CONTROL OF *SPARTINA* WITH FLUAZIFOP-P AND CLETHODIM

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Summary *Spartina* or cord grass (*Spartina anglica* and *S.* × *townsendii*) is an introduced summer-growing perennial grass which grows in the inter-tidal zone of estuaries and sheltered inlets. Its invasion of mudflats and sandy beaches in Victoria and Tasmania is concerning coastal managers. Two herbicide trials were set up on an established meadow of *Spartina* growing in the inter-tidal zone at the northern end of Corner Inlet, south-west of Foster, Victoria. The first trial evaluated six application times, between early December and mid-May, of fluazifop-P applied with a hand-gun at a concentration of 212 g 100 L^{-1} in a spray volume of 1000 L ha^{-1}. At each date the herbicide was applied alone, with BS1000 surfactant at 0.2% v/v and with D-C-Trate spray oil at 2% v/v. The intervals between the various spray applications and tidal inundation ranged from about 3–7 hours. With no adjuvant, control after one year was best with the February application (>99%), while January and March applications gave 97% control. The addition of BS1000 resulted in January, February, March and April applications giving 97 to >99% control, while the inclusion of D-C-Trate resulted in 97 to 100% control by all six application times. The second trial evaluated clethodim at rates of 84, 120 and 180 g 100 L^{-1} applied (with D-C-Trate at 2% v/v) in a spray volume of 1000 L ha^{-1} at four application times between February and May. One year after application, 96–100% control was given by all rates applied in February and March and the two higher rate applied in April. All rates applied in May gave inadequate control.

INTRODUCTION

Spartina (*Spartina anglica* C.E. Hubbard and *S.* × *townsendii* H. & J. Groves) is an introduced summer-growing rhizomatous perennial grass. It colonizes mudflats and sandy shorelines in the inter-tidal zone of sheltered bays and estuaries, forming a dense monospecific sward. This degrades the recreational value of beaches, brings changes in tidal flow patterns and decreases the feeding habitat available to wading birds. *S.* × *townsendii* is a natural hybrid, which is infertile, while *S. anglica* is a fertile form which arose from the primary hybrid by chromosome doubling. The two species are difficult to distinguish apart.

From the first successful establishment in the north-west corner of Corner Inlet in 1930 (Boston 1981). *Spartina* has spread in Victoria both naturally, and by deliberate planting, to the north-eastern side of Corner Inlet and the Nooramunga Marine and Coastal Park**,** to Shallow Inlet, Anderson Inlet, Westernport Bay, and small infestations in the Barwon River estuary, south of Geelong (Williamson 1995, Boekel 1995). The total area of *Spartina* in Victoria is estimated to be between 150 and 280 ha (Williamson 1995). In Tasmania there is an estimated 700 ha (Wells 1995), mostly in the Tamar and Rubicon estuaries on the north coast.

In Victoria the evaluation of herbicides for the control of *Spartina* commenced in 1990–91. This work identified four herbicides with good activity against the grass, namely fluazifop-P, clethodim, haloxyfop and imazapyr. High volume sprays of fluazifop-P at a concentration of 212 g 100 L^{-1} and clethodim at 180 g 100 L^{-1} gave effective control when applied in February and March. The two trials reported here examined:

i. the effect of application date and spray adjuvant on the efficacy of fluazifop-P and,
ii. the effect on clethodim efficacy of rate and date of application.

MATERIALS AND METHODS

Two trials were set up on an established meadow of *Spartina*, growing in the inter-tidal zone, south-east of Foster in Corner Inlet. The site had originally been a sandy beach, but the substrate in the *Spartina* sward was now a dark silt. The site was inundated by most (possibly all) high tides. Seed was present in the heads in autumn 1996, and the form present at the trial site was considered to be mainly or even entirely *S. anglica*. In both trials the treatments were set out in a randomized complete block design with five replications and the plot size was 4 × 4 m. The blocks were aligned approximately parallel to the shoreline. Application was made with an 'Azo' LP-gas pressurized sprayer, operating at a pressure of 345 kPa, through a Spraying Systems 43LA hand-gun with a SS 8005 fan jet nozzle. This gave a constant output of 33.2 mL sec^{-1}, and sprayings were timed to give a volume of 1600 mL $plot^{-1}$, equivalent to 1000 L ha^{-1}. Both trials were assessed in the year after application by visual estimate of the amount of regrowth.

Trial 1 Fluazifop-P, (Fusilade™, 212 g a.i. L^{-1}) at a spray concentration of 212 g 100 L^{-1} was applied alone or with

the adjuvants BS1000 (alcohol alkoxylate 1000 g L^{-1}) or D-C-Trate (emulsified petroleum oil), at six different application dates. The 3 × 6 factorial arrangement, plus an Untreated control gave a total of 95 plots. The development stage of *Spartina* at each application date, and the time interval between application and tidal inundation of the plots is given in Table 1. Assessment was on 14 March 1996, approximately one year after application (depending on application date).

Trial 2 Single applications of clethodim, (Select™, 240 g a.i. L^{-1}) at concentrations of 84, 120 and 180 g 100 L^{-1} were made on each of four dates between February and May 1995. For all applications D-C-Trate was included in the spray at 2% v/v. The date of each application, along with the development stage of *Spartina* and the approximate interval between spraying and tidal inundation are given in Table 2. Assessment was on 15 March 1996, approximately one year after application (depending on application date).

The results of both trials were analysed by a factorial ANOVA after transforming the percentage control values to arcsin Ö(%/100) to stabilize the variances.

Table 1. Application dates, growth stage of *Spartina*, and approximate time between application and tidal inundation in Trial 1.

Application date	*Spartina* growth stage	Approx. time to inundation (h)
2.12.94	Vegetative, to 20 cm high	5½
23.1.95	Some flowering, leaves to 40 cm high	3
13.2.95	Flowering	7
15.3.95	Post-flowering	6
13.4.95	Some foliage senescence	6½
12.5.95	Seeding, foliage senescence, green leaves at base	5½

Table 2. Application dates, growth stage of *Spartina*, and approximate time between application and tidal inundation in Trial 2.

Application date	*Spartina* growth stage	Approx. time to inundation (h)
28.2.95	Some flowering, mostly post-flowering, leaves up to 40 cm high	6
28.3.95	Post-flowering, stems yellow	6½
27.4.95	Some foliage senescence, green leaves at base	5½
24.5.95	Foliage senescence, seeds mostly shed, green leaves at base	5½

RESULTS

Trial 1 On 14 March 1996, 10 to 15½ months after the various application dates, most fluazifop-P treatments were giving a very high level of control (Table 3). Regrowth was usually confined to a few individual shoots or small groupings of shoots, and many plots had no regrowth. There was a significant interaction between adjuvant and application date ($F_{10, 67\ df}$=5.87, P=0.001), that is, the best application time varied, depending on whether an adjuvant was included in the spray, and the type of adjuvant. When no adjuvant was used, the February application time, with >99% control, was significantly better than all other application times (P<0.05), although application in January and March still gave acceptable control. Application of fluazifop-P without adjuvant in May resulted in poor control. With the addition of BS1000 at 0.2% of the spray volume, March and February applications with >99% control were the most effective, but January (97%) and April (98%) were also excellent. When D-C-Trate was added at 2% of the spray volume, all six application dates resulted in 97–100% control, although the control given by the December and May applications was significantly less (P<0.05) than that given by the three best application times (January, February and March).

Trial 2 There was a significant interaction between clethodim concentration and application date ($F_{6, 44\ df}$ =3.54, P=0.006) in the level of control on 15 March 1996, 9½ to 12½ months after the various application dates. While control by the May applications showed a strong response to increasing dose, and there was some dose response at the April applications, there was no significant dose response (P>0.05) at the two earlier application dates (Table 4). Applied in late February, all three concentrations (84, 120 and 180 g 100 L^{-1}) gave excellent and equivalent (P=0.05) control, and this result was repeated by the March applications. Control given by each concentration of clethodim applied in April tended to be less than that achieved by the same concentration at the two earlier application dates, but it was only at 84 g 100 L^{-1} that control was significantly less (P<0.05). When applied in late May, clethodim gave increasing control with increasing rate, but at all rates control was unsatisfactory and was significantly less (P<0.05) than that given by earlier applications.

DISCUSSION

It was not unexpected that the application of both herbicides in May resulted in poorer control than earlier applications. By May the foliage had substantially senesced, with the only green growth being at the base of the stems, often as new shoots. As well as being a small target for herbicide uptake, the green growth was partially screened from the spray by the dead foliage.

In Trial 1 the interval between application and tidal inundation on the various dates ranged between approximately three and seven hours (Table 1). The intervals given are estimates of the shortest interval at each application date, and for some treatments the interval could have been up to an hour longer than that given. There was no indication from the results that the January applications were adversely affected by the 3-hour interval. The treatment without adjuvant was applied first, so had the longest period before inundation, and the treatment with D-C-Trate had the shortest.

In a previous trial, fluazifop-P at 212 g 100 L^{-1} plus BS1000, applied in late February gave significantly better control than application in mid-January or early December. The present trial has confirmed that application of fluazifop-P with BS1000 in February gives better control than application in December. However, the January application did not result in significantly less control than application in February.

In earlier trials, the adjuvant used with fluazifop-P was BS1000. These results indicate that some enhancement in the control given by fluazifop-P can be obtained by using D-C-Trate instead of BS1000 for spraying conducted in December, January and May.

The results from Trial 2 indicate that clethodim at 84 g 100 L^{-1} can give very effective control when applied in February and March, but at least 120 g 100 L^{-1} is required for similar control when application is in April. Comparable control cannot be obtained by application in May, even with 180 g 100 L^{-1}.

In both trials the only non-target species present was white mangrove (*Avicennia marina* (Forsk.) Vierh.), which was growing in many plots, usually as seedlings or young plants. None of the treatments had any effect on the mangroves.

Table 3. Control of *Spartina* in March 1996 following a single application of fluazifop-P alone or with adjuvants in December 1994, or in January, February, March, April or May 1995. Arcsin transformed values in parentheses.

Fluazifop-P		Adjuvant and Concentration	Application date					
			2.12.94	23.1.95	13.2.95	15.3.95	13.4.95	12.5.95
g 100 L^{-1}	kg ha^{-1}	(% v/v)	Control (%) on 14 March 1996					
212	2.12	Nil	91	97	99.8	97	95	50
			(72.69)	(80.28)	(88.85)	(80.28)	(77.58)	(45.57)
212	2.12	BS1000 0.2%	90	97	99.6	99.8	98	85
			(71.20)	(81.43)	(87.70)	(88.85)	(81.30)	(66.90)
212	2.12	D-C-Trate 2%	98	100	99.8	100	99	97
			(82.33)	(90.00)	(88.85)	(90.00)	(85.60)	(80.91)
		LSD (P=0.05)				(7.47)		

Table 4. Control of *Spartina* in March 1996 following a single application of clethodim in February, March, April or May 1995. Arcsin transformed values in parentheses.

Clethodim[A]		Application date			
		28.2.95	28.3.95	27.4.95	24.5.95
g 100 L^{-1}	kg ha^{-1}	Control (%) on 15 March 1996			
84	0.84	99.6	98	89	38
	(87.70)	(82.56)	(71.41)	(37.90)	
120	1.2	99	99	96	65
	(86.75)	(86.86)	(78.58)	(54.87)	
180	1.8	100	100	97	85
	(90.00)	(90.00)	(82.31)	(68.54)	
LSD (P=0.05)			(9.51)		

[A] D-C-Trate spray oil included in spray at 2% v/v.

ACKNOWLEDGMENTS

Y. Fares and J. Bonilla provided valuable assistance in setting up and spraying the trials.

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