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Effect of spray droplet size on herbicide efficacy on four winter annual grasses

J. Connor Ferguson[a,b,*], Rodolfo G. Chechetto[b,c], Steve W. Adkins[b], Andrew J. Hewitt[b], Bhagirath S. Chauhan[d], Greg R. Kruger[e], Chris C. O'Donnell[b]

[a] Mississippi State University, MS State, Mississippi, USA
[b] The University of Queensland Gatton, Gatton, Queensland, Australia
[c] AgroEfetiva Serviços SS Ltda, Botucatu, São Paulo, 18603-760, Brazil
[d] Queensland Alliance for Agriculture and Food Innovation (QAAFI), The University of Queensland, Toowoomba, Queensland, Australia
[e] University of Nebraska-Lincoln, North Platte, NE, USA

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ABSTRACT

In Australia, winter annual grasses provide the strongest competition against wheat for resources which detrimentally affects grain yield. With increasing action from government, industry, and grower groups to reduce herbicide spray drift, adoption of drift reduction technologies (DRTs) especially DRT nozzles has increased over recent years. Some herbicides are less effective when sprays are too coarse as droplets may not be retained on target weed surfaces or not intercepted by target leaves. This is particularly an issue with winter annual grasses, whose small, narrow leaves and ability to grow within the wheat canopy makes their control more difficult. This study sought to understand the effect of droplet size on herbicide efficacy by evaluating the effect of six nozzles, five of which have DRT features across six different herbicides (amitrole, clodinafop, glyphosate, imazamox plus imazapyr, metribuzin, and paraquat) for the control of four winter annual grasses (annual ryegrass, Italian ryegrass, rescuegrass, and tame oats). Plants were grown in pots outdoors on the University of Queensland Gatton campus and were sprayed at 28 days after emergence in August and repeated in October 2015. Results from this study indicate DRT nozzles that produce sprays classified as Ultra-Coarse (> 650 μm $D_{v0.5}$) can preserve efficacy for some herbicides. Differences were not observed for herbicide efficacy of clodinafop, imazamox plus imazapyr, and glyphosate across both years. Coarse sprays appear to provide the most herbicide efficacy across a wide array of modes of action, and yet reduce spray drift potential compared to finer sprays.

1. Introduction

Wheat (*Triticum aestivum* L.) is Australia's most planted crop, which comprises 6% of the total wheat crop worldwide (FAO, 2011; ABARES, 2012). Winter annual grass weeds are the most competitive against wheat, but due to their similarities are difficult to control (Stone et al., 1999). Spray drift is a growing concern in agriculture, where the off-target movement of sprays can contaminate the environment, is wasteful of herbicides, and impact human health (Hewitt, 2000). Spray drift can influence herbicide-resistant weed evolution by increasing selection pressure on populations due to sub-lethal rates (Manalil et al., 2011). The need to reduce spray drift has led to the introduction of nozzles that increase droplet size which reduce drift (Ferguson et al., 2015). The spray droplet spectrum is one of the most crucial factors influencing spray drift (Hewitt, 1997a). Sprays where a majority of droplets have diameters less than 150 μm have the highest spray drift potentials (Grover et al., 1978; Byass and Lake, 1977). Pesticide spray drift is defined by the US Environmental Protection Agency (EPA) as the “the physical movement of a pesticide through the air at the time of application or soon thereafter, to any site other than the one intended for application” (EPA, 1999). Increasing the efficacy of pesticide treatments requires the utilization of optimally sized sprays for a given situation. If sprays are optimized for drift avoidance, they can also reduce environmental losses (Uk, 1977).

With increased concerns of pesticide spray drift exposure the adoption of nozzles using the Venturi process to entrain air into the spray (Dorr et al., 2013) has been encouraged. These so-called air-induction DRT nozzles utilize a pre-orifice chamber which constricts the fluid flow and drops the pressure within the nozzle, thereby reducing velocity of fluid flow which increases the droplet size once atomized. DRT features allow spray applications to be made across a wider range of environmental conditions than would be allowed for non-DRT,

* Corresponding author. Mississippi State University, MS State, Mississippi, USA
E-mail address: connor.ferguson@msstate.edu (J.C. Ferguson).

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Table 1
Herbicide treatments and their adjuvant additions applied over tillering winter annual grasses in both timings of the study in 2015.

Common name	Trade Name	Herbicide rate (g ai/ae ha^{-1})	Manufacturer	HRAC Group	Adjuvant Addition	Adjuvant Rate (% v/v)
amitrole	Amitrole T	1400	NuFarm Australia Ltd, Laverton North' Victoria, Australia	F3	soy-oil surfactant **Li700®**	0.1
clodinafop	Topik® 240 EC	50.4	Syngenta Australia Pty Ltd., Macquarie Park, New South Wales, Australia	A	methylated seed oil **Adigor®**	0.5
glyphosate	Roundup® Attack™	570	NuFarm Australia Ltd., Laverton North' Victoria, Australia	G	none	N/A[a]
imazamox + imazapyr	Intervix®	25 + 11.4	BASF Australia Ltd., Southbank, Victoria, Australia	B	ethoxylated vegetable oil **Hasten®**	0.5
metribuzin	Sencor® 480 SC	330	Bayer CropScience Pty. Ltd. Hawthorn East, Victoria, Australia	C3	none	N/A[a]
paraquat	Gramoxone® 250	300	Syngenta Australia Pty Ltd., Macquarie Park, New South Wales, Australia	D	none	N/A[a]

[a] Indicates not applicable as the label does not require the use of an adjuvant.

conventional nozzles.

Spray droplet size classification is based on the standard developed by the British Crop Protection Council (Southcombe et al., 1997) and has been updated and approved under the American Society of Agricultural and Biological Engineers (ASABE, formerly ASAE) producing the current version of its S572.1 standard in 2009 (ASABE, 2009). The spray droplet size classes according to the ASABE standard (in increasing droplet size order) are: Extremely-Fine, Very-Fine, Fine, Medium, Coarse, Very-Coarse, Extremely-Coarse, and Ultra-Coarse. The exact delineation of the spray droplet size classes are based on a set of certified reference nozzles operated at specified spray pressures using a given laboratory's droplet measurement system (ASABE, 2009).

With increasing adoption of DRT nozzles and the greater prevalence of coarser sprays, the influence on weed control efficacy is not well understood. Previous research has shown that DRT nozzles produced similar or better levels of weed control compared to conventional nozzles with glyphosate, an EPSP synthase inhibitor (HRAC group G) (Sikkema et al., 2008; Etheridge et al., 2001; Ramsdale and Messersmith, 2001a; Wolf, 2000), glufosinate, a glutamine synthesis inhibitor (group H) (Brown et al., 2007; Wolf, 2002; Etheridge et al., 2001; Jensen et al., 2001), paraquat, a photosystem I (PS I) membrane disrupter (group D) (Etheridge et al., 2001; Ramsdale and Messersmith, 2001a; Wolf, 2000) phenmedipham, a photosystem II inhibitor (group C3) (Jensen et al., 2001); imazamox (Sikkema et al., 2008; Ramsdale and Messersmith, 2001b), imazamox plus imazethapyr, imazethapyr (Wolf, 2000), chloransulam-methyl (Sikkema et al., 2008), chlorimuron, thifensulfuron, thifensulfuron plus tribenuron and flucarbazone (Wolf, 2000), all acetolactate synthase (ALS) inhibitors (group B). Additional herbicides were carfentrazone (Ramsdale and Messersmith, 2001b), a protoporphyrinogen oxidase (PPO) inhibitors (group E), fluoroxypyr plus 2,4-D, dicamba, and fluoroxypyr plus clopyralid plus MCPA (Wolf, 2000), all synthetic auxin herbicides (group O). DRT nozzles reduced efficacy of quizalofop-p-ethyl (Sikkema et al., 2008), sethoxydim, tralkoxydim, and fenoxaprop (Wolf, 2000), all acetyl-coA carboxylase (ACCase) inhibitors (group A); nicosulfuron, an ALS inhibitor (group B); bromoxynil (Brown et al., 2007) and bentazon (Wolf, 2000), both photosystem II inhibitors (group C3) and fomesafen, a PPO inhibitor (group E) (Sikkema et al., 2008). In the above studies, DRT nozzles either maintained efficacy or reduced efficacy with them, with no conflicting results across studies.

This study sought to understand the effect of droplet size on herbicide efficacy across multiple winter annual grass species. Objectives sought to compare the efficacy of multiple herbicides on Italian ryegrass, annual ryegrass, rescuegrass (*Bromus catharticus* Kunth), and tame oats and were: 1. Determine the effect of spray droplet size on the efficacy of six herbicide modes of action, 2. Assess the influence of droplet size on mode of action across grass species.

2. Materials and methods

2.1. Herbicide application and nozzle parameters

A study to compare the effect of spray droplet size on the herbicide efficacy for control of four winter annual grasses was conducted at the University of Queensland in Gatton, Queensland (QLD), Australia. The study compared herbicide efficacy across six different nozzles, five of which are DRTs, which produce four spray droplet sizes (Fine, Medium, Coarse, and Extremely-Coarse) with water when sprayed at a pressure of 350 kPa according to the results from each manufacturer. Nozzles selected for the study were the XR11002, TT11002, AIXR11002, TTI11002 (Spraying Systems Inc., Wheaton, IL, USA); MD11002 (Hardi International, Taastrup, Denmark); and the TADF11002 (Agrotop GmbH, Obertraubling, Germany). Treatments in the study were applied at 100 L ha^{-1} at a 10.4 km h^{-1} at 350 kPa. Nozzles were selected from prior research focused on the effect of spray droplet size across different application scenarios based on the Coarse spray they produced (Ferguson et al.; 2015, 2016a; 2016b). Herbicide treatments included both contact active herbicides: amitrole - carotenoid biosynthesis inhibitor (group F3) (Ashtakala et al., 1989) and paraquat - PSI inhibitor (group D) and systemic herbicides: clodinafop - ACCase inhibitor (group A), glyphosate - EPSP synthase inhibitor (group G), imazamox plus imazapyr - ALS inhibitors (group B), and metribuzin - photosystem II inhibitor (group C3). The rates and their respective adjuvant additions are listed in Table 1. Herbicide treatment rates were selected based on recommended control for tillering grasses in Queensland.

2.2. Winter annual grasses

The winter annual grasses selected for the study were: tame oats, var. 'Yarran'; rescuegrass, var. 'Atom'; annual ryegrass, var. 'Mach 1'; and Italian ryegrass, var. 'Knight'; all varieties were supplied by AusWest Seeds, Forbes, New South Wales, Australia. The annual ryegrass var. 'Mach1' is an improved tetraploid variety which has larger leaves than the diploid wild types (Anonymous, 2016). The reason that cultivated varieties were selected was to avoid confounding results from herbicide resistance possibly present in wild populations and as each seed population is bred for uniformity, ensuring consistent results across each population. Each pot had one seed planted at the recommended depth for each species (5–7 cm for tame oats, 3–5 cm for rescuegrass, and 1.5 cm for both Italian and annual ryegrass). Seeds were planted into 10 by 10 cm diameter pots, filled with 0.5 L of a standard UQ Gatton nursery potting media [1 m^3 of composted pine