Field evaluation of preseason applications of residual herbicides to control annual ryegrass (*Lolium rigidum* Gaud.)

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Summary

Delaying crop sowing to use a non-selective herbicide to control the first germination flush of annual ryegrass results in reduced growing season length and hence yield potential. These studies aim to evaluate the efficacy of residual herbicides applied during the summer-autumn period to control annual ryegrass seedlings emerging at the commencement of the growing season. Two herbicides, diuron and oryzalin, effectively persisted through the hot dry conditions experienced over the summer-autumn periods of 2000 and 2001 in the field at Merredin and Muresk, Western Australia. High rates of diuron (3.6 kg ha^{-1}) and oryzalin (1.5 kg ha^{-1}) applied to ryegrass pasture residue 157 days pre-sowing reduced annual ryegrass seedlings emerging at the start of the growing season by around 90%. A lower level of annual ryegrass control of between 75–80% was achieved for these same treatments applied to wheat stubble. Diuron at 2.5 kg ha^{-1} applied to annual ryegrass pasture residues 51 and 86 days pre-sowing resulted in a 93% reduction in ryegrass seedlings. Similarly, oryzalin at 2.0 kg ha^{-1} reduced annual ryegrass emergence by 99 and 95% for the 51 and 86 days pre-sowing application timings respectively. These results clearly indicate the potential for applying residual herbicides pre-season to control ryegrass emerging after the season commencing rains thereby allowing the earliest possible sowing time.

Keywords: diuron, oryzalin, s-metolachlor, propyzamide, annual ryegrass, *Lolium rigidum*, wheat, *Triticum aestivum* cv. Callingiri, residual herbicide, pre-season treatment application.

Introduction

The southern Australian cereal growing areas experience a Mediterranean-type climate which is characterized by a short, cool, moist, winter-spring growing season from May to October alternating with extended periods of hot, dry conditions over the summer-autumn period. The short growing season of this region, generally 4–5 months, limits the yield potential for wheat production. The need to sow crops as early as possible along with the fragile nature of the soil types has driven the widespread adoption of no-tillage seeding systems and stubble retention. These practices have been incorporated into an intensive, wheat dominated crop production system that has been adopted across vast areas of the Western Australian cereal growing area. While having many benefits, this system is reliant on in-crop selective herbicides for weed control and as a result large scale evolution of herbicide resistance in annual ryegrass (*Lolium rigidum* Gaud.) populations has occurred as indicated in a survey carried out in the Western Australian crop growing areas (Llewellyn and Powles 2001, Heap 2004). Pre-seeding weed control is currently being achieved with non-selective herbicides such as glyphosate and/or paraquat often leading to delayed sowing which can significantly reduce crop yields (Anderson and Sawkins 1997, French and Schultz 1984, Hocking and Stapper 2001). Additionally, reliance on the use of glyphosate for pre-sowing control of ryegrass has led to the evolution of resistance to this herbicide in ryegrass populations (Powles *et al.* 1998, Pratley *et al.* 1999). This has created strong demand for an alternative weed control practice that allows early sowing whilst effectively controlling the early cohorts of annual ryegrass.

In earlier glasshouse studies Walsh *et al.*, 2004) identified the potential for some residual herbicides to persist on the soil surface under extended periods of hot, dry, high sunlight conditions while still retaining their efficacy on emerging annual ryegrass seedlings. The ability to persist under these conditions is essential for this technique to work. This is because of the high variability in timing of the season commencing rains and the extreme conditions found in the Mediterranean type climates of southern Australian. Interestingly, these conditions may assist in the use of residual herbicides for innovative pre-season herbicide application timing. In very dry soils, where soil water potential is below wilting point, there is reduced competition for binding sites with water in the soil matrix. Consequently herbicide sorption generally increases following application to very dry soils (Bailey and White 1964, Green and Obien 1969). Often there are no significant rainfall events between the end of one growing season and the start of the next one in the Mediterranean type climate of southern Australia. This combined with very high summer temperatures ensures that soil moisture levels are very low for an extended period prior to the start of the late autumn growing season. Therefore, a residual herbicide once bound to the soil should persist through the summer autumn period without interference from increasing soil moisture levels. As well as signalling the start of the growing season the opening rainfall events will also allow residual herbicides to move from binding sites when displaced by water into the soil solution (Scott and Lutz, 1971) to act on germinating weed seeds.

The adoption of stubble retention systems has also increased the potential for the persistence of residual herbicides in southern Australian cropping systems. Crop and pasture residues, present on the soil surface, are the primary source of interception of spray droplets and they generally have a much greater capacity of herbicide sorption than the soil (Harper, 1994). Herbicide sorption to these residues is also reversible so that herbicides will be released into the soil solution following a rainfall event (Ghadiri *et al.* 1984).

It follows then that southern Australia has, potentially, an ideal system for prolonging the persistence of residual herbicides. The general absence of rainfall over the summer early autumn period will allow herbicides to be retained on surface stubble residues and in the soil matrix until they are released by the season commencing rainfall event/s. This also coincides with the largest flush of annual ryegrass creating the potential for an optimal control strategy for this environment.

The objective of these studies is therefore to evaluate the efficacy of selected residual herbicides on annual ryegrass, as identified by Walsh *et al.* (2004), in a series of field studies following their application at a range of rates, timings and residue conditions.

Materials and methods

Field trials were conducted over the December–May period of 2000/2001 at Merredin (31.52°S, 118.17°E.) and on March 6, 2002 at Muresk (31.75°S, 116.80°E.). There were slight differences in soil properties between these two locations (Table 1) as well as large differences in rainfall patterns over the two seasons (Figure 1). Additionally, annual ryegrass seedlings emerged from established seedbanks at the Merredin sites while annual ryegrass seed were introduced to the sites at Muresk (Table 2).

Merredin site details

A trial investigating the effect of herbicide dose response on annual ryegrass seedling control was replicated on two residue types, namely annual ryegrass pasture and wheat stubble. The ryegrass pasture had been purposely established over several years to allow the development of a large annual ryegrass seedbank while the wheat residue site had a known annual ryegrass population present. An additional, time of application trial was carried out on the annual ryegrass pasture site. The three trials were slashed prior to the application of herbicide treatments. The initial treatment in the application timing experiment and all treatments in the annual ryegrass pasture and wheat stubble herbicide rate experiments were applied on December 19 (157 days pre-sowing). Plot sizes were 5 × 12 m in each experiment. Surface residue was collected from three 1.0 m^2 quadrat areas in each control plot in each of the three experiments. These were oven dried at 70°C for two days and stubble levels present on the soil surface at the start of the experiment were determined (Table 2). Annual ryegrass seed numbers present on the soil surface at the start of the experiments were determined by vacuuming 1.0 m^2 areas from the untreated control plots in each experiment. Ten soil cores, 5 cm diameter, were collected from these same quadrat areas to determine annual ryegrass seedbank levels (Table 2).

Herbicide treatments applied in the herbicide rate and application timing experiments are listed in Tables 3, 4 and 7. All treatments were applied using a spray boom mounted on a four wheel drive utility vehicle. The boom was equipped with 10 flat fan nozzles (50 cm spacing) delivering a rate of 105 L ha^{-1}. Application timing treatments were applied on December 19 (157 days pre-sowing), March 1 (86 days pre-sowing), April 5 (51 days pre-sowing) and May 5 (21 days pre-sowing). All three sites were sprayed on May 14 with glyphosate at 0.45 kg ha^{-1} to control annual ryegrass seedlings prior to crop sowing (Table 2). Wheat (*Triticum aestivum* cv. Callingiri) was sown at a rate of 80 kg ha^{-1} across all experiments on May 28 using a tyned seeder fitted with knife points.

Annual ryegrass counts were conducted on May 1 to determine herbicide effects on the emergence of the first ryegrass cohort. Annual ryegrass seedling counts were also recorded on July 19 to determine residual herbicide effects on the emergence of the second cohort. At both times annual ryegrass seedlings were counted in 5 × 0.1 m^2 quadrats in each plot of all three experiments. At the second time of counting annual ryegrass seedlings were collected from these quadrat areas and placed in an oven at 70°C for two days and dry matter productions determined. Wheat plants for the determination of biomass production levels were collected on October 12. Because of the complete failure of some treatments in controlling annual ryegrass,

Table 1. Soil physical and chemical properties at the four sites used in the evaluation of the efficacy of residual herbicides following pre-season applications in 2000 and 2001.

	Merredin		Muresk	
Property	Ryegrass pasture	Wheat stubble	Lupin stubble	Canola stubble
pH (H_2O)	5.2	5.5	6.5	5.6
Organic carbon (%)	0.84	0.59	1.80	2.10
Textural class	Loamy sand	Sandy loam	Sand	Sand
Sand (%)	84	75	87	88
Silt (%)	5	7	4	3
Clay (%)	11	18	9	9

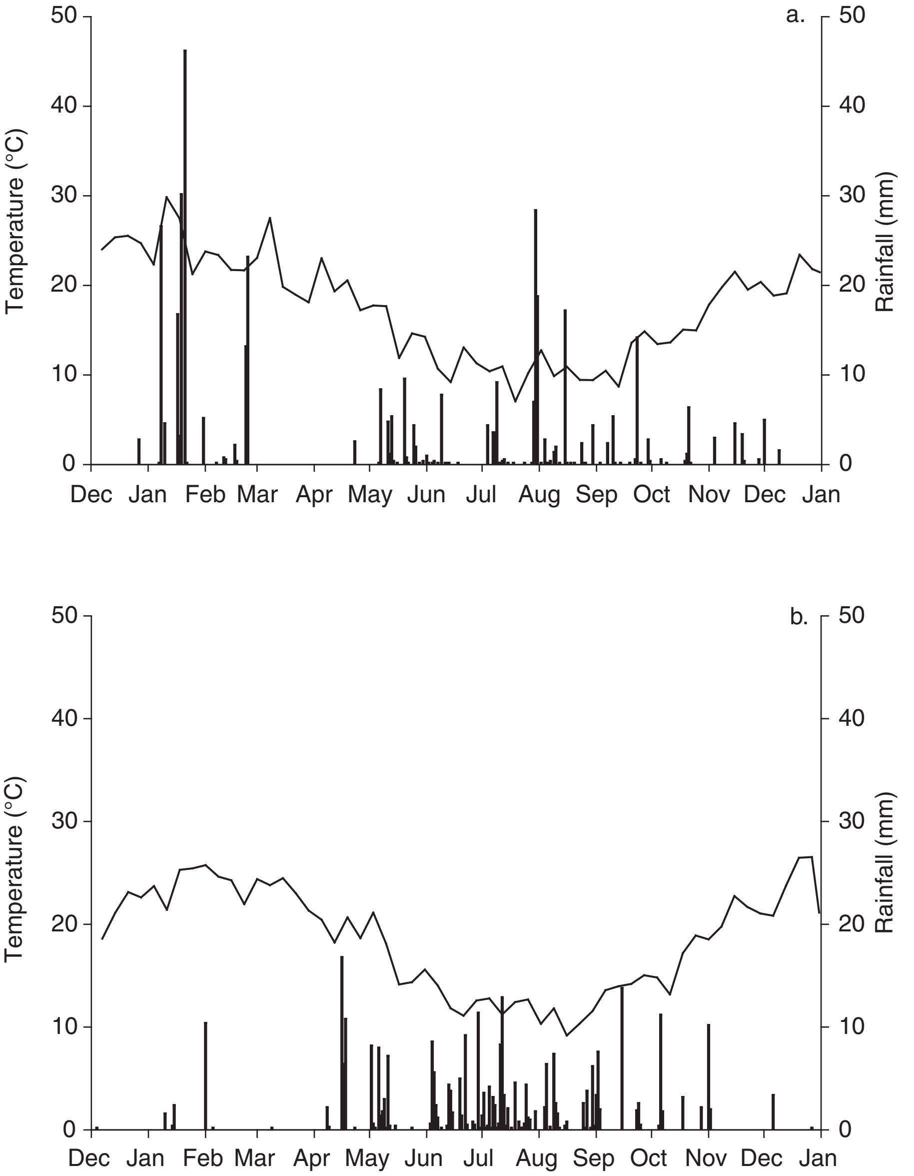

Figure 1. Daily rainfall and seven day average temperature data at (a) Merredin (December 2000 to December 2001) and (b) Muresk (December 2001 to December 2002).

Table 2. Residue levels and ryegrass seed numbers on the soil surface, ryegrass seedbank (0–2 cm) at the start of each experiment and cohort emergence from untreated controls in each of the studies evaluating the efficacy of residual herbicides following pre-season applications at Merredin in 2000 and Muresk in 2001.

Location	Experiment	Residue level ($t\ ha^{-1}$)	Soil surface ($seed\ m^{-2}$)	Seedbank ($seed\ m^{-2}$)	Ryegrass emergence	
					Pre-sowing	In-crop
Merredin 2001	Herbicide rate – Ryegrass residue	3.7	5238	2227	554	89
	Herbicide rate – Wheat stubble	2.0	944	18	118	57
	Application timing	2.2	6967	78	627	131
Muresk 2002	Lupin stubble	2.5	500	0		311
	Canola stubble	2.8	500	0		388

Table 3. Control of ryegrass in late autumn by residual herbicides applied in the preceding summer to ryegrass pasture residue at Merredin, Western Australia, in 2000. Numbers in brackets are ryegrass plant densities (plants m^{-2}).

Herbicide	Application rate ($kg\ ha^{-1}$)	Pre-sowing (% control)	In-crop (% control)	Ryegrass biomass ($t\ ha^{-1}$)	Wheat biomass ($t\ ha^{-1}$)	Wheat yield ($t\ ha^{-1}$)
Untreated control		(554)	(100)	1.33	1.80	0.68
Diuron	0.9	31 (383)	0 (127)	1.72	2.95	0.94
	1.8	64 (197)	22 (77)	0.72	3.79	0.96
	3.6	88 (67)	30 (69)	0.03	4.27	1.61
S-metolachlor	0.48	0 (581)	0 (104)			
	0.96	0 (617)	0 (100)			
	1.92	0 (626)	12 (87)			
Propyzamide	0.25	0 (731)	5 (95)			
	0.5	0 (565)	22 (78)			
	1.0	17 (462)	22 (78)	1.49	2.68	1.17
Oryzalin	1.0	0 (641)	0 (136)	2.25	1.96	0.80
	1.5	88 (90)	50 (50)	0.3	5.29	1.62
Weed free yield					5.43	1.98
LSD (0.05)		57	86	1.2	2.11	0.77

Weed free yields were not included in the analysis.

these were assumed to be the same as the control and, therefore, only selected treatments were harvested for yield comparisons with a plot harvester on November 14.

Muresk site details

Prior to the application of herbicide treatments a density of 500 germinable annual ryegrass seed m^{-2} was established by spreading seed onto the soil surface in lupin and canola stubbles. Herbicide treatments as detailed in Tables 5 and 6 were applied using a handheld 2.0 m boom equipped with four flat fan nozzles at 50 cm spacings and a delivery rate of 100 L ha^{-1}. The sites were sown with wheat (*Triticum aestivum* cv. Callingiri) on May 9 (65 days post treatment application) with a disc seeder at 80 kg ha^{-1}. Annual ryegrass seedling counts were conducted on July 5 by recording seedling density in 5 × 0.1 m^2 quads per plot. Both sites were sprayed with bromoxynil at 0.32 kg ha^{-1} plus MCPA at 0.32 kg ha^{-1} on July 5 to control broad leaf weeds. Because of the poor finish to the growing season only selected plots at the lupin stubble site were hand harvested for the determination of treatment effects on wheat grain yield. Five 1.0 m row lengths were collected from plots on November 20 for this purpose.

Experimental design and analysis

Each study was established in a randomized complete block design with three replicates. For all experiments, analysis of variance was performed on ryegrass seedling counts and grain yields. For presentation annual ryegrass seedling counts were calculated as the percent reduction (control) in ryegrass plant numbers when compared with the untreated control. The data from the four studies comparing effects

Table 4. Control of ryegrass germination in late autumn by residual herbicides applied to wheat stubble in the preceding summer at Merredin, Western Australia, in 2000. Numbers in brackets are ryegrass plant densities (plants m^{-2}).

Herbicide	Application rate (kg ha^{-1})	Pre-sowing (% control)	In-crop (% control)	Ryegrass biomass (t ha^{-1})	Wheat biomass (t ha^{-1})	Wheat yield (t ha^{-1})
Untreated control		(118)	(41)	1.56	2.0	0.93
Diuron	0.9	0 (124)	49 (21)	0.31	2.79	1.83
	1.8	58 (50)	73 (12)	0.32	4.34	2.13
	3.6	75 (30)	98 (0.7)	0.16	4.11	2.28
S-metolachlor	0.48	0 (119)	0 (43)			
	0.96	1 (116)	0 (44)			
	1.92	7 (109)	1 (40)			
Propyzamide	0.25	9 (107)	8 (37)			
	0.5	20 (95)	15 (34)			
	1.0	3 (102)	3 (39)			
Oryzalin	1.0	63 (39)	38 (26)		3.86	1.94
	1.5	79 (22)	95 (2)	0.04	5.08	1.98
Weed free					5.43	1.98
LSD (0.05)		115	100	0.93	1.62	0.65

Weed free yields were not included in the analysis.

of stubble residue on herbicide efficacy (annual ryegrass, wheat, lupin and canola residue) were initially combined for analysis. However, despite there being no effect due to stubble residue differences, there was a large degree of variability possibly due to site and climatic differences (Tables 1 and 2, Figure 1). Therefore, individual site data were subsequently analysed separately. In each case, herbicide treatment was significant ($P < 0.05$) and, therefore, treatment means for each site are presented for comparison with LSD at $\alpha = 0.05$ level of significance. For the time of application experiment, herbicide treatments only were significant ($P < 0.05$). Therefore, application timing was removed as a factor in subsequent analyses to allow comparison of herbicide treatments with LSD at $\alpha = 0.05$ level of significance.

Results and discussion

Herbicide evaluations – annual ryegrass control

Results from these studies indicate that the herbicides, diuron and oryzalin, applied during summer to a dry soil surface, are capable of effectively controlling the emergence of annual ryegrass after germinating rains in autumn. This finding may lead to a new herbicide strategy for growers to control annual ryegrass and ensure higher yields.

At Merredin in 2000, high rates of diuron (3.6 kg ha^{-1}) or oryzalin (1.44 kg ha^{-1}) provided good control of emerging annual ryegrass seedlings following the season opening rains in both pasture and wheat stubble residues (Table 3). These treatments were applied five months (157 days) pre-sowing of the wheat crop yet both provided 88% control of annual ryegrass seedlings emerging from the pasture residue before crop seeding. Additionally, these treatments also provided around 75% control of seedlings emerging from the wheat stubble before crop seeding (Table 4). Diuron and oryzalin continued to control annual ryegrass seedling emergence (2nd cohort) within the wheat crop at both residue sites. Oryzalin and diuron reduced in-crop annual ryegrass numbers by 95 and 98% respectively, within the wheat stubble residue site but by only 50 and 30% at the annual ryegrass residue site. The difference in effective persistence between the pasture residue and wheat stubble sites for these two herbicide treatments may be associated with the lower levels of plant residue and ryegrass seedbank numbers than at the wheat stubble site, i.e. more herbicide sorption took place on the wheat residue and became active with the germinating rains (Table 2).

At Muresk in 2002, the highest application rate of diuron was effective in controlling annual ryegrass seedlings following application to lupin and canola stubbles in separate herbicide screening trials. In both experiments, diuron at the highest rate of 1.5 kg ha^{-1} provided an acceptable level of annual ryegrass control (Tables 5 and 6). This treatment resulted in 73 and 74% reductions in the number of ryegrass seedlings emerging within the wheat crop that was sown on lupin and canola stubbles respectively. Propyzamide at the highest application rate of 1.0 kg ha^{-1} reduced annual ryegrass numbers by 68% at the lupin stubble site and 54% at the canola stubble site. The highest rate of s-metolachlor was less effective at both sites, providing around 55% reductions in annual ryegrass numbers (Tables 5 and 6). The poor performance of s-metolachlor and propyzamide at the lupin and canola stubble sites was similar to the results recorded for these herbicides at Merredin in 2000. Both s-metolachlor and propyzamide were generally not effective in controlling pre-sowing or in-crop ryegrass emergence at the pasture residue and wheat stubble sites (Tables 3 and 4).

Herbicide evaluations – biomass and wheat yield responses

Diuron and oryzalin, applied in summer at elevated rates 157 days prior to sowing, resulted in substantial wheat yield increases due to the control of annual ryegrass seedlings emerging pre- and post-sowing of the wheat crop. At Merredin, the 3.6 kg ha^{-1} and 1.5 kg ha^{-1} rates of diuron and oryzalin respectively produced an additional 1.0 t ha^{-1} of wheat yield above that of the untreated control at both the pasture residue and wheat stubble sites (Tables 3 and 4). At the wheat stubble site all rates of oryzalin and diuron produced 100% increases in wheat yields. Only the highest application rates of these two herbicides produced similar yield increases at the annual ryegrass pasture residue site. The highest rate of diuron also resulted in an increased wheat yield at the lupin stubble site at Muresk (Table 5). Yield increases at these sites were most likely due to a combination of factors including soil moisture and nutrient conservation as well as reduced in-crop competition resulting from reductions in pre-sowing and in-crop annual ryegrass numbers. Evidence of reduced in-crop competition is seen with large reductions in annual ryegrass biomass corresponding with large increases in wheat biomass for the oryzalin and diuron treatments (Tables 3 and 4).

Table 5. Control of ryegrass emerging in wheat crops following early autumn application of residual herbicides to lupin stubble at Muresk, Western Australia, in 2001. Numbers in brackets are ryegrass plant densities (plants m^{-2}).

Herbicide	Application rate (kg ha^{-1})	Lupin stubble (% control)	Wheat yield (t ha^{-1})
Untreated control		(311)	3.36
Diuron	0.25	28 (224)	
	0.5	48 (162)	3.85
	1.0	57 (134)	3.3
	1.5	73 (84)	4.02
S-metolachlor	0.48	34 (205)	
	0.96	42 (181)	
	1.92	32 (211)	
	2.88	57 (134)	3.87
Propyzamide	0.125	31 (215)	
	0.25	35 (202)	
	0.5	41 (183)	4.11
	1.0	68 (100)	3.99
LSD (0.05)		20	0.55

Table 6. Control of ryegrass emerging in wheat crops following early autumn application of residual herbicides to canola stubble at Muresk, Western Australia, in 2001. Numbers in brackets are ryegrass plant densities (plants m^{-2}).

Herbicide	Application rate (kg ha^{-1})	Canola stubble (% control)
Untreated control		(388)
Diuron	0.25	26 (285)
	0.5	46 (210)
	1.0	66 (132)
	1.5	74 (100)
S-metolachlor	0.48	24 (294)
	0.96	43 (221)
	1.92	29 (276)
	2.88	53 (182)
Propyzamide	0.125	34 (256)
	0.25	20 (308)
	0.5	17 (321)
	1.0	54 (179)
LSD (0.05)		20

Application timing and herbicide persistence

The efficacy of oryzalin and diuron on annual ryegrass remained high with increasing periods of exposure to hot and dry conditions as experienced in Merredin following application during the summer-autumn period in 2000. These treatments (diuron at 2.5 kg ha^{-1} and oryzalin at 2.0 kg ha^{-1}) were particularly effective in reducing the emergence of ryegrass pre-sowing following applications at 51 and 86 days pre-sowing (Table 7). These application timings resulted in 93% reductions in ryegrass seedling numbers for diuron and 99 and 95% reductions respectively for the oryzalin treatment. Remarkably, the diuron treatment at the earliest application timing of 157 days (5 months) pre-sowing resulted in a 63% reduction in pre-sowing annual ryegrass numbers. Although this treatment did not result in the lowest annual ryegrass plant density pre-sowing, it did produce the highest wheat grain yield of 1.99 t ha^{-1}. In contrast, at the last application timing of 21 days pre-sowing the diuron treatment gave a very poor level of annual ryegrass control (15%). However, this treatment gave the highest level of in-crop control of annual ryegrass indicating that a lack of soil incorporation was possibly the reason for the poor pre-sowing result. In general, in-crop annual ryegrass control with diuron was poor – averaging a 35% reduction. Despite this, all except the final diuron application timing, produced increases ($P < 0.05$) in grain yield of around 1.0 t ha^{-1} above that of the untreated control. It was also observed that the last application timing of diuron caused severe crop damage. Oryzalin treatments produced an acceptable level of control of annual ryegrass plants that emerged within the wheat crop at all application timings (Table 7). However, it was only the last two application timings

Table 7. Ryegrass control and wheat grain yield following four field application timings of residual herbicides to ryegrass pasture stubble, Merredin, Western Australia, in 2000. Numbers in brackets are ryegrass plant densities (plants m^{-2}).

Herbicide	Application rate (kg ha^{-1})	Time pre-sowing (days)	Ryegrass seedlings		Ryegrass biomass (t ha^{-1})	Wheat biomass (t ha^{-1})	Wheat yield (t ha^{-1})
			Pre-sowing (% control)	In-crop (% control)			
Untreated control			(627)	(131)	0.93	0.29	0.61
Diuron	2.5	157	63 (231)	32 (84)	0.32	3.85	1.99
		86	93 (45)	37 (82)	0.15	2.36	1.58
		51	93 (44)	36 (83)	0.07	3.10	1.90
		21	15 (532)	85 (19)	0.13	0.72	0.46
S-metolachlor	0.96	157	18 (514)	51 (63)			
		86	45 (398)	57 (56)			
		51	66 (213)	20 (104)	0.05	2.2	1.16
		21	33 (420)	44 (72)	0.62	1.7	0.99
Oryzalin	2.0	86	92 (33)	78 (28)	0.44	2.15	0.93
		51	99 (8)	84 (21)	0.08	3.04	1.97
		21	75 (157)	73 (35)	0.18	2.62	1.73
Weed free						5.43	1.98
LSD (0.05)			35	57	0.65	1.24	0.92

that resulted in significant yield increases ($P < 0.05$).

The effective persistence of the oryzalin and diuron herbicides was possibly related to the high levels of annual ryegrass pasture residues remaining on the soil surface at the time of treatment application and subsequent summer rainfall events. At the application timing site 2.2 t ha^{-1} of ryegrass pasture residue was present on the soil surface at the time of treatment application. Several studies have identified the ability of diuron (Hamilton and Arle 1972, Khan *et al.* 1976, Majka and Lavy 1977) and oryzalin (Kennedy and Talbert 1977, Krieger *et al.* 1998, Landry *et al.* 2004) to persist for prolonged periods following high application rates. Although many herbicides suffer reduced efficacy following application to plant residues as is frequently observed in no-till systems (Buhler *et al.* 1993, Erbach and Lovely 1975, Banks and Robinson 1986), there is also evidence that residues can aid the persistence of some herbicides (Kells *et al.* 1990). The interception of herbicides by plant residues may subject them to high rates of dissipation by microbial and photo-degradation. Alternatively herbicides may experience a greater level of retention due to binding with these residues (Locke and Bryson 1997). The influence of plant residues on intercepted herbicide treatments is also greatly dependant on rainfall where increased levels of rainfall will leach herbicides out of the plant residues and into the soil. It is likely that the large summer rainfall events that occurred at Merredin in January and February 2000 (Figure 1) were responsible for the movement of both oryzalin and diuron into the soil increasing the persistence of these herbicide treatments. It was observed that there was excellent summer weed control in both oryzalin and diuron treatments following these rainfall events. Once in the soil, persistence would have also been aided by the presence of surface residues reducing losses due to photo-degradation and volatilization.

There were large losses of efficacy of s-metolachlor and propyzamide with increasing lengths of time of exposure to harsh summer-autumn conditions. There were reductions in annual ryegrass numbers at all four application rates of s-metolachlor and propyzamide following applications to canola and lupin stubbles at Muresk (Tables 5 and 6). In contrast, there was little or no control of annual ryegrass at any of the application rates of these herbicides applied to annual ryegrass pasture residue and wheat stubble at Merredin. The increasing efficacy of s-metolachlor with a reduction in the period between application and seeding in the application timing experiment at Merredin indicates that this herbicide suffered a greater loss of residual activity than the other herbicides evaluated in these studies. S-metolachlor and propyzamide degradation is elevated in warm soils with increased levels of soil moisture (Chesters *et al.* 1989, Walker 1991). It appears that the occurrence of summer rainfall events and elevated soil temperatures substantially reduced the efficacy of these two herbicides. Previous studies have shown that the degradation rates of s-metolachor and propyzamide are greater than those of diuron and oryzalin in warm moist soils (Walker 1991). Therefore, neither s-metolachlor nor propyzamide appear to be suited for use in early pre-season application timings in these environments.

Early season application timing potential. Effective weed control during the early period of the growing season is critical for effective wheat production in the southern Australian environment. The benefit of early season annual ryegrass seedling control on subsequent wheat yields in this Mediterranean environment has been demonstrated previously (Gill and Davidson 2000, Lemerle *et al.* 2001). In these studies we have determined that residual herbicides applied up to three months prior to the start of the growing season were capable of reducing annual ryegrass seedling numbers pre-sowing and at the early post-emergence stage. In particular two herbicides, oryzalin and diuron, were found to persist effectively following this novel application timing to adequately control annual ryegrass emerging at the start of the growing season. These preliminary field evaluations have clearly identified the potential for the use of this application timing in controlling annual ryegrass in the southern Australian no-till stubble retention cropping systems.

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