Genotype ? Environment ? Herbicide interaction in narrow-leafed lupin (*Lupinus angustifolius* L.)

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Abstract

Adequate tolerance to herbicides is an essential agronomic characteristic for lupin cultivars in broadacre agriculture of Western Australia (WA). Eleven field trials under weed free conditions were conducted from 2002 – 2008 at 2-3 sites each year across WA wheatbelt to determine the tolerance of new lupin cultivars to herbicides. The trials were laid out in a "criss-cross" design having four lupin cultivars and 15-25 herbicide/herbicide mixture treatments with 3 replications. A mixed linear model fitted on grain yield data indicated that genotype ? herbicide interaction was statistically significant (P = 0.05), whereas genotype ? environment ? herbicide interaction was not significant (P>0.05). The cultivars responded differently to metribuzin and its mixtures with other herbicides. Cultivar Tanjil consistently showed sensitivity to metribuzin and its mixtures with diflufenican and simazine. The commonly grown cultivar Mandelup showed better tolerance to herbicides including metribuzin than other cultivars. A significant genotype ? herbicide interaction emphasises the importance of screening of new or potential new lupin cultivars for herbicide tolerance, so that lupin growers know herbicide tolerance status of new cultivars before adoption. A non-significant genotype ? environment ? herbicide interaction indicates that a particular genotype ? herbicide combination responded similarly across environments, and thus multi-environment trials may not be necessary.

Key Words

Lupin, herbicide tolerance, genotype, environment, interaction.

Introduction

Narrow-leafed lupin (*Lupins angustifolius* L.) is a major grain legume crop in WA. Within no-tillage farming systems, herbicides are widely used to control weeds; hence tolerance to herbicides is an essential agronomic characteristic for lupin production (Si et al. 2006). Broadleaf weeds like wild radish (*Raphanus raphanistrum*), capeweed (*Arctotheca calendula*) and doublegee (*Emex australis*) are a major production problem for lupins in WA. Lupin, being a broadleaf crop, is much more sensitive to damage from broadleaf-weed herbicides than grass-weed herbicides. Lupin cultivars have previously shown differential tolerance to broadleaf weed herbicides in WA (Dhammu 2006). The environmental conditions under which a crop is growing before, at or after herbicide application can influence the amount of crop damage by a herbicide (Bowran 1993). Lupin herbicide tolerance research in WA revealed that cultivars responded differentially to some herbicides at different locations within the same year (Dhammu et al. 2003; Dhammu and Nicholson 2010). The aim of this paper was to investigate genotype ? environment ? herbicide interactions using 11 lupin cultivar x herbicide tolerance trials conducted throughout the WA wheatbelt.

Methods

Eleven "cultivar by herbicide tolerance" field trials were conducted over seven years (2002-2008) at four DAFWA Research Station sites within the WA wheatbelt (Table 1). The trials were laid out in a criss-cross design on acidic soils (pH $CaCl_2$ 4.3-4.9) under weed-free conditions with three replications and four cultivars in each trial. Lupin cv Mandelup was included in all the trials, whereas Tanjil was present in 9 (2002-06), Kalya in 7 (2002-04), Belara in 5 (2002-03), Coromup in 4 (2004-06), Jenabillup in 3 (2006-08), WALAN 2274 and WALAN 2275 in 2 (2008) and Pootallong in 1 (2005) trials. The cultivars in these

trials were sown in 10 m wide parallel strips at 100 kg ha^{-1} seeding rate and around 5 cm sowing depth using knife points with press-wheels.

The herbicide treatments were applied in 3 m wide strips across the cultivars using a boom sprayer calibrated to deliver 70-95 L ha^{-1} at 200 kPa with flat fan or air induction nozzles. The cultivars and herbicide treatments were randomised within each replication. From 2002 to 2004, systematic plots of simazine 1250 g a.i/ha were used as a standard check for treatment comparison, whereas from 2005 to 2008 systematic untreated control plots were included in the trials. A total of 15 herbicide treatments were evaluated during 2002, 22 during 2003 and 2004, 25 during 2005 and 2006 and 18 during 2008. In each year, the same herbicide treatments and cultivars were tested at different locations. Standard crop management practices including disease and pest management were used. Low densities of broadleaf weeds were hand-weeded in some trials. Grain yield was measured by machine-harvesting entire plots (9-10 m ? 1.44-1.8 m).

Table 1. Trial site details for 2002 to 2008.

Location	Lat. (^{o}S)	Long. (^{o}E)	Rainfall (mm) May-Dec	Soil type	Sowing date	Harvest date
			2002			
Mullewa	28.58	115.35	117.4	Red sandy loam	13-Jun-02	1-Nov-02
Wongan Hills	30.51	116.37	157.2	Sandy loam	12-Jun-02	27-Nov-02
			2003			
Mullewa	28.58	115.35	182.4	Red sandy loam	28-May-02	6-Nov-02
Wongan Hills	30.51	116.37	336.8	Sandy loam	6-Jun-02	16-Dec-02
Esperance	33.62	121.77	546.6	Sandy loam	26-May-03	Dec-03
			2004			
Eradu	28.68	114.97	320	Yellow sandplain	27-May-04	10-Nov-04
Wongan Hills	30.51	116.37	134	Sandy loam	11-Jun-04	17-Dec-04
			2005			

Eradu	28.68	114.97	389.2	Yellow sandplain	18-May-05	14-Nov-05
			2006			
Wongan Hills	30.51	116.37	176.8	Shallow sandy duplex	6-Jul-06	4-Dec-06
			2008			
Eradu	28.68	114.97	281.4	Yellow sandplain	30-May-08	12-Nov-08
Wongan Hills	30.51	116.37	277.6	Sandy loam	11-Jun-08	6-Dec-08

Data Analysis

A mixed linear model was fitted to the $\log_{10}$-transformed yield kg/ha using the REML procedure in GenStat for Windows, 12th edition. The model terms in GenStat notation comprised the random effects terms TRIAL/REP/(CPLOT+HPLOT). The fixed effects in GenStat notation were Cultivars*Herbicide.

As a summary of the model, the estimated BLUPS (best linear unbiased predictors) for each TRIAL ? CULTIVAR ? HERBICIDE combinations were taken, and for each variety, herbicide responses across different locations were plotted against the standard check or control. A one-sided (P=0.05) LSD line is shown below the 1-1 line. The BLUPS below that line indicate significant effects compared to the standard check or control (nil).

Results and Discussion

Lupin grain yield varied from 365 kg/ha to 3492 kg/ha across 11 trials. Eighty-nine percent of the variation in grain yield was explained by differences among these trials, indicating sites and years were the main source of variation in grain yield. Average grain yield of individual trials recorded significant ($P<0.05$) correlations with respective site and year rainfall ($r = 0.87$) and length of crop growing period ($r = 0.67$).

There was a significant cultivar x herbicide interaction. In general, herbicides which were included in most of the trials like simazine, simazine + atrazine, diuron , diuron + metribuzin applied pre-emergent, and diflufenican, picolinafen, diflufenican + metosulam, picolinafen + metosulam, and metosulam applied post-emergent were not damaging (no significant yield loss) to the cultivars tested (data not shown). However, cultivars responded differently to post-emergent application of metribuzin alone, in two-way mixture with diflufenican or picolinafen, and three-way mixture with diflufenican and simazine or picolinafen and simazine. Thus metribuzin alone and in three-way mix with diflufenican and simazine are the main focus of this paper. Tanjil grain yield was reduced significantly (> 15 %) with post-emergent metribuzin at 187.5 g a.i/ha and diflufenican 50 g a.i + metribuzin 75 g a.i + simazine 250 g a.i/ha in all trials (Fig. 1a and1d), where as Mandelup was affected negatively (> 15%) in 1 trial only with three-way mix during 2002 at Mullewa (Fig. 1b, and 1e). Jenabillup registered significant yield loss (> 16-17%) with metribuzin 225 g a.i /ha in all (2) trials (Fig. 1c) and with diflufenican 50 g a.i + metribuzin 75 g a.i + simazine 250 g a.i/ha in 1 out of 3 trials (Fig. 1h). Si et al. (2006) also identified large and consistent differences in tolerance to metribuzin among lupin cultivars and advanced breeding lines across controlled temperatures (20^{o}C during day and 12^{o}C at night) and in natural winter conditions. Similarly, other grain legumes like soybean and field pea cultivars have also shown differential tolerance to metribuzin (Hardcastle 1974; Al-khatib et al. 1997).

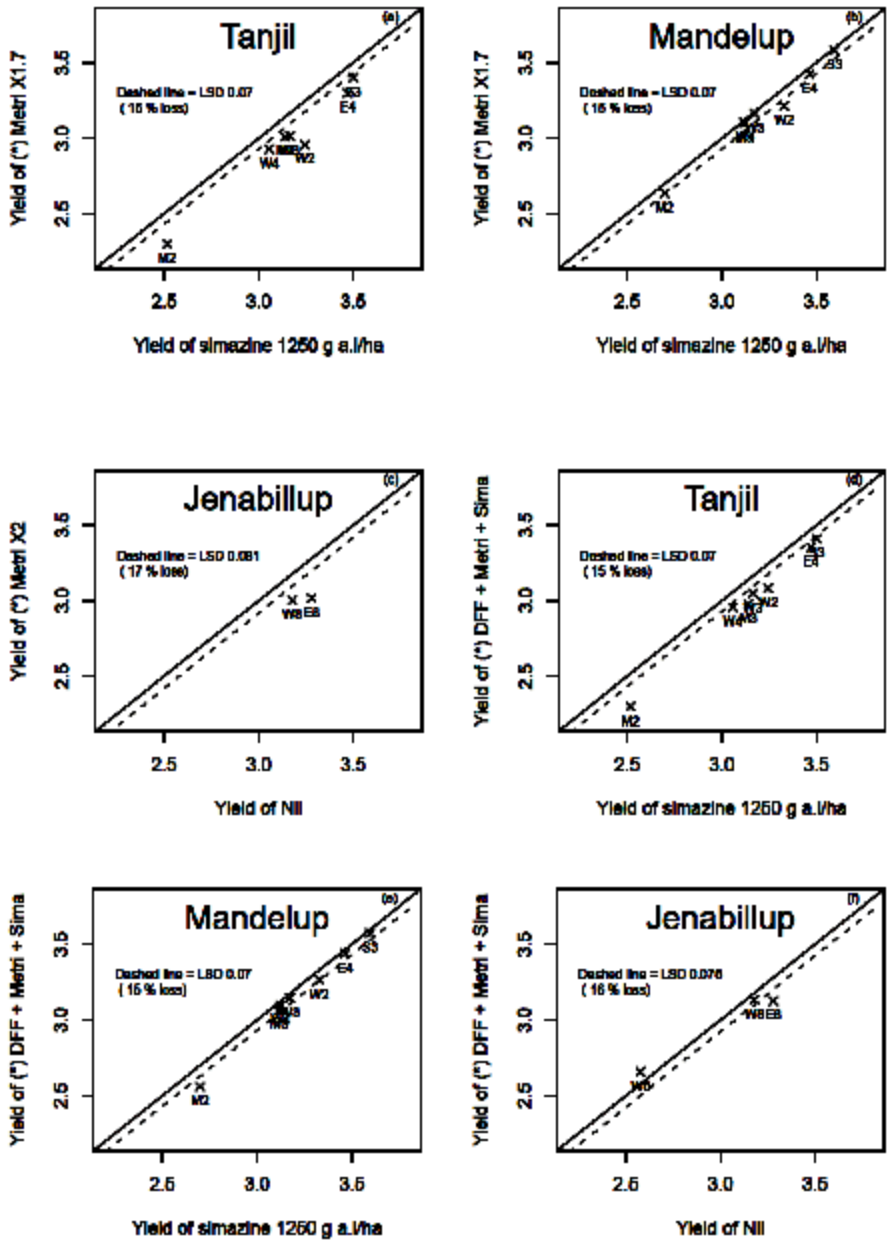

Fig. 1a - 1c: Yield BLUPs (log_{10} scale) for Tanjil and Mandelup with Mertibuzin 187.5 g a.i/ha (Metri X1.7) from 2002-2004, and for Jenabillup with metribuzin 225 g a.i/ha (Metri X2) during 2008 applied at 2-4 leaf stage of lupin. The dashed line indicates the one-sided LSD line (P=0.05). The BLUPs below this line are significantly lower as compared to simazine 1250 g a.i/ha (a standard check) or nil (untreated control).

Fig. 1d - 1f: BLUPs of yield on log_{10} scale for Tanjil, Mandelup and Jenabillup with diflufenican 50 g a.i + metribuzin 75 g a.i + simazine 250 g a.i/ha (DFF+Metri+Sima) applied at 6-8 leaf stage of lupin.

Metribuzin alone and in mixture with diflufenican and simazine followed a basal treatment of simazine 1250 g a.i /ha (*) during 2002-2004 and 1000 g a.i/ha (*) during 2005-2008 applied before seeding the trials. M2=Mullewa 2002, W2=Wongan Hills 2002, M3=Mullewa 2003, S3=Esperance

2003, W3=Wongan Hills 2003, E4=Eradu 2004, W4=Wongan Hills 2004, W6= Wongan Hills 2006, E8=Eradu 2008, W8= Wongan Hills 2008.

The data analysis indicated that environment ? genotype ? herbicide interaction was not statistically significant. Although year and sites affected absolute yields, they were not important factors in determining the relative effect of herbicides (in comparison to a standard check or untreated control) on grain yield. Thus, lupin varietal tolerance or sensitivity to herbicides did not vary with the environments for particular cultivar ? herbicide combinations (Fig. 1a-1f). This suggests that within the range of environments examined in this study, replication of similar herbicides and cultivars sensitivity studies in different years or location may be unnecessary in WA. However, it may not be logical to extend these results to different environments without appropriate confirmation (Dear et al.1995).

Even though the reaction of each cultivar to specific herbicides/herbicide mixtures was similar across environments in this study, environmental factors such as moisture stress, soil nutrient deficiencies, low or high temperatures and soil characteristics, which increase plant stress, could increase the level of crop damage by a herbicide (Bowran 1993). For example, during the 2002 trial at Mullewa, conditions were very dry (Table 1). Plants here were stressed throughout the growing season such that many post-emergent herbicides which were safe at Wongan Hills in 2002 caused significant yield loss at Mullewa (Fig 1b and 1d; Dhammu et al. 2003). Similarly, during 2008, application of post-emergent herbicides under good soil moisture conditions to lupin plants, already suffering from some simazine phytotoxicity, might have caused significant yield reduction from all the post-emergent herbicides across all the lupin cultivars and recorded differential response at Eradu than Wongan Hills (Fig. 1f; Dhammu and Nicholson 2010).

Conclusions

The genotype ? herbicide interaction identified in this study emphasises the need to continue to screen new or potential new cultivars against a range of herbicides/herbicide mixtures in WA to avoid releasing cultivars susceptible to important herbicides. Moreover this will also help lupin growers understand herbicide tolerance status of new cultivars before their adoption in the cropping systems. A non-significant genotype ? environment ? herbicide interaction suggests there is little value in conducting multi-location herbicide evaluation trials over years in WA.

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