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AGRONOMY AND SOILS

Performance of Cotton Agrochemicals when Spray Solution Application is Delayed

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ABSTRACT

When agrochemical spray solutions are prepared, unforeseen circumstances can prevent spray solution application, resulting in agrochemical remaining in the spray tank for 1 or more days. Information about the impact of delayed applications on agrochemical performance is limited. Experiments were conducted in 2009 and 2010 to determine the effect of delayed spray applications on efficacy of defoliants, insecticides, and plant growth regulators commonly applied to cotton. Each agrochemical was mixed individually on the day of application and 3, 6, and 9 d prior to application using the same water source, and all applications were made on the same day. Defoliation by ethephon and thidiazuron was affected when products were left in solution for extended periods of time. Efficacy of ethephon, indoxacarb, methomyl, spinosad, and thidiazuron was influenced when spray solution application was delayed, whereas efficacy of acephate, carfentrazone, diuron plus thidiazuron, ethephon plus cyclanalide, indoxacarb, lambda-cyhalothrin, lambda-cyhalothrin plus thiamethoxam, methomyl, thiadiazuron, and thiodicarb was not affected by mixing interval. When changes in efficacy occurred, the magnitude of the effect was relatively minor and most likely would be of little biological significance.

Defoliants, insecticides, and plant growth regulators are commonly used in cotton production. Tobacco thrips (*Frankliniella fusca* Hinds), heliothinae—comprised of the tobacco budworm (*Heliothis virescens* F.) and the bollworm (*Helicoverpa zea* Boddie)—, green stink bugs (*Acrosternum hilare* Say), and brown stink bugs (*Euschistus servus* Say) are major insect pests in cotton that can reduce yield and lint quality (Leonard et al., 1999). Tobacco thrips are sucking pests and are especially troublesome early in the season when plants are young and susceptible to injury. Thrips feeding results in chlorosis, necrosis, and plant deformation and subsequent maturity delays and yield loss (Leonard et al., 1999). Seed treatments, in-furrow insecticides, and foliar-applied insecticides are used to control tobacco thrips (Cook et al., 2003). Bollworms and tobacco budworms burrow into cotton squares and bolls causing squares to abort and bolls to rot (Bell, 1999; Leonard et al., 1999). Control of the heliothinae might include using transgenic cotton containing Cry1A(c) plus Cry2A(b)2 (Bollgard II) and Cry1A(c) plus Cry1F (Widestrike) genes for *Bacillus thuringiensis* (*Bt*) endotoxin production, chemical control, or a combination of these methods (Hamilton et al., 2004). Stink bug feeding might cause young bolls to abort and stain the lint of older bolls or transmit organisms that cause boll rot and hard lock (Bell, 1999). Stink bugs might not be problematic in fields where insecticides have been applied (Bacheler, 2010; Leonard et al., 1999).

Cotton plant growth regulators reduce vegetative growth, increase fruit retention, and might lead to increased lint yield (Cothren and Oosterhuis, 2010; Edmisten, 2010a; Silvertooth et al., 1999). Mepiquat chloride and mepiquat pentaborate are commonly used cotton plant growth regulators. Mechanization of cotton harvesting increased the need for cotton defoliation prior to harvest. Without adequate defoliation, mechanical harvesters might take in excessive leaf and plant parts resulting in cotton lint staining (Crawford et al., 2001).

When agrochemical spray solutions are prepared, unforeseen circumstances such as wind, rain, and equipment failure can prevent spray solution application, resulting in agrochemical remaining in the spray tank for 1 d or more. There is little published research concerning agrochemical efficacy when left in spray solution for extended periods of time. It is possible that agrochemicals could be influenced when they remain in the tank for an extended period of time. Permethrin remaining in ultra-low volume spray tanks for 4 mo averaged 55.5% degradation of the product when analyzed by gas chromatography (Xue et al., 2008). In corn (*Zea mays* L.), tank mixes of dimethenamid plus

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dicamba plus atrazine, isoxaflutole plus atrazine, and rimsulfuron plus *S*-metolachlor plus dicamba mixed 1 or more d prior to application resulted in reduced weed control (Stewart et al., 2009). When left in spray solution for extended periods of time, the efficacy of agrochemicals used in cotton is poorly understood. Therefore, the objective of this research was to determine the effect of mixing interval on efficacy of cotton defoliants, insecticides, and plant growth regulators commonly applied to cotton.

MATERIALS AND METHODS

General methodology. Field experiments were conducted in North Carolina during 2009 and 2010 at the Peanut Belt Research Station near Lewiston-Woodville and the Upper Coastal Plain Research Station near Rocky Mount. Soil at Rocky Mount was a Norfolk loamy sand (fine-loamy, kaolinitic, thermic Typic Kandiudults); soil at Lewiston-Woodville was a Goldsboro sandy loam (fine-loamy, siliceous, subactive, thermic Aquic Paleudults). Insecticides, plant growth regulators, and defoliants were mixed individually the day of application or 3, 6, and 9 d prior to application, unless otherwise noted. Spray solutions were mixed in plastic spray bottles (3 L volume), sealed for storage in the dark at room temperature, and were agitated every third day to bring agrochemicals back into solution. A municipal supply of water in Wake County, NC was used with a pH of 6.7, hardness of 31 ppm, and concentrations of boron, calcium, magnesium, and zinc of 0.04, 7.3, 0, and 0.06 ppm, respectively. On the day of application, agrochemicals were agitated thoroughly to ensure uniform spray solutions. Plant growth regulators and defoliants were applied using a CO_2-pressurized backpack sprayer equipped with DG11002 nozzles (Spraying Systems Co., Wheaton, IL) spaced 45 cm apart and calibrated to apply 140 L/ha at 210 kPa. Insecticides were applied using a CO_2-pressurized backpack sprayer equipped with a TX-8 nozzle (Spraying Systems Co.) calibrated to apply 75 L/ha at 345 kPa.

Plot size was two rows (91-cm spacing) by 9 m in conventional tillage using raised seed beds. Production and pest management practices other than specific treatments followed North Carolina Cooperative Extension Service recommendations and were held constant over the entire experiment. Seed cotton yield was determined in some, but not all, experiments. The experimental design was a randomized complete block with treatments replicated three or four times. Data for all parameters were subjected to analysis of variance (ANOVA) using the PROC GLM procedure in SAS (SAS Institute Inc., Cary, NC). Although included in all experiments, non-treated controls were not included in the statistical analysis. The treatment of agrochemicals applied the same day solutions were prepared was considered the most appropriate control to compare other treatments. However, data for the non-treated control are provided as an indication of pest damage and levels in absence of pest control or cotton growth without management inputs. Means of significant main effects and interactions were separated using Fisher's Protected LSD test at $p \leq 0.05$.

Thrips control. In 2010, tobacco thrips control using acephate (®Orthene 97; Amvac Chemical Corp., Los Angeles, CA) applied at 280 g ai/ha was evaluated in two separate fields at both Rocky Mount and Lewiston-Woodville (four sites). Cotton cultivars DP 0920 B2RF and DP 0912 B2RF (Monsanto Company, St. Louis, MO) were planted at Rocky Mount and Lewiston-Woodville, respectively, without an in-furrow insecticide or insecticidal seed treatment to increase thrips establishment. Visual estimates of damage from tobacco thrips feeding were recorded 10 and 20 d after treatment (DAT) using a 0-5 ordinal scale where 0 = no damage, 1 = noticeable feeding but no stunting, 2 = noticeable feeding and 25% stunting, 3 = feeding with blackened terminals and 50% stunting, 4 = severe feeding and 75% stunting, and 5 = severe feeding and 90% stunting (Carley et al., 2009). Additionally, five cotton plants per plot were collected 5 and 10 DAT and gently placed into glass jars with 250 ml of water and 1.0 ml of detergent (®Palmolive Original; Colgate-Palmolive Company, New York, NY) and sealed for transportation to the laboratory. Following gentle agitation for 20 sec, solutions were decanted onto a 250 µm mesh screen (U.S. standard sieve; Fisher Scientific, Pittsburgh, PA). Jars and lids were then rinsed onto the screen thoroughly to remove any remaining thrips. Plants were thoroughly rinsed to separate thrips from plants. Thrips and small sediment were collected on the mesh screen and rinsed from the screen through a funnel into 25-ml vials using 70% isopropyl alcohol. Excess alcohol was decanted from the vials and remaining solution, thrips, and sediment were then poured onto a gridded petri dish (Fisher Scientific) and examined using a microscope (10X by 44X Stereoscope; Fisher Scientific). The number of nymphs and adult thrips were recorded for each sample. Seed cotton yield was also determined by harvesting each plot using a spindle picker modified for small-plot research.

Bollworm control. Bollworm control was evaluated during 2009 and 2010 at Rocky Mount using a non-*Bt* cotton cultivar (®DP 174 RF; Monsanto Company, St. Louis, MO). Indoxacarb (®Steward EC insecticide; DuPont Agricultural Products Company, Wilmington, DE) was applied at 1100 g ai/ha, lambda-cyhalothrin (®Karate with Zeon Technology insecticide; Syngenta Crop Protection, Inc., Greensboro, NC) was applied at 30 g ai/ha, lambda-cyhalothrin plus thiamethoxam (®Endigo ZC insecticide; Syngenta Crop Protection, Inc.) was applied at 25 g ai/ha plus 19 g ai/ha, methomyl (®Lannate LV insecticide; DuPont Agricultural Products Companywas applied at 490 g ai/ha, spinosad (®Tracer Naturalyte Insect Control; Dow AgroSciences, Indianapolis, IN) was applied at 70 g ai/ha, and thiodicarb (®Larvin brand 3.2 insecticide/ovicide; Bayer CropScience, Research Triangle Park, NC) was applied at 840 g ai/ha. Each insecticide was prepared the day of application and 1, 3, or 7 d prior to application. Insecticides were applied when bollworm eggs or small larvae were found on fruiting structures based on Cooperative Extension Service threshold recommendations (Bacheler, 2010). Twenty-five bolls and 25 squares were removed from each plot 5 DAT and examined for damage and live bollworms. Cotton yield was not determined in this experiment. Data for damaged bolls and squares and live bollworms on bolls and squares were subjected to ANOVA for a six (insecticide) by four (mixing interval) factorial treatment arrangement.

Cotton response to plant growth regulators. Mepiquat chloride (®Pix Plus plant regulator; BASF Corp., Research Triangle Park, NC) was applied at 30 g ai/ha and mepiquat pentaborate (®Pentia plant regulator; BASF Corp.) was applied at 1100 g ai/ha and evaluated during 2009 at Rocky Mount and during 2010 in two separate fields at Rocky Mount to determine the influence of delayed applications of spray solution on performance of these plant growth regulators. Mepiquat chloride and mepiquat pentaborate were applied to actively growing cotton with a height of 50 to 60 cm and internode length of at least 6 cm based on Cooperative Extension Service recommendations (Edmisten, 2010b). Plant height and the number of nodes were recorded from five plants per plot 10 and 20 DAT and used to calculate the height/node ratio. Cotton yield was recorded as previously described.

Cotton response to defoliants. Efficacy of the defoliants carfentrazone (®Aim EC; FMC Corporation, Philadelphia, PA) was applied at 20 g ai/ha, diuron plus thidiazuron (®Ginstar EC; Bayer CropScience) was applied at 50 g ai/ha plus 100 g ai/ha, respectively, ethephon (®Prep; Bayer CropScience) was applied at 1680 g ai/ha, ethephon plus cyclanalide (®Finish 6 Pro; Bayer CropScience) was applied at 1370 g ai/ha plus 90 g ai/ha, respectively, and thidiazuron (®Dropp SC; Bayer CropScience was applied at 1700 g ai/ha. Defoliants were compared in one experiment during 2009 at Lewiston-Woodville on the cotton cultivar DP 0912 B2RF and during 2010 in Rocky Mount on the cotton cultivar DP 0942 B2RF (Monsanto Company, St. Louis, MO). Defoliants were applied when 50 to 60% of bolls were cracked, based on Cooperative Extension Service recommendations (Edmisten, 2010b). Visual estimates of percent defoliation of cotton foliage were recorded 10 DAT using a scale of 0 to 100, where 0 = no canopy defoliation and 100 = all leaves removed from plants. Cotton yield was also determined as described previously.

RESULTS AND DISCUSSION

Thrips control. The main effect of mixing interval and the interaction of experiment by mixing interval were not significant for visual estimates of tobacco thrips damage 10 and 20 DAT, populations of immature and adult tobacco thrips 5 and 10 DAT, and seed cotton yield (Table 1). This analysis did not include the non-treated control because the treatment associated with applying solutions the day of mixing was considered the more appropriate control. However, thrips damage to cotton seedlings and relatively higher populations of thrips were noted in non-treated controls (Table 2). The numerical differences between cotton yield when acephate was applied compared with when acephate was not applied were relatively small (Table 2). Delayed applications of acephate spray solution mixed up to 9 d prior to application did not influence thrips damage at 10 and 20 DAT, thrips populations at 5 and 10 DAT, and seed cotton yield. Previous research has shown that acephate controls tobacco thrips when applied timely before prolonged feeding by thrips (Leonard et al., 1999). Also, yield response to tobacco thrips damage can be variable. Application of acephate can prevent yield loss by minimizing damage caused by thrips feeding compared with non-treated cotton (Layton and Reed, 2002). In contrast, protection from early season thrips damage with insecticide might not be necessary if weather conditions are conducive for subsequent rapid cotton growth and compensatory fruiting (Layton and Reed, 2002).

Table 1. ***P*** **> F for visual estimates of tobacco thrips damage 10 and 20 DAT, thrips counts per five plants 5 and 10 DAT, and seed cotton yield when application of acephate was delayed for 3, 6, and 9 d after solution preparation or applied the day of solution preparation.**

Source	Thrips damage		Thrips populations				Seed cotton yield
			5 DAT		10 DAT		
	10 DAT	20 DAT	Immature	Adults	Immature	Adults	
	----	----	----	*p* value	----	----	----
Experiment (Exp)	<0.0001	0.5928	<0.0001	0.0001	<0.0001	<0.0001	<0.0001
Mixing interval (Interval)	0.6884	0.4962	0.6470	0.5377	0.7929	0.5715	0.5559
Exp * Interval	0.2814	0.6875	0.4181	0.9389	0.8462	0.3909	0.4425
Coefficient of variation (%)	26.4	105.4	37.3	108.3	53.3	89.6	27.1
No. of experiments	4	4	4	4	4	4	4

Table 2. Visual estimates of tobacco thrips damage 5 and 10 DAT, populations of immature and adult tobacco thrips 10 and 20 DAT, and seed cotton yield[z].

Mixing Interval	Damage		Thrips populations				Seed cotton yield
			5 DAT		10 DAT		
	10 DAT	20 DAT	Immature	Adults	Immature	Adults	
days	Scale 0-5[y]		No./5 plants				kg/ha
0	1.5 a	1.1 a	33 a	3 a	8 a	4 a	2,770 a
3	1.5 a	1.2 a	30 a	4 a	9 a	3 a	2,850 a
6	1.4 a	1.0 a	27 a	2 a	7 a	3 a	2,790 a
9	1.6 a	1.8 a	29 a	3 a	8 a	3 a	2,360 a
Non-treated control	2.8	2.6	65	10	33	5	2,790

[z] Means within a column followed by the same letter are not different at $p \leq 0.05$. Data for non-treated cotton were not included in the analysis. Data are pooled over four experiments.

[y] Ordinal scale where 0 = no damage, 1 = noticeable feeding but no stunting, 2 = noticeable feeding and 25% stunting, 3 = feeding with blackened terminals and 50% stunting, 4 = severe feeding and 75% stunting, and 5 = severe feeding and 90% stunting.

Bollworm control. The interaction of experiment by insecticide by mixing interval was not significant for damaged bolls and live bollworms on bolls 5 DAT (Table 3). However, interactions of experiment by mixing interval and experiment by insecticide were significant for these parameters (Table 3). The interaction of insecticides by mixing interval also was significant for damaged bolls but not live bollworms. The interaction of experiment by insecticide by mixing interval was significant for damaged squares and live bollworms associated with squares (Table 3). When analyzed by year, the main effect of insecticide was significant for damaged squares during both years (Table 4). However, the interaction of insecticide by mixing interval was not significant for damaged squares during both years and live bollworms in 2009 (Table 4). The interaction of insecticide by mixing interval was significant for live bollworms in 2010 (Table 4).

The number of damaged bolls and live bollworms associated with bolls and squares was not affected by mixing interval in 2009 (Table 5). However, differences in damaged bolls and squares and live bollworms associated with damaged bolls were noted among mixing intervals in 2010 (Table 5). The number of damaged bolls was higher when insecticide solutions were prepared 3 d prior to application compared with application the day of mixing or 6 and 9 d after mixing (Table 5). No difference in live bollworms associated with bolls was noted when comparing solutions prepared on the same day with those prepared 1, 3, or 7 d prior to application (Table 5). In contrast, mixing insecticides 1 or 3 d prior to application resulted in a higher number of damaged squares compared with applying solutions on the same day of mixing (Table 5). Although not included in the statistical analysis, damage from bollworms on both bolls and squares as well as populations of bollworms associated with these fruiting structures were relatively high compared to measurements associated with non-treated cotton.

Table 3. *P* > F for damage and live bollworms found on cotton bolls and squares 5 DAT.

Source	Fruiting structures			
	Bolls		Squares	
	Damaged	Live bollworms	Damaged	Live bollworms
	---------- *p* value ----------			
Experiment (Exp)	<0.0001	<0.0001	<0.0001	0.2022
Mixing Interval (Interval)	0.0337	0.3059	0.2073	0.7417
Insecticide (Insct)	0.0017	0.0055	0.0044	0.2379
Interval*Insct	0.0232	0.4484	0.6116	0.2459
Exp*Interval	0.0051	0.0124	0.1026	0.5372
Exp*Insct	<0.0001	0.0344	<0.0001	0.2563
Exp*Insct*Interval	0.0954	0.3657	0.0218	0.0161
Coefficient of variation (%)	42.8	97.4	55.2	136.3
No. of experiments	2	2	2	2

Table 4. *P* > F for damage and live bollworms found on cotton squares 5 DAT.

Source	Cotton squares			
	2009		2010	
	Damaged	Live bollworms	Damaged	Live bollworms
	---------- *p* value ----------			
Mixing Interval (Interval)	0.6473	0.9177	0.0783	0.4300
Insecticide (Insct)	0.0059	0.3385	0.0002	0.1961
Interval*Insct	0.4069	0.2747	0.1074	0.0267
Coefficient of variation (%)	75.3	150.2	45.6	125.3

Table 5. Influence of mixing interval on damaged fruit and live bollworms 5 DAT[z].

Mixing Interval	2009				2010			
	Bolls		Squares		Bolls		Squares	
	Damaged	Live Bollworms	Damaged	Live Bollworms	Damaged	Live Bollworms	Damaged	Live Bollworms
days	---------- No./25 plant structures ----------							
0	2.8 a	0.9 a	2.3 a	0.5 a	7.5 b	1.9 ab	4.6 b	0.6 a
1	2.3 a	0.8 a	2.2 a	0.5 a	9.2 a	3.0 a	6.5 a	0.9 a
3	2.5 a	1.1 a	2.0 a	0.5 a	6.6 b	1.5 b	6.3 a	0.5 a
7	2.3 a	0.7 a	2.7 a	0.6 a	6.9 b	2.7 ab	6.0 ab	0.8 a
Non-treated check	6	2	3.9	3.0	11.8	3.3	8.3	4.3

[z] Means within a column followed by the same letter are not different according to Fisher's Protected LSD test at $p \leq 0.05$. The non-treated control was not included in analysis. Data are pooled over insecticide treatments.

When comparing among insecticides, the efficacy of lambda-cyhalothrin, lambda-cyhalothrin plus thiamethoxam, and thiodicarb was not affected by mixing interval with respect to the number of live bollworms associated with squares in 2010 (Table 6). However, applying indoxacarb prepared 7 d prior to application resulted in a higher number of live bollworms per 25 squares compared with application the day of mixing (Table 6). Methomyl spray solution prepared 1 d prior to application resulted in a higher number of bollworms when compared with spray solution prepared the day of application and 3 or 7 d prior to application (Table 6). In contrast, application of spinosad prepared 1 d prior to application resulted in fewer bollworms when compared to spinosad spray solutions prepared the day of application (Table 6). Although sporadic differences were noted when comparing efficacy of insecticides mixed at different intervals, populations ranged from 0.1 to 1.4 bollworms per 25 squares with insecticide treatment compared with 3 to 4.3 bollworms per 25 squares when insecticide was not applied. Consequently, differences noted among insecticide treatments most likely are of no biological significance.

Plant growth regulator performance. Cotton height 10 and 20 DAT and number of nodes 10 DAT were influenced by the interaction of experiment by mixing interval by plant growth regulator (Table 7). The number of nodes 20 DAT was affected by plant growth regulator but not by interaction of plant growth regulator and mixing interval (Table 7). Height:node ratio was not affected by plant growth regulator or mixing interval treatments (Table 7).

When analyzed by experiment, the main effect of mixing interval and plant growth regulator by mixing interval was not significant for plant height and the number of nodes 10 and 20 DAT regardless of experiment (Table 8). The interaction of experiment by mixing interval by plant growth regulator occurred because of differences in plant growth regulator performance at Lewiston-Woodville and Rocky Mount irrespective of mixing interval (Table 8). Height 20 DAT and number of nodes 10 and 20 DAT differed when comparing growth regulators (Table 9). Cotton height 20 DAT was 11 cm shorter when mepiquat chloride was applied compared to mepiquat pentaborate (Table 9). Similar results were not observed for plant height 10 DAT. Treatments including mepiquat chloride had 1.2 and 0.8 fewer nodes than mepiquat pentaborate 10 and 20 DAT, respectively.

Table 6. Interaction between insecticide and mixing interval on number of live bollworms per 25 squares 5 DAT at Rocky Mount during 2010[z].

Insecticide	Live bollworms			
	Number of days mixed prior to application			
	0	1	3	7
	---------- No./25 squares ----------			
Indoxacarb	0.1 e	0.4 cde	0.4 cde	1.0 abc
Lambda-cyhalothrin plus thiamethoxam	0.9 a-d	1.1 ab	0.9 a-d	0.8 a-d
Lambda-cyhalothrin	0.4 cde	0.5 b-e	0.5 b-e	0.5 b-e
Methomyl	0.3 de	1.4 a	0.4 cde	0.4 cde
Spinosad	1.0 abc	0.3 de	0.8 b-e	1.0 abc
Thiodicarb	0.8 a-d	0.5 b-e	0.4 cde	0.5 b-e
Non-treated control	4.3	-	-	

[z] Means followed by the same letter are not different according to Fisher's Protected LSD at $p \leq 0.05$. Data for the non-treated control were not included in the analysis.

Table 7. *P* > F for cotton plant height, number of nodes, and height to node ratio 10 and 20 DAT as influenced by experiment, mixing interval, and plant growth regulator treatment.

Source	Height		No. of nodes		Height:Node ratio		Seed cotton yield
	10 DAT	20 DAT	10 DAT	20 DAT	10 DAT	20 DAT	
	---------- *p* value ----------						
Experiment (Exp)	<0.0001	0.1329	0.0003	<0.0001	0.0005	<0.0001	0.2342
Mixing interval (Interval)	0.2754	0.4148	0.9113	0.8204	0.1334	0.1225	0.4874
Plant growth regulator (PGR)	0.0036	0.0188	0.0065	0.0140	0.1555	0.3557	0.2845
Interval*PGR	0.5746	0.1247	0.3198	0.0798	0.9892	0.6586	0.6031
Exp*Interval	0.0860	0.0691	0.0527	0.6686	0.1855	0.0534	0.3910
Exp*Interval*PGR	0.0002	0.0098	0.0002	0.3334	0.1160	0.0746	0.8020
Coefficient of variation (%)	6.9	7.9	7.9	5.9	5.4	7.3	29.1
No. of experiments	3	3	3	3	3	3	2

Table 8. *P* > F for cotton plant height and number of nodes 10 and 20 DAT as influenced by mixing interval and plant growth regulator.

Source	Lewiston-Woodville				Rocky Mount			
	10 DAT		20 DAT		10 DAT		20 DAT	
	Height	Nodes	Height	Nodes	Height	Nodes	Height	Nodes
	---------- *p* value ----------							
Mixing Interval (Interval)	0.0896	0.2294	0.0678	0.9094	0.2358	0.2621	0.3867	0.6593
Plant growth regulator (PGR)	<0.0001	<0.0001	0.0001	0.0014	0.2679	0.1598	0.4353	0.6237
Interval*PGR	0.1914	0.1264	0.3955	0.1672	0.6210	0.9412	0.2408	0.3094
Coefficient of variation (%)	6.3	4.9	7.8	5.5	8.0	6.0	9.7	6.7

Table 9. Influence of plant growth regulator on plant height and number of nodes 10 and 20 DAT[z].

Source	Lewiston-Woodville, 2009				Rocky Mount, 2010							
					Field 1				Field 2			
	Height		Nodes		Height		Nodes		Height		Nodes	
	10 DAT	20 DAT	10 DAT	20 DAT	10 DAT	20 DAT	10 DAT	20 DAT	10 DAT	20 DAT	10 DAT	20 DAT
	------- cm -------		------ No. ------		------- cm -------		------ No. ------		------- cm -------		------ No. ------	
Mepiquate chloride	54 a	62 b	10.2 b	12.0 b	65 a	66 a	11.6 a	13.7 a	67 a	68 a	11.7 a	13.1 a
Mepiquat pentaborate	64 a	71 a	11.4 a	12.8 a	63 a	64 a	11.3 a	13.6 a	65 a	67 a	11.6 a	13.2 a
Non-Treated control	67	72	10.2	12.6	65	73	10.6	13.3	71	73	11.3	11.6

[z] Means within a column followed by the same letter are not different according to Fisher's Protect LSD test at $p \leq 0.05$. Data for the non-treated control were not included in the analysis. Data are pooled over mixing intervals.

Defoliant performance. Cotton defoliation was influenced by the interaction of experiment by mixing interval by defoliant (Table 10). When analyzed by experiment, the interaction of mixing interval and defoliant was significant at Rocky Mount but not at Lewiston-Woodville (Table 11). At Rocky Mount during 2010, thidiazuron and ethephon efficacy were sporadically influenced by mixing interval (Table 12). Defoliation was 10% greater using the 3-d mix of ethephon than the solution mixed the day of application (Table 12). Defoliation using thidiazuron mixed the day of application and 6 and 9 d prior to application had 7 to 16 percentage points higher defoliation then thidiazuron mixed 3 or 6 d prior to application (Table 12). When comparing defoliant performance when solutions were prepared the day of application at Rocky Mount and Lewiston-Woodville, diuron plus thidiazuron was the more effective defoliant, resulting in 98% defoliation (Table 12). Ethephon plus cyclanalide defoliated cotton 90 to 91% and was more effective than ethephon or thidiazuron alone (Table 12). Carfentrazone was the least effective defoliant in both experiments (Table 12). Seed cotton yield was not affected by defoliant treatments regardless of product or mixing interval (Table 10).

Table 10. *P* > F for cotton defoliation 10 DAT and cotton yield as influenced by experiment, mixing interval, and defoliant treatment.

Source	Defoliation 10 DAT	Seed cotton yield
	------------ value ------------	
Experiment (Exp)	<0.0001	<0.0001
Mixing Interval (Interval)	0.4868	0.7926
Defoliant	<0.0001	0.5908
Exp*Interval	0.8359	0.5706
Interval*Defoliant	0.1776	0.6471
Exp*Interval*Defoliant	<0.0001	0.3957
Coefficient of variation (%)	7.4	16.8

Table 11. *P* > F for defoliation as influenced by mixing interval and defoliant.

Source	Lewiston	Rocky Mt
	----------- *p* value -----------	
Mixing Interval (Interval)	0.8418	0.5226
Defoliant	<0.0001	<0.0001
Interval*Defoliant	0.4277	0.0404
Coefficient of variation (%)	7.2	7.6

Table 12. Influence of delayed applications of spray solution on cotton defoliation by selected defoliants at Rocky Mount in 2010[z].

Defoliant	Rocky Mount, 2010				Lewiston-Woodville, 2009
	Number of Days Mixed Prior to Treatment				
	0	3	6	9	
	% Defoliation				
Carfentrazone	69 f	66 f	70 f	64 f	67 e
Diuron plus thidiazuron	98 a	98 a	98 a	98 a	98 a
Ethephon	80 de	90 bc	84 cd	86 bcd	85 c
Ethephon plus cyclanalide	91 b	88 bc	89 bc	91 b	90 b
Thidiazuron	81 d	65 f	74 ef	81 d	75 d

[z] Means within a location followed by the same letter are not different according to Fisher's Protected LSD test at $p \leq 0.05$.

When comparing the insecticides, plant growth regulators, and defoliants over all pests and cotton growth parameters, ethephon, indoxacarb, methomyl, spinosad, and thidiazuron showed sporadic changes in efficacy due to mixing interval. However, changes were relatively minor and would likely be difficult to notice at the farm level. In the case of ethephon, spray solutions mixed 3 to 9 d prior to application performed better than spray solution mixed on the day of application. These results do not suggest that mixing ethephon in advance is advisable but offers reassurance that efficacy is not compromised when remaining in the spray tank for up to 9 d provided that adequate agitation is provided. These experiments were conducted using a single water source at pH 6.7 with relatively low water hardness. Leaving agrochemicals in spray tanks in water with other characteristics might lead to a dramatically different response in performance than observed in these experiments. Results from these experiments also demonstrate variability of biological systems and development of results that are difficult to explain even when experimental procedures are implemented to minimize variation and statistical procedures are used to account for variation.

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