BioOne COMPLETE

Survey of ground and aerial herbicide application practices in Arkansas agronomic crops

Authors: Butts, Thomas R., Barber, L. Tom, Norsworthy, Jason K., and Davis, Jason

Source: Weed Technology, 35(1) : 1-11

Published By: Weed Science Society of America

URL: https://doi.org/10.1017/wet.2020.81

BioOne Complete (complete.BioOne.org) is a full-text database of 200 subscribed and open-access titles in the biological, ecological, and environmental sciences published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Complete website, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/terms-of-use.

Usage of BioOne Complete content is strictly limited to personal, educational, and non - commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

Downloaded From: https://complete.bioone.org/journals/Weed-Technology on 29 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

Weed Technology

www.cambridge.org/wet

Survey of ground and aerial herbicide application practices in Arkansas agronomic crops

Thomas R. Butts[1], L. Tom Barber[2], Jason K. Norsworthy[3] and Jason Davis[4]

[1]Assistant Professor, Extension Weed Scientist, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Lonoke, AR, USA; [2]Professor, Extension Weed Scientist, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Lonoke, AR, USA; [3]Distinguished Professor, Department of Crop, Soil, and Environmental Sciences, University of Arkansas-Fayetteville, Fayetteville, AR, USA and [4]Instructor, Application Technologist, Department of Agriculture and Natural Resources, University of Arkansas System Division of Agriculture, Batesville, AR, USA

Research Article

Cite this article: Butts TR, Barber LT, Norsworthy JK, Davis J (2021) Survey of ground and aerial herbicide application practices in Arkansas agronomic crops. Weed Technol. **35**: 1–11. doi: 10.1017/wet.2020.81

Received: 9 May 2020
Revised: 5 July 2020
Accepted: 15 July 2020
First published online: 21 July 2020

Associate Editor:
Michael Walsh, University of Sydney

Keywords:
Application optimization; application technology; boom height; coverage; drift; efficacy; nozzles; precision agriculture; weed control

Author for correspondence:
Thomas R. Butts, Assistant Professor, Extension Weed Scientist, University of Arkansas System Division of Agriculture, 2001 Hwy 70 E, Lonoke, AR 72086. Email: tbutts@uaex.edu

Abstract

A thorough understanding of commonly used herbicide application practices and technologies is needed to provide recommendations and determine necessary application education efforts. An online survey to assess ground and aerial herbicide application practices in Arkansas was made available online in spring 2019. The survey was direct-emailed to 272 agricultural aviators and 831 certified commercial pesticide applicators, as well as made publicly available online through multiple media sources. A total of 124 responses were received, of which 75 responses were specific to herbicide applications in Arkansas agronomic crops, accounting for approximately 49% of Arkansas' planted agronomic crop hectares in 2019. Ground and aerial application equipment were used for 49% and 51% of the herbicide applications on reported hectares, respectively. Rate controllers were commonly used application technologies for both ground and aerial application equipment. In contrast, global positioning system-driven automatic nozzle and boom shut-offs were much more common on ground spray equipment than aerial equipment. Applicator knowledge of nozzles and usage was limited, regardless of ground or aerial applicators, as only 28% of respondents provided a specific nozzle type used, indicating a need for educational efforts on nozzles and their importance in herbicide applications. Of the reported nozzle types, venturi nozzles and straight-stream nozzles were the most commonly used for ground and aerial spray equipment, respectively. Spray carrier volumes of 96.3 and 118.8 L ha^{-1} for ground spray equipment and 49.6 and 59.9 L ha^{-1} for aerial application equipment were the means of reported spray volumes for systemic and contact herbicides, respectively. Respondents indicated application optimization was a major benefit of utilizing newer application technologies, herbicide drift was a primary challenge, and research needs expressed by respondents included adjuvants, spray volume efficacy, and herbicide drift. Findings from this survey provided insight into current practices, technologies, and needs of Arkansas herbicide applicators. Research and education efforts can be implemented as a result to address aforementioned needs while providing applied research-based information to applicators based on current practices.

Introduction

Herbicides are the most extensively used pesticide applied to agronomic crops in the United States. Since 2013, more than 93% of the planted hectares for corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), peanut (*Arachis hypogaea* L.), rice (*Oryza sativa* L.), and soybean [*Glycine max* (L.) Merr.] have received a herbicide application (USDA-NASS 2020). In contrast, the next most frequently used pesticides were fungicides in peanut (88% of planted hectares) followed by other chemicals (65%) and insecticides (56%) in cotton. All other pesticide applications were reported on less than 50% of the planted hectares for the respective crop (USDA-NASS 2020).

Although herbicide applications are common occurrences, the specific application techniques and delivery methods are often overlooked fundamental steps required for optimizing herbicide performance (Kudsk 2017). The herbicide application process is complex with numerous opportunities for failure even before spray deposits reach the intended target (Ebert et al. 1999). Improper herbicide application practices, such as incorrect nozzle selection, boom or flight height, equipment setup, spray volume, and sprayer speed, can lead to increased drift potential (Alves et al. 2017; Bueno et al. 2017; Hewitt et al. 2002; Nordby and Skuterud 1974), reduced spray pattern uniformity (Azimi et al. 1985; Forney et al. 2017), reduced coverage (Ferguson et al. 2016; Legleiter and Johnson 2016), and reduced weed control (Butts et al. 2018;

© The Author(s), 2020. Published by Cambridge University Press on behalf of Weed Science Society of America. This is an Open Access article, distributed under the terms of the Creative Commons Attribution licence (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted re-use, distribution, and reproduction in any medium, provided the original work is properly cited.

Downloaded From: https://complete.bioone.org/journals/Weed-Technology on 29 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

Knoche 1994; Meyer et al. 2016). Herbicide drift to roadsides and field borders caused by application miscues has led to the evolution of herbicide resistance within two generations of *Amaranthus* spp. (Vieira et al. 2020). As a result, focus should be placed on using precise application procedures to maximize efficacy of herbicide applications while maintaining environmental safety (Matthews et al. 2014).

Droplet size is often one of the primary management decisions for herbicide applications because increasing droplet size has been shown to reduce drift potential (Hewitt 1997). Numerous application practices and decisions influence droplet size from both ground and aerial spray equipment including herbicide formulations (Fritz et al. 2009; Miller and Butler Ellis 2000), spray mixtures (Bouse et al. 1990; Butler Ellis et al. 1997), spray pressure (Nuyttens et al. 2007), and nozzle type and size (Bouse 1994; Creech et al. 2015a; Nuyttens et al. 2007). Droplet size can be increased on ground spray equipment, and particle drift potential can be decreased by changing the nozzle type (venturi nozzles), increasing the orifice size, decreasing the pressure, and reducing the boom height (Anonymous 2014; Matthews et al. 2014). On aerial spray equipment, managing droplet size and particle drift potential is different as wind shear becomes the driving force for spray atomization (Matthews et al. 2014; O'Connor-Marer 2014). Droplet size can be increased by increasing pressure, equipping straight-stream nozzles, using a zero-degree deflection angle, and decreasing flight speed, which results in reduced particle drift potential (Bouse 1994; Hewitt et al. 2002; O'Connor-Marer 2014). However, it is unknown how prevalent these application practices are among current herbicide applicators.

New technologies have also been developed in recent years that can improve application efficiency. A wide range of nozzle types and designs are now available that influence numerous spray characteristics such as droplet size, velocity, and spray angle to suit specific herbicide application requirements (Greenleaf Technologies 2020; Pentair Hypro 2018; TeeJet Technologies 2014; Transland 2020; Wilger 2017). The adoption of global positioning system (GPS)-driven automatic boom section control on ground spray equipment has been shown to reduce the area applied by up to 17.5% compared to no section control (Luck et al. 2010a), and reduced over-application from 12.4% to 6.2% when compared to manual boom section control (Luck et al. 2010b). Pulse-width modulation (PWM) sprayers provide application flexibility because they allow for several factors, including application pressure and spray droplet size, to be held constant across a range of sprayer speeds while still precisely maintaining the required flow output (Butts et al. 2019a; Butts and Kruger 2018). Weed sensing technologies with the ability to selectively apply herbicides to detected weeds are becoming commercially available (Blue River Technology 2019; Weed-It 2020). With the abundance of new technologies available, there is a need to identify the levels of adoption and understanding of these technologies by applicators. Research and educational efforts revolving around precision weed control techniques can then be implemented toward ensuring effective future applications of herbicides (Westwood et al. 2018).

A survey of consultants in the mid-South of the United States indicated a need for research to evaluate various herbicide application practices, including coverage and efficacy as a function of nozzle selection, hooded sprayers, adjuvant selection, and application techniques to minimize spray drift and maximize herbicide performance (Norsworthy et al. 2013; Riar et al. 2013; Schwartz-Lazaro et al. 2018). For application research to be applicable, a baseline of current herbicide application practices and technologies used needs to be established. The objective of this survey was to determine common ground and aerial herbicide application practices and technologies used in Arkansas agronomic crop production. A more thorough understanding of commonly used herbicide application practices and technologies would help to correctly diagnose misapplication errors quicker, direct future research methods to account for standard practices, and assist with determining necessary education efforts.

Materials and Methods

A survey to determine and assess commonly used ground and aerial herbicide application practices in Arkansas was made available online in spring 2019. The online survey was conducted using the Qualtrics survey platform (Qualtrics, Provo, UT) and was distributed through multiple vectors. A link to the survey and a short description of it was direct-emailed to 272 agricultural aviators and 831 certified commercial pesticide applicators; email addresses were obtained from the Arkansas Agricultural Aviation Association and the Arkansas State Plant Board Pesticide Division, respectively. Additionally, the survey link was distributed and publicized through multiple online media sources. Specific survey questions can be found in Supplementary Appendix S1.

The survey included 24 questions divided into five sections according to requested information. The first section consisted of demographic and background information such as age of respondent, years as a certified applicator, county location and number of hectares under supervision, and the percentage of those hectares under various agronomic cropping systems. The second section focused on the prevalence of ground versus aerial herbicide applications and the use of precision sprayer equipment. The premise of the third section was to gather in-depth nozzle and spray volume information for herbicide applications. The fourth section determined details on ground equipment boom height or agricultural aircraft flight height and ground or flight speed. The final section included several open-ended opinion questions to identify respondent views on the benefits of application technology, herbicide application challenges, and future application research needs.

Data collected from the online survey software were directly imported into a spreadsheet software (Microsoft Excel for Office 365, version 2002, Redmond, WA) for analysis (Shaw et al. 2009). Individual responses for the open-ended opinion questions were reduced to one keyword to summarize each respondent's statement. Keywords were then analyzed for word frequency using the "tm" and "SnowballC" packages in R 3.5.1 statistical software (R Core Team 2018). Not all respondents provided an answer to every survey question. The total number of observations (n) are included for each survey question presented in the results and discussion.

Results and Discussion

Demographic and Background Information

A total of 124 survey responses were recorded, which resulted in about an 11% response rate to the emailed survey. However, because of publicizing the survey openly on multiple online media sources, it is not possible to determine the total pool of survey recipients. Of the 124 total survey responses, 75 were primarily associated with Arkansas agronomic crops, and are the focus of the research presented here.

Downloaded From: https://complete.bioone.org/journals/Weed-Technology on 29 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

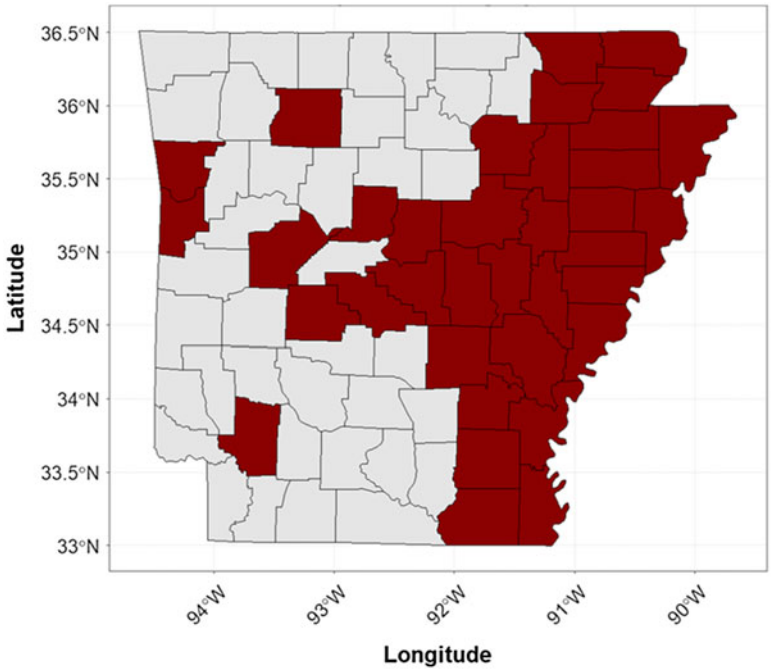


Figure 1. Counties of Arkansas that were represented by survey respondents for agronomic crop herbicide applications (red shading).

Survey responses were recorded from 36 counties in Arkansas representing nearly all agronomic crop-producing counties in the state (Figure 1). Respondents accounted for a total of 1,057,000 Arkansas agronomic crop hectares planted with corn, cotton, grain sorghum [*Sorghum bicolor* (L.) Moench ssp. bicolor], peanut, rice, soybean, and wheat (*Triticum aestivum* L.). The reported hectares accounted for approximately 49% of Arkansas' planted agronomic hectares in 2019 (USDA-NASS 2019). The key demographic for this survey was well represented because the primary role of respondents was pesticide applicator (54%) followed by farmer (28%), agronomist/salesperson (9%), and crop consultant (8%), respectively. Although some respondents indicated a primary role other than a pesticide applicator, all respondents indicated holding a pesticide applicator certification, and therefore, were included in the subsequent discussions.

Respondent age and years as a certified applicator elucidate several intriguing aspects of the Arkansas pesticide applicator industry because both response variables exhibited a skewed left distribution (Figure 2). Because most applicators had significant herbicide application experience (68% had more than 15 years as a certified applicator), applications should be more accurate and efficacious with reduced errors. Conversely, the skewed left distribution of applicator age can have negative consequences for the herbicide application industry. As more applicators near retirement, data suggest fewer younger certified applicators are being effectively trained first-hand to replace the workforce, which may lead to improper applicators due to insufficient training and experience of the younger workforce. Additionally, the lack of younger professionals in the industry may lead to a deficiency in available certified applicators to cover all hectares requiring a herbicide application, especially in a timely, safe, and effective manner. Similar results and industry concerns emerged from a survey of National Agricultural Aviation Association members as 67% of operators were 50 years of age or older (SM Bretthauer, personal communication).

Technologies Used in Ground and Aerial Applications

Averaged across respondents and crops, it was reported that herbicides were applied nearly equally from ground and aerial equipment in Arkansas (Table 1). Respondents indicated ground spray equipment and aerial application equipment were used for 49% and 51% of the herbicide applications on reported hectares, respectively. Of the 72 respondents who answered this question, 14 (19%) and 23 (32%) individuals indicated that ground equipment or agricultural aircraft were exclusively used for herbicide applications, respectively. Therefore, approximately 49% of respondents used a combination of ground and aerial equipment to apply herbicides across agronomic crops throughout a growing season.

It is expected that rice hectares account for most of the aerial herbicide applications in the state due to the flooded environment. A large proportion of the preflood rice area (62%) received an aerial herbicide application; however, the use of ground spray equipment for preflood treatment is likely to increase with changing irrigation practices. As furrow-irrigated rice hectares continue to increase (Hardke 2019), ground equipment may become more popular among rice growers to apply herbicides.

Survey respondents were asked about usage of application technologies such as rate controllers, GPS-driven boom and nozzle control, and specialty-type sprayers. Survey results indicated rate controllers were commonly used with both ground and aerial application equipment (Table 1). Seventy-two percent of ground equipment respondents (n = 46) and 75% of aerial equipment respondents (n = 55) reported using rate controllers. Although rate controllers were common for both ground and aerial equipment, the use of GPS-driven technology with automatic boom and nozzle shut-offs differed between the two application methods.

The use of ground spray equipment with GPS-driven automatic boom and nozzle shut-offs was reported by 72% of the respondents (n = 46; Table 1). The high use rates of these technologies on

Downloaded From: https://complete.bioone.org/journals/Weed-Technology on 29 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

Table 1. Application method used on total reported hectares and pre-flood rice hectares, rate controllers used, and global positioning system-driven boom and nozzle shut-offs used from ground and aerial spray equipment as reported by Arkansas certified pesticide applicators in a 2019 survey.[a]

	Ground		Aerial	
	% of respondents	Number of obs. (n)	% of respondents	Number of obs. (n)
Application method used on total reported hectares	49	72	51	72
Application method used on reported preflood rice hectares	38	54	62	54
Rate controllers used	72	46	75	55
GPS-driven boom and nozzle shut-offs used	72	46	56	55

[a]Abbreviation: GPS, global positioning system.

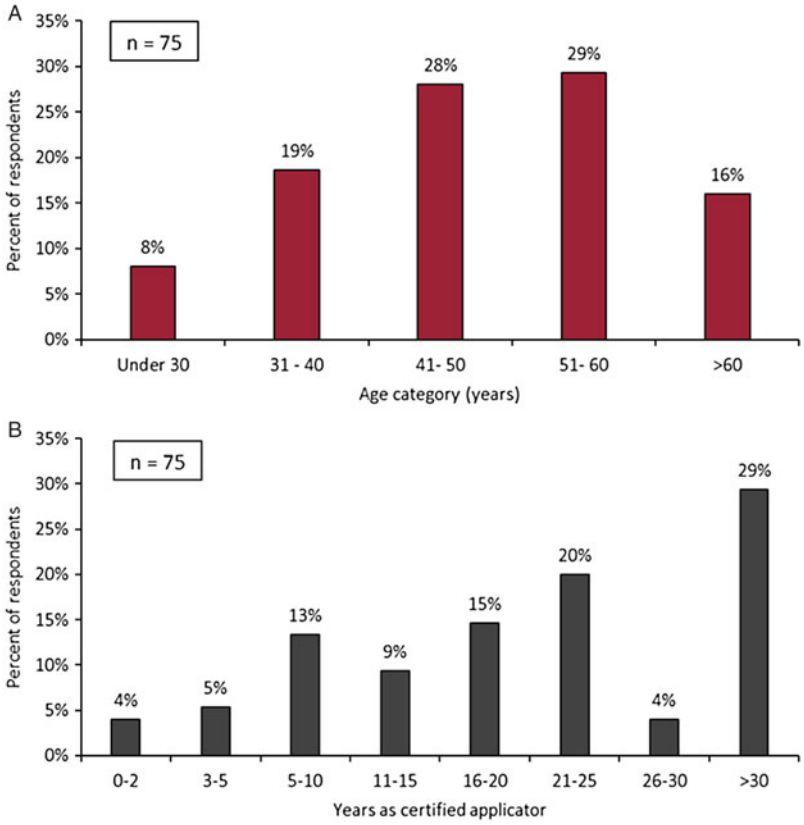


Figure 2. Age (A) and years as a certified applicator (B) of survey respondents for Arkansas agronomic crop herbicide applications. Percentages may not total 100% due to rounding. The number of total observations is noted in the boxes at top left.

ground spray equipment was expected as other research has reported high adoption rates (Sharda et al. 2011, 2013), but it is a positive attribute for Arkansas agriculture that these technologies are readily available to help improve the accuracy of herbicide applications. In contrast, only 56% of respondents indicated the use of GPS-driven automatic boom and nozzle shut-offs on aerial spray equipment (n = 55). It is unclear why GPS-driven automatic shutoffs are not as common on agricultural aircraft because the technology is available. One possible reason for the lack of adoption of GPS-driven automatic boom and nozzle shutoffs by agricultural pilots may be because the technology is still relatively new to aerial application equipment compared with ground sprayer equipment (SM Bretthauer, personal communication).

Specialty-type sprayers such as PWM, electrostatic, and direct injection, are application technologies that may affect the outcome of herbicide applications (Figure 3). More than 70% of respondents did not use any specialty-type sprayer. However, 23% of total respondents (n = 71) used PWM, and when aerial application-only respondents were removed, 35% of the remaining respondents used PWM (n = 46). Therefore, a substantial number of agronomic crop hectares received herbicide applications from PWM ground spray equipment. Pulse-width modulation spray equipment has numerous benefits including individual nozzle control, overlap and turn compensation, and capability to make real-time flow rate adjustments that minimally affect droplet size (Butts and Kruger 2018); however, specific application parameters need to be followed to achieve the most effective application possible (Butts et al. 2019a, 2019b). Direct injection and electrostatic technologies were not widely used, with only four and two respondents indicating use of these types of sprayers, respectively.

Nozzles and Spray Volume

Survey results indicated that few nozzle types were used for ground and aerial herbicide applications during a typical growing season (Table 2). A range of 1 to 5 (mean, 2) nozzle types were used for

Downloaded From: https://complete.bioone.org/journals/Weed-Technology on 29 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

Table 2. Mean, median, mode, minimum, and maximum number of nozzle types used in a growing season from ground and aerial spray equipment as reported by Arkansas certified pesticide applicators in a 2019 survey.

	Ground	Aerial
Mean	2	2
Median	2	1
Mode	3	1
Minimum	1	1
Maximum	5	5
No. of observations	35	45

Table 3. Mean, median, mode, minimum, and maximum spray carrier volumes for systemic and contact herbicides applied from ground and aerial application equipment reported by Arkansas certified pesticide applicators in a 2019 survey.

	Ground		Aerial	
	Systemic	Contact	Systemic	Contact
	L ha^{-1}			
Mean	96.3	118.8	49.6	59.9
Median	93.5	116.9	46.8	46.8
Mode	93.5	93.5	46.8	46.8
Minimum	46.8	46.8	28.1	46.8
Maximum	187.1	187.1	70.2	93.5
No. of observations	30	25	27	24

Table 4. Nozzle types used on ground and aerial spray equipment as reported by Arkansas certified pesticide applicators in a 2019 survey.

	Respondents (%)	Observations (n)
Ground spray equipment		
Non-venturi	47	17
Venturi	53	
Aerial spray equipment		
Non-venturi flat-fan	46	13
Straight-stream	54	

both ground and aerial spray equipment. However, the median and mode indicated two and three different nozzle types, respectively, were used in a growing season on ground spray equipment, while the median and mode of nozzle types used for aerial spray equipment was one each. Findings indicate ground spray equipment operators use more nozzle types in a growing season than aerial applicators; however, the total number of nozzle types used is still limited. The hesitancy to change nozzle types on ground spray equipment is puzzling with the relative ease of switching between nozzle types on current ground sprayers due to quick attach nozzle caps and turret nozzle bodies. In contrast, changing nozzles on agricultural aircraft tends to be more time-consuming and complex due to threading individual nozzles directly onto the spray boom outlets.

Survey results revealed spray carrier volumes of 96.3 and 118.8 L ha^{-1} were used on average (mean) for systemic and contact herbicides, respectively, by ground spray equipment operators (Table 3). A range of 46.8 to 187.1 L ha^{-1} was reported for spray carrier volumes used for both systemic and contact herbicide applications from ground spray equipment. Survey respondents indicated an average (mean) spray carrier volume of 49.6 and 59.9 L ha^{-1} for systemic and contact herbicides, respectively, using agricultural aircraft. A range of 28.1 to 70.2 L ha^{-1} and 46.8 to 93.5 L ha^{-1} aerial application spray carrier volumes were used for systemic and contact herbicides, respectively. The increase in average spray carrier volume regardless of ground or aerial application equipment when switching from systemic to contact herbicides indicates a working knowledge of the importance coverage plays in herbicide efficacy. By increasing the spray volume, a greater number of herbicide spray droplets are available for potential impaction and retention on weed surfaces, thereby increasing weed control (Creech et al. 2015b; Knoche 1994).

Limited data was available on the specific types of nozzles used by Arkansas applicators. Only 28% of respondents provided information on a specific nozzle type used across ground and aerial spray equipment. Specifically, 35% of respondents who indicated that at least a portion of reported hectares were sprayed with ground equipment (n = 49) provided a nozzle type used, and 22% of respondents who indicated that at least a portion of reported hectares were sprayed with aerial equipment (n = 58) provided a nozzle type used. From these data we assume that the absence of nozzle type information indicates a lack of knowledge on nozzles used by both ground and aerial applicators because the Qualtrics survey required respondents to input information for each question prior to proceeding to the next question in the survey. Previous survey research from Missouri also concluded an apparent lack of knowledge by applicators was evident regarding technologies that may help reduce herbicide drift including nozzles and drift control agents (Bish and Bradley 2017). The deficiency in understanding nozzles is problematic because nozzles affect numerous herbicide application outcomes, including spray drift potential (Bueno et al. 2017; Vieira et al. 2018), coverage (Ferguson et al. 2016), and weed control (Butts et al. 2018; Creech et al. 2016; Meyer et al. 2016). Educational efforts should be undertaken to increase knowledge and awareness about nozzle types and their importance in herbicide applications.

From the nozzle types reportedly used on ground spray equipment, 47% were non-venturi nozzles, whereas the other 53% were venturi nozzles (Table 4). However, a large portion of the non-venturi nozzles (75%) were used on PWM spray equipment. Because most non-venturi nozzles were reported on PWM spray equipment, the use rate was biased as venturi nozzles are not recommended for use on PWM sprayers (Butts et al. 2019a, 2019b). Therefore, venturi nozzles were more commonly used for ground spray applications overall, because PWM sprayers accounted for only 23% of the ground spray equipment. The nozzle types reported to be used on aerial application equipment were nearly evenly split between non-venturi flat-fan nozzles (46%) and straight-stream nozzles (54%; Table 4). Straight-stream nozzles may be slightly more popular due to the coarser droplet size produced compared to non-venturi flat-fan nozzles, which results in reduced drift potential (Hewitt et al. 2002).

The limited nozzle information provided by survey participants indicated minimal instances of applicators changing nozzle types when switching from systemic to contact herbicides. Only two of the respondents who use ground spray equipment and provided nozzle type information (n = 17) noted using different nozzles when applying a contact herbicide compared to a systemic herbicide. None of the aerial applicator respondents who provided nozzle type information (n = 13) stated nozzle type or deflection angle were changed when switching herbicides. The low proclivity for changing nozzles when applying different herbicides corroborates previous survey research from Missouri (Bish and Bradley 2017). The result is troublesome because previous research has indicated

Downloaded From: https://complete.bioone.org/journals/Weed-Technology on 29 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

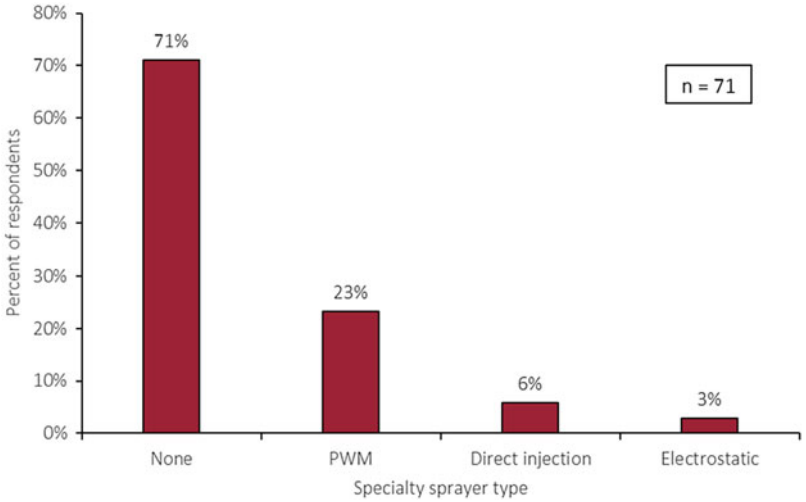


Figure 3. The percentage of survey respondents using specific specialty-type sprayers for Arkansas agronomic crop herbicide applications. Percent total is greater than 100% due to some respondents indicating more than one type of specialty sprayer was used. The number of total observations is noted in the box at the top right. PWM, pulse-width modulation.

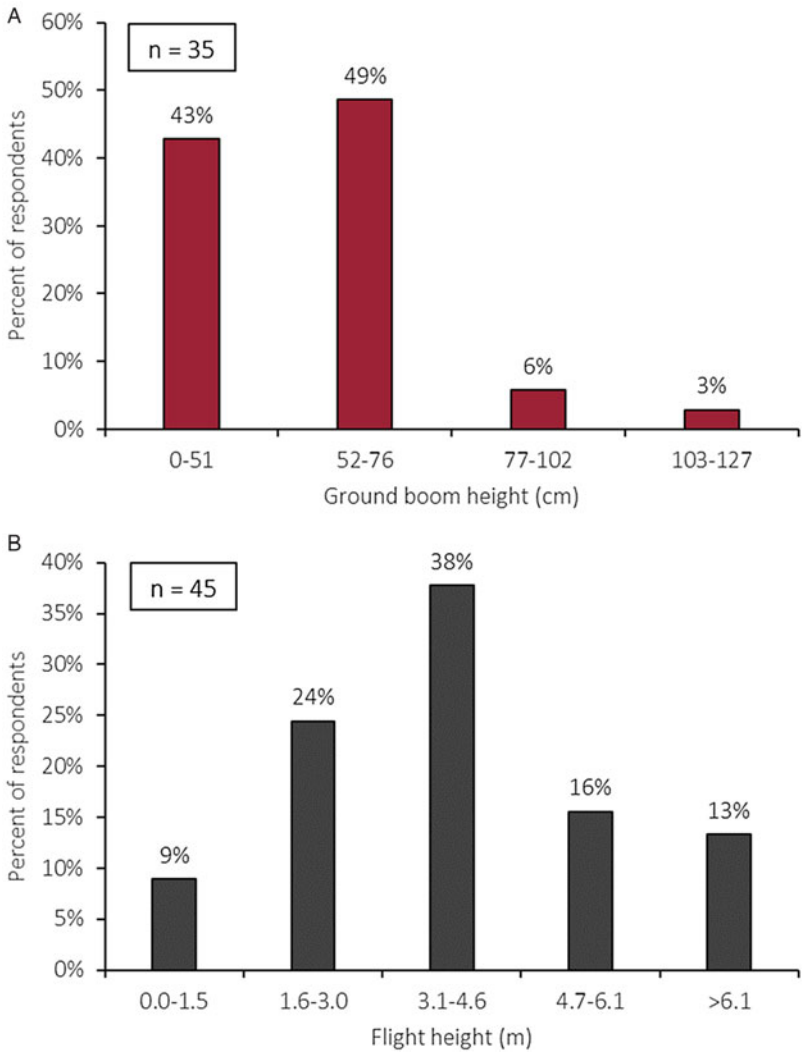


Figure 4. Ground spray equipment boom height (A) and agricultural aircraft flight height (B) used for Arkansas agronomic crop herbicide applications as measured by percentage of survey respondents. Percentages may not total 100% due to rounding. The number of total observations is noted in boxes at top left.

Downloaded From: https://complete.bioone.org/journals/Weed-Technology on 29 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

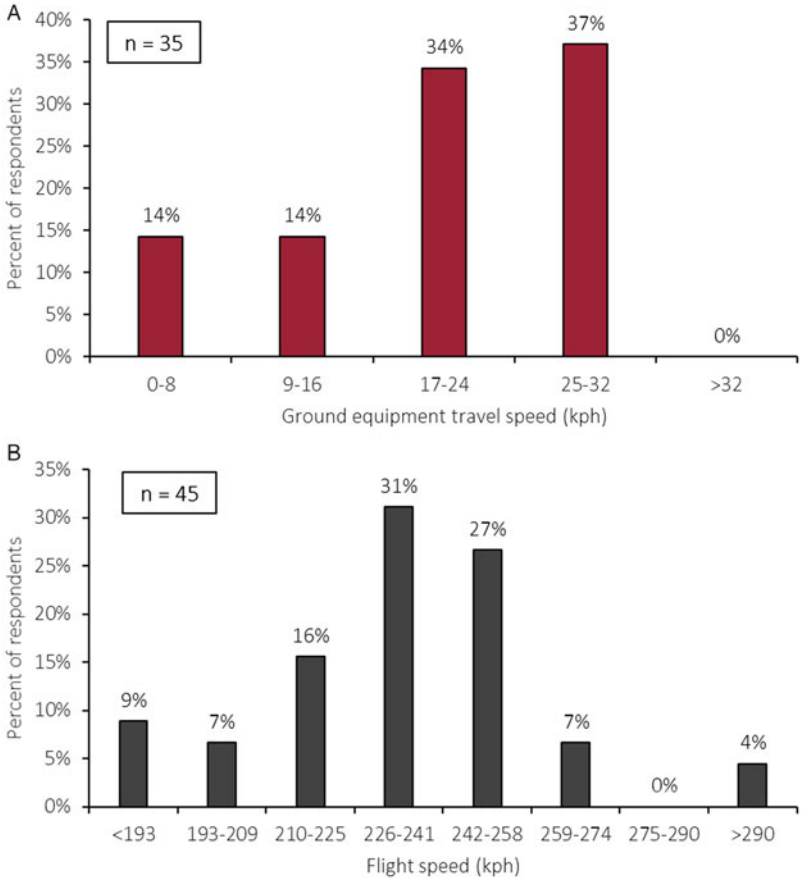


Figure 5. Ground spray equipment travel speed (A) and agricultural aircraft flight speed (B) used for Arkansas agronomic crop herbicide applications as measured by percentage of survey respondents. Percentages may not total 100% due to rounding. The number of total observations is noted in boxes at top left.

nozzle selection was the most important factor affecting spray droplet size (Creech et al. 2015a), and droplet size should be tailored for the herbicide being used and the targeted weed species to optimize efficacy (Butts et al. 2018; Creech et al. 2016). It should be noted that other application parameters (spray pressure, spray equipment speed, nozzle orifice size) can be changed to achieve the increase in average spray volume without changing nozzles when switching from systemic to contact herbicides. Further survey research should be conducted to evaluate changes in other application parameters that would also influence droplet size and may still result in acceptable droplet sizes for use without changing nozzles.

Other Common Herbicide Application Parameters

The effectiveness of herbicide applications is further influenced by application parameters such as the sprayer boom or flight height and the equipment's travel speed. Survey participants were asked to report typical spray heights and travel speeds for both ground and aerial spray equipment. Of the 35 survey participants who used ground spray equipment, 92% reported a boom height of less than 76 cm (Figure 4). Boom height less than 76 cm is very advantageous for drift mitigation purposes by reducing the distance between spray emission and the target, thereby limiting the potential for wind to carry spray droplets off target. Additionally, for most broadcast nozzles and nozzle spacings used on commercial ground sprayers today, 51 cm to 76 cm is the recommended boom height to optimize overlap between nozzles and maximize spray coverage (TeeJet Technologies 2014). Flight heights reported for agricultural aircraft were much more diverse than ground sprayer boom heights. The most frequently reported flight height (38%) was 3.1 m to 4.6 m from the ground (Figure 4). Flight heights between 3.1 m to 4.6 m from the ground are commonly recommended for aerial applications to maximize effectiveness. Additionally, when the nearest flight heights reported were summed, a total of 78% of respondents indicated agricultural aircraft flight heights of 1.6 m to 6.1 m, all of which are still advisable for successful aerial herbicide applications. A minimal percentage of reported ground boom heights (9%) and aerial flight heights (22%) would be inadvisable for use as increased drift potential or unsafe application conditions may result.

Ground travel and flight speeds are important facets to indicate the safety and accuracy potential of herbicide applications. Survey results indicated that 71% of respondents using ground spray equipment reported travel speeds of 17 kph to 32 kph (Figure 5). Sixty-two percent of respondents reported ground sprayer speeds (<25 kph) that would be considered acceptable for safe and accurate application procedures in the Arkansas delta region to maintain uniformity (Womac et al. 2001). Agricultural aircraft flight speeds were reported to be less than 193 kph to greater than 290 kph (Figure 5). The diversity of flight speeds may be partially explained by the type of aircraft used for applying the herbicide. It is highly probable that aircraft with a flight speed reported less than 193 kph were rotary wing aircraft (helicopter).

Downloaded From: https://complete.bioone.org/journals/Weed-Technology on 29 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

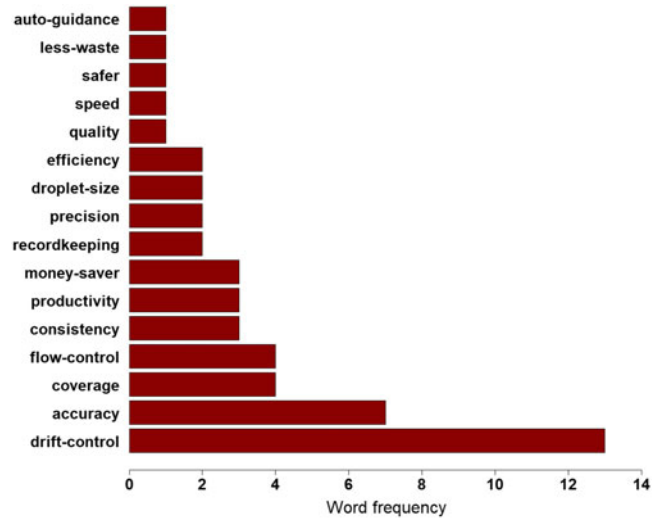


Figure 6. Word frequency analysis results from a survey of Arkansas agronomic crop herbicide applicators for the question, "What do you feel is the biggest advantage of using newer application technologies?" The total number of observations was 50.

Conversely, all other flight speeds greater than 193 kph were likely fixed-wing aircraft (airplane). The greatest percentage of respondents (58%) indicated flight speeds between 226 kph and 258 kph, which is a commonly recommended flight speed range for the types of fixed wing agricultural aircraft typically used to apply herbicides (SM Bretthauer, personal communication). Additionally, flight speeds between 226 kph and 258 kph allow applicators to achieve safe operating conditions by maintaining the necessary amount of lift to carry the high payload capacity of current agricultural aircraft (Air Tractor 2020). Collectively, 0% and 11% of the reported ground travel and flight speeds, respectively, would not be recommended because the speeds may be too great for safe, accurate, and consistent herbicide applications.

Benefits of Technologies, Challenges, and Future Research

Survey participants were asked three open-ended opinion questions about herbicide applications. The first was, "What do you feel is the biggest advantage of using newer application technologies?" Fifty responses were received, and when responses were summarized into one-word descriptions, the four most frequent narratives for biggest advantages of newer technologies were drift-control (26%), accuracy (14%), coverage (8%), and flow-control (8%; Figure 6). As spray drift has become an increasing concern for all of agriculture, the ability of new technologies to assist with mitigation of this concern is a necessity. It is positive that new application technologies being used by Arkansas applicators have provided assurance with spray drift mitigation efforts. Overall, responses indicated that survey participants believed newer application technologies assisted with the optimization of herbicide applications as evidenced by descriptive words such as accuracy, precision, efficiency, quality, productivity, and consistency.

The second question was, "What is your biggest herbicide application challenge?" Drift (34%), weather (14%), timeliness (12%), regulations (8%), and spray volume (3%) were the top five most frequent descriptors from a total of 65 respondents (Figure 7). The concepts presented were commonly reiterated as challenges from farmers, applicators, and crop consultants across the state at various Extension related activities. It was not surprising that drift was the most frequently cited challenge. Due to the variety of cropping systems and herbicide traits found across the Arkansas delta, symptoms of off-target movement are more readily visible as a wider range of herbicides are utilized. Additionally, the nationwide focus on auxin herbicide movement in recent years has brought spray drift problems to the forefront of agriculture for many herbicide applicators.

The third opinion question was, "What application research would you like to see the University of Arkansas conduct in the next three years to address your concerns?" Forty-two responses were received. Responses included adjuvants (14%), spray volume efficacy (12%), drift (10%), volatility (7%), environmental efficacy (7%), and dicamba (7%; Figure 8). Adjuvant research requested typically involved drift reduction adjuvants and how drift, pattern development, and weed control may be influenced. The term "environmental efficacy" grouped together responses that included factors such as temperature, relative humidity, soil moisture, and wind speed effects on herbicide efficacy. Responses provided an insight into the needs of current Arkansas herbicide applicators.

Current herbicide application practices and technologies used by Arkansas applicators including nozzles, spray volumes, equipment travel speed, boom heights, specialty-type sprayers, and other application technologies were documented for ground and aerial spray equipment in this research. Most of the applicator survey participants had significant herbicide application experience (68% had more than 15 years of experience as a certified applicator); however, as a result, fewer younger certified applicators may be effectively trained to replace the workforce. Respondents reported herbicides were applied using ground versus aerial application equipment in nearly equal percentages. Rate controllers were commonly used in both ground and aerial application equipment. In contrast, GPS-driven automatic nozzle and boom shut-offs were much more common on ground spray equipment than aerial equipment. Specialty-type sprayer technologies were uncommon among respondents with PWM being the most used (23%). The majority of reported boom heights and equipment travel speeds for both ground and aerial application equipment were in recommended ranges for effective herbicide applications. Overall, applicator knowledge of nozzles and usage was limited as minimal respondents reported specific nozzle information used, regardless of ground or aerial applicators, indicating a need for nozzle educational efforts. Venturi nozzles and straight-stream nozzles were most commonly used with ground and aerial spray equipment, respectively. Ground and aerial applicator survey participants alike reported using greater spray carrier volumes when switching to contact herbicides from systemic herbicides. Respondents indicated that optimization of applications was a major benefit of using newer application technologies, and herbicide drift was highlighted as a primary challenge. Research needs expressed by survey participants included adjuvants, spray volume efficacy, and herbicide drift. The results of this survey provided critical insight into current practices, technologies, and needs of Arkansas herbicide applicators. Research and education efforts focused on aforementioned needs can be developed and implemented while also providing applied, research-based information to applicators based on current practices.

Downloaded From: https://complete.bioone.org/journals/Weed-Technology on 29 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

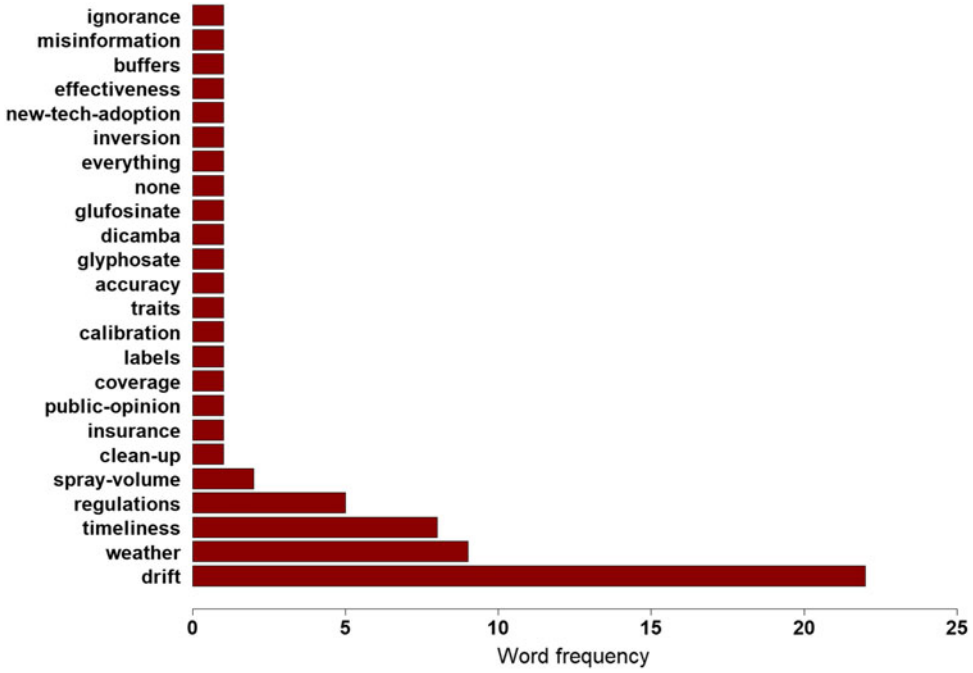


Figure 7. Word frequency analysis results from a survey of Arkansas agronomic crop herbicide applicators for the question, "What is your biggest herbicide application challenge?" The total number of observations was 65.

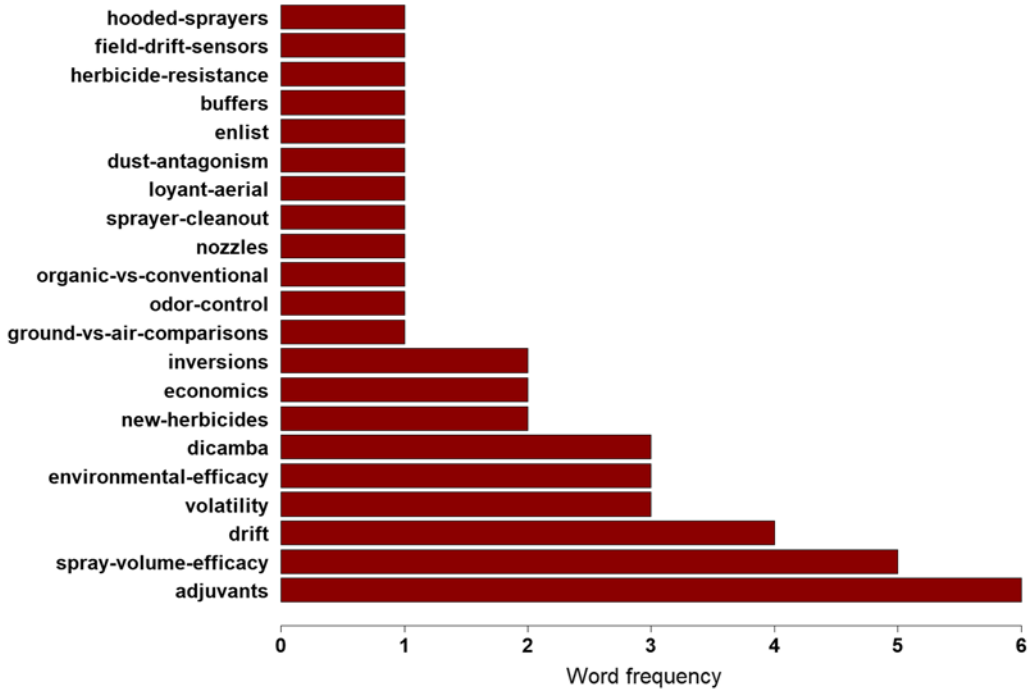


Figure 8. Word frequency analysis results from a survey of Arkansas agronomic crop herbicide applicators for the question, "What application research would you like to see the University of Arkansas conduct in the next three years to address your concerns?" The total number of observations was 42.

Acknowledgments. This project was supported through Checkoff funding provided by the Arkansas Rice Research and Promotion Board and Arkansas Soybean Promotion Board. We thank the University of Arkansas System Division of Agriculture for their support of this research. We also thank the Arkansas State Plant Board Pesticide Division and Arkansas Agricultural Aviation Association for providing contact information of applicators and for their efforts in publicizing the survey. Finally, we thank all Arkansas certified pesticide applicators, farmers, crop consultants, and agronomists that took time to complete the survey. No conflicts of interest have been declared.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/wet.2020.81

Downloaded From: https://complete.bioone.org/journals/Weed-Technology on 29 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

References

Air Tractor (2020) AT-802A Specifications. Olney, TX: Air Tractor, Inc. https://airtractor.com/aircraft/at-802a/. Accessed: April 7, 2020

Alves GS, Kruger GR, da Cunha JP, de Santana DG, Pinto LA, Guimaraes F, Zaric M (2017) Dicamba spray drift as influenced by wind speed and nozzle type. Weed Technol 31:724–731

Anonymous (2014) National Pesticide Applicator Certification Core Manual, 2nd Edition. Arlington, VA: National Association of State Departments of Agriculture Research Foundation. 196 p

Azimi AH, Carpenter TG, Reichard DL (1985) Nozzle spray distribution for pesticide application. T ASAE 28:1410–1414

Bish MD, Bradley KW (2017) Survey of Missouri pesticide applicator practices, knowledge, and perceptions. Weed Technol 31:165–177

Blue River Technology (2019) Sunnyvale, CA: See & Spray. http://www.bluerivertechnology.com/. Accessed: April 23, 2020

Bouse LF (1994) Effect of nozzle type and operation on spray droplet size. T ASAE 37:1389–1400

Bouse LF, Kirk IW, Bode LE (1990) Effect of spray mixture on droplet size. T ASAE 33:783–788

Bueno MR, da Cunha JP, de Santana DG (2017) Assessment of spray drift from pesticide applications in soybean crops. Biosyst Eng 154:35–45

Butler Ellis MC, Tuck CR, Miller PC (1997) The effect of some adjuvants on sprays produced by agricultural flat fan nozzles. Crop Prot 16:41–50

Butts TR, Butts LE, Luck JD, Fritz BK, Hoffmann WC, Kruger GR (2019a) Droplet size and nozzle tip pressure from a pulse-width modulation sprayer. Biosyst Eng 178:52–69

Butts TR, Kruger GR (2018) Pulse-Width Modulation (PWM) Sprayers: Why, Why, and How? G2302 NebGuide. Lincoln: University of Nebraska-Lincoln Extension. 3 p

Butts TR, Luck JD, Fritz BK, Hoffmann WC, Kruger GR (2019b) Evaluation of spray pattern uniformity using three unique analyses as impacted by nozzle, pressure, and pulse-width modulation duty cycle. Pest Manag Sci 75:1875–1886

Butts TR, Samples CA, Franca LX, Dodds DM, Reynolds DB, Adams JW, Zollinger RK, Howatt KA, Fritz BK, Hoffmann WC, Kruger GR (2018) Spray droplet size and carrier volume effect on dicamba and glufosinate efficacy. Pest Manag Sci 74:2020–2029

Creech CF, Henry RS, Fritz BK, Kruger GR (2015a) Influence of herbicide active ingredient, nozzle type, orifice size, spray pressure, and carrier volume rate on spray droplet size characteristics. Weed Technol 29:298–310

Creech CF, Henry RS, Werle R, Sandell LD, Hewitt AJ, Kruger GR (2015b) Performance of postemergence herbicides applied at different carrier volume rates. Weed Technol 29:611–624

Creech CF, Moraes JG, Henry RS, Luck JD, Kruger GR (2016) The impact of spray droplet size on the efficacy of 2,4-D, atrazine, chlorimuron-methyl, dicamba, glufosinate, and saflufenacil. Weed Technol 30:573–586

Ebert TA, Taylor RA, Downer RA, Hall FR (1999) Deposit structure and efficacy of pesticide application. 1: Interactions between deposit size, toxicant concentration and deposit number. Pestic Sci 55:783–792

Ferguson JC, Hewitt AJ, O'Donnell CC (2016) Pressure, droplet size classification, and nozzle arrangement effects on coverage and droplet number density using air-inclusion dual fan nozzles for pesticide applications. Crop Prot 89:231–238

Forney SH, Luck JD, Kocher MF, Pitla SK (2017) Laboratory and full boom-based investigation of nozzle setup error effects on flow, pressure, and spray pattern distribution. Appl Eng Agric 33:641–653

Fritz BK, Hoffmann WC, Bagley WE (2009) Effects of spray mixtures on droplet size under aerial application conditions and implications on drift. Appl Eng Agric 26:21–29

Greenleaf Technologies (2020) Covington, LA: Greenleaf Technologies Nozzles. http://www.greenleaftech.com/index.php. Accessed: April 23, 2020

Hardke JT (2019) Trends in Arkansas rice production, 2018. Pages 15–24 *in* RJ Norman, KA Moldenhauer, eds. Arkansas Rice Research Studies 2018. University of Arkansas System Division of Agriculture

Hewitt AJ (1997) Droplet size and agricultural spraying, Part I: Atomization, spray transport, deposition, drift, and droplet size measurement techniques. Atomization Spray 7:235–244

Hewitt AJ, Johnson DR, Fish JD, Hermansky CG, Valcore DL (2002) Development of the Spray Drift Task force database for aerial applications. Environ Toxicol Chem 21:648–658

Knoche M (1994) Effect of droplet size and carrier volume on performance of foliage-applied herbicides. Crop Prot 13:163–178

Kudsk P (2017) Optimising Herbicide Performance. Pages 149–179 *in* PE Hatcher, RJ Froud-Williams, eds. Weed Research: Expanding Horizons, 1st ed. Chichester, UK: John Wiley & Sons, Ltd

Legleiter TR, Johnson WG (2016) Herbicide coverage in narrow row soybean as influenced by spray nozzle design and carrier volume. Crop Prot 83:1–8

Luck JD, Pitla SK, Shearer SA, Mueller TG, Dillon CR, Fulton JP, Higgins SF (2010a) Potential for pesticide and nutrient savings via map-based automatic boom section control of spray nozzles. Comput Electron Agr 70:19–26

Luck JD, Zandonadi RS, Luck BD, Shearer SA (2010b) Reducing pesticide over-application with map-based automatic boom section control on agricultural sprayers. T ASABE 53:685–690

Matthews G, Bateman R, Miller P (2014) Pesticide Application Methods, 4th ed. Chichester, UK: Wiley-Blackwell. 536 p

Meyer CJ, Norsworthy JK, Kruger GR, Barber TL (2016) Effect of nozzle selection and spray volume on droplet size and efficacy of Engenia tank-mix combinations. Weed Technol 30:377–390

Miller PC, Butler Ellis MC (2000) Effects of formulation on spray nozzle performance for applications from ground-based boom sprayers. Crop Prot 19:609–615

Nordby A, Skuterud R (1974) Effects of boom height, working pressure, and wind speed on spray drift. Weed Res 14:385–395

Norsworthy JK, Bond J, Scott RC (2013) Weed management practices and needs in Arkansas and Mississippi rice. Weed Technol 27:623–630

Nuyttens D, Baetens K, de Schampheleire M, Sonck B (2007) Effect of nozzle type, size and pressure on spray droplet characteristics. Biosyst Eng 97:333–345

O'Connor-Marer PJ (2014) Aerial Applicator's Manual. Arlington, VA: National Association of State Departments of Agriculture Research Foundation. 124 p

Pentair Hypro (2018) Pumps, spray nozzles, and accessories. New Brighton, MN: Pentair Hypro. 278 p

R Core Team (2018) R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/. Accessed: April 1, 2020

Riar DS, Norsworthy JK, Steckel LE, Stephenson IV, Eubank TW, Scott RC (2013) Assessment of weed management practices and problem weeds in midsouth U.S. soybean: A consultant's perspective. Weed Technol 27:612–622

Schwartz-Lazaro LM, Norsworthy JK, Steckel LE, Stephenson DO, Bish MD, Bradley KW, Bond JA (2018) A midsouthern consultant's survey on weed management practices in soybean. Weed Technol 32:116–125

Sharda A, Fulton JP, McDonald TP, Brodbeck CJ (2011) Real-time nozzle flow uniformity when using automatic section control on agricultural sprayers. Comput Electron Agr 79:169–179

Sharda A, Luck JD, Fulton JP, McDonald TP, Shearer SA (2013) Field application uniformity and accuracy of two rate control systems with automatic section capabilities on agricultural sprayers. Precis Agr 14: 307–322

Shaw DR, Givens WA, Farno LA, Gerard PD, Jordan D, Johnson WG, Weller SC, Young BG, Wilson RG, Owen MD (2009) Using a grower survey to assess the benefits and challenges of glyphosate-resistant cropping systems for weed management in U.S. corn, cotton, and soybean. Weed Technol 23:134–149

TeeJet Technologies (2014) Catalog 51A-M. Wheaton, IL: Spraying Systems Co. 164 p

Transland (2020) CP Products aerial nozzles. https://www.translandllc.com/product/nozzles/cp-aerial-nozzles/. Accessed: April 23, 2020

[USDA-NASS] U.S. Department of Agriculture–National Agricultural Statistics Service (2019) Arkansas state agricultural overview. https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=ARKANSAS. Accessed: March 15, 2020

Downloaded From: https://complete.bioone.org/journals/Weed-Technology on 29 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

[USDA-NASS] U.S. Department of Agriculture–National Agricultural Statistics Service (2020) Agricultural chemical use survey. https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Chemical_Use/. Accessed: April 22, 2020

Vieira BC, Butts TR, Rodrigues AO, Golus JA, Schroeder K, Kruger GR (2018) Spray particle drift mitigation using field corn (*Zea mays* L.) as a drift barrier. Pest Manag Sci 74:2038–2046

Vieira BC, Luck JD, Amundsen KL, Werle R, Gaines TA, Kruger GR (2020) Herbicide drift exposure leads to reduced herbicide sensitivity in *Amaranthus* spp. Sci Rep 10, Article 2146

Weed-It (2020) Weed-It Precision Spraying. https://www.weed-it.com/. Accessed: April 23, 2020

Westwood JH, Charudattan R, Duke SO, Fennimore SA, Marrone P, Slaughter DC, Swanton C, Zollinger R (2018) Weed management in 2050: Perspectives on the future of weed science. Weed Sci 66: 275–285

Wilger (2017) COMBO-JET® ER, SR, MR, DR Droplet Size Selective Tip-1 Caps. Lexington, TN. https://www.wilger.net/wp-content/uploads/Brochures/CJTCBrochures/cjtc_brochure_usgpa.pdf. Accessed: April 24, 2020

Womac A, Etheridge R, Seibert A, Hogan D, Ray S (2001) Sprayer speed and venturi-nozzle effects on broadcast application uniformity. T ASAE 44:1437–1444

Downloaded From: https://complete.bioone.org/journals/Weed-Technology on 29 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use