Developing a comprehensive Drift Reduction Technology risk assessment scheme

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Abstract: Drift Reduction Technologies (DRTs) are becoming increasingly important for improving spray applications in many countries including New Zealand (NZ). Although there is a growing database on the performance of DRTs, there is no rating system showing the effectiveness of the DRT's performance. In Europe, DRTs are classified relative to current reference technologies as part of the rating systems used to establish spray drift risk reduction. We have recommended some key elements of such a comprehensive exposure risk reduction scheme for any country, based on prior and on-going research into the performance of specific DRTs in row, tree, and vine crops. Our intention was to create a rating system to determine the effectiveness of a given technology. This rating system would improve spray application practices and environmental stewardship for a wide range of crops and application scenarios.

Key words: adjuvant, DRT, exposure risk assessment, spray drift

Introduction

Pesticide spray drift is defined by the United States Environmental Protection Agency (US EPA) as 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). The consequences of pesticide spray drift, such as possible damage to non-target sensitive areas, wastage of chemicals, and increased regulatory attention to exposure mitigation regulations are well documented (Hewitt 2000). Pesticide spray drift can also impact human health and leach into waterways. Many in Europe have characterised these impacts as part of the risk assessment calculus (De Schampheleire *et al.* 2007). Herbicide spray drift can negatively impact adjoining sensitive non-target crops, thereby decreasing their yields (Reddy *et al.* 2010). Spray drift may also contribute to herbicide resistance in some weeds (Londo *et al.* 2010; Manalil *et al.* 2011). Resistance can create future challenges for farmers trying to control those weeds in their own crops. In an effort to reduce spray drift, technologies have been developed to improve the performance of atomized droplets during application. Most Drift Reduction Technologies (DRTs) are aimed at reducing spray drift during application. Some DRTs, such as landscape features like hedges and netting may reduce exposure to sensitive areas in their downwind wake. Hardware and chemistry DRTs that are currently marketed include spray nozzles such as those which minimise the production of small droplets with diameters below 100 or 200 μm, sprayer modifications such as hoods, spray delivery assistance such as air booms, spray liquid physical-property modifiers such as adjuvants, and/or landscape modifications (*e.g.* Yates *et al.* 1976; Wolf *et al.* 1993; Reichard *et al.* 1996; Ucar and Hall 2001).

While Europe has had DRT schemes in place for several decades (the Department of Environmental, Food and Rural Affairs, DEFRA 2001), Canada and other countries have only recently added such schemes (Health Canada 2011). Australia is considering its own DRT scheme according to the Australian Pesticides and Veterinary Medicines Authority (APVMA 2008). Across the United States, the US EPA has been working with stakeholders to develop a comprehensive risk assessment of DRTs to aid in the adoption of these technologies and reduce pesticide spray drift (EPA ETV 2012). The final EPA test protocols expected in mid to late 2013, will outline how DRTs can be evaluated in wind tunnels and/or field studies and aid in the understanding of factors that influence spray drift (Fritz *et al.* 2011). This type of standard testing protocol has been evaluated by the EPA since 2004 (Sayles *et al.* 2004).

New Zealand (NZ) is a small island nation and opportunities to put new ideas on trial before scaling them up to larger countries such as the US, is possible. A potential DRT system for trial in NZ could be based on the principles of those used by Canada and the United Kingdom.

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The Local Environmental Risk Assessments for Pesticides (LERAP) star system for reporting drift reduction (DR) ratings of various technologies could be used. The star system assigns a rating based on the theoretical lessening of spray drift based on changes from the reference spray at standard operating procedures. This LERAP star system has been in implementation for buffer zone reduction since the 2001 DEFRA (2001) and has likewise become the foundation for the proposed US system Environmental Protection Agency Environmental Technology Verification (EPA ETV) (2012).

In addition to the LERAP system, our proposed DRT classification system will have a component which will assign one of three colours, depending on how the DRT affected the pesticide's performance in tests. It works like this: if the DRT addition reduced pesticide efficacy down between 26 and 100% compared to the standard non-DRT application, the assigned colour is red; if pesticide efficacy was reduced between 10 and 25% the colour is yellow; and if pesticide efficacy was reduced by less than 10% control of the selected pest with the DRT addition, the colour is green. This three colour system will help growers and applicators select the DRT that lowers the chances of spray drift while maintaining efficacy of the grower's selected pesticide.

Explanation of LERAP and proposed DRT Classification System

The LERAP system classifies DRTs based on the reduction in driftable characteristics of an application using the change in drift potential as compared to the reference standard. This change is usually measured with monofilament in a wind tunnel but a modified scheme is used for the US, Australia, and other countries such as NZ, also using droplet size. The stars in the LERAP system are meant to help identify those DRTs that will decrease the possibility of drift during an application (Table 1). The stars are assigned based on the equation:

$$DRT_{reduction} = \frac{\text{Reference} - \text{DRT}}{\text{Reference}} \times 100.$$

Our proposed DRT system includes the zero to four star rating system based on the LERAP classification. Also included is a colour for the observed effect that a DRT has on the activity or efficacy of a pesticide with the DRT (Table 2). This three colour system will allow growers and applicators to easily select a DRT that will lessen the likelihood of spray drift during application. The growers and applicators can also easily select a DRT that will not lessen the efficacy/activity of the application itself.

To show how this DRT classification system could be administered, a study of a specific candidate DRT adjuvant at various concentrations will be used. It is well established that spray droplet size influences spray drift (Yates *et al.* 1976; Bouse *et al.* 1988; Bird *et al.* 1996; Hewitt 1997; Carlsen *et al.* 2006). The study will measure how this water soluble drift reduction agent affects glyphosate efficacy and median droplet size. Furthermore, fine droplets less than 200 μm in diameter are more likely to drift (Zhu *et al.* 1994). Drift reduction adjuvants reduce the number of fine droplets in the droplet size spectrum through changes in liquid physical properties (Dexter *et al.* 1996; Butler-Ellis *et al.* 1997; Miller *et al.* 2001). The DRT adjuvant selected is a generic polyethylene oxide (PEO) that was added to a glyphosate solution at different concentrations. PEO is a water soluble resin that is used in agriculture, construction materials, cosmetics, mining, and the pharmaceutical industry (Anonymous 2002). PEO is used in the agricultural industry primarily as an adjuvant to increase spray droplet size and reduce drift in a spray solution. The hypothesis is that PEO at a given concentration will increase median droplet size but will not lessen the efficacy of the 1,061 g a.e./ha glyphosate solution.

Materials and Methods

A field study was conducted at the University of Nebraska's West Central Research and Extension Centre near North Platte, NE USA. This study was conducted to compare droplet performance of a DRT adjuvant added to a glyphosate solution. The study compared four concentrations of PEO (POLYOX WSR N-750, Dow Chemical Company, Midland, MI USA 48640) mixed at 2 g per 10 ml ethanol. The mixtures were then added to 90 ml of water to make a 2% volume by volume (v/v) PEO stock solution. The PEO solution was added to the treatments at 5, 10, 20, and 40% PEO v/v, respectively, in a 1,061 g a.e./ha (1.6 l/ha) glyphosate (Roundup PowerMax, Monsanto, St.

Table 1. LERAP Star System for DRT classification

Drift reduction	< 25%	25–49%	50–74%	75–90%	> 90%
LERAP rating	no star	*	**	***	****[a]

[a] the maximum (four-star) rating is still under consideration in the Environmental Risk Assessments for Pesticides (LERAP) system but will be included to help select the best Drift Reduction Technology (DRT) with inclusion in the scheme

Table 2. Colour and LERAP Star System for DRT classification

Drift reduction and Pest control	< 25%	25–49%	50–74%	75–90%	> 90%
LERAP rating	no star	*	**	***	****
Colour rating		red		yellow	green

Explanations – see table 1

Louis, MO USA 63167) plus a 5% v/v ammonium sulphate (Bronc, Wilbur-Ellis Company, Fresno, CA USA 93755) solution. Each treatment was analysed using laser diffraction (Sympatec Varios KF, Sympatec Inc., Clausthal-Zellerfeld, Germany 38768) to determine its relative droplet size spectrum. The laser diffraction instrument was set-up in a static spray chamber. In the chamber, an actuating arm traversed the nozzle and spray pattern through the laser. Treatments were applied at an application carrier volume of 76 l/ha with flat-fan XR11003-SS (stainless steel) nozzles (Spraying Systems Company, Wheaton, IL USA 60187) at a pressure of 255 kPa. Three replicates at each concentration were done. Each treatment was compared to the LERAP reference treatment at 94 l/ha with a flat-fan XR11003-SS nozzle (Spraying Systems Company, Wheaton, IL USA 60187) at 300 kPa. The spraying parameters selected for discussion were the $D_{v0.5}$ which is the median droplet diameter in the spectrum, and the percentage of droplets less than 210 μm (a proxy for driftable fines), and the relative span. The relative span (RS) is defined as the $(D_{v0.9} – D_{v0.1})/D_{v0.5}$, which is better defined as the 10th percentile droplet diameter subtracted from the 90th percentile droplet diameter and divided by the 50th percentile droplet diameter.

Efficacy comparison

The efficacy comparison study contained the five PEO concentration treatments and an untreated check (6 total treatments) arranged in a randomised complete block design with four replications. The field study was applied over 12 row plots, which were planted with six different plant species in two row increments at 76 cm spacing. Plant species used were non-glyphosate-resistant corn (*Zea mays* L.) non-glyphosate-resistant soybeans (*Glycine max* (L.) Merr.), amaranth (*Amaranthus hypochondriacus* L.), quinoa (*Chenopodium quinoa* Willd.), velvetleaf (*Abutilon theophrasti* Medik.), and green bristle grass (*Setaria viridis* (L.) Beauv.). Five plants of each species from each plot were harvested at four weeks after treatment. The chosen plants were dried for 48 h at 60°C.

In 2012, drought conditions persisted which prevented the emergence and establishment of amaranth, quinoa, velvetleaf, and green bristle grass. For this reason, only the corn and soybean data from 2012 will be presented.

Statistical parameters

The spray droplet size data were analysed using a mixed model with replication as the random variable, and PEO concentration as the fixed (main effect) variable. The main and simple effect variables were the same as the dry weight data. The Tukey-Kramer adjustment was also implemented. The dry weight data were converted to one plant per plot. Analysis was done using a general linear mixed model with replication as the random variable and PEO concentration as the fixed variable. Each species was analysed separately. The Tukey-Kramer adjustment was implemented to insure that differences were correctly reported. The two years of data were different ($p < 0.0001$), so, we analysed the data from each year separately. The data for both studies were analysed in SAS (Statistical Analysis System – SAS) software. Version 9.2. SAS Institute, Inc., Cary, NC 27513) with a significance of $\alpha = 0.05$.

Results

With respect to droplet size and distribution, there were main effect differences observed where the 20 and 40% PEO treatment had a larger $D_{v0.5}$ than the reference treatment (Table 3). The 10, 20, and 40% PEO treatment had a lower percentage of droplets with a diameter < 210 μm than the reference treatment. There were no differences observed in the relative span for all treatments. In terms of drift reduction, the 10% PEO treatment reduced drift by 27%, and the 20% PEO treatment reduced drift by 40%. Both treatments were given a one-star rating in the LERAP DRT classification. The 40% PEO solution reduced drift by 60% which meant that this treatment received a two-star rating in the LERAP system. The 0 and the 5% PEO solutions did not reduce drift over 25% and thus did not receive a star according to the LERAP system.

PEO concentration and efficacy results

In 2011, there were no differences between the treatments for all six species across all PEO concentrations (Table 4). In 2012, there was no main effect difference observed in corn and soybeans. At all concentrations of PEO across all plant species over both years, no loss in herbicide efficacy was observed. Since there was no observed change in glyphosate efficacy, the colour designation for all treatments in the proposed DRT classification scheme would be green (Table 3).

Discussion

The concentration of PEO did not lessen dry weight reductions with glyphosate, even at a 40% v/v addition. It appears that PEO additions should equal at least 20% v/v to see a significant improvement in the reduction of fine droplets with the XR11003 nozzle. Additions at this per cent drastically enhance the spray quality and drift reduction characteristics of the tank mix. Polyethylene oxide's effect can also vary on droplet formation based on the viscosities that can be observed at varying molecular weighted PEO solutions (Tirtaatmadja *et al.* 2006). Thus, depending on the concentration and the molecular weight of a selected PEO adjuvant, the DRT characteristics will vary. Selected adjuvant additions improve the performance of spray droplets (Kirk 2003; Lan *et al.* 2008). Such additions can also increase the droplet surface tension and viscosity which improve the drift reduction and deposition characteristics (Miller and Ellis 2000; Hewitt 2007). Increasing the volume of drift reduction adjuvants in a tank mix can coarsen the spray, thereby reducing its drift potential (Kirk 2003).

The study gives an insight into how our proposed DRT scheme could classify the results of a drift study for the benefit of growers and applicators. The same DRT at different concentrations can change the rating received from the LERAP system. The dry weight data from the

Table 3. Droplet size spectra from a laser diffraction instrument of polyethylene oxide (PEO) additions and the subsequent modified the Local Environmental Risk Assessments for Pesticides Drift Reduction Technology (LERAP DRT) and the proposed colour classification

PEO addition [%]	Sprayer type	Pressure [kPa]	$D_{v0.5}$[a] [µm]	< 210 µm [%]	RS[b]	Drift reduction	LERAP	Colour
0	reference	300	163 c	70 d	1.70 a	N/A[c]	N/A	N/A
0	conventional	255	171 c	63 d	1.57 a	10	NS[d]	green
5	conventional	255	184 bc	58 cd	1.65 a	17	NS	green
10	conventional	255	206 bc	51 bc	1.64 a	27	*	green
20	conventional	255	243 b	42 b	1.65 a	40	*	green
40	conventional	255	333 a	28 a	1.50 a	60	**	green

[a] $D_{v0.5}$ – median droplet diameter
[b] RS – relative span, $(D_{v0.9} - D_{v0.1})/D_{v0.5}$ – the 90th percentile droplet size divided by the 10th percentile droplet size that is then divided by the 50th percentile droplet size
[c] N/A – not applicable
[d] NS – no star. The 0 and 5% PEO solutions did not reduce drift > 25%
The letters represent differences between the treatments and their corresponding droplet parameters with an $\alpha = 0.05$

Table 4. Dry weight reductions with PEO additions to a 1,061 g a.e./ha solution with a row-crop sprayer

PEO concentration [%]	Corn	Soybean	Amaranth	Quinoa	Velvetleaf	Bristlegrass	Corn	Soybean
	2011						2012	
	[g]						[g]	
Untreated check	18.54	1.21	2.17	2.70	8.12	11.90	55.38	8.59
0	6.98	0.87	1.87	0.66	2.27	0	36.02	1.78
5	19.17	2.28	2.26	0.75	4.23	9.08	43.57	4.67
10	17.90	2.58	1.93	1.14	5.10	7.09	28.74	2.92
20	17.63	1.80	0.95	1.84	2.54	4.04	36.44	2.97
40	4.38	1.70	1.57	1.48	3.48	5.00	32.82	4.34

Explanations – see table 3

two years of the study, indicate that PEO would be a beneficial DRT when glyphosate applications are made. The decrease in predicted drift based on droplet size (Table 3) indicates that at any concentration, PEO would be a beneficial DRT with an XR11003 nozzle. The new proposed classification scheme will be a valuable tool for informing growers and applicators about the benefits and performance of a DRT that will reduce pesticide spray drift. The growers and applicators will be able to select a technology that does not reduce chemical efficacy.

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