The efficacy of simulated and aerial foliar herbicides on *Chromolaena odorata*

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Summary Two ground-based pot trials were conducted in northern Queensland. Across both trials double passes and double concentrations of herbicides containing fluroxypyr, triclopyr and triclopyr + picloram + aminopyralid were more effective. Single passes and herbicides containing metsulfuron-methyl, aminopyralid and metsulfuron + aminopyralid were less effective. Observations of the field efficacy of an aerially applied double pass of a fluroxypyr herbicide were collected from infestations on two Northern Territory field sites in three different months, with greater efficacy observed from earlier and double pass treatments.

Keywords aerial herbicides, Siam weed, timing, simulation, tropics, *Chromolaena odorata*

INTRODUCTION

Chromolaena odorata (Siam weed) (L.) King was discovered in Queensland in 1994 and the target of an eradication program until 2012, and since 2019, infestations have also been discovered in the Northern Territory (Price 2022). Across Queensland and the Northern Territory, Siam weed occurs in areas that are difficult to access for ground-based weed control. Anecdotal reports of variable efficacy from aerial control activities have been received across seasonally dry tropical areas. Due to the operational complexities of researching aerial applications it was more practical and informative to simulate the active ingredient rates, droplet size and volumes used in aerial applications, using ground-based boom applied treatments to potted plants.

MATERIALS and METHODS

Queensland Pot trials In two trials, potted Siam weed plants were wheeled at 4 km hour^{-1} under a stationary boom at a height of 1.8 m. The spray solution was applied using XR Teejet® AIRX110 (015) nozzles at 1 bar of pressure to deliver very coarse droplets at a volume of 102 L ha^{-1}.

In the first trial, three herbicides were applied as a single boom pass at a spray volume equivalent to 102 L ha^{-1}. The same herbicides were also applied at half the original concentration but with a double boom pass, which is equivalent to a spray volume of 204 L ha^{-1} but applying the same amounts of active ingredients. Trial 1 treatments (Table 1) were applied to four replicates of three plants on 14/6/22, after they were raised in the same pots from cuttings in 2019.

In the second trial, eight herbicides were applied with a single pass at 102 L ha^{-1} and a double pass at 204 L ha^{-1} (Table 1). The same concentrations were used in both pass treatments, so the rates of active ingredient were doubled in the two pass treatments. Trial 2 treatments were applied to two replicates of five plants on 29-30/6/22. Plants were raised from cuttings in late 2021 and were younger with more active growth than those in Trial one.

The active ingredients and application rates for both herbicide trials are shown in Table 1. The treatments correspond to the following products: N1-5 was Anon (600 g kg^{-1} metsulfuron methyl)). N6 and 7 Ray 675 (300 g kg^{-1} metsulfuron methyl + 375 g kg^{-1} aminopyralid)). N8 and 9 Komachi Activator (80 g L^{-1} aminopyralid). N10 and 11 Hotshot® (140 g L^{-1} fluroxypyr + 10 g L^{-1} aminopyralid). N12 to 17 Starane Advanced™ (333 g L^{-1} fluroxypyr). N18 and 19 Fireball (400 g L^{-1} fluroxypyr). N20 and 21 Garlon® (600 g L^{-1} triclopyr). N22 to 25 Grazon Extra® (300 g L^{-1} triclopyr + 100 g L^{-1} picloram + 8 g L^{-1} aminopyralid). Water was applied for treatments 26 and 27. 'Activator'® was added to treatments 1 to 7 at a rate of 2 mL L^{-1}. 'Uptake'® was added to the remaining herbicide treatments at 2 mL L^{-1}.

At treatment, the basal diameter of each leader, standing height and plant health were recorded per plant. The health of each plant was assessed at 0, 1, 3, 4.5 and 7 months after treatment and any re-growth and herbicide affected re-growth were also noted (this data is not shown). Pre-and post-spray flower development was also categorised up until removal on 11/8/22, when reproductive material was weighed and a single most advanced flowerhead selected per pot. Seed was removed from each flower head, counted, and germinated under a 30/20ºC, 12-hour diurnal incubator regime. The survival data, mean plot health and seed viability data for each trial were analysed separately as randomised complete block designs in Genstat® V22 VSN International and pooled standard errors of means calculated per trial.

Table 1. Pot trial treatment rates with active ingredients in post-emergent herbicides grouped across the 2 trials, with final mean survival data (February 2022) and frequency of pots with viable seed. Double pass treatments shaded blue. *T 1-7 granular products in grams, remaining treatments millilitres.

N	Trial	Application volume (L ha^{-1})	Active ingredients (ai g or mL ha^{-1})*	Mean Plot Survival %	Pots with viable seed/ sampled
1	2	102	metsulfuron methyl (36)	100	2/7
2	1	102	metsulfuron methyl (48)	83	0/10
3	1	204	metsulfuron methyl (48)	92	1/11
4	2	204	metsulfuron methyl (72)	40	0/2
5	2	102	metsulfuron methyl (96)	60	0/7
6	2	102	metsulfuron methyl (36) + aminopyralid (45)	50	0/9
7	2	204	metsulfuron methyl (72) + aminopyralid (90)	0	0/9
8	2	102	aminopyralid (24)	70	5/9
9	2	204	aminopyralid (48)	70	5/8
10	2	102	aminopyralid (45) + fluroxypyr (630)	20	2/8
11	2	204	aminopyralid (90) + fluroxypyr (1260)	30	0/1
12	1	102	fluroxypyr (600)	42	8/10
13	1	204	fluroxypyr (600)	17	1/11
14	2	102	fluroxypyr (600)	30	7/9
15	2	204	fluroxypyr (1200)	0	1/9
16	1	102	fluroxypyr (1200)	17	2/9
17	1	204	fluroxypyr (1200)	0	1/11
18	2	102	fluroxypyr (600)	40	0/9
19	2	204	fluroxypyr (1200)	0	0/7
20	2	102	triclopyr (900)	40	3/10
21	2	204	triclopyr (1800)	0	1/9
22	1	102	triclopyr (900) + picloram (300) + aminopyralid (24)	0	0/12
23	2	102	triclopyr (900) + picloram (300) + aminopyralid (24)	50	8/9
24	1	204	triclopyr (900) + picloram (300) + aminopyralid (24)	0	0/10

25	2	204	triclopyr (1800) + picloram (600) + aminopyralid (48)	0	0/8
26	1	102, 204	control (water)	80	8/11
27	2	204	control (water)	83	6/9

Northern Territory field observations During the months shown in Table 2, single block applications of herbicides were mixed in a 300 L tank and applied from a 10 m aerial (helicopter) boom spray through SS11015 nozzles. For the December 2021 treatments single monitoring plots with up to five plants were marked and photographed in each treated block. Each treatment of Grazon Extra was applied at a product rate of 3 L ha^{-1} (900 g ai ha^{-1} triclopyr + 300 g ai ha^{-1} picloram + 24 g ai ha^{-1} aminopyralid). Starane Advanced was applied at 1.8 L ha^{-1} (fluroxypyr at 600 g ai ha^{-1}) and Anon (metsulfuron at 48 g ai ha^{-1}). These are label rates for controlling other NT weeds and match QLD pot trial 1 rates. Treatments were applied to different blocks as either single passes of 100 L ha^{-1}, or with a double pass at half the concentration (200 L ha^{-1}) (Table 2).

Table 2. Treatments applied to aerial blocks at Northern Territory properties, lower mix rates were applied as double passes (double volume). Each pass applied 100 L ha^{-1}.

Month	Active ingredients (g ai L^{-1})	Pass	Mix rate (L^{-1})
Dec 21	fluroxypyr (333)	2	9 mL
		1	18 mL
	metsulfuron methyl (600)	2	0.12 g
		1	0.24 g
	picloram (100) + triclopyr (300) + aminopyralid (8)	2	15 mL
		1	30 mL
May 23	fluroxypyr (333)	2	9 mL
July 23	fluroxypyr (333)	2	9 mL

For the 2023 treatments blocks were treated at 200 L ha^{-1} with two passes of Starane Advanced (1.8 L product ha^{-1}) (Table 2). Within three blocks treated on 22/5/23, five plants each were tagged, measured, and photographed on 25/5/23. Within two blocks that were treated on 18/7/23, three plants each were marked, measured, and photographed on 13/7/23. At 2 or 3, and 6 months after treatment marked plants were assessed with similar health and re-growth scores to the pot trials. Recruitment across each block was also noted. Within May and July 2023 treated blocks, bulked samples of flower heads were collected (where present) and germinated under the same conditions as the pot trial.

RESULTS

QLD Pot Trials The final data for the two pot trials is shown in Table 1, the following treatment numbers refer to N (Table 1). The trial 1 pooled standard error of the survival means was $\pm$16.2% and 25 of 96 plants with flowers had viable seed. The trial 2 pooled standard error of survival means was $\pm$28.1% from 2 replicates and 40 of the 139 plants that reproduced had viable seed. Maximising the treatments and minimising the plants per replicate lead to large variances and some inconsistencies amongst active ingredients between the trials. Some of the variance may have resulted from higher survival in the first blocks treated due to insufficient flushing time (water) between treatments. Higher replicate 1 survival was recorded in treatments 4, 10, 11, 13, 14, 15, 18 and 23, which influenced the data from single pass fluroxypyr treatments.

Single and double passes of metsulfuron (treatments 1-3, 5) were ineffective as post-emergent treatments, survival was even across the replicates and comparable to the controls. The double pass at 72 g ha^{-1} (4) was more effective in replicate 2. Across treatments 1-7, viable seed production was limited to 3 plants. Individually there was little efficacy data to recommend metsulfuron or aminopyralid, though they reduced viable seed production they were more effective when applied together as a double pass in trial 2 (7). Aminopyralid was not effective as a post – emergent herbicide (8, 9) and was unlikely to be contributing to any efficacy of pot trial treatments (10, 11, 22, 24 or 25). The double pass (11) was applied after treatment 10 and 3 surviving plants were recorded.

Between 17 and 42% of Siam weed plants survived single pass applications of herbicides containing fluroxypyr (12, 13, 14, 18) and this was not consistently effective and reflected the rinsing problem above. The double pass, 204 L ha^{-1} treatments with fluroxypyr (15, 16, 17, 19) were all as, or more effective than the single pass treatments. No viable seed was recovered from the alternate source of fluroxypyr (18, 19), compared with some viable seed in treatments 12 to 17. The double pass fluroxypyr treatments with 1200 g ai ha^{-1} were all effective.

There were survivors in both replicates of the single pass triclopyr treatment (20), but the double pass treatment (21) was effective. Viable seed was recovered off 3 plants (20) and 1 plant that died (21). The efficacy of the triclopyr + picloram + aminopyralid is thought to be mostly via the triclopyr component of treatments 22-25. Amongst these four treatments only plants in the single pass treatment 24 survived, 8 of those plants produced viable seed.

NT Field observations Three months after blocks treated in December 2021, some leaf damage was recorded within the double pass metsulfuron block. No damage was recorded in the 100 L ha^{-1} metsulfuron treated block. At 6 months the effects of the metsulfuron treatments could not be distinguished from flowering Siam weed recruitment so this herbicide was ineffective. After 3 months a high level of control was recorded across the other 200 L ha^{-1} treatments and single pass fluroxypyr treatment. Similar observations were made 6 months after treatment but with controlled marked plants also surrounded by newly recruited flowering plants. After 3 and 6 months more than half the single pass picloram + triclopyr + aminopyralid plants survived.

In the May 2023 treated blocks, after 2 and 6 months, 1 of the 15 monitored plants was alive, all others were dead. The live plant was on the margin of a sprayed strip. One developed flowerhead was obtained from the surviving plant, and 50% of the 14 seeds recovered were germinable.

Within the blocks treated in July 2023, the monitored plants were herbicide affected and died back, but four had reshot after six months, with herbicide damaged re-growth noted. From the bulk field collection, multiple mature flowerheads were obtained from these plants and an average of 16.7% germinated, from 3 x 50 seeds subsampled. Growth and viable seed production was suppressed by the July application of fluroxypyr, but mortality was limited to 2 of the 6 monitored plants.

DISCUSSION

It is infeasible to replicate a range of treatments in field situations. Small volumes and sample sizes provided some anomalous results, but some general trends were consistent across the field and pot trials.

Efficacy Some of the less effective treatments identified under more ideal pot trial conditions can be excluded from aerial testing as efficacy is unlikely to improve under field conditions. Across the field and pot trials the metsulfuron-methyl products were largely ineffective and there was no mortality data to recommend further testing. On its own the aminopyralid seemed similarly ineffective in the pot trials. Given the higher product rates needed for active parity with other fluroxypyr treatments, there is little to recommend further low volume, low concentration testing of the fluroxypyr + aminopyralid (treatments 10 and 11). In pot trial 2, treatment 7 was effective but aerial application would be outside the current use of this product and it would require further testing to be permitted. Triclopyr based herbicides may warrant field testing as a double pass application. Across pot trials and field observations herbicides containing fluroxypyr or triclopyr + picloram + aminopyralid were also effective. Post-emergent efficacy of triclopyr + picloram or solely picloram herbicides were not assessed.

Application Volumes In both pot trials and the December 2021 field treatment, double passes of fluroxypyr, triclopyr, and triclopyr + picloram + aminopyralid herbicides showed more effective or consistent control than the single pass treatments. Across both pot trials, seven of the eight treatments with no surviving plants were double pass treatments. The single pass efficacy of treatment 22 was not repeated 2 weeks later (23) on younger fresher plants, nor evident in the December 2021 field block. This highlights the variability from single run applications, with more consistent control from double passes with 200 L ha^{-1} application volumes. With inconsistent results from single passes under a stationary boom, single passes under field conditions are less likely to be effective in June. Higher rates of double pass fluroxypyr (1200 g ai ha^{-1}) were more effective than the double pass half rates. With similar results for the 2 herbicides containing triclopyr (21, 24, 25) although the double pass volume seems more critical than doubling the active rate as well.

Timing Siam weed plants germinating in December can flower the following May (S. Brooks unpublished data). This was observed with dense recruitment within the blocks treated in December 2021. Although operationally convenient (when aerial treatment of *Mimosa pigra* occurs in the NT), it was also reported that non-flowering plants are harder to detect in December. Siam weed plants are easier to detect from the air when flowers are present. Whilst the early wet season applications were effective (except metsulfuron) additional treatments, such as early dry season fire would be required to reduce the recruitment and mid-year seed production. The level of control of fluroxypyr field treatments was more consistent in May. Viable seed production was prevented on plants effectively treated in May. Seed was produced from plants treated (mostly with products containing fluroxypyr or aminopyralid) in June (some of which died) and July. Implementing treatments as close to initial flowering as possible would be most effective. After June, as plants dry and become more mature, effective treatment and preventing seed production is less consistent.

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