Herbicide residues from summer spraying: Are they an issue for crop growth?

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Abstract
Despite the acknowledged benefit of summer spraying of weeds to conserve soil moisture, the subsequent presence of herbicide residues has led to growers and advisors questioning whether these residues may be affecting biomass and early vigour of the following crop. This is particularly of concern in low rainfall regions with sandy soils where rainfall is sporadic and microbial activity low. Through a combination of field and glasshouse experiments across the Mallee region of South Australia and Victoria, we investigated the impact of summer spraying of glyphosate, 2-4, D amine or a mixture of both on early biomass, vigour and yield of four crop species wheat, barley, lentils, and lupins. The herbicide applied over the summer period established high concentrations of the active ingredient in soil when measured prior to sowing. The herbicide residues did not negatively affect the early biomass, vigour, or yield of cereal crops wheat or barley at any of the three 2018 field sites despite the autumn period being among the driest on record. Only negative biomass and yield responses were measured for 2,4-D herbicide treatments when label plant back recommendations were not adhered to with the lightest textured soil more prone to crop damage. These results suggest that current summer spraying practices of glyphosate and 2,4-D amine as recommended by label rates are unlikely to cause any significant crop damage in wheat, barley, lentils and lupins.

Key Words
glyphosate, 2,4-D amine, low rainfall, sandy soils

Introduction
In low rainfall farming systems, there has been an increase in the frequency and diversity of herbicide usage following the adoption of summer spraying to keep paddocks free of weeds and preserve soil water. Farmers and advisors are beginning to raise production issues relating to emergence and establishment of some crops, which they are attributing to herbicide residues. There is increasing anecdotal speculation that routinely sprayed summer herbicides such as 2,4-D and glyphosate are causing soil health issues and negative impacts on the growth and establishment of the subsequent crop. Furthermore, the management of residues in the low rainfall areas is difficult because most plant back interval and residue management guidelines were developed based on studies in medium to high rainfall areas and on medium to heavy texture soils rather than the sandy soils that dominate some of the low rainfall areas. Previous work in this area (Macdonald et al. 2017; Rose et al. 2018, Van Zwieten 2016) has shown that most cropping soils have herbicide residues accumulating with glyphosate, its primary metabolite AMPA and 2,4-D among those herbicides detected most frequently. While the herbicides can be detected in the soil, there has been less work showing the link between residue concentrations and their effect on early vigour, biomass and yield. The aim of this work was to evaluate whether levels of glyphosate and 2,4-D amine residues in the soil measured at sowing affects early biomass, vigour and yield of the subsequent crop grown.

Methods
Field trials were conducted at three locations in the South Australian and Victorian Mallee: Cooke Plains (35°21'47.2"S, 139°38'44.5"E), Lameroo (35°14'46.7"S, 140°23'47.0"E), and Mittyack (35°09'35.3"S, 142°30'17.6"E) targeting low rainfall environments. Soils at each location were light textured sandy soils with low organic carbon (0.35-1.1%) and pH ranging from 6.3 to 7.1 (1:5 water). At each location, the trial treatments were structured to generate different levels of herbicide residues in the soils by applying a high rate (the equivalent of spraying summer weeds four times at label rates) in either summer (16th February 2018 at Cooke Plains, 12th February 2018 at Lameroo and 2nd February 2018 at Mittyack) or the day before sowing. These rates were deliberately applied for research purposes to create high concentrations in the soil and are considered outside of best economically viable practice. The herbicide treatments were unsprayed, Glyphosate 450 CT, 2,4-D amine 475 and a mixture of both herbicides. This approach had the added benefit of two unsprayed controls; one from the summer spray timing and another from the pre-sowing spray timing.

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Field trials were set up as a randomised complete block design with 4 crops, 8 herbicide treatments and 3 replicates. The crops were lupins *cv. Mandelup*, lentils *cv. Jumbo 2*, wheat *cv. Scepter* and barley *cv. Spartacus CL*. Plots were sown as 6 rows by 22.86cm spacing (1.37 metres wide) and 5 metres in length. Cooke Plains was sown on the 31st of May, Lameroo on the 29th of May, and Mittyack on the 3rd of June. Plots were monitored for weeds, pests and disease and sprayed as necessary. Measurements on each plot consisted of plant counts for establishment, NDVI and biomass cuts at GS30 or 6-8 weeks post sowing to assess early growth and vigour, and harvest yield. For each of the unsprayed and sprayed (mixture herbicide) plots that were sown to wheat, 4 soil cores (13mm diameter) of the top 10cm were collected and bulked the day before sowing. These samples were analysed for glyphosate, AMPA its primary metabolite and 2,4-D amine residues by CSIRO using standard analytical methods. Differences between treatments were analysed using analysis of variance (ANOVA) and multiple comparisons using Tukey's test ($p \leq 0.05$) with Genstat V19.1 Statistical Package.

Results

Environment information

Rainfall prior to sowing was low for all sites with the majority falling in May (Figure 1). Annual rainfall for each site in 2018 was between the 5th and 10th percentile from long-term rainfall data: 261.2 *(364.2)* at Cooke Plains, 208.4 *(308.9)* at Lameroo and 139.1 *(297.2)* at Mittyack in mm for annual and long-term median rainfall (in brackets) respectively.

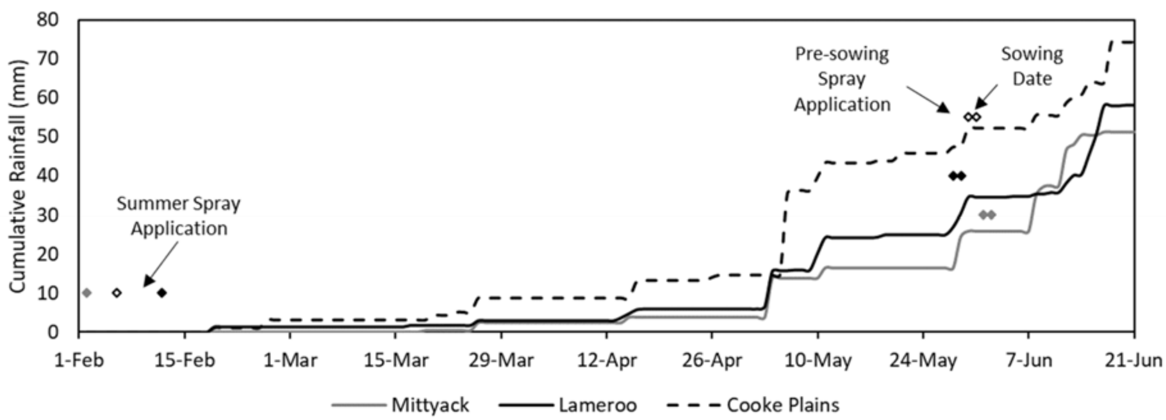

Figure 1: Cumulative rainfall for all three field sites from the summer spray application to post crop sowing date. The timing of herbicide application and sowing date are shown on graph. Rainfall data was taken from the nearest Bureau of Meteorology (BOM) Station with a complete data set for 2018 (Mittyack BOM station 76069, Lameroo BOM Station 25562, Cooke Plains BOM station 25502).

Herbicide residues

Each site had a different starting herbicide residue profile but all soils contained some background level of glyphosate, AMPA and 2,4-D (Figure 2). Glyphosate levels in control plots were on par with the average load measured in SA soils by Van Zwieten et al (2016) although 2,4-D residues were higher and more on par with NSW-Qld soils and AMPA levels less than the average load suggesting less breakdown in the soils in our study. A single application of 2L/ha of glyphosate 450 would result in 0.57 mg of active ingredient (a.i.)/kg of soil whereas a single application of 1.8L/ha of 2,4-D amine 475 would result in 0.54 mg a.i./kg of soil assuming a soil bulk density of 1.6 g/cm^3 and. All sites had glyphosate levels equivalent to a single application of glyphosate in the control plots but had starting 2,4-D levels well below a single application.

Glyphosate residues were present in all plots with highest levels for those applied just prior to sowing and summer application rates not completely degrading back to unsprayed control levels by the time of residue testing. Importantly the glyphosate residues from the pre-sowing spray timing for all 3 sites were above the critical threshold of 1.2 mg/kg observed by Rose et al (2017) to cause biomass reduction of lupins in the presence of phosphorus fertiliser. The AMPA residues remained constant and did not seem to accumulate during the time from application to sowing suggesting minimal breakdown of glyphosate to AMPA in these soils.

Soil analysis determined that 2,4-D was present at higher concentrations only when it was applied the day prior to sowing whilst the summer application in all soils had degraded back to similar levels as the unsprayed control. Despite one of the hottest and driest autumns on record, this finding is consistent with label plant back recommendations which are defined by time and rainfall, in the case of 2,4-D, 15mm of rain must fall prior to the commencement of the plant back period; 3 days for barley, 7 for wheat, 10 for lentils and 21 for lupins.)

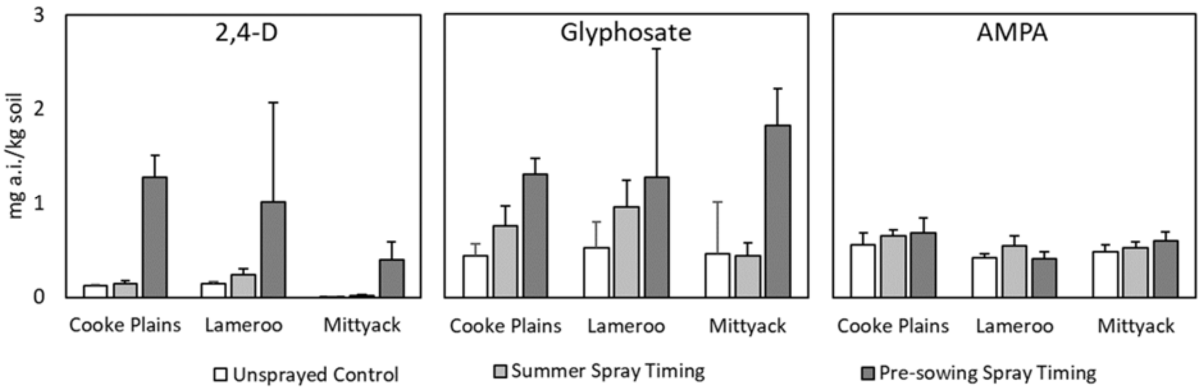

Figure 2: Herbicide residue concentrations detected at sowing in soil samples taken from the top 10cm of wheat control and herbicide mixture treated plots. Concentrations reported as mg of active ingredient per kg of soil.

Plant health responses

At both the South Australian sites, there were no differences in plant density, NDVI or early biomass between herbicide treatments. Only differences existed between crop types (data not shown).

At Mittyack, both the mix and the 2,4-D treatment that was applied the day before sowing reduced lentil establishment from 95 to 10 and 18 plants/m^2 respectively when compared to the control (ANOVA $p \leq 0.05$ l.s.d. 16 plants/m^2). In this case, crops were sown the day after herbicide application, well short of the plant back period for lentils of 10 days after 15mm of rainfall and is not recommended. This was the only interaction between crop type and herbicide treatment for any of the results across the three sites. At Mittyack a significant reduction in early vigour and biomass was also measured by NDVI 6.5 weeks after sowing and by a dry matter cut at GS30 (Table 1) in response to the 2,4-D amine application that occurred within a day of sowing and did not adhere to plant back periods for any of the crops.

Table 1: NDVI and Biomass for Mittyack site

	NDVI	Biomass (t/ha)
Crop effect		
Lentils	0.164	0.14 a
Lupins	0.164	0.20 a
Barley	0.181	0.55 c
Wheat	0.179	0.40 b
l.s.d (p ≤ 0.05)	*n.s*	*0.07*
Herbicide Effect		
Summer Control	0.185 b	0.37 bc
Pre-sowing Control	0.190 b	0.39 c
Summer 2,4-D	0.181 b	0.44 c
Pre-sowing 2,4-D	0.137 a	0.19 a
Summer Glyphosate	0.194 b	0.31 abc
Pre-sowing Glyphosate	0.183 b	0.35 abc
Summer Mix	0.173 b	0.32 abc
Pre-sowing Mix	0.134 a	0.23 ab
l.s.d (p ≤ 0.05)	*0.02*	*0.10*

Table 2: Yield (t/ha) for all three field sites

	Lameroo	Cooke Plains	Mittyack
Crop effect			
Lentils	0.07 a	0.10 a	*
Lupins	0.13 a	0.12 a	0.11 a
Barley	1.54 b	2.42 c	0.41 c
Wheat	1.69 b	1.96 b	0.29 b
l.s.d (p ≤ 0.05)	*0.26*	*0.17*	*0.06*
Herbicide Effect			
Summer Control	1.09	1.32	0.35 c
Pre-sowing Control	0.74	1.08	0.32 c
Summer 2,4-D	0.79	1.18	0.31 bc
Pre-sowing 2,4-D	0.89	0.96	0.17 ab
Summer Glyphosate	0.73	1.26	0.29 abc
Pre-sowing Glyphosate	1.07	1.15	0.31 bc
Summer Mix	0.83	1.15	0.25 abc
Pre-sowing Mix	0.73	1.10	0.15 a
l.s.d (p ≤ 0.05)	*n.s.*	*n.s.*	*0.09*

*Severely droughted no harvest

For both South Australian sites Lameroo and Cooke Plains, the only yield differences detected were for crop type (Table 2). Both lentils and lupins had very low yields at both these sites of less than 0.2 t/ha[1] and struggled in the 2018 drought. Cereal yields at both Lameroo and Cooke Plains were higher than Mittyack.

However, there were no differences due to the herbicide treatments despite higher 2,4-D levels being measured in soil samples at both sites than measured for the Mittyack soil.

The very dry season at Mittyack resulted in low yields for all crops with the lentil plots suffering crop death and complete crop failure. The early biomass and NDVI effects reported earlier from Mittyack translated to a significant yield penalty, suggesting biomass was important for yield at this site in 2018. Once again, the 2,4-D and the mixture treatment applied pre-sowing resulted in a reduced yield compared to the unsprayed controls.

Not many studies have determined critical thresholds for glyphosate and AMPA in sandy soils with only a few on selected crops. For lupins in the presence of P fertiliser it is 1.2 mg of glyphosate/kg of soil and for wheat 6.75 mg/kg (Rose et al 2017). We achieved soil concentrations higher than 1.2mg/kg in our study but did not record any biomass reductions in lupins due to glyphosate. To achieve the wheat critical threshold we would need to have sprayed equivalent to 12 applications at label rates with no herbicide losses or breakdown. However, in a Canadian study, for a 20% reduction in shoot biomass of wheat the critical thresholds were substantially higher at 120-320 mg of glyphosate/kg of soil and 80-120 mg of AMPA/kg of soil (Blackshaw and Harker 2016). The likelihood of achieving these concentrations under field conditions is extremely low.

Conclusion

Given the 2018 season was one of the hottest and driest autumns on record we expected little breakdown of crop herbicide from summer spraying. While we observed higher concentrations of herbicides in the soil at sowing compared to unsprayed controls, we did not see any negative establishment, biomass or yield response from our summer spraying treatments at any of the sites.

Glyphosate and AMPA did not cause any significant negative plant health responses in any crop type, spraying time or location. The only negative responses were due to 2,4-D amine residues from spraying the day before sowing. This practice is not recommended and is outside of label plant back recommendations. Based on these findings it is likely that herbicide residues will be present in soils and may not completely breakdown within a season or prior to sowing. However, if herbicide labels are adhered to and plant back recommendations are followed, they are unlikely to cause a problem in most soils. Lighter textured soils, along with crops that have greater plant back recommendations such as legumes are likely to show the first signs of issues particularly in a dry season.

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References

Blackshaw RE and Harker KN (2016) Wheat, field pea and canola response to glyphosate and AMPA soil residues. Weed Technology 30:985-991

Macdonald L, Kookana R, Wilhelm N, McBeath T, and Llewellyn R (2017) Herbicide residues in sandy soils of the Southern region, MSF 2017 Compendium www.msfp.org.au/wp-content/uploads/Herbicide-residues-in-sandy-soils-Lynne-Macdonald-Full.pdf

Rose M, van Zwieten L, Zhang P, McGrath G, Seymour N, Scanlan C, and Rose T (2018). Herbicide residues in soil – what is the scale and significance? GRDC Updates Adelaide grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2019/02/herbicide-residues-in-soil-what-is-the-scale-and-significance

Rose TJ, Claassens A, Scanlan C, Van Zwieten L and Rose MT (2017). Glyphosate residues in Australian soils and implications for crop growth. Proceedings of the 18th Australian Society of Agronomy Conference, Ballarat, Australia

Van Zwieten L, Rose M, Zhang P, Nguyen D, Scanlan C, Rose T, McGrath G, Vancov T, Cavagnaro T, Seymour N, Kimber S, Jenkins A, Claassens A and Kennedy I (2016). Herbicide residues in soils – Are they an issue? GRDC Grains Research Updates (Northern)