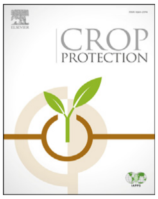
Crop Protection 83 (2016) 1–8

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro



Herbicide coverage in narrow row soybean as influenced by spray nozzle design and carrier volume

Travis R. Legleiter*, William G. Johnson

Purdue University, Department of Botany and Plant Pathology, Lilly Hall of Life Sciences, 915 W. State Street, West Lafayette, IN 47907, USA

ARTICLE INFO

Article history:
Received 10 September 2015
Received in revised form
15 January 2016
Accepted 21 January 2016
Available online 1 February 2016

Keywords:
Herbicide spray coverage
Nozzles
Postemergence herbicide applications
Carrier volume
Soybean

ABSTRACT

The use of reduced drift nozzles that produce larger droplet sizes that are less prone to drift will likely be required for use of future postemergence herbicide applications in soybean in the USA. Experiments to evaluate the effect of reduced drift spray nozzles on spray solution coverage were conducted in the field in Indiana. Air induction extended range (AIXR) and turbo TeeJet air induction (TTI) nozzles that produce extremely coarse to ultra coarse droplets were compared to extended range (XR) and Turbo TeeJet (TT) nozzle that produced fine to coarse droplets. Each nozzle was evaluated for spray coverage at 94 and 140 l ha^{-1} spray volumes using water sensitive cards. Precipitation varied between site years and resulted in differences in soybean canopy development and spray solution coverage. Coverage was greater at the top of the canopy than at the bottom of the soybean canopy as expected. An interaction occurred at the top and middle of the canopy in which the AIXR and TTI nozzles had similar coverage between the two spray volumes, whereas the XR and TT nozzles had greater coverage at 140 l ha^{-1} carrier volume than 94 l ha^{-1} carrier spray volume. Spray solution coverage at the bottom of the canopy, where target weeds would be, was similar between all nozzle types. Coverage was greater at the bottom of the canopy at 140 l ha^{-1} spray volume than with the 94 l ha^{-1} carrier volume. Spray volume has a greater influence on coverage than spray nozzle type and AIXR and TTI nozzles are less prone to coverage differences due to spray volume than the XR and TT nozzles.

1. Introduction

There are currently 17 weed species resistant to glyphosate that occur in soybean production, and this is the highest number of glyphosate-resistant weed species in any major grain crop (Heap, 2015). Glyphosate-resistant weeds in United States soybean include six economically important dicots: Palmer amaranth (*Amaranthus palmeri* S. Wats.), Tall waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer), common ragweed (*Ambrosia artemisiifolia* L.), giant ragweed (*Ambrosia trifida* L.), and horseweed (*Conyza Canadensis* (L.) *Cronq.*) (Heap, 2014). Commercial use of soybean that is resistant to dicamba or 2,4-D will aid farmers in controlling these economically important dicot weeds that are susceptible to the growth regulator herbicides (Behrens et al., 2007; Wright et al., 2010). The 2,4-D and dicamba resistant soybean varieties will be especially useful in providing effective postemergence control of glyphosate-resistant horseweed, tall waterhemp, and Palmer amaranth (Johnson et al., 2010; Robinson et al., 2012; Craigmyle et al., 2013).

Despite the potential utility of dicamba or 2,4-D resistant soybean technology, there are concerns that off-site movement of growth regulator herbicides onto sensitive vegetation will cause the technology to falter (Johnson et al., 2012). Dicamba and 2,4-D are active at relatively low doses, with stem epinasty, leaf cupping, and bud suppression occurring to susceptible dicot plants at doses as low as 1/1000th of labeled use rates (Marth and Mitchell, 1944; Chang and Vanden Born, 1971; Robinson et al., 2013). Soybean that are not resistant to 2,4-D or dicamba are likely to be grown adjacent to resistant-soybean fields and will be susceptible to injury and yield loss from off-site movement of 2,4-D and dicamba. The low doses that would be typically associated with off target movement of the 2,4-D and dicamba have been shown to cause soybean injury and yield losses (Wax et al., 1969; Auch and Arnold, 1978; Robinson et al., 2013). Processing tomatoes are grown on 3000 ha of Indiana agricultural ground and are dispersed amongst corn and soybean (USDA, 2014). Tomatoes are of concern for drift injury due to high sensitivity, with only 1/228th of a labeled dose of dicamba causing five percent flower loss (Kruger

---

* Corresponding author.
E-mail addresses: tlegleit@purdue.edu (T.R. Legleiter), wgj@purdue.edu (W.G. Johnson).

http://dx.doi.org/10.1016/j.cropro.2016.01.009

et al., 2012). Finally the large rural population of 21 people km^{-2} in the state of Indiana is also of great concern as many of those living in rural areas have ornamental and vegetable plants that are susceptible to off target 2,4-D and dicamba (USCB, 2010). Successful adoption of these new herbicide resistant traits will be dependent on the ability of users to minimize off-site movement to sensitive vegetation.

The quantity of off-site droplet movement or drift is influenced by wind speed, boom height, formulation, and droplet spectra (Combellack, 1982; Carlsen et al., 2006). While meteorological factors cannot be controlled, application factors can be manipulated to ensure decreased likelihood of herbicide drift, most specifically droplet spectra or droplet size. Droplets that are larger are less apt to move horizontally or off-site by air currents due their greater mass, as well as decreased time in the state of fall (Bode, 1987). The spectrum of droplet sizes in a spray pattern is affected by the nozzle type, nozzle size, and pressure (Combellack et al., 1996; Nuyttens et al., 2007). Nozzles with a pre-orifice and/or air induction design produce larger diameter droplets than traditional single stage flat fan nozzles at equivalent nozzle sizes and spray pressures (Johnson et al., 2006). Reducing off-site movement of dicamba and 2,4-D will require use of nozzles types with air induction and pre-orifice designs at specified sizes and pressures that produce larger droplets.

It has been well documented that droplet size and carrier volume can influence herbicide coverage and performance. An extensive review by Knoche (1994) found that decreasing droplet size increased herbicide performance in general and that carrier volume also influenced performance with carrier volumes at the far ends of the spectrum reducing herbicide performance. Further analysis showed that drift reduction nozzles that produced larger droplets provided equivalent glyphosate performance as conventional nozzles, despite a reduction in coverage (Ramsdale and Messersmith, 2001). As suggested in the review by Knoche (1994) droplet size and carrier volume are interrelated and major factors of herbicide coverage and performance, although the influence of the specific species being targeted, crop canopy, and herbicides must also be considered. A large number of studies which evaluated the effects of droplet size on herbicide coverage of weeds exclude a crop canopy as a factor, although a couple of studies have demonstrated that a soybean crop canopy can filter spray droplets and thus reduce spray coverage lower in the canopy (Bradley and Sweets, 2008; Hanna et al., 2008).

Utilization of dicamba and 2,4-D resistant soybeans will likely be on fields in which glyphosate-resistant weeds exist (Norsworthy et al., 2012). The application of the 2,4-D and dicamba products can occur preplant and postemergence after a partial soybean canopy development. The manufacturers label will likely require the herbicide to be applied with low-drift nozzles producing very coarse to ultra coarse droplets. The target weeds at postemergence application timings should be lower in the canopy, if applications are made at appropriate labeled weed heights, and thus the influence of the crop canopy on spray coverage with drift reduction nozzle types warrants investigation. The objective of this study was to evaluate differences in spray coverage in a narrow row soybean canopy at two spray carrier volumes using four spray nozzle designs that include two traditional nozzles and two label required drift reduction nozzles.

2. Material and methods

2.1. Herbicide coverage field experiments

2.1.1. Site descriptions and plot maintenance

Field trials were conducted at the Purdue University Diagnostic Training Center in West Lafayette, Indiana on Starks-Fincastle complex silt loam and Rockfield silt loam soils during the 2012 and 2013 growing seasons, respectively. Glyphosate-resistant soybean varieties were planted in 38-cm rows at approximate seeding rates of 299,000 seeds ha^{-1} on May 29, 2012 and June 5, 2013. Plot areas were maintained weed free throughout the duration of the trials with use of burndown treatments prior to planting, protoporphyrinogen oxidase inhibitor (Group 14) residual herbicides applied at planting, and glyphosate applied postemergence as needed.

2.1.2. Herbicide application

Herbicide applications were made on July 16, 2012 and July 12, 2013 when the soybean height reached an average of 31-cm tall in an effort to mimic a mid-to late-postemergence herbicide application following a preemergence herbicide application. Soybean canopy development differed between the two years due differences in precipitation. During the 2012 season droughty conditions occurred and thus soybean plants were at the five to six trifoliate stage as compared to 2013 when precipitation was closer to the 30-year average and soybean plants were at the seven to eight trifoliate stage. Weather conditions at the time of application as well as precipitation totals are outlined in Table 1. Herbicide treatments were applied using a self-propelled multi-boom sprayer traveling at 5.6 km h^{-1} with eight booms containing the appropriate nozzles as described below, pressurized at 138 kPa. A herbicide tank mix of 840 g ha^{-1} glyphosate, 560 g ha^{-1} 2,4-D amine, and 2 g l^{-1} ammonium sulfate were applied to mimic a growth regulator plus glyphosate postemergence application.

2.1.3. Experimental design, data collection, and analysis

A two-way factorial treatment structure in a randomized complete block design with four replications was used for both site years. Individual plots were 3 m wide by 6 m in length and included eight 38-cm soybean rows. The two factors included nozzle type and spray volume. Four 110° flat fan nozzles from the TeeJet[1] brand including Extended Range (XR), TurboTeeJet (TT), Air Induction Extended Range (AIXR), and Turbo TeeJet Induction (TTI) were selected for use in the study. The four nozzles were selected to represent a traditional flat fan nozzle (XR), a pre-orifice nozzle design (TT), and two air induction nozzles that will be among the list of required nozzles for postemergence growth regulator applications (AIXR and TTI). The second factor in the factorial design was spray volume with 94 l ha^{-1} and 140 l ha^{-1} representing two

Table 1
Environmental conditions at the time of herbicide application and accumulated precipitation for 2012 and 2013 field trials.

		Trial year	
		2012	2013
Application date		July 16	July 12
Application time		9:00 AM	12:30 PM
Temperature	C	32.2	26.7
Relative humidity	%	50	60
Wind speed	km h^{-1}	3.2	4.8
Accumulated precipitation[a]	cm	4.17	9.54
Crop stage	trifoliate	5 to 6	7 to 8

[a] Precipitation accumulated from planting (May 29, 2012 & June 5, 2013) to application date.

---

[1] Spraying Systems Co., Wheaton, Illinois.