Field assessment of herbicides to aid establishment of manuka (*Leptospermum scoparium*)

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Abstract Herbicide treatments were assessed in two concurrent experiments for improving the establishment of manuka seedlings (three provenances) transplanted into hillside pastures for honey production. Height and trunk diameters 18 months after planting were still significantly reduced by initial poor control of weeds. Controlling weeds in a patch of 1.0 m diameter gave better manuka growth than doing so in a 0.5 m diameter patch. Two of the more effective treatments were a mixture of glyphosate, simazine and clopyralid applied before planting, and a post-planting application of glyphosate and simazine sprayed while shielding the manuka. A mixture of haloxyfop, clopyralid and simazine applied in August then again in December following planting in July gave no further improvement in manuka growth than when applied only in August. Residues of metsulfuron equivalent to 120 g ai/ha applied just prior to transplanting caused no adverse effects in any of the three provenances of manuka.

Keywords herbicide tolerance, weed control, manuka, simazine, terbuthylazine, haloxyfop, clopyralid, glyphosate.

INTRODUCTION

Manuka (*Leptospermum scoparium*) is a New Zealand native species that has been considered a weed of hill country pastures for many decades, being estimated to have occupied about 2.3 million ha of reverted hill country by the early 1960s (Grant 1967). However, some provenances of manuka are now being planted in hill country for the production of high-value manuka honey, which has antibiotic properties (Nickless et al. 2014).

Farmers establishing manuka wish to minimise competition from weeds to protect their investment. The process of establishment is similar to that for radiata pine (*Pinus radiata*), as their seedlings are similar in size when transplanted and are planted into similar environments. A survey by Rolando et al. (2013)

showed that glyphosate and metsulfuron are commonly used to prepare sites for planting of radiata pine, that terbuthylazine is a commonly used selective residual herbicide, and that there is also some use of clopyralid.

Preliminary work on herbicide tolerance of young manuka plants both in the glasshouse (Harrington & Schmitz 2007) and the field (Harrington & Gregory 2009) has shown they tolerate simazine, clopyralid and haloxyfop, while metsulfuron, glyphosate and high rates of terbuthylazine can be damaging.

The main objective of the current work was to determine which combination of herbicides would result in best establishment of manuka planted on a hillside pasture site. A secondary

objective was to determine whether residues of metsulfuron remaining after clearing a site of weeds are likely to affect the establishment of manuka, with three provenances being assessed to check for differences in sensitivity.

MATERIALS AND METHODS

Experiment 1

This experiment was established on a hillside pasture (5 to 20° slope) on a Tokomaru silt loam soil previously grazed by sheep at the Moginie Pasture and Crop Research Unit at Massey University, Palmerston North. Plant species present at the start of the experiment included perennial ryegrass (*Lolium perenne*), browntop (*Agrostis capillaris*), Yorkshire fog (*Holcus lanatus*), white clover (*Trifolium repens*), creeping buttercup (*Ranunculus repens*) and catsear (*Hypochaeris radicata*).

The herbicide treatments are listed in Table 1. Treatments 2 to 5 were applied on 9 June 2011 prior to planting of manuka. These treatments were all applied to pasture that had just been grazed by sheep. Treatments were all applied to circular patches 1.0 m in diameter (0.78 m²) spaced 2 m apart using a plastic ring to define the edges of the area to be sprayed. Herbicides were applied using a calibrated 15 litre Solo back-pack sprayer with a flat-fan nozzle applying 78 ml of spray solution evenly to each patch over 11.7 sec, giving a water rate of 1000 litres/ha. An electronic metronome assisted with timing applications correctly. This allowed herbicide rates to be calculated per ha for each patch (Table 1). For treatments that included glyphosate, organosilicone surfactant (Pulse Penetrant) was added at 0.1% v/v to the solutions as per label.

Table 1 Herbicides applied to 1.0 m diameter circular patches (except Treatment 11, with 0.5 m diameter) around manuka plants planted on 18 July 2011 for each experiment, with application rates, date of application and cost to treat 1000 plants.

Treatment	Active ingredients (kg ai/ha)	Date applied	Cost/1000 plants (\$)¹
Experiment 1 (only using Provenance B)			
1	untreated		
2	glyphosate (gly)(1.8)	9/6/11	3.92
3	gly (1.8) + terbutylazine (4.5)	9/6/11	9.22
4	gly (1.8) + simazine (sim)(4.5)	9/6/11	9.22
5	gly (1.8) + sim (4.5) + clopyralid (clo)(0.45)	9/6/11	16.48
6	gly (1.8)(shielded)	29/8/11	3.92
7	gly (1.8) + sim (4.5)(shielded)	29/8/11	9.22
8	haloxyfop-P (hal) (0.3) + sim (4.5)	29/8/11	17.07
9	hal (0.3) + sim (9.0)	29/8/11	22.37
10	hal (0.3) + sim (4.5) + clo (0.45)	29/8/11	22.37
11	hal (0.3) + sim (4.5) + clo (0.45) 0.5 m diameter	29/8/11	5.59
12	hal (0.3) + sim (4.5) + clo (0.45) twice	29/8, 1/12/11	44.75
Experiment 2 (using Provenances A, B and C)			
1	untreated		
2	hal (0.3) + sim (4.5) + clo (0.45) twice	29/8, 1/12/11	44.75
3	gly (1.8) + metsulfuron (0.03)	9/6/11	4.24
4	gly (1.8) + metsulfuron (0.12)	9/6/11	5.18

¹Costs are GST exclusive for chemicals (including 1 litre/ha Pulse Penetrant for all glyphosate treatments) using prices in March 2015 from <http://www.agpro.co.nz>.

Manuka was planted across the site at 2.0 m spacings on 18 July 2011 after another grazing of the site, with one plant being transplanted into the centre of each dead patch of pasture created by the treatments applied on 9 June. The manuka plants (seedlings) were obtained from Naturally Native nurseries, Tauranga, and had been propagated in 50-cell trays, average height 34 cm; potting mixture around the roots was kept intact when planting into the soil. Seedlings were of a Northland provenance (*Leptospermum scoparium* var. *scoparium*) (Provenance B). Plants were also transplanted throughout the experiment site ready for the remaining treatments (Table 1), which were applied on 29 August 2011 once plants were considered to have recovered from transplant shock. The procedures used were the same for the pre-planting herbicide treatments.

All of these remaining treatments were also applied to patches 1.0 m in diameter (with the plants at the centre of the patch), apart from Treatment 11, which was applied to 0.5 m diameter patches (0.20 m², also at 1000 litres/ha). Treatments were applied around each plant, with some herbicides being applied to basal parts of the manuka, apart from Treatments 6 and 7 (based on glyphosate). These treatments were applied using half a bucket as a shield so all parts of the patch were sprayed but herbicide was prevented from contacting the manuka. Treatment 12 was applied on 29 August then again on 1 December 2011.

The experiment used a randomised complete block design with five replicates, and blocking was based on location in the paddock, which differed in aspect. Average daily temperatures in the 2 weeks following herbicide application were 10.5°C for the June application and 10.2°C for the August application. Monthly rainfall in June, July, August and September 2011 were 98.6, 110.6, 52.4 and 37.0 mm, respectively. Trade names for herbicides used in the experiment were Roundup 360 Pro (glyphosate), Gallant NF (haloxyfop-P-methyl), Versatill (clopyralid), Nufarm Flowable Simazine (simazine) and Agpro Terbutylazine 500 (terbutylazine).

Plant height was measured regularly from July to December 2011, then again on 30 August

2012 and 20 December 2012. The percentage of ground occupied by various plant species within the treated patches was estimated on a regular basis until December 2011. The stem diameter of the manuka was measured using callipers on 31 January 2012 and 20 December 2012. Analyses of variance were conducted on all data using SAS and least significant differences were calculated where significant treatment effects were detected ($P < 0.05$).

Experiment 2

The second experiment was conducted at the same site as Experiment 1 and used the same techniques described above, including times of application. Treatment 2 for Experiment 2 was the same as Treatment 12 in Experiment 1, to allow comparisons between the two experiments (Table 1). One difference was that metsulfuron (Escort) was applied at 120 g ai/ha in combination with glyphosate on 9 June 2011 to simulate the highest residue levels likely to be found in soil if manuka was planted after use of metsulfuron for site preparation. Another treatment had 30 g ai/ha of metsulfuron to simulate levels that might be expected if the herbicide had begun to dissipate prior to planting.

The other difference to Experiment 1 was that the four treatments were applied to three different provenances of manuka to check for differences in sensitivity between provenances. Provenance A, also from Northland, matches the description of *L. scoparium* var. *incanum* and is thought to have some drought tolerance but not very tolerant to cold conditions. Provenance B is the same as that used in Experiment 1 and probably tolerates both drought and cool conditions quite well. Provenance C, from Waikato, fits the description of *L. scoparium* var. *linifolium* and is considered to tolerate water-logging as well as drought and coldness. Seed of all three provenances was collected from natural stands known to produce honey with high Unique Manuka Factor (UMF®) content (Stephens et al. 2005).

A randomised block design with five replicates was used for the experiment, with each combination of the three provenances and four weed control

strategies considered as separate treatments within the analyses of variance conducted.

RESULTS

Effects of treatments from both experiments on manuka are assumed to be due to competition from weeds, as symptoms of herbicide damage were seldom seen on the manuka. The only treatment that appeared to affect manuka significantly was Treatment 9, in which the high rate of simazine applied at post-emergence caused chlorosis and stunting of manuka from about 6 weeks after application then remained for several months (data not shown). The stem tips of some plants treated with shielded glyphosate (Treatments 6 and 7) did show chlorosis typical of mild glyphosate exposure for several weeks but the effect soon disappeared.

For herbicide treatments applied in June before manuka was planted, weeds were covering over 70% of the ground by the end of November for all treatments (Table 2), but prior to this, the two treatments with simazine (4 and 5) had less weed cover than Treatments 2 (glyphosate) and 4 (glyphosate + terbuthylazine). This difference was due to creeping buttercup re-establishing more slowly in the former two treatments than the latter two (data not shown).

Herbicide treatments applied after planting of manuka varied in persistence of their effects, and the treatment with the least weeds present in early January 2012 (apart from Treatment 12, which was reapplied in December 2011) was the glyphosate/simazine mixture applied with a shield in August (Treatment 7). The other two treatments with significantly less ($P < 0.05$) weeds than the untreated control plots in January were the glyphosate + simazine + clopyralid mixture applied in June (Treatment 5) and the high rate of simazine applied with haloxyfop and clopyralid in August (Treatment 10).

The variable nature of plant height resulted in many of the treatment means shown in Table 3 not being significantly different following analyses of variance. However, the cumulative increase in height measured from time of planting to 19 December 2011 did produce significant differences. High simazine application rate (Treatment 9) retarded stem elongation the most; the 0.5 m diameter patch (Treatment 11) also adversely affected stem elongation when compared with 1.0 m diameter treatments. Height increase was greatest in Treatment 5, glyphosate + simazine + clopyralid applied in June (pre-planting).

Table 2 The percentage of the treated area around manuka plants (Provenance B) covered by weeds at different dates for each treatment in Experiment 1.

Treatment	Percentage cover of ground around manuka plants			
	22/9/11	16/10/11	23/11/11	5/1/12
1	91.4	100.0	93.4	97.8
2	29.0	63.2	99.8	93.0
3	31.4	57.8	94.0	96.8
4	10.2	31.0	78.8	87.0
5	3.8	21.0	69.4	73.8
6	8.2	19.4	77.6	92.8
7	8.6	10.4	38.8	64.0
8	42.0	28.0	79.2	91.6
9	36.2	25.8	49.0	75.4
10	37.2	19.8	59.4	83.2
11	38.2	24.6	66.6	84.0
12	31.0	18.8	51.2	2.2
LSD ($P=0.05$)	16.3	17.7	20.6	20.1

Table 3 The effect of herbicide treatments on cumulative incremental height increase, total height and stem diameter of manuka plants (Provenance B) planted on 18 July 2011 in Experiment 1.

Treatment	Height increase (cm)		Total height (cm)		Stem diameter (mm)	
	18/10/11	19/12/11	30/8/12	20/12/12	31/1/12	20/12/12
1	2.56	18.7	84	118	4.9	10.2
2	4.18	27.1	94	130	6.1	15.6
3	5.42	27.2	90	109	5.9	13.6
4	5.02	19.5	103	134	7.6	16.0
5	6.03	29.3	112	152	9.9	19.2
6	2.04	18.0	106	138	7.3	16.5
7	2.64	19.6	109	149	9.3	20.7
8	6.88	27.7	111	154	9.0	17.9
9	1.96	12.2	108	145	5.8	14.3
10	2.78	20.9	113	155	8.6	20.6
11	3.02	16.2	101	134	6.9	15.1
12	4.38	19.8	112	145	8.9	17.4
LSD (P=0.05)	NS	9.0	NS	NS	2.4	5.9

Stem diameter measurements of manuka plants gave more consistent results, and treatment differences were still apparent in December 2012, 18 months post-planting. All herbicide treatments resulted in larger stem diameters than untreated plants, although not all differences were statistically significant. Treatment 5 resulted in high stem diameter measurements in both January and December 2012; Treatment 7 (glyphosate + simazine in August) also produced good stem diameters (Table 3).

In Experiment 2, manuka treated with a high rate of metsulfuron (Treatment 4) generally grew at least as well as the untreated plants (Treatment 1) and were usually not significantly smaller than plants with a low weed burden (Treatment 2) for any of the three manuka varieties (Table 4). Treatment 4 had significantly less weeds than the untreated plots for many months after the June application. The only significant differences in manuka growth traits in Experiment 2 were due to Provenance A plants growing less well than Provenance B and C for all four treatments, especially in the absence of herbicides (Table 3). This resulted in a significant provenance $\times$ herbicide interaction ($P < 0.05$); Provenance

A plants in untreated plots had particularly poor growth compared with treatments where herbicide was applied, indicating that Provenance A was less tolerant of weed competition than the other provenances.

DISCUSSION

Measurements of stem diameters 18 months after planting the manuka indicated that weed control did allow plants to get established more rapidly than if no herbicides were applied. Weeds did not cause plant mortality under the conditions of this experiment, but may have if more aggressive weed species had been present. If plants cost \$1.00 each, herbicide costs of \$20 per 1000 plants are only 2% of the cost of the plants.

Although costs could be reduced further by having a smaller area sprayed around each plant, the 50 cm diameter patches resulted in reduced growth compared with 100 cm diameter patches. It was noticeable later in the experiment that tall grass in surrounding untreated areas fell over onto the manuka plants in the 50 cm diameter patches.

One treatment involved clearing weeds both in August 2011 then again in December 2011. Stem diameter measurements made in December 2012

Table 4 The cumulative incremental height increase, stem diameter (cm) and total height (cm) of manuka plants from three provenances subjected to four weed control treatments on 18 July 2011, and the percentage ground cover within the treated 1 m diameter area around plants on 19 October 2011 in Experiment 2.

Prov	Trt	Height increase (cm)		Weeds %	Diameter	Height
		22/9/11	23/11/11	19/10/11	31/1/12	30/8/12
A	1	-0.6	9.1	100.0	3.5	54.5
A	2	3.7	26.4	19.8	7.3	109.8
A	3	3.3	29.9	69.8	4.6	68.0
A	4	1.4	22.4	39.8	6.2	78.7
B	1	6.2	27.8	100.0	5.0	80.0
B	2	5.4	27.3	25.8	8.1	94.4
B	3	7.6	32.8	56.8	7.4	89.4
B	4	9.0	40.0	41.2	6.7	93.2
C	1	6.5	32.3	100.0	5.1	90.0
C	2	7.3	29.7	19.8	8.9	99.0
C	3	6.8	35.0	63.6	5.2	91.4
C	4	6.6	36.7	48.4	6.2	74.4
LSD (P=0.05)		5.0	13.2	15.4	3.1	23.6

suggested there was no advantage gained from a second post-planting application of herbicide.

Simply applying glyphosate to clear an area prior to planting was insufficient to give good establishment of the manuka, and addition of a residual treatment with the glyphosate stopped weeds reinvading for a longer period of time. The treatment that was most easily applied to give the longest period of control was the mixture of glyphosate + simazine + clopyralid applied before planting, and cost \$16.48/1000 plants. By avoiding the need to apply herbicide after planting, it reduced time involved with herbicide spraying, as spraying with a shield was time consuming, and trying to locate the small manuka plants for post-planting applications also took time. Bare ground around the manuka stopped competition occurring during the period immediately after planting, and also reduced accidental damage from workers treading on manuka plants as they could easily be seen.

If post-plant spraying was required, clopyralid and haloxyfop were both tolerated well by the manuka but were more expensive than other options. Using a glyphosate/simazine mixture

with shielded spraying kept chemical costs down (\$9.22/1000 plants) and gave good establishment of the manuka but would be more expensive in labour costs. Damage to plants from accidental spraying of lower branches protruding under the shield could have been avoided by using secateurs to remove sprayed twigs when the error was noticed.

The cost of the glyphosate was doubled due to using a high rate of surfactant to allow for the high water rate (1000 litres/ha) used for spraying. Although the high water rate was used to ensure even application in the experiment, back-pack spraying in hill country would doubtlessly result in spraying being conducted with lower water rates to reduce the need to fill the sprayer as often. Although application might not be as even, it would suffice, and would then allow lower surfactant rates to be used, reducing costs.

Damage from the high rate of simazine was not surprising. Most of the simazine treatments used 4.5 kg ai/ha to maximise persistence, yet simazine is often recommended in pipfruit and newly transplanted radiata pine at 2.5 kg ai/ha (Young 2015). Although the 4.5 kg ai/ha rate

appeared safe for the manuka, testing of the double rate showed the importance of applying the correct amount of spray solution when using rates as high as 4.5 kg ai/ha.

Although 4.5 kg ai/ha of terbuthylazine was found to be damaging to manuka by Harrington & Gregory (2009), in that study the herbicide was applied after planting, rather than 6 weeks before planting used for the current study in which no damage to manuka was noted. However, weed control from terbuthylazine was not as good as from simazine applied at the same rate and time, possibly due to differences between these two herbicides in effectiveness against creeping buttercup.

If metsulfuron should need to be used in preparing a site for planting, for example in combination with glyphosate for removing scrub weeds, residues remaining in the soil after this spraying should not cause problems for manuka seedlings transplanted into the treated soil. However, there was a 6-week delay from the time of this application until planting; planting earlier after high metsulfuron application rates has the potential to damage manuka seedlings as manuka can be susceptible to metsulfuron (Harrington & Schmitz 2007).

The best system for establishing manuka is probably to apply a mixture of glyphosate, clopyralid and simazine in 1 m diameter patches at whatever water rate will allow even application, and plant manuka seedlings in the middle of these patches once the pasture has begun dying off. Manuka seedlings were tolerant of this herbicide mix applied pre-planting; initial and residual vegetation control was good, the seedlings grew well and the cost was moderate.

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