Herbicide tolerance and weed control in lentil on sandy soils

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Location
Bute
Nathan Hewett
Rainfall
Av. Annual: 394 mm
Av. GSR: 295 mm
2019 Total: 216 mm
2019 GSR: 213 mm
Yield
Actual: 1.3t in control treatments, highest yielding treatmants were up to 1.4t/ha
Paddock history
2018: Wheat
2017: Lentil
Soil type
Neutral to alkaline sand hill, with deep sand (>1m) in a dune swale environment
Soil test
0-10 cm: PBI 41, DGT P 84, N 42, SOC 0.69%, $pH_{(H20)}$ 7.7
10-30 cm: PBI 58, DGT P >5, N 22, SOC 0.24%, $pH_{(H20)}$ 8.6
Plot size
1.5 m x 10 m on 2 m centres x 3 reps
Trial design
Randomised complete block design
Yield limiting factors
Low rainfall and terminal drought, moderate effects, low levels of pod drop prior to harvest

Key messages

- **Sandy soils can have narrow safety margins for commonly used broadleaf herbicides used in lentils. Herbicide damage from some Group C and B herbicides reduced lentil growth and grain yield on a sandy soil at Bute.**
- **Herbicide efficacy on four weed species was variable between products. Herbicide combinations were required to provide high levels of control of all four weed species.**
- **Optimising the herbicide strategy in lentils on sandy soils requires a balance between minimising crop effect, but achieving acceptable weed control. This requires knowledge of the target weeds and their resistance status to determine which herbicides to use and in what combination. The benefit of high level weed control then needs to be weighed against the risk of herbicide damage to the crop.**

Why do the trial?

Herbicide damage in lentils can occur readily on sandy soils from both pre and post emergent applications. Low clay content, low organic carbon and low cation exchange capacity of sand hills predispose these areas to increased risk from herbicide damage. It is possible that even without visible plant injury symptoms, there is an underlying level of herbicide damage restricting biomass production and yield of lentils on these soil types. Previous work conducted on a similar soil type in 2015, 2017 and 2018 showed that in some cases when more than one herbicide is applied the level of damage can be greater than the sum of the damage of the single herbicides on their own. The results from trials such as these can be influenced greatly by soil type and weather events and therefore need to be repeated to explore the range of responses that can occur.

In previous trials, the weeds that are present in the plots have been removed so that the effect of the herbicide is the only factor that is influencing crop performance. It is possible that higher weed density as a result of either no or low efficacy herbicide treatments being applied, will lead to reduced grain yield compared to more damaging, higher efficacy treatments.

This trial aimed to test the safety level of several commonly used herbicide options and combinations on PBA Hurricane XT lentils in both plots with natural weed populations present and plots with weeds removed by hand to limit competition with the crop.

How was it done?

The trial was a randomised complete block design with 17 herbicide treatments and two weed population treatments. In the plots with weeds removed, all weeds were removed by hand during the counting process and this was done at a time to limit the competition with the crop. The trial had three replicates.

The plots were 10 m x 1.5 m and were sown with PBA Hurricane XT using knife points and press wheels on 250 mm spacing with 60 kg MAP on 17 May 2019.

Pre-emergent herbicides were applied on 16 May 2019 prior to sowing using a hand boom, post emergent treatments with diflufenican and Intercept were applied using a shielded sprayer to prevent herbicide movement between plots on 27 June and 9 July respectively. Herbicide treatments are displayed in Table 1.

Measurements throughout the season included vigour and herbicide damage scores, GreenSeeker NDVI, weed density, weed biomass scores, pod drop prior to harvest and grain yield. Crop lower limit soil samples were taken post-harvest to a depth of 120 cm, these were segmented to 10-20, 20-40, 40-60, 60-90, and 90-120. Results were analysed with the statistical package R.

What happened and what does this mean?

Crop performance

Weed competition

The hand weeding treatment, plus and minus weeds, only affected NDVI recorded on the 19 August and 24 September. As a result of removing the weeds from the plots by hand, the total plot biomass was reduced and therefore the NDVI readings were reduced by 4% and 5% respectively. Unexpectedly, hand weeding the plots to remove the weeds did not increase the grain yield of lentils, indicating that the weed competition did not cause significant yield loss even in the nil herbicide treatments.

Group C herbicides (simazine, diuron, metribuzin, Terbyne, simazine/diuron mixture)

The Group C herbicides simazine, diuron and Terbyne reduced GreenSeeker NDVI by an average of 23% on 22 July (Table 2). This level of damage from these three herbicides continued until 19 August (24% reduction). By 24 September the damage from the simazine and diuron treatments was no longer significant whereas the Terbyne treatment NDVI was still 16% lower than the control. The metribuzin treatments caused less damage than the other Group C herbicides with an 11% and 9% reduction in NDVI for the 22 July and 19 August respectively. Grain yield was not significantly reduced by metribuzin, diuron or the simazine/diuron combination applied alone. The other Group C herbicide treatments of simazine and Terbyne reduced grain yield by 17 and 26%, respectively.

Group F herbicide (diflufenican)

Diflufenican applied alone had no significant negative impact on any crop performance attribute measured. However, there is a trend for the NDVI to be lower where simazine/diuron was applied in combination with diflufenican compared to simazine/diuron applied alone.

Group B herbicides (chlorsulfuron and Intercept)

Chlorsulfuron applied alone (IBS) reduced crop NDVI 22 July by 14% compared to the control. However, at later timings NDVI was unaffected when chlorsulfuron was applied alone. Despite little effect on crop NDVI at later timings, grain yield (0.93 t/ha) was still reduced by 27% with no other herbicides present. This suggests there was significant effect on the crop below the soil surface that was not obvious in above ground canopy growth.

Table 1. Herbicide treatments for the lentil herbicide tolerance weed control trial at Bute 2019.

Herbicide treatment	Treatment code	Group C	Group C Rate (g/ha)	Diflufenican (mL/ha)	Chlorsulfuron (g/ha)	Intercept (mL/ha)
1	Nil	0	0	0	0	0
2	Sim	Simazine900	400	0	0	0
3	Diu	Diuron900	800	0	0	0
4	Ter	Terbyne750	750	0	0	0
5	Met	Metribuzin750	180	0	0	0
6	Si/Di	Sim/Diu	200/400	0	0	0
7	Chl	0	0	0	5	0
8	Int	0	0	0	0	500
9	Si/Di+Chl	Sim/Diu	200/400	0	5	0
10	Si/Di+Int	Sim/Diu	200/400	0	0	500
11	Chl+Int	0	0	0	5	500
12	Si/Di+Ch+Int	Sim/Diu	200/400	0	5	500
13	Dff	0	0	150	0	0
14	Si/Di+Dff	Sim/Diu	200/400	150	0	0
15	Si/Di+Ch+Dff	Sim/Diu	200/400	150	5	0
16	Si/Di+Dff+Int	Sim/Diu	200/400	150	0	500
17	Complete	Sim/Diu	200/400	150	5	500

Note: Not all rates and herbicides used in this trial are registered for use in lentil and the results and findings reported in this article do not constitute a recommendation of their use by the authors.

Table 2. Crop performance, including vigour score 22 July (0=poor vigour 9=high vigour), GreenSeeker NDVI for 22 July, 19 August and 24 September and grain yield (t/ha) for the lentil herbicide tolerance trial at Bute 2019. NDVI values are predicted from a REML spatial analysis conducted using the statistical package R, letters denote statistical differences.

Treatment code	Group C	Group C Rate (g/ha)	Diflufenican (mL/ha)	Chlorsulfuron (g/ha)	Intercept (mL/ha)	Pred. Vigour score 22 July		Pred. NDVI 22 July		Pred. NDVI 19 Aug		Pred. NDVI 24 Sept		Grain yield (t/ha)	
Nil	0	0	0	0	0	7.1	d	0.304	h	0.563	f	0.670	ef	1.27	ab
Sim	Simazine	400	0	0	0	5.2	abcd	0.230	abcdf	0.410	abc	0.592	cde	1.06	cdef
Diu	Diuron	800	0	0	0	4.4	abc	0.228	abcd	0.433	bcd	0.609	cdef	1.15	bcd
Ter	Terbyne	750	0	0	0	5.2	abcd	0.240	bcde	0.415	bc	0.565	c	0.95	def
Met	Metribuzin	180	0	0	0	5.3	abcd	0.264	efg	0.514	def	0.674	ef	1.26	ab
Si/Di	Sim/Diu	200/400	0	0	0	5.5	bcd	0.241	abcdeg	0.451	cde	0.619	cdef	1.13	bcde
Chl	0	0	0	5	0	6.0	cd	0.262	eg	0.506	def	0.597	cde	0.93	ef
Int	0	0	0	0	500	7.1	d	0.299	h	0.534	f	0.662	def	1.44	a
Si/Di+Chl	Sim/Diu	200/400	0	5	0	5.0	abc	0.235	abcde	0.443	bcde	0.567	c	1.00	cdef
Si/Di+Int	Sim/Diu	200/400	0	0	500	5.1	abc	0.247	cdeg	0.427	bc	0.583	cd	1.28	ab
Chl+Int	0	0	0	5	500	5.5	bcd	0.258	deg	0.438	bcde	0.554	bc	0.65	g
Si/Di+Ch+Int	Sim/Diu	200/400	0	5	500	4.5	abc	0.225	abc	0.363	ab	0.475	ab	0.55	g
Dff	0	0	150	0	0	6.2	cd	0.275	gh	0.524	ef	0.688	f	1.39	a
Si/Di+Dff	Sim/Diu	200/400	150	0	0	4.0	ab	0.217	abc	0.399	abc	0.576	cd	1.16	bc
Si/Di+Ch+Dff	Sim/Diu	200/400	150	5	0	3.6	ab	0.211	ab	0.383	abc	0.562	c	0.92	f
Si/Di+Dff+Int	Sim/Diu	200/400	150	0	500	3.2	a	0.217	abc	0.368	ab	0.543	bc	1.14	bcd
Complete	Sim/Diu	200/400	150	5	500	3.7	ab	0.209	a	0.337	a	0.454	a	0.61	g
LSD (P=0.05)						*REML*		*REML*		*REML*		*REML*		*0.2*	
CV														*16.9*	
Fpr						*<0.001*		*<0.001*		*<0.001*		*<0.001*		*<0.001*	

Intercept applied alone on 9 July did not have any impact on NDVI or grain yield. However, when applied in combination with chlorsulfuron, which did not affect NDVI at these timings either, NDVI was reduced by 23% and 19% on 19 August and 24 September, respectively. Although Intercept applied alone (1.44 t/ha) did not reduce grain yield and chlorsulfuron reduced grain yield by 27%, when these two Group B products were applied in combination, grain yield (0.65 t/ha) was reduced by 49% compared to the control. When the Group B herbicides and simazine/diuron were applied in combination, the grain yield (0.55 t/ha) was not significantly lower than the two Group B products applied together. This is in contrast to previous trials, where damage from Group B and C herbicides combined has increased the crop effect.

NDVI and grain yield relationship

Data from previous trials has shown that there is a strong relationship between crop biomass, measured as NDVI, and grain yield on these sandy soil types. The data from this trial supports this, in that the herbicide treatments that caused significant reductions in NDVI also reduced grain yield. Where this trial differs to previous trials is that the slope of the curve is much steeper than has been observed in most previous trials. This means that the reduction in crop biomass has had a more severe impact on grain yield than in previous trials.

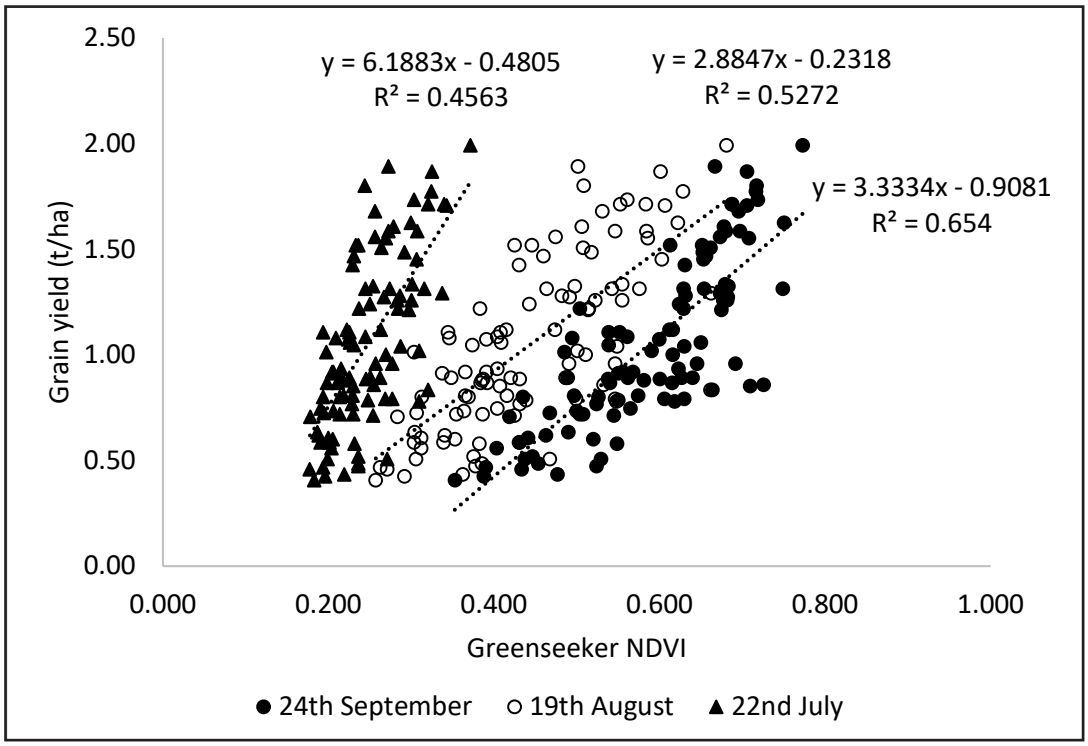

Figure 1. The relationship between plot GreenSeeker NDVI and lentil grain yield (t/ha) for the lentil herbicide tolerance and weed control trial at Bute 2019.

Table 3. Weed efficacy statistics for the lentil herbicide tolerance trial at Bute 2019 including medic populations (5 August), medic score (5 August) (0=no medic remaining, 100=no impact on medic biomass), sow thistle/m² (5 August), sow thistle/plot (30 September), mustard/m2 (5 August), mustard/plot (30 September) and wild turnip/plot (30 September).

Treatment code	Medic /m²	log (1+ Medic /m²)	Medic Score	Log (1+ Medic Score)	Thistle /m²	Thistles /plot	Log (1 + Thistles /plot)	Mustard /m²	Mustard / plot	Log (1 + Mustard /plot)	Turnip /plot	Log (1 + Turnip /plot)
Nil	232.1	5.0	100.0	4.6	4.1	18.0	2.9	2.1	23.0	2.9	1.3	0.7
Sim	86.0	4.1	60.0	4.0	0.4	5.3	1.7	0.5	5.7	1.9	0.3	0.2
Diu	68.9	3.9	41.7	3.6	1.1	6.3	1.8	1.1	5.7	1.7	2.3	1.2
Ter	42.1	2.9	45.0	3.8	1.2	7.0	2.0	0.7	4.0	1.4	0.3	0.2
Met	56.1	3.3	66.7	4.2	1.9	20.3	3.0	0.7	7.3	2.0	2.3	1.0
Si/Di	89.5	4.0	34.0	3.3	1.3	5.0	1.7	0.5	3.7	1.4	0.7	0.4
Chl	44.9	3.3	2.5	1.1	4.7	30.7	3.4	9.9	31.7	3.5	1.0	0.5
Int	82.7	4.2	13.3	2.6	1.5	4.7	1.7	3.5	38.3	3.2	0.3	0.2
Si/Di+Chl	21.5	2.8	2.7	1.0	0.4	6.3	1.9	0.5	6.3	1.7	0.0	0.0
Si/Di+Int	35.2	3.0	2.3	1.0	0.3	3.0	1.1	0.9	8.7	2.3	0.0	0.0
Chl+Int	27.2	3.1	1.2	0.7	2.0	8.0	2.2	4.8	27.7	3.4	0.0	0.0
Si/Di+Ch+Int	30.3	2.5	0.8	0.6	0.3	2.0	1.0	0.5	6.0	1.8	0.0	0.0
Dff	51.2	3.4	65.0	4.1	0.5	0.7	0.5	0.7	0.0	0.0	0.0	0.0
Si/Di+Dff	23.3	2.8	10.5	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Si/Di+Ch+Dff	15.9	2.1	1.3	0.6	0.7	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Si/Di+Dff+Int	18.3	2.3	1.7	1.0	0.5	0.0	0.0	0.1	0.3	0.2	0.0	0.0
Complete	19.7	2.8	1.0	0.6	1.3	0.0	0.0	0.4	0.0	0.0	0.0	0.0
LSD (0.05)		*1.1*	*15.9*	*0.6*	*1.8*	*7.1*	*0.7*	*2.5*	*20.1*	*1.0*	*1.5*	*0.7*
CV		*28.6*	*52.3*	*24.04*	*118.8*	*61.90*	*27.18*	*136.9*	*121.80*	*37.70*	*170.40*	*161.20*
Fpr		*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*0.003*	*<0.001*	*0.014*	*0.017*

Weed efficacy

Medic *(Medicago spp.)*

Medic control was evaluated through plant population and a score of biomass. In some treatments medic population did not truly represent the efficacy of the herbicide, as although there may have been high plant numbers, the biomass of the medic had been reduced by over 90%, so the second score was conducted.

Of the Group C herbicides, Terbyne and metribuzin reduced the medic population by 82% and 76% respectively (Table 3) where simazine and diuron, or the mixture, did not significantly reduce the population at this time. Chlorsulfuron applied alone reduced the medic population by 81% and, despite being applied post emergent, the diflufenican was able to produce 78% control. Combining the three herbicide treatments, Si/Di, Dff and Chl produced the greatest level of control at this time.

The medic score better represents the efficacy of the herbicides on medic populations at this site. The Group C herbicide metribuzin and simazine were not effective at reducing medic biomass significantly, but diuron, Terbyne and the simazine and diuron mix reduced the biomass score by 55%, 58% and 66%, respectively. A general observation was that any medic surviving Group C application did not suffer ongoing suppression, where the surviving plants were more or less unaffected by Group C herbicide application in the spring. This is in contrast to the Group B herbicide effects on medic which were long lasting. When the simazine/diuron mixture was applied with diflufenican a 90% reduction in biomass score was achieved where diflufenican alone did not have any significant effect. The Group B herbicide, chlorsulfuron, had the biggest impact on the medic biomass with a 96% reduction. Intercept, applied post emergent did not perform as well as chlorsulfuron when applied individually, but produced a similar level of control to chlorsulfuron when applied in combination with other herbicides such as the simazine and diuron mix.

Common sow thistle *(Sonchus oleraceus)*

Early population counts of sow thistle (5 August) show a population in the untreated plots of 4.3 plants/m^2. All Group C herbicide treatments were able to provide significant early suppression with an average 75% reduction in numbers. Diflufenican produced a greater level of control with 94% control. Of the Group B herbicides, chlorsulfuron did not have any impact on sow thistle population but the application of Intercept on 9 July reduced the population by 61%.

Once the sow thistles commenced stem elongation and were above the crop canopy, a second count (30 September) was conducted where all sow thistles in the plot were counted. From this data, the efficacy of the Group C herbicides simazine, diuron and Terbyne was maintained, with control of the sow thistle population averaging a 65% reduction in population. However, by this time metribuzin was no longer providing any control. The Group F herbicide diflufenican maintained control of sow thistle with a 96% reduction in population, and in combination with simazine and diuron provided 100% control. As in the early assessment, chlorsulfuron applied alone did not provide any control. There was actually a significant increase in sow thistle density in response to chlorsulfuron application; this may have been due to the reduction in lentil biomass and crop competition increasing weed seedling recruitment and making it easier for the sow thistle to grow beyond the lentil canopy. Intercept maintained control with a 74% reduction in thistle sow population.

Indian hedge mustard *(Sisymbrium orientale)*

At the time of the first assessment of mustard (5 August) there was only a low population with the untreated control plots having only 2 plants/m^2 and no significant reduction in population was identified. At the timing of the second assessment (30 September) the Group C herbicides simazine, diuron and Terbyne provided an average of 78% control reducing the population to only 0.3 plants/m^2. Metribuzin appeared to have an impact on the population, but likely due to the low population and variation across the site, this was not found to be significant. Neither of the Group B herbicides provided any control, indicating that the Indian Hedge Mustard population at this site is likely resistant to these Group B herbicides. In contrast, the diflufenican treatments provided 100% control.

Wild Turnip (*Brassica tournefortii*)

Wild turnip had the lowest population of all species. The untreated control only had an average of 1.3 plants/plot. Despite the low population, some treatment differences were still evident. Diflufenican provided virtually 100% control, with only a single wild turnip plant being found in all 15 plots treated with it. Also, any combination of two herbicides was able to provide virtually complete control.

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