Preliminary evaluation of salflufenacil herbicide for New Zealand forestry use

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Summary Salflufenacil was tested to evaluate its activity against several crop and weed species. A hydroponic screening test demonstrated its herbicidal activity against radiata pine (*Pinus radiata* D.Don), gorse (*Ulex europaeus* L.) and broom (*Cytisus scoparius* (L.) Link) in comparison to terbuthylazine and metsulfuron-methyl. A small field trial showed that salflufenacil residues in soil did not affect radiata pine relative to controls at 2 or 4 weeks after 25–200 g a.i. ha^{-1} spray application. The same rates applied over radiata, regnans (*Eucalyptus regnans* F.Muell.) and nitens (*E. nitens*, H.Deane & Maiden) as well as gorse and buddleia (*Buddleja davidii* Franch.), caused relatively severe foliar and stem damage only to the eucalypt species. Foliage on the other species was affected temporarily but plants recovered within 8 weeks. The surviving eucalypts also recovered but more slowly. Field trials using salflufenacil sprays with metsulfuron-methyl, triclopyr and glyphosate products over mature gorse and broom, showed that it could provide rapid brown-out and at times enhance control of these weeds. The low use rates, physical and biological activity profiles and rapid degradation appear to make salflufenacil a potential forestry herbicide.

Keywords Salflufenacil, herbicide, radiata pine, eucalypts, gorse, broom, buddleia.

INTRODUCTION

Although satisfactory herbicide regimes for weed control in forestry were developed in the 1980s (Davenhill *et al*. 1997), there have been no significant new herbicide introductions since then. The pressure from consumer and environmental groups to reduce or replace herbicides perceived as being harmful to the environment is now driving the search for acceptable products. One new candidate is salflufenacil (Grossman *et al*. 2010), which complies with Forest Stewardship Council criteria (FSC 2007) as a safe agrichemical, and could be used in New Zealand if sufficiently effective. The studies reported here are the first tests on forest tree species (radiata pine; regnans and nitens eucalypts) and forest weeds (gorse, broom, buddleia). These include hydroponic bioassays to compare plant susceptibility; small plot spray trials for tolerance to spray application and soil residues; and with forest herbicides (metsulfuron-methyl, triclopyr/picloram and glyphosate) for efficacy against mature gorse and broom.

MATERIALS AND METHODS

Chemicals Salflufenacil, (BAS 800-00H 70% WG) was from BASF NZ. Other herbicides were terbuthylazine (BASF Click® and Agpro Terbuthylazine 500 SC), metsulfuron-methyl (Escort® or Answer®, Du Pont), glyphosate (Roundup® Transorb 540 SC, Nufarm) and triclopyr/picloram (Tordon® Brushkiller or with aminopyralid as Brushkiller XT, Dow AgroScience).

Hydroponic studies The method used is similar to that previously described (Zabkiewicz 1979) using pre-germinated gorse, broom and radiata seedlings suspended in floating mesh rafts supported by polystyrene beads (2–3 cm in height, 20 per raft) in solutions of herbicides at concentrations ranging from 0.5×10^{-6}M to 40×10^{-6}M. The herbicides tested were salflufenacil, terbuthylazine and metsulfuron-methyl. Survival assessments were made at regular intervals over a period up to 60 days. Controls were seedlings in distilled water. All treatments received small quantities of liquid fertiliser at weekly intervals.

Field studies Rotorua All treatments were in the Scion nursery area (allophonic sandy loam soils, derived from volcanic ash). The tolerance trials used approx. 9–12 month old seedlings of radiata, regnans and nitens (planted August 2009), buddleia seedlings (10–20 cm tall, planted September 2009) or 4-month gorse seedlings in pots. The tree species had 15 replicates per treatment (5 × 3 plots) and the weed species 24 replicates (8 × 3 plots). The soil herbicide residue trial used radiata pine (18 replicates, 6 × 3 plots) planted into bare ground (previously sprayed with glyphosate) either 2 or 4 weeks after salflufenacil was applied. Both trials were set out as randomised blocks (1 m by 5 m) with a 1 m buffer zone between plots. Salflufenacil was used at 25, 50, 100 and 200 g a.i.

ha^{-1} plus an untreated control. Sprays were applied in early November 2009 with a 0.5 m long boom fitted with two twinjet 8002EVS nozzles (2 bar pressure) delivering 200 L ha^{-1}. The health of all plants was assessed over 3 months at monthly intervals using a 1–5 scale with 1 = completely dead and 5 = no effect. An analysis of variance was performed within each species treatment series.

Field studies at Fairview Farm, Canterbury Randomised single plots (30–40 m^2) of ten 1.5–2.0 m tall plants within a plot were assessed each time. Plants were sprayed to run off on 28 October 2008 using a knapsack sprayer, 400 kPa, D5 nozzle. Single person visual assessments were made over a year as per Tables 3 and 4, with scores of 0% no effect, 70% full defoliation and progressive stem death above 80% (confirmed by destructive cambial check). All data are presented as means within each plot.

Field studies at Tikokino, Central Hawke's Bay Treatments (replicated three times) were applied to randomised single plots (2–4 m^2) with one to three grouped plants 1–2 m tall. Sprays were applied to run-off on 28 March 2009 with a motorised knapsack pressure sprayer, with a multi-head hand lance. Single person visual assessments were made over 7 months (Tables 3 and 4), with a 0–100% brown-out score; 0% representing no damage and 100% no green material.

RESULTS AND DISCUSSION

Salflufenacil was tested against radiata, gorse and broom seedlings in water solutions of the herbicides at concentrations used previously, and that approximate field equivalents of between 0.5 and 1.5 kg a.i. ha^{-1} for salflufenacil, terbuthylazine and metsulfuron-methyl. The use of water solutions without any soil material removes differences due to soil character although are not representative of operational rates. All three species were killed by salflufenacil within 30 days or less at concentrations around 10 × 10^{-6}M (Table 1). All radiata were dead within 15 days in comparison to 25 days required with metsulfuron-methyl; none were killed by terbuthylazine, which is selective to radiata. Gorse was all dead within 15 days with salflufenacil and within 25 days with terbuthylazine at 10 × 10^{-6}M; metsulfuron-methyl killed less than 40% within 50 days. Broom responded similarly to gorse, i.e. all dead by 15 days with salflufenacil, all dead by 30 days with terbuthylazine and less than 20% dead at 50 days with metsulfuron-methyl. The toxicity of metsulfuron-methyl to radiata was a known effect, but its relative ineffectiveness against gorse and broom seedlings has not been reported before.

Table 1. Survival of radiata, gorse and broom seedlings (%) after 30 days with three herbicides at different rates in a hydroponic system.

Herbicide and concentration	Radiata	Gorse	Broom
Salflufenacil			
1.0 × 10^{-6}M	10	nt	nt
6.5 × 10^{-6}M	nt[A]	5	0
10 0 × 10^{-6}M	0	nt	nt
12.7 × 10^{-6}M	nt	0	0
Terbuthylazine			
10.0 × 10^{-6}M	100	0	0
Metsulfuron-methyl			
10.0 × 10^{-6}M	0	95	nt
40.0 × 10^{-6}M	nt	95[B]	100[B]
Nil (control)	100	100	100

[A] nt = not tested.
[B] = >80% survival at 50 days.

In the soil residue trial (Rotorua site), radiata seedlings that were planted at 2 or 4 weeks after the ground was sprayed with rates of 25 to 200 g a.i. ha^{-1} equivalent of salflufenacil, were not significantly affected ($P = 0.05$) compared to the control plants in unsprayed ground (data not presented). Rainfall was 20.5 mm and 7 mm respectively within the first and second fortnights after spray application. This indicates that salflufenacil is either bound or degraded rapidly in this soil. There was no injury at any time up to 11 weeks after planting for the +4 weeks series nor was height growth affected. The +2 weeks series seedlings were statistically ($P > 0.05$) no different from the untreated controls, but all treatments including the controls showed substantial damage and eventually some death due to stressful drought conditions immediately after planting. In the tolerance trial (Rotorua site), all plants were sprayed with the same salflufenacil rates as for the soil residue trial. All species showed initial foliar damage within 2 days but gorse and buddleia recovered within 8 weeks (Table 2) and radiata within 11 weeks. Radiata seedling height growth was significantly reduced (by about 20%) at rates above 50 g a.i. ha^{-1}. The eucalypt seedlings, which were affected by a frost event earlier in the season and had new foliage, were affected much more, losing most of their foliage. However, at 8 weeks post treatment, plants of both species had re-growth, although there was some mortality by week 11. Height growth of all eucalypt seedlings at all concentrations was affected. The indications are that salflufenacil can be used around the base of seedling radiata and eucalypts, especially after the first year of growth, without causing serious damage.

Table 2. Health assessment scores for five plant species at 3, 8 and 11 weeks after foliar application of salflufenacil at four rates.

Salflufenacil g a.i. ha^{-1}	3 WAT[A]	8 WAT	11 WAT
Radiata			
0	5.0a[B]	5.0a	5.0a
25	3.5b	4.9ab	5.0a
50	3.4b	4.4cd	5.0a
100	3.4b	4.6bc	5.0a
200	3.4b	4.3d	5.0a
Regnans			
0	5.0a	5.0a	5.0a
25	2.6b	3.7b	4.5ab
50	2.5bc	3.0c	3.9bc
100	2.2cd	3.2bc	3.7c
200	2.2d	2.9c	3.5c
Nitens			
0	5.0a	5.0a	5.0a
25	2.6b	3.1b	3.7b
50	2.5b	3.1b	3.6b
100	2.5b	2.9b	3.2b
200	2.3b	2.5b	2.9b
Buddleia			
0	5.0a	5.0a	5.0a
25	4.0c	5.0a	5.0a
50	3.8d	5.0a	5.0a
100	4.2b	5.0a	5.0a
200	3.8cd	5.0a	5.0a
Gorse			
0	4.9a	5.0a	5.0a
25	3.9b	5.0a	5.0a
50	3.6c	5.0a	5.0a
100	3.7bc	5.0a	5.0a
200	3.2d	5.0a	5.0a

[A] WAT = weeks after treatment,
[B] Values within columns and species with same letters indicate no difference (LSD P = 0.05).

Control of mature gorse or broom is unlikely with salflufenacil alone so its value lies in being used with other herbicides as an enhancer and providing rapid knock down or brown-out.

Application of salflufenacil with other herbicides onto mature gorse and broom plants in Hawke's Bay and Canterbury provided consistently good long term control (Tables 3 and 4). There were some short term differences in response, due to site or timing (autumn and spring application).

Metsulfuron-methyl with 17.5 g salflufenacil gave improved brown-out on gorse (84%) and broom (30%) vs. 3% and 8% without it in Hawke's Bay (40 DAT); in Canterbury it was 30% and 20% vs. 0% and 5% (28 DAT). Over time, the herbicidal effect improved to give approx. 10–20% better control than metsulfuron-methyl alone in both regions on gorse (at 221–5 DAT). The effect of metsulfuron-methyl on broom was different to gorse, with little or no improvement from inclusion of salflufenacil in Hawke's Bay (all around 96%) but in Canterbury the response was strongly dependent on the salflufenacil rate (50% and showing re-growth with nil or 0.7 g salflufenacil; 100% with 17.5 g salflufenacil added but only 30% and showing re-growth without salflufenacil at 377 DAT).

Salflufenacil improved brown-out on both weed species with triclopyr/picloram in Hawke's Bay in the short term. In the long term, there was no significant improvement over triclopyr/picloram alone, as in all cases control was either 100% or close to it for all combinations. In Canterbury the responses were different. Initially brown-out was reduced by the higher rates of added salflufenacil, but ultimately there were again no long term differences between treatments.

Glyphosate with salflufenacil, even at the lowest 0.7 g amount added, showed greatly increased brown-out in the short term in Canterbury, rising from 0–5% with just glyphosate in both gorse and broom, to 40–50% (28 DAT); the 17.5 g rate of salflufenacil gave 65–70% brown-out (28 DAT). All treatments had 95% to 100% control in the longer term at this site. In Hawke's Bay, in the short term, there were no significant brown-out differences between glyphosate alone or with added salflufenacil on both species (range from 83% to 95%). Long term control was close to 100% for all treatments.

CONCLUSIONS

Salflufenacil has the potential to be used for pre-plant weed control with very short withholding times. Post-plant application around growing seedlings is also a possibility but some growth reduction may occur if tree foliage is sprayed.

The rapid brown-out effect, and in some cases improved long term control, also raises the possibility of developing innovative multi-active forest herbicide prescriptions for pre-plant use.

Since salflufenacil is FSC compliant it could be used with reduced rates of compliant or non-compliant herbicides to reduce the overall herbicide environmental loading in forest operations.

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Table 3. Mean gorse brown-out (%; 0 = no damage, 100 = no green material) after spraying with sulflufenacil plus metsulfuron-methyl, triclopyr/picloram and glyphosate in Hawke's Bay in autumn and Canterbury in spring.

	Hawke's Bay			Canterbury			
Herbicide (g a.i. 100 L^{-1})	+40 DAT[A]	+83 DAT	+221 DAT	+28 DAT	+90 DAT	+ 225 DAT	+377 DAT
Nil	0	0	0	0	0	0	0
Metsulfuron-methyl – 9 g	3	23	86	0	30	50	80
+ sulflufenacil – 0.7 g	23	47	93	0	75	90	96
+ sulflufenacil – 3.5 g	57	74	96	20	60	80	90
+ sulflufenacil – 17.5 g	84	83	96	30	60	70	90
Triclopyr/picloram – 100 g[B]	47	82	96	80	85	90	100
+ sulflufenacil – 0.7 g	82	96	100	80	90	90	100
+ sulflufenacil – 3.5 g	95	99	100	30	90	95	99
+ sulflufenacil – 17.5 g	99	100	100	50	90	95	99
Glyphosate – 540 g	91	94	98	0	60	80	90
+ sulflufenacil – 0.7 g	94	99	100	40	60	80	100
+ sulflufenacil – 3.5 g	83	96	99	56	70	85	99
+ sulflufenacil – 17.5 g	87	98	100	65	70	80	95

[A] DAT = days after treatment. [B] 122 g a.i. in Canterbury (Tordon XT).

Table 4. Mean broom brown-out (%; 0 = no damage, 100 = no green material) after spraying with sulflufenacil plus metsulfuron-methyl, triclopyr/picloram and glyphosate in Hawke's Bay in autumn and Canterbury in spring.

	Hawke's Bay			Canterbury			
Herbicide (g a.i. 100 L^{-1})	+40 DAT[A]	+83 DAT	+221 DAT	+28 DAT	+90 DAT	+ 225 DAT	+377 DAT
Nil	0	0	0	0	0	0	0
Metsulfuron-methyl – 9 g	8	12	96	5	20	60[B]	30[B]
+ sulflufenacil – 0.7 g	8	22	95	10	30	5[B]	40[B]
+ sulflufenacil – 3.5 g	18	33	97	15	40	60	85
+ sulflufenacil – 17.5 g	30	30	96	20	40	80	100
Triclopyr/picloram – 100 g[C]	77	87	100	70	90	100	100
+ sulflufenacil – 0.7 g	70	76	98	60	70	95	100
+ sulflufenacil – 3.5 g	70	68	97	50	75	100	100
+ sulflufenacil –17.5 g	87	88	99	60	80	95	100
Glyphosate – 540 g	90	94	100	5	90	95	100
+ sulflufenacil – 0.7 g	96	98	100	50	80	100	100
+ sulflufenacil – 3.5 g	91	96	100	70	85	95	99
+ sulflufenacil – 17.5 g	93	96	100	70	80	90	95

[A] DAT = days after treatment. [B] = re-growth. [C] 122 g a.i. in Canterbury (Tordon XT).

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