CORPUS PUBLISHERS

Archives of Agriculture Research and Technology (AART)

ISSN: 2832-8639

Volume 5 Issue 1, 2024

Article Information

Received date : February 14, 2024

Published date: March 04, 2024

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DOI: 10.54026/AART/1066

Keywords

Dicamba-tolerant cotton; Glufosinate; Glyphosate; Mepiquat chloride; Particle drift

Research Article

Cotton (*Gossypium hirsutum*) Response to Plant Protection Products using Different Spray Nozzles

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Abstract

Application of dicamba to dicamba-tolerant cotton (*Gossypium hirsutism* L.) cultivars (Xtend Cotton, Bayer Crop Science, Research Triangle Park, NC) requires use of nozzles that deliver large spray droplets to avoid off-site movement through particle drift onto susceptible crops and other plants including endangered species. Twenty trials over a three-year period were conducted to determine if nozzles required to deliver dicamba plus glyphosate would be equally effective in delivering other pesticides including the herbicide glufosinate, the plant growth regulator mepiquat chloride, the insecticide bifenthrin plus dichrotophos and co-application of ethephon plus thidiazuron plus tribufos for removal of cotton foliage to improve harvest efficiency. Agrichemicals were applied using:

a) Air Induction (AI) nozzles for agrichemicals except dicamba plus glyphosate
b) Turbo Teejet Induction (TTI) nozzles for all agrichemicals
c) TTI nozzles for glufosinate and dicamba plus glyphosate and AI nozzles for other agrichemicals.

Applications were made in 145 L/ha at 152 kPa at a ground speed of 5 km/h. Cotton height at the end of the season, node above first fruiting branch, nodes above cracked boll, node of uppermost boll, total nodes, lint yield, and cotton fiber quality were similar regardless of nozzles used to deliver agrichemcials. Control of a complex of broadleaf signal grass (*Urochloa platyphylla* L.), goosegrass [*Eleusine indica* (L.) Gaert.], and large crabgrass (*Digitaria sanguinalis* L.) and Palmer amaranth (*Amaranthus palmeri* Watts.) was slightly lower when glufosinate was applied with TTI nozzles rather than AI nozzles. However, control of these weeds was similar regardless of nozzle selection when dicamba plus glyphosate was applied after glufosinate. These results suggest that growers can use nozzles that limit off-site movement through particle drift of agrichemicals throughout the cropping cycle with no major adverse effect on weed control and cotton growth and yield.

Introduction

Particle drift is a major concern in crop production systems where pesticides are applied frequently with biological, legal, and financial ramifications [1-3]. Adjacent crops, plants grown for non-crop uses, and natural plants including endangered species have created a need for improved delivery of herbicides to prevent non-target effects [4]. Factors that minimize off-site movement include:

a) application when wind speed is relatively low
b) not applying pesticides when thermal inversions are likely
c) using lower spray pressure
d) traveling at slower ground speeds to minimize turbulence that increases the likelihood that droplets will remain suspended in air
e) not using adjuvants and tank mixtures that alter properties of spray solutions in a manner that increases spray droplet suspension
f) using spray nozzles that deliver larger droplets that do not stay suspended in air and decrease the percentage of fine droplets that stay suspended and can move from the source of delivery [5].

These factors are a component of product labels and Extension Service recommendations for dicamba-tolerant cotton *(Gossypium hirsutum* L.*)* and soybean [*Glycine max* (L.) Merr.] [6]. While not currently mandated for other pesticides, use of nozzles across agrichemical categories that reduce risk of particle drift could become a key part pesticide stewardship. Spray droplet size can affect coverage of weeds and subsequent control. However, efficacy of herbicides is not always affected and can be variable depending upon a range of factors [7-15]. Efficacy of dicamba, glufosinate, and glyphosate was not affected by droplet size [8,11,12].

Concern over off-site movement of dicamba to susceptible crops and natural vegetation, especially endangered species, has created an environment where movement of all pesticides from crop fields is considered. If growers could use nozzles delivering large droplets for all agrichemical applications that are less prone to drift, there would be fewer concerns about off-site movement. However, like herbicides, efficacy of insecticides, plant growth regulators, and defoliants used for cotton can be impacted by coverage of cotton by spray solution [16-18]. In peanut (Arachis hypogaea L.), Virk et al. [19] reported that pesticide performance was affected only marginally when applied using nozzles that deliver large droplets compared to traditional nozzles that produce smaller droplets that are more likely to drift but are considered more effective in increasing pesticide coverage of target weed species and peanut plants to protect from pathogens. Research has not been conducted to determine if pest control and cotton growth, yield, and fiber quality are affected when pesticides, mepiquat chloride, and defoliants are applied using spray nozzles that deliver large droplets compared to nozzles that deliver smaller droplets with all applications throughout the cropping cycle. Therefore, research was conducted to determine if weed control and cotton growth, yield, and fiber quality were affected by nozzle selection throughout the cropping cycle.

Materials and Methods

Twenty trials were conducted in multiple fields in North Carolina at the Central Crops Research Station near Clayton, the Peanut Belt Research Station near Lewiston-Woodville, and the Upper Coastal Plain Research Station near Rocky Mount on soils typically found in the coastal plain of North Carolina from 2017-2019. The cotton cultivar DP 1522 B2XF (Monsanto Co., St. Louis, MO) was planted in conventionally-prepared raised seedbeds spaced 91-cm apart at a rate to establish 15 plants/m-row. Herbicides were not applied at planting.

Treatments consisted of the following spray nozzle systems:

a) Air Induction (AI) nozzles (AIXR 11002 TeeJet Air Induction XR flat fan spray nozzles, TeeJet Technologies, Wheaton, IL) for all agrichemicals except for dicamba plus glyphosate

b) Turbo Teejet Induction (TTI) nozzles (TTI 11002-VP Turbo TeeJet Air Induction VP flat fan spray nozzles, TeeJet Technologies, Spraying Systems Co., Wheaton, IL) for all agrichemicals

c) TTI nozzles for glufosinate and dicamba plus glyphosate and AI nozzles other agrichemicals (Table 1).

Table 1: Nozzle selection for herbicides, acephate, mepiquat chloride, bifenthrin plus dichrotophos, and ethaphon plus thidiazuron plus tribufos.[a]

Nozzle system	Glufosinate	Dicamba	Acephate	Mepiquat chloride	Bifenthrin plus dichrotofos	Ethephon plus thidiazuron plus tribufos
Air induction (AI)	AI	TTI	AI	AI	AI	AI
Turbo Teejet Induction (TTI)	TTI	TTI	TTI	TTI	TTI	TTI
AI and TTI	TTI	TTI	AI	AI	AI	AI

[a]Agrichemicals were applied in 145 L/ha at 152 kPa for both nozzle systems.

Applications were made in 145 L/ha at 152 kPa at a ground speed of 5 km/h. Glufosinate (Liberty Herbicide, Bayer Crop Science, Research Triangle Park, NC) at 0.60 kg ai/ha was applied 2 weeks after planting. Dicamba (0.56 kg ai/ha) formulated as Xtendimax Herbicide® with VaperGrip® Technology (Bayer Crop Science, Research Triangle Park, NC) plus glyphosate (0.84 kg ae/ha) formulated as Roundup Power Max (Bayer Crop Science, Research Triangle Park, NC) was applied 4 weeks after planting. Mepiquat chloride was applied at rates and timings based on Cooperative Extension service recommendations [20]. Bifenthrin (0.052 kg ai/ha) plus dichrotophos (0.41 kg ai/ha) to control plant bugs *(Lygus* spp.*)* and green stink bug (*Chinavia halaris* Say) based on economic thresholds for these insect pests [21]. Acephate (1.12 kg ai/ha) was applied in 2019 to suppress tobacco thrips *(Frankliniella fusca* Hinds*)*. The defoliants ethephon (1.7 kg/ha) plus thidiazuron (0.18 kg ai/ha) plus tribufos (0.84 kg ai/ha) were co-applied two to three weeks prior to harvesting cotton with a spindle-picker modified for small-plot harvest.

Visual estimates of percent control of Palmer amaranth and a complex of annual grasses including broadleaf signalgrass *(Urochloa platyphylla* L.*)*, goosegrass [*Eleusine indica* (L.) Gaert.], and large crabgrass *(Digitaria sanguinalis* L.*)* was recorded 2 weeks after application of glufosinate and 2 weeks after application of dicamba plus glyphosate on a scale of 0 to 100% where 0 no control and 100 = complete control. Foliar chlorosis, necrosis, plant stunting, and population were considered when making the visual estimates of weed control based on non-treated border rows adjacent to the experiment. Annual grasses were present in all experiments. Palmer amaranth was present in 16 of 20 experiments. The effect of insecticide treatment on insect populations or damage caused by insects and defoliation of cotton was not determined. Cotton height at the end of the season, node above first fruiting branch, nodes above cracked boll, node of uppermost boll, total nodes, lint yield, and cotton fiber quality measurements using high volume instrumentation testing were determined. The experimental design was a randomized complete block with treatments replicated for times. Data for all parameters were subjected to analysis of variance using the GLMMIX procedure in SAS (SAS Institute, Cary, NC). Experiment and replication were considered random effects. Spray nozzle system was considered a fixed effect. Means were separated using Fishers Protected LSD test at $\alpha = 0.05$ pooled over experiments.

Results and Discussion

Palmer amaranth and annual grass control by glufosinate was lower when applied using TTI nozzles compared with control when AI nozzles delivered the herbicide (Table 2). These results were not unexpected given glufosinate is not translocated at an appreciable amount and adequate coverage of weed foliage is needed for adequate control. Application of glufosinate using AI nozzles results in a higher percentage of smaller droplets that often increase coverage of weeds. However, Meyer et al. [11,12] reported that weed control was similar when glufosinate was applied using AI and TTI nozzles. The difference in control in our study was relatively minor when comparing efficacy of glufosinate applied with AI or TTI nozzles. Control of Palmer amaranth and annual grasses was similar when dicamba plus glyphosate was applied 2 weeks after glufosinate regardless of nozzle selection (Table 2). Adequate control of these weeds has been reported previously [22] when dicamba plus glyphosate was applied in a sequence similar to the sequence in our study.

Table 2: Influence of nozzle selection on Palmer amaranth and annual grass control with glufosinate and glufosinate followed by dicamba plus glyphosate.[a,b,c]

Nozzle system	Glufosinate		Glufosinate followed by dicamba plus glyphostae	
	Palmer amaranth	Annual grasses	Palmer amaranth	Annual grasses
	%			
Air Induction (AI)	89 a	92 a	87 a	84 a
Turbo Teejet Induction (TTI)	85 b	88 b	89 a	82 a
AI and TTI	84 b	88 b	87 a	81 a
P > F	0.0016	0.0011	0.2245	0.1238

*Means within a column followed by the same letter are not significantly different based on Fishers Protected LSD test at $\alpha = 0.05$. Data are pooled over 20 environments from 2017-2019.

[a]Dicamba, glufosinate, and glyphosate applied at 0.56, 0.60, and 0.84 kg/ha.

[b]Annual grasses were a combination of broadleaf signalgrass, goosegrass, and large crabgrass.

[c]Agrichemicals were applied in 145 L/ha at 152 kPa for both nozzle systems.

No difference in cotton height at the end of the season, node above first fruiting branch, nodes above cracked boll, and lint yield when herbicides, insecticide, mepiquat chloride, and defoliant were applied throughout the cropping cycle (Table 3). Lack of a difference in cotton height, node above first fruiting branch, nodes above cracked boll, node of uppermost boll, and total nodes suggest that efficacy of mepiquat chloride is similar when applied with AI and TTI nozzles. However, a no-mepiquat chloride control was not present in experiments and would be needed to conclusively determine if efficacy of mepiquat chloride is not compromised by nozzle systems.

Table 3: Influence of nozzle selection on main stem cotton height, node of first fruiting branch, nodes above cracked boll, node above uppermost boll, total nodes, and lint yield.[a]

Nozzle system	Plant height	Node of first fruiting branch	Nodes above cracked boll	Node of uppermost boll	Total nodes	Lint yield
	cm	No.	No./plant	No.	No./ plant	kg/ha
Air Induction (AI)	259 a	7a	10a	15 a	18 a	810 a
Turbo Teejet Induction (TTI)	257 a	7a	11a	15 a	19 a	840 a
AI and TTI	264 a	7a	11a	15 a	18 a	820 a
P > F	0.1474	0.9206	0.1491	0.0815	0.2075	0.5373

*Means within a column followed by the same letter are not significantly different based on Fishers Protected LSD test at $\alpha = 0.05$. Data are pooled over 20 environments from

2017-2019.

[a]Agrichemicals were applied in 145 L/ha at 152 kPa for both nozzle systems.

Micronaire, fiber length, fiber length uniformity, and short fiber content was similar regardless of nozzle system (Table 4). However, minor differences in fiber strength were observed (Table 4). Fiber strength was higher when agrichemicals were applied throughout the cropping cycle with AI nozzles compared with TTI nozzles. However, differences in fiber strength observed in this experiment are likely of no biological and financial significance.

Table 4: Influence of nozzle selection on micronaire, fiber length, fiber length uniformity, fiber strength, and short fiber content.[a]

Nozzle system	Micronaire	Fiber length	Fiber length uniformity	Fiber strength	Short fiber content
	microns	cm	percent	g/tex	percent
Air Induction (AI)	4.46 a	3.00 a	83.7 a	31.5 a	8.1 a
Turbo Teejet Induction (TTI)	4.43 a	2.97 a	83.7 a	31.1 b	8.2 a
AI and TTI	4.43 a	3.00 a	84.0 a	31.2 b	8.0 a
P > F	0.7565	0.2603	0.3262	0.0321	0.1875

*Means within a column followed by the same letter are not significantly different based on Fishers Protected LSD test at $\alpha = 0.05$. Data are pooled over 20 environments from 2017-2019.

[a]Agrichemicals were applied in 145 L/ha at 152 kPa for both nozzle systems.

Conclusion

Results presented in this paper are the first data reported in the peer-reviewed literature comparing AI and TTI nozzles use over the entire cropping cycle for cotton that included herbicides, insecticides, mepiquat chloride, and defoliants. Results suggest that growers can use TTI rather than AI nozzles to minimize particle drift with no loss in performance of agrichemicals used routinely in cotton. One caveat in interpretation of results is that the research was conducted using small-plot equipment, most notably a ground speed that is substantially lower than typical commercial applications. However, Meyer et al. [12] reported that ground speed did not affect efficacy of herbicides used in the current study when applied with a range of spray nozzles. Research using farmer equipment throughout the cropping cycle for cotton is needed to verify or refute the findings we report in this paper where small-plot equipment was used.

Acknowledgement

Appreciation is expressed to Cotton Incorporated for partial funding and staff at research stations for assistance with this research.

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