Developing best practice roadside *Parthenium hysterophorus* L. control

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Summary Field trials were established on central Queensland roadsides to compare the efficacy of herbicide treatments on parthenium weed (*Parthenium hysterophorus* L.) germination and growth, as well as potential effects on grass cover.

A key finding was the increased pre-emergent control of parthenium weed from a higher rate (36 g a.i. ha^{-1}) of metsulfuron-methyl (Brush-off™) compared to current practices (4.2 g a.i. ha^{-1}), whilst maintaining comparable grass cover. The herbicides atrazine (Atrazine™ 500), imazapic (Flame™), and tebuthiuron (Graslan™) also reduced parthenium weed emergence. Varying post-emergent activity was exhibited by the herbicides tested, which included imazapyr (Arsenal™ 250) and glyphosate (Roundup™).

The roadside trials focused on primary herbicide treatments that selectively removed parthenium weed and reduced height growth of vegetation, but retained perennial ground cover in order to reduce the likelihood of parthenium weed re-invasion.

Keywords *Parthenium hysterophorus*, roadside, weed control.

INTRODUCTION

Parthenium weed (*Parthenium hysterophorus* L.) is an opportunistic and aggressive plant, rapidly colonising sparsely covered ground, flowering four to eight weeks after germination and producing thousands of seeds per plant for up to six months (Navie *et al*. 1996). Roadsides have long been recognised as one of the primary habitats for parthenium weed growth, seed production and spread. Initial expansion of parthenium weed often follows major road corridors (Haseler 1976). Despite the long term and widespread roadside spraying programs in central Queensland (the use of 2,4-D and atrazine since the mid 1970s, and metsulfuron-methyl in more recent times), outbreaks still occur on roadsides inside and outside core infested areas, including interstate. Unchecked roadside infestations produce seed with the potential to further infest roadsides and agricultural lands at an economic, environmental and health cost to landholders and the wider community.

Parthenium weed occurrence on roadsides is favoured by road run-off, ground disturbance and proximity to seed vectors. Run-off from the road surface helps provide roadside verges with adequate soil moisture important for parthenium weed seed germination (Williams and Groves 1980). While good grass cover can suppress parthenium weed establishment (Anon. 2000), parthenium weed seed germination can be enhanced by disturbance of the existing ground cover through road maintenance works or the use of non-selective herbicides (Anon. 2000). Seed vectors such as vehicles, machinery and stock enable the spread of parthenium weed seed via road corridors. Given the utility value of roadways, a roadside noxious weed management program needs to incorporate roadside vegetation, road user safety and asset protection.

Information on the current management practices for roadside parthenium weed and alternative methods for roadside weed control, combined with results from recent experiments, will be used to develop specific and integrated parthenium weed control measures, with the longer-term aim of developing a best practice manual for parthenium weed on roadsides. This paper reports on the results of a preliminary trial involving six herbicides applied to central Queensland roadsides infested with parthenium weed.

MATERIALS AND METHODS

In July 2002, four roadsides (three Peak Down shire-controlled bitumen roads and a gravel road controlled by Queensland Department of Main Roads) were selected north of Capella (23°05´S, 148°01´E) and west of Clermont (22°49´S, 147°38´E), in the Central Highlands of Queensland, for parthenium weed studies. Each site was approximately 1.5 km long and the predominant soil type across all sites was a black cracking clay (Ug 5.12).

The experimental design was a 4 × 10 factorial replicated four times within each road, using a randomised complete block design. Factor A comprised the four roads, and factor B was the 10 treatments (Table 1). Each plot was 50 m (along road) × 4 m (in from the road edge), with a 5 m buffer strip between plots.

The treatments listed in Table 1 were applied in March 2003, with the exception of the tebuthiuron granules, applied in November 2002. In January 2004, an additional glyphosate treatment was applied using a wick wiper. The glyphosate 2160 g a.i. ha^{-1} and 270 g a.i. ha^{-1} plots were retreated with metsulfuron-methyl at 36 g a.i. ha^{-1} and imazapic 240 g a.i. ha^{-1} respectively, in

October 2003. This re-spraying was undertaken to limit the potential spread of parthenium weed seed from the two glyphosate treatments. Re-spraying occurred after the pre- and post-emergent activity of glyphosate had been established in the August 2003 assessment.

Tebuthiuron granules were applied by a custom-made granule spreader, converted from a Sthil™ air blower backpack (loaned by Macspread). The backpack was field calibrated by adjusting customised augers to deliver 200 g of product over a 200 m^2 plot. As the backpack had a 2 m swath, two adjacent runs were conducted within each plot.

All March and October 2003 herbicide treatments were applied using a 4.5 m spray boom 1 m above the ground with nine fan nozzles (4680 25E) spaced 50 cm apart. Spraying was conducted at a water volume of 335 L ha^{-1} behind a four-wheel drive bike travelling at 3 km h^{-1}. Where recommended on the label, herbicide solutions included 0.5% non-ionic surfactant (BS 1000™, containing 1000 g L^{-1} alcohol alkoxylate).

The trial design allowed for the application of a broader scale follow-up treatment once the initial herbicide effects were documented. In October 2003, two of the four replicate blocks at the three bitumen sites were slashed. Following the slashing treatment, a glyphosate wick wiping treatment was applied at all sites in January 2004, using a two-metre Landwise™ weed wiper front-mounted on a four-wheel drive bike. The bike travelled at 3 km h^{-1} and used 5.4 litres of 2:1 water to glyphosate solution in treating the plots at all four sites.

All plots were assessed in March, May and August 2003, and February 2004. Additional assessments were made of the control and tebuthiuron plots in November 2002. Assessments were also made of the control plots and all glyphosate treatments in October 2003 and control and glyphosate wick plots in January 2004, although these data are not presented.

In each 50 m plot, data were recorded from 10 quadrats each 4 m × 0.25 m at 5 m intervals along the road. Each quadrat ran 4 m at right angles from the road edge and was split into four 1 m by 0.25 m sub-quadrats. The parthenium density was determined in each sub-quadrat by counting individual plants and recording their stage of development. Grass height and ground coverage data were recorded from six (randomly selected) of the 10 quadrats in each plot.

An analysis of variance was performed on parthenium weed count data. Where the F-test was significant ($P < 0.05$), the mean differences were determined using Fisher's Protected Least Significance Difference (LSD) test. Prior to analysis, all parthenium weed count data required logarithmic transformation. Data were then back-transformed for presentation. Genstat 6 (VSN International, Oxford) was used for all analyses.

RESULTS

The number of live parthenium plants across the four roadside sites was significantly different ($P < 0.0005$) for each assessment period. At all assessment times the three bitumen roadside sites recorded higher live parthenium weed densities than the gravel roadside site, with no significant difference between the bitumen sites. Plant numbers ranged from 23 (bitumen sites) to two live parthenium weed plants m^{-2} (gravel roadside site) at pre-treatment, to 6.5 (bitumen sites) to 0.4 live parthenium weed plants m^{-2} (gravel roadside site) at post-treatment (February 2004). The site by treatment interaction was not significant at any assessment period.

The mean live parthenium weed densities at pre-treatment (March 2003) and post-treatment (May and August 2003) are presented in Figure 1. In all treatments, including the controls, a decline in the number of live parthenium weed plants was recorded in May 2003. The sites had experienced no significant rainfall

Table 1. Herbicides used on roadside parthenium weed in Peak Downs shire of central Queensland.

Herbicide	Active ingredient	Product rate ha^{-1}	Rate (g a.i ha^{-1})
#Arsenal™ 250	imazapyr	0.5 L	125
Atrazine™ 500	atrazine	6 L	3000
#Brush-off™	metsulfuron-methyl	7 g	4.2
#Brush-off	metsulfuron-methyl	60 g	36
#Flame™	imazapic	1 L	240
Graslan™ 10%	tebuthiuron	10 kg	1000
#Roundup™	glyphosate	6 L	2160
#Roundup	glyphosate	0.75 L	270
Control			

Solutions included a 0.5% (v/v) non-ionic surfactant (BS 1000™, containing 1000 g L^{-1} alcohol alkoxylate).

(four rainfall events less than 8 mm each) between March and May 2003, limiting the effectiveness of the herbicide treatments. Herbicide activity was more evident in August 2003 (Figure 1) following rainfall in June at all sites (33 mm on 25/6/03). The largest decline (95.3%) in the live parthenium weed density by August 2003 occurred in the metsulfuron-methyl (36 g a.i. ha^{-1}) treatment, when compared with the pre-treatment density in March 2003.

Conversely, by August 2003, the parthenium weed population in the glyphosate 2160 g ha^{-1} plots had increased 74.3%, compared with the pre-treatment values. Within this treatment, the removal of a competitive grass cover and June rainfall had encouraged parthenium weed germination, particularly on the gravel road site.

The tebuthiuron pre-treatment data were collected in November 2002. There were no significant differences between the treatments prior to herbicide application ($P > 0.05$); however, significant differences were evident at both the May and August 2003 assessments ($P < 0.05$). In May 2003 (Figure 1) and February 2004 (Table 2) the live parthenium weed density was significantly less in the tebuthiuron treatment than all the other treatments. Despite the rainfall received at the sites in December 2003 (158 mm), and January 2004 (170 mm), only a small proportion (7.5%) of the small parthenium weed rosettes counted in the tebuthiuron plots from August 2003 survived to become reproductive plants in February 2004.

A significantly higher number of senescent plants were identified in the glyphosate wick wiped plots in February 2004. However, this application method only treated plants >15 cm tall. In all assessments, at least 55% of the parthenium population consisted of non-reproductive plants usually <10 cm tall. Persistence of these smaller plants meant that the parthenium weed density remained high after a single wick wiping treatment (Table 2).

In February 2004, few rosettes were evident in the plots that were re-treated (October 2003). However, the live population was dominated by mature parthenium weed plants. At the time of re-treatment, the population was dominated by rosettes (18.5 m^{-2}); subsequent dry conditions (until December 2003) limited the post-emergent activity of the re-applied herbicides. The least effective treatments in February 2004 were the imazapyr and glyphosate wick treatments. No significant difference in the density of live parthenium plants was observed between these treatments and control

Table 2. Mean density of live parthenium weed in February 2004. Means followed by the same letter do not differ significantly at $P < 0.05$.

Treatment	Live parthenium density (plants m^{-2})
Glyphosate wick	12.87 a
Control	11.54 a
Imazapyr	6.86 ab
#Metsulfuron-methyl 36 g a.i. ha^{-1}	3.93 bc
Metsulfuron-methyl 4.6 g a.i. ha^{-1}	2.59 cd
Atrazine	2.54 cd
#Imazapic 240 g a.i. ha^{-1}	2.44 cd
Metsulfuron-methyl 36 g a.i. ha^{-1}	1.79 d
Imazapic	1.59 d
Tebuthiuron	0.53 e

The metsulfuron-methyl 36 g a.i. ha^{-1} and imazapic 240 g a.i. ha^{-1} treatments were applied in October 2003 to plots that had been previously treated with glyphosate 2160 and 270 g a.i. ha^{-1} respectively, in March 2003.

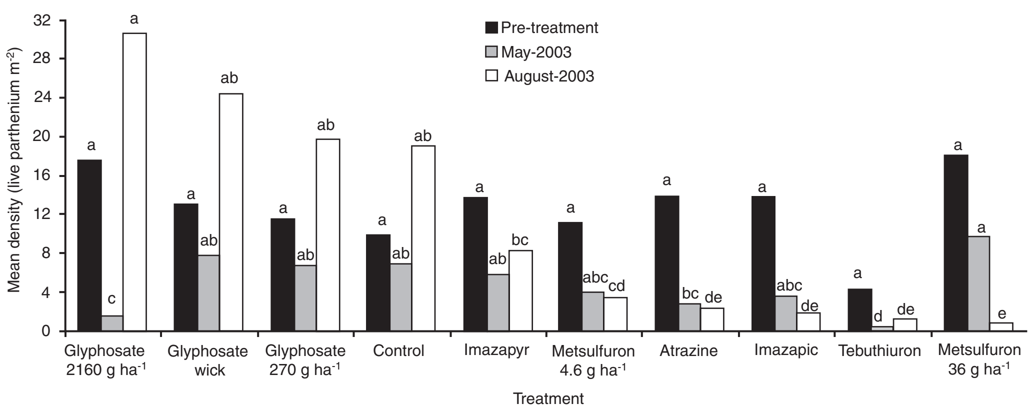

Figure 1. Live roadside parthenium weed density at pre- (black bars) and post-treatment (grey and white bars) times. Means within each time period bar superimposed by the same letter do not differ significantly at P = 0.05.

plots. The densities of live parthenium weed plants for imazapic and both metsulfuron-methyl treatments (applied in March 2003) were not significantly different to those in the atrazine treatment (Table 2). A significant advantage in using the higher rate of metsulfuron-methyl was evident in the August 2003, with no adverse effects on grass cover.

Introduced grasses were the predominant roadside grasses across all roads, accounting for 95% of the grass species. Over the course of the trial similar levels of grass cover and growth were recorded in most of the treatments, with the exception of the tebuthiuron and imazapic treatments. The tebuthiuron and imazapic (October 2003) treatments prevented the seasonal germination and growth of some introduced grasses (particularly *Echinocloa colona* L.Link and *Eriocloa cerbra* S.T.Blake), creating large bare patches 2–4 m from the road edge on the bitumen sites. The presence of *Chloris vigata* Sw. and *Sorghum × almum* Parodi species was more evident in tebuthiuron treatments. The imazapic (October 2003) and the glyphosate wick wiper treatments suppressed the height growth of buffel grass (*Cenchrus ciliaris* L.) for up to three months particularly on the gravel road site where buffel grass was dominant. The glyphosate 2160 g a.i. ha^{-1} removed much of the perennial ground cover, although grass coverage increased after the metsulfuron-methyl 36 g a.i. ha^{-1} treatment was applied to these plots on October 2003.

Throughout the trial, data from the control plots showed 103 ± 28 (± SE) of the live parthenium weed plants occurred 0–2 m from the road surface, and 20 ± 13 (± SE) of the live parthenium weed plants occurred 3–4 m from the road surface edge. This finding supports an earlier report that infestations of parthenium weed are close to the road surface edge and that lateral seed movement by wind is generally limited (Haseler 1976). Soil seed sampling at 1 m intervals in March 2004 may help verify this observation (data currently being analysed).

DISCUSSION

The field trial investigated herbicides with potential pre- and post-emergent activities on parthenium weed control whilst retaining a low perennial grass cover to limit parthenium weed re-invasion. Tebuthiuron exhibited the greatest pre-emergent control of parthenium weed. The findings that tebuthiuron (1000 g a.i. ha^{-1}) restricted annual grass cover on the bitumen road sites may limit the use of this herbicide on a larger scale. Imazapic also exhibited pre- and post-emergent control of parthenium weed. However, this was the most expensive treatment trialled and, like tebuthiuron, is best suited to sites with an existing perennial grass cover.

While no significant difference was observed between the metsulfuron-methyl and atrazine, there would be significant advantages in using metsulfuron-methyl at 36 g a.i. ha^{-1} to control parthenium weed along roadsides, over the currently registered rate of 4.2 g a.i. ha^{-1}. Atrazine has been the most commonly used herbicide for roadside spraying of parthenium weed in central Queensland since 1975 and though effective as a pre-emergent treatment, it has been under increasing scrutiny to minimise its use Australia-wide (NRA 2002).

The imazapyr, imazapic, glyphosate 270 g a.i. ha^{-1} and glyphosate wick wiping treatments were investigated as options for suppressing the growth of roadside vegetation. Height suppression can assist with meeting safety benchmarks by improving road user visibility. Combining height or seed head suppression with noxious weed control with one herbicide application can reduce the need for repeated slashing operations. However, none of the treatments applied exhibited a consistent combination of parthenium weed control and grass suppression with cover retention. A combination of herbicides may be more effective in providing parthenium weed knockdown and parthenium weed residual control along roadsides, especially where grass suppression is also desirable. While herbicides were applied at times with adequate soil moisture, the post-emergent activity of several of the herbicides was affected by dry conditions following application.

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