Field trials with C.D.A. spot sprayers

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SUMMARY

The results of tests comparing the suitability of a range of hand-held controlled drop application (C.D.A.) equipment for spot spraying some woody and herbaceous noxious weeds are reported. The results show that all the equipment tested gave similar control of herbaceous weeds and blackberry (*R. fruticosus*). Variegated thistle (*Silybum marianum*), shore thistle (*Carduus tenuiflorus*) and Paterson's curse (*Echium plantagineum*) sprayed at the rosette stage were equally well controlled by C.D.A. formulations of 2,4-D amine and ester with droplet densities ranging from 7.8 to 499.3 droplets per cm^2 thus indicating that droplet density does not influence control of these species. Ester 2,4-D was found to be more active than amine 2,4-D when C.D.A. formulations were used to control ragwort (*Senecio jacobaea*). In the case of woody weeds droplet size and coverage did not appear to influence the control of blackberry with 2,4,5-T. Control of furze (*Ulex europaeus*) with 2,4,5-T required small droplets ($<120\mu$) or complete coverage whilst sweet briar (*Rosa rubiginosa*) required complete coverage as is obtained in high volume spraying.

Some studies on droplet density indicate that the Micron 'Herbi' unit produces a more uniform droplet range than the Turbair 'Forester'.

INTRODUCTION

In a review of spot spraying techniques for noxious weed control Combellack (1978) concluded that hand-held controlled droplet application (C.D.A.) equipment offered a viable alternative to conventional spot spray units where small infestations of noxious weeds occur and control of drift is essential.

The term "controlled droplet application" was coined by Fryer (Matthews, 1976) although a definition for the term was not given. The following definition was prepared by Rogers (1975) "the production and application of droplets that are the appropriate size both for the target and the method of delivery". However Combellack (1978) has defined C.D.A. as "the production and application of droplets of the appropriate size for the target which have a narrow and predictable variation in droplet size at any volume". In this latter definition emphasis is placed on the variation of droplet size, as it is this aspect which gives the C.D.A. concept value as an alternative spot spray technique by allowing the operator to more accurately predict the fate of the spray.

Ideally, before this technique can be successfully developed it is necessary to understand the effects of droplet distribution on the plant, drop size, spacing and herbicide concentration in relation to phytotoxicity. Unfortunately this area of research has been given scant attention and the work that has been conducted has often resulted in contradictory results. For example, early work by Smith (1946), Fisher and Young (1950), and Fisher, Meadows and Behrens (1956) showed that coarse droplets (500 μ diameter) of phenoxy herbicides were more phytotoxic than smaller droplets (100 μ), whilst work by Vega and Obien (1963), Bengtsson (1961) and Ennis and Williamson (1951) showed that small droplets of the phenoxy herbicides were more phytotoxic than large droplets. This contradictory evidence is not confined to the phenoxy herbicides as Douglas (1968) showed that droplets of paraquat of 450 to 500 μ diameter were most phytotoxic, when droplets over the range of 250 to 1000 μ diameter were compared, whilst McKinley, Ashford and Ford (1974) have shown that 100 μ diameter droplets were more effective than droplets of 350 μ diameter.

The work of Behrens (1957) is the most comprehensive study on this subject that has been reported. Working with 2,4,5-T for mesquite control he found that when oil was used neither droplet size (200 to 800 μ diameter) nor volume affected phytotoxicity, although droplet spacing was important. When water was used, mesquite showed an increased response to larger droplets and higher volumes. Overall, the results clearly show that for optimum efficiency one needs to define the optimum droplet size, number, and concentration for each species.

This paper reports on some hand-held C.D.A. units which produce a range of droplet sizes at the same flow rate due to a variation in the angular velocity of the different rotary atomizers and the design of the rotary atomizer. Comparative efficacy data between the machines on a range of both woody and herbaceous plant species are also presented.

MATERIALS AND METHODS

Woody weeds

The following units were evaluated:-

- 'SS Herbi'*(modified Micron Herbi unit, Combellack *et al*, 1978).
- Turbair 'Forester'**
- Turbair 'Sprite'. **

This equipment was used so that a range of droplet sizes could be produced, thus permitting application of the test chemicals at a constant volume per ha, hence a constant amount of active ingredient per ha, but with variation in droplet density. According to Bals (1969) the formulae - diameter (μ) = $\frac{500,000}{\text{r.p.m.}}$ gives the approximate

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* Available from Micron Sprayers, Three Mills, Bromyard, Herefordshire, U.K. or

** Available from Turbair Ltd., Britannica House, Waltham Cross, Hertfordshire, U.K.

size of droplets produced by a spinning disc. If this formulae is applied to the units tested then the nominal droplet size for the 'SS Herbi' was 233 μ; the 'Forester' at 6 v, 230 μ; the 'Forester' at 12 v, 117 μ; and the 'Sprite', 76 μ. As these figures vary with flow rate onto the disc (Bals, 1969) and with the concentration of surfactant (Johnstone et al, 1977) they can only be used as a rough guide.

The formulations used in these tests were made up in the laboratory and have been described by Combellack and Shaw (1977). The C.D.A. spraying technique used was that described in an instruction manual for the spot spraying of noxious weeds with hand-held C.D.A. equipment (Combellack and Harris, 1978). The rotary atomizer was moved over the face of the thicket at 1 m/sec with the atomizer 25 to 50 cm away from the face of the thicket. High volume spot spraying was achieved by spraying the plants until thoroughly wetted at a pressure of 700 kPa and using a Spraying Systems D6 orifice and No. 45 swirl plate.

The method of assessment used was a 0 to 10 foliage reduction assessment where 0 = no effect and 10 = complete defoliation.

Herbaceous plants

Tests were conducted on plants raised in the glasshouse and hardened off in the shadehouse for 2 to 3 weeks before spraying. After spraying the plants were returned to the shadehouse for the remainder of the assessment period.

Shore thistle (*Carduus tenuiflorus*) and Paterson's curse (*Echium plantagineum*) were grown from seed in 10 cm pots. Flowering plants were 6 months old at spraying whilst the rosette plants were 5 months old. The variegated thistle (*Silybum marianum*) plants were transplanted from the field into 10 cm pots 5 months before spraying. The ragwort (*Senecio jacobaea*) plants were collected from the field and transplanted into 10 cm pots 5 months before spraying.

The plants were sprayed with C.D.A. formulations of 2,4-D amine (5 and 15% a.i.) and 2,4-D iso-octyl ester (5 and 15% a.i.). These formulations were made up in the laboratory using the method described by Shaw and Combellack (1978). Flow rates for these materials for the equipment under test are given in Table 1. This table also shows the calculated volume rate per ha for each machine.

Ten pots of each of ragwort, Paterson's curse (rosette and flowering), shore thistle (rosette and flowering) and variegated thistle (rosette) were arranged in three rows on the floor of a large shed for spraying. Each pot was separated by 10 cm in each direction. A 10 cm x 10 cm piece of grey kromokote paper was placed between alternate pots on either side of the central row, and was used to determine the droplet density. The unit under test was then moved over the central row of test plants at a speed of 1 m/sec at a height of 30 cm above the plants.

Assessment of plant mortality was made 1 month and again at 2 months after spraying using a 1 to 9 assessment of reduction in photosynthetic tissue where 1 = no effect and 9 = complete destruction of all photosynthetic tissue.

Table 1. C.D.A. equipment tested and flow rates for the C.D.A. formulations used

Unit	R.P.M.	Calculated droplet size (μ)		Flow rates and volumes			
				2,4-D amine		2,4-D ester	
				5% a.i.	15% a.i.	5% a.i.	15% a.i.
'SS Herbi'	2150	279	ml/sec*	1.80	1.75	1.73	1.73
			ℓ/ha **	14.7	14.3	14.2	14.2
'Forester' 6v	2170	277	ml/sec	1.43	1.41	1.53	1.52
			ℓ/ha	11.7	11.6	12.5	12.5
'Forester' 12v	4263	140	ml/sec	1.43	1.41	1.53	1.52
			ℓ/ha	11.7	11.6	12.5	12.5

* Flow rates measured through nozzles supplied by manufacturer.

** ℓ/ha based on a forward speed of 1 m/sec and a swathe of 1.2 m.

Droplet density on the cards was measured by using either a 2 mm x 2 mm graticule for the larger droplets or 1 mm x 1 mm graticule for the smaller droplets. In the case of the former, 100 squares per card were counted and in the latter case 10 squares per card were counted.

RESULTS

Woody weeds

Blackberry (*Rubus fruticosus* L. agg.)

The blackberries at both sites sprayed were vigorously growing, had completed flowering and were approximately 1.5 to 2.5 m in height. A mixture of *R. ulmifolius* hybrids and *R. procerus* was present at each site, the former species comprising 80 to 90% of the infestation at each site. Two replicates of each treatment were sprayed at both sites.

The results (Table 2) show that the 10% a.i. C.D.A. formulation of 2,4,5-T was slightly superior to the 5% a.i. for almost all treatments, however there was only a significant different ($P<0.05$) for one application method at one site viz. the 'Forester' 4263 r.p.m. at site 77-5. As there were no significant differences in control between the machines at any given dose rate one can conclude that droplet size did not influence the control of these weeds with 2,4,5-T and that the C.D.A. equipment tested provided control equal to high volume spot spraying.

Table 2. Control (0 = no effect, 10 = complete defoliation) of woody weeds with C.D.A. spraying

Trt No.	Herbicide	% a.i.	Method of Application		Blackberry		Furze		Sweet briar
				Site	77-6(C)	77-5	77-9(A)	77-7(A)	77-10(A)
				Date applied	28/2/77	31/3/77	25/2/77	24/3/77	1/3/77
				Date evaluated	17/10/77	11/10/77	7/12/77	11/10/77	17/10/77
1	2,4,5-T iso octyl ester	5	'SS Herbi' 2150 rpm		5.0 (a)	5.5 (abc)	6.8 (bc)	2.9 (cd)	2.67 (c)
2	" " " "	10	" "		7.5 (a)	5.0 (bc)	5.3 (cd)	2.0 (cd)	5.67 (ab)
3	2,4,5-T iso octyl ester	5	'Forester' 2170 rpm (6v)		6.0 (a)	5.0 (bc)	3.0 (d)	4.67(ab)	5.67 (ab)
4	" " " "	10	" "		5.5 (a)	6.0 (abc)	7.4 (abc)	4.0 (ab)	7.33 (ab)
5	2,4,5-T iso octyl ester	5	'Forester' 4263 rpm (12v)		6.5 (a)	4.5 (c)	6.7 (bc)	3.33(bc)	4.67 (bc)
6	" " " "	10	" "		7.0 (a)	7.0 (ab)	6.8 (bc)	5.33(a)	5.67 (ab)
7	2,4,5-T iso octyl ester	5	'Sprite' 6600 rpm		6.5 (a)	5.5 (abc)	9.3 (a)	4.0 (ab)	5.33 (ab)
8	" " " "	10	" "		7.5 (a)	6.5 (abc)	8.9 (ab)	4.0 (ab)	5.67 (ab)
9	2,4,5-T butyl ester 80%		High volume spot spray at 700 kPa		7.0 (a)[1]	7.5 (a)[1]	9.0 (ab)[3]	1.33(d)[2]	8.0 (a)[2]
10	Control				0[+]	0[+]	0[+]	0[+]	0[+]

[+] Not included in analysis

() Values followed by the same letter are not significantly different ($P<0.05$) as determined by Duncan's Multiple Range Test (comparisons in columns only).

[1,2,3] Herbicide concentrations used were 1 part 80% 2,4,5-T formulation in 1199, 799 and 599 parts water, respectively.

Furze (*Ulex europaeus* L.)

This weed was 1 to 2 m high and flowering at the time of spraying at both sites. Three replicates of each treatment were sprayed at both sites in the late summer of 1977.

The results (Table 2) show that at site 77-9(A) excellent control of this species was obtained with the high volume spot spraying and 'Sprite' treatments. The control obtained with the 'SS Herbi' was worse at both rates, than for the 'Spritė' and high volume spot spray. The results with the 'Forester' 6v were varied at this site. Also, the results at this site indicated that the two C.D.A. formulations of 2,4,5-T gave similar results with each application system, the 'Forester' 6v being the only exception. Overall, the results show that C.D.A. equipment which produces smaller droplets provides better control.

The results at site 77-7(A) were very disappointing, particularly the poor control obtained with high volume spraying. The results were similar for the 'Forester' 6 and 12v and 'Sprite' whilst the 'SS Herbi' gave poor control. The 5 and 10% a.i. C.D.A. formulations of 2,4,5-T gave similar results except with the 'Forester' 12v. The overall poor results may have been due to the low rainfall before and after spraying.

The control of furze with C.D.A. and high volume techniques was erratic at the two test sites; the results indicate that comparable control of this weed was obtained with each machine with both formulations tested. Further trials are necessary to establish the effectiveness of the C.D.A. technique on this species. However the results do indicate that smaller droplets (<140µ) give better control than larger droplets with the C.D.A. units tested.

Sweet briar (*Rosa rubiginosa* L.)

Plants were 1.5 to 2.5 m high, flowering was complete and the hips were turning red to orange when sprayed in the late summer of 1977. Three replicates of each treatment were sprayed.

The results (Table 2) show that high volume spraying was the best treatment although it proved to be only significantly better ($P<0.05$) than the 5% a.i. 2,4,5-T treatment when applied with the 'SS Herbi' and the 'Forester' at 12v. It will be noted that the 10% a.i. formulation of 2,4,5-T always gave slightly superior control.

Herbaceous weeds

Variegated thistle

This weed had 3 to 6 leaves, was 20 cm in diameter and 12 cm high when sprayed. The results in Table 3 clearly show that, although there were marginal differences between treatments 1 month after spraying, there were no significant differences ($P<0.05$) by 2 months after spraying. The results indicate that this weed is equally well controlled by both the amine and ester formulations of 2,4-D at 5 and 15% a.i. with a droplet density ranging from 7.8 to 499.3 per cm^2.

Table 3. Control of herbaceous weeds with C.D.A. spraying

I Evaluation 20/12/77 (1 month after treatment)
II Evaluation 25/1/78 (2 months after treatment)
Foliage reduction score 1 to 9 1 = no damage; 9 = no green tissue

Chemical and rate	Unit	Variegated thistle I	Variegated thistle II	Ragwort I	Ragwort II	Paterson's curse (flowering) I	Paterson's curse (non-flowering) I	Paterson's curse (non-flowering) II	Shore thistle (flowering) I	Shore thistle (non-flowering) I	Shore thistle (non-flowering) II	Drops/sq.cm
2,4-D amine 5% a.i.	'SS Herbi'	6.8(ab)[1]	9.0(a)	2.0(c)	3.4(e)	2.2 (c)	5.3 (bcd)	8.2(ab)	2.5(b)	3.1(cd)	7.6(bcd)	26.1 ± 3.4
	'Forester' 6v	6.0(ab)	9.0(a)	1.7(c)	3.3(e)	2.4(bc)	2.8(d)	7.2(b)	3.25(ab)	2.2(d)	6.8(d)	45.0 ± 8.7
	'Forester' 12v	7.3(ab)	8.8(a)	4.4(ab)	8.3(ab)	2.4(bc)	4.6(cd)	8.6(a)	5.0(a)	5.7(ab)	8.8(a)	499.0 ± 69.6
2,4-D amine 15% a.i.	'SS Herbi'	5.4(b)	9.0(a)	2.5(bc)	6.1(cd)	2.5(bc)	4.4(cd)	9.0(a)	2.75(b)	3.3(cd)	7.5(cd)	7.8 ± 1.3
	'Forester' 6v	7.1(ab)	9.0(a)	3.7(abc)	8.2(ab)	2.7(abc)	4.5(cd)	9.0(a)	5.0(a)	4.5(abc)	8.5(ab)	32.1 ± 5.8
	'Forester'12v	6.1(ab)	9.0(a)	2.4(bc)	4.7(de)	2.1(c)	5.4 (bcd)	9.0(a)	2.75(b)	3.5(bc)	7.5(bcd)	499.3 ± 79.7
2,4-D ester 5% a.i.	'SS Herbi'	5.4(b)	8.9(a)	2.7(abc)	6.6(abc)	3.4(ab)	3.5(d)	8.6(a)	3.14(ab)	4.0(bcd)	8.8(a)	18.2 ± 2.7
	'Forester' 6v	5.7(b)	8.9(a)	4.3(ab)	7.6(abc)	2.3(c)	7.3(ab)	9.0(a)	2.5(b)	3.8(bcd)	8.4(ab)	19.6 ± 2.2
	'Forester'12v	5.6(b)	8.9(a)	3.5(abc)	6.9(abc)	-	7.0(ab)	8.6(a)	-	3.1(cd)	7.8(abc)	197.8 ± 45.4
2,4-D ester 15% a.i.	'SS Herbi'	7.0(ab)	8.8(a)	3.7(abc)	7.9(abc)	2.7(abc)	6.3(abc)	9.0(a)	2.88(b)	3.1(cd)	8.4(ab)	14.7 ± 2.4
	'Forester' 6v	7.3(ab)	9.0(a)	3.6(abc)	6.5(bcd)	3.7(a)	8.4(a)	9.0(a)	5.0(a)	3.1(cd)	7.7(abcd)	47.4 ± 13.2
	'Forester' 12v	7.9(a)	9.0(a)	4.7(a)	8.6(a)	-	-	-	-	6.1(a)	8.2(abc)	497.0 ± 93.0
Control		1.0[2]	5.4(b)	1.3(de)	1.2(f)	1.9(c)	1.4[2]	4.6(c)	1.4[2]	1.4[2]	4.3(e)	

[1] Values followed by the same letter are not significantly different ($P<0.05$) as determined by Duncan's Multiple Range Test (comparisons in columns only).

[2] Not included in analysis

Ragwort

Plants were 5 cm high, 15 cm in diameter and had 6 to 10 leaves when sprayed. The results (Table 3) show that the 5% a.i. 2,4-D amine formulation gave significantly worse control ($P<0.05$) when sprayed with the 'SS Herbi' and 'Forester' 6v than with the 'Forester' 12v. However the results with the 15% a.i. 2,4-D amine show that the 'Forester' 6v gave significantly better control ($P<0.05$) than the 'SS Herbi' or 'Forester' 12v. There was no significant difference ($P<0.05$) between the machines where the 5% a.i. 2,4-D ester was used although with the 15% a.i. ester, the 'Forester' 6v gave significantly worse control ($P<0.05$) than the 'Forester' 12v. Thus there was no consistent differences between units, and hence droplet density, for any given chemical treatment.

The results also indicate that the amine form of 2,4-D was less active than the ester form on this weed.

Paterson's curse

This weed was sprayed at the flowering stage when the plants were 12 cm high, 10 cm in diameter and with 6 to 10 leaves; and at the rosette stage when the plants were 6 cm high, 10 cm in diameter and with 5 to 8 leaves.

The control of the flowering plants was very poor in all treatments. The results are thus in accord with those reported by Parsons (1973).

Plants in the rosette stage were well controlled by most treatments when assessed 2 months after spraying. The earlier assessment, 1 month after spraying, showed that the ester formulations of 2,4-D produced better foliage reduction than the amine formulations but only the 15% a.i. 2,4-D ester treatment applied with the 'Forester' 6v was significantly better ($P<0.05$) than all amine treatments.

There was no apparent relationship between the level of control obtained and the unit used.

Control of flowering plants of this species was unacceptable with the C.D.A. units. Control of plants at the rosette stage, although better with the ester after 1 month was similar at all rates by 2 months after spraying. Therefore control of this weed when sprayed at the rosette growth stage was not dependent upon droplet density.

Shore thistle

This plant was sprayed in the flowering stage when plants were 12 cm high, 7 cm in diameter and with 4 to 8 leaves; and in the young rosette stage when the plants were 6 cm high, 5 cm in diameter and with 3 to 6 leaves.

The results for the flowering plants (Table 3) show that poor control was obtained with all treatments. As the results show variable control with varying droplet density, no positive conclusion can be made. The variable results obtained concur with previous reports, e.g. Parsons (1973).

Control of the plants in the rosette stage was also poor when assessed 1 month after spraying; however by 2 months after spraying a reasonable level of control had been obtained. The figures show that there was no difference between the amine and ester formulations of 2,4-D or the 5 and 15% a.i. formulations of each. Furthermore there was no difference between the machines tested which indicates that control of this plant in these tests was not dependent on droplet density, which ranged from 7.8 to 499.3 per cm^2.

DISCUSSION

The results on woody weeds indicate that droplet size, and hence density, does not greatly influence the control of blackberry when sprayed with 2,4,5-T. Control of furze improves with an increase in coverage, thus control was better with C.D.A. treatments producing small droplets (i.e. <140 µ) and high volume spraying. With sweet briar, control was also improved with increased coverage, however in this case complete coverage, as occurs with high volume spot spraying, appears to be essential.

Variegated thistle, Paterson's curse and shore thistle when in the rosette stage appeared to be equally well controlled by C.D.A. amine and ester formulations with droplet densities varying from 7.8 to 499.3 per cm^2. The results also indicate that there was no difference between the C.D.A. units evaluated as they produced similar results on herbaceous weeds and on blackberry. However for the control of furze, equipment which produces small droplets (e.g. <140 µ) is necessary. Thus the choice of unit depends in part upon its efficiency to produce droplets of uniform size.

The figures in Table 4 show that the formula of Bals (1969) is essentially correct for the 'SS Herbi'. The difference in numbers between actual and estimated for the 'Forester' 6v and 12v reflects the wide range of droplet sizes noted during counting. This variation was probably due to ligamenting and satellite droplets produced from the blunt surface of the upper disc. One can thus conclude that the 'SS Herbi' atomizer produced a much narrower and more predictable droplet range than the 'Forester' atomizer.

Table 4. Comparison of calculated (Bals, 1969) and obtained droplet densities

Unit	Volume ℓ/ha	Calculated droplet size (µ)	Droplet density No./cm^2 Calculated [1]	Droplet density No./cm^2 Obtained
'SS Herbi'	14.5	279	19.4	16.7
'Forester' 6v	12.0	277	16.7	36.0
'Forester' 12v	12.0	140	110.4	42.3

[1] Based on tables of Potts (1958).

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