Herbicide resistance status of barley grass (*Hordeum glaucum* Steud.) populations in low rainfall zones of southern and Western Australia

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Summary Barley grass populations from the random survey of 2018 (n=143) showed no resistance to glyphosate or paraquat. However, resistance to FOP (group 1) herbicide quizalofop was present in 4% of the populations tested (n=7). Resistance to imidazolinone (IMI) herbicide Intervix® was only detected in two populations of barley grass from the Eyre Peninsula. These populations also exhibited cross-resistance to sulfonylurea (SU) herbicide mesosulfuron. There were large regional differences in the level of resistance detected. Barley grass populations from New South Wales (n=42) and Victorian Mallee (n=3) showed no resistance to any of the four herbicide groups used in resistance screening. In contrast, resistance to the SU herbicide mesosulfuron was identified in 16% of the populations from South Australia (SA) and Western Australia (WA).

Butroxydim had greater efficacy on quizalofop resistant populations of barley grass than clethodim. In the short term, it may be possible to improve weed control of clethodim resistant populations in the field by adding butroxydim to the mixture or by using it on its own.

Targeted sampling of barley grass in SA and Victoria in 2019 and 2020 showed higher levels of resistance to group 1 herbicides than in the random survey of 2018. Resistance to knockdown herbicides glyphosate and paraquat was also confirmed in some of the samples collected in 2020.

Keywords Barley grass, herbicide resistance.

INTRODUCTION

Over the past 10 years, many growers in southern Australia have reported an increase in barley grass (*Hordeum glaucum* Steud.) infestation in cereal crops. There are several possible explanations for this increasing incidence of barley grass in these farming systems. Adoption of early sowing (sometimes dry sowing) has increased in this region, which could allow more plants to escape pre-sowing weed control. Another possibility is that barley populations have developed adaptive mechanisms to escape pre-sowing weed control practices used in crop production. Fleet and Gill (2012) showed that barley populations collected from cropping fields in the Eyre Peninsula and the Mid North regions of SA had a much longer seed dormancy than those from non-crop habitats.

Prior to this survey, the extent of herbicide resistance in barley grass was unclear. In a previous survey of barley grass in the Upper North and Eyre Peninsula in 2012 by Shergill et al. (2015a), group 1 resistance was detected in 15% of the populations. Grain growers in low rainfall regions are still seeking information on the current status of herbicide resistance in barley grass. The aim of this random survey was to determine herbicide resistance status of barley grass in low rainfall regions of NSW, VIC, SA and WA.

MATERIALS AND METHODS

Barley grass populations (n= 143) were collected from farms in NSW, VIC, SA and WA in late spring and summer of 2018. To avoid any bias, fields for sampling were selected randomly on the basis of presence of barley grass without any consideration of previous control failures or management history. Additional targeted surveys of barley grass were undertaken in 2019 in Eyre Peninsula and Mid North of SA and in Eyre Peninsula and Victorian Mallee in 2020.

Barley grass samples to be used in resistance testing were stored at ambient conditions at the Roseworthy campus of the University of Adelaide. In April of each year, barley grass seeds were sown into potting mix (cocoa peat) in seedling trays and irrigated if needed. At the one leaf stage, barley grass seedling were carefully uprooted and transplanted into pots (10 plants pot^{-1}) for resistance screening.

Herbicide resistance screening Barley grass seedlings were sprayed with the label rates of group 1 (quizalofop as Leopard®), 2 (mesosulfuron as Atlantis® and imazamox + imazapyr as Intervix®), 9 (glyphosate as Weedmaster® DST®) and 22 (paraquat as Para-Ken®) herbicides. Adjuvants recommended by the manufacturers were added to the spray solution of all herbicides. Herbicide treatments were applied in a spray chamber (De Vries Manufacturing, Hollandale, United States), which was calibrated to deliver 100 L ha^{-1} through a single TeeJet® 8002E (TeeJet Technologies, Illinois, United States) flat-fan nozzle at a speed of 3.6 km h^{-1}. Herbicide susceptible barley grass population collected from Yaninee in 2006 was used as the susceptible control. This population has been used in previous studies of herbicide resistance at the University of Adelaide. Plants were assessed for survival 4 weeks after the herbicide treatment and individuals with new shoot growth were counted as survivors.

RESULTS

Random survey 2018 All populations of barley grass collected in NSW and VIC were susceptible to the four herbicide groups used in resistance screening (Figure 1). However, some populations from SA and WA showed resistance to group 1 and 2 herbicides. Resistance to the SU herbicide mesosulfuron was identified in 16.1% of the populations tested. The level of growth inhibition of barley grass plants differed considerably between mesosulfuron resistant populations. Some of the populations showed 100% survival and no reduction in plant growth when sprayed with mesosulfuron, whereas others showed high survival but >50% reduction in barley grass height and biomass. It is quite likely that the mechanisms of resistance present in these two types of populations are different. The presence of resistance to the imidazolinone herbicide imazamox + imazapyr (Intervix®) was relatively low (1.4%).

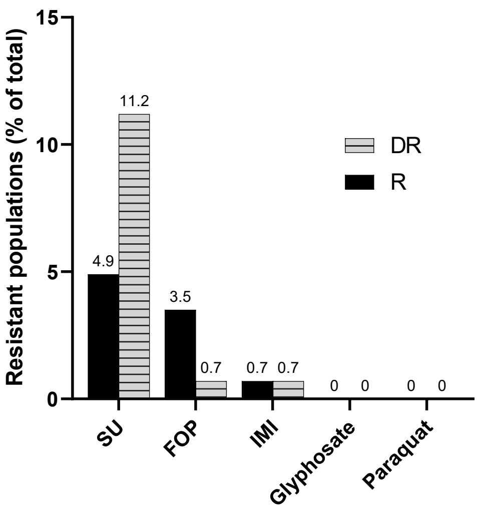

Figure 1. Detection of resistance to different herbicide groups in the random survey of barley grass (n=143). R = resistant (>20% survival) and DR = developing resistance (6-19% survival).

Resistance to quizalofop was detected in 4.2% of the barley populations tested. Four of these populations came from the upper Eyre Peninsula in SA and 2 from WA. There was no resistance detected to glyphosate or paraquat in barley grass samples in this survey.

Cross-resistance to group 1 herbicides Five barley grass populations confirmed to be resistant to quizalofop were also resistant to haloxyfop (Verdict®) (data not shown). Four of the five FOP resistant populations also showed complete (95-100%) survival when sprayed with clethodim (Clethodim®). Butroxydim (Factor®) provided much greater control of barley grass than quizalofop, haloxyfop and clethodim. At the higher rate of butroxydim (Factor® 180 g/ha), there was a complete kill of all barley grass plants even in resistant populations that had 100% survival when sprayed with clethodim.

Targeted surveys 2019 and 2020 In the targeted survey of 2019, there was a high level of resistance to quizalofop in barley grass populations from Eyre Peninsula and mid to upper north regions of SA. Out of 32 barley grass populations investigated, 50% were classified as resistant and 19% were developing resistance (Table 1). The frequency of resistance to clethodim (44%) was slightly lower than to quizalofop (69%) but still a cause for concern. The level of resistance to quizalofop in the targeted survey of 2019 was much greater than in the random survey of 2018 (4.1% V 69%). On a positive note, none of the populations collected in 2019 were resistant to glyphosate (Weedmaster® DST® @ 760 mL ha^{-1}) or paraquat (Para-Ken® @ 1200 mL ha^{-1}).

Resistance to imidazolinone herbicide Intervix® was very low in 2019 with only 1 population classified as resistant and 1 developing resistance. This low frequency of imidazolinone resistance is consistent with the results from resistance screening of randomly collected samples from previous year. However, it is important to note that this imidazolinone resistant population from Eyre Peninsula showed no adverse response to Intervix® at 375 or 750 mL ha^{-1}. Interestingly this imidazolinone resistant population was not resistant to the FOP or DIM herbicides, which indicates direct selection through the use of group 2 herbicides. This result also highlights the importance of resistance testing when planning weed management strategies.

Table 1. Frequency (%) of resistance detected to different herbicides in targeted surveys. R = resistant >20% survival; DR = developing resistance 6-19% survival.

HERBICIDE (GROUP)	2019		2020	
	R	DR	R	DR
Fop (1)	50.0	19.0	37.0	0.0
Dim (1)	38.0	6.0	25.9	3.7
Imidazolinone (2)	3.1	3.1	0.0	0.0
Glyphosate (9)	0.0	0.0	7.4	0.0
Paraquat (22)	0.0	0.0	11.1	3.7

Barley grass populations collected from Eyre Peninsula (n=12)) and Victorian Mallee (n=15) in 2020 were tested for herbicide resistance status in the winter of 2021. Resistance to quizalofop and clethodim (group 1) was confirmed in samples from both regions but the level of resistance was higher in the samples from EP. There was no resistance detected to group 2 herbicide Intervix® in 2020 populations. Some of the populations from the Victorian Mallee were resistant to glyphosate (13%) and paraquat (27%) but none of the samples possessed resistance to both of these herbicides. There was no resistance detected to glyphosate or paraquat in barley grass samples from Eyre Peninsula.

DISCUSSION

Resistance to group 1 and 2 herbicides was confirmed in all 3 years of testing. Based on previous experience with other weed species, the highest level of resistance was expected to group 2 herbicides. However, this was not the case with resistance to group 1 herbicides being much more frequent than to group 2 herbicides.

Survivors of FOP herbicide quizalofop (group 1) were vigorous and usually showed no inhibition in growth. As these herbicides have been extensively used for in-crop and pasture weed control, herbicide resistance was expected. There is no doubt, presence of resistance to group 1 herbicides in the southern and western region will complicate management of barley grass in break crops and pastures. In previous research at the University of Adelaide, sequencing of the CT domain of the ACCase gene from barley grass populations confirmed the presence of previously known mutations Ile1781Leu and Gly2096Ala (Shergill *et al.* 2015b). These mutations can provide effective levels of resistance to quizalofop but variable level of resistance to the DIM herbicides.

It was interesting to observe much greater efficacy of butroxydim on quizalofop resistant populations. This unexpected greater sensitivity of group 1 resistant barley grass to butroxydim may prove beneficial for weed control in the short term. However, use of integrated weed management practices would be needed to delay the onset of butroxydim resistance.

Among group 2 herbicides, there was much greater resistance to mesosulfuron than imazamox + imazapyr (Figure 1). The level of resistance detected to imidazolinone (IMI) herbicides was relatively low (~3%). Therefore, growers can still use Clearfield® crops and imidazolinone herbicides with confidence but efforts should be made to diversify crop rotations and herbicide use as well as integration of non-chemical weed control tactics.

These studies also confirmed presence of resistance to glyphosate and paraquat in barley grass populations collected in the Victorian Mallee. Samples with paraquat resistance came from paddocks with extensive use of paraquat in lucerne, which is consistent with previous reports of paraquat resistance in barley grass in Australia (Powles 1986). Recently resistance to glyphosate was reported in barley grass from non-crop habitat in South Australia (Adu-Yeboah *et al.* 2020). In our survey, glyphosate resistance was identified in two barley grass populations collected from cropping paddocks in Victorian Mallee. Therefore, growers need to be vigilant so that resistance to these important knockdown herbicides can be detected early prior to a large build-up in weed infestations.

The level of herbicide resistance detected in the random survey of 2018 was much lower than in targeted sampling in 2019 and 2020. Even though targeted surveys are likely to inflate herbicide resistance frequencies, they can play an important role in early detection of new resistance issues.

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