.
[B] Least significant difference.

toxicity to mammals and, at the rates tested, causes higher mortality than either of the other chemicals. At 60 kg ha^{-1} applied in water (1000 L ha^{-1}) in June, fosamine ammonium produced 86% mortality and 11% dead-topping — a satisfactory result.

It is not surprising that this chemical, being a contact herbicide, permits some regeneration by failing to kill seedlings hidden within the thickets and protected from the spray. Thus for maximum effect, the trees should be sprayed while they are still small and the canopy has not closed over the thicket.

Owing to the high cost of fosamine (*c.* \$1860 ha^{-1} at 125 L Krenite ha^{-1}) further work is required in order to attain optimum contact between the spray and its target and hence least use of the product and tolerable cost for a satisfactory result. Such investigations are currently being pursued and preliminary trials suggest that satisfactory control of germinating seedlings may be obtained with an application of < 15 L ha^{-1}.

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References

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