Increased carrier volume and reduced crop residue for improved trifluralin efficiency

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Summary Pre-emergent herbicides are generally less effective in no tillage farming systems due to high levels of crop residue. However, performance can be improved if the herbicides are applied with a high carrier volume. This research investigated the interaction of carrier volume and height or spacing of crop residue on the control of annual ryegrass with trifluralin. To create plots with varying crop residue characteristics in 2011, wheat was sown in 2010 using a narrow row spacing, wide spacing or left bare (i.e. not sown to wheat), at Wongan Hills and Cunderdin, Western Australia (WA). The wheat was harvested to produce tall, medium or short crop residue. Annual ryegrass seeds were broadcast onto each site in 2011 and trifluralin was sprayed using 50, 75 or 100 L ha^{-1} carrier volume (directly prior to sowing). Increased carrier volume increased spray coverage at both sites (average cover of 9.0%, 15.0% and 25.5%), leading to improved control of annual ryegrass (average density of 24, 19 and 11 plants m^{-2}). However, altered row spacing or harvest height in 2010 (i.e. altered crop residue characteristics) did not consistently affect spray coverage. Reduced crop residue height or increased row spacing improved annual ryegrass control at Cunderdin but had no impact at Wongan Hills. It is clear that carrier volume has a more consistent impact on the performance of trifluralin than crop residue (in WA where the biomass of crop residues is relatively low). These results are encouraging as it is usually easier for growers to increase carrier volume than to adjust crop residues, for improved annual ryegrass control in no tillage systems.

Keywords Conservation farming, crop residue, no tillage seeding system, water rate, water sensitive paper.

INTRODUCTION

No tillage or minimum tillage farming systems have been widely adopted in southern Australian grain cropping systems, as they increase crop yield and are environmentally beneficial (D'Emden *et al.* 2008). However, these farming systems have increased reliance on pre-emergent herbicides for weed control, in the absence of physical weed control from cultivation (D'Emden *et al.* 2008). Unfortunately, the increased retention of crop residues due to reduced cultivation may cause reduced efficiency of pre-emergent herbicides.

Prior studies have shown that crop residues can intercept 15% to 80% of pre-emergent herbicide, which may reduce herbicide efficacy (reviewed by Chauhan *et al.* 2006b). Trifluralin is heavily relied on for pre-emergent annual ryegrass (*Lolium rigidum* Gaudin) control in cereal crops, particularly in no tillage systems (i.e. no cultivation, use of knife points to sow the crop with minimal soil disturbance). This product has low water solubility (i.e. solubility of 0.2 mg L^{-1} in water at 20°C), causing it to bind to the crop residue rather than reaching the annual ryegrass seeds on the soil surface (Lewis and Green 2013). The intercepted proportion of trifluralin is lost through volatilisation or photodegradation (Chauhan *et al.* 2006a, Lewis and Green 2013). These losses increase in the no tillage system as soil disturbance and incorporation of the crop residue is reduced (Chauhan *et al*. 2006b). The label of trifluralin (Triflur Xcel 500 g a.i. L^{-1}, Nufarm) indicates that crop residue coverage of 40% to 50% can reduce weed control below acceptable levels, and this level of cover is common in no tillage systems (Nufarm Australia 2009, Borger *et al.* 2013). The extent to which varying levels of crop residue (i.e. crop residue at varying height or row spacing) influence trifluralin performance in the no tillage system in Australia has not been investigated.

Trifluralin performance in conditions of high crop residue can be improved through use of high carrier volume (70 to 450 L ha^{-1} recommended by the herbicide label) (Nufarm Australia 2009). Increased carrier volume (from 30 to 150 L ha^{-1}) improved the control of annual ryegrass by pre-emergent herbicides in the WA no tillage system from 53% to 78% (Borger *et al*. 2013). However, this research was conducted by adjusting the speed of spraying (from 4.7 to 24 km h^{-1}), rather than changing the nozzle type. These speeds were often below those used by growers when spraying herbicides, and may have affected herbicide deposition or efficiency. Further research is required to determine the impact of increasing carrier volume while application speed is held constant.

The current research hypothesised that increased carrier volume or reduced crop residue (reduced residue height or increased residue spacing) would improve the control of annual ryegrass by trifluralin.

MATERIALS AND METHODS

Trials were conducted at Cunderdin and Wongan Hills, WA. In 2010, paraquat/diquat at 270/230 g a.i. ha^{-1} was used to remove emerged weeds and trifluralin at 1250 g a.i. ha^{-1} was applied directly prior to sowing. Both trials were sown to wheat (cv. Magenta) using normal row spacing (25 cm at Cunderdin, 22 cm at Wongan Hills), wide row spacing (achieved by blocking every second head outlet on the airseeder) or were not cropped (left bare). The crop was sown using knife points and press wheels (no tillage seeding system) at a rate of 40 kg ha^{-1} at Cunderdin (5 May 2010) and 80 kg ha^{-1} at Wongan Hills (10 June 2010). Fertilisers applied at seeding included 100 kg ha^{-1} of CSBP Agras® at Cunderdin and 80 kg ha^{-1} of Macropro Plus® at Wongan Hills. Selective herbicides were used to control weeds in the crop, but very few weeds were apparent at either site. At the end of 2010, trials were harvested (19 November 2010 at Cunderdin and 25 November 2010 at Wongan Hills), perpendicular to the direction of sowing. Harvest height was altered to create short, medium and tall crop residue. Spreaders were used at harvest (i.e. devices on the back of the harvester that spread all chaff back onto the ground, over the full width of the harvester), to ensure that adjusting the height of the harvest would not affect total crop residue. The spreaders ensured that some residue was spread to the plots that were not cropped.

In 2011 non-selective herbicides were applied to clear weeds that emerged prior to sowing (as for 2010). Annual ryegrass seeds (cv. Wimmera) were broadcast on the soil surface at a rate of approximately 100 seeds m^{-2}. Trifluralin at 1250 g a.i. ha^{-1} was applied directly prior to sowing, at 0 L ha^{-1} (control), 50 L ha^{-1} (Spraying Systems® Turbo TwinJet nozzle TTJ110025, 3.1 bar pressure), 75 L ha^{-1} (nozzle TTJ11003, 4.9–5 bar) and 100 L ha^{-1} (nozzle TTJ11004, 4.8–5 bar). The nozzles used for each carrier volume were selected to deliver a coarse spray quality, at high operating pressures of 3 to 5 bar (to give high droplet speed), delivered at a spraying speed of 22 to 24 km h^{-1} (realistic speed of spraying for growers). Boom height was 55 to 60 cm above the ground. A Kestrel 3500 Delta T (Nielsen-Kellerman, Boothwyn PA) was used to assess climatic conditions prior to spraying (average wind speed of 14 and 10 km h^{-1}, maximum wind speed of 19 and 15 km h^{-1}, temperature of 17.7 and 18.4°C and delta T of 7.4 and 4.1°C at Cunderdin and Wongan Hills). The wheat (cv. Wyalkatchem) was sown using a no tillage seeding system (at 75 kg ha^{-1} on 9 June 2011 at Cunderdin and 80 kg ha^{-1} on 20 June 2011 at Wongan Hills), at 22 cm row spacing, at a depth of 3–4 cm, using the same fertiliser rates as in 2010. Trials were arranged in a split plot design, with harvest height in the main plots and row spacing by trifluralin carrier volume in the sub-plots, replicated three times (plot size of 2 m by 20 m).

Annual ryegrass density was relatively low at both sites. Growing season (May to October) rainfall was above average during the 2011 season, with 283 mm at Cunderdin weather station 010035 and 411 mm at Wongan Hills weather station 008138 (compared to the long term average of 269 mm at Cunderdin and 266 mm at Wongan Hills) (Bureau of Meteorology 2014). As a result, annual ryegrass did not affect crop growth (determined by visual assessment). To prevent annual ryegrass seed set, non-selective herbicides were applied to both trials prior to harvest.

Measurements Prior to application of trifluralin in 2011, four water sensitive paper strips per plot (i.e. cards of 7.6 by 2.6 cm, coated with a layer of bromoethyl blue, which turn from yellow to blue following contact with water, Hardi Australia) were placed between the rows of 2010 standing crop residue. After spraying, cards were air dried and the percent coverage of each card by spray droplets was assessed according to the method in Borger *et al*. (2013). Percent card cover is a recognised technique for assessing high spray volumes. However, it cannot take spread factor into account (due to overlapping droplets from high spray volumes), so this method gave a comparative rather than an actual indication of spray coverage (Fox *et al.* 2003, Borger *et al.* 2013).

Eight weeks after crop emergence, the number of wheat plants was assessed over a 1 m length, twice in each plot. Annual ryegrass was assessed from six quadrats per plot (50 cm by 50 cm) at Cunderdin and two quadrats at Wongan Hills.

Statistical analysis The data were analysed using a split-plot design ANOVA (Genstat 15th edition, VSN International 2012). Harvest height was the main plot factor, crop residue row spacing and trifluralin carrier volume were the sub-plot factors and block was the blocking factor. The variates included percent spray coverage, crop density and annual ryegrass density. A square root transformation was applied to the annual ryegrass density data from both sites, to normalise the distribution of the residuals. The initial analysis indicated no significant difference between annual ryegrass densities in varying crop residue treatments (harvest height or row spacing) in the no herbicide control treatment (carrier volume of 0 L ha^{-1}). As crop residue did not affect annual ryegrass germination, the data were re-analysed without the control treatment to allow a linear contrast to be used to determine differences between levels of carrier volume (50, 75 and 100 L ha^{-1}). Significant differences for each factor or the significance of the linear contrast for carrier volume are indicated by P values. The standard errors of differences of means are presented to separate means. Differences between means of harvest height and row spacing were separated using least significant difference. Where a transformation was performed, the results from the analysis are presented as back-transformed means.

RESULTS

Spray coverage At both sites, spray coverage increased with increasing carrier volume (Table 1).

At Cunderdin, the harvest height and row spacing did not significantly influence spray coverage. At Wongan Hills, the row spacing affected spray coverage, with greater coverage in the no crop plots compared to the narrow row spacing plots (17.7%, 15.1% and 14.3% coverage in the no crop, wide and narrow row spacing plots, P: 0.043, SE: 1.4, LSD: 2.7).

Plant density There were 171 wheat plants m^{-2} at Cunderdin and 146 plants m^{-2} at Wongan Hills. None of the treatments affected wheat density. Annual ryegrass in the 0 L ha^{-1} carrier volume treatments averaged 44 plants m^{-2} at Cunderdin and 255 plants m^{-2} at Wongan Hills, and as stated previously there was no significant impact of harvest height or row spacing on annual ryegrass emergence in the control plots. At both sites, annual ryegrass density significantly decreased with increasing carrier volume (Table 1). At Cunderdin, there were fewer plants in the no crop plots compared to the wide and narrow row spacing plots (5, 14 and 15 plants m^{-2}, P <0.001, SE: 0.1, LSD: 0.4). Annual ryegrass density also increased with increasing harvest height (4, 14 and 17 plants m^{-2} in the low, medium and high harvest plots, P: 0.013, SE: 0.2, LSD: 1.2). The interactions between these factors were not significant. At Wongan Hills, the row spacing and harvest height and the interactions between factors did not significantly affect annual ryegrass control.

DISCUSSION

High carrier volume increased spray coverage and improved annual ryegrass control at both sites, confirming the results of Borger *et al*. (2013). The current study altered the nozzle type to allow the spray to be delivered while maintaining a consistent speed, unlike Borger *et al*. (2013) where speed of application was varied. The current study confirms that increased carrier volume can improve trifluralin performance at the application speeds commonly used by growers. The trifluralin label suggests using a carrier volume of 70 to 450 L ha^{-1} in the minimum tillage system (Nufarm Australia 2009). While a carrier volume of 450 L ha^{-1} would rarely be acceptable in WA cropping system (due to shortage of spray quality water or increased time of spraying leading to delayed seeding), it is clear that growers should select the highest practical carrier volume when applying trifluralin (Nufarm Australia 2009, Borger *et al.* 2013).

Altering residue height or row spacing did not have a consistent impact on spray coverage, and only influenced annual ryegrass control at Cunderdin. As stated, growing season rainfall at Wongan Hills was above average (and higher than that at Cunderdin),

Table 1. The spray coverage of water sensitive cards and surviving annual ryegrass for each carrier volume. The P value indicates the significance of the linear contrast for carrier volume and the standard error of the difference of the means (SE) are presented to separate means.

		Carrier volume (L ha^{-1})				
Site	Measurement	50	75	100	P	SE
Cunderdin	Spray coverage (%)	9.5	17	25	<0.001	1.0
	Annual ryegrass (m^{-2})	14	11	8	0.023	0.1
Wongan Hills	Spray coverage (%)	8.4	13	26	<0.001	1.9
	Annual ryegrass (m^{-2})	34	26	14	<0.001	0.3

which would increase the likelihood that the poorly soluble trifluralin could wash off the crop residue to reach the weed seeds on the soil surface (Chauhan *et al.* 2006b, Lewis and Green 2013). Prior research has indicated that crop residue can affect pre-emergent herbicide performance, but these studies were generally conducted in the USA or Europe, where crop residue biomass is higher than in Australia (Banks and Robinson 1982, Banks and Robinson 1984, Ghadiri *et al.* 1984, Lal 2005, Chauhan *et al.* 2006b).

Further research is required on the interaction of trifluralin and crop residue, as crop residue may have a more consistent impact on pre-emergent herbicides in systems with greater residue biomass. Further, the type of crop residue (i.e. crop species) or age/stage of degredation of crop residue may influence the efficacy of pre-emergent herbicides. However, it is clear that carrier volume has a more consistent impact on trifluralin efficiency than crop residue height or spacing in south-western WA, where the biomass of crop residues is relatively low. This is a positive result, as carrier volume is easy for growers to alter (if they have access to scheme water). Crop residue is not easily controlled as it depends on crop species/cultivar, crop agronomy and seasonal conditions (Lal 2005, Chauhan *et al.* 2006b).

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