Management of broadleaf weeds in lentils on different soil types

Navneet Aggarwal[1,2], Amanda Cook[1,2], Amy Keeley[1,2], Brianna Guidera[1] and Penny Roberts[1,2]

[1]SARDI; [2]The University of Adelaide



Location
Minnipa and Mudamuckla

Key messages

- **Reflex® applied alone as incorporated by sowing (IBS), or in combination with metribuzin, showed higher stunting in GIA Metro[P] compared to IMI lentils, though the severity of herbicide damage was dependent on soil type, with alkaline sandy loam to clayey sand soils reducing plant height than near neutral loam/clay soils.**
- **Reflex® provided control of wards weed, common sowthistle, wild turnip and Indian hedge mustard, however, it was in-effective for controlling medic. Including Group 5 herbicides applied as post-sowing pre-emergent (PSPE), and Group 2 and 12 herbicides as post-emergence at 5-6 crop-node stage (POST) improved broadleaf weed control compared to IBS herbicides only.**
- **Metribuzin applied POST in GIA Metro[P] gave more flexibility and improved medic control compared to its post-sowing pre-emergent application.**
- **Sub-lethal rates of Group 5 herbicides were not as effective as the label rates for controlling broad-leaf weeds. Furthermore, previous studies have found recurrent selection with exposure to reduced herbicides rates results in rapid evolution of herbicide resistance in weeds.**
- **GIA Metro[P] was lower yielding compared to PBA Highland XT[P] and GIA Thunder[P] , where weeds were effectively controlled. However, this yield gap was reduced in the situations of unsatisfactory weed control in IMI lentils.**

Why do the trial?

With their potential for impressive economic returns, some pulse crops are becoming increasingly popular among South Australian (SA) growers. As a break crop, pulses can contribute to soil health through nitrogen fixation and can help to reduce the impact of carryover cereal diseases.

The adoption of new herbicide tolerant pulse crops - such as Group 2 Imidazolinone (IMI) tolerant lentil and faba bean - has helped growers to control broadleaf weeds more effectively in the pulse phase of their crop rotation. However, the availability of multiple IMI-tolerant varieties across cereals, pulses and canola has helped to create over-reliance on herbicides with this mode of action (MOA). This in turn has increased the prevalence and risk of IMI herbicide-resistant weeds developing. Accordingly, relying on IMI herbicides alone is not an effective long-term strategy for broadleaf weed management in pulses.

Growers in some SA regions, particularly the Yorke Peninsula and Eyre Peninsula, are expanding lentils into more acidic or highly alkaline sandy soils. The research work carried out in these regions (SAGIT funded TC121 and GRDC funded UOA2105-013RTX) highlighted that lentil crop safety from herbicide damage and effective weed control can be an even greater challenge on such soil types (Bruce *et al*, 2022; EPFS 2022, p. 132). This research work was extended into highly alkaline soils at Kimba, Minnipa and Mudamuckla in the 2023 season to develop improved strategies for better weed control and herbicide resistance management of broadleaf weeds in lentil grown on the upper Eyre Peninsula, with funding support from GRDC (UOA2303-007RTX and UOA2105-013RTX).

How it was done

The site details including soil type, varieties grown, and sowing and harvest dates of three research experimental trials are summarised in Tables 1 and 2. A pre-seeding spray of glyphosate at 1200 g/ha and carfentrazone at 30 g/ha was applied to control existing weeds in the field. Lentil was sown at a depth of 4-5 cm with a target plant density of 120 plants/m^2 by using a no-till plot seeder fitted with knife-point tines and press wheels. Plots were 10 m long and contained six crop rows spaced 22.5 cm apart. Fertilizer rate was consistent with the local grower practice of 80 kg/ha of monoammonium phosphate banded below the seed at sowing. The experiments were laid out in a randomized complete-block design with three replications.

Table 1. The range of soil pH (in H_2O), organic carbon % and soil texture of the experimental sites in 2023.

Location	pH H_2O		OC %		Texture	
	0-10 cm	10-20 cm	0-10 cm	10-20 cm	0-10 cm	10-20 cm
Minnipa	8.8	8.9	0.98	0.70	Sandy clay loam	Sandy clay loam
Mudamuckla	8.8	8.9	0.96	0.93	Sandy loam	Clayey sand
Kimba	7.7	9.5*	0.65	0.24*	Loam/Clay	Clay

**sample represented 10-30 cm soil depth*

Table 2. Target weed species, lentil variety and sowing and harvest dates of three upper EP trial sites in 2023.

Location	Target weed species	Variety	Sowing date	Harvest date
Minnipa	Medics	GIA Metro^P and PBA Highland XT^P	28 April	16 October
Mudamuckla	Medics and wards weed	GIA Metro^P and PBA Highland XT^P	27 April	30 October
Kimba	Common sowthistle and brassica weeds	GIA Metro^P and GIA Thunder^P	10 May	2 November

Table 3. Solubility and adsorption coefficient values of herbicides used in three experiments on the UEP in 2023 (source: GRDC pre-emergent herbicide fact sheet).

Herbicide (Group)	Application timing in the experiments	Active ingredient	Solubility (mg/L @ 20°C)		Adsorption coefficient, Koc value	
Diuron (5)	IBS*/PSPE**	900 g/kg diuron	36	Low solubility	813	Slightly mobile
Metribuzin (5)	IBS/PSPE	750 g/kg metribuzin	1165	High solubility	60	Mobile
Reflex® (14)	IBS	240 g/L fomesafen	50	Moderate solubility	228	Moderately mobile
Terbyne® (5)	IBS	750 g/kg terbuthylazine	7	Low solubility	230	Moderately mobile
Terrain® (14)	IBS	500 g/kg flumioxazin	0.8	Low solubility	889	Slightly mobile

**IBS: Incorporated by sowing, **PSPE: Post-sowing pre-emergence*

The solubility and adsorption coefficient values of the herbicides used as incorporated by sowing (IBS) or post-sowing pre-emergent (PSPE) in the study are summarised in Table 3. All herbicide rates used in the experiments are mentioned in terms of the commercial product (Tables 4-8). Broadleaf weed pod/seed set was assessed near crop harvest from three randomly selected spots within a plot using a 50 cm × 50 cm quadrant. The statistical analysis was done with ANOVA, GENSTAT version 23.

Rainfall conditions

All three experimental sites received lower than average growing season rainfall (GSR) (Figure 1). Minnipa site received 83% of the average GSR rainfall, while the corresponding values for Mudamuckla and Kimba were 50% and 56%, respectively. No significant rainfall event occurred within the first and second weeks after seeding at any of the experimental sites that could carry the risk of washing of pre-emergent herbicides applied either IBS or PSPE on to the crop rows.

What happened?

Crop safety

Crop damage in lentil was assessed using plant emergence counts, and visual assessments for chlorosis, necrosis and stunting. The level of crop damage in lentil from the use of Group 14 herbicides, Reflex® and Terrain®, and Group 5 herbicides, diuron and metribuzin varied across the different sites and is summarised below.

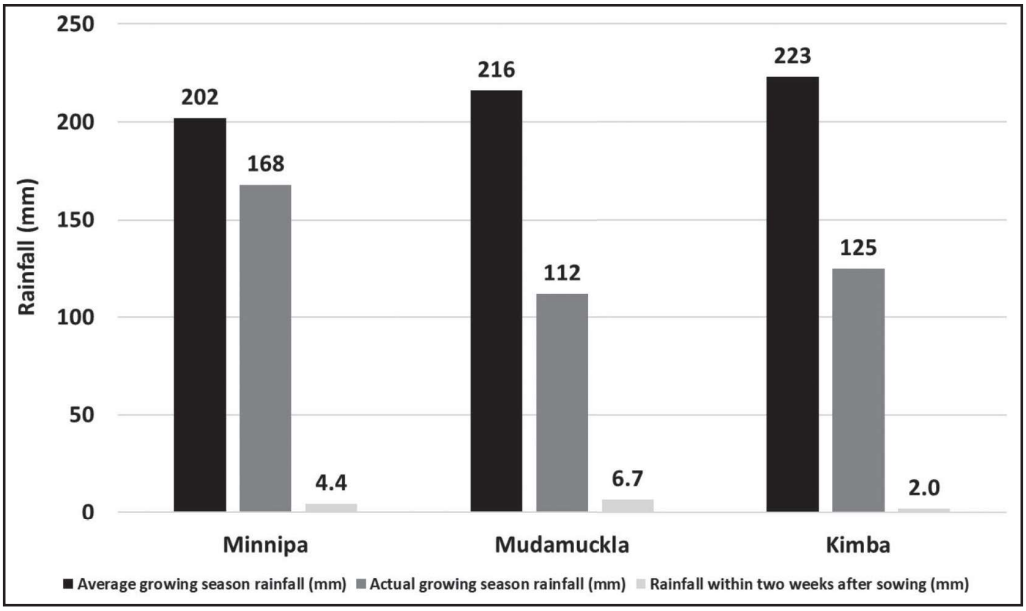

Figure 1. Long term, 2023 and two-weeks post sowing rainfall totals for three sites on the upper Eyre Peninsula in 2023.

Plant establishment

There was no reduction in plant establishment observed from the application of any herbicide treatment compared with the untreated control at all the three experimental sites in 2023 (Tables 4, 6 and 8). Metribuzin applied as post-sowing pre-emergence (PSPE) at 380 g/ha in GIA Metro^{P} proved safe, and the plant establishment was similar to off-label industry practices of using sub-lethal rates of Group 5 metribuzin at 120 g/ha, Terbyne® at 500 g/ha and diuron at 200 g/ha as IBS in imidazolinone tolerant lentils.

Reduction in plant biomass (stunting)

Plant stunting is recognised as a symptom of crop phytotoxicity from the application of Group 14 herbicides. Plant stunting visual scores at 12 weeks post-sowing were generally higher in GIA Metro than PBA Highland XT^{P} in the Reflex® and Reflex + metribuzin treatments (Tables 4 and 6). These visual stunting symptoms in GIA Metro^{P} were present at the more alkaline sites of Minnipa and Mudamuckla within the first twelve weeks post-seeding, however, plant height measurements at sixteen weeks post-seeding showed no reduction in plant height between the treated and untreated plots of GIA Metro^{P}, suggesting a level of plant recovery had occurred. Minnipa and Mudamuckla sites received 43 mm and 28 mm rainfall, respectively, distributed over more than 20 days during a six-week period prior to the plant height measurements carried out in mid to late August. The resultant favourable growing condition after this rainfall is thought to be responsible for plant recovery from the herbicide. At the Kimba site, with near-neutral soil pH, plant height measurements indicated no difference between treated and untreated plots of both GIA Metro^{P} and GIA Thunder^{P} These results are consistent with previous findings of Bruce, *et al*. (2022), where lentils grown on alkaline sandy soils recorded higher stunting from Group 14 herbicides compared to medium textured soils with near-neutral soil pH.

Chlorosis and necrosis

Metribuzin applied post-sowing pre-emergent (PSPE) or post-emergent at 5-6 crop node stage (POST) did not cause chlorosis or necrosis in GIA Metro^{P} at 180 and 380 g/ha (Tables 4 and 6). Furthermore, off-label industry practices including a combination of Reflex® and metribuzin applied at the sub-lethal rate of 120 g/ha (IBS) caused higher levels of chlorosis in PBA Highland XT^{P} compared to GIA Metro^{P} sprayed at highest label rate of 380 g/ha . Reflex® at 500 mL/ha (IBS) followed by (f.b.) Brodal® at 150 mL/ha at 3-4 node growth stage in PBA Highland^{P} caused a higher level of chlorosis and necrosis than Reflex® at 500 mL/ha (IBS) f.b. Intercept® at 500 mL/ha (POST) in PBA Highland, and Reflex® at 500 mL/ha (IBS) f.b. metribuzin at 380 g/ha (POST) in GIA Metro^{P} (Table 4).

Grain yield

The average lentil yields were low at Minnipa (average 0.35 t/ha), very low at Mudamuckla (average 0.17 t/ha), but yields were higher at Kimba (2.02 t/ha) in 2023. Highly alkaline soils at Mudamuckla (Table 3) coupled with 48% lesser rainfall received in the growing season compared to the average GSR (Figure 1) might have resulted in very low yields. Overall, the yields of the GIA Metro^{P} averaged 19-42% lower in untreated plots than the best herbicide strategy. Similarly, GIA Thunder^{P} and PBA Highland XT^{P} yielded up to 35% and 15% lesser yields, respectively, in untreated plots than the best herbicide strategy in these varieties.

Reflex at 500® mL/ha (IBS) f.b. Intercept® at 500 mL/ha (POST) recorded the highest yield of PBA Highland XT^{P} at Minnipa (Table 5). It was 25% higher than GIA Metro^{P} sprayed with Reflex® at 500 (IBS) f.b. metribuzin 380 g/ha (POST), though both the treatments recorded similar level of weed control. NVT evaluation of GIA Metro^{P} in SA, Victoria, Western Australia and New South Wales in 2021 and 2022 suggested it is 20 to 30% lower yielding than PBA Hurricane XT^{P} where weeds are controlled effectively and in the absence of herbicide damage (Fact sheet Metro, Grains Innovation Australia, 2023). However, there was no yield gap between two varieties in the absence of effective weed control in PBA Highland XT^{P} when relied either on Reflex (IBS) alone, off-label industry practices of Group 5 herbicides at sub-lethal rates applied alone as IBS or their combinations with Reflex.

Further, GIA Thunder^{P} recorded up to 28% higher grain yield in the plots treated with Reflex® at 750 mL/ha (IBS) f.b. diuron 550 g/ha (PSPE) f.b. Intercept® at 750 mL/ha (POST) compared to GIA Metro^{P} sprayed with Reflex® at 750 mL/ha (IBS) f.b. metribuzin at 380 g/ha (PSPE) at Kimba, though both the herbicide strategies recorded similar level of weed control (Table 8). However, this yield gap between two varieties was reduced up to 16% in the absence of effective weed control in GIA Thunder^{P} while relying on Reflex 500-750 mL/ha (IBS) only.

Broadleaf weed control

Medics were the dominant broadleaf weed species at the Minnipa and Mudamuckla experimental sites. The Mudamuckla site also had additional background population of wards weed. Common sowthistle, and brassica weeds including Indian hedge mustard and wild turnip were the dominant broadleaf weed species at the Kimba site.

The dose and timing of metribuzin application had a significant impact on its efficacy on medics. Metribuzin applied at 180 g/ha either as PSPE or POST did not improve medic control compared to the unsprayed control in GIA Metro^{P} (Table 7). Further, metribuzin applied at 380 g/ha (POST) was more effective in reducing medic pod set (28 pods/m^2 compared to 225 pods/m^2) when applied at the PSPE timing at Minnipa (Table 5). Similarly, POST application of metribuzin at 380 g/ha (POST) reduced medic pod set by 92% compared to the PSPE application at Mudamuckla.

Group 14 herbicides Reflex® and Terrain® applied IBS alone did not provide control of medics (Tables 5 and 7). A follow up application of metribuzin (POST) in GIA Metro^{P}, and Intercept® (POST) in PBA Highland XT^{P} was needed after Reflex® IBS to achieve some level of control of medic (7-27 pod/m^2 at Minnipa, 5-9 at pod/m^2 Mudamuckla). Off-label industry practices of using sub-lethal rates of Group 5 herbicides metribuzin (120 g/ha), diuron (200 g/ha), Terbyne® (500 g/ha) IBS proved in-effective for medic control. Previous studies have revealed that recurrent selection with exposure to reduced herbicides rates resulted in rapid evolution of herbicide resistance in some weeds and should be avoided (Neve and Powles, 2005; Gressel 2011).

Reflex® (IBS) at 500-750 mL/ha reduced plant numbers of wards weed to 1.5-2.5 plants/m^2 compared to 27.5 plants/m^2 in the unsprayed control plots (Table 7). A follow up application of metribuzin (POST) in GIA Metro^{P}, and Intercept® (POST) in PBA Highland XT^{P} provided control of ward weed plants that survived in intra-row spaces. Metribuzin on its own applied at both 180 g/ha and 380 g/ha, either PSPE or POST, proved effective for wards weeds control. Terrain® did not prove effective for wards weed control (17.2 plants/m^2).

Common sowthistle control improved with increased rates of Reflex® from 500 ml/ha to 1000 mL/ha (Table 8). Most of the surviving plants of common sowthistle in Reflex® treated plots were found in the intra-row spaces, from where the applied herbicide was likely moved out by the seeding operation. Where Reflex® was applied IBS and f.b. Group 5 herbicides metribuzin applied as PSPE/ POST, or diuron PSPE, the surviving weeds in the intra-row area were mostly controlled. Further, metribuzin at 380 g/ha applied POST proved more effective in reducing common sowthistle pod set (0.3 pods/m^2) compared to its PSPE application (27.6 pods/m^2).

Reflex® applied IBS alone or in combinations with Group 5 herbicide metribuzin/diuron PSPE, plus a follow up application of Group 2 herbicide Intercept® or Group 12 herbicide Brodal® post-emergent provided effective control of brassica weeds such as Indian hedge mustard and wild turnip (<1 pod/m^2) compared to unsprayed control plots (Table 8).

What does this mean?

Group 2 IMI herbicides will continue to be a valuable tool for broadleaf weed control in lentil for weeds that have not evolved resistance to this mode of action. The Group 14 herbicide Reflex® applied in combination with other registered Group 2, 5 and 12 herbicides has increased the options for broadleaf weed control in lentil. However, consideration should be given to the associated risks of crop damage when applied alone or with Group 5 herbicides, depending on the soil type and herbicide rates. Furthermore, results in these experiments showed the limitations of weed control with IBS applications of various chemistries compared to PSPE or POST applications where available.

New dual metribuzin and IMI tolerant lentil, GIA Metro^{P} has provided new opportunities to control multiple broadleaf weeds, including improved medic control in lentil. The increased adoption of this variety will potentially help to reduce selection pressure and delay resistance build up to the IMI herbicides. Grain yield of GIA Metro^{P} is significantly lower than existing lentil varieties in the absence of weeds, or where weeds are controlled effectively without crop damage from Group 5 herbicides due to a fitness penalty associated with the metribuzin tolerance. GIA Metro^{P} is an option for lentil growers where weed competition and/or current herbicide options (e.g. IMI-resistant broadleaf weeds) prohibit economical and sustainable lentil production. The strategic use of GIA Metro^{P} in some cropping rotations may assist in improved weed control in lentil and reduced weed seed bank burdens of Group 2 resistant weeds allowing for a return to other lentil varieties in subsequent seasons. Growers must refer to the new permit for metribuzin use in GIA Metro^{P} in varying soil and weather conditions, as granted by the Australian Pesticides and Veterinary Medicines Authority (PER92810, 2022).

More research work is needed to understand the safest and most efficient way of controlling weeds in lentil in low rainfall areas, including the effective and judicious use of GIA Metro^{P}. More studies in low rainfall areas with growers' preferences of lower cost herbicide options, means metribuzin POST could be a cost-effective strategy compared to other strategies with IBS and PSPE herbicides, but needs further investigation. It will enable growers to make more informed and confident decisions about adopting these new tools for managing broadleaf weeds in lentil, especially in the regions where they have not been grown in the past.

Acknowledgements

Thank you to GRDC for funding projects UOA2303-007RTX and UOA2105-013RTX to enable the research. The research undertaken as part of this project is made possible by the significant contributions of the Cliff family at Kimba and Peter Kuhlmann at Mudamuckla through both trial cooperation and the support of the GRDC. The authors would like to thank them for their continued support. The help received from David Holmes at SARDI Port Lincoln, and the technical staff members at SARDI Minnipa in the field is greatly appreciated. The authors also thank consultants and agronomists from the Eyre Peninsula region in conducting this research work.

References

Bruce J, Aggarwal N, Sherriff S, Trengove S, and Roberts P (2022). Broadleaf weed control and crop safety in lentils. Eyre Peninsula Farming Systems Summary 2022, p. 132.

Fact sheet Metro, Grains Innovation Australia (2023). GIA Metro MET+IMI Lentil brochure April2023.pdf (pbseeds.com.au)

Gressel J (2011). Low pesticide rates may hasten the evolution of resistance by increasing mutation frequencies. Pest Management Science 67 (3): 253-57.

Neve, P. and Powles, S (2005). Recurrent selection with reduced herbicide rates results in the rapid evolution of herbicide resistance in Lolium rigidum. Theoretical and Applied Genetics 110, 1154–1166. https://doi.org/10.1007/s00122-005-1947-2

PER92810 (2022). Permit to allow minor use of a registered AGVET chemical product for control of broadleaf and grass weeds in metribuzin tolerant lentils. PERMIT1 = FIELD TRIAL / REGISTERED PRODUCTS (apvma.gov.au)