The Influence of Nozzle Type on Peanut Weed Control Programs

O.W. Carter[1]*, E.P. Prostko[1], J.W. Davis[2]

ABSTRACT

The increase in herbicide-resistant weeds over the past decade has led to the introduction of crops that are resistant to auxin herbicides. Strict application procedures are required for the use of auxin herbicides in auxin-resistant crops to minimize off-target movement. One requirement for application is the use of nozzles that will minimize drift by producing coarse droplets. Generally, an increase in droplet size can lead to a reduction in coverage and efficacy depending upon the herbicide and weed species. In studies conducted in 2015 and 2016, two of the potential required auxin nozzle types [(AIXR11002 (coarse) and TTI11002 (ultra-coarse)] were compared to a conventional flat-fan drift guard nozzles [DG11002 (medium)] for weed control in peanut herbicide systems. Nozzle type did not influence annual grass or Palmer amaranth control in non-crop tests. Results from in-crop tests indicated that annual grass control was 5% to 6% lower when herbicides were applied with the TTI nozzle when compared to the AIXR or DG nozzles. However, Palmer amaranth control and peanut yield was not influenced by coarse-droplet nozzles. Peanut growers using the coarse-droplet nozzles need to be aware of potential reduced grass control.

Key words: nozzle, dicamba, 2,4-D, droplet size

The introduction and mass adoption of glyphosate resistant crops in the late 1990's led to the reliance of glyphosate alone as a weed control method in many instances (Vencill *et al.,* 2012; Sosnoskie and Culpepper, 2014). This reliance on glyphosate and the reduction in use of herbicides with different modes of action (MOA) have led to the evolution of herbicide resistant (HR) weed species (Vencill *et al.,* 2012; Cahoon *et al.,* 2015). Glyphosate resistance has now been confirmed in 17 species in the United States and one weed specie in Georgia (Heap, 2017). Herbicide resistance in Georgia has been documented for 4 other herbicide MOA's (Heap, 2017). The increasing occurrence of HR-weeds due to selection pressure, has led agrichemical companies to develop auxin-resistant corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L), and soybean [*Glycine max* (L.)] (USDA-APHIS, 2015). The addition of auxin herbicides into a grower's weed management program may extend the lifespan of glyphosate, glufosinate, and other critical herbicides (Behrens *et al.,* 2007).

One concern with applying auxin herbicides in current production systems is the sensitivity that many other plant species have to these herbicides (Egan *et al.,* 2014). For some broadleaf species, sensitivity is so great that significant damage can be seen at sub-lethal or drift rates (Egan *et al.,* 2014; Leon *et al.,* 2014; Mohsen-Moghadan and Doohan, 2015). In order to mitigate the potential of off-target movement of these herbicides current labels contain certain application requirements. Auxin herbicide labels denote specific environmental conditions for application, buffer zones between tolerant and susceptible crops, applicator speeds and boom height, and nozzle type. For example, the current label for 2,4-D choline + glyphosate permits 23 different nozzle types designed to produce coarser (larger) droplets, thus minimizing potential off-target movement (Anonymous, 2017). By increasing droplet size, applicators can successfully reduce the number of fine droplets that are considered driftable and minimize off-site movement (Mueller and Womac, 1997; Taylor *et al.,* 2004).

Herbicide efficacy can be directly related to droplet size but also can differ greatly depending on herbicide and weed species being controlled (Mckinlay *et al.,* 1974; Ramsdale and Messersmith, 2001). Generally, finer droplet nozzles are needed for use with contact herbicides, where increased coverage is required for control (Etheridge *et al.,* 2001). Weed control programs in Georgia for agronomic crops such as corn, cotton, peanut and soybean contain both systemic and contact herbicides (Horton, 2017).

Auxin-resistant technologies will likely be widely adopted by growers. In 2016, 43% of the cotton ha in the Southeastern United States were planted to dicamba-resistant cultivars (USDA-AMS, 2016). It is anticipated that the addition of these auxin-resistant crops to production practices, and the subsequent application of auxin herbicides

[1]Graduate Research Assistant and Professor and Extension Weed Specialist, respectively. Dept. of Crop & Soil Sciences, The University of Georgia, Tifton, GA 31793.

[2]Agricultural Research Statistician, The University of Georgia, Griffin, GA 30223.

*Corresponding author's E-mail: owcarter@uga.edu.

would mean a change to coarse-droplet producing nozzles for every herbicide application.

Peanut has long been an important rotational crop with cotton for Georgia growers due to its many benefits, such as reduced disease and insect pressure, decreased/easier to manage weed pressure, and its ability to provide nitrogen to the soil (Elkan, 1995; and Vencill *et al.,* 2012). In 2016, 308,000 ha of peanut were planted in Georgia, comprising approximately 49% of the United States total production (USDA-NASS, 2016). The importance of having a cotton/peanut crop rotation and the knowledge that some Georgia growers do not routinely change nozzles depending upon pesticide application could lead to a reduction in weed control in peanut due to compromised spray coverage.

Weed control research has been conducted on the effect of nozzle type and droplet size on individual herbicides and herbicide tank-mixture efficacy (Etheridge *et al*., 2001; Creech e*t al.,* 2015; Meyer *et al.,* 2016). However, there is limited data regarding the use of an entire (i.e. season-long) herbicide program with the nozzle types required for use when applying auxin herbicides to auxin-resistant crops. Growers do not rely solely on a single herbicide or a single herbicide application to successfully manage weeds. Therefore, the objective of this research was to evaluate the performance of complete peanut weed control programs applied using nozzles that produce coarse droplets.

Materials and Methods

Non-crop study

A non-crop study was conducted during 2015 and 2016 at the Ponder Research Farm located near Ty Ty, Georgia (31.507654^{0}N, -83.658395^0) on a Tifton loamy sand soil with 93% sand 3% silt, 4 % clay, 1% organic matter, and pH of 6.0. The trial was arranged in a randomized complete block design with a 4 by 3 factorial arrangement of treatments. Four herbicide treatments and 3 nozzle types were used. The herbicide treatments were as follows: Non-treated control (NTC); paraquat (0.21 kg ai/ha) plus bentazon (0.37 kg ai/ha) plus acifluorfen (0.19 kg ai/ha) plus *S*-metolachlor (1.23 kg ai/ha); imazapic (0.07 kg ai/ha) plus *S*-metolachlor (1.23 kg ai/ha) plus 2,4-DB (0.25 kg ai/ha); lactofen (0.22 kg ai/ha) plus *S*-metolachlor (1.23 kg ai/ha) plus 2,4-DB (0.25 kg ai/ha); acifluorfen (0.19 kg ai/ha) plus *S*-metolachlor (1.23 kg ai/ha) plus 2,4-DB (0.25 kg ai/ha). The following nozzles types were evaluated: DG11002, AIXR11002, and TTI11002 (TeeJet Technologies, Springfield, IL 62701). Nozzle sizes are determined by the volume median diameter (VMD), measured in microns, of the droplets produced According to the manufacturer, the VMD of droplets produced by these nozzle types at 262 kPa are as follows: DG11002, medium, ~ 178 - 218 microns; AIXR11002, coarse, ~ 219 – 349 microns; TTI11002, ultra coarse, > 622 microns (TeeJet Technologies, Springfield, IL 62701).

Plot size was 7.6 m by 0.9 m. Each treatment was replicated 3 or 4 times depending upon field availability. Palmer amaranth and a non-uniform mixture of annual grasses including, Texas millet (*Brachiaria texana,* Buckley), crowfootgrass (*Dactyloctenium aegyptium,* L. Wild), goosegrass (*Eleusine indica,* L. Gaertn.), and crabgrass (*Digitaria* spp.) were present in the non-treated check plots at densities of 50 – 100 plants/m^2 and 20 – 40 plants/m^2, respectively. The treatments were applied when weeds were 5 to 8 cm tall using a CO_2-pressurized backpack sprayer calibrated to deliver 141 L/ha at 262 kPa and 4.83 km/ha. Visual estimates of percent weed control were obtained at 7, 14, and 21 days treatments (DAT) using a scale of 0% = no control; 100% = complete control or plant death. Plant stunting, chlorosis, and necrosis were considered when making the visual estimates.

In-crop study

An in-crop trial was also conducted at the Ponder Research Farm and the Attapulgus Research and Education Center (30.763629^{0}N, -84.479938^0) on a Faceville loamy sand with 84% sand, 10% clay, 6% silt, 1.6% organic matter, and pH of 6.0 during 2015 and 2016 (4 site-years). Conventional tillage practices were used and 'Georgia-06G' (Branch, 2007) peanut was planted at both locations. A vacuum planter (Monosem Precision Planters, 1001 Blake St., Edwardsville, KS 66111) was calibrated to deliver 18 peanut seed/m at a depth of 5 cm. Peanut was planted in 2 twin rows (90 cm by 22 cm spacing) at Ponder and 2 single rows (90 cm spacing) in Attapulgus. Plot size was 7.6 m by 0.9 m.

The trial was arranged in a randomized complete block design with a 4 by 3 factorial design (4 herbicide programs and 3 nozzle types) with 4 replications. The herbicide programs presented in Table 1 were applied at their specified timings. Each herbicide program was applied with each nozzle throughout the entire season (DG11002, AIXR11002, TTI11002). Treatments were applied using a CO_2-pressurized backpack sprayer calibrated to deliver 141 L/ ha at 262 kPa and 4.83 km/h. Visual estimates of peanut crop injury were obtained 7 days after the EPOST treatment. Visual injury ratings of peanut crop

Table 1. Herbicide program, active ingredient, rate, and timings for in-crop/peanut nozzle studies, 2015-2016.

Program	Herbicide	Rate	Timing[a]
		kg ai/ha	
1	pendimethalin	0.84	PRE
	flumioxazin	0.12	PRE
	diclosulam	0.03	PRE
	imazapic	0.07	POST
	S-metolachlor	1.23	POST
	2,4-DB	0.25	POST
2	pendimethalin	0.84	PRE
	flumioxazin	0.12	PRE
	diclosulam	0.023	PRE
	lactofen	0.23	POST
	S-metolachlor	1.23	POST
	2,4-DB	0.25	POST
3	pendimethalin	0.84	PRE
	paraquat	0.21	EPOST
	acifluorfen	0.19	EPOST
	S-metolachlor	1.23	EPOST
	imazapic	0.23	POST
	S-metolachlor	1.23	POST
	2,4-DB	0.25	POST
4	pendimethalin	0.84	PRE
	paraquat	0.21	EPOST
	acifluorfen	0.19	EPOST
	S-metolachlor	1.23	EPOST
	lactofen	0.23	POST
	S-metolachlor	1.23	POST
	2,4-DB	0.25	POST
NTC			

[a]PRE= Preemergence, EPOST= early-postemergence, POST= postemergence, NTC= non-treated control

injury consisted of a combination of leaf burn and stunting (0%= no crop injury; 100%= no crop present). Later crop injury ratings were not collected due to dense weed populations in the non-treated checks which prevented reliable visual evaluations. Visual estimates of weed control were collected 7, 14, and 21 days after the POST treatment. Annual grass control ratings were not taken at 21 days after treatment due to dense Palmer amaranth populations in the NTC preventing accurate visual estimates. Palmer amaranth and a non-uniform mixture of annual grasses including, Texas millet, crowfootgrass, goosegrass, and crabgrass were present in the NTC plots as described in the non-crop test. Peanuts were inverted, allowed to air dry, and harvested 4 days later using commercial equipment. Peanut yields were adjusted to 10% moisture.

University of Georgia Extension peanut production recommendations were used and supplemental irrigation was applied to maximize peanut growth and development (Anonymous, 2017). Soil types, planting, application peanut stages of growth, weed heights, and harvest dates are presented in Table 2.

Data for all parameters in both the non-crop and in-crop studies were analyzed as factorial plot designs and subjected to ANOVA using the PROC MIXED procedure in SAS (SAS Institute 107 Inc., Cary, NC 27511). Nozzle type and herbicide treatment/program were considered fixed effects and locations and replications (nested within year) were considered random effects. No treatment by location and herbicide/program by nozzle interactions were significant ($P \geq 77$), therefore data were combined over locations and only treatment main effects are presented. Least square means of significant main effects were separated using pairwise t-tests (alpha=0.10).

Results and Discussion

Non-crop

When data were pooled over the four herbicide treatments, nozzle type had no effect on the control of Palmer amaranth and a non-uniform mixture of annual grasses (Table 3). Nozzle type has previously been reported to impact control of grass species, with coarse-droplet producing nozzles reducing control (Etheridge *et al*. 2001). However, other research has revealed that nozzle type did not play a factor in weed control (Ramsdale and Messersmith, 2001; Berger *et al*., 2014). Our tests differ from previous reports, in that multiple herbicide active ingredients are included in a single treatment in order to more accurately represent a typical grower program. A similar test using multiple active ingredients also indicated that nozzle type did not influence Palmer amaranth control (Meyer *et al.,* 2016).

At 7 and 14 DAT, Palmer amaranth control with imazapic + 2,4-DB + *S*-metolachlor was 35% less when compared to the other herbicide treatments (Table 4). This reduction in control can be attributed to the fact that this population of Palmer amaranth is resistant to the ALS-inhibiting herbicides. At 7 and 14 DAT, treatments with imazapic + 2,4-DB + *S*-metolachlor provided better control of annual grasses than paraquat, lactofen, and acifluorfen treatments. Although primarily used for nutsedge (*Cyperus* spp.) and broadleaf weed control in peanut, imazapic provides some level of annual grass control (Monks *et al.,* 1996; Wilcut *et al.,* 1999; Jordan *et al.,* 2009). Although commercially unacceptable, lactofen based treatments provided better control of annual grasses than acifluorfen treatments.

Table 2. Soil type, planting dates, application dates, peanut stages of growth, weed heights, and harvest dates for in-crop/peanut nozzle studies in Georgia, 2015-2016[a].

	Ty Ty		Attapulgus	
	2015	2016	2015	2016
Soil Type	Dothan ls	Tifton ls	Dothan ls	Faceville sl
Planting Date	Apr. 27	Apr. 25	May 4	May 2
PRE	Apr. 29	Apr. 26	May 5	May 2
EPOST	May 12	May 12	May 27	May 23
Peanut Stage[b]	V3	V3	V4	V4
Palmer amaranth	5-7 cm	5-7 cm	5-7 cm	5-7 cm
Annual grass	4-8 cm	4-8 cm	4-8 cm	4-8 cm
POST	June 8	June 8	June 9	June 13
Peanut Stage	R1	R1	R1	R2
Palmer amaranth	5-7 cm	5-7 cm	5-7 cm	5-7 cm
Annual grass	4-8 cm	4-8 cm	4-8 cm	4-8 cm
Inverting	Sept. 14	Sept. 8	———[c]	Sept. 22
Harvesting	Sept. 18	Sept. 12	———[c]	Sept. 26

[a]Abbreviations: ls = loamy sand, sl = sandy loam, PRE= preemergence, EPOST= early-postemergence, POST= postemergence.
[b]Peanut stages according to Boote 1982.
[c]Yield data was not collected at this location due to weather and wildlife problems at harvest.

In-crop

Crop injury. Nozzle type had no effect on peanut injury (Table 5). In cotton, crop injury was reduced when single fan nozzles that delivered larger droplets were used (Reeves *et al.,* 2016). When herbicide programs were pooled over nozzle type, the programs that included paraquat were more injurious than similar programs without paraquat (Table 6). Although paraquat causes stunting and necrosis, peanut tolerance has been thoroughly studied (Wilcut *et al*., 1991; Tubbs *et al*., 2010; Eure *et al.,* 2015). Paraquat continues to be an important component of many peanut weed control programs.

Palmer amaranth. Palmer amaranth control, when averaged over all four herbicide programs, was not significantly influenced by nozzle type at any rating date (Table 5). This is similar to what was reported for the non-crop test as well as previous research suggesting that nozzle type does not influence broadleaf weed control (Etheridge *et al*., 2001; Berger *et al.,* 2014). Broadleaf weed control is often less affected by nozzle type than grass control. The compact more upright structure of grasses makes them more difficult to control with a less uniform spray pattern produced by drift reducing nozzle types compared to broadleaf weeds (McKinlay *et al*., 1974; Etheridge *et al.,* 2001). When Palmer amaranth control was pooled over all nozzle types, herbicide programs provided similar control at all rating dates (Table 6). The fact that a significance difference in Palmer amaranth control was observed in the non-crop test and not in the in-crop test can be attributed to the multiple herbicide modes of action that were incorporated into the in-crop programs. By using a complete herbicide program, issues with resistant species and reduced herbicide efficacy can be minimized. The sequential herbicide applications in a complete program also increase control by killing survivors of previous applications.

Annual Grass Control. Herbicides applied with the TTI11002 nozzle which produced the coarsest droplet of the nozzles evaluated, were 5 to 6% less effective at controlling annual grasses at both rating dates than the AIXR and DG nozzles (Table 5). Reduced grass control has previously been reported when using coarse droplet producing nozzles when compared to nozzles that produce smaller droplet sizes (Mckinlay *et al*., 1974; Etheridge *et al.,* 2001; Meyer *et al.,* 2016). The narrower

Table 3. Influence of nozzle type on weed control (non-crop study) in Georgia, 2015-2016[a]

	Palmer amaranth control		Annual grass[b] control	
	Days after treatment		Days after treatment	
Nozzle type	7	14	7	14
	%		%	
DG11002	90 a	88 a	64 a	57 a
AIXR11002	89 a	86 a	62 a	51 a
TTI11002	90 a	87 a	65 a	57 a

[a]Least square means with the same letter in the same column are not significantly different according to pairwise t-tests, (alpha=0.10). Data are pooled over 4 herbicide treatments and 2 site-year combinations.
[b]A non-uniform mixture of *Urochloa texana*, *Dactyloctenium aegyptium*, *Eleusine indica*, and *Digitaria* spp.

Table 4. Influence of herbicide treatment on weed control (non-crop study) in Georgia, 2015-2016[abc].

		Palmer amaranth control		Annual grass[b] control	
		Days after treatment		Days after treatment	
Herbicide treatment	Rate	7	14	7	14
	kg ai/ha	%		%	
Paraquat plus bentazon plus acifluorfen plus *S*-metolachlor	0.21 + 0.37 + 0.19 + 1.23	97 a	94 a	74 a	60 b
Imazapic plus *S*-metolachlor plus 2,4-DB	0.07 + 1.23 + 0.25	64 b	63 b	81 a	82 a
Lactofen plus *S*-metolachlor plus 2,4-DB	0.228 + 1.23 + 0.25	99 a	97 a	60 b	47 c
Acifluorfen plus *S*-metolachlor plus 2,4-DB	0.19 + 1.23 + 0.25	98 a	94 a	40 c	32 c

[a]Least square means in the same column with the same letter are not significantly different according to pairwise t-tests (alpha= 0.10). Data combined over 3 nozzles and 2 site-years.

[b]A non-uniform mixture of *Urochloa texana, Dactyloctenium aegyptium, Eleusine indica*, and *Digitaria* spp.

leaf structure of grass species allows for a more difficult area for herbicide to contact, thus the more thorough coverage provided by smaller droplet sizes should provide better control. As observed in the non-crop study, herbicide programs that included imazapic resulted in greater control of annual grass than those that contained lactofen (Table 6). Although typically a broadleaf and sedge herbicide, imazapic can exhibit a range of control on small grass species. Previous research has shown upwards of 90% control on Texas panicum and crabgrass (Monks *et al.,* 1996; Ducar *et al.,* 2004). Lactofen is a broadleaf herbicide and does not adequately control grasses (Grichar, 1991; Minton *et al.,* 1989).

Peanut Yield. Peanut yield was not affected by nozzle type or herbicide program (Tables 5 and 6). The reduction in grass control observed with the TTI11002 did not result in a reduction in yield. Research has shown that peanut yield loss from grasses varies with the species, density, and duration of interference (Everman *et al.,* 2008).

In summary, growers who use coarse-droplet producing nozzles for weed control in auxin tolerant crops should not have to change nozzles for weed control in peanut when Palmer amaranth is present. In some instances, annual grass control may be slightly reduced when TTI nozzles are used. It is also important to note that these trials were conducted under irrigated conditions and results could differ in non-irrigated or dryland production systems. Additional nozzle performance data is needed for other troublesome weeds in peanut including sicklepod (*Senna obtusifolia*, L. Irwin & Barneby), yellow/purple nutsedge (*Cyperus* spp.), Florida beggarweed (*Desmodium tortuosum*, Sw.), smallflower morningglory (*Jacquemontia tamnifolia,* L. Griseb.), and annual morningglories (*Ipomoea* spp.). Future nozzle studies should evaluate herbicide treatments applied in lower carrier volumes, since reduced carrier volumes can negatively influence control (Etheridge *et al.*, 2001; Sikkema *et al.,* 2008; Berger *et al.,* 2014)

Acknowledgements

The technical support of Charlie Hilton, Dwayne Dales, Timothy Richards, and the Attapulgus Research and Education Center is greatly appreciated.

Table 5. Influence of nozzle type on peanut weed control programs and yield in Georgia, 2015-2016[a].

		Palmer amaranth control			Annual grass control[c]		
		Days after POST treatment			Days after POST treatment		
Nozzle type	Peanut injury[b]	7	14	21	7	14	Peanut yield
	%						kg/ha
DG11002	9 a	99 a	99 a	98 a	94 a	93 a	6,494 a
AIXR11002	8 a	99 a	98 a	98 a	95 a	93 a	6,505 a
TTI11002	8 a	99 a	98 a	99 a	89 b	88 b	6,266 a

[a]Least square means in the same column with the same letter are not significantly different according to pairwise t-tests (alpha=0.10). Data combined over 4 herbicide programs and 4 site-years.

[b]7 days after early postemergence.

[c]A non-uniform mixture of *Urochloa texana, Dactyloctenium aegyptium, Eleusine indica,* and *Digitaria spp.*

Table 6. Herbicide program effects on peanut weed control and yield in Georgia, 2015-2016[ab].

Herbicide program	Rate	Timing[b]	Peanut injury[cde]	Palmer amaranth control: Days after treatment 7	14	21	Annual grass control[e]: Days after treatment 7	14	Peanut yield
	kg ai/ha		%	—%			—%		kg/ha
pendimethalin	0.84	PRE	1 b	98 a	98 a	98 a	93 b	96 a	6,470 a
flumioxazin	0.12	PRE							
diclosulam	0.03	PRE							
imazapic	0.07	POST							
S-metolachlor	1.23	POST							
2,4-DB	0.25	POST							
pendimethalin	0.84	PRE	1 b	99 a	99 a	99 a	89 c	86 b	6,450 a
flumioxazin	0.12	PRE							
diclosulam	0.04	PRE							
lactofen	0.23	POST							
S-metolachlor	1.23	POST							
2,4-DB	0.25	POST							
pendimethalin	0.84	PRE	15 a	99 a	98 a	98 a	97 a	95 a	6,420 a
paraquat	0.21	EPOST							
acifluorfen	0.19	EPOST							
S-metolachlor	1.23	EPOST							
imazapic	0.07	POST							
S-metolachlor	1.23	POST							
2,4-DB	0.25	POST							
pendimethalin	0.84	PRE	15 a	99 a	98 a	98 a	93 b	88 b	6,350 a
paraquat	0.21	EPOST							
acifluorfen	0.19	EPOST							
S-metolachlor	1.23	EPOST							
lactofen	0.23	POST							
S-metolachlor	1.23	POST							
2,4-DB	0.25	POST							

[a]Abbreviations: PRE= preemergence, EPOST= early-postemergence, POST= postemergence .

[b]Least square means in the same column with the same letter are not significantly different according to pairwise t-tests (alpha=0.10). Data combined over 3 nozzle types and 4 site-years.

[c]A combination of peanut leaf burn and crop stunting.

[d]7 days after EPOST.

[e]A non-uniform mixture of *Urochloa texana, Dactyloctenium aegyptium, Eleusine indica,* and *Digitaria spp*.

Literature Cited

Anonymous. 2017. Enlist Duo™ herbicide product label. DowAgro-Sciences, Indianapolis, IN.

Anonymous. 2017. Peanut Production Update. Cooperative Extensions Service Series CSS-17-0118. ed. W.S. Montfort. Athens, GA: University of Georgia. Pages 67.

Behrens, M.R., N. Mutlu, S. Chakraborti. 2007. Dicamba resistance: enlarging and preserving biotechnology-based weed management strategies. Science 316:1185–1187.

Berger, S.T., M.H. Dobrow, J.A. Ferrell, and T.M. Webster. 2014. Influence of carrier volume and nozzle selection on Palmer amaranth control. Peanut Sci. 41:120–123.

Boote, K.J. 1982. Growth stages of peanut (*Arachis hypogaea* L.) Peanut Sci. 9:35–40.

Branch, W.D. 2007. Registration of 'Georgia 06G' peanut. J. Plant Reg. 1:121

Cahoon, C.W., A.C. York, D.L. Jordan, W.J. Everman, R.W. Seagroves, A.S. Culpepper, and P.M. Eure. 2015. Palmer amaranth (*Amaranthus palmeri*) management in dicamba-resistant cotton. Weed Technol. 29:758–770.

Creech, C.F., R.S. Henry, B.K. Fritz, and G.R. Kruger. 2015. 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.

Ducar, J.W., J.T. Wilcut, J.S. Richburg III. 2004. Weed management in imidazolinone-resistant corn with imazapic. Weed Technol. 18:1018–1022.

Egan, J.F., K.M. Barlow, and D.A. Mortensen. 2014. A meta-analysis on the effects of 2,4-D and dicamba drift on soybean and cotton. Weed Sci. 62:193–206.

Elkan, G.H. 1995. Biological nitrogen fixation in peanuts. 286-297 in H.E. Pattee and H.T. Stalker. (eds). Advances in Peanuts Science. American Peanut Research and Education Soc.

Etheridge, R.E., W.E. Hart, R.M. Hayes, and T.C. Mueller. 2001. Effect of venturi-type nozzles and application volume on postemergence herbicide efficacy. Weed Technol. 15:75–80.

Eure, P.M., E.P. Prostko, and R.M. Merchant. 2015. Peanut response to postemergence applications of pyroxasulfone. Peanut Sci. 42:44–48.

Everman, W.J., I.C. Burke, S.B. Clewis, W.E. Thomas, and J.W. Wilcut. 2008. Critical period of grass vs. broadleaf weed interference in peanut. Weed Technol. 22:68–73.

Grichar, W.J. 1991. Sethoxydim and broadleaf herbicide interaction effects on annual grass control in peanuts (*Arachis hypogaea*). Weed Technol. 5:321–24.

Heap, I. The international survey of herbicide resistant weeds. Online. Internet. Wednesday, April 5, 2017. Available: www.weedscience.com

Horton, D. 2017. Georgia Pest Management Handbook. University of Georgia Ext. Pub., Spec. Bull. 28, Vol. 1.

Jordan, D.L., S.H. Lancaster, J.E. Lanier, B.R. Lassiter, and P.D. Johnson. 2009. Weed management in peanut with herbicide combinations containing imazapic and other pesticides. Weed Technol. 23:6–10.

Leon, R.G., J.A. Ferrell, and B.J. Brecke. 2014. Impact of exposure to 2,4-D and dicamba on peanut injury and yield. Weed Technol. 28:465–470.

McKinlay K.S., R. Ashford, R.J. Ford. 1974. Effects of drop size, spray volume, and dosage on paraquat toxicity. Weed Sci 22:31–34.

Meyer, C.J., J.K. Norsworthy, G.R. Kruger, and T.L. Barber. 2016. Effect of nozzle selection and spray volume on droplet size and efficacy of Engenia™ tank-mix combinations. Weed Technol. 30: 377–390.

Minton, B.W., M.E. Kurtz, and D.R. Shaw. 1989. Barnyardgrass (*Echinochloa crus-galli*) control with grass and broadleaf weed herbicide combinations. Weed Sci. 37:223–27.

Mohsen-Moghadan, M., and D. Doohan. 2015. Response of bell pepper and broccoli to simulated drift rates of 2,4-D and dicamba. Weed Technol. 29:226–232.

Monks, C.D., J.W. Wilcut, J.S. Richburg, J.H. Hatton, and M.G. Patterson. 1996. Effect of AC 263,222, imazethapyr, and nicosulfuron on weed control and imidazolinone-tolerant corn (*Zea mays*) yield. Weed Technol. 10:822–827.

Mueller, T.C. and A.R. Womac. 1997. Effect of formulation and nozzle type on droplet size with isopropylamine and trimesium salts of glyphosate. Weed Technol. 11:639–643.

Ramsdale, B.K. and C.G. Messersmith. 2001. Drift reducing nozzle effects on herbicide performance. Weed Technol. 15:453–460.

Reeves, J., L.E. Steckel, and S. Steckel. 2016. Examining nozzle effects on POST-applied herbicide burn to cotton. Proc. Weed Sci. Soc. Am. 56:184 (abstr.)

Sikkema, P.H., L. Brown, C. Shropshire, H. Spieser, N. Soltani. 2008. Flat fan and air induction nozzles affect soybean herbicide efficacy. Weed Bio. And Mgmt. 8.1: 31–38

Sosnoskie, L.M. and A.S. Culpepper. 2014. Glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) increases herbicide use, tillage, and hand-weeding in Georgia cotton. Weed Sci. 62: 393–402.

Taylor, W. A., A.R. Womac, P.C.H. Miller, and B.P. Taylor. 2004. An attempt to relate drop size to drift risk. Proceedings of the International Conference on Pesticide Application for Drift Management: 210–223.

Tubbs, R.S., E.P. Prostko, R.C. Kemerait, T.B. Brenneman, and D.Q. Wann. 2010. Influence of paraquat on yield and tomato spotted wilt virus for Georgia-02C and Georgia-03L peanut. Peanut Sci. 37:39–43.

[USDA-APHIS] United States Department of Agriculture–Animal and Plant Health Inspection Service. 2015. Monsanto Co.; Determination of Nonregulated Status of Herbicide Resistant Soybean and Cotton. https://www.federalregister.gov/articles/2015/01/20/2015-00723/monsanto-co-determination-of-nonregulated-status-of-herbicide-resistant-soybean-and-cotton. Accessed March 10, 2015.

[USDA-AMS] U.S. Department of Agricultures- Agricultural Marketing Service. 2016. Cotton varieties planted 2016. https://www.ams.usda.gov/mnreports/cnavar.pdf. Accessed: September 27, 2016.

[USDA-NASS] U.S. Department of Agriculture- National Agriculture Statistics Service. 2016. U.S. acreage summary. http://www.usda.gov/nass/PUBS/TODAYRPT/acrg0616.pdf. Accessed: October 10, 2016.

Vencill, W.K., R.L. Nichols, T.M. Webster, J.K. Soteres, C. Mallory-Smith, N.R. Burgos, W.G. Johnson, and M.R. McClelland. 2012. Herbicide resistance: toward an understanding of resistance development and the impact of herbicide-resistant crops. Weed Sci. 60:2–30.

Wilcut, J.W. 1991. Economic yield response of peanut (*Arachis hypogaea*) to postemergence herbicides. Weed Technol. 5: 416–20.

Wilcut, J.W., J.S. Richburg III, and F.R. Walls Jr. 1999. Response of johnsongrass (*Sorghum halepense*) and imidazolinone-resistant corn (*Zea mays*) to AC 263,222. Weed Technol. 13:484–88.