RESEARCH REPORTS continued

Response of six temperate annual grass weeds to six selective herbicides

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Summary

The responses of wild oats, *Avena fatua* L., annual ryegrass, *Lolium rigidum* Gaud., paradoxa grass, *Phalaris paradoxa* L., great brome, *Bromus diandrus* Roth., silver grass, *Vulpia myuros* (L.) Gmel., and barley grass, *Hordeum leporinum* Link. to fluazifop-P, haloxyfop, quizalofop-ethyl, fenoxaprop-ethyl, sethoxydim, and clethodim were compared in a glasshouse pot experiment. Fluazifop-P, haloxyfop, quizalofop-ethyl and clethodim were active on all species except silver grass, while fenoxaprop-ethyl and sethoxydim were active only on wild oats, ryegrass, and paradoxa grass.

The same herbicides were evaluated in field experiments with silver grass, barley grass, and great brome. These experiments confirmed the tolerance of silver grass to all herbicides. Barley grass and great brome were effectively controlled by fluazifop-P, haloxyfop, quizalofop-ethyl, and clethodim. Sethoxydim at 186 g ha^{-1} (a higher rate than that used in the pot experiment) gave reasonable control of barley grass but was ineffective on great brome.

Introduction

Annual grasses are the most important group of weeds in winter crops in southern Australia (Velthius and Amor 1983; Leys and Dellow 1986; Kloot 1987). They are important not only because of their direct competitive effect on crops, but also because they are hosts of several important root diseases of cereal crops (Butler 1961). The following species have been identified as the most widespread and important grasses in winter crops in Australia: wild oats, *Avena fatua* and *A. ludoviciana* Dur., annual ryegrass, *Lolium rigidum*, paradoxa grass, *Phalaris paradoxa*, great brome, *Bromus diandrus*, silver grass, *Vulpia myuros* and *V. bromoides* (L.) Gray, and barley grass, *Hordeum leporinum* and *H. glaucum* Steud. (Stephenson *et al* 1986).

All the above species, except wild oats and ryegrass, are poorly controlled by the herbicides currently available for use in winter cereals. Two herbicides (fluazifop-P and sethoxydim) have recently been introduced for post-emergence control of some of these grasses in broad-leaf crops, while haloxyfop (Wall and Phimister 1987), quizalofop-ethyl (Davis 1987), fenoxaprop-ethyl (Henderson and McGregor 1984) and clethodim (Rappo, pers. comm.) are currently under development. All of these herbicides belong to one of two new groups of herbicides: the aryloxyphenoxypropionates or the cyclohexanediones. Although herbicides belonging to these two groups are often referred to as graminicides (Velovitch 1983), differential species responses are known to occur (Appleby 1984; Gilbey 1984; Davis 1987; Wall and Phimister 1987).

In this paper we report the results of field and pot experiments in which we compared the response of wild oats, ryegrass, great brome, barley grass, paradoxa grass, and silver grass to fluazifop-P, haloxyfop, quizalofop-ethyl, fenoxaprop-ethyl, sethoxydim, and clethodim.

Methods

Pot experiments

Seeds of five common annual grass weeds were collected from locations near Wagga Wagga in December 1986 and stored in paper bags at room temperature until April 1987. The species were wild oats, *Avena fatua*, paradoxa grass, *Phalaris paradoxa*, great brome, *Bromus diandrus*, silver grass, *Vulpia myuros*, and barley grass, *Hordeum leporinum*. Seed of the sixth species, annual ryegrass, *Lolium rigidum*, was purchased from a local seed merchant in late 1986 and stored under the same conditions as the other species.

In late April, 10–20 seeds of each species were sown into pots (15 cm diam.) filled with potting mix. One to 2 weeks after emergence the pots were thinned to eight (silver grass), six (ryegrass and paradoxa grass), or four (wild oats, barley grass and great brome) plants per pot. Pots were watered daily and fertilized once per fortnight with Aquasol. The experiment was conducted in a glasshouse from May to June during which the daily average temperatures ranged from 5–18° C.

When the grasses were at the early tillering stage (Zadoks growth stage 14/22) six rates (0, 10, 20, 40, 60, and 100 g a.i. ha^{-1}) of fluazifop-P, haloxyfop, quizalofop-ethyl, fenoxaprop-ethyl, sethoxydim, and clethodim, were applied. The active ingredient for the aryloxyphenoxypropionate herbicides refers to the parent acid for fluazifop-P and haloxyfop, and to the appropriate ester for quizalofop-ethyl and fenoxaprop-ethyl. The herbicides were applied with a pot sprayer using a TeeJet 8001E flat fan nozzle tip delivering 125 l ha^{-1}. A non-ionic surfactant (Agral 60) was added at 0.25% (v/v) to all herbicides except sethoxydim and clethodim to which 1% mineral oil (DC-Tron) was added.

Six weeks after herbicide application the plants were harvested, dried at 80°C for 48 h, and the shoot dry weights were recorded. A completely randomized design with five replicates was used.

An analysis of variance of the shoot dry weight indicated that the variance was not independent of the mean, and hence linear plateau models were fitted to treatment means assuming a gamma distribution for the errors. From the computed regression models, GR_{50} values were calculated for each species/herbicide combination. GR_{50} is defined here as the rate of herbicide in g a.i. ha^{-1} that reduced shoot dry weight by 50% compared to the unsprayed control means.

Field experiments

Two sites were used for field experiments in each year (1986 and 1987); barley grass and silver grass grew together on one site, while great brome was present on the other site.

Table 1 Control of barley grass and great brome in field experiments at Wagga Wagga in 1986 and 1987

Rate (g a.i. ha^{-1})	Barley grass 1986		Barley grass 1987		Great brome 1986		Great brome 1987	
	(Ang.(% control))[A]							
Fluazifop-P								
63	48.5	(56)	63.6	(80)	38.2	(38)	46.3	(52)
94	75.0	(93)	71.5	(90)	69.2	(87)	55.7	(52)
125	72.8	(91)	71.8	(90)	70.1	(88)	61.5	(77)
Haloxyfop								
52	73.2	(92)	84.4	(99)	55.0	(67)	53.9	(65)
78	82.7	(98)	86.9	(100)	71.6	(90)	76.6	(95)
104	76.8	(95)	90.0	(100)	78.7	(96)	80.7	(97)
Quizalofop-ethyl								
48	81.8	(98)	82.6	(98)	59.3	(74)	53.0	(64)
72	74.2	(93)	82.6	(98)	67.4	(85)	63.9	(81)
96	78.6	(96)	90.0	(100)	72.0	(90)	70.3	(89)
Fenoxaprop-ethyl								
60	15.9	(7)	—		8.9	(2)	—	
90	23.0	(15)	—		0	(0)	—	
120	27.6	(21)	—		0	(0)	—	
Sethoxydim								
93	45.9	(52)	0	(0)	15.1	(7)	37.4	(37)
140	46.7	(53)	41.5	(44)	40.2	(42)	30.3	(25)
186	68.1	(86)	60.2	(75)	45.6	(51)	30.9	(26)
Clethodim								
30	—		48.5	(56)	—		35.2	(33)
60	—		75.2	(93)	—		53.8	(65)
90	—		86.9	(100)	—		62.7	(79)
120	—		83.9	(99)	—		72.9	(91)
l.s.d. (P = 0.05)	19.7		18.1		12.4		16.9	

[A] Values were transformed using the angular transformation prior to statistical analysis. The values in parenthesis have been re-transformed to percentages of the control.

The herbicide treatments listed in Table 1 were applied with a hand-held boom using 8001 LP TeeJet tips at 150 kPa in 87 l water ha^{-1}. A non-ionic surfactant (Agral 60) was added at 0.25% (v/v) to all herbicides except sethoxydim and clethodim to which 1% mineral oil (DC-Tron) was added. In both years applications were made under good growing conditions when most of the grasses had three to four leaves and two to three tillers. For the barley grass/silver grass sites this occurred on 21 July 1986 and 2 July 1987, while the treatments were applied to great brome on 11 July 1986 and 12 August 1987 (the late date of application at this site resulted from it being cultivated on 1 June 1987). Because it was ineffective, fenoxaprop-ethyl was included in the field experiments only in 1986. Clethodim became available only in 1987, and hence was not included in 1986.

In 1986 visual estimates of weed control were used to assess great brome and silver grass. At all other sites weed control was determined by taking plant counts (10 × 0.1 m^2 quadrats per plot for barley grass and great brome, and 20 × 8 cm diameter soil cores for silver grass). In both years the plant counts or visual assessments were made 6–8 weeks after application of the herbicides.

The plots were arranged as randomized complete blocks with three replications. For uniform presentation all plant counts were expressed as percentage reductions in plant numbers, and these results, along with the visual estimates (percentage reduction in plant numbers) made on great brome and silver grass in 1986, were statistically analysed using angular transformation.

Results

Pot experiments

The responses of the six grasses to each of the herbicides are shown in Figures 1–6.

Fluazifop-P. With the exception of silver grass, fluazifop-P had similar activity on all species, with ryegrass being the most susceptible. Fluazifop-P had no effect on silver grass.

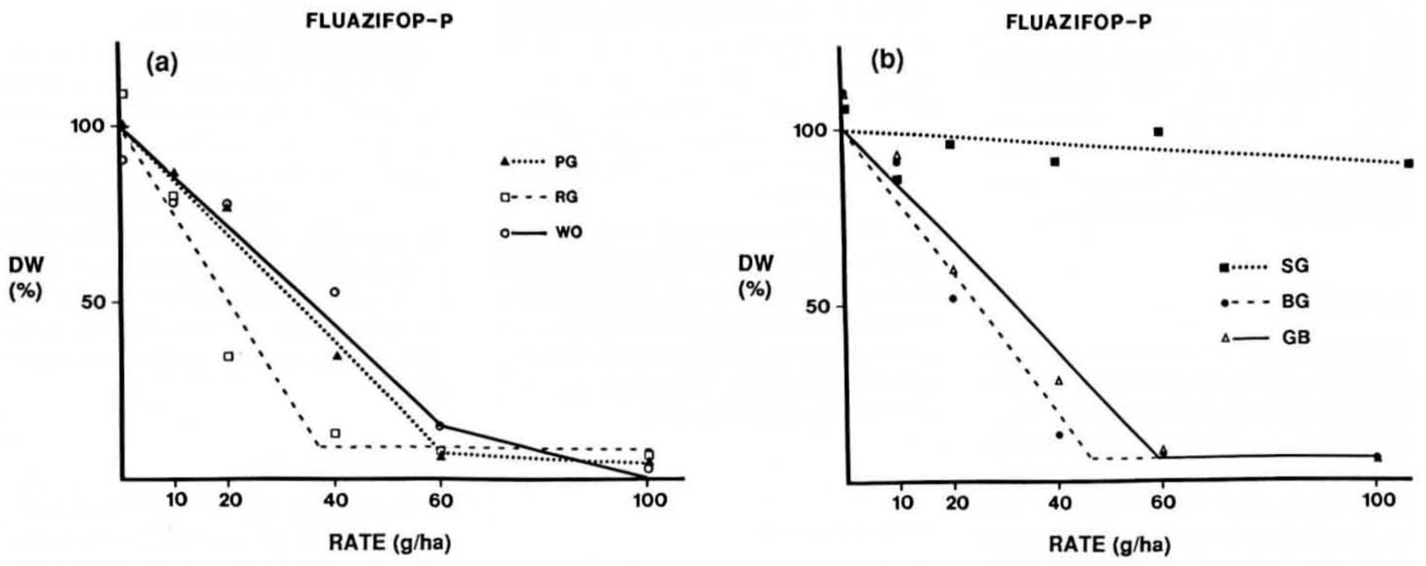

Figure 1 Response (dry weight as a percentage of unsprayed controls) of (*a*) paradoxa grass (PG), annual ryegrass (RG), wild oats (WO), and (*b*) silver grass (SG), barley grass (BG) and great brome (GB) to rate of fluazifop-P.

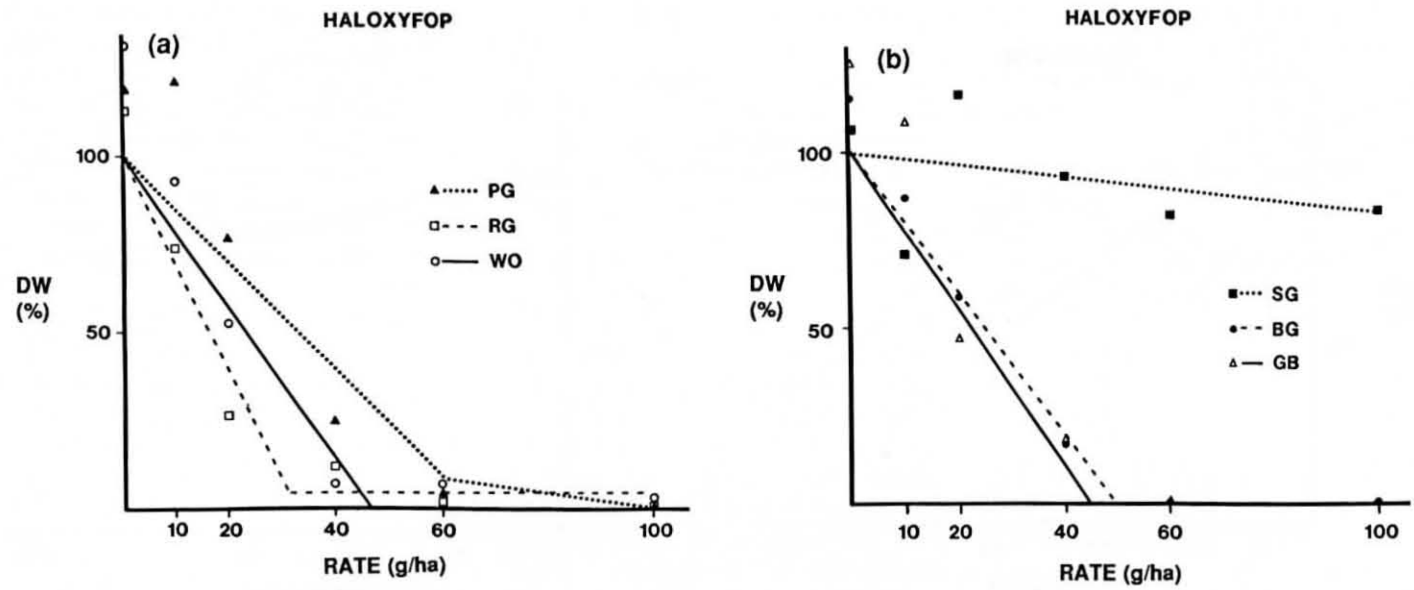

Figure 2 Response (dry weight as a percentage of unsprayed controls) of (*a*) paradoxa grass (PG), annual ryegrass (RG), wild oats (WO), and (*b*) silver grass (SG), barley grass (BG) and great brome (GB) to rate of haloxyfop.

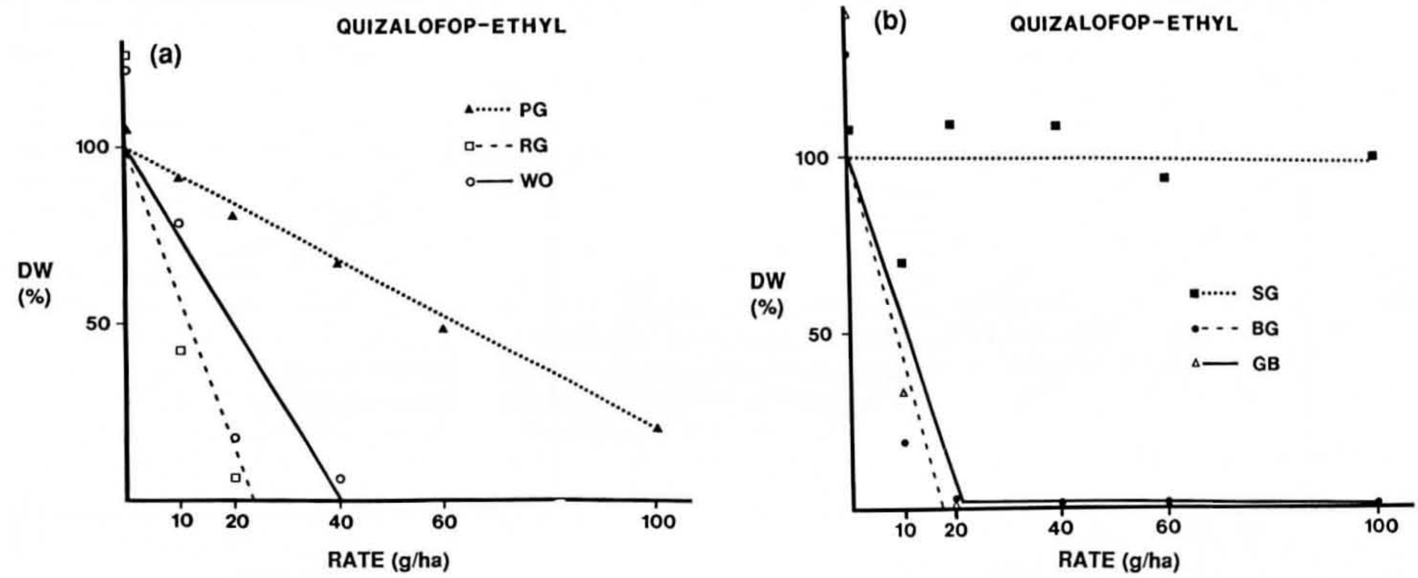

Figure 3 Response (dry weight as a percentage of unsprayed controls) of (*a*) paradoxa grass (PG), annual ryegrass (RG), wild oats (WO), and (*b*) silver grass (SG), barley grass (BG) and great brome (GB) to rate of quizalofop-ethyl.

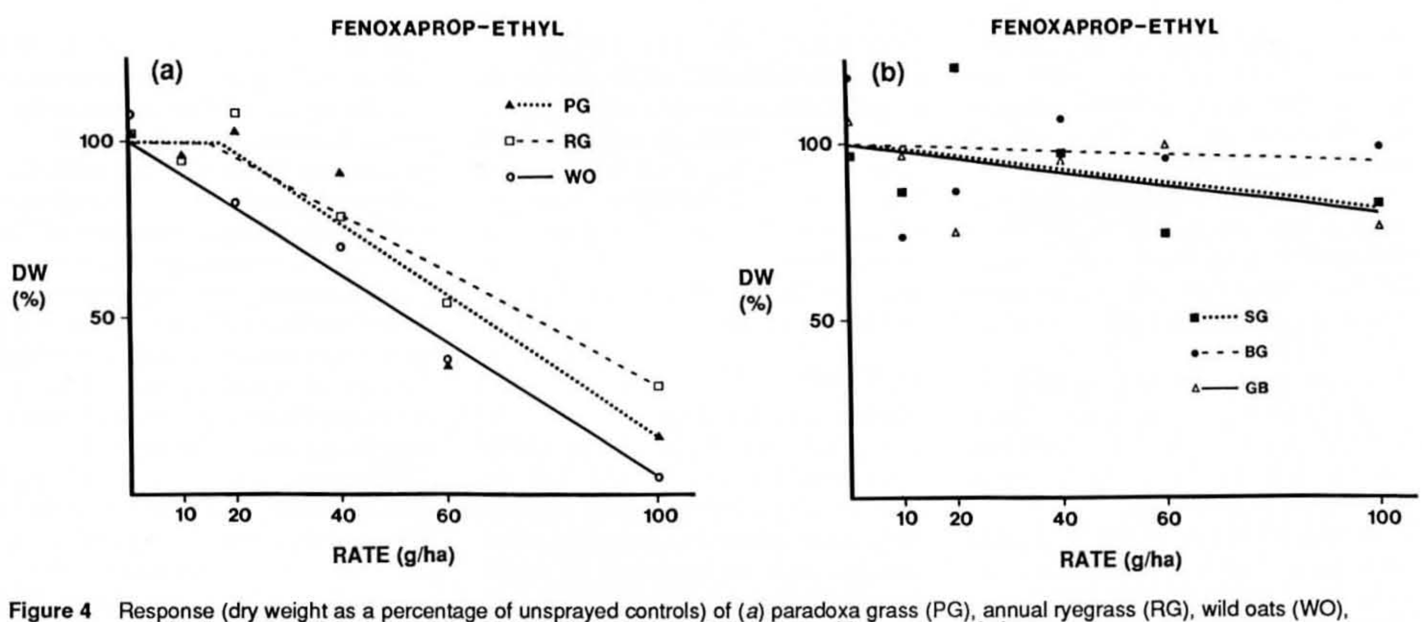

Figure 4 Response (dry weight as a percentage of unsprayed controls) of (*a*) paradoxa grass (PG), annual ryegrass (RG), wild oats (WO), and (*b*) silver grass (SG), barley grass (BG) and great brome (GB) to rate of fenoxaprop-ethyl.

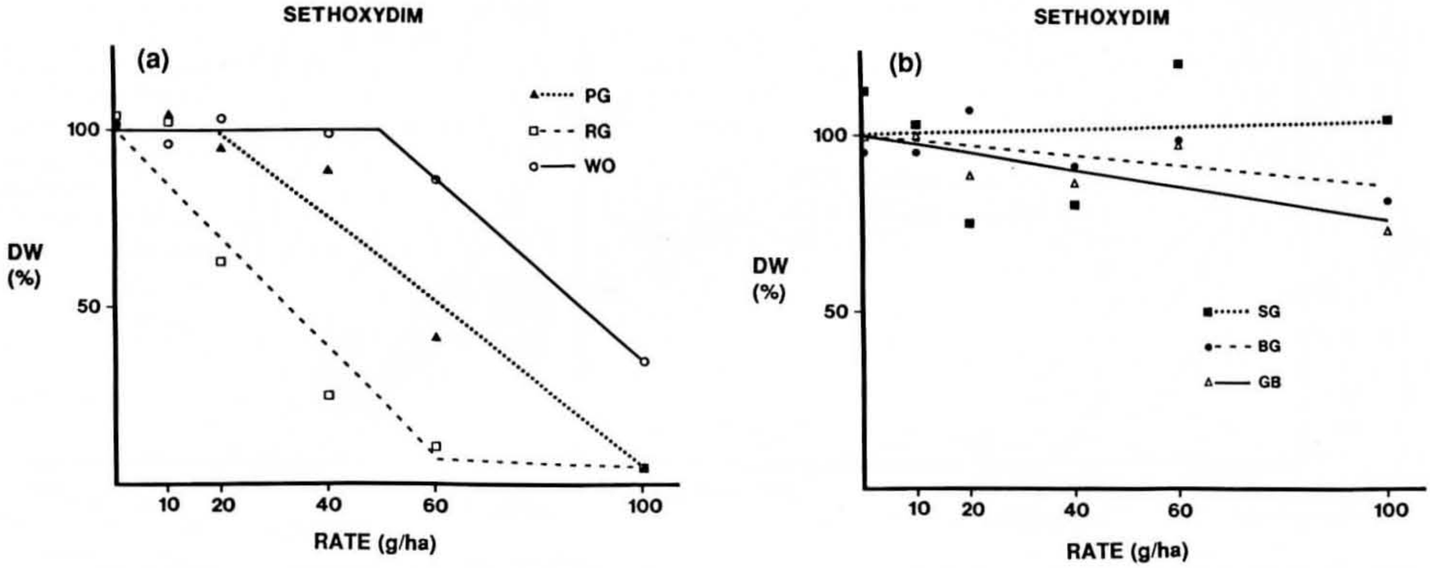

Figure 5 Response (dry weight as a percentage of unsprayed controls) of (*a*) paradoxa grass (PG), annual ryegrass (RG), wild oats (WO), and (*b*) silver grass (SG), barley grass (BG) and great brome (GB) to rate of sethoxydim.

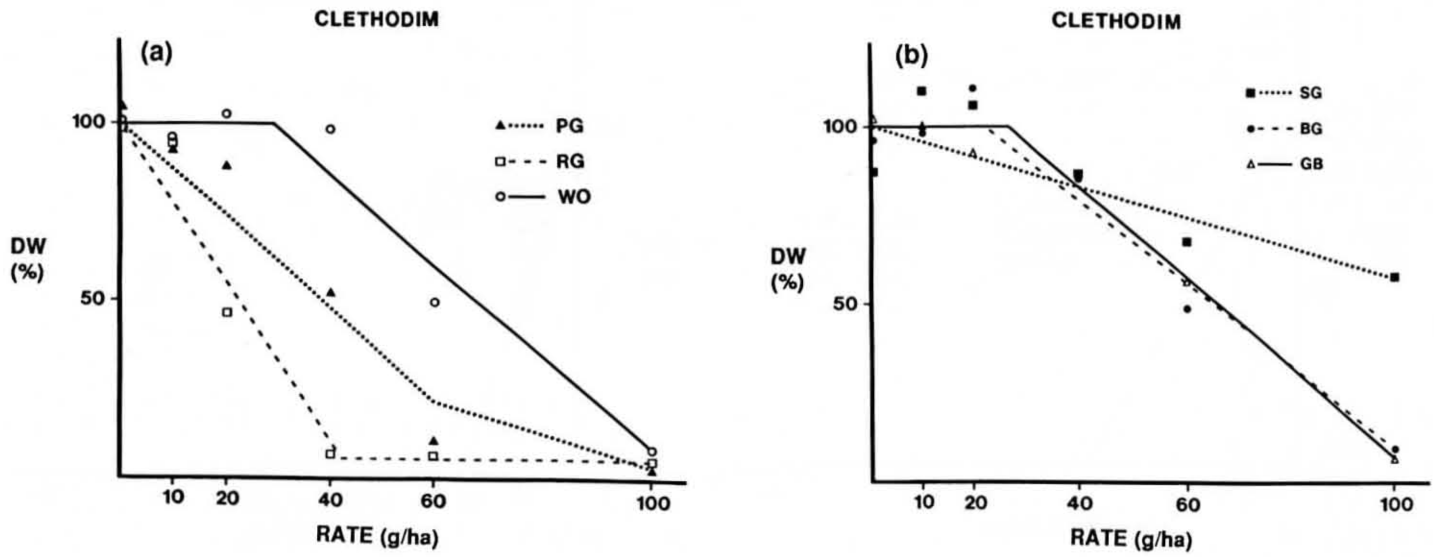

Figure 6 Response (dry weight as a percentage of unsprayed controls) of (*a*) paradoxa grass (PG), annual ryegrass (RG), wild oats (WO), and (*b*) silver grass (SG), barley grass (BG) and great brome (GB) to rate of clethodim.

Haloxyfop. Haloxyfop was very active on ryegrass (most susceptible), wild oats, barley grass and great brome, but was slightly less active on paradoxa grass. It had virtually no effect on silvergrass.

Quizalofop-ethyl. Quizalofop-ethyl was very active on barley grass (most susceptible), great brome and ryegrass, slightly less active on wild oats, and much less active on paradoxa grass. It had no effect on silver grass.

Fenoxaprop-ethyl. Fenoxaprop-ethyl had similar activity on wild oats (most susceptible), paradoxa grass and ryegrass, but very little activity on barley grass, great brome or silver grass.

Sethoxydim. Sethoxydim was most active on ryegrass, less active on paradoxa grass, less active again on wild oats and had very little effect on great brome and barley grass. It had no effect on silver grass.

Clethodim. Clethodim was most active on ryegrass, less active on paradoxa grass, and much less active on wild oats, great brome and barley grass. Clethodim was the only herbicide that had some activity on silver grass; rates of 40 g ha^{-1} and greater reduced the dry weight of silver grass and the GR_{50} value (117g ha^{-1}) was just outside the limits of this experiment.

Field experiments

Plant numbers of silver grass were reduced by high rates of clethodim, but the results were variable and would not be commercially acceptable (<50% control). None of the other herbicides had any effect on silver grass and hence only the results from the barley grass and great brome field experiments are presented (Table 1)

At one of the rates used in these experiments haloxyfop, quizalofop-ethyl, fluazifop-P, and clethodim gave greater than 85% control of both barley grass and great brome. This is a good result in view of the fact that the poor sub clover pastures exerted little, if any, competition. All the treatments were less effective on great brome than barley grass, but this may have been the result of differences between sites in growing conditions or stage of growth at the time of spraying, since, with the exception of fluazifop-P, such differences were not apparent in the pot trial.

Sethoxydim was less active on great brome and barley grass than the herbicides discussed above. However, at the highest rate, 186 g ha^{-1}, sethoxydim effected reasonable control of barley grass (86% control in 1986 and 75% control in 1987).

This is well above the highest rate included in the pot trial (100 g ha^{-1}) but is commonly used for control of annual ryegrass and wild oats. Sethoxydim was much less effective on great brome than it was on barley grass.

Fenoxaprop-ethyl gave very poor control of barley grass and great brome in 1986 and hence was deleted from the 1987 trial.

Discussion

All herbicides were generally more effective in the pot trial than in the field experiments. This is often the case because conditions favour plant growth in pots which are more frequently watered and, moreover, root space is confined (Muzik 1976; Fuhr 1985).

The primary aim of the pot experiment was to determine the response of the six grasses to each herbicide. However, as all treatments were imposed under exactly the same conditions it is possible to make comparisons between herbicides (Table 2). By averaging the GR_{50} values for the three species on which all herbicides were effective (ryegrass, wild oats, and paradoxa grass) they can be ranked in the following order (most to least active): fluazifop-P = haloxyfop = quizalofop-ethyl > clethodim > sethoxydim = fenoxaprop-ethyl. The ranking varies with species, and on a gram for gram basis quizalofop-ethyl was the most active herbicide on all species except paradoxa grass and silver grass. As the herbicides are formulated with different concentrations of active ingredient, the choice of herbicide will ultimately be determined by the cost of the lowest rate that will effectively control all target species.

Fluazifop-P and haloxyfop have similar activities on the weeds we evaluated, and this is not surprising considering their very similar chemical structures.

Our results from the pot trial suggest that fluazifop-P, haloxyfop, and quizalofop-ethyl are more active on ryegrass than wild oats, barley grass and great brome. However, this is not supported by field trials in which ryegrass tends to be the most tolerant species, especially when applications are made to more advanced growth stages (Gilbey 1984; Wall and Phimister 1987; Warner, pers. comm.; Swinnerton, pers. comm.). Selection for increased herbicide resistance may be a possible explanation for the greater herbicide tolerance of annual ryegrass in the field. The ryegrass seed used in the pot trial was purchased from a local seed merchant and has most likely been grown on paddocks that have never been subjected to aryloxyphenoxypropionate herbicides; such is unlikely to have been the case for the field trials since diclofop-methyl, and to a much lesser extent fluazifop-P, have been used widely in Australia. Populations of annual ryegrass resistant to herbicides, especially aryloxyphenoxypropionates, have been confirmed from over 40 sites in southern Australia (Howatt, pers. comm.), and less obvious increases in tolerance may be present over a much greater area.

While most of the species varied in their sensitivity to these herbicides, silver grass tolerated all compounds (clethodim had a slight effect). Recent work has suggested that herbicidal selectivity of aryloxyphenoxypropionate and cyclohexanedione herbicides is due to differences in the sensitivity of acetyl-CoA carboxylase, an enzyme involved in fatty acid synthesis (Burton *et al.* 1988; Secor and Cseke 1988). Herbicide metabolism studies using radiolabelled herbicides would be required to determine whether such differences are responsible for the marked tolerance of silver grass to these herbicides.

Table 2 GR_{50} values[A]

Ryegrass	Wild oats	Paradoxa grass	Barley grass	Great brome	Silver grass
		(g a.i. ha^{-1})			
		Fluazifop-P			
19.8	35.2	32.5	24.7	32.1	—
		Haloxyfop			
19.9	28.1	39.7	30.1	26.6	—
		Quizalofop-ethyl			
11.7	19.3	62.7	8.7	10.6	—
		Fenoxaprop-ethyl			
75.9	52.5	66.3	—	—	—
		Sethoxydim			
32.6	88.1	61.2	—	—	—
		Clethodim			
22.2	67.6	38.8	65.1	66.3	(117)

[A] GR_{50} is defined as the rate of herbicide in g a.i. ha^{-1} that reduced shoot dry weight by 50% compared to the unsprayed control means. Absence of a GR_{50} value means that the herbicide did not reduce shoot dry weight of that species by 50% within the range of rates used in this experiment (0–100 g ha^{-1}).

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