Interaction of Genotype, Environment and Herbicides in wheat (*Triticum aestivuum* L.) and barley (*Hordeum vulgare* L.) across a range of environments in Australia

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Abstract
Wheat and barley cultivars can display differential tolerance to herbicides used in Australian cereal production. Seasonal variability can be seen across single cultivars in response to herbicide application. However, it is unknown how much herbicide damage can be explained by seasonal variability, and whether cultivars respond similarly across a range of environments. Currently five Australian states are conducting herbicide by cultivar tolerance research projects; however crossover between these projects has been limited due to differing nature of cultivar and herbicide uses in each state. To overcome this, from 2010 to 2012, a series of genotype x environment x herbicide trials were simultaneously conducted across five states (NSW, QLD, SA, WA and Vic). Trials comprised of barley cultivars Hindmarsh and Buloke and wheat cultivar Janz with eight herbicide treatments and an untreated control to ensure uniformity across all states. Observations made throughout the year included normalized difference vegetative index (NDVI), grain yield, grain protein, small grain screenings and test weight. Results identified that environmental effects can significantly impact the herbicide response of barley and wheat cultivars with considerable amounts of variation observed site-to-site and year-to-year. Grouping of barley cultivars Hindmarsh and Buloke showed similar trends in results, suggesting that herbicide responses can be repeated from one season to the next. The limited correlation between the sites highlighted the degree of variation in herbicide response across environment and genotype, and therefore agro-ecological region specific testing over longer periods would be advantageous to gain increased confidence in identifying levels of herbicide tolerance.

Key words
Genotype, cultivar, herbicides, seasonal variability, cultivar response

Introduction

Wheat and barley cultivars can display differential tolerance to herbicides used in Australian crop production (Belfry and Sikkema, 2015). Similarly a single cultivar over seasons and locations can show seasonal variability in its response to herbicide application (Kong *et al*. 2009). However, it is largely unknown how much herbicide damage can be explained by seasonal conditions, and whether cultivars respond similarly across a range of environments. Despite the existence of five state based herbicide tolerance research programs across Australia, crossover between these programs has been limited due to differing cultivar and herbicide uses in each region. To overcome this, in 2010, a series of genotype x environment x herbicide trials were simultaneously conducted across each of the five states (NSW, QLD, SA, WA and Vic).Sites where responses to herbicides were highly correlated may indicate the need for fewer sites nationally to assess herbicide tolerance. However, data must be collected over subsequent seasons to support this. These data may be used to identify the optimal number of sites and seasons to determine the genetic component of herbicide tolerance and environmental conditions conducive to crop damage. These data may also aid in identifying crucially differing ecotypes to produce tolerance information spanning a broader range of environments than current national programs.

Method

A series of field experiments were conducted across the major Australian wheat-belt regions during 2010-2012 to assess the stability of herbicide tolerance of various wheat and barley cultivars. During this period 20 field experiments were conducted in South Australia, Western Australian, Victoria, Queensland and New South Wales. These experiments examined the effect of 8 different herbicides treatments on three crop

cultivars Buloke (barley), Hindmarsh (barley) and Janz (wheat). The herbicide treatments consisted 2, 4-D amine, tralkoxydim (Achieve®), metsulfuron-methyl (Ally®) and chlorsulfuron (Glean®) and an untreated control. Each of these herbicides was applied at two rates including a recommended label rate and twice the recommended label rate (Table 1).

Table 1. Herbicide treatments applied in all field experiments from 2010-2012.

Herbicide	Crop growth stage at application	Label recommended rate (a.i./ha)	Twice recommended rate (a.i./ha)
2, 4-D amine	Zadoks 15	812.5 g	1625 g
Chlorsulfuron	Zadoks 13	15 g	30 g
Metsulfuron-methyl	Zadoks 13	4.2 g	8.4 g
Tralkoxydim	Zadoks 13	380 g	760 g

Each field experiment was conducted under weed free conditions, using a strip split-plot design, with herbicides applied to strips and cultivars applied to main plots with three replications. The cultivar main plots were latinised so as not to occur more than once in the same bay. The field experiments were sown using a knife point and press wheel seeding systems. Sowing dates of experiments were different in each region depending on the season break. Seeding usually occurred within 3-4 weeks following opening rains to enable sufficient weed germination for a good 'knock-down' to be applied before seeding. This usually resulted in experiments being sown in late May to early June. An exception to this was in Wagga Wagga, NSW, where in two years an early and late time of sowing separated by approximately one month were evaluated. Herbicide treatments were applied using a small experimental plot spraying equipment fitted with air induction nozzles to deliver 80-100 L/ha water volume. Timing of herbicide treatments were based on those recommended by product labels (Table 1). After four weeks following each herbicide application, NDVI readings were recorded using a hand-held Greenseeker®. Plots were then harvested with small experimental plot machinery at maturity to determine grain yields. Grain samples were also used to measure quality parameters such as, 1000 grain weight, grain protein, small grain screenings and test weight. Statistical analysis was performed using an ANOVA in GenStat (version 16) and if the trial design deviated from a regular strip-plot the REML procedure was used.

Results

Significant interactions were observed between environment and herbicide (Table 2) with limited crossover between each region of the herbicide tolerance program. In terms of herbicide by cultivar interactions to identify experiment locations that either responded similar or distinctly different to one another, data was analysed and examined by the effects on each cultivar. The analysis of variance summary for experiment (trial) by variety by herbicide is shown in Table 2. Barley cultivars, Buloke and Hindmarsh showed a significant interaction between experiment and herbicide treatments unlike the wheat cultivar Janz which showed no significant interaction, but did show a significant interaction between the main effect of herbicides (at(Variety, Janz:HerbTrt). As the cultivar Janz had no effect of experiment location in Table 2, it would suggest that Janz responded in the same way to all herbicide treatments in all the experiments across sites and seasons.

Table 2. Analysis of variance summary across all field experiments (MET). (* indicates P<0.001 and * indicates P<0.05)**

	Df	Sum of Sq	Wald statistic	Pr(Chisq)	Sig
(Intercept)	1	49521	49521	< 2.2e-16	***
Trial	19	3650	3650	< 2.2e-16	***
Variety	2	359	359	< 2.2e-16	***
at(Variety, Buloke):HerbTrt	8	18	18	0.0239082	*
at(Variety, Hindmarsh):HerbTrt	8	32	32	0.0001121	***
at(Variety, Janz):HerbTrt	8	52	52	1.64E-08	***
Trial:Variety	38	2355	2355	< 2.2e-16	***
Trial:at(Variety, Buloke):HerbTrt	152	241	241	5.78E-06	***
Trial:at(Variety, Hindmarsh):HerbTrt	152	222	222	0.0001727	***
Trial:at(Variety, Janz):HerbTrt	152	174	174	0.1070871	NS

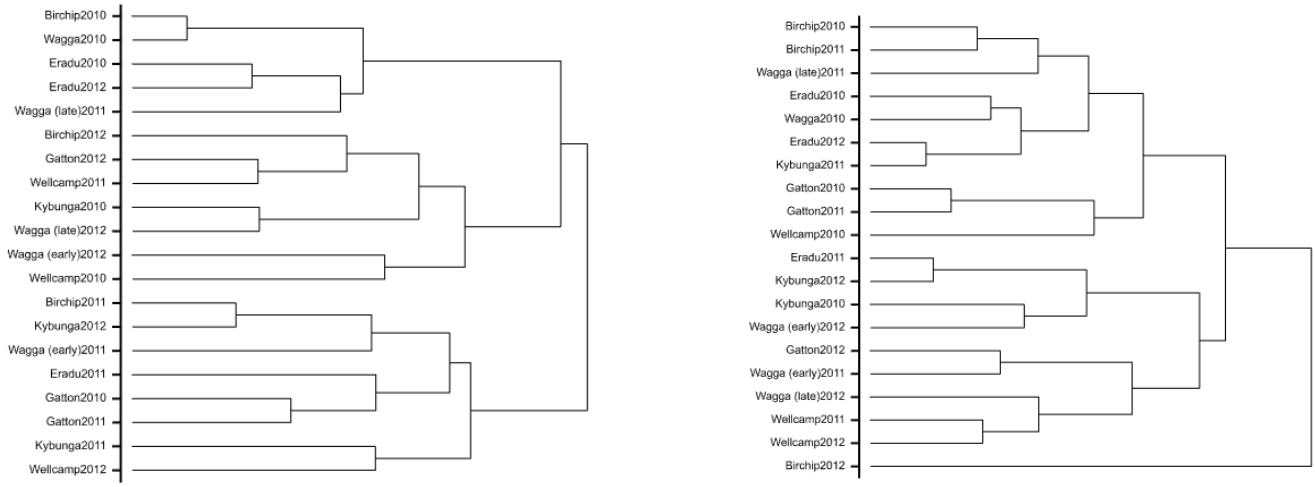

Figure 1. Denogram of the cultivar Buloke (left) and Hindmarsh (right) for each field experiment based on normalized gain yields.

The analysis of variance showed a significant interaction between experiment and herbicide treatments for the cultivar suggesting that Buloke responded differently to herbicide treatments depending on the experimental site or season. Individual experiments could be group together based on herbicide treatment response similarities (Figure 1). From the dendrogram (Figure 1) there were three main groups of experiments that were found to respond similar. These groups are as follows; Group 1, Birchip 2010, Wagga 2010, Eradu 2010, Eradu 2012 and Wagga (late) 2011. Group 2; Birchip 2012, Gatton 2012, Wellcamp 2011, Kybunga 2010, Wagga (late) 2012, Wagga (early) 2012 and Wellcamp 2010. Group 3; Birchip 2011, Kybunga 2012, Wagga (early) 2011, Eradu 2011, Gatton 2010, Gatton 2011, Kybunga 2011 and Wellcamp 2012.

The other barley cultivar Hindmarsh also was found to have a significant interaction with experiments, but the groupings of similar responding experiments was much different to those identified for Buloke. From the dendrogram showing the relationship between field experiments (Figure 1), it initially identified 3 groups with Birchip 2012 in a group of its own. The first major group consisted of 10 experiments and was still found to have a significant interaction, so it was further divided into 3 groups. This divided experiments up into five groups to show which experiments were most closely related. The groups are as follows; Group 1, Birchip 2010, Birchip 2011 and Wagga (late) 2011. Group 2; Eradu 2010, Wagga 2010, Eradu 2012, Kybunga 2011. Group 3; Gatton 2010, Gatton 2011, Wellcamp 2010. Group 4; Eradu 2011, Kybunga 2012, Kybunga 2010, Wagga (early) 2012, Gatton 2012, Wagga (early) 2011, Wagga (late) 2012, Wellcamp 2011 and Wellcamp 2012. Group 5; Birchip 2012. These groupings are different to those identified for Buloke, but show some similarities between experiments. Looking at specific sites for example Eradu 2010 and 2012 experiments are in the same group for both Buloke and Hindmarsh. Similarly Gatton 2010 and 2011 experiments and Kybunga 2010 and 2012 experiments are also consistently grouped.

Conclusion

Findings from analysis across environments would suggest there is a considerable amount of variation from site-to-site and year-to-year. Excluding findings from the cultivar, Janz, groupings of field experiments of each of the barley cultivars showed similar trends in results. This provides confidence that herbicide responses can be repeated from one season to the next, as many sites had at least 2 of the 3 years of experiments in the same grouping. This also highlights that the herbicide responses are influenced by seasonal effects; therefore three years of testing for herbicide effects should be regarded as a minimum time frame to identify the level of herbicide tolerance in each environment (Rolston *et al*. 2003). Apart from the wheat cultivar included in this study there was found to be an effect of environment (experiment location) on the herbicide response shown by the groupings of trials. These groups were not consistent for both barley cultivars. Therefore environmental effects can significantly impact the herbicide response to different genotypes (Kong *et al*. 2009).

As a result of this, it would suggest there is limited crossover between the five state based herbicide tolerance programs across Australia. The adaption of cereal genotypes is often very region specific and this appears to have an influence on the herbicide response in combination with the different soil types and weather conditions at each location (soil and weather data from each location was not available for this report). As there is limited correlation between the current sites, there is no evidence from this study to reduce the number of sites it the national herbicide tolerance program. Findings highlighted the degree of variation in herbicide response and would be beneficial to test herbicide and genotype combinations over longer time frames to gain increased confidence in identifying the level of herbicide tolerance at different sites (Rolston *et al*. 2003).

References

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