Cereal cultivars show differential tolerance to in-crop herbicides in South Australia

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Abstract

Cereal species can display differential cultivar tolerance to in-crop herbicides. In South Australia, experiments have been conducted in wheat, barley and oat, annually since 1993 to assist farmers in selecting appropriate cultivar and herbicide combinations to minimise yield loss. A range of commonly used herbicides and tank mixes were applied at label-recommended and higher rates to provide information on cultivar tolerances and safety margins, assessed by comparing grain yield responses between two herbicide rates and unsprayed controls. Results of most significance for wheat cultivars of interest include a 17 to 19% yield reduction in the cultivar Gladius in response to iodosulfuron-methyl sodium, compared to an average reduction across all cultivars of 6-8% in the applicable years. Metsulfuron-methyl application produced an 8 to 15% reduction in Correll and 9 to 18% reduction in Gladius over several seasons, compared to an average 4-9% loss across all cultivars. Barley experiments highlighted a 9 to 11% yield reduction in the cultivar Buloke in response to dicamba, as compared to an average 4-10% loss across all evaluated cultivars. Large varietal differences were also identified in oat, with Kangaroo showing 16 to 20% yield loss under a diuron plus MCPA treatment as compared to the average yield loss of only 8% across all cultivars. An MCPA, dicamba mix was the most damaging oat treatment with up to 44% average yield reduction in 2007, with cultivar Yallara recording 27 to 54% yield loss in all years of testing. In addition to assisting farmer choice in appropriate variety and herbicide combinations, these studies could be utilised by breeding programs to improve herbicide tolerance in these crops.

Key Words

Wheat, barley, oat

Introduction

In-crop herbicides have long shown varying damage across cultivars of common crop species and problems with herbicide and cultivar selection in farming systems (Tottmann et al. 1982; Wicks et al. 1987). To gauge the extent of this issue within South Australian (SA) cropping systems, a series of experiments were initiated in 1993 with funding from Grains Research and Development Corporation and the SA Government. Experiments aimed to characterize cultivar sensitivities within wheat, barley and oat grown in the Mid North of SA over three seasons. Grain yield from herbicide treatments, as compared to untreated controls, is widely utilised as the indicator of herbicide tolerance and has shown high seasonal variation (Baker et al. 1990). Therefore, trials on herbicide tolerance must be repeated across at least 2-3 seasons. It is important for these trials to take place under weed free environments and on soils with adequate fertiliser applied to remove the confounding effects of weed competition and nutrient deficiency (Baker et al. 1990, Leonard 2007).

Methods

Each year since 2003, field experiments located near Kybunga in the Mid North of SA were conducted to assess the tolerance of selected newly commercialised wheat, barley and oat cultivars to a range of herbicides. Annual cultivar selection was aimed at attaining two seasons of data prior to wide-scale commercial use, and included 2-4 oat, 5 barley and 6-8 wheat cultivars. To eliminate any potential weed competition, experiments were sown relatively late each season to allow weed germination and subsequent control prior to sowing. Commercially acceptable seeding protocols, including the use of diammonium phosphate fertilizer, no-till seeding with knife points and press wheels, were employed. Within each experiment a wide range of herbicides and tank mixes (11-14 herbicide treatments and unsprayed controls) were sprayed at label-recommended and higher rates to give information on varietal tolerances and safety margins, achieved through comparing grain yields. The trials were arranged as strip plot designs and trial yield data was analysed using the spatial methods of Gilmour et al. (1997).

Results

Based upon grain yield analysis, large variance in herbicide tolerance amongst cultivars of all species was recorded.

Wheat

Long-term yield data from experiments since 2006 highlighted iodosulfuron-methyl sodium (10 g ai/ha) (Hussar?) and metsulfuron-methyl (4.2 g ai/ha) (Ally?) as two generally damaging herbicides. The application of each produced significantly different grain yield responses between cultivars (Table 1). Wheat cultivars Frame, Catalina, Guardian and Peake were found to be more tolerant than other cultivars to both herbicides across all years of testing. In contrast, Gladius has proven to be one of the more severely affected cultivars when iodosulfuron-methyl sodium is applied, recording a 17-19% grain yield reduction. It is thought this may be due to the root pruning effects often associated with sulfonylureas (Rengel et.al. 1996), such as iodosulfuron-methylsodium and metsulfuron-methyl, which also induced significant yield loss in Gladius (9-18%).

Table 1. The effect of iodosulfuron-methyl sodium and metsulfuron-methyl on wheat cultivar grain yield (t/ha and as % untreated control) during 2006 to 2009 at Kybunga, South Australia.

?	Herbicide, Rate and Application Timing											
	Untreated control				Iodosulfuron-methyl sodium (10 g ai ha^{-1}) Z(13)				Metsulfuron-methyl (4.2 g ai ha^{-1}) Z(13)			
	Year											
Cultivar	06	07	08	09	06	07	08	09	06	07	08	09
	t/ha				as % untreated control							
Frame	0.93	0.99	1.67	2.41	97	99	96	94	105	101	95	96
Carinya	1.09	1.12	-	-	93	98	-	-	90*	96	-	-
Derrimut	1.14	1.41	-	-	98	94	-	-	93	98	-	-
Gladius	1.09	1.28	1.91	2.72	83*	81*	105	97	82*	91*	99	97

Correll	0.97	1.25	1.72	2.77	88*	97	102	96	85*	89*	92*	98
Catalina	-	1.34	1.89	2.74	-	94	91*	98	-	96	95	103
Axe	-	-	2.16	2.79	-	-	97	90*	-	-	93*	99
Guardian	-	-	1.92	2.72	-	-	96	95	-	-	94	103
Peake	-	-	1.91	2.70	-	-	95	100	-	-	101	95
Mean	1.04	1.23	1.88	2.69	92	94	97	96	91	95	96	99

* Denotes mean yields that were significantly less than the associated control at the $P<0.05$ level.

Seasons in which both herbicides incurred the greatest yield losses occurred during 2006 and 2007 which were also the years of lowest growing-season rainfall (Table 2). Considering subsequent years of testing did not show the same yield effects from these treatments, it appears Gladius may be more sensitive to iodosulfuron-methyl sodium and metsulfuron-methyl in seasons with low early rainfall (Ramsey et al. 2009). The cultivar Correll also appears to have a low tolerance to these herbicides with 8-15 % yield loss recorded relatively consistently when treated with metsulfuron-methyl and to a lesser extent iodosulfuron-methyl sodium. As sensitive cultivars Gladius, Correll and Axe have some parental linkage there could be some genetic basis for herbicide tolerance to this herbicide.

Table 2. Historical annual growing season rainfall (GSR) (April-October) at Kybunga 1993-2009. Approximate values c/o 'Cloverlea,' stationed 5.0 km from Kybunga (Bureau of Meteorology 2010)

Year	2003	2004	2005	2006	2007	2008	2009
Growing Season Rainfall (mm**)**	327.3	289.5	349.4	161	236.3	277.4	397.8

Oat

From 2003, some of the most significant differences in cultivar responses to herbicide applications have occurred within oat cultivars. Throughout testing, Kangaroo appeared to be less tolerant than others to many herbicide treatments with significant yield reductions of 16 to 20% (diuron plus MCPA mixtures) and 6 to19% (terbutryn), compared to 8 and 2-11% average yield losses respectively across all cultivars in the applicable years (Table 3). MCPA plus dicamba was the most damaging herbicide treatment with yield losses averaging up to 46% in the dry years of 2006 and 2007. Cultivars Yallara, Kangaroo, Possum and Mitika were among the least tolerant, showing yield losses up to 54%, and Yallara was seemingly the least tolerant overall (Table 3). In the dry year 2007, Tungoo appeared to show more robust tolerance to this treatment than other cultivars tested.

Table 3. The effect of MCPA plus dicamba, diuron plus MCPA amine, terbutryn, MCPA plus diflufenican and 2,4-D Amine herbicide mixtures on oat cultivar grain yield (t/ha and as % untreated control)) during 2003 to 2009 at Kybunga, South Australia.

?	Herbicide, Rate and Application Timing

Cultivar	Untreated Control							MCPA+Dicamba (476+112 g ai ha^{-1}) Z(15,21)							Diuron+MCPA amine (140+175 g ai ha^{-1}) Z(15,21)						
	Year																				
	03	04	05	06	07	08	09	03	04	05	06	07	08	09	03	04	05	06	07	08	09
	t/ha							as % untreated control													
Wintaroo	3.61	-	-	-	1.79	-	-	100	-	-	-	65*	-	-	100	-	-	-	102	-	-
Brusher	3.17	1.20	-	-	-	-	-	95*	99	-	-	-	-	-	94*	101	-	-	-	-	-
Possum	4.89	1.47	-	-	-	-	-	83*	78*	-	-	-	-	-	101	87*	-	-	-	-	-
Kangaroo	-	0.76	3.60	0.93	-	-	-	-	89	85*	65*	-	-	-	-	84*	98	80*	-	-	-
Mitika	5.13	1.86	4.30	1.99	-	-	-	98	92*	87*	60*	-	-	-	99	97	98	99	-	-	-
Yallara	-	-	4.14	1.54	2.02	-	-	-	-	73*	55*	46*	-	-	-	-	98	96	96	-	-
Tungoo	-	-	-	-	1.17	1.88	2.05	-	-	-	-	88*	93	99	-	-	-	-	100	99	102
Mean	4.20	1.32	4.01	1.49	1.66	1.88	2.05	? 94	90	82	60	56	93	99	? 99	92	98	92	99	99	102

?	Herbicide, Rate and Application Timing		
	Terbutryn	MCPA + Diflufenican (250 + 25 g ai ha-1)	2, 4-D Amine

Cultivar	(425 g ai ha^{-1}) Z(13)							Z(15,21)							(625 g ai ha^{-1}) L Z(18,32)						
	Year																				
	03	04	05	06	07	08	09	03	04	05	06	07	08	09	03	04	05	06	07	08	09
	t/ha							as % untreated control													
Wintaroo	99	-	-	-	99	-	-	99	-	-	-	90*	-	-	99	-	-	-	95	-	-
Brusher	100	92*	-	-	-	-	-	93	87*	-	-	-	-	-	93*	98	-	-	-	-	-
Possum	99	88*	-	-	-	-	-	92	82*	-	-	-	-	-	92*	105	-	-	-	-	-
Kangaroo	-	81*	97	94*	-	-	-	-	86*	95*	83*	-	-	-	-	93	96*	83*	-	-	-
Mitika	104	93*	100	97	-	-	-	94	87*	91*	89*	-	-	-	94*	103	100	97	-	-	-
Yallara	-	-	93*	103	102	-	-	-	-	92*	89*	94*	-	-	-	-	94*	96	96	-	-
Tungoo	-	-	-	-	97	99	97	-	-	-	-	92	95	98	-	-	-	-	100	101	98
Mean	101	89	97	98	101	99	97	? 95	86	93	87	92	95	98	? 95	100	97	92	96	101	98

* Denotes mean yields that were significantly less than the associated control at the P<0.05 level.

MCPA plus diflufenican mixture and 2, 4-D amine were among the most damaging treatments in oats. Consistently significant grain yield losses were found in, Kangaroo (5 to 17%) and Mitika (9 to 13%) with respect to MCPA plus diflufenican. 2, 4 -D amine application resulted in yield losses up to 17% in Kangaroo as compared to a 3-8% average reduction across all cultivars in the years where significant damage was recorded. Tungoo appeared to be a safer cultivar option for almost all herbicides tested, although it must be noted seasons 2008 and 2009 did not exert the same drought pressures as some of the prior years where other cultivars were tested.

Barley

Barley experiments highlighted dicamba (140 g ai ha^{-1}) (Cadence?) as one of the more damaging herbicides across several years, with an average 1-10% yield reduction recorded across all cultivars. Among cultivars, Buloke was found to be significantly less tolerant than most other cultivars with a 9 and11% yield penalty recorded for 2 of the 4 years of testing (Table 4). The years where most damage occurred were the drier seasons of 2006 and 2007, suggesting there may be a rainfall by cultivar interaction leading to greater sensitivity to Cadence? in this cultivar. Large yield losses of 12 and 14% were also recorded in Commander and Flagship respectively, however these effects were seen only in one year of testing and further seasonal dissection would be required to investigate this effect further. Early-maturing Hindmarsh and later-maturing Yarra did not suffer any significant yield penalties as a result of dicamba application in any years of testing.

MCPA, diflufenican mix (Tigrex?) was another herbicide where significant differences in tolerance between cultivars was found, with Fleet yielding 7 to 8% below controls in 2 out of 3 years of testing. Many other varieties also suffered losses in one year of testing, notably Capstan, incurring a 10% yield reduction in 2004. These yield reductions contrast with no significant effects on the yields of Buloke, Commander, and Yarra within all years of testing. Responses to MCPA, diflufenican mix occurred across differing seasons in respect to growing season rainfall (Table 2), suggesting mechanisms leading to MCPA, diflufenican sensitivity are not rainfall dependent. Further study is required of the seasonal features encountered in 2004, when all cultivars were found to be less tolerant than in other years

Table 4. The effect of MCPA, diflufenican mixtures and dicamba on barley cultivar grain yield (t/ha and as % untreated control)) during 2003 to 2009 at Kybunga, South Australia.

?	Herbicide, Rate and Application Timing																	
	Untreated Control							MCPA + Diflufenican							Dicamba			
								(250 + 25 g ai ha-1) Z(16,22)							(140 g ai ha^{-1}) Z16,22)			
	Year																	
Cultivar	03	04	05	06	07	08	09	03	04	05	06	07	08	09	06	07	08	09
	t/ha							as% untreated control										
Buloke	-	-	-	1.45	2.07	1.71	3.46	-	-	-	96	94	101	100	89*	91*	93	105
Capstan	5.52	1.86	-	-	-	-	-	99	90*	-	-	-	-	-	-	-	-	-
Commander	-	-	4.74	1.45	1.9	-	-	-	-	100	98	99	-	-	88*	101	-	-

Dhow	4.86	-	-	-	-	-	-		101	-	-	-	-	-	-		-	-	-	-
Flagship	-	-	4	1.57	2.04	1.93	3.1		-	92*	97	96	101	94	101		94	93	100	86*
Fleet	-	1.84	4.33	1.68	-	-	-		-	93*	99	92*	-	-	-		-	-	-	-
Hindmarsh	-	-	-	-	2.65	2.41	3.54		-	-	-	-	92*	95	102		-	100	105	102
Maritime	5.34	1.8	4.07	-	-	-	-		97	93*	97	-	-	-	-		-	-	-	-
Torrens	4.17	-	-	-	-	-	-		98	-	-	-	-	-	-		-	-	-	-
Yarra	-	-	4.67	1.65	1.95	-	-	?	-	-	99	96	100	-	-	?	91	94	-	-
Mean	4.97	1.83	4.36	1.56	2.12	2.02	3.37	?	99	92	98	96	97	97	101	?	90	96	99	98

* Denotes mean yields that were significantly less than the associated control at the P<0.05 level.

Conclusion

The high degree of variability in response within wheat, barley and oat cultivars to herbicides in these experiments and the consequential financial losses which can result, flag a need for a holistic approach to cultivar and herbicide selection. Cultivar and herbicide packages should be planned in unison with weed-control strategies to reduce herbicide-related yield losses resulting from generic label recommendations for crop species. To ensure scope across highly seasonally dependent results, warnings presented from long-term data should be utilised to assist farmers with cultivar and herbicide selection to minimise herbicide-related yield losses. This information could also be utilised by breeding programs to improve herbicide tolerance in these crops.

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