

## Incidence of herbicide resistance in relation to cropping practices of south-eastern Australia

John C. Broster and James E. Pratley

EH Graham Centre, Charles Sturt University, Locked Bag 588, Wagga Wagga,  
New South Wales 2678, Australia

Email: jbroster@csu.edu.au

**Summary** Herbicide resistance is a common occurrence in weeds of winter crops in southern Australia. In particular, annual ryegrass (*Lolium rigidum*) has evolved resistance to most herbicides. The extent of resistance is influenced by tillage practices, farming system, intensity of use of herbicides and the herbicide mode of action.

Since 2001, approximately 1500 annual ryegrass samples from south-eastern Australia have been received by the herbicide resistance testing service at Charles Sturt University. The results obtained from these samples were entered in a GIS database, as well as several agricultural parameters. This allowed a study of relationships between the mode of action of resistance, the geographic distribution of resistances in south-eastern Australia and farming practices employed in these regions. Resistance incidence was related to the farming system as influenced by soil type. The geographic pattern of incidence provides a useful basis for implementing management practices to limit the incidence of herbicide resistance.

**Keywords** Herbicide resistance, annual ryegrass, cropping practices.

### INTRODUCTION

Herbicide resistance is a common occurrence in weeds of winter crops in southern Australia. In particular, annual ryegrass (*Lolium rigidum*) has evolved resistance to most herbicides. Results from the herbicide resistance testing service at Charles Sturt University have shown great variation in the level of resistance between locations across south-eastern Australia (Broster and Pratley 2006).

### MATERIALS AND METHODS

Samples of ryegrass seed are received by Charles Sturt University for resistance testing between November and March each year. The methodology used for testing both post-emergent and pre-emergent herbicides has been described in Broster and Pratley (2006).

The results for all samples are entered into a Geographical Information System (GIS) to allow the identification of any main effects. For this paper only samples provided from southern New South Wales

and Victoria between 2001 and 2007 were considered for analysis.

Shire based data from Australian Bureau of Statistics (ABS) Agricultural Surveys were added to the GIS. The data obtained included information on winter crops grown (2001–07), amount of cultivation (2001–02), stubble management (2001–02) and the predominant soil pH for the shire.

Shires were considered if they fulfilled two criteria:

- Greater than 3000 ha of winter crop each year,
- Four or more samples tested for resistance between 2001 and 2007.

The shires were then classified into six regions, three each in New South Wales and Victoria, and the data were recalculated on a regional basis (Figure 1).

Variations in the various classes of data were analysed using chi-square analysis to compare results to the overall mean. Correlations were calculated to evaluate the relationships between the various farming parameters.

### RESULTS AND DISCUSSION

Data from 41 shires (26 in New South Wales and 15 in Victoria) were available for analysis. Of these, 34 were considered to be predominately acidic (NSW – 25, Vic – 9) and seven alkaline (NSW – 1, Vic – 6).

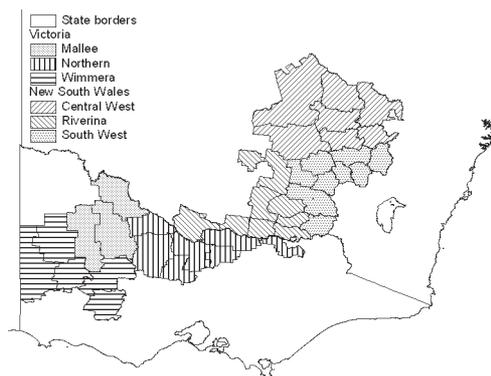


Figure 1. Regions used for data analysis.

**Regional differences** Significant differences were observed between individual regions and the overall means for herbicide resistance, crops grown, number of cultivations and stubble management practices

Overall, 80% of samples were resistant to Group A 'fop', 22% to the 'dims', 48% to Group B and 7% to Group D herbicides. No regions recorded levels of 'fop' resistance different from the overall mean. However, several regions had levels of resistance to Group A 'dim, B and D herbicides that differed ( $P < 0.05$ ) from the overall mean (Table 1).

In shires classified as predominately alkaline, the mean proportion of resistant annual ryegrass populations to both Group A 'dims' and Group B herbicides was lower and, for Group D, higher than in the acidic shires, although these differences were not significant.

Crop species grown also varied in their proportions between regions. Wheat area was 52% of all winter crops sown, with barley 21%, canola 11% and grain legumes 9%. Differences between regions were recorded for all commodities (Table 1).

Twenty seven percent of all crops sown had no cultivation prior to sowing, 47% either one or two cultivations and 26% more than two cultivations. Variations from the overall mean among the regions were recorded for both the zero cultivation and greater than two cultivation categories but not the 1–2 cultivations (Table 1).

Eighteen percent of stubble was left intact, 11% was mulched, 21% incorporated, 42% burnt and the remaining 8% was removed. No differences were found for the amount of stubble left intact or removed, but there were significant differences for the other parameters (Table 1).

**Correlations between parameters** Significant correlations were observed between different herbicide groups and resistance incidence. Regions with high levels of Group A 'fop' resistance had higher 'dim' resistance levels (Table 2). Similarly, regions with higher 'dim' resistance also had higher Group B resistance while regions with higher Group B resistance had lower Group D resistance.

A higher proportion of barley sown in a region corresponded with an increase in Group D ( $r = 0.83$ ) and a decrease in Group B ( $r = -0.79$ ) resistance. Similarly, significant relationships were present between canola and clethodim resistance ( $r = 0.78$ ) and Group D resistance with both wheat ( $r = -0.86$ ) and legume ( $r = 0.96$ ) percentages.

Significant positive correlations were found between no-till and the level of Group A 'fop' ( $r = 0.83$ ) and clethodim ( $r = 0.857$ ) resistances and a negative

**Table 1.** Parameters in which regional results differed from the overall mean (Nth – Northern, Wimm – Wimmera, Mal – Mallee, Riv – Riverina, SWS – South West Slopes, CW – Central West) (significant at  $P < 0.05$ ).

	Increase	Decrease
<b>Herbicides</b>		
A 'dim'	Nth	
B	Nth	Mal
D	Mal, Wimm	SWS, Riv
<b>Crops</b>		
Wheat %	CW	Wimm
Barley %	Mal	SWS
Canola %	SWS	
Legume %	Wimm	CW
<b>Cultivation frequency</b>		
0 (no-till)	SWS, Riv	Mal
>2	Mal	SWS, Riv
<b>Stubble treat</b>		
Mulched	Mal, Wimm	SWS
Incorporated	Mal	SWS, Riv, Wimm
Burnt	SWS	Mal

**Table 2.** Correlations between different herbicide groups (\*  $P < 0.05$ , \*\*  $P < 0.01$ ).

	A 'fop'	A 'dim'	B
D	-0.160	-0.405	-0.763*
B	0.528	0.793*	
A 'dim'	0.865**		

correlation between more than two cultivations and clethodim resistance ( $r = -0.84$ ).

Stubble treatment was also related to herbicide resistance incidence. Positive correlations were recorded between mulching and Group D resistance ( $r = 0.94$ ) and burning and clethodim resistance ( $r = 0.77$ ). Negative correlations were found between mulching and Group B resistance ( $r = -0.906$ ) and incorporation of stubble and Group A 'fop' ( $r = -0.77$ ) and clethodim ( $r = -0.89$ ).

Herbicide usage reflects the crops grown (Table 3), the farming practices used and the environmental constraint to their efficacy. It follows therefore that the incidence of herbicide resistance would also be influenced by these factors. This study confirms that such relationships exist.

The occurrence of 'fop' and 'dim' resistances in annual ryegrass is well documented as these are in widespread use on winter crops in Australia. This study shows that the correlation of resistances between

**Table 3.** Herbicides used for annual ryegrass in selected crops (Brooke *et al.* 2007).

	A 'fop'	A 'dim'	B	D
Wheat	diclofop	tralkoxydim	chlorsulfuron, triasulfuron	trifluralin
Barley	diclofop	tralkoxydim	chlorsulfuron <sup>A</sup>	trifluralin
Canola	fluazifop, haloxyfop, quizalofop	sethoxydim, clethodim	imazapic and imazapyr <sup>B</sup>	trifluralin
Grain legumes	fluazifop, haloxyfop, quizalofop	sethoxydim, clethodim		trifluralin

<sup>A</sup>post emergent only. <sup>B</sup> Clearfield only.

these subgroups is strong, reflecting the widespread use, although a previous study by Broster and Pratley (2006) has shown that on an individual population basis the level of cross-resistance between 'fops' and 'dims' is not strong.

The use of group B herbicides is also widespread. Groups A and B herbicides are often interchanged and it is therefore not unexpected that a strong relationship exists. The relationship changes, however, when the components of the 'dims' are examined. Whilst the correlation of resistance incidence between Group B and tralkoxydim is high ( $r = 0.898$ ), there is no relationship between Group B and clethodim resistance, likely due to clethodim not being used in wheat crops.

Group B herbicides are generally confined to acidic soils because of the risks of residual activity in alkaline soils (Black *et al.* 1999). In the latter case trifluralin is the alternative option and so resistance is more likely to that chemical under those higher usage patterns. As herbicide resistance incidence is more likely with regular application, these differential usage patterns of B and D herbicides creates the inverse relationship in herbicide resistance incidence.

The positive relationship between canola production and clethodim resistance is explained by this herbicide being the major post-emergent herbicide for ryegrass control in that crop. Similarly the relationship between grain legume production and Group D resistance is a reflection of the limited range of pre-emergent herbicides for that crop. The positive relationship between canola and no-till ( $r = 0.855$ ) provides the circumstances for a strong negative correlation to occur between cultivation and clethodim resistance.

Analysis also shows a positive relationship between stubble mulching and group D resistance and

a negative relationship between mulching and Group B resistance. Closer examination of the data shows that within the area of study, mulching is largely confined to the Wimmera and Mallee regions which are also the major producers of barley in this study. An incompatibility between barley and pre-emergent Group B herbicides and higher pH soils precluding B herbicide usage as well provides a reason for the inverse relationship for B herbicides and the direct relationship with D herbicides which are therefore more commonly used.

In summary, there appears to be good circumstantial evidence to indicate that herbicide resistance incidence closely reflects farm practice. This suggests that greater diversity in crop species and in farm practice would be appropriate to reduce the rate and extent of herbicide resistance build-up.

#### ACKNOWLEDGMENTS

The assistance of Neil Clark and Associates who provided the ABS data is acknowledged.

#### REFERENCES

- Black, I.D., Pederson, R.N., Flynn, A., Moerkerk, M.R., Dyson, C.B., Kookana, R. and Wilhelm, N. (1999). Mobility and persistence of three sulfonylurea herbicides in alkaline cropping soils of south-eastern Australia. *Australian Journal of Experimental Agriculture* 39, 465-72.
- Brooke, G., Haskins, B., Schipp, A. and McNee, T. (2007). Weed control in winter crops 2007. NSW Department of Primary Industries.
- Broster, J.C. and Pratley, J.E. (2006). A decade of monitoring herbicide resistance in *Lolium rigidum* in Australia. *Australian Journal of Experimental Agriculture* 46, 1151-60.