Herbicide screening pot trial for wildling conifer control (*Pinus contorta*, *P. mugo* and *Pseudotsuga menziesii*)

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Summary

In New Zealand, wildling conifers threaten over 210,000 hectares of land administered by the Department of Conservation in the South Island alone. Currently, diquat is applied aerially at 3 kg/ha active ingredient in 400 litres per hectare total volume to control *Pinus contorta*. As this treatment is not very effective, the objective of this study was to evaluate if there are more effective alternative herbicide treatments to control *P. contorta*, *P. mugo* and *Pseudotsuga menziesii*.

Alternative herbicide treatments and the current operational diquat treatments were applied during late spring in a pot trial in Rotorua. Except for diquat which was applied at 300 litres per hectare, all herbicides were applied in a spray volume of 150 litres per hectare. Percentage damage to the foliage of the trees was visually recorded in increments of 10%, prior to treatment and post treatment at monthly intervals, to a maximum of 190 days after the treatments were applied. A score of zero percent means no damage and 100 percent means the tree has died.

Analysis of variance showed highly significant differences between herbicide treatments ($F_{9,87}=16.7$, $P<0.0001$), between species ($F_{2,87}=64.3$, $P<0.0001$) and also detected a significant interaction between species and treatment ($F_{18,87}=5.0$, $P<0.0001$). When averaged across all treatments damage differed significantly between the three species. Damage to *P. contorta*, *P. menziesii* and *P. mugo* averaged, respectively 99.1, 91.6 and 83.1%.

Triclopyr, applied as Grazon at 20 litres per ha, was overall the most effective alternative herbicide treatment to diquat, with damage averaging 97%, and causing a minimum of 94% damage for all species. Results indicate that glyphosate based treatments were less effective than triclopyr based treatments.

Introduction

Wilding conifers (*Pinus contorta*, *P. mugo* and *Pseudotsuga menziesii*) are regarded as primary colonisers that are capable of invading sparsely vegetated sites that are not intensively managed (Paul, 2008; Ray, 1991). Ledgard (2001) describes 40 - 50 000 hectares being adversely affected by wilding conifers. These wilding conifers threaten over 210,000 hectares of land administered by the Department of Conservation (DOC) in the South Island alone (Harding, 2001). According to Ledgard (2003) the area that could potentially be infested by exotic conifers is likely to be more than 300,000 hectares in the South Island of New Zealand.

The Department of Conservation and numerous other landowners are attempting to control and eradicate wildling conifers. Under the Reserves Act 1977, National Parks Act 1980, and Conservation Act 1987, DOC is required to control these wilding conifers on the land it administers. If wilding conifers are allowed to fully establish and form dense forests, the cost of control can be up to $10,000/ha (P. Raal, DoC, *pers. comm.*, May 2009).

Historically *P. contorta* was controlled successfully with diquat, followed by burning (Ray, 1991). This treatment was effective because the diquat treatment desiccated the plant tissue and the resulting dry fuel produced a hot burn that killed most of the remaining conifers and viable seed. However, burning is no longer an acceptable management practice on DOC administered land. The current practice of spraying with diquat alone is ineffective at controlling most mature wildling conifers (Raal et. al., 2008; Gratkowski, 1975; Donald, 1982).

This paper investigates the efficacy of alternative herbicide treatments for the control of wildling conifers. To ensure optimum efficacy, foliar herbicide application should be undertaken during conditions that favour systemic herbicide translocation. These conditions typically occur during spring and summer within New Zealand, when days are long, temperatures are high and trees are actively growing (Raal, 2005; Radosevich and Bayer, 1979). To replicate the efficacy of these herbicides under ideal conditions, treatments in this trial were applied to well watered potted plants during the first week of November, at Rotorua, in the Central North Island of New Zealand.

The trialled herbicide treatments can be categorised into five groups; those based on Diquat, triclopyr, triclopyr/picloram, glyphosate and glyphosate/metsulfuron. Triclopyr and triclopyr/picloram herbicides are selective systemic treatments intended for use in areas where non-target native monocotyledon vegetation is present and should be protected if possible. Glyphosate and glyphosate/metsulfuron treatments are non selective systemic treatments to be used on dense conifer infestations, where non-target species are not at risk. The mode of action of the above alternative herbicides contrasts with the current

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operationally applied diquat, which is a non-selective contact herbicide.

Materials and Methods

Two hundred and twenty 300 mm high saplings each of *P. contorta*, *P. mugo* and *P. menziesii* were collected in the field and transplanted into five litre plastic pots, ten months prior to treatment.

Twenty healthy trees of each species were divided into 4 replications of five trees each and treated with 10 different herbicides during the first week of November 2008 in a randomised complete block design. An untreated control was also included in the experiment (Table 1). All herbicides were applied by calibrated boom sprayer, using Turbo Teejet Induction nozzles (TTI 02) producing a spray characterised by droplets with a volume mean diameter greater than 500 micro metres (Spraying Systems Co. 2008).

Percentage damage to the foliage of the trees was visually recorded in increments of 10%, prior to treatment and post treatment at monthly intervals, to a maximum of 190 days after the treatments were applied. A score of zero percent means no damage and 100 percent means the tree has died.

An analysis of variance appropriate for a factorial design was used to test the main and interactive effects of herbicide and species on foliar damage, 190 days after the treatment was applied (SAS, 2004). The analysis of variance excluded the untreated control to ensure that the test was sensitive to variation in herbicide treatments, rather than the considerable differences between the herbicide treatment and the untreated control. The untreated control was included for the multiple range tests, to provide a full comparison of all treatments.

Results and Discussion

The analysis of variance showed highly significant differences between herbicide treatments ($F_{9,87}=16.7$, $P<0.0001$), between species ($F_{2,87}=64.3$, $P<0.0001$) and also detected a significant interaction between species and treatment ($F_{18,87}=5.0$, $P<0.0001$). Damage, when averaged across all treatments, differed significantly between the three species. Damage to *P. contorta*, *P. menziesii* and *P. mugo* averaged, respectively 99.1, 91.6 and 83.1%.

Damage from the contact herbicide diquat was visible within one month after application (see solid line in Fig. 1) and, when averaged across the three species, caused the highest damage (98.5%) after 190 days (Table 2). Systemic

Table 1: Herbicide treatments for the wilding conifer pot trial. For all treatments apart from, 1 and 5, Pulse penetrant[#] was added at a rate of 1.5 litres per hectare.

Treatment no.	Active ingredient rate (g a.i./ha)	Herbicide product rate (litres/ha)	Total spray volume (litres/ha)
1	Control		0
2	Diquat 3,000 g a.i.	Reglone 15 litres	300
3	Triclopyr 9,000 g a.i.	Grazon 15 litres	150
4	Triclopyr 12,000 g a.i.	Grazon 20 litres	150
5	Triclopyr 12,000 g a.i. Mineral spray oil 130 litres/ha	Grazon 20 litres	150 (oil & herbicide)
6	Glyphosate 5,400 g a.i.	Roundup 15 litres	150
7	Glyphosate 5,400 g a.i. Metsulfuron 90 g a.i.	Roundup 15 litres Escort 150 g	150
8	Glyphosate 7,200 g a.i.	Roundup 20 litres	150
9	Glyphosate 7,200 g a.i. Metsulfuron 120 g a.i.	Roundup 20 litres Escort 200 g	150
10	Triclopyr 4,500 g a.i. Picloram 1,500 g a.i.	Tordon 15 litres	150
11	Triclopyr 6,000g a.i. Picloram 2,000g a.i.	Tordon 20 litres	150

[#] *Pulse Penetrant is a registered trademark of Nufarm Technologies, USA*

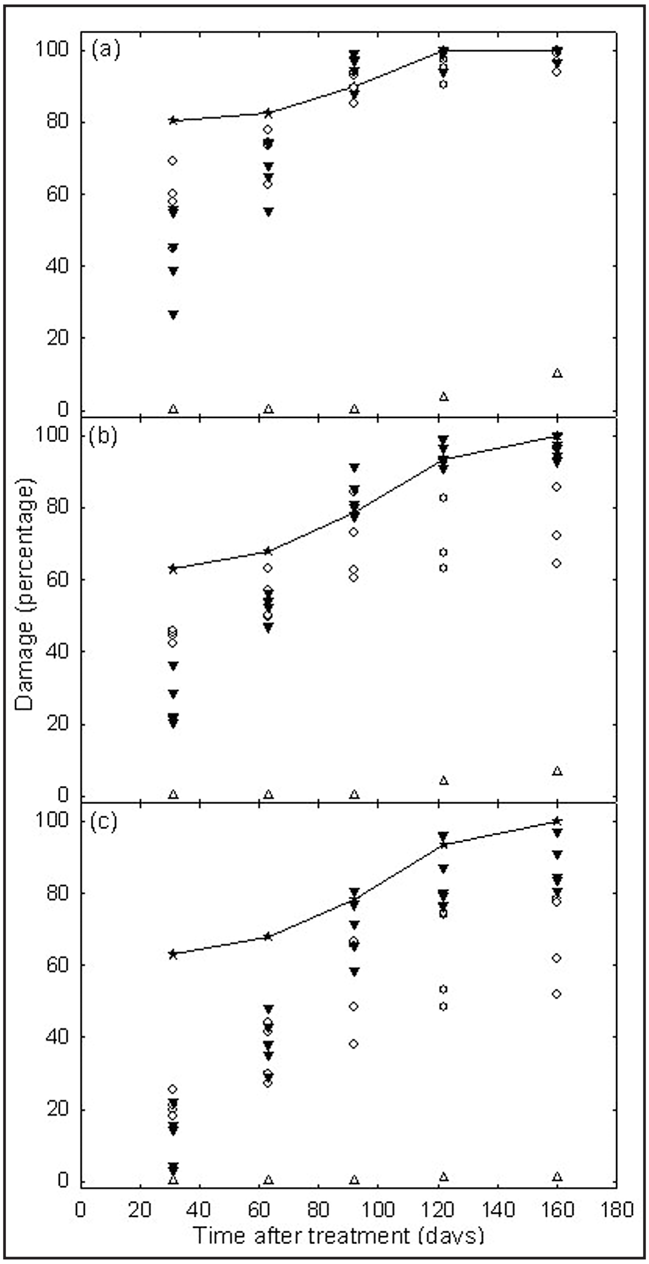

Figure 1. Changes in damage with time, by treatment for (a) Pinus contorta *(b)* Pseudotsuga menziesii *and (c)* Pinus mugo*, for diquat (line and star symbols), triclopyr based treatments (downward facing triangles), glyphosate based treatments (open circles) and the control (upward facing triangles).*

based herbicide treatments took between two and three months to show similar visual effects (Fig. 1). Averaged across species, triclopyr applied at the equivalent of 20 litres per hectare Grazon in oil (treatment 5) and in water (treatment 4) caused the second and third highest damage after 190 days, averaging 97% and 95.8% respectively for all three species (Table 2). These two treatments did not differ significantly. Triclopyr applied in water with 1.5 litres per hectare Pulse, is less expensive and logistically easier to use operationally than triclopyr in oil.

After 190 days there was no significant difference between any of the herbicide treatments for *P. contorta* (Table 2), with all treatments resulting in 97% or greater mortality. For *P. menziesii* diquat (Treatment 2) and Tordon (Treatment 11) were most effective, (100% mortality). All other treatments apart from glyphosate only treatments, were effective (Fig. 1, Table 2). Although glyphosate only treatments were significantly less effective at killing *P. menziesii*, the addition of metsulfuron to glyphosate caused an increase in damage to this species (Fig. 1). *Pinus mugo* showed the most tolerance to all herbicide treatments. Triclopyr applied in oil (treatment 5) and water (treatment 4) together with diquat (treatment 2) caused the most damage of all treatments tested. The two treatments with only glyphosate were the least effective on this species (Table 2), and in general glyphosate based treatments were markedly less effective than diquat and triclopyr based treatments (Fig. 1).

Table 2. Mean damage, by treatment and species, 190 days after application of the treatment, for Pinus contorta *(C),* Pseudotsuga mensiesii *(D) and* Pinus mugo *(M). Means followed by the same letter are not significantly different at* P<*0.05. For the analysis of variance* F*-values are shown, followed by the* P*-categories. Asterisks *** represent significance at* P<*0.001.*

Treatment	Mean damage (percentage)					
	C		D		M	
1	8	b	0.65	c	0.1	d
2	100	a	100	a	95.5	a
3	100	a	95	a	83.5	ab
4	97.5	a	97	a	93	a
5	100	a	94	a	97	a
6	100	a	75.5	b	57.5	c
7	97.5	a	90	a	79	ab
8	97	a	68.5	b	69.5	bc
9	99	a	98	a	81.5	ab
10	100	a	98	a	86.5	ab
11	100	a	100	a	87.5	ab
Significance of one way ANOVA						
Treatment	466.2***		110.6***		39.9***	

Comparison of these results to previous research using a similar set of treatments during sub-optimal conditions (Gous *et al.*, submitted), in mid-winter, highlights the efficacy of triclopyr based treatments on wildings. Although Grazon was not tested, the most effective treatment applied in this winter trial was triclopyr/picloram applied as 20 litres/ha of Tordon (treatment 11 in this trial). Efficacy for this treatment exceeded that of diquat averaging 99.5%, over all three species, with a minimum efficacy of 98.4% for *P. mensiesii*. This high efficacy is consistent with our results, and highlights the utility of this particular herbicide in providing high levels of control over a range of conditions. This is a useful finding as herbicide application in the field is often undertaken, through necessity, during sub-optimal conditions. One of the major benefits in using triclopyr based treatments over diquat is that this group of herbicides have a lower impact on non-target native monocotyledon vegetation. Triclopyr is also a systemic herbicide which means it can be mobilised throughout the treated trees.

Conclusions

All herbicide treatments were highly effective against *P. contorta*. Herbicide damage to the three conifer species differed significantly. *Pinus contorta* was more susceptible to herbicide damage than *P. menziesii* which was more susceptible to herbicide damage than *P. mugo*. Efficacy varied significantly between herbicides, with results showing that triclopyr at 12,000 g a.i./ha was as effective as diquat at 3,000 g a.i./ha. Glyphosate based treatments were generally less effective than triclopyr based treatments. Results indicated that triclopyr applied at the equivalent of Grazon @ 20 litres per hectare in water (treatment 4) and oil (treatment 5) may be suitable alternatives to the operational diquat treatment for all three species.

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