Nationwide field survey for herbicide residues in soil

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Key findings

- Growers need to be aware that glyphosate, trifluralin and diflufenican residues, plus the glyphosate metabolite AMPA, can accumulate to agronomically significant levels in certain soils.
- These findings suggest that the current risk of damage to crops in NSW is minor compared with some sites in WA that have lower rainfall and sandy soils with low organic matter.
- The risk to soil biological processes is generally minor when herbicides are used at label rates and given sufficient time to dissipate before re-application.
- However, given the frequency of glyphosate application and the persistence of trifluralin and diflufenican, further research is needed to define site-specific critical thresholds for these chemicals to avoid potential negative effects on soil function and crop production.

Introduction

Due to the high cost of herbicide residue analysis, information about herbicide residue levels in Australian grain cropping soils is scarce. This report presents the results of a national field survey of herbicide residues in 40 cropping soils before sowing and pre-emergent herbicide application in 2015. It looks at the relevance of these residues to soil biological processes and crop health with a focus on those herbicides most frequently detected.

Site details

A total of 40 paddocks were surveyed including 12 from Western Australia, 15 from South Australia, 10 from New South Wales and three from Queensland. Eight of these sites were located in southern NSW between Wagga Wagga, Young and Ardlethan. Two sites in northern NSW were located in the Coonamble area.

The topsoil (0–10 cm) pH (H_2O) ranged from 5.4 to 7.5 in southern NSW and 7.3–8.2 in northern NSW. The subsoil (10–30 cm) pH (H_2O) ranged from 5.4 to 7.0 in southern NSW and 8.8–8.9 in northern NSW.

Treatments/sampling

Soil sampling was undertaken to provide a representative snapshot of herbicide residue levels in cropping soils at the beginning of the 2015 growing season (April/May) before applying pre-emergent herbicides. Composite samples (12 subsamples) were taken from a randomly chosen 50 × 50 m grid in each paddock at two depths (0–10 cm and 10–30 cm). Samples were analysed for 15 commonly used herbicides using advanced analytical techniques developed and validated by the project team.

Results

Which herbicides are remaining in soil?

The soil survey of 40 different paddocks from around Australia detected residues of 11 chemicals out of the 15 analysed (Figure 1). Glyphosate and its primary break-down product (metabolite) aminomethylphosphonic acid (AMPA) were the most commonly detected residues, with AMPA residues present in every topsoil sample taken.

Trifluralin residues were also detected in over 75% of the paddocks surveyed, both in topsoil and in the 10–30 cm soil layer, indicating some vertical movement, despite the strong tendency of trifluralin to remain close to the application site. This is possibly due to cultivation, however, leaching or movement of particle-bound trifluralin can also occur on lighter textured soils that have low organic matter content.

Diflufenican and diuron residues were frequently detected in samples from WA paddocks, but less so in NSW, Qld and SA.

crop protection

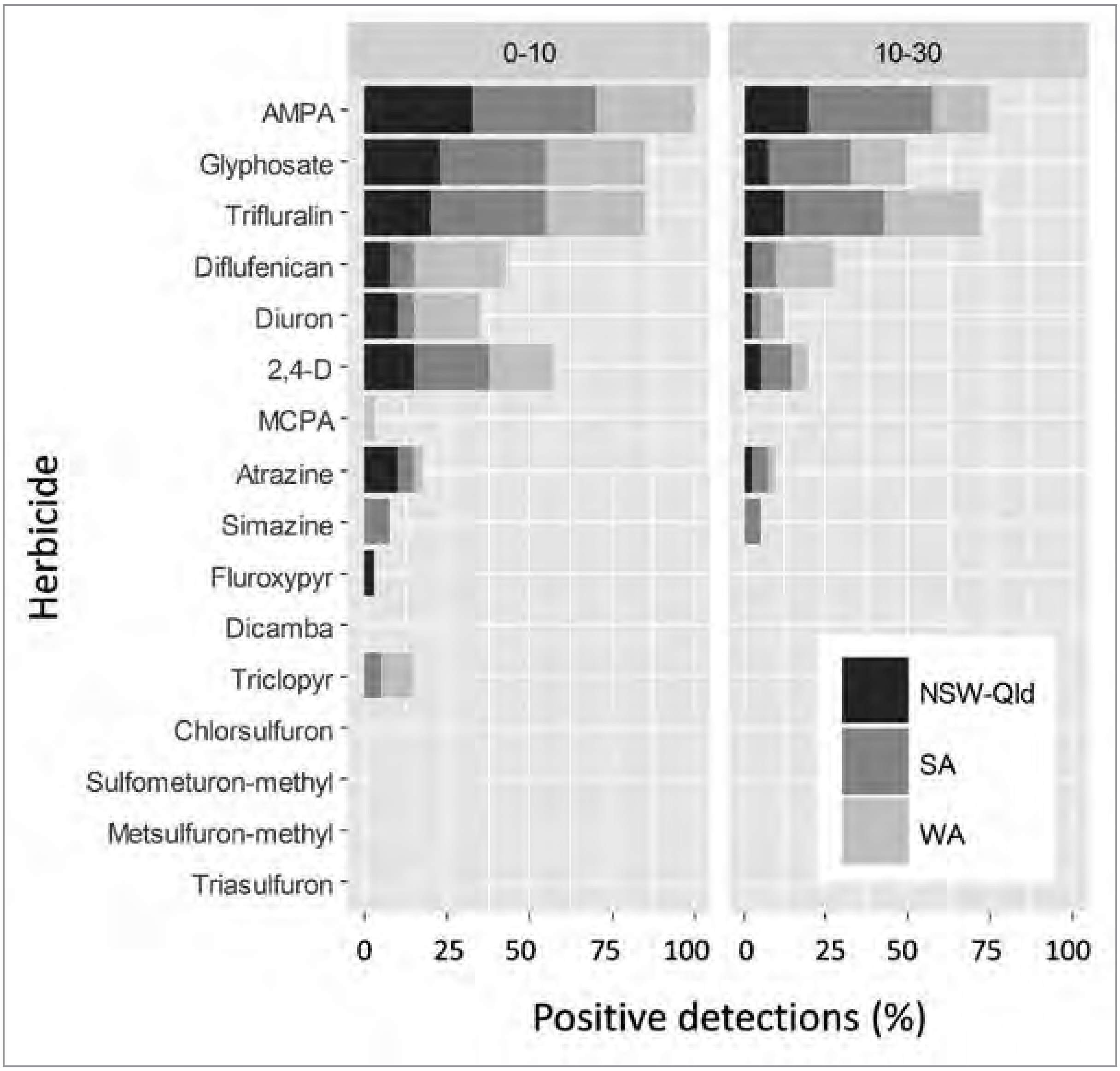

Figure 1. Number of positive detections of herbicides and the glyphosate metabolite AMPA in soil samples from 40 grain cropping paddocks around Australia.

Interestingly, despite known application of triasulfuron and metsulfuron-methyl in many of the surveyed paddocks, neither of these residual herbicides were detected in any of the samples tested. This is probably a reflection of low application rates, close to the limit of analytical detection. It should be noted that sulfonylurea (SU) herbicides might still have some residual activity at levels below the limit of (currently available) analytical detection. By contrast, the lack of positive detections of frequently applied MCPA reflects its relatively short persistence.

By multiplying herbicide concentrations (mg/kg) by soil bulk density (kg/dm [dry matter]) and area, the estimated total load of herbicide in the 0–30 cm soil profile for each paddock was calculated (Table 1). The average and maximum estimated loads of glyphosate, trifluralin, diflufenican and diuron were all significantly higher in paddocks in WA compared with those in SA, NSW and Qld. This probably reflects the lighter soil types, lower organic matter, dry summers and cool winters, which contribute to lower microbial activity and constrained herbicide breakdown. The higher load of atrazine in SA paddocks is probably due to the higher persistence of s-triazine herbicides in alkaline soils. The higher values for 2,4-D in the NSW and Qld soil profiles was due to a high value in a single paddock that had recently been sprayed.

Notably, in a number of paddocks (especially in WA but also in other states), there was a higher load of glyphosate than was applied in the previous spray, demonstrating glyphosate accumulation and its metabolite AMPA over time. Although the half-life of glyphosate is relatively low (10–40 days), a significant portion of the glyphosate (and AMPA) is bound to the soil and is much less accessible for continued degradation. This, combined with the high frequency of glyphosate use, can lead to a build-up of glyphosate and AMPA in soil. An accumulation of trifluralin was also apparent in a number of paddocks in WA. It should be reiterated that these levels represent the total loads, rather than the bio-available fraction. Residues aging in the soil results in stronger binding over time, and a reduction in bioavailability, so any biological effect can be difficult to predict.

How do soil functions respond to herbicide residues?

A literature review of over 300 published studies identified common themes for herbicide impacts on soil function (Rose et al. 2016). Most papers had reports of negligible impacts from herbicides on beneficial soil functions when applied at recommended rates. Even in the cases where negative effects were observed, they were usually minor and only lasted for less than one month.

However, some exceptions were apparent, especially regarding the effects from repeated herbicide application. For example, there is evidence that the accumulation of some sulfonylurea (SU) herbicides after repeat application can reduce plant-available nitrogen (N) by slowing down the processes involved in N-cycling. Persistence of SUs in soil has also been linked with increased incidences of rhizoctonia diseases in cereals and legumes. These effects are more likely to occur in alkaline soils, where SU herbicides are significantly more persistent. There are also cases in which other herbicides (e.g. glyphosate) can increase the incidence of disease, but these interactions appear to be site-specific and often occur under stressful growing conditions.

Based on this information and the herbicide residues detected in the soil survey, it is unlikely that SU residues are having ongoing negative effects on soil functions in the paddocks surveyed. However, the high residue loads of glyphosate, its metabolite AMPA and trifluralin could be altering some soil functions or plant-pathogen interactions. The localised nature of interactions with glyphosate, and the lack of specific data on trifluralin, means that firm conclusions cannot yet be made with respect to the residues detected.

How do crops respond to herbicide residues?

Because the potential for each herbicide to damage crops varies according to soil, agroclimate and crop, comprehensive damage thresholds (given as soil residue concentrations) for assessing plant-back risk are not readily available. However, there is the potential for glyphosate (+AMPA) or trifluralin residues to cause seedling damage given their high frequency of application and subsequent detection in the residue survey.

Table 1. Residue loads (average and maximum) of herbicide active ingredients (a.i.) in the 0–30 cm soil profile of paddocks by region.

Herbicide	Estimated average load across all sites (kg a.i./ha)*			Estimated maximum load detected (kg a.i./ha)*		
	NSW/Qld	SA	WA	NSW/Qld	SA	WA
AMPA	0.91	0.95	0.92	1.92	1.97	2.21
Glyphosate	0.56	0.48	0.79	2.05	1.05	1.75
Trifluralin	0.08	0.11	0.53	0.14	0.26	1.34
Diflufenican	0.01	0.03	0.04	0.02	0.05	0.09
Diuron	0.14	0.05	0.17	0.16	0.05	0.29
2,4-D	0.20	0.02	0.01	1.00	0.05	0.02
MCPA	0	0	0	0	0	0
Atrazine	0.02	0.03	0.02	0.03	0.05	0.02
Simazine	0	0.04	0	0.00	0.05	0
Fluroxypyr	0.03	0	0	0.03	0	0
Dicamba	0	0	0	0	0	0
Triclopyr	0	0.04	0.01	0	0.07	0.01
Chlorsulfuron	0	0	0	0	0	0
Sulfometuron-methyl	0	0	0	0	0	0
Metsulfuron-methyl	0	0	0	0	0	0
Triasulfuron	0	0	0	0	0	0

*Calculated by multiplying mass concentration (mg/kg) detected by area and average bulk density (derived from soilquality.org) for each soil layer.

It is generally accepted that glyphosate is deactivated when it reaches the soil and poses little risk to crops. However, recent research has shown that under certain circumstances glyphosate can be remobilised and become plant bioavailable, including:

» in the event of phosphorus (P) fertilisation, which can compete with glyphosate for binding sites on soil and remobilise bound glyphosate residues
» in the event of glyphosate applied to a high weed density shortly before sowing, such that dying weeds translocate glyphosate into the soil and act as a more soluble pool of glyphosate to the germinating crop.

A sandy, low organic matter soil from Wongan Hills, WA, was used to construct dose-response curves for wheat and lupin encountering glyphosate residues applied one month before sowing. To demonstrate circumstance, half the test plots received a one-off application of 20 kg/ha P fertiliser (as soluble potassium phosphate) at sowing.

In the soil not receiving P fertiliser, wheat was not affected by levels of glyphosate in soil resulting from a 27 kg/ha application rate, whilst lupin biomass was only significantly reduced at rates above 12 kg/ha (when upper 95% confidence level falls below 100% biomass) (Figure 2). When P fertiliser was added at 20 kg P/ha, both wheat and lupin showed signs of damage at a lower glyphosate concentration – for lupin this occurred at levels of glyphosate >3.5 kg/ha and for wheat >12.5 kg/ha (Figure 2). Previous research has shown that increasing levels of P fertiliser application will continue to lower the toxicity threshold to glyphosate/AMPA residues in soil. The soil samples from this experiment are currently being analysed to determine the residue level of both glyphosate and AMPA in soil. This will provide a more accurate understanding of whether the residues found in the field survey are likely to affect crop growth following P fertilisation.

For trifluralin, plant-back damage thresholds for oats vary from 0.1 to 0.2 mg/kg, and wheat from 0.2 to 0.4 mg/kg depending on the soil type (Hager & Refsell 2008). Table 2 shows the number of paddocks in which the topsoil trifluralin residue concentration exceeds the lower threshold for oats and wheat, respectively. Again, it must be stressed that the residues detected in our field survey constitute 'aged' residues, which are likely to be less bioavailable and hence less of a threat to crop growth. Nevertheless, considering that some of these paddocks will receive a pre-emergent application of trifluralin in 2016, the risk of some plant-back damage is tangible.

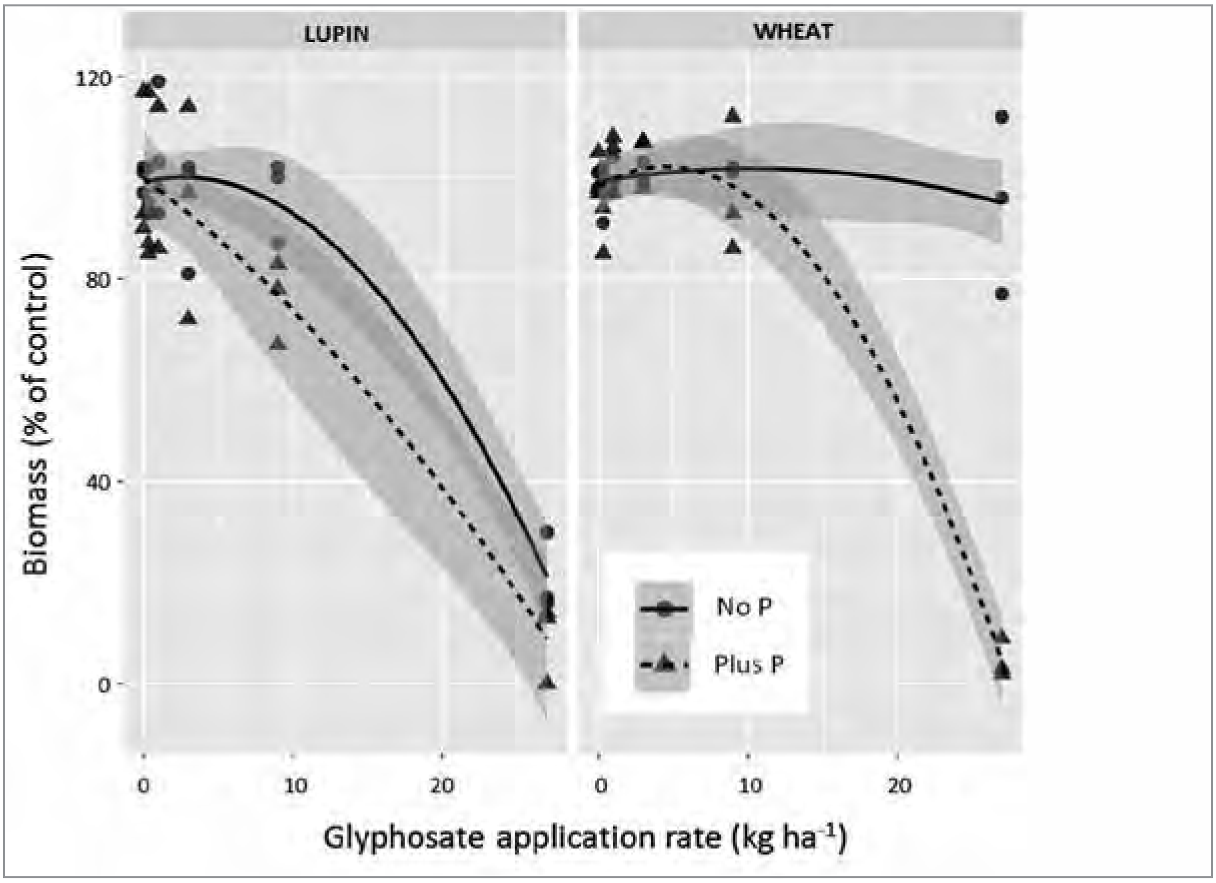

Figure 2. Growth response of lupin and wheat to glyphosate applied to soil one month before sowing with and without P fertiliser (20 kg/ha) added at sowing.

Table 2. Number of paddocks exceeding trifluralin lower phytotoxicity thresholds for oats (0.1 mg/kg) and wheat (0.2 mg/kg) in topsoil (0–10 cm).

Region	Trifluralin >0.1 mg/kg	Trifluralin >0.2 mg/kg	Number of paddocks surveyed
WA	10	5	12
SA	2	0	15
NSW–Qld	0	0	13

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