Aerial spraying of pampas grass in difficult conservation sites

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ABSTRACT

Pampas grass (*Cortaderia selloana*) has invaded many coastal cliff, dune and swamp communities throughout New Zealand, displacing native species. Control of pampas grass in some of these places can be challenging. Three different devices for spraying herbicide from a helicopter were tested: beer keg spot sprayer, a weighted nozzle, and a directed lance. Their relative cost and effectiveness were assessed at Pouto Swamp, Northland—40 plots were assessed prior to, at 3 months, and at 12 months after spraying with haloxyfop. The pampas grass clumps defined the sampling points within the plot (10 adjacent pampas plants per plot). The relative efficiency of the three devices in spraying three large blocks of pampas grass was also measured. All three devices gave effective control of pampas grass with minimal non-target damage. The keg was the cheapest because it used the least herbicide mixture and could be used with a smaller and cheaper helicopter. The original experimental design was not followed in its entirety so some variables were confounded. Most treated plots were showing regrowth 12 months after treatment, and follow-up treatment would be needed to effect complete control of the infestation.

Keywords: weeds, control, monitoring, trials, pampas grass, *Cortaderia selloana*, environmental weeds, haloxyfop, aerial spraying, conservation sites, protected natural areas, Pouto Swamp, New Zealand

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1. Introduction

1.1 THE PROBLEM

Pampas grass (*Cortaderia selloana*) and purple pampas grass (*C. jubata*) are invasive weed species. They were originally introduced from South America and widely planted as shelterbelts and, to a lesser extent, as stock fodder or garden ornamentals. Now they are a major problem in forestry, where they compete with young trees, and in many conservation areas where they replace and prevent the regeneration of native species. Haloxyfop (Gallant) has been shown to be an effective herbicide against pampas grass because it kills grasses without affecting other herbaceous or woody species (Gosling 2000). But controlling pampas grass is still challenging where it has invaded sites that are isolated or where access for control operations is difficult, e.g. sand dunes, coastal cliffs, coastal dune slacks. This investigation sought to determine the best method of applying herbicide from a helicopter to pampas grass in such difficult places.

1.2 STUDY SITE

Pouto Swamp, a 2000 ha sand-dune complex with a mixture of swamp and drier habitats, near the north head of Kaipara Harbour, was chosen as the study site because it is infested with pampas grass and access is difficult. The site is both geographically isolated and difficult to traverse with its mixture of sand and swamp communities. The predominant native cover reflects the dry and wet habitats. It comprises a mosaic of small-leaved pohuehue (*Muehlenbeckia complexa*), sand coprosma (*Coprosma acerosa*), and manuka (*Leptospermum scoparium*) on the dry, and the native rush *Leptocarpus similis* with native sedge *Baumea juncea* in the wet sites. Exotic species such as marram grass (*Ammophila arenaria*), tree lupin (*Lupinus arboreus*) and pasture herbs and grasses also grow in the area. The pampas grass tends to occur on drier dunes. The native toetoe (*Cortaderia splendens*) grows throughout the area, often at drier sites than the pampas grass, such as on tops of dunes, but in places intermingled with the pampas grass. In parts of the swamp there is continuous pampas grass. These places were probably bulldozed in the past in preparation for forestry, but were then never planted and were instead invaded by pampas grass.

1.3 PAMPAS GRASS

Pampas grass is tussock-forming and grows into large clumps. Small, young clumps have live foliage in the middle of the clump. As they age, the centre of the clump increasingly consists of dead foliage. Large clumps, 2–3 m across, consist of a thin, often incomplete, outer ring of live foliage surrounding a large centre of dead leaves. These dead, dry leaves forming the crown of the clump take a long time to break down. At Pouto, the centre was sometimes partly colonised by scrambling species such as sand coprosma and small-leaved pohuehue. As mentioned above, toetoe also occurs at Pouto. Fortunately, toetoe flowers in spring (from mid-November) whereas pampas grass flowers in autumn so at either of these times the two species can be readily distinguished.

1.4 OBJECTIVES

There were two objectives:

- To compare the effectiveness of three different devices for spraying herbicide from a helicopter on to pampas grass plants
- To estimate and compare the relative costs of the three different spray systems

2. Methods

Two experiments were conducted—one for each objective:

- Experiment 1 to compare the effectiveness of the three spray devices
- Experiment 2 to compare their cost effectiveness over large areas

The preferred herbicide was Gallant NF, containing 100 g/litre haloxyfop. The label claims that the best effects on pampas grass are achieved when plants are less than 1 m tall. The rate of Gallant NF recommended by Dow AgroSciences for pampas grass, and used in these trials, is 500 ml/100 litres of water with Uptake adjuvant oil added to the spray mix at the rate of 500 ml/100 litres.

Three herbicide spray devices were tested, all using a helicopter: beer **keg** spot sprayer; weighted **nozzle**; and directed **lance**. In addition, control plots, to which no herbicide was applied, were established.

- The **keg** was a 50 litre beer keg fitted with six solid-cone nozzles mounted to a frame at its base and slung under the helicopter on a 10 m strop (Wooster 1998). Air from a compressor displaces the spray solution through a solenoid valve. The helicopter hovers with the keg spray unit 1 m above the target weed. The keg releases a fine spray when operated by the pilot. The spray covers a 3 m diameter area and this is carried into the foliage by the vortex from the helicopter rotor.
- The **nozzle** was a single, solid-cone nozzle, suspended under the helicopter on a 25 m chain entwined with the spray hose. The pilot lowers the nozzle immediately above the plant to be sprayed, and activates it.
- The **lance** is a handgun fitted with a 1.5 m long lance. The helicopter hovers about 5 m above the pampas grass. A passenger in the helicopter operates the lance, which directs a narrow stream of herbicide directly onto the target plant.

2.1 PRELIMINARY CALIBRATION TESTS

Flow rates of herbicide through the three spraying systems were assessed on the ground, using the same operating pressures as the aerial operation. For the keg, the spray unit was filled with water then turned on until it ran dry. The time taken and the amount of water used were both recorded. For the lance and the nozzle, the time taken to spray 100 litres of water was recorded. Armed with this flow rate information, we could calculate how much herbicide was applied to a particular pampas grass clump if we knew how long it took to spray that clump.

To assess spray coverage, coloured dye was added to water. The mixture was applied to two large and two small pampas clumps, outside the experimental area, using the three different spray devices. After spraying, pampas grass leaves from different parts of the treated clumps were examined for spray coverage on both leaf surfaces. Leaves were taken from each clump and the percent covered by dye visually assessed.

2.2 EXPERIMENT 1: EFFECTIVENESS OF THREE SPRAY DEVICES

2.2.1 Herbicide application

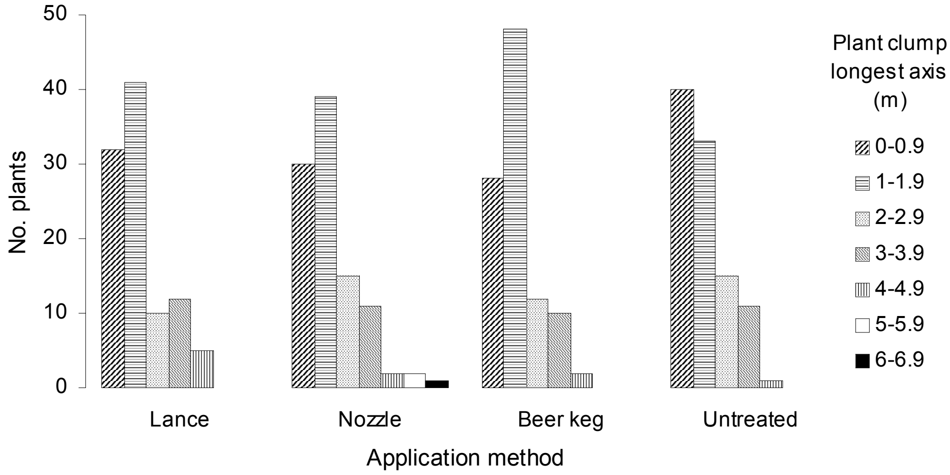
Plots were established in a portion of Pouto Swamp and their boundaries marked with fluorescent paint so they were obvious from the air. A plot comprised 10 discrete, adjacent, clumps of pampas grass, all to be given the same treatment. Large and small clumps were included in a plot as they occurred in the field. Some plots had more large clumps, others more small clumps (see Fig. 1). Four such plots, one for each of the three spray devices, plus an untreated control, made up one experimental replicate, and there were 10 replicates in total. There were thus $10 \times 4 = 40$ plots. The treatment applied to each plot in each replicate was determined at random. Each plot was separated from the next by at least 10 m to reduce the chance of spray drift.

Spraying took place in fine weather on 15 November 1999. A Hughes 500 helicopter carried the keg and a larger Squirrel helicopter the lance and nozzle. For practical and safety reasons, as well as for time considerations, using the same helicopter and pilot for all operations was not possible. The Hughes helicopter pilot controlled the keg sprayer. A different pilot flew the Squirrel and activated the nozzle. A passenger in the Squirrel aimed the lance. Thus, each treatment had a different operator.

Half the appropriate plots were treated with the lance. Next the nozzle was used for all the relevant plots, applied in numerical order of replicate. Then the remaining replicates were treated with the lance. Finally all the keg plots were treated. The results were statistically analysed as randomised blocks, which allowed for any variation in local ecological conditions that may have affected the pampas grass.

Measuring the time taken to spray each plot of 10 pampas grass clumps was attempted, but air sickness of the observer meant that the results were patchy and varied with treatment. In some cases application was only timed for a few clumps.

Figure 1. Distribution of plant clump size before treatment in each application treatment. Total of 100 plants in each treatment group.



2.2.2 Field measurements

Each pampas grass clump was individually identified and tagged for later recognition and measurement as follows:

1. Clump size: length (diameter of longest axis), and width (diameter of shortest axis)
2. Maximum height of clump, excluding flower spikes
3. Visual estimate of percent completeness of live foliage around the circumference of the clump
4. Visual estimate of desiccation of the pampas grass foliage (percentage of foliage apparently dead)
5. Number of new pampas grass shoots
6. Visual estimate of percentage cover of other plant species within the clump, often on the dead foliage in the middle of the clump
7. Visual estimate of signs of herbicide effects on non-target native species growing within or adjacent to the clump, particularly toetoe.

Baseline measurements (measures 1, 2, 3, and 6 only) were made in the plots on 8–10 November 1999, prior to the herbicide spraying. Follow-up assessments (all measures) were made at three and 12 months after spraying (February and November 2000).

2.2.3 Data analysis

The overall size of the pampas grass clumps did not change noticeably during the course of the experiment and was not analysed. Analysis of variance was used to assess the effects of the spray treatments on pampas grass height, percent completeness of live foliage and percent desiccation of the foliage. All three herbicide treatments had obvious effects on the pampas grass, and untreated plots were excluded from the statistical analysis to improve the precision of statistically differentiating between the three sprayed treatments.

2.3 EXPERIMENT 2: COST COMPARISON OF THREE SPRAY DEVICES

The aim was to estimate the costs of applying herbicide to large areas of pampas grass by comparing the helicopter time to treat large areas using the three spray devices. The cost comparison was based on cost of herbicide and cost of helicopter time. It did not include the cost of DOC staff time on the ground. All treatments in this experiment were completed on the same day.

Three blocks of between 0.21 and 0.24 ha were marked out. Each of the three blocks was sprayed with the keg under the Hughes 500, then with the lance and finally with the nozzle under the Squirrel helicopter. As in Experiment 1, a passenger operated the lance and the pilot operated the nozzle.

The time taken to treat each block, including time taken in flying, spraying and re-filling the tanks, was noted. The amount of spray mixture used was recorded for each block on each spraying occasion. Pampas grass clump size and density was assessed in three 100 × 1 m transects in each block as an estimate of clump size and density in the three large blocks. No assessments after spraying were needed in this experiment.

3. Results

3.1 PRELIMINARY CALIBRATION

3.1.1 Flow rate

The keg had the lowest herbicide flow rate of 6 litres/minute. It produced a very fine spray that covered a wide area under the keg, i.e. the target plant and sometimes beyond. The flow rate through the nozzle was 8.2 litres/minute. The lance had the highest flow rate of herbicide measured at 15.3 litres/minute.

3.1.2 Spray coverage

All three devices gave complete spray coverage of the upper surfaces of the pampas grass leaves. The undersides of the leaves near the base occasionally had herbicide on them too, probably from contact with the upper surfaces of other leaves. The nozzle and keg achieved an even distribution of herbicide on the leaf. The force of the spray jet from the lance blew some droplets off the leaf tips but it also forced herbicide into the leaf bases.

3.2 EFFECTIVENESS OF THREE SPRAY DEVICES

3.2.1 Size of pampas grass clumps

When the plots were first established, the pampas grass clumps varied in size from 0.5 to 6 m in diameter along longest axis. Some replicates had a wide range of plant sizes, others had mostly smaller plants. Clump size distribution was similar for each of the three delivery systems, although the untreated control plots had more small plants (Fig. 1). For the other size measurement—height—over a third of the clumps were 1.1–1.5 m tall, about quarter of the plants were <1 m tall and a few were over 2.6 m tall at the beginning of the experiment.

As mentioned previously, the overall size of the pampas grass clumps did not change noticeably during the course of the experiment, so later data on clump size are not reported here.

All the herbicide treatments affected the height of the pampas grass plants, so that these were, on average, about 0.5 m shorter than the untreated controls at both 3 and 12 months after treatment. These data are not presented here as other parameters better demonstrate the effect of the spray treatments.

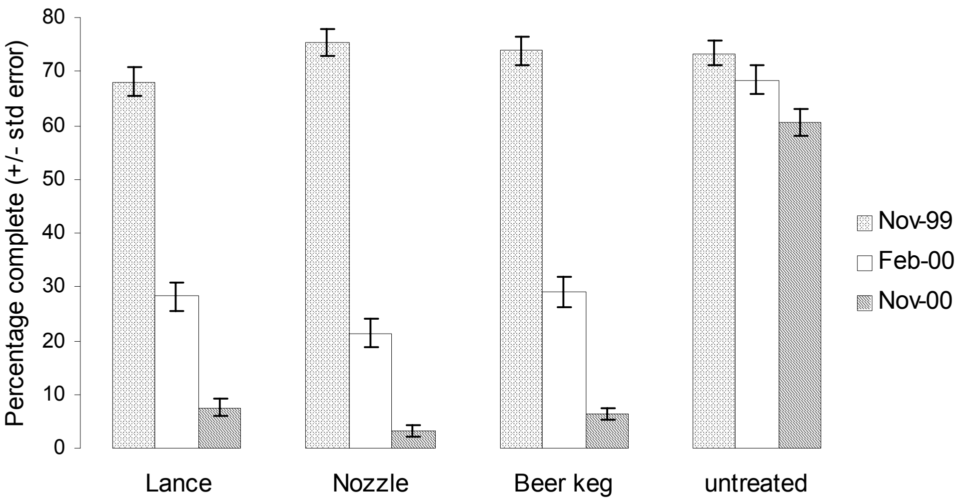
3.2.2 Percent live foliage, percent desiccation

Differences between treated and untreated plots were obvious (Fig. 2). Untreated plots were excluded from statistical analyses to allow better separation of treatment effects. Prior to spraying, the percent live foliage around the circumference of the pampas grass clumps averaged 73% with a range of 20–100%. By 3 months after spraying the percentage of encircling live foliage had dropped in all three spray plots compared to the untreated plots (average reduction at 95% confidence limits was 41.77 ± 13.14). The pampas grass clumps sprayed with the nozzle were significantly less complete than those sprayed with the lance or keg—the least significant difference (95%) between application treatments was 10.61. By 12 months after the spraying there was little live foliage left around the circumference of the sprayed pampas grass clumps and there were no significant differences between the three treatments (Fig. 2).

In all sprayed plots, the foliage in the pampas grass clumps was desiccated by over 80% three months after spraying, with a further slight increase by 12 months after spraying . Again, there was no significant difference between the three treatments. Data on this desiccation are not presented here, but are available from the authors.

At three months after herbicide application, both desiccation and percentage completeness of live foliage were affected by clump size, with larger clumps

Figure 2. The effect of herbicide on mean live foliage encircling the pampas grass clumps by delivery system and over time—prior to herbicide application, and at 3 and 12 months after spraying.



being less desiccated and more complete. Correlations between desiccation (r^2 = 0.076) and completeness (r^2 = 0.16) were both significant (p = 0.01), but only very small parts of the relationships could be accounted for by clump size. At 12 months, however, clump size no longer had a significant effect on either desiccation or completeness of live foliage. Gallant, applied at these rates and using these techniques was, 12 months after application, equally effective on large and small pampas grass plants.

3.2.3 Regrowth of pampas grass

Three months after treated plants had been sprayed new shoots were apparent on the untreated pampas grass clumps but new shoots were only observed on six of the 300 sprayed clumps. By 12 months after spraying, the untreated pampas grass clumps had many new shoots—often too many to count accurately—and a few new shoots had also appeared on 67% of the sprayed clumps (Table 1). There were no significant differences in the level of re-sprouting between the treatments.

TABLE 1. EFFECT OF HERBICIDE APPLICATION ON NUMBERS OF NEW SHOOTS PER PAMPAS GRASS CLUMP, AT 3 AND 12 MONTHS AFTER SPRAYING (95% CONFIDENCE LIMITS).

DELIVERY SYSTEM	NO. OF NEW SHOOTS ON PAMPAS GRASS CLUMPS AFTER SPRAYING	
	3 MONTHS	12 MONTHS
Lance	0.07	3.37
Nozzle	0.00	2.39
Keg	0.08	2.68
Untreated*	large numbers	large numbers
Average number of new shoots per treated plot	0.05 (too few to attach standard error)	2.81 (± 0.531)
Least significant difference	Too few to analyse	1.540

* For the untreated plots the number of new shoots, especially at 12 months after spraying, were often too many to count accurately and were recorded as 'large numbers'.

3.2.4 Percentage cover of other species

Small-leaved pohuehue and the sedge *Baumea juncea* were the most common species present in and around the pampas grass clumps when the plots were first established. A further nine native species and several herbaceous introduced species were also recorded as present in the pampas grass clumps. As the pampas grass foliage progressively desiccated in the sprayed plots, the mounds of dead foliage were colonised by these and other native and exotic species (Table 2 and Appendix 1).

3.2.5 Non target impacts on native toetoe

Three months after the spraying, 51 native toetoe plants with some dead foliage—41 within sprayed plots and 10 in an untreated plot—were marked and then checked again at 12 months after spraying (Table 3). The dead toetoe foliage in the untreated plot appeared to be natural dieback as there was not the

TABLE 2. SPECIES MOST COMMONLY FOUND IN ASSOCIATION WITH PAMPAS GRASS CLUMPS (EXPRESSED AS PERCENTAGES, BOTH ROUNDED UP/DOWN), 3 AND 12 MONTHS AFTER SPRAYING.

SPECIES	PERCENTAGE OF CLUMPS WITH SPECIES				PERCENTAGE COVER ESTIMATE IN CLUMPS WHERE SPECIES PRESENT			
	3 MONTHS		12 MONTHS		3 MONTHS		12 MONTHS	
	TREATED	UNTREATED	TREATED	UNTREATED	TREATED	UNTREATED	TREATED	UNTREATED
Muehlenbeckia complexa	70	44	76	60*	13	12	14	9*
Baumea juncea	20	25	22	31	5	3	3	3
Leptocarpus similis	14	13	14	15	7	2	6	11*
Coprosma acerosa	14	7	15	10	5	4	7	3*
Total no. spp	17	12	30	15				

* Some of the apparent changes over time may be due to observer error.

TABLE 3. OBSERVATIONS ON 51 TAGGED NON TARGET NATIVE TOETOE (*Cortaderia splendens*) PLANTS—41 IN TREATED, 10 IN UNTREATED PAMPAS GRASS PLOTS.

MEASURED ATTRIBUTE	TREATED PLOTS		UNTREATED PLOTS	
	3 MONTHS	12 MONTHS	3 MONTHS	12 MONTHS
Diameter (m)	0.4	0.5	0.7	0.9
Height (m)	1.2	0.9	1.5	1.4
% live foliage encircling clump	37	17	60	47
% desiccated	60	88	40	0
Number new shoots	0	c.1	0–many	2–many

intense yellowing of the foliage associated with herbicide damage. The dead foliage in the sprayed plots appeared to be from both natural dieback and herbicide damage, resulting from accidental spraying or spray drift. Given the herbicide was grass-specific we would expect it to damage any toetoe plants which caught some spray.

3.3 TIME AND COST COMPARISONS

3.3.1 Time taken to spray pampas clumps in Experiment 1

The average time taken to apply herbicide to four plots using the lance was 2.78 minutes per plot. The average time taken to apply herbicide to eight plots using the keg was 4.09 minutes per plot. We could not estimate a time for the nozzle because too few spray times were recorded; just a few pampas grass plants in each plot.

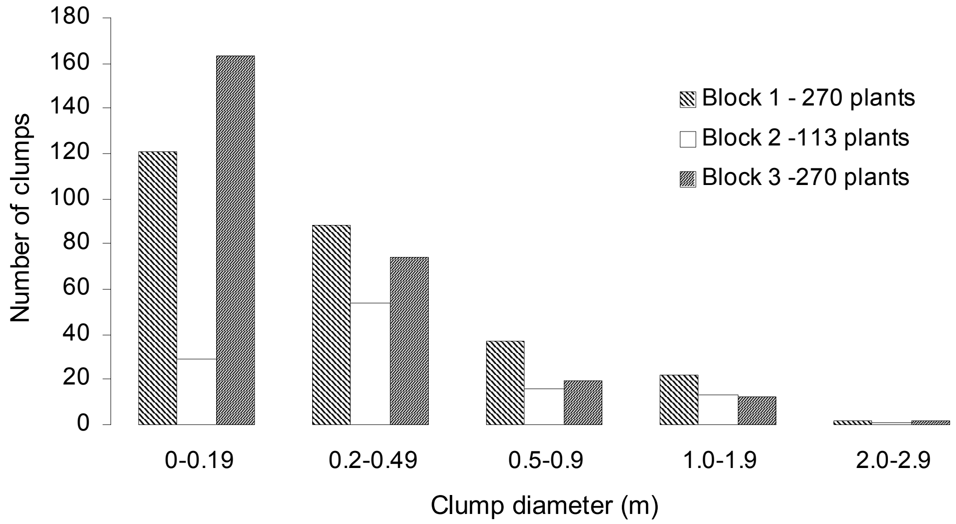


Figure 3. Size distribution of pampas grass clumps in the three large blocks used to assess time taken to apply herbicide using the three different delivery systems.

3.3.2 Time taken to spray large blocks in Experiment 2

The size distribution of pampas grass plants within the three large blocks conform approximately to a reverse-J curve (Fig. 3). Block 2 differed from the other two blocks in having fewer pampas grass clumps (113 cf. 270), proportionately more large pampas clumps, and some tall flax (*Phormium tenax*).

The time taken to spray each of the three blocks using the different spray devices was recorded (Table 4). Both the lance and the keg sprayed Block 2 more quickly than the other two blocks; partly because this one contained fewer pampas grass clumps. In addition, the keg did not need to be refilled while treating Block 2.

Because the original design of this experiment was not followed, and because there was considerable variation in the time taken with the keg for operations such as spraying and refilling, the recorded times were not statistically analysed. Instead, the average time taken for each part of the operation was converted to a time per hectare so the systems could be compared (Table 5). These times should be taken as approximations only.

The lance was the fastest device in practice, and also required the shortest flying and spraying times. This meant that the overall time to complete spraying

TABLE 4. TIME (MINUTES) TAKEN TO SPRAY THREE LARGE BLOCKS OF PAMPAS GRASS INFESTATION USING THREE DIFFERENT DELIVERY SYSTEMS FROM HELICOPTER.

DELIVERY SYSTEM	TIME TO SPRAY BLOCK			TOTAL TIME
	BLOCK 1 ($2090\ m^2$)	BLOCK 2 ($2375\ m^2$)	BLOCK 3 ($2400\ m^2$)	
Lance	41.32	23.65	38.67	103.64
Weighted nozzle	72.45	57.87	39.43	169.75
Keg	70.00	20.83	65.48	161.31

TABLE 5. TIME AND COST PER HECTARE TO APPLY HERBICIDE TO PAMPAS GRASS-INFESTED AREAS USING THREE DIFFERENT DELIVERY SYSTEMS.

DELIVERY	COSTS ($/ha)*			TIME (min/ha)			
SYSTEM	HERBICIDE†	HELICOPTER‡	TOTAL	FLYING	SPRAYING	RELOADING	TOTAL
Lance	859	3446	4305	18.98	107.06	24.91	150.95
Nozzle	851	5643	6494	25.59	197.90	23.69	247.17
Keg	373	3512	3885	49.77	118.70	65.68	234.12

* Costs do not include cost of DOC staff time.

† Haloxyfop (Gallant) at $1896/20 litres plus Uptake at $201/20 litres (retail prices at Wrightsons, April 2001).

‡ Squirrel helicopter at $1370/hour; Hughes 500 helicopter at $900/hour.

with this device was much shorter than for the other two delivery systems. Although actual spraying with the keg was relatively quick, flying and refilling times were greater than for the other systems. Spraying time for the nozzle was much greater than for the other devices but, overall, there was little difference in time between nozzle and keg.

3.3.3 Cost of spraying the large blocks

Approximate costs of applying haloxyfop herbicide to large blocks, based on the data from this study, are given in Table 5. The keg method used least herbicide per minute and was used with the smaller, cheaper Hughes 500 helicopter, but needed regular refilling. On the basis of our estimates, the keg is the cheapest application device, and the nozzle the most expensive.

4. Discussion

Our aim in these experiments was to find the best technique for applying a herbicide to pampas grass in conservation areas with difficult terrain or access. Despite practical difficulties that led to the confounding of some experimental variables, differences in the effectiveness of the three spray systems were assessed, although with less precision than originally planned.

All three spray devices were effective, giving similar, high levels of pampas grass control. The label for the commercial product Gallant recommends application to pampas less than 1 m high, so these results on larger pampas plants were very satisfactory. Spraying large blocks of pampas with the lance and keg took the shortest spraying times and the lance was fastest overall because it required less flying and refilling time. The keg used the least herbicide mixture, and was cheapest overall because it was used with the smaller, cheaper Hughes 500 helicopter. The lance, used with a Hughes 500, could be cheaper than the keg, but both the lance and the nozzle need to use the larger helicopter for safety reasons.

Although there was good knock-down of the large clumps of pampas grass, a year after spraying most clumps had produced new shoots. These small plants will eventually grow into large clumps unless they too are controlled. They would best be treated with herbicide while relatively young and small; Gallant (haloxyfop) or glyphosate could be used. At the Pouto site, a ground-based application would be most effective with a hand-held weedstick or weedwiper, or a motorised knapsack sprayer. This follow-up work was not done as part of this investigation, and therefore not included in the costings, but can be assumed to be similar for all devices.

While Gallant herbicide appeared to damage native toetoe, it had no apparent effect on the other native species colonising or adjacent to the pampas grass clumps.

Application with the nozzle can be difficult, especially in windy conditions, because the nozzle is suspended on a very long chain. The lance requires two operators, but is more reliable in windy conditions. The keg is more likely to produce herbicide drift under windy conditions.

5. Conclusion and recommendations

All three spray devices gave effective control of large pampas grass clumps within a year. Gallant damaged toetoe if it contacted that species, but the herbicide did not seem to affect other native species growing in association with treated plants.

The keg proved to be the cheapest spray device because it used least herbicide mixture and could be used with the smaller Hughes 500 helicopter. Where appropriate, this would therefore appear to be the best of the three spraying methods to use. However, the keg is not necessarily the most appropriate technique to use in all circumstances.

Follow up herbicide treatment is needed to kill the new shoots that have appeared on the old pampas grass clumps. Experimental work may be needed to determine when and how this re-growth is best treated. Ground treatment with knapsack sprayers or weed wipers would probably be the most efficient and effective approach at Pouto. At other difficult sites where a helicopter is essential for the initial herbicide application, the follow-up treatment may need to be from a helicopter.

6. Acknowledgements

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7. References

Gosling, D. S.; Shaw, W.B.; Beadel, S.M. 2000: Review of control methods for pampas grasses in New Zealand. *Science for Conservation 165*. 32 p.

Wooster, M. 1998: A practical application for a beer keg—spot spraying from a helicopter. Pp. 38–42 in Proceedings of New Zealand Biosecurity Institute 48th National Education & Training Seminar, Working together for success, 13–14 July 1998, Wellington, New Zealand.

Appendix 1

PLANT SPECIES RECORDED

All native and exotic (*) species recorded within the pampas grass clumps, both treated and untreated, at either assessment, i.e. 3 months or 12 months after spraying. Their occurrence in November 2000 is given as a percentage of all pampas grass clumps.

SPECIES NAME	COMMON NAME	OCCURRENCE 12 MONTHS AFTER SPRAYING (%)
**Aira caryophyllea*	silvery hair grass	(not found)
**Anthoxanthum odoratum*	sweet vernal	2
Baumea juncea		24
**Briza maxima*	quaking grass	1
**Briza minor*	shivery grass	0.2
**Bromus* sp.	brome grass	2
Carex sp.	sedge	0.08
**Centaurium erythraea*	centaury	0.2
**Conyza albida*	broad-leaved fleabane	5
Coprosma acerosa	sand coprosma	14
Coprosma robusta	karamu	0.2
Cortaderia splendens	toetoe	0.2
Cyathodes fasciculata	mingimingi	(not found)
**Cynodon dactylon*	Indian doab	0.5
**Dichelachne crinita*	long-hair plume grass	0.2
*grass		0.5
**Hypochaeris radicata*	catsear	0.7
Isolepis nodosa	clubrush	8
**Juncus pallidus*	rush	1
Kunzea ericoides	kanuka	2
Leptocarpus similis	leptocarpus	14
Leptospermum scoparium	manuka	1
**Lotus pedunculatus*	lotus	2
**Lotus suaveolens*	hairy birdsfoot trefoil	0.2
**Lupinus arboreus*	tree lupin	6
moss		0.2
Muehlenbeckia complexa	small-leaved pohuehue	72
Ozothamnus leptophyllus	tauhinu	0.5
Pomaderris phylicifolia var. *ericifolia*	Whatitiri	(not found)
**Rumex acetosella*	sheep's sorrel	2
**Senecio bipinnatisectus*	Australian fireweed	0.5
Senecio minimus	fireweed	0.2
**Sporobolus africanus*	ratstail	0.2
**Vicia sativa*	vetch	0.2