Impact of herbicide residues on crop and pasture productivity in alkaline sandy soils

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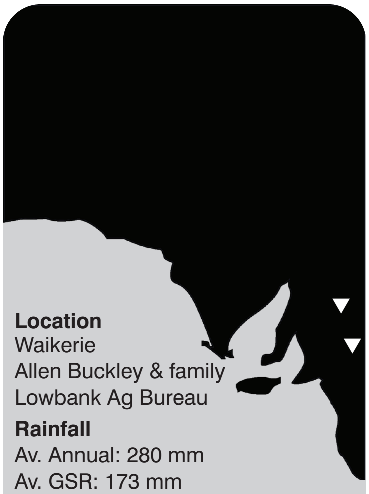

Location
Waikerie
Allen Buckley & family
Lowbank Ag Bureau
Rainfall
Av. Annual: 280 mm
Av. GSR: 173 mm
2019 Total: 120 mm
2019 GSR: 108 mm
Paddock history
2018: Scope barley
2017: Cereal Rye
2016: Fallow
Soil type
Sand
Soil test
pH(water) 6.86
Plot size
15 m x 2 m x 3 rep
Trial design
RCBD with 3 replicates and two treatment factors
Yield limiting factors
Moisture

Location
Peebinga
George Gum and family
Rainfall
Av. Annual: 319 mm
Av. GSR: 210 mm
2019 Total: 191 mm
2019 GSR: 152 mm
Paddock history
2018: Scope barley
2017: Fallow
2016: Fallow
Soil type
Sand
Soil test
pH(water) 7.27
Plot size
15 m x 2 m x 3 reps
Trial design
RCBD with 3 replicates and two treatment factors
Yield limiting factors
Moisture

Key messages

- **Traces of Lontrel residues can severely damage shoot dry matter of field peas and vetch.**
- **Intervix residues above 10 ml/ha can reduce grain yield of Gladius wheat and Nipper lentils by 44% and 36% respectively.**
- **Around 50% of applied Lontrel and Intervix can carry over into the next season, when rainfall from spraying to sowing is below 150 mm.**

Why do the trial?

Herbicide residues pose a new challenge to growers, particularly in low to medium rainfall farming systems, as they can reduce flexibility in terms of rotation options. Although there are economic and productivity benefits from carryover herbicides providing longer term weed control, there are issues with some herbicides that are remaining active in the soil longer than intended and in sufficient quantities that may damage sensitive crop or pasture species sown in subsequent years. This issue can be compounded by environmental stresses such as drought or waterlogging. Without taking action, herbicide residues could result in subclinical losses in crop yield and could also influence crop rotations in the future, as much as weed, pest and disease considerations do now.

To investigate this issue, shadehouse experiments were conducted to evaluate the lower limits of tolerance of wheat, lentils, field peas and vetch to Lontrel (Clopyralid), Intervix (Imazamox/Imazapyr) and Logran (Triasulfuron) residues. Two replicated field trials were also conducted on different sandy soils in the northern (Waikerie) and southern (Peebinga) Mallee.

How was it done?

Pot experiment

A pot experiment was set up on 9 May 2019 using the protocol reported in previous article (EPFS Summary 2018 The impact of herbicide residues on selected tolerant and susceptible crop and pasture species, p135). Herbicide residue concentrations were lower than the ones used in the pot experiment in 2018 (Table 1). This time, the goal was to refine the lower level critical limits for Intervix on conventional wheat and susceptible lentil varieties, and Lontrel on field peas and vetch. Emerged plants were counted 10 days after sowing (DAS) to determine germination percentage. At 20 DAS (29 May) all pots were thinned down to four plants per pot. All pots were terminated at 80 DAS (29 July), and the effects of herbicides on shoot biomass recorded. A representative soil sample was also collected from each pot to determine the amount of remaining herbicide.

Field trial

Herbicide treatments (Table 2) were imposed on 26 July 2018 by spraying different herbicide concentrations on plots sown to Scope barley at 3 bar pressure, 4.5 km/hr speed and 200 L/ha water rate.

Table 1. Herbicide treatments and simulated residues (product/ha) for the Loxton pot experiment.

Herbicide rate (relative to RFR, x)	Intervix (ml/ha)	Logran (g/ha)	Herbicide rate (relative to RFR)	Lontrel (ml/ha)
0x	0	0	0x	0
0.02x	10	0.5	0.002x	0.6
0.04x	20	1.0	0.004x	1.2
0.06x	30	1.5	0.006x	1.8
0.08x	40	2.0	0.008x	2.4
0.1x	50	2.5	0.01x	3
	wheat, lentils		field peas, vetch	

RFR = recommended field rate

Soils

This approach allowed 10 months for treatments to settle and move into the soil profile to simulate herbicide carryover. Prior to sowing in 2019, 0–10 cm soil cores were sampled from each plot to determine the level of herbicides still present. Samples were prepared and analysed with liquid chromatography and mass spectrometry at the CSIRO lab (Waite). Trials were then sown on 21 May 2019 to wheat, lentils, field peas or vetch. On 12 August, Clethodim was applied @ 500 ml/ha plus oil @ 1L/ha to control grasses in legumes, and MCPA 750 @ 1.2 L/ha to control broadleaf weeds in wheat. Nodule sampling was done on 10 plants per plot on 21 August at Peebinga and 3 September at Waikerie. Flowering dry matter (DM, 1 square metre) cuts were done on 17 September and the trials were harvested on 18 November (Waikerie) and 19 November (Peebinga).

What happened?

Pot experiment

The conventional wheat variety Gladius was affected by Intervix residues at or above 4% recommended field rate (RFR, 0.04x) and Nipper lentils by residues at or above 2% RFR (0.02x). Gunyah field peas shoot DM was reduced by Lontrel residues as low as 0.8% of RFR (0.008x), and Volga vetch by residues above 0.4% of RFR (0.004x). These very low herbicide residue limits are suggesting that damage can occur to sensitive crops from herbicide levels which may be hard to detect.

Field trial

Plantback periods for southern Australian winter dominant rainfall areas stipulate that a minimum of 25 mm rain event in the post-harvest summer to autumn period, with a subsequent extended period of at least 1 week where the top 10 cm of the soil stays moist is required for substantial breakdown of soil residues. Fastest residue breakdown will occur under good soil moisture and warm conditions, which promote microbial activity. Dry hot conditions in summer and autumn in the Mallee do not promote degradation of these herbicides. From the Intervix applied at RFR (500 ml/ha), 42% and 55% of imazamox residues were detected prior to sowing; and 50% and 60% of imazapyr residues were detected at Peebinga and Waikerie respectively (Table 4). Logran residues were very low at both sites, indicating that more than 90% of the triasulfuron had broken down during the summer and autumn months. Waikerie received 25 mm and Peebinga 45 mm of rainfall over a 2 day period in December 2018. The low level of Logran residues might be attributed to the summer rainfall received, because sulfonylurea (su) herbicide's primary mode of breakdown begins with chemical hydrolysis which is moisture dependent.

At both sites, Intervix residues did not affect crop establishment, early and late shoot DM or grain yield of Kord CL Plus wheat (Table 5). Kord CL Plus is derived from a cross between Gladius and an imi tolerance donor. Kord CL Plus carries two genes for Clearfield resistance, providing improved levels of tolerance to imidazolinone (imi) herbicides, and therefore offers more options for in-crop weed management and crop rotation.

Crop establishment of Gladius was not affected by the residues present at either site. However, there was a reduction in flowering shoot DM at 2x RFR residues, and grain yield at residues above 0.5x RFR at both sites (Table 5).

Table 2. Field trial herbicide treatments.

Herbicide rate (relative to RFR, x)	Intervix (ml/ha)	Logran (g/ha)	Lontrel (ml/ha)
0x (control)	0	0	0
0.5x	250	12.5	150
1x (RFR)	500	25	300
2x	1000	50	600
Crops	wheat, lentils	lentils	peas, vetch

RFR = recommended field rate

Table 3. Mean shoot dry matter (g/plant) for wheat, lentils, field peas and vetch.

Residue rate	Intervix				Residue rate	Lontrel			
	Gladius (wheat)		Nipper (lentil)			Gunyah (peas)		Volga (vetch)	
0x	1.59	b	0.96	d	0x	1.76	b	3.17	b
0.02x	1.29	b	0.26	c	0.002x	1.32	b	2.21	ab
0.04x	0.05	a	0.20	bc	0.004x	1.13	b	1.64	a
0.06x	0.16	a	0.10	ab	0.006x	1.25	b	1.64	a
0.08x	0.00	a	0.03	a	0.008x	0.11	a	0.65	a
0.1x	0.10	a	0.08	ab	0.01x	0.97	b	1.16	a
F.Pr	*p<0.001*		*p<0.001*			*p<0.001*		*p<0.001*	

Table 4. Applied and remaining imazamox, imazapyr, triasulfuron and clopyralid herbicides in autumn of 2019 after application in 2018 at two Mallee field sites.

Site	Rate	Detected Imazamox residues*	Remaining residues (%)	Detected Imazapyr residues*	Remaining residues (%)	Detected triasulfuron residues*	Remaining residues (%)	Detected clopyralid residues*	Remaining residues (%)
Peebinga	0x	0.0	0	0.00	0	0.00	0.0	0.0	0
	0.5x	1.5	55	0.80	64	0.06	1.9	5.0	34
	1x	2.3	42	1.30	52	0.12	1.9	12.7	42
	2x	5.4	49	3.20	64	0.22	1.8	20.1	33
Waikerie	0x	0.0	0	0.00	0	0.00	0.0	0.0	0
	0.5x	1.2	44	0.60	48	0.03	1.1	7.7	52
	1x	3.0	55	1.50	60	0.05	0.8	17.3	58
	2x	5.2	47	2.60	52	0.08	0.7	31.7	53

**% detected residues 10 months after application (ug/kg soil)*

These results imply that a yield penalty of 17% (Peebinga) and 40% (Waikerie) can occur to conventional non Clearfield wheat varieties when 50% of Intervix is carried over into the next growing season. For a 1 t/ha wheat crop @ $250/ton, these losses could translate to approximately $42.50/ha at Peebinga and $100/ha at Waikerie. This scenario of high residues is breaking the plantback guidelines and illustrates the importance of heeding them.

At both sites, Intervix residues did not affect crop establishment, early and late shoot DM, nodulation and grain yield of PBA Hurricane lentils (Table 6). PBA Hurricane XT lentils are high yielding small red lentil variety with improved tolerance to residual levels of SU and imi herbicides. In the case of Nipper (small red lentil sensitive to SU and imi herbicides), crop establishment and nodulation was not affected by Intervix residues. However, at Peebinga, there was a reduction in flowering shoot DM at 0.5x of RFR. No grain yield was recorded at Peebinga as the crop ran out of moisture post flowering. At Waikerie flowering shoot DM of lentils was not affected by Intervix residues, however grain yield was reduced by 36% at 1x residues relative to the control (Table 6).

Triasulfuron residues did not affect noduation of PBA Hurricane lentils (Table 7) at both sites. At Peebinga, triasulfuron residues at 0.22 ug/kg reduced flowering shoot DM of both PBA Hurricane and Nipper lentils. At Waikerie triasulfuron residues had small but inconsistent effects on plant population. Flowering shoot DM was reduced by 38% at 0.05 ug/kg and grain yield by 40% at 0.03 ug/kg residue level, all relative to the untreated control. No lentil grain yield was recorded at Peebinga.

Clopyralid residues did not affect field peas establishment at both sites (Table 8), however as the growing season progressed, some of the emerged plants eventually died, particularly in the 2x RFR treatments. Flowering shoot DM was reduced at Peebinga by 42% at 5 ug/kg, and by 78% at 32 ug/kg clopyralid residue level at Waikerie relative to the control. Nodule numbers per root were not affected by clopyralid residues at Waikerie but at Peebinga there was a reduction at 13 ug/kg level. At Waikerie, grain yield was reduced by 49% at 8 ug/kg clopyralid residue level. No grain yield was recorded at Peebinga.

Plant population and flowering shoot DM of Volga vetch was reduced by Lontrel herbicide residues at both sites. Relative to the control, flowering shoot DM at Peebinga was reduced by 50% at 17 ug/kg and at Waikerie by 68% at 8 ug/kg clopyralid residue level. No grain yield was recorded at both sites for vetch.

Table 5. Effect of Intervix on wheat plant density, GS31 and flowering shoot DM and grain yield.

Crop	Herbicide rate	Peebinga				Waikerie			
		Plants/m²	GS31 Shoot DM (t/ha)	Flowering shoot DM (t/ha)	Grain yield (t/ha)	Plants/m²	GS31 Shoot DM (t/ha)	Flowering shoot DM (t/ha)	Grain yield (t/ha)
Kord CL wheat	0x	150	1.63	3.53	0.88	147	0.91	1.5	0.42
	0.5x	146	1.97	3.89	0.61	146	1.14	1.52	0.4
	1x	150	2.05	3.99	0.67	148	0.98	1.31	0.33
	2x	171	1.85	4.38	0.74	162	1.00	1.26	0.27
	F.Pr	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Gladius wheat	0x	166	1.98	3.91	0.81	154	1.06	1.47	0.5
	0.5x	162	1.78	3.91	0.67*	150	1.11	1.49	0.3*
	1x	143	1.65	3.65	0.60*	148	0.74*	1.12	0.28*
	2x	171	1.06	2.86*	0.49*	139	0.21*	0.55*	0.24*
	F.Pr	*ns*	*ns*	*p<0.03*	*p<0.004*	*ns*	*p<0.001*	*p<0.02*	*p<0.003*

*Significantly different to nil

Table 6. Effect of Intervix on lentil plant density, nodulation, shoot DM and grain yield.

Crop	Residue rate	Peebinga				Waikerie			
		Plants/m²	Flow-ering shoot DM (t/ha)	Nodules per root	Grain yield (t/ha)	Plants/m²	Flow-ering shoot DM (t/ha)	Nodules per root	Grain yield (t/ha)
PBA Hurricane lentils	0x	156	1.45	23	*	161	0.70	6	0.79
	0.5x	150	1.35	9	*	158	0.69	7	0.74
	1x	138	1.37	13	*	155	0.70	6	0.77
	2x	154	1.57	12	*	146	0.79	6	0.80
	F.Pr	*ns*	*ns*	*ns*	*	*ns*	*ns*	*ns*	*ns*
Nipper lentils	0x	164	1.19	12	*	15	0.49	7	0.69
	0.5x	151	0.99*	12	*	165	0.61	4	0.79
	1x	160	1.04	9	*	160	0.41	3	0.44*
	2x	140	0.94*	8	*	155	0.31	5	0.43*
	F.Pr	*ns*	*p<0.05*	*ns*	*	*ns*	*ns*	*ns*	*p<0.05*

*Crop failed due to drought.

Table 7. Effect of Logran on lentil plant density, nodulation, shoot DM and grain yield.

Crop	Residue rate	Peebinga				Waikerie			
		Plants/m²	Flow-ering shoot DM (t/ha)	Nodules per root	Grain yield (t/ha)	Plants/m²	Flow-ering shoot DM (t/ha)	Nodules per root	Grain yield (t/ha)
PBA Hurricane lentils	0x	148	1.29	21	*	169	0.78	15	0.99
	0.5x	152	1.04	21	*	145	0.69	16	0.88
	1x	140	1	33	*	122*	0.64	18	0.9
	2x	112	0.8*	23	*	152	0.69	14	0.93
	F.Pr	*ns*	*p<0.01*	*ns*	*	*p<0.001*	*ns*	*ns*	*ns*
Nipper lentils	0x	130	0.83	18	*	144	0.56	11	0.86
	0.5x	128	0.7	20	*	159	0.44	10	0.52*
	1x	145	0.66	29	*	138*	0.35*	9	0.35*
	2x	105	0.45*	19	*	148	0.38*	11	0.39*
	F.Pr	*ns*	*p<0.01*	*ns*	*	*p<0.001*	*p<0.04*	*ns*	*p<0.01*

Table 8. Effect of Lontrel on field peas plant density, nodulation, shoot DM and grain yield.

Crop	Residue rate	Peebinga				Waikerie			
		Plants/ m^2	Flowering shoot DM (t/ha)	Nodules per root	Grain yield (t/ha)	Plants/ m^2	Flowering shoot DM (t/ha)	Nodules per root	Grain yield (t/ha)
Gunyah field peas	0x	46	2.4	35	*	46	1.37	56	0.63
	0.5x	30	1.39*	37	*	56	1.12	52	0.32*
	1x	40	0.86*	26*	*	52	0.96	60	0.17*
	2x	28	0.19*	23*	*	34	0.3*	44	0.09*
	F.Pr	*ns*	*p<0.002*	*p<0.01*	*	*ns*	*p<0.004*	*ns*	*p<0.01*

Table 9. Effect of Lontrel on vetch plant density, nodulation and flowering shoot DM.

Crop	Residue rate	Peebinga				Waikerie			
		Plants/ m^2	Flowering shoot DM (t/ha)	Nodules per root	Grain yield (t/ha)	Plants/ m^2	Flowering shoot DM (t/ha)	Nodules per root	Grain yield (t/ha)
Volga vetch	0x	40	1.35	54	*	53	1	20	*
	0.5x	40	1.13	35	*	30	0.32*	18	*
	1x	33	0.68*	40	*	22	0.09*	15	*
	2x	29*	0.49*	33	*	18*	0.04*	20	*
	F.Pr	*p<0.05*	*p<0.01*	*ns*	*	*P<0.05*	*p<0.001*	*ns*	*

Table 10. Herbicide residue tolerance for wheat, lentils field peas and vetch in 2018 and 2019 pot experiment.

Crop	Herbicide residues tolerance (lower limit)*			
	Intervix		Lontrel	
	2018	2019	2018	2019
Wheat (Gladius)	50	10		
Lentil (Nipper)	50	10		
Field peas (Gunyah)			0	2.4
Vetch (Volga)			0	1.2

**Limit in ml/ha soil residues*

What does this mean?

Herbicide residues are often too small to be detected by chemical analysis, and the real problem for growers is detecting the level of residues in the field before they cause a problem. Quantifying yield penalties from low residue levels on susceptible crops is a much bigger issue which has the potential to further increase risk in marginal environments. Our results from the pot experiment have demonstrated that crop damage can occur to susceptible lentils and non-Clearfield wheat varieties when Intervix residues remaining in soil are above 10 ml/ha (Table 10). For legumes like field peas and vetch, the residue tolerance limit for Lontrel is under 3 ml/ha, which is hard to detect, but can however cause reduction in shoot dry matter.

The field experiment has also demonstrated that yield losses can occur to susceptible crop species when Intervix, Logran and Lontrel herbicide residues are present in the soil. However, it should be noted that some of the crop responses to residues may have been affected by the tough season with only 108 mm growing season rainfall at Waikerie and 152 mm at Peebinga. It is also important to note that some of the damage recorded is outside plantback guidelines, and only done for experimental purposes. Such damage can be avoided if growers stick to the recommended re-cropping intervals. The trial will continue in 2020/21 to investigate the impact of the remaining residues on conventional vs Clearfield canola varieties.

Acknowledgements

Thanks to the Gum and Buckley family for their enthusiasm in providing suitable trial sites at their properties, and GRDC for funding this trial through the SARDI/GRDC Mallee Bilateral project - Improving sustainable productivity and profitability of Mallee farming systems with a focus on soil improvements (DAS00169-BA).