Foliar application of 2,4-D/picloram, imazapyr, metsulfuron, triclopyr/picloram, and dicamba kills individual rubber vine (*Cryptostegia grandiflora*) plants

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Abstract

As part of a program to develop effective and affordable integrated pest management systems for the control of rubber vine (*Cryptostegia grandiflora*), 10 foliar-applied herbicides were trialled at various dose rates in north Queensland to determine their effectiveness in controlling scattered rubber vine infestations (<1000 plants/ha). Five herbicides (2,4-D/picloram (Tordon 50-D) at 1.33/0.33 g/L; imazapyr (Arsenal 250A) at 1.25 g/L; metsulfuron (Brush-Off) at 0.09 g/L; triclopyr/picloram (Grazon DS) at 1.5/0.5 g/L; and dicamba (Banvel 200) at 2.0 g/L) killed 90–100% of the treated plants. The other 5 herbicides (2,4-D ethyl ester (Estercide 800) at 8 g/L (51% kill); 2,4-D butyl ester (AF Rubber Vine Spray) at 2.0 g/L (49%); glyphosate (Glyphosate 360) at 3.6 g/L (44%); fluroxypyr (Starane) at 3.0 g/L (19%); and 2,4-D amine (Amicide 500) at 2.5 g/L (18%)) performed poorly. The chemical cost of the 5 effective herbicides is $476–1863/ha, excluding cost of labour. It would require $333–1304 million in herbicides alone to treat the current rubber vine infestation, and, even then, follow-up action would be necessary. In this context, these herbicides are best seen as useful tools for controlling scattered rubber vine plants. Foliar herbicides producing kills greater than 90% remain tools for controlling scattered rubber vine on higher value land or on strategic parts of properties.

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Introduction

Rubber vine (*Cryptostegia grandiflora* Roxb. ex R. Br.) is native to Madagascar, and was introduced into Australia as a garden plant in the late nineteenth century (Dale 1980; Marohasy and Forster 1991). It is widely distributed in Mexico, Central America, the drier West Indian Islands, New Caledonia and Australia (McFadyen and Harvey 1990). Rubber vine has spread throughout north Queensland, with the original centres of dispersal being the old mining settlements. In the early 1940s, it was cultivated as a potential source of rubber both in Australia and overseas (Curtis and Blondeau 1946; Dale 1980). The latex quality is similar to that of *Hevea* spp. (Curtis and Blondeau 1946), but there is no economic method of extraction.

In Australia, it has become a serious weed of rangeland and native plant communities in tropical and subtropical Queensland (400–1400 mm isohyets). It is a poisonous woody climber, forms shrubs when unsupported and is capable of forming dense impenetrable monospecific thickets (McGavin 1969). Dense infestations along watercourses impede access to water for cattle, reduce pasture production, and severely restrict movement of cattle during mustering. Feral and stock animals learn to hide in the rubber vine and thus avoid muster, making disease control and maintenance of herd quality difficult. Rubber vine is capable of smothering vegetation 30–40 m above ground. This places habitats of high conservation value such as riparian systems, dry rainforest remnants in the monsoonal belt and gallery forests of the Gulf of Carpentaria under threat (Humphries *et al.* 1991). Also threatened are the specific habitat requirements of native fauna such as the greater glider (*Petauroides volans*) and squirrel glider (*Petraurus norfolcensis*) (B.C. Lawrie, personal communication). Rubber vine is broadly distributed over 20% of Queensland (34.6 million hectares of which 700 000 hectares is densely infested) (Chippendale 1991) and is spreading at an estimated 1–3% per annum (Dale 1980). It currently costs the north Queensland cattle industry $8 million per year (Chippendale 1991) in direct costs and increased stock management costs.

Several foliar herbicides [2,4-D formulations (acid, amine and esters); 2,4-D/dicamba; 2,4-D/picloram; 2,4-D/2,4,5-T; 2,4-D/triclopyr; 2,4,5-T; 2,4,5-T/dicamba; 2,4,5-T/picloram; asulam; atrazine; clopyralid; dicamba; dicamba/MCPA; fosamine; glyphosate; hexazinone; MCPA; picloram and triclopyr] have been tested on rubber vine (Harvey 1981; 1982; 1987b). Of these, 2,4-D/picloram, dicamba and 2,4-D were effective against seedlings (Harvey 1982; McFadyen and Harvey 1990). Commercial experience has been that the recommended 2,4-D sprays have been ineffective or at least unreliable. The effect of imazapyr, metsulfuron and fluroxypyr have been examined on several woody and herbaceous species (Love 1989; Marshall 1989; Meyer and Bovey 1990), but not on rubber vine in field studies.

This study evaluated the response of mature rubber vine in the field to foliar applications of 2,4-D amine, 2,4-D ethyl ester, 2,4-D butyl ester, dicamba, fluroxypyr, glyphosate, imazapyr, metsulfuron, 2,4-D/picloram and triclopyr/picloram.

Materials and methods

Four field experiments were conducted during 1988–1990 near Charters Towers, Queensland (20°04′S, 146°16′E), to determine the effect of 10 high-volume, foliar-spray applied herbicides on scattered rubber vine (Table 1). Herbicides and doses tested on rubber vine are shown in Table 2. All solutions contained 0.2% (v/v) nonionic surfactant (a nonyl phenol ethoxylate). Not all herbicides and doses were tested at all sites. The experimental design was a randomised complete block with 3 replicates. Plots were approximately 5m × 20m.

Plant condition

Individual mature rubber vine plants (2670 plants) were 1.5–2.5m tall, uniformly lush, actively growing and flowering at the time of herbicide application. Large rubber vine clumps or vines climbing trees were excluded from the experiment to ease herbicide application. Rubber vine density was between 5000–5500 rubber vine plants per hectare at all sites. The basal diameter of treated plants was recorded at ground level at sites 3 and 4.

Table 1. Site description and conditions during herbicide application on rubber vine (*Cryptostegia grandiflora*) at 4 sites near Charters Towers during 1988–1990.

Site	Location	Soil type	Treatment date	Plants per plot	Time applied	Temp.	Relative humidity	Wind speed	Final assessment date
					(h)	(°C)	(%)	(km/h)	
1 Sandy Bend	12 km E of Charters Towers	Sandy loam	3.4.88	20	600–1000	22–32	60–76	6–13	11.2.90
2 Plum Tree	20km E of Charters Towers	Sandy loam	8.1.88	10	530–1000	25–32	63–78	2–6	12.8.89
3 Sandy Creek	8km W of Charters Towers	Sandy loam	11.4.89	10[1]	840–1140	27–31	51–60	4–19	2.10.90
4 Black Soil	11km S of Charters Towers	Black soil	12.4.89	10[1]	730–1000	21–27	52–67	4–19	2.10.90

[1] Ground basal diameter was recorded for each plant.

Table 2. Herbicides and dose rates tested on rubber vine (*Cryptostegia grandiflora*).

Herbicide (active ingredient)	Trade name	Rates applied (g active ingredient per litre)
2,4-D amine	Amicide 500	2.5, 3.3, 5.0
2,4-D butyl ester	AF Rubber Vine Spray	2.0, 2.6, 4.0
2,4-D ethyl ester	Estercide 800	2.0, 2.6, 4.0, 8.0
2,4-D/picloram	Tordon 50-D	1.0/0.25, 1.33/0.33, 2.0/0.5, 4.0/1.0
dicamba	Banvel 200	1.3, 2.0, 4.0
fluroxypyr	Starane	1.0, 1.5, 3.0
glyphosate	Glyphosate 360	1.8, 3.6, 7.2
imazapyr	Arsenal 250A	0.625, 0.83, 1.25, 2.5, 5.0
metsulfuron	Brush-Off	0.06, 0.09, 0.12
triclopyr/picloram	Grazon DS	1.5/0.5, 2.25/0.75, 3.0/1.0, 6.0/2.0

Spray equipment and herbicide application

A 10-litre, hand-carried pneumatic sprayer with variable cone nozzle with operating pressure at 200 kPa was used at sites 1 and 2. A twin-diaphragm pump, powered by a 3.7 kW motor was used to reduce spray application time, at sites 3 and 4. The handgun was fitted with a D6 nozzle and the operating pressure adjusted to 700 kPa. At each site, the plants were thoroughly sprayed to the point where the spray mixture dripped from the foliage (spray volume 5000L/ha).

Herbicide evaluation

A visual rating assessment system (Vitelli 1990) was used to measure leaf and stem dieback at 30, 90, 180 and 360 days after treatment (DAT). Final assessment was made at 679, 582, 539 and 538 DAT for sites 1, 2, 3 and 4 respectively, and only these data are presented. The main stem and tap root of plants recorded as dead were cut to ensure no live tissue remained.

Statistical analysis

Percentage plant mortality was subjected to analysis of variance after an arcsine transformation. Each site was analysed separately to compare the particular herbicides at that site. An across-site analysis was constructed to estimate average treatment responses. In this analysis, the site by treatment interaction term was used as the appropriate error for comparing the average herbicide effects. (The very unbalanced nature of the whole data set meant that no realistic test of significance for this interaction was possible.) Due to the imbalance, a table of LSD values was calculated.

Basal diameter data from sites 3 and 4 were pooled prior to fitting polynomial regressions of % mortality vs. basal diameter.

Results

Only those results from the overall across-site analysis will be considered. Plant mortality greater than 95% is commercially accepted by herbicide contractors and graziers as an effective control level in the field (Harvey 1987c). Four herbicides — 2,4-D/picloram (1.33/0.33 g/L), imazapyr (1.25 g/L), metsulfuron (0.09 g/L) and triclopyr/picloram (1.5/0.5 g/L) — produced >95% mortality (Table 3). Dicamba (2.0 g/L) was the next most effective herbicide, killing 91% of the rubber vine plants. There was no significant difference between these 5 effective herbicides.

Irrespective of dose rate, none of the 2,4-D formulations (amine, butyl ester and ethyl ester), glyphosate or fluroxypyr killed more than 52% of the rubber vine plants (Table 3). Of the 2,4-D formulations, ethyl ester (8.0 g/L) and butyl ester (2.0 g/L) killed half of the treated rubber vine plants, whereas the amine (2.5 g/L) killed less than 20% of the plants. Similar results were obtained by Harvey (1981), who found 2,4-D

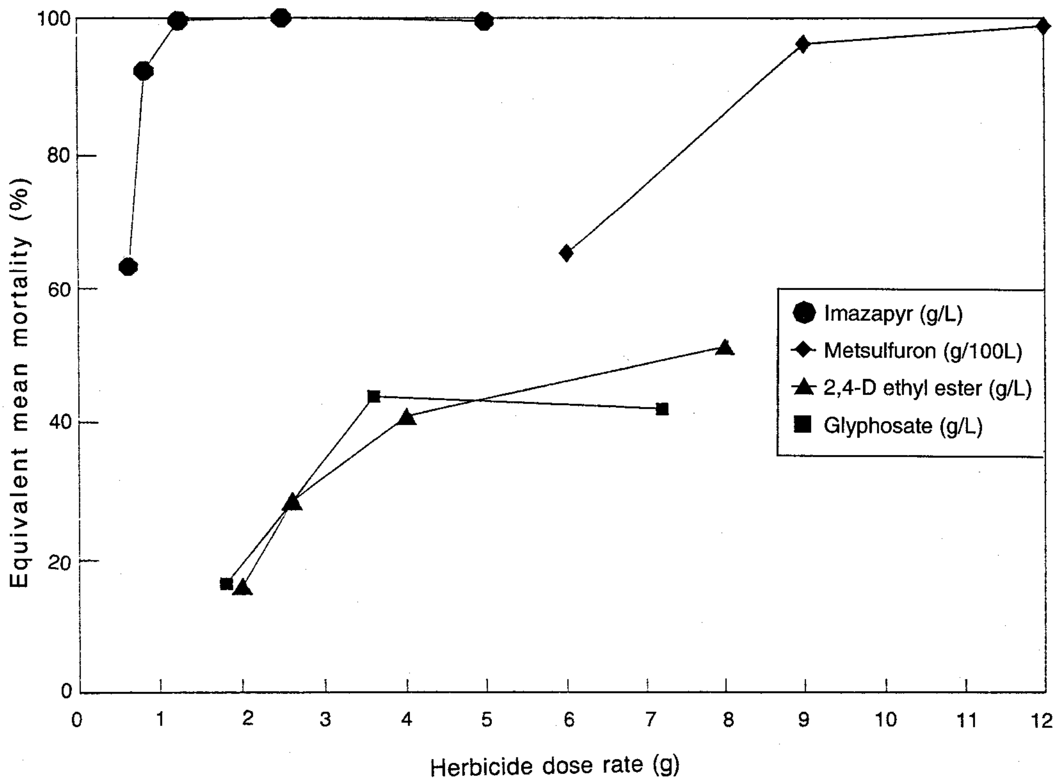

Figure 1. Equivalent mean mortality (%) of rubber vine (*Cryptostegia grandiflora*) high volume foliar-sprayed with 2,4-D ethyl ester, glyphosate, imazapyr and metsulfuron at different doses across 4 sites near Charters Towers.

ester formulations to be more effective than 2,4-D amine formulations.

Within each herbicide a dose response was observed. To demonstrate the importance of selecting the correct dose rate within each herbicide, 4 herbicides are shown in Figure 1 — 2 effective herbicides (metsulfuron and imazapyr) and 2 ineffective herbicides (2,4-D ethyl ester and fluroxypyr). Imazapyr applied at 0.625, 0.83, 1.25, 2.5 and 5.0 g/L killed 63–100% of the treated plants, and metsulfuron at 6.0, 9.0 and 12.0 g/100L killed 66–99% of the rubber vine plants. Glyphosate and 2,4-D ethyl ester gave poor control. Application of 2,4-D ethyl ester at 2.0, 2.6, 4.0 and 8.0 g/L killed 16–51% of the plants, whereas glyphosate at 1.8, 3.6 and 7.2 g/L killed 16–44%.

Plant size (stem basal diameter) had a significant effect ($P<0.05$) on herbicide performance only for imazapyr at 0.625 g/L. This treatment killed small plants (13–22 mm), but large plant mortality was variable (59% mortality for plant basal diameters of 46–67 mm). Imazapyr at concentrations >1.25 g/L killed all the plants (52–81 mm). A similar trend was apparent for the other 4 effective herbicides — 2,4-D/picloram, metsulfuron, triclopyr/picloram and dicamba, though not enough data were collected to show statistical significance. Variable plant size ranges and non-uniform spread within the ranges will certainly have influenced the test (fitting polynomial regressions of % mortality vs. basal diameter) for each herbicide.

The cost of 100L of spray solution (herbicide concentrate diluted with water) ranges from $2.78–37.25 (Table 3) depending on the herbicide and dose rate. Prices were retail prices prevailing in September 1993 and were for purchases of 20L or more (or, in the case of metsulfuron, at least 1kg).

Table 3. Rubber vine (*Cryptostegia grandiflora*) mortality (arcsine and equivalent % units) across 4 sites, near Charters Towers, previously high-volume sprayed with foliar-applied herbicide. Herbicide costing per 100 litres of spray solution (herbicide concentrate diluted with water) based on retail prices for September 1993. No single LSD value is possible due to the imbalance of treatments and sites. To compare arcsine values use the LSD table. NA = not available.

Herbicide	Rate	No. sites treatment applied	Arcsine values	Mortality	Basal diameter range	Cost per 100 L spray solution
	(g a.i./L solution)			(%)	(mm)	($)
2,4-D/picloram	1.33/0.33[1,2]	1	1.59	100	13–99	14.66
imazapyr	1.25[1]	3	1.51	99.6	17–81	37.25
	0.625	2	0.92	63.4	13–185	18.63
metsulfuron	0.09[1]	2	1.37	96.2	14–120	15.00
triclopyr/picloram	1.5/0.5[1]	4	1.36	95.4	16–262	9.51
dicamba	2.0[1]	1	1.27	90.9	NA	14.00
	1.3	2	1.21	87.2	19–221	9.33
2,4-D ethyl ester	8.0[2]	2	0.80	51.2	NA	11.75
	4.0	4	0.69	40.8	14–122	5.88
2,4-D butyl ester	2.0[2]	2	0.78	49.3	13–172	2.78
glyphosate	3.6[2]	1	0.72	43.7	NA	12.00
fluroxypyr	3.0[2]	2	0.45	18.8	NA	34.75
2,4-D amine	2.5[2]	3	0.44	18.1	17–166	2.90

LSD (P = 0.05) table for comparing arcsine values of treatment A and treatment B across sites. (For the convenience of the reader a working example for comparing arcsine is presented: Paired comparisons between 2,4-D/picloram (1.59) with triclopyr/picloram (1.36) give a difference of 0.23 which is < 0.448 [LSD value obtained from the table for no. of sites 2,4-D/picloram applied (1) and no. of sites triclopyr/picloram applied (4)] and hence is not significant.

No. of sites treatment B applied	No. of sites treatment A applied: 4	3	2	1
4	.283	.306	.347	.448
3		.327	.366	.463
2			.401	.491
1				.567

[1] Lowest herbicide rate which gave > 95% mortality.
[2] Highest mortality for individual herbicide.

Discussion

Effective herbicides and dose rate

This study has established that actively growing mature rubber vine plants can be killed with foliar-applied herbicides, and the desired kill level is obtained by selecting the correct herbicide and dose rate. Five herbicides — 2,4-D/picloram (1.33/0.33 g/L), imazapyr (1.25 g/L), metsulfuron (0.09 g/L), triclopyr/picloram (1.5/0.5 g/L) and dicamba (2.0 g/L) were not significantly different in efficacy — and killed between 91–100% of the treated rubber vine plants. This level of kill in the field is accepted by commercial herbicide contractors and graziers as an effective control level (Harvey 1987c). Harvey (1987b) obtained similar results (100% mortality) with 2,4-D/picloram and dicamba at 30 g/L, using a mister. Herbicide concentrations applied by a mister are normally a factor of 10 times higher than herbicides applied with pneumatic or motorised sprayers (Toth *et al.* 1981). In addition, caution must be exercised in the widespread application of dicamba, triclopyr/picloram, 2,4-D/picloram, imazapyr and metsulfuron as desirable native woody species may be killed. Imazapyr may affect short-term pasture production (12–18 months, J.S. Vitelli, unpublished data), by killing some grasses.

Poor control with 2,4-D

2,4-D has previously been recommended for rubber vine control (McFadyen and Harvey 1990). Desirable characteristics of this herbicide include its effectiveness and short half-life (7 days) and the lack of effect on non-target woody species. Formulations of 2,4-D have also been investigated to reduce volatility (Harvey 1989), and to maximise uptake and translocation in rubber vine (Harvey 1982; 1987a).

The 2,4-D formulations (amine, butyl ester and ethyl ester) used in our research performed poorly with maximum kills of only 50%. Previous research on rubber vine using 2,4-D was on either seedlings (Harvey 1982; 1987a; 1989) with stem basal diameters approximately 5mm or field plants 1.0–2.5m tall (Harvey 1981). Efficacy was rated on either a stem-dieback assessment method in which control was calculated as the degree of stem dieback as a percentage of the original plant height (Harvey 1987a; 1989) or a biomass-reduction assessment method in which control was calculated as the percentage reduction of rubber vine biomass (Harvey 1981). Results reported here are based on mature (flowering and podding) plants in the field (basal diameter 13–262mm) and a whole-plant mortality assessment. These differences may explain poor kills by the 2,4-D formulations in our study and the poor commercial field success of 2,4-D in north Queensland, relative to results reported by Harvey (1981; 1982; 1987a; 1989).

Cost considerations

The cost of control is of paramount importance, due to the vast areas and difficult terrain in which rubber vine occurs. A high initial mortality is required (to minimise the need for follow-up treatment) together with a low cost per plant killed. For the most effective 5 herbicides (>90% kill) reported here, 100L of spray solution costs between $9.51–37.25. Approximately 5000L/ha is required for high volume spraying of a rubber vine infested paddock. Effective foliar spraying of a dense hectare of rubber vine would take between 500–600 minutes, at a labour cost of $133–160 (labour cost $16/h; J.A. Ready, personal communication), and the herbicide cost would be between $476–1863. Triclopyr/picloram is the most cost-effective chemical. Herbicides that can control >90% of the treated rubber vine in the first application would substantially reduce the high labour costs required for follow-up applications. Incorrect volume application will lead to variable control (McMillan 1987).

Cost of control is greater than the value of the land. However, control of introduced weed species should be regarded as insurance because, as Scanlan *et al.* (1991) stated: "it protects larger areas, and so the cost per hectare treated is not a useful criterion for judging cost/benefit". Thus high cost, labour intensive methods can be justified.

Integrated pest management approach

An integrated pest management (IPM) approach should be implemented for rubber vine which is both effective and economically feasible. Combinations of herbicides (ground and aerial), biological control agents, mechanical control (bulldozing, cutterbar, blade plough and slashing) and burning are currently being investigated for stands of varying rubber vine density. Dale (1980) reduced rubber vine density by 19–73% after 4 successive annual burns. Biological control agents and fire are potentially the cheapest options for controlling large, dense infestations. However, development of suitable fire and mechanical control procedures, and successful establishment of biological control agents remain to be achieved, so chemical control methods are the only practical option to control existing rubber vine problems. Even with successful biological control, a need for chemical control of rubber vine on higher value land or on strategic parts of certain properties would still exist. In these areas, 5 foliar herbicides, 2,4-D/picloram, imazapyr, metsulfuron, triclopyr/picloram and dicamba, will effectively control scattered to medium infestations (<1000 plants/ha) of rubber vine.

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