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ARTHROPOD MANAGEMENT & APPLIED ECOLOGY

Efficacy of Acephate on Thrips in Cotton (*Gossypium hirsutum* L.) when Applied at Various Droplet Sizes

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ABSTRACT

With fewer agrichemical compounds and molecules being discovered by private industry, innovative ways of using current modes of action and application technologies are not only necessary but imperative to maintain and improve pest management strategies. This research was conducted during 2019 and 2020 at the Edisto Research and Education Center in Blackville, SC. The objective was to determine if sprayer droplet size (150-900 µm) had an impact on the efficacy of a standard insecticide used to control tobacco thrips, *Frankliniella fusca* (Hinds), in cotton, *Gossypium hirsutum* (L.). Three separate fields were used where 1- to 2-leaf cotton was sprayed with Orthene 97SG (acephate) applied at a rate of 197 g ai ha^{-1} to control thrips. Treatments consisted of droplet diameters of 150, 300, 450, 600, 750, and 900 µm. In 2019, acephate applied at a droplet size of 450 µm resulted in the greatest number of thrips on cotton 3 days after application (DAA) when compared with all other droplet sizes. Visual injury ratings at 3 DAA were greater on cotton where acephate was applied at 300-µm droplets when compared with other droplet sizes. In 2020, acephate applied at a droplet size of 150 µm resulted in the lowest number of thrips on cotton at 14 DAA when compared with all other droplet sizes. Based on these results, South Carolina cotton farmers might have more flexibility in nozzle selection and droplet size ranges when using acephate to effectively control thrips in cotton than previously hypothesized.

In South Carolina, production of cotton, *Gossypium hirsutum* (L.), on 119,382 harvested hectares in 2019 contributed $141 million (USD) to the economy (NASS, 2020). Tobacco thrips, *Frankliniella fusca* (Hinds), are recognized as consistent and predictable insect pests that infest more than 97% of cotton seedlings in the southeastern U.S. (Herbert et al., 2016). Thrips injury occurs from meristem feeding, which can cause terminal malformation, abnormal growth, and ultimately complete termination of the cotton seedling terminal (Burris, 1989; Kerns et al., 2018). Even though cotton can tolerate some early season thrips pressure, extreme thrips pressure can be detrimental to a cotton crop (Cook et al., 2011). Researchers in the southeastern U.S. found a 34 to 43% yield loss when thrips were not managed properly (Herbert et al., 2016). Thrips have been controlled historically by in-furrow insecticides (liquid or granular), seed treatments, and the use of rescue treatments applied as foliar insecticides (e.g., acephate) (Greene et al., 2020). In recent history, resistance to neonicotinoid seed treatments across the U.S. Cotton Belt resulted in farmers applying one to two foliar applications to control tobacco thrips (Huseth et al., 2016). Improper uptake of systemic insecticides due to unfavorable soil and weather conditions during pesticide application also results in additional foliar treatments (Greene et al., 2020).

Several researchers have conducted research trials to determine the most appropriate droplet size for foliar insecticide applications. Historically, cotton farmers have used smaller droplet sizes when applying foliar insecticides to achieve better coverage than obtained with larger droplet sizes (Ferguson et al., 2015; Himel, 1969; Knoche, 1994). Reed and Smith (2001) found a trend of increasing pesticide efficacy in the mid-canopy of a cotton plant when applying smaller droplet sizes to control tobacco budworm, *Heliothis virescens* (Fabricius). However, the same researchers did not find any significant difference between droplet sizes at the upper- and mid-canopy levels the year before (Reed and Smith, 1999). A study in the mid-southern U.S. by Samples et al. (2020) found that thrips control was maximized three days after treatment by larger droplet sizes (300, 400, and 500 µm) when applying acephate. Further research is needed to determine the efficacy of

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a broad range of droplet sizes when applying acephate to control tobacco thrips in the southeastern U.S.

Droplet size, however, impacts more than just pesticide efficacy. Spray drift has been a concern since chemical control methods were developed and adopted (Smith and Luttrell, 1997). Spray drift can be defined as "the movement of pesticide dust or droplets through the air at the time of application or soon after, to any site other than the area intended" (EPA, 2024). Farmers are required to meet regulatory demands and use medium to coarse droplet sizes when applying certain herbicides (dicamba and 2,4-D) to reduce off-target drift (Butts et al., 2018). Previous research showed that increasing droplet size helped limit potential off-target drift (Butts et al., 2019; Hewitt, 1997). New herbicide technologies often require the identification or development of additives and adjuvants to reduce drift or enhance product efficacy (Bayer Crop Science, 2022). Klein et al. (2009) reported that droplet size could vary by as much as 75 µm depending upon the spray solution used. Therefore, altering pesticide spray solutions could inadvertently impact pesticide performance.

Even though data suggest that different droplet sizes should be used for different pesticide categories (herbicides, insecticides, etc.), the likelihood of a farmer changing spray nozzles to alter droplet size for each product being applied is unlikely. A survey conducted by Bish and Bradley (2017) found that commercial and noncommercial applicators change spray nozzles between spray applications less than 50% of the time. Because farmers are required to reduce spray drift with herbicides by using larger droplet sizes, an objective of this research was to determine if droplet size (150-900 µm) had an impact on the efficacy of a common insecticide (acephate) used to control tobacco thrips. With the possibility of farmers applying herbicides and insecticides concurrently, data on the effects of droplet size on insecticide efficacy are needed.

MATERIALS AND METHODS

This experiment was conducted at Clemson University's Edisto Research and Education Center (EREC) in Blackville, SC, in 2019 and 2020. Blackville is located on the Coastal Plain of South Carolina, and the three cotton fields used in this research contained a Barnwell loamy sand (fine-loamy, kaolinitic, thermic Typic Kanhapludults). Replicated plots were arranged in a randomized complete block design, with four replications. At the 1- to 2-true leaf stage, applications of acephate (Orthene® 97SG; AMVAC Chemical Corporation, Collierville, TN) at 197 g ai ha^{-1} were applied at droplet sizes of 150, 300, 450, 600, 750, and 900 µm. An untreated control was included for comparison purposes. Acephate is a soluble organophosphate insecticide readily absorbed by plants (roots and foliage), providing contact and systemic control of feeding insects (AMVAC Chemical Corporation, 2021). All applications were made using a carrier volume of 93.5 L ha^{-1} of water. A high-clearance plot sprayer equipped with Capstan Ag Pinpoint II blended pulse width modulation system (Capstan Ag Systems, Inc. Topeka, KS) was used to spray all treatments (Fig. 1). The addition of this system allowed for rate to be maintained while keeping a constant boom pressure regardless of ground speed. This technology ensured that the targeted droplet size was applied uniformly for each treatment.

Figure 1. Mudmaster plot sprayer equipped with pulse width modulation used during the droplet size experiment at EREC in Blackville, SC, in 2019 and 2020.

During both growing seasons, no insecticide was used at planting. In 2019, Nexgen 3729 B2XF was planted on 10 May in Field 1. In 2020, Deltapine 1646 B2XF was planted on 12 May in Field 1 and on 23 May in Field 2. Research plots consisted of 8 rows with 96-cm row spacing and were 15 m in length. Cotton was seeded at 111,197 seeds ha^{-1} at a depth of 2.5 cm. Plots were managed throughout the growing season (Table 1) based on recommendations from the South Carolina Cotton Grower's Guide (Jones et al., 2019).

Prior to all insecticide applications, specific nozzle types and pressure settings were determined at the University of Nebraska Pesticide Application Technology (PAT) Lab in North Platte, NE. The PAT lab used a low-speed wind tunnel equipped with a laser diffraction instrument to determine what nozzle

Table 1. Planting, spray application, and harvest dates for cotton field trials on spray droplet size conducted at EREC in Blackville, SC, in 2019 and 2020

Location	Planting Date	Spray Application Date[z]	Harvest Date
	---2019---		
EREC	May 10	May 28	November 11
	---2020---		
Field 1	May 12	June 6	October 15
Field 2	May 23	June 17	November 19

[z]Acephate was applied on 1- to 2-leaf cotton for all application dates.

type and pressure setting were needed to achieve the desired droplet size. Once the appropriate nozzle type and pressure settings were matched, the PAT lab conducted a three-replication study to ensure that the desired droplet size was achieved. Wilger spray tips (Wilger Inc., Lexington, TN) were used to apply the desired droplet size for each treatment (Table 2).

Table 2. Nozzle type and pressure settings for spray droplet size treatments at EREC in Blackville, SC, in 2019 and 2020

Targeted Droplet Size (µm)	Nozzle Type[z]	Pressure Setting[y] (psi)
150	ER11002	70
300	SR11003	50
450	MR1105	40
600	MR11008	32
750	UR11004	40
900	UR11006	32

[z]Wilger spray nozzles were used for this experiment to achieve the desire droplet size.

[y]All nozzle and pressure settings were derived from the PAT lab at Univ. Nebraska.

Before pesticide application, spray cards made of water-sensitive paper (Spraying Systems Co.®, Wheaton, IL) were placed on the ground between the rows in each plot. After plots were sprayed, each spray card was collected separately, placed into pre-labeled bags, and taken to the lab for further analysis. After the spray cards dried, each card was scanned using an HP Scanjet 4850 scanner (HP Development Company, L.P, Spring, TX), and image files were downloaded for further analysis. Droplet size data were analyzed using a Spray Card Analyzer created by Dr. Kirk at Clemson University to quantify spray coverage and estimated mean droplet size from images.

Thrips were sampled and injury rated at 3, 6, 9, and 12 d after application (DAA) in 2019 and 0, 3, 7, and 14 DAA in 2020. On each sampling date, 10 plants per plot were cut at the soil surface, placed carefully into pre-labeled jars filled with 70% isopropyl alcohol in 2019 or soapy water solution in 2020 (due to unavailability of alcohol), and taken to the laboratory for thrips counting. At the lab, jar contents were poured into a filtration flask with filter paper placed on top of each flask. Filter paper was carefully transported to a dissecting microscope where thrips were counted as immature or adult. On each sampling date and in each plot, seedling injury caused by thrips was visually rated on a 0 to 5 scale, where rating 0 indicated no visible injury, and 5 indicated the terminal or plant was destroyed (Kerns et al., 2018). Also for each sampling date, growth stage (number of true leaves) was noted, and plant heights were collected by measuring five plants from the ground to terminals randomly throughout each plot. At 42 d after planting (DAP), 10 plants per plot were randomly selected, measured for height, counted for nodes, cut at the soil level, weighed for fresh weight, dried in propane-fueled driers, and weighed again for dry biomass estimates. Cotton plant heights and number of nodes were recorded at first bloom and at harvest.

All plots were harvested using a 4-row John Deere 9986 spindle-type cotton picker modified for small-plot research. Prior to plots being harvested, 25 bolls were hand harvested and ginned using an 8-saw laboratory gin. Percent gin turnout was calculated by dividing the lint weight of each sample by the seed cotton weight of each sample and multiplying by 100. Gin turnout was used to calculate total lint yield for all plots in 2019 and 2020. All data were subjected to analysis of variance using the PROC GLIMMIX procedure in SAS 9.4 (SAS Institute, 2013), and means were separated using multiple pairwise t-tests at $\alpha = 0.05$. Random effects consisted of field and replication, and fixed effects consisted of droplet size.

RESULTS AND DISCUSSION

Weather conditions between the 2019 and 2020 growing seasons were drastically different. Rainfall was limited in 2019, with 66.1 cm of rain, compared with 100.4 cm of rain in 2020 (Table 3). In 2019, thrips pressure was seemingly high due to the prolonged dry weather and high temperatures experienced in May. Data were analyzed separately for each field, as densities of and injury from thrips were significantly different by individual fields in 2019 and 2020.

Table 3. Average daily maximum and minimum temperatures and rainfall totals[z] for EREC in Blackville, SC, during the growing season[y] in 2019 and 2020

Location	Max. Avg. Temp.	Min. Avg. Temp.	Rainfall
	(˚C)	(˚C)	(cm)
	----------------------2019----------------------		
EREC	27.8	15.9	66.1
	----------------------2020----------------------		
EREC	26.9	16.2	100.4

[z]Temperature and rainfall data from Edisto REC Weather Data from Clemson Cooperative Extension Services

[y]Growing season (March-November)

Thrips Counts. In 2019, significant differences in thrips counts were observed at 3, 9, and 12 DAA among droplet size treatments and with the untreated control (Table 4). At 3 DAA, thrips counts ranged from 14 to 103 thrips per 10 plants, with the smallest droplet size treatment (150 µm) having the lowest number of thrips (Table 4). Acephate applied at a droplet size of 450 µm at 3 DAA resulted in a thrips density statistically equivalent to the untreated control and greater than all other droplet sizes (Table 4). These findings disagree with Samples et al. (2020), who found a decrease in the number of thrips when acephate was applied at 0.28 kg ai ha^{-1} using a 400-µm droplet size. In 2019, thrips density peaked in the untreated control at 6 DAA and did not significantly differ from all spray treatments (Table 4). At 9 DAA, all treatments sprayed with acephate statistically reduced thrips densities (Table 4), compared with the untreated control. In 2020, there were no significant differences in thrips counts between all treatments, including the untreated control in Field 1 (Table 5). However, at the later planting date (14 DAA) in Field 2, thrips densities in all droplet sizes were

Table 4. Thrips densities on cotton plants on days after application (DAA) for droplet size treatments and an untreated control at EREC in Blackville, SC, in 2019

Droplet Size (µm)	Total # of Thrips/10 Plants			
	3 DAA	6 DAA	9 DAA	12 DAA
Untreated	103.0 a[z]	123.3 a	41.5 a	17.0 a
150	14.0 c	69.5 a	10.0 b	5.3 b
300	44.0 bc	119.8 a	13.8 b	8.3 ab
450	71.3 ab	45.3 a	8.8 b	10.5 ab
600	20.8 c	60.3 a	16.5 b	3.0 b
750	25.8 c	108.5 a	11.5 b	8.5 b
900	27.0 c	105.3 a	14.8 b	7.8 ab
p-value	0.0001[y]	0.6087	0.0006	0.1597

[z]Means within a column followed by the same letter are not significantly different at α = 0.05.

[y]*P* values were obtained from ANOVA table in output of SAS using PROC GLIMMIX procedure.

Table 5. Thrips densities on cotton plants on days after application (DAA) for droplet size treatments and an untreated control at EREC in Blackville, SC, in 2020

Droplet Size (µm)	------------------------Field 1------------------------				------------------------Field 2------------------------			
	0DAA	3DAA	7DAA	14DAA	0DAA	3DAA	7DAA	14DAA
Untreated	52.5 a[z]	10.5 a	6.8 a	5.3 a	71.5 a	--	30.0 a	12.3 a
150	70.5 a	17.5 a	7.3 a	6.5 a	56.0 a	--	6.3 b	1.0 c
300	62.0 a	16.5 a	7.0 a	7.0 a	79.0 a	--	15.8 ab	5.8 b
450	82.8 a	8.3 a	7.0 a	4.0 a	50.8 a	--	10.8 a	3.0 bc
600	86.1 a	13.3 a	5.0 a	3.5 a	47.8 a	--	13.5 ab	3.5 bc
750	92.3 a	8.8 a	5.0 a	7.0 a	55.0 a	--	8.0 b	3.3 bc
900	91.8 a	14.5 a	3.8 a	5.0 a	77.8 a	--	23.0 ab	2.3 c
p-value	0.1956[y]	0.7004	0.8762	0.7452	0.8912	--	0.1816	<0.0001

[z]Means within a column followed by the same letter are not significantly different at α = 0.05.

[y]*P* values were obtained from ANOVA table in output of SAS using PROC GLIMMIX procedure.

significantly lower than thrips counts in the untreated control (*p*-value < 0.0001). Acephate applied at the smallest (150 µm) spray droplet size resulted in the greatest control of thrips at 14 DAA (Table 5). These results are similar to the findings of Reed and Smith (2001) and Sumner et al. (2000), who found that using smaller droplet sizes increased the coverage and provided better control as compared with larger droplet sizes.

Visual Injury Ratings. Visual injury ratings were generally reduced in acephate spray treatments with any droplet size when compared with the untreated control across all tests (Tables 6 and 7). In 2019, injury ratings at 3, 9, and 12 DAA were significantly lower in most droplet size treatments when compared with the untreated control. At 9 DAA, injury ratings in sprayed treatments were all numerically lower than the untreated control, and most of the sprayed treatments had injury ratings statistically lower than the untreated control (Table 6). In 2020, there were no statistical differences in injury ratings at 0 and 3 DAA in Field 1 (Table 7) or on any sample date in Field 2 (data not shown). In Field 1, the highest visual injury ratings were observed in the untreated control plots, and the lowest levels of feeding injury were detected with the 600- and 900-µm droplet sizes on 7 and 14 DAA, respectively (Table 7).

Table 6. Visual injury ratings of thrips feeding damage on cotton plants on days after application (DAA) of acephate date for all droplet size treatments and an untreated check at EREC in Blackville, SC, in 2019

Droplet Size (µm)	Visual Injury Ratings (0-5)^{z}			
	3 DAA	6 DAA	9 DAA	12 DAA
Untreated	2.5 ab^{y}	3.5 a	4.0 a	4.1 a
150	2.0 b	3.3 a	2.8 c	3.1 b
300	2.8 a	3.5 a	3.5 ab	3.1 b
450	2.0 b	3.5 a	3.5 ab	3.5 b
600	2.0 b	3.3 a	3.3 bc	3.4 b
750	2.5 ab	3.3 a	3.3 bc	3.3 b
900	2.0 b	3.0 a	2.8 c	3.4 b
p-value	0.0262^{x}	0.8602	0.0199	0.0246

^{z}Scale of injury 0 = no damage; 5 = dead terminals or plants.

^{y}Means within a column followed by the same letter are not significantly different at α = 0.05.

^{x}*P* values were obtained from ANOVA table in output of SAS using PROC GLIMMIX procedure.

Table 7. Visual injury ratings of thrips feeding damage on cotton plants on days after application (DAA) of acephate date for all droplet size treatments and an untreated check at EREC in Blackville, SC, in 2020

Droplet Size (µm)	Visual Injury Ratings (0-5)^{z}			
	0 DAA	3 DAA	7 DAA	14 DAA
Untreated	3.5 a^{y}	2.8 a	3.3 a	2.8 a
150	3.3 a	2.8 a	2.5 ab	1.3 bc
300	3.5 a	2.8 a	3.0 ab	1.5 bc
450	3.5 a	3.0 a	2.5 ab	2.0 ab
600	3.5 a	2.5 a	2.3 b	1.5 bc
750	3.3 a	2.5 a	3.0 ab	1.8 bc
900	3.5 a	2.8 a	2.5 ab	1.0 c
p-value	0.9758^{x}	0.9014	0.3230	0.0246

^{z}Scale of injury 0 = no damage; 5 = dead terminals or plants.

^{y}Means within a column followed by the same letter are not significantly different at α = 0.05.

^{x}*P* values were obtained from ANOVA table in output of SAS using PROC GLIMMIX procedure.

Spray Card Results. Data from water-sensitive paper (Fig. 2) placed in each plot for analysis of spray coverage and mean droplet size diameter indicated as droplet size increased, percent coverage decreased (Table 8). Plots sprayed with a targeted 150-µm droplet size provided 53.6% coverage, whereas plots sprayed at a targeted 900-µm droplet size resulted in only 21.1% coverage when applying acephate to seedling cotton to control tobacco thrips (Table 8). Mean droplet size captured on spray cards confirmed that droplet size increased with targeted sizes, but deposited droplet sizes were much greater than the targeted droplet sizes (Table 8). At the PAT lab in Nebraska, droplet sizes were measured using a laser diffraction instrument measuring droplet size while they were suspended in air. Droplets measured using spray cards were measured after the spray droplet contacted the spray card, resulting in a spread of solution and a larger diameter than what the spray droplet would be in air. Therefore, mean droplet size observed increased as the application of larger droplet sizes were applied (Table 8).

Cotton Growth Parameters. Spray droplet size affected cotton growth parameters only in 2020 at Field 1 (Table 9). The number of nodes present at harvest varied by droplet size at Field 1 in 2020 (Table 9). Number of nodes ranged from 14.9 to 16.3 with the smallest spray droplet sizes (150 and

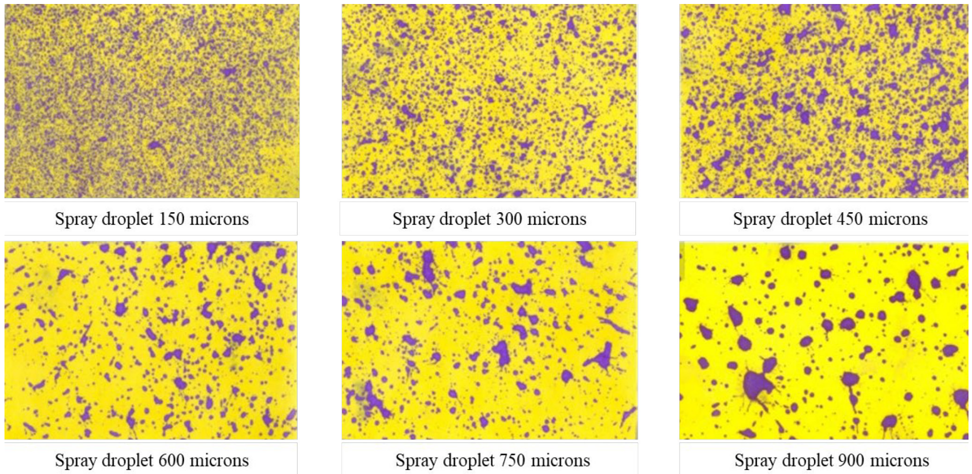

Figure 2. Spray card results from acephate applications at 150, 300, 450, 600, 750, and 900 µm target droplet sizes at EREC in Blackville, SC, in 2019.

Table 8. Targeted mean droplet size, percent coverage, and observed deposition droplet size for spray cards averaged across both site years at EREC in Blackville, SC, in 2019 and 2020

Droplet Size (µm)	Coverage (%)	Observed Mean Droplet Size (µm)
150	53.6 a[z]	772.9 c
300	40.7 b	794.4 c
450	31.3 c	1000.4 bc
600	30.5 c	1164.1 ab
750	24.7 cd	1272.2 a
900	21.1 d	1367.2 a
p-value	< 0.0001[y]	< 0.0001

[z]Means within a column followed by the same letter are not significantly different at $\alpha = 0.05$.

[y]*P* values were obtained from ANOVA table in output of SAS using PROC GLIMMIX procedure.

Table 9. Total nodes at harvest when compared across all droplet sizes at Field 1 at EREC in Blackville, SC, in 2020

Droplet Size (µm)	Mainstem Nodes at Harvest
150	16.1 ab[z]
300	16.3 a
450	15.4 bc
600	15.3 bc
750	14.9 c
900	15.2 c
p-value	0.0249[y]

[z]Means within a column followed by the same letter are not significantly different at $\alpha = 0.05$.

[y]*P* values were obtained from ANOVA table in output of SAS using PROC GLIMMIX procedure

300 µm) resulting in the greatest number of nodes per plant. With limited differences in biomass, plant heights, total nodes, and nodes above white flower counts, different droplet sizes of acephate sprays for thrips appeared to have little effect on cotton growth parameters.

Yield. In 2019 and 2020, no significant differences were observed in cotton lint yield when compared between all droplet sizes and the untreated control. Cotton yield differed between years, with average overall lint yield greater in 2019 than in 2020 (Table 10). Cotton lint yield ranged from 1,131 to 1,325 kg ha^{-1} in 2019, and 628 to 1,079 kg ha^{-1} at Field 1 and 670 to 885 kg ha^{-1} at Field 2 in 2020 (Table 10). Though no significant differences were observed between droplet size treatments and the untreated control, trends in cotton lint yield were observed at all fields during this experiment. Cotton lint yield for the 900-µm droplet size in 2019 and Field 1 in 2020 was the highest as compared with all other treatments (Table 10). These results are similar to those found by Samples et al. (2020), who showed that cotton lint yield was maximized when acephate was applied at a 500-µm droplet size, which was the largest droplet size used in their experiment. Data from this research demonstrated that acephate applied at 197 g ai ha^{-1} was enough to suppress thrips and prevent yield loss regardless of droplet size.

Table 10. Cotton lint yield (kg ha^{-1}) for spray droplet size field trials at EREC in Blackville, SC, in 2019 and 2020

Droplet Size (µm)	-----------Lint Yield (kg ha^{-1}) -----------		
	2019	-----------2020-----------	
	———	Field 1	Field 2
Untreated	1211 a	910 ab	841 a
150	1218 a[z]	954 ab	754 a
300	1206 a	849 ab	670 a
450	1131 a	628 b	785 a
600	1253 a	676 b	832 a
750	1298 a	888 ab	885 a
900	1325 a	1079 a	750 a
p-value	0.5604[y]	0.1838	0.8168

[z]Means within a column followed by the same letter are not significantly different at α = 0.05.

[y]*P* values were obtained from ANOVA table in output of SAS using PROC GLIMMIX procedure

CONCLUSION

Application of acephate at any droplet size generally resulted in reduction of thrips but did not affect yield, compared with the untreated control. This suggests that South Carolina farmers have flexibility in nozzle selection and droplet size ranges when using acephate to control thrips in cotton. This will allow an applicator to use the larger droplet sizes required for the application of restrictive herbicides and still achieve acceptable levels of tobacco thrips control. By making one spray pass throughout a field to control weeds and thrips, farmers can reduce overall sprayer application costs compared with individual trips to control each pest category. Continued research on application technologies, droplet size, and the efficacy of products is needed to provide cotton farmers an accurate recommendation when applying multiple pesticides to control various pests. Future research is needed to determine if droplet size affects tobacco thrips control at reduced rates of acephate, along with control of other arthropod pests when pesticides are applied later in the season, when larger crop canopies could impact coverage and efficacy.

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REFERENCES

AMVAC Chemical Corporation. 2021. Orthene®97SG. [Online] Available at https://s3-us-west-1.amazonaws.com/agrian-cg-fs1-production/pdfs/Orthene_97_Label1d.pdf (verified 30 Jan. 2025).

Bayer Crop Science. 2022. Xtendimax with VaporGrip Technology. [Online] Available at https://www.xtendimaxapplicationrequirements.com/pdf/xtendimax_label.pdf (verified 30 Jan. 2025).

Bish, M.D., and K.W. Bradley. 2017. Survey of Missouri pesticide applicator practices, knowledge, and perceptions. Weed Tech. 31(2):165–177. https://doi.org/10.1017/wet.2016.27

Burris, E., K.J. Ratchford, A.M. Pavloff, D.J. Boquet, B.R. Williams, and R.L. Rodgers. 1989. Thrips on seedling cotton: related problems and control. [Online] Louisiana Agric. Exp. Stan. No. 811. Available at https://repository.lsu.edu/agexp/881/ (verified 30 Jan. 2025).

Butts, T.R., C.A. Samples, L.X. Franca, D.M. Dodds, D.B. Reynolds, J.W. Adams, R.K. Zollinger, K.A. Howatt, B.K. Fritz, W.C. Hoffman, and G.R. Kruger. 2018. Spray droplet size and carrier volume effect on dicamba and glufosinate efficacy. Pest Manag. Sci. 74(9):1–38. https://doi.org/10.1002/ps.4913

Butts, T.R., C.A. Samples, L.X. Franca, D.M. Dodds, D.B. Reynolds, J.W. Adams, R.K. Zollinger, K.A. Howatt, B.K. Fritz, W.C. Hoffman, J.D. Luck, and G.R. Kruger. 2019. Droplet size impact on efficacy of a dicamba-plus-glyphosate mixture. Weed Tech. 33:66–74. https://doi.org/10.1017/wet.2018.118

Cook, D., A. Herbert, D.S. Akin, J. Reed. 2011. Biology, crop injury, and management of thrips (Thysanoptera: Thripidae) infesting cotton seedlings in the United States. J. Integ. Pest Manag. 2(2):1–9. https://doi.org/10.1603/IPM10024

Ferguson, J.C., C.C. O'Donnell, B.S. Chauhan, S.W. Adkins, G.R. Kruger, R. Wang, P.H.U. Ferreira, and A.J. Hewitt. 2015. Determining the uniformity and consistency of droplet size across spray drift reducing nozzle in a wind tunnel. Sci. Direct. 76:1–6. https://doi.org/10.1016/j.cropro.2015.06.008

Greene J.K., F.P.F. Reay-Jones, and S. Conzemius. 2020. Best management practices for thrips (Thysanoptera: Thripidae) in cotton. Clemson Coop. Ext., Land-Grant Press by Clemson Extension. LGP 1096. Available at https://lgpress.clemson.edu/publication/best-management-practices-for-thrips-thysanoptera-thripidae-in-cotton/ (verified 30 Jan. 2025).

Herbert A, D. Reisig, A. Huseth, G. Kennedy, J. Greene, F.P.F. Reay-Jones, P. Roberts, M. Toews, A. Jacobson, R. Smith, and T. Reed. 2016. Managing thrips in cotton: research in the southeast region. Virginia Coop. Ext., ENTO-182NP. Available at https://cottoncultivated.cottoninc.com/wp-content/uploads/2016/04/Thrips-Management-in-SE.pdf (verified 30 Jan. 2025).

Hewitt, A. 1997. Droplet size and agricultural spraying, part 1: atomization, spray transport, deposition, drift, and droplet size measurement techniques. Atomization and Sprays. 7(3):235–244. https://doi.org/10.1615/AtomizSpr.v7.i3.10

Himel, C.H. 1969. The optimum size for insecticide spray droplets. J. Econ. Entomol. 62(4):919–925. https://doi.org/10.1093/jee/62.4.919

Huseth, A.S., T.M. Chappel, K. Langdon, S.C. Morsello, S. Martin, J.K. Greene, A. Herbert, A.L. Jacobson, F.P.F. Reay-Jones, T. Reed, D.D. Reisig, P.M. Roberts, R. Smith, and G.G. Kennedy. 2016. *Frankliniella fusca* resistance to neonicotinoid insecticides: an emerging challenge for cotton pest management in the eastern United States. Pest Manag. Sci. 72(10):1934–1945. https://doi.org/10.1002/ps.4232

Jones, M.A., B.S. Farmaha, J.G. Greene, M. Marshall, J.D. Mueller, and N.B. Smith. 2019. South Carolina Cotton Growers' Guide. Clemson Univ. Coop. Ext. Serv., Clemson, SC.

Kerns, C.D., J.K. Greene, F.P.F. Reay-Jones, and W.C. Bridges, Jr. 2018. Effects of planting date on thrips (Thysanoptera: Thripidae) in cotton. J. Econ. Entomol. 112(2): 699–707. https://doi.org/10.1093/jee/toy398

Klein, R.N., J.A. Golus, and K.L. Nelms. 2009. The effect of adjuvants, pesticide formulation, and spray nozzle tips on spray droplet size. J. ASTM Inter. 6(6):1–7. https://doi.org/10.1520/JAI102156

Knoche, M. 1994. Effect of droplet size and carrier volume on performance of foliage-applied herbicides. Sci. Direct. 13:163–178. https://doi.org/10.1016/0261-2194(94)90075-2

United States Department of Agriculture National Agricultural Statistics Service [NASS]. 2020. Harvested cotton acreage. United States Department of Agriculture, Washington D.C.

Reed, J.T., and D.B. Smith. 2001. Droplet size and spray volume effects on insecticide deposit and mortality of *Heliothine* (Lepidoptera: Noctuidae) larvae in cotton. J. Econ. Entomol. 94(3):640–647. https://doi.org/10.1603/0022-0493-94.3.640

Reed, J.T., and D.B. Smith. 1999. Droplet size and spray volume effects on cotton canopy penetration and third instar *Heliothis virescens* (Lepidoptera:Noctuidae) mortality. pp. 1069–1072 In Proc. Beltwide Cotton Conf., Orlando, FL. 3-7 Jan. 1999. Natl. Cotton Counc. Am., Memphis, TN.

Samples, C.A. 2020. Evaluation of pesticide application technology in cotton production. Ph.D. Diss., Mississippi State Univ., Mississippi State, MS.

SAS Institute Inc 2013. SAS/ACCESS® 9.4 Interface to ADABAS: Reference. SAS Institute Inc., Cary, NC.

Smith, D.B. and R.G. Luttrell. 1997. Application technology. pp. 379–404 *In* E.G. King. J.R. Phillips. and R.J. Coleman. (eds.) Cotton Insects and Mites: Characterization and Management. The Cotton Foundation, Memphis, TN.

Sumner, H.R., G.A. Herzog, P.E. Sumner, M. Bader, and B.G. Mullinix. 2000. Chemical application equipment for improved deposition in cotton. J. Cotton Sci. 4:19–27.

United States Environmental Protection Agency [EPA]. 2024. Introduction to Pesticide Drift. Retrieved from https://www.epa.gov/reducing-pesticide-drift/introduction-pesticide-drift (verified 30 Jan. 2025).