EFFICACY OF SEVERAL ORGANIC HERBICIDES AND GLYPHOSATE FORMULATIONS UNDER SIMULATED RAINFALL

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ABSTRACT

Glasshouse studies were conducted to determine the efficacy and rainfall interval of several organic and glyphosate-based herbicides marketed for use in home gardens. The test species used were white clover (*Trifolium repens*), annual ryegrass (*Lolium multiflorum*) and couch (*Elytrigia repens*). After spraying the 6-week-old plants, some pots were set aside and received no simulated rainfall while others were placed under the rainfall simulator (11 mm rain over 30 minutes) at 2, 3 or 6 h after application. Plants were visually assessed for herbicide efficacy and after 4 weeks all the new growth was harvested and dry matter measured. Rainfall applied 2 or 3 h after application did not reduce the efficacy of organic herbicides. In the case of glyphosate, rain applied at 2 h after spraying reduced efficacy by 4–40% while rain 6 h after application reduced it by 0–20% depending on formulation and plant type.

Keywords: organic herbicide, glyphosate, simulated rainfall, rainfastness, herbicide efficacy.

INTRODUCTION

There are currently several herbicides being marketed as “organic” for home garden use. All are derived from plant oils and work by inhibiting plants’ respiration causing rapid desiccation and brown-off (James & Rahman 1992; James et al. 2002). These herbicides have no systemic action. To meet the strict requirements of the organics industry, organic herbicides must be derived from natural substances by physical means and not be chemically transformed in any synthetic way. They are not allowed to be combined with any synthetic substance before use. Of the herbicides tested here, only one has Biogrow registration. The others have either not been submitted or have been declined on the basis that they are using synthetic adjuvants or emulsifiers.

The herbicide glyphosate is a non-selective, systemic herbicide that is rapidly absorbed through green leaf tissue and translocated to the growing points of the plants where it inhibits protein synthesis. Glyphosate is an ideal product for home garden use. It has no residual soil activity, it is effective against a wide range of plants, it has low mammalian toxicity and a low non-target environmental impact. Glyphosate in both concentrate and ready-to-use formulations is supplied by a number of manufacturers for this market.

Numerous studies have reported that rainfall can greatly affect the efficacy of post-emergence herbicides. In reviewing the influence of environmental factors on herbicide toxicity to plants, Muzik (1976) concluded that the effectiveness of most foliar-applied herbicides is reduced if rain falls soon after application, although the extent of herbicide penetration, surface retention and washoff will depend on the type and formulation of herbicide, diluents, adjuvants and plant species. Detailed studies have been conducted on the weed control efficacy of two ‘organic’ herbicides and the influence of various factors on their behaviour (James & Rahman 1992; James et al. 2002), but little information is available on their rainfastness. The activity of glyphosate has been reported to be reduced by rainfall occurring up to 24 h after application (Rahman 1985; Bariuan et al. 1999; Reddy 2000).

In this study six different products currently marketed in New Zealand as 'organic' herbicides and nine formulations of glyphosate sold for home garden use, were evaluated for their efficacy and for the effect of rainfall soon after application.

MATERIALS AND METHODS

This study was conducted at Ruakura Research Centre using three test species viz. white clover (*Trifolium repens*), annual ryegrass (*Lolium multiflorum*) and couch (*Elytrigia repens*). White clover and couch are common garden weeds that can be difficult to control while annual ryegrass was chosen as a representative annual grass weed. All were grown in 100 mm diameter pots. The white clover plants were established from 75 mm diameter soil plugs collected from a clover-dominant pasture on 21 December 2001. Unwanted plant species were removed by hand at approximately 2-week intervals. Annual ryegrass was established from seed on 19 December 2001, thinned to 6 plants per pot on 17 January 2002 and trimmed to a height of 40 mm on 21 January to promote tillering before spraying. The couch was established on 19 December 2001 by planting 40–50 mm lengths of rhizomatous material collected from the field. The couch plants were trimmed to 150 mm height on 30 January 2002, the day before spraying. The soil used in all cases was a Horotiu silt loam with 6.8% organic carbon and a pH of 5.2. All plants were grown in the glasshouse without supplementary light and watered by sub-irrigation as required. Average temperatures during this time were 10–15°C during the night and 25–35°C during the day. On 18 January 2002, the white clover and annual ryegrass plants were sprayed with chlorpyrifos (Lorsban, 0.5 g/litre) to control aphids.

Six organic products and nine formulations of glyphosate (Table 1) were tested on the three plant species. All were applied on 31 January 2002 at concentrations recommended on the label. In addition, Weedmaster Blue (Treatment 16) was also applied at half the recommended application volume so that the application volume used was comparable to that of the other glyphosate treatments. The application volume was calculated on the basis of label instructions. Thus, for the organic herbicides, the common instruction on product labels is to thoroughly wet all the plant. Past experience has shown that >2000 litres/ha was required to thoroughly wet all parts of the plant and achieve effective control with desiccant type herbicides (James et al. 2002). Surplus test plants were used to determine that an application volume of 2400 litres/ha achieved this requirement. For all but one of the glyphosate formulations (Weedmaster Blue), the instructions on the label are to "just wet" or to "wet" the target plant. After several test plants were put through the sprayer using different water application rates, a panel of three people all agreed that the plant was "wet" at an application rate of 400 litres/ha. For Weedmaster Blue, because the label specifically stated that the target plants should be "thoroughly wet", this formulation was also applied at 800 litres/ha. The different application volumes required to achieve what appear to be similar label recommendations reflect two points. Firstly, with the desiccant herbicides it is critical to thoroughly wet all the plant including the stems and secondly the glyphosate-based herbicides contain synthetic adjuvants that make the plant look "wet" at lower application volumes. When concentrate formulations were diluted according to label instructions and applied at 400 litres/ha, it was found that they were applied at half the active ingredient rate of the ready-to-use products.

Except for Treatment 3, all treatments were applied using a single nozzle, moving belt, pot sprayer operated at 200 kPa and with the nozzle 400 mm above the top of the pot. Treatment 3 was applied with its own foaming trigger pack that the chemical was purchased in. For Treatments 1, 2 and 4–7 the sprayer used a TeeJet 11005 nozzle and a belt speed of 15 rpm to apply 2400 litres/ha of spray solution. For Treatments 8–17 a TeeJet 8002E nozzle and a belt speed of 40 rpm was used to apply 400 litres/ha of spray solution. The plants for Treatment 17 were passed through the sprayer twice to comply with the label application rate and the instruction to thoroughly wet the foliage.

After treating with herbicides, some pots were set aside and received no simulated rainfall while others were placed under the rainfall simulator for 30 min at exactly 2, 3 or 6 h after herbicide application. The rainfall simulator was an overhead oscillating nozzle

that applied the equivalent of 11 mm of rain during the 30 min period. There were four replications for every treatment/rainfall combination for both white clover and annual ryegrass and three replications for the couch. After the rainfall events were completed the pots were laid out on the glasshouse benches in a randomised block design.

The damage to plants (0–100 scale, 0=no damage) was visually assessed relative to the untreated control plants on 12 and 27 February 2002. On 28 February all green top growth was harvested from each pot, dried at 80°C for 24 h and then weighed. Dry matter yields as a percentage of the untreated plants were calculated and these data subjected to analysis of variance. The data for the untreated controls were excluded from the analysis to avoid bias.

TABLE 1: Organic and glyphosate-based herbicides and the rates of these applied to white clover, annual ryegrass and couch.

Trt no.	Herbicide	Conc. (g ai/litre)	Label use rate	Application volume used (litres/ha)	Applied rate (kg ai/ha)
1	Untreated control	-	-	2400	-
2	AgPro Bio-Safe ¹	700	70 ml/litre	2400	117.6
3	Organic Weed Control (tp) ²	24	ready to use	NA ⁶	NA
4	Organic Weed Control ²	24	ready to use	2400	57.6
5	Eco Store Organic Weed Control Concentrate ³	680	1:7 (125 ml/litre)	2400	204
6	Natures Way Greenscape (concentrate) ⁴	700	70 ml/litre	2400	117.6
7	Natures Way Greenscape (ready to use) ⁵	100	ready to use	2400	240
8	Butlers Glyphosate Weedkiller	360	10 ml/litre	400	1.4
9	McGregor's Weedout	360	10 ml/litre	400	1.4
10	Watkins Weedkiller	360	10 ml/litre	400	1.4
11	Westminster G360	360	10 ml/litre	400	1.4
12	Roundup Renew	360	10 ml/litre	400	1.4
13	Yates Zero	100	35 ml/litre	400	1.4
14	No Frills General Weedkiller	50	70 ml/litre	400	1.4
15	Zero Weedspray	7.2	ready to use	400	2.8
16	Weedmaster Blue	3.6	ready to use	400 ⁷	1.4
17	Weedmaster Blue	3.6	ready to use	800 ⁸	2.8

¹70% fatty acids – coconut oil derivatives.

²2.4% natural fatty acids.

³68% pine oil (emulsifiable concentrate).

⁴70% fatty acids (emulsifiable concentrate).

⁵10% fatty acids.

⁶NA=not applicable because it was used as a foam formulation from its own applicator.

⁷Half recommended label application volume.

⁸Application volume used to achieve the label instruction to “thoroughly wet the foliage”.

RESULTS AND DISCUSSION

Organic herbicides

All the organic herbicides evaluated (Treatments 2–7) gave very rapid desiccation of the target plants. Within hours of application the plants were wilting and turning a blackish green colour. Within 24 h all the plants were “browned-off” and within 48 h maximum damage had been achieved.

The effects of the organic herbicides on white clover were variable with some plants dying but most plants had produced green regrowth within 5 days of treatment. However, at the end of the trial period, plant regrowth was still only about 16% of the untreated control (Table 2). All herbicides applied through the precision pot sprayer gave similar results. The least effective treatment on white clover was the foam formulation of Organic Weed Control, which was applied using its own applicator according to label instructions. Rainfall applied 2 or 3 h after spraying did not reduce the efficacy of any of the products, with these data being nearly identical to the no rain data.

All of the organic herbicides tested here killed the annual ryegrass when they were not subjected to simulated rain (data not presented). However, similar to the white clover, the Organic Weed Control through its own applicator was ineffective, with most of the annual ryegrass plants surviving. In both the 2 h and 3 h rainfall intervals there were occasional surviving plants although they were too few in number to draw valid conclusions.

Couch is a difficult and problematic rhizomatous weed that was not expected to be controlled by the organic herbicides, which desiccate top growth but have no systemic action. However, greater than 70% control of this weed was achieved in many cases. AgPro Bio-safe and the foam formulation of Organic Weed Control gave significantly poorer control of couch than Eco Store Organic and Greenscape concentrate when no rain was applied (Table 3). Rainfall after application had no adverse effects on control of couch.

TABLE 2: Dry matter yield (% of untreated control) of white clover, 4 weeks after treatment with organic herbicides and simulated rainfall 2 and 3 h after herbicide application.

Herbicide	Applied rate (kg ai/ha)	Percent dry matter		
		No rain	Rain at 2 h	Rain at 3 h
Untreated control		100 (4.19) ¹	100 (3.84) ¹	100 (4.26) ¹
AgPro Bio-Safe	117.6	9	12	13
Organic Weed Control (tp)	NA	44	48	31
Organic Weed Control	57.6	9	5	4
Eco Store Organic	204	3	15	5
Greenscape (conc.)	117.6	10	10	9
Greenscape (ready)	240	11	9	3
LSD (P<0.05) ²		15.6	13.6	12.9

¹Actual dry matter yield (g/pot).

²LSD (P<0.05) for the rainfall treatments (i.e. between columns) is 12.2.

Glyphosate formulations

Glyphosate is a systemic herbicide and slower acting than the organic herbicides. Yellowing of the leaves, the first visual symptom of toxicity, usually appears about a week after treatment with total brown-off taking up to a month depending on the resilience of the weed. All of the glyphosate formulations evaluated in this study (Treatments 8–17, Table 1) produced similar early symptoms on the target plants. Several treatments completely killed white clover in the absence of rain while some stunted regrowth ranging up to 3.8% of untreated occurred with others (Table 4). Rainfall applied 2 h after application significantly reduced the efficacy of all the glyphosate products. At the end of the trial period, regrowth ranging from 6.8 to 48% of the untreated had occurred in all treatments. There were no significant differences between any of the concentrate formulations, including Roundup Renew which is the only product to claim a 2 h rainfall period. The two 'ready to use' formulations gave the highest efficacy under this rainfall regime with significantly less regrowth for these treatments than for Westminster G360.

However, recommended application rates for these two products resulted in twice the amount of active ingredient applied compared to the concentrate formulations. When one of these 'ready to use' formulations, Weedmaster Blue, was applied at the same rate of active ingredient and in the same application volume as the concentrates, the level of control was similar to that of the concentrates. When rainfall was delayed for 6 h, there was improved performance from all the glyphosate formulations with most of them further reducing regrowth by more than 50% from the 2 h level. Weedmaster Blue at the higher application rate performed as well as when no rain was applied and significantly better than several other treatments. After the 6 h rainfall, Butlers Glyphosate had significantly more regrowth than No Frills General, Zero Weedspray and the both rates of Weedmaster Blue.

TABLE 3: Dry matter yield (% of untreated control) of couch, 4 weeks after treatment with organic herbicides and simulated rainfall 2 and 3 h after herbicide application.

Herbicide	Applied rate (kg ai/ha)	Percent dry matter		
		No rain	Rain at 2 h	Rain at 3 h
Untreated control		100 (1.71) ¹	100 (1.35) ¹	100 (2.06) ¹
AgPro Bio-Safe	117.6	118	58	92
Organic Weed Control (tp)	NA	109	92	61
Organic Weed Control	57.6	58	11	22
Eco Store Organic	204	26	6	26
Greenscape (conc.)	117.6	53	49	19
Greenscape (ready)	240	71	87	37
LSD (P<0.05) ²		40.6	39.4	41.5

¹Actual dry matter yield (g/pot).

²LSD (P<0.05) for the rainfall treatments (i.e. between columns) is 36.5.

TABLE 4: Dry matter yield (% of untreated control) of white clover, 4 weeks after application of glyphosate-based herbicides and simulated rainfall at 2 or 6 h after application.

Herbicide	Applied rate (kg ai/ha)	Percent dry matter		
		No rain	Rain at 2 h	Rain at 6 h
Untreated control	-	100 (4.19) ¹	100 (3.84) ¹	100 (4.26) ¹
Butlers Glyphosate	1.4	4	29	22
McGregor's Weedout	1.4	1	28	13
Watkins Weedkiller	1.4	1	28	14
Westminster G360	1.4	3	48	13
Roundup Renew	1.4	0	32	12
Yates Zero	1.4	1	24	11
No Frills General	1.4	2	35	7
Zero Weedspray	2.8	0	7	5
Weedmaster Blue	1.4	0	19	8
Weedmaster Blue	2.8	0	7	0
LSD (P<0.05) ²		1.6	29.9	11.6

¹Actual dry matter yield (g/pot).

²LSD (P<0.05) for the rainfall treatments (i.e. between columns) is 10.5.

All of the glyphosate products tested here killed the annual ryegrass and simulated rain at either 2 or 6 h had no observable effect on the results (data not presented). When no rain was applied all the products killed the couch within 12 days (Table 5). For all herbicides except Zero Weedspray, rainfall resulted in lower damage scores. Rainfall had the greatest effect on Roundup Renew, which performed significantly worse than most of the other concentrate formulations. However, all the products gave 100% control of the couch by the end of the study period.

TABLE 5: Percent damage to couch 12 days after application of glyphosate-based herbicides and simulated rainfall at 2 or 6 h after application.

Herbicide	Applied rate (kg ai/ha)	Percent damage on 12.2.02 ¹		
		No rain	rain at 2 h	rain at 6 h
Untreated control		0	0	0
Butlers Glyphosate	1.4	100	93	98
McGregor's Weedout	1.4	100	93	98
Watkins Weedkiller	1.4	100	87	93
Westminster G360	1.4	100	93	100
Roundup Renew	1.4	100	80	83
Yates Zero	1.4	100	85	98
No Frills General	1.4	100	87	98
Zero Weedspray	2.8	100	100	100
Weedmaster Blue	1.4	100	97	98
Weedmaster Blue	2.8	100	93	100
LSD (P<0.05) ²		-	11.2	5.5

¹On 27.2.02 all treatments except untreated resulted in 100% control.

²LSD (P<0.05) for the rainfall treatments (i.e. between columns) is 4.8.

There is very little literature on the performance of organic herbicides. However, the efficacy shown here for Eco Store Organic Weed Control Concentrate and Natures Way Greenscape concentrate is similar to that found previously (James & Rahman 1992; James et al. 2002). The effect of rainfall on the efficacy of glyphosate on difficult-to-control weeds has been the topic of several studies, which have usually demonstrated that the herbicide requires optimum environmental conditions to provide adequate control. For example, Reddy (2000) reported reduced control of redvine (*Brunnichia ovata*) by glyphosate (Roundup Ultra) when 25 mm of simulated rain was applied 6 or 24 h after the herbicide, while Bariuan et al. (1999) found that activity of glyphosate (Roundup Ultra) was reduced by one-half and one-third respectively by 25 mm of simulated rain applied 1 and 24 h after application. Herbicide formulation has also been shown to affect rainfastness with Roundup Ultra performing significantly better than the Roundup Original when 6.4 mm of simulated rain was applied 2 h after application, although both formulations performed significantly worse than when no rain was applied (Feng et al. 2000).

CONCLUSION

Two of the five organic herbicide products have a rainfast period of 3 h on their labels while the remaining three products do not mention rainfastness. In this study all the organic products tested satisfactorily met their label claims. Seven of the nine glyphosate formulations have a rainfast period of 6 h on their labels while one has a 2 h rainfast period and another has an 8 h rainfast period. When these products were tested on susceptible target species such as annual ryegrass, all met their respective rainfast

label claims. However, when evaluated on more difficult-to-control species, such as white clover, most products demonstrated reduced efficacy when simulated rain was applied at 2 and 6 h after application.

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