Management of glyphosate resistant weeds in non-agricultural areas

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Summary A survey of non-agricultural areas including roadsides, railway right-of-ways and irrigation channels was conducted across Australia to investigate the extent of glyphosate resistance in four weed species. A total of 150 windmill grass (*Chloris truncata* R.Br.) and 84 fleabane (*Conyza bonariensis* (L.) Cronquist) populations were collected from QLD, NSW, VIC, SA and WA. A total of 7% of the windmill grass and 52% of the fleabane populations contained individuals resistant to glyphosate. Of 186 populations of annual ryegrass (*Lolium rigidum* Gaudin) collected from SA, NSW and WA, 50% were found to contain high numbers of resistant individuals. Nine barnyard grass (*Echinochloa colona* (L.) Link) populations were collected from northern NSW and three of these were resistant. Glyphosate resistance in these non-agricultural areas has the ability to spread into other areas, such as crops, and cause management difficulties elsewhere. Therefore, the high degree of resistance found in this study highlights the importance for the development and application of management strategies for these areas.

Keywords Glyphosate, herbicide resistance, roadsides.

INTRODUCTION

Glyphosate [N-(phosphonomethyl)glycine] is one of the most important herbicides for weed management. It is used to control a broad spectrum of annual and perennial species and has become the most widely used herbicide worldwide since its commercial introduction in 1974 (Baylis 2000). In Australian farming systems, glyphosate is extensively used to control weeds in agricultural situations, such as fallows, prior to crop seeding and for inter-row spraying in orchards and vineyards, as well as in non-agricultural situations (Duke and Powles 2008, Preston *et al*. 2009).

The first glyphosate resistant weed population in Australia was confirmed in 1996 in annual ryegrass. Since then, resistance has been found in a growing number of other weed species including barnyard grass, first documented in 2007, and fleabane and windmill grass in 2010. Currently, there are over 300 documented glyphosate-resistant populations of annual ryegrass, 49 of fleabane, 21 of barnyard grass, and 2 of windmill grass (Heap 2011, Preston 2011).

While glyphosate resistance has occurred in several situations within agricultural systems in Australia, it has also begun to appear in non-agricultural settings including roadsides, railway rights-of-way and irrigation channels (Heap 2011, Preston 2011). Herbicide resistance in non-agricultural situations has not been reported often and little is known about the risks of herbicide resistance in these areas.

In this study, physical surveys of annual ryegrass, fleabane, windmill grass and barnyard grass were conducted in non-agricultural areas of Australia where glyphosate is intensively used and therefore likely to be at risk of developing glyphosate resistance. The aim was to obtain a better understanding of the extent of glyphosate resistance in non-cropping areas.

MATERIALS AND METHODS

Sample collection Surveys were conducted across Western Australia (WA), South Australia (SA), Victoria (VIC), New South Wales (NSW) and Queensland (QLD) by driving along major roads and highways and stopping every 5 to 10 kilometres to collect any of the weed species present on the roadsides. Other collections were made along railway right-of-ways, around buildings and irrigation channels. Fleabane and windmill grass samples were collected as seed, with seed from multiple plants within a small area pooled and treated as a population. Ryegrass and barnyard grass samples were collected as whole plants, with multiple plants from a small area at each location pooled into a single population.

Plant growth and resistance testing For fleabane and windmill grass about 100 seeds of each population were sown directly into standard potting mix in 6 × 0.55 L square pots (Masrac, SA), and grown outdoors at the Waite Campus, University of Adelaide. After germination the plants were thinned to around 6–9 per pot for fleabane and 9–18 per pot for windmill grass. Glyphosate (Touchdown HiTech, Syngenta, NSW,), including 0.2% (v/v) of surfactant (Wetter TX®, Nufarm, VIC) was applied at 1500 g a.i. ha^{-1}

to fleabane plants at the 6–8 leaf stage and windmill grass plants at tillering. Glyphosate was applied to 3 pots of each population, and the 3 remaining pots were non-treated controls. Herbicide was applied using a laboratory moving boom pesticide applicator and applied in the equivalent of 109 L ha^{-1} water at a pressure of 250 kPa and a speed of 1 m s^{-1} using Tee-Jet 001 nozzles (TeeJet 8001E Spraying system Co., Wheaton, IL, USA). Plants surviving 2–3 weeks after herbicide application were considered resistant and population deemed resistant if total survival was greater than 20%.

Ryegrass and barnyard grass samples were tested in the state in which they were collected using the Quick-test method (Boutsalis 2001). Briefly, individual plants were divided into 9 sections and planted into pots as described above. Glyphosate (Roundup PowerMax®, Monsanto, Australia) was applied at rates of 450, and 900 g a.i. ha^{-1}, with 3 replicates at each rate and 3 control pots that were not treated with glyphosate. A population was deemed resistant if there were over 50% survival at the lower rate of glyphosate, or if there were less than 50% survival at the low rate but at least 20% survival at the higher rate.

RESULTS AND DISCUSSION

A total of 186 populations of annual ryegrass were collected as whole plants from NSW, SA and WA and subsequently tested for resistance to glyphosate following pruning and re-growth. Of these populations, 93 or 50% were found to contain high numbers of resistant individuals, and resistance was found in all three states. The largest proportion of resistance was found in SA, with 76% of the populations collected being resistant. NSW had 49% of populations resistant and WA 26%. For fleabane, 84 populations were collected as seed from all five states surveyed. When tested, 44 populations were found to contain resistance to 1500 g a.i. ha^{-1} glyphosate. Resistance was only found in populations from QLD, NSW and SA. A total of 150 windmill grass populations were collected across all states. However, germination was poor in a number of populations, resulting in only 118 populations being tested. Of these, only 7% contained any resistance. Most of the resistant populations were from VIC, with one population from WA and one from NSW. Nine populations of barnyard grass were also collected, 1 from QLD and 8 from NSW. The QLD population and 2 populations from NSW were found to contain resistant individuals.

Glyphosate resistance was found in many different non-agricultural areas. Roadsides, often adjacent to crops, were where a majority of the samples were taken from, and where resistance occurred the most. A large number of resistant populations were also found in irrigation channels, and a smaller number of cases of resistance were present around railway rights-of-ways and buildings such as silos.

Pollen-mediated gene flow in annual ryegrass has been reported to occur over a distance of 3 km (Busi *et al.* 2008), meaning resistant alleles from ryegrass populations in these non-cropping areas could easily be

Table 1. Summary of the location and number of populations collected, and number of glyphosate resistant populations for each species collected from the non-cropping area survey.

Species	Location	No. Collected/No resistant	Total	Total % resistant
L. rigidum	NSW	75/37	186	50%
	SA	54/41		
	WA	57/15		
C. bonariensis	QLD	9/7	84	52%
	NSW	41/31		
	VIC	14/0		
	SA	12/6		
	WA	8/0		
E. colona	QLD	1/1	9	33%
	NSW	8/2		
C. truncata	VIC	65/6	150*	7%
	WA	22/1		
	SA	6/0		
	NSW	55/1		
	QLD	2/0		

*118 of the 150 populations were tested for resistance and this has been taken into account to determine total % resistance.

introduced into ryegrass populations in nearby crops. A single *Conyza canadensis* plant can produce up to 200 000 tiny seeds which are easily spread *via* wind (Bhowmik and Bekech 1993) and seeds have been found to spread up to 500 km (Shields *et al.* 2006). Similarly, windmill grass plants produce many, small, wind-borne seeds (Groves and Whalley 1982). Therefore, seed from resistant plants of non-agricultural areas could easily move into crops.

The results of this study have shown that there is a large amount of resistance in non-cropping areas that has the potential to spread into nearby crops, and highlights the need to focus on management of these areas before they cause management problems elsewhere.

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