

Novel herbicide tolerance in Lentils.

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Abstract

Broadleaf weeds are difficult to manage in lentils and can result in significant yield loss when not adequately controlled. Current chemical control methods rely on minimising weed populations in crops preceding lentils in the rotation, which may involve the use of residual herbicides which are potentially damaging to lentils or the application of a limited range of herbicides either pre or post sowing. Recently the lentil breeding program has developed new genotypes with improved tolerance to imidazolinone herbicides, which may offer alternative chemical control strategies for broadleaf weeds in lentils. In this study we conducted four field experiments in 2011 across south-eastern Australia on three new lentil genotypes which have been bred for improved tolerance to imidazolinone herbicides, in comparison with an intolerant control variety. The impact of a range of Group B herbicides (flumetsulam, imazethapyr, metsulfuron, mesosulfuron, metosulam, triasulfuron and a imazamox + imazapyr mix), application rates and timings (from pre- to post sowing), was investigated. Herbicide damage was visually assessed during vegetative growth and grain yield at maturity.

Results showed that all herbicides caused some visual damage and in some cases complete plant death in the intolerant genotype, however the herbicide tolerant genotypes displayed insignificant crop damage for most herbicides. Some variation in visual damage across trial sites was observed. Grain yield of the intolerant genotype was significantly reduced by a majority of the herbicides, in some cases by 100%. Grain yield of tolerant genotypes was generally unaffected. The release of this technology could result in significant farming systems benefits through improved weed control, increased control options in lentil crops and in the previous rotation phase, and decreased pressure on herbicides currently employed for broadleaf weed control in lentil crops.

Key Words

Lentil, herbicide tolerance, imidazolinone, weed control, mutation breeding.

Introduction

Lentils compete poorly with weeds and yield reductions in excess of 80% due to competition have been recorded in literature worldwide (Saxena and Wassimi 1980; Al Thahabi et al 1994, Boerboom and Young 1995; Brand et al 2007). Broadleaf weeds are particularly difficult to manage in lentils and current control methods rely on minimising weed populations in crops preceding lentils in the rotation through both cultural and chemical methods and via pre or post sowing chemical applications in the lentil crop. In crops preceding lentils in the rotation, cultural methods may include burning of stubbles or cultivation of the soil (Brand et al 2007). These options, however, have become less desirable as growers have sought to implement no-till practices which generally preclude removal of stubble. In addition, significant harvestability and grain yield benefits from growing lentils in standing stubbles have been recorded (Brand 2010). Hence, chemical weed control is the predominant method of management in southern Australian cropping systems. Many chemicals used to minimise weed populations in crops (primarily cereal) preceding lentils in the rotation are inhibitors of acetolactate synthase (ALS; Group B), have residual activity in the soil and can be potentially damaging to lentils.

Pre sowing, post sowing pre-emergence and post emergence chemical control methods often involve the use of a limited range of selective herbicides. In many cases these herbicides can cause significant visual damage and resultant grain yield loss, similar to those used in preceding crops. In addition, many of the selective herbicides are applied at concentrations which are toxic to the target weed, but not the lentil crop and there is commonly a narrow margin between toxicity to the weed and toxicity to the crop. For example, metribuzin applied at recommended rates resulted in no crop damage, while when applied at double recommended rates significant crop damage and yield loss occurred (Nitschke 2003).

Recently the Pulse Breeding Australia lentil program has developed new genotypes through EMS (Ethyl Methanesulphonate) mutation breeding techniques with improved tolerance to imidazolinone and sulfonurea

herbicides, which may offer alternative chemical control strategies for broadleaf weeds in lentils. The mutation responsible for imidazolinone tolerance is a point mutation of a single nucleotide in one of the acetohydroxyacid synthase genes. Mutation breeding has been utilised in a range of pulse crops and has resulted in similar herbicide tolerance traits being developed in Canada with an imidazolinone tolerant variety released in 2006 (Toker et al 2007). Preliminary research has also indicated that this trait may also offer improved tolerance to other Group B chemicals including sulfonureas and triazolopyrimidines.

This study investigated the impact of a range of Group B herbicides (ALS Inhibitors), application rates and timings on the growth and grain yield of three new lentil genotypes bred for improved tolerance to imidazolinone herbicides, in comparison with an intolerant control variety across south-eastern Australia.

Methods

Experimental design

In 2011, four small plot field trials were sown across Victoria and South Australia comparing three herbicide tolerant lentil genotypes (PBAHeraldXT, CIPAL1101, CIPAL1102) with a common commercially grown, intolerant genotype (PBAFlash or Nipper). Thirteen herbicide treatments (Group B; ALS inhibitors) encompassing a range of imidazolinones, sulfonylureas and triazolopyrimidines were applied at various application rates and timings in comparison with an untreated control (Table 1). All herbicides were applied with a water rate of 100 l/ha. All experiments were replicated 4 times in a randomised split-plot design with herbicide treatment as the main block and cultivar in plots.

In Victoria all plots (8m long with 5 rows at 30cm spacing) were sown inter-row into standing stubble via a small plot seeder with narrow lucerne points, press wheels to imitate a no till cropping system. Plots in South Australia were sown no till into burnt cereal stubbles using knife points. The Victorian field trials were located in the southern Mallee (Curyo) on a sandy loam soil (pH 7.8 at 10cm) over a medium clay (pH 8.9 at 60cm) and in the Wimmera (Rupanyup) on a black cracking clay (pH 8.1 at 10cm, 8.8 at 60cm). The South Australian field trials were located in the Mid North (Pinery, sandy loam containing free limestone, pH 8.4 at 10cm) and Yorke Peninsula (Arthurton, sandy clay loam, pH 8.2 at 10cm).

In all trials genotypes were sown to achieve a targeted plant density of 120 plants/m². All seed was inoculated with appropriate rhizobium at or prior to sowing. Plots were sown with fertilizer rates representative of the region in which the trial was conducted. In all experiments, weeds, insects and fungal diseases were controlled by the application of suitable herbicides, pesticides and fungicides at relevant stages of crop growth.

Measurements and analysis

Weather conditions (rainfall and air temperature) were recorded daily by automatic weather stations or taken from the nearest bureau of meteorology weather station. Measurements presented are a visual herbicide damage score recorded at approximately 8 weeks after the PEB treatments were applied (Table 1) and grain yield recorded at maturity. To test for significant differences a two-way analysis of variance between cultivar, herbicide treatment was conducted for each trial site. Data presented is part of a larger data set including further visual damage scores, establishment, biomass at maturity, grain weight and quality (JD Brand, unpubl.)

Results

Climate

Growing season rainfall was 20-25% below average at all trial sites (data not shown). However, extreme summer rainfall (decile 10) meant that the soil profiles at all sites were close to field capacity at sowing in 2011. This meant that there was sufficient moisture to draw on during dryer periods. Temperatures were close to average at all sites throughout 2011 and few isolated frost events or major heat events occurred which can significantly impact lentil grain yields.

Visual Herbicide Damage

Visual herbicide damage scores showed similar trends at all sites (Table 1). As the response of all tolerant genotypes was similar only data for PBA HeraldXT is presented here. All of the herbicides used caused some visual damage on the intolerant genotypes PBA Flash or Nipper at all sites except Arthurton where imazethapyr applied PSPE and mesosulfuron caused no damage. However, damage from flumetsulam

applied at both rates at Curryo, and mesosulfuron and metsulfuron (Res) at Rupanyup and Pinery caused only insignificant damage. In the herbicide tolerant genotype, PBA HeraldXT, the only treatments to cause significant visual damage at all sites were the higher rate of imazamox + imazapyr, metosulam and metsulfuron applied PEb (Table 1). All imazethapyr and flumetsulam treatments generally caused limited or no symptoms except the low rate of imazamox + imazapyr at Curryo, which caused moderate visual damage.

Table 1. The effect of various Group B herbicide treatments on visual damage score (VS; 0 – no damage, 100 – complete plant death) of the new imidazolinone lentil genotype, PBA HeraldXT in comparison with an intolerant genotype, PBA Flash or Nipper at four field sites throughout Victoria and South Australia in 2011. Significant damage scores have been shaded.

Herbicide Treatment ¹	Rupanyup		Curryo		Arthurlton		Pinery	
	PBA Flash	PBA HeraldXT	PBA Flash	PBA HeraldXT	Nipper	PBA HeraldXT	Nipper	PBA HeraldXT
Nil	0	0	0	0	0	0	0	0
<i>Imidazolinones</i>								
Imazethapyr (70) PSPE	34	0	53	0	0	0	60	8
Imazethapyr (140) PSPE	69	0	69	6	0	0	73	7
Imazethapyr (70) PEb	59	0	61	9	80	0	30	8
Imazethapyr (140) PEb	72	0	91	6	87	0	23	10
Imazamox (25) + Imazapyr (11) PEb	100	6	88	41	87	7	50	7
Imazamox (50) + Imazapyr (22) PEb	100	34	100	37	100	40	60	27
<i>Triazolopyrimidines</i>								
Flumetsulam (20) PEb	25	0	16	3	13	13	40	10
Flumetsulam (40) PEb	44	13	11	4	40	17	50	8
Metosulam (7) PEb	92	33	88	34	90	73	77	63
<i>Sulfonylureas</i>								
Metsulfuron (1.2) Res	9	0	50	3	10	0	37	10
Metsulfuron (3) PEb	91	22	100	50	99	80	77	57
Mesosulfuron (4.5) Res	6	3	53	12	0	0	7	7
Triasulfuron (11) Res	50	0	69	13	73	10	67	27
<i>LSDherbxgen (P<0.05)</i>	12		18		11		10	

1. Herbicide active ingredient, (application rate, gai/ha), application time: PSPE – Post sowing/pre-emergence; PEb – Applied at the 4 node stage of lentil crop growth targeting small broadleaf weeds; Res – Applied 4-6 weeks prior to sowing to mimic residual concentrations.

Grain Yield

Grain yields for the intolerant genotypes PBA Flash and Nipper were generally well related to herbicide damage scores. Most herbicide treatments resulted in a significant grain yield loss, up to 100% for imazamox + imazapyr and metsulfuron applied PEb (Table 2). The tolerant genotype PBA HeraldXT only showed a significant grain yield loss in the metosulam and metsulfuron treatments applied PEb at Arthurlton of 40% and 50%, respectively. None of the imidazolinone treatments resulted in a significant grain yield loss.

Conclusion

These trials demonstrate the improvements in tolerance of the new genotype, PBA HeraldXT compared with intolerant commercial genotypes, PBA Flash and Nipper. None of the imidazolinone treatments resulted in a significant grain yield loss for PBA HeraldXT, despite some minor to moderate visual symptoms of crop damage being observed (eg imazamox + imazapyr at the higher application rate). In addition, the improved imidazolinone tolerance results in improved tolerance to most sulfonylureas and triazolopyrimidines assessed in these trials. Other research has also found that imazamox + imazapyr had no impact on nodulation and nitrogen fixation of PBA HeraldXT (P Kennedy, pers. comm.).

It is important to note that climatic conditions in 2011 were suitable for recovery from earlier damage. This is also supported by the insignificant grain yield loss observed in the intolerant genotypes in response to imazethapyr (70) applied PEb, despite showing significant crop damage symptoms. Due to the previous summer rainfall there was significant amounts of stored moisture that could be accessed and minimal high or low temperature stress events were experienced during the lentil growth phase. So it will be important to repeat trials in seasons with drier spring conditions to observe the full impact of those herbicides that caused significant visual damage on the tolerant genotype, but didn't result in any yield loss.

The introduction of these herbicide tolerant lentils could result in significant farming systems benefits through improved weed control, increased control options in lentil crops and in the previous rotation phase, and decreased pressure on herbicides currently employed for broadleaf weed control in lentil. Currently all herbicides used in these trials other than flumetsulam (20) are not registered for use in lentils in Australia, but some are registered for use in other pulse crops. So, whilst the improved tolerance to flumetsulam and sulfonylureas will reduce risks of weeds in lentil production, to realise the full benefits of the tolerance trait registration will need to occur for other chemicals to allow use in crop.

Table 2. The effect of various Group B herbicide treatments on grain yield (t/ha) of the new imidazolinone lentil genotype, PBAHeraldXT in comparison with an intolerant genotype, PBAFlash or Nipper at four field sites throughout Victoria and South Australia in 2011. Significant grain yield losses have been shaded.

	<i>Rupanyup</i>		<i>Curyo</i>		<i>Arthurton</i>		<i>Pinery</i>	
Herbicide Treatment ¹	PBA Flash	PBA HeraldXT	PBA Flash	PBA HeraldXT	Nipper	PBA HeraldXT	Nipper	PBA HeraldXT
Nil	3.47	3.31	1.87	1.63	3.79	3.98	2.30	1.99
<i>Imidazolinones</i>								
Imazethapyr (70) PSPE	3.30	3.28	1.54	1.65	3.8	3.94	0.58	2.17
Imazethapyr (140) PSPE	2.40	3.27	0.60	1.79	3.99	4.11	0.11	2.11
Imazethapyr (70) PEb	3.49	3.25	1.65	2.11	1.83	4.47	1.65	2.36
Imazethapyr (140) PEb	2.20	3.27	0.42	1.91	1.1	4.24	1.68	1.96
Imazamox (25) + Imazapyr (11) PEb	0.06	2.81	0.18	1.64	0.3	3.83	0.52	2.26
Imazamox (50) + Imazapyr (22) PEb	0.06	3.36	0.50	1.50	0	3.7	0.12	2.06
<i>Triazolopyrimidines</i>								
Flumetsulam (20) PEb	3.06	3.26	1.63	1.59	3.39	3.77	1.57	1.98
Flumetsulam (40) PEb	2.53	3.26	1.78	1.72	3.3	3.72	1.01	1.88
Metosulam (7) PEb	1.95	3.23	0.64	1.70	0.83	2.49	1.03	1.81
<i>Sulfonylureas</i>								
Metsulfuron (1.2) Res	3.40	3.73	1.41	1.78	3.54	3.6	1.09	2.06
Metsulfuron (3) PEb	1.50	3.15	0.01	1.71	0	1.98	0.12	1.62
Mesosulfuron (4.5) Res	3.74	3.47	0.75	0.94	3.99	3.82	1.80	2.01
Triasulfuron (11) Res	1.93	3.27	0.41	1.58	0.8	3.58	0.12	1.64
LSDherbtxgen ($P < 0.05$)	0.51		0.72		0.44		0.36	

1. Herbicide active ingredient, (application rate, gai/ha), application time: PSPE – Post sowing/pre-emergence; PEb – Applied at the 4 node stage of lentil crop growth targeting small broadleaf weeds; Res – Applied 4-6 weeks prior to sowing to mimic residual concentrations.

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References

- Al-Thahabi SA, Yasin JZ, Abu-Irmaileh BE, Haddad NI and Saxena MC (1994) Effect of weed removal on productivity of chickpea (*Cicer arietinum* L.) and lentil (*Lens culinaris* Med.) in a Mediterranean environment. *J. Agron Crop Sci.* 172(5), 333-341
- Boerboom CM and Young FL (1995) Effect of postplant tillage and crop density on broadleaf weed control in dry pea (*Pisum sativum*) and lentil (*Lens culinaris*). *Weed Tech.* 9(1), 99-106.
- Nitschke SJ (2003) Herbicide tolerance within cereal and pulse varieties. *In* South Australian Field Crop Evaluation Program Post Harvest Report 2002/2003 pp 93-104. Eds Wheeler RD and McMurray LS, SARDI, Primary Industries and Resources, Adelaide, South Australia, Australia.
- Saxena MC and Wassimi N (1980) Crop weed competition studies in lentils. *Lens.* 7:55-57.
- Brand J, Yaduraju NT, Shivakumar BG and McMurray L (2007) Ch 10. Weed Management. *In* Lentil: An Ancient Crop for Modern Times. Eds SS Yadav, DL McNeil and PC Stevenson. pp 159-172, Springer, The Netherlands.
- Toker C, Yadav SS and Solanki IS (2007) Ch13. Mutation Breeding. *In* Lentil: An Ancient Crop for Modern Times. Eds SS Yadav, DL McNeil and PC Stevenson. pp 159-172, Springer, The Netherlands.
- Brand J, Lines M, Gaynor L, McMurray L and Matthews P (2010) The impact of row spacing on the growth and yield of lentil cultivars in southern Australia. *In* Proc. 15th Australian Agronomy Conference. Lincoln, New Zealand 15th-18th Nov.