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AGRONOMY AND SOILS

Mepiquat Chloride Applications across Two Nitrogen Rates in a Conservation Tillage Cotton System

Kipling S. Balkcom*, C. Dale Monks, and Steve M. Brown

ABSTRACT

In cotton production, a plant growth regulator is a management tool used to limit excessive cotton (*Gossypium hirsutum* L.) vegetative growth, but over-application can promote early cut-out and potentially decrease yield. Specific information on how different plant growth regulator application strategies perform in a conservation tillage system is limited. The objective of this research was to compare how different plant growth regulator strategies affected plant growth and yield across two N rates in a conservation tillage system during the 2006 to 2008 growing seasons in Alabama. Treatments were arranged in a randomized complete block design with a split-plot treatment restriction and four replications across five site-years. Main plots were two N rates (101 and 134 kg N/ha), and subplots were six mepiquat chloride application strategies. The 134 kg N/ha rate increased plant height two out of three years, but the most effective strategy to control plant height varied across growing season. No clear application strategy was identified that consistently minimized height to node ratios. Whole plant biomass decreased with a high mepiquat chloride application rate and late application, but only for one site-year out of five. Yield responses to mepiquat chloride application were inconsistent across growing seasons and varied from a 16% yield decrease to a 9% yield increase. Variable environmental conditions occurred across growing seasons that likely resulted in inconsistent cotton yield response to mepiquat chloride application. Although variable, our results suggest that cotton, grown in a conservation system, responded comparably to mepiquat chloride applications in conventional systems.

Managing cotton vegetative growth is an agronomic practice that growers must exercise each growing season. Nitrogen fertilization and subsequent growing conditions (i.e., frequency and amount of rainfall or irrigation) affect the level of management required to suppress excessive cotton vegetative growth (Reddy et al., 1990). Uncontrolled excessive growth can lead to many potential problems during the growing season. For example, unwanted vegetative cotton growth can increase insect pressure, delay maturity, expose cotton to unfavorable late-season harvest weather conditions, increase boll rot, decrease harvest efficiency, and potentially reduce yields (Collins et al., 2017; Johnson and Pettigrew, 2005; Nichols et al., 2003; Nuti et al., 2006).

Mepiquat chloride (1,1-dimethylpiperidinium chloride), registered in 1980, is a common plant growth regulator used in cotton production to alter growth and maturity (Collins et al., 2017; Dodds et al., 2010; Nichols et al., 2003). Specifically, mepiquat chloride inhibits cell elongation, thus reducing plant leaf area, internode elongation, and height, to create a more compact plant that can be more efficiently harvested (Collins et al., 2017; Nichols et al., 2003; Nuti et al., 2006). In the southeast US, the recommended application timing is pre-bloom with applications continuing until mid-bloom (Collins et al., 2017). This application period was designed to promote blooms and allow additional bolls produced after this period to moderate terminal growth (Collins et al., 2017). When applied early, mepiquat chloride application strategies have focused on multiple applications at lower rates (Wilson et al., 2007).

Mepiquat chloride applications after mid-bloom have only been recommended if early applications did not suppress growth (Collins et al., 2017). Collins et al. (2017) also reported consultants, industry representatives, and some product labels suggest that mepiquat chloride applications as late as cutout could be beneficial by enhancing boll and leaf maturity in addition to suppressing potential regrowth.

K.S. Balkcom*, USDA-ARS National Soil Dynamics Laboratory, 411 S. Donahue Dr., Auburn, AL 36832; C.D. Monks, North Carolina State University Extension, Campus Box 7602, Raleigh, NC 27695; and S.M. Brown, Auburn University Department of Crop, Soil and Environmental Sciences, 249 Funchess Hall, Auburn, AL 36849.
*Corresponding author: kip.balkcom@usda.gov

However, Collins et al. (2017) reported no advantage to mepiquat chloride applications at cutout on plant growth with a yield decrease following late season mepiquat chloride application.

In addition to inconsistent responses of late season mepiquat chloride applications with respect to management of vegetative growth, yield benefits following mepiquat chloride applied during traditional application periods have also been erratic. For example, York (1983) reported yield increases up to 26% and yield decreases of 5% following mepiquat chloride applications. Collins et al. (2017) reported no yield increase following early bloom mepiquat chloride applications, but advantages for growth management under certain conditions justified application. Cathey and Meredith Jr. (1988) reported a 4.5% yield reduction in early planted cotton and a 5.4 and 12.7% yield increase in optimum and late-planted cotton following mepiquat chloride applications, respectively.

Cotton planting dates and the erratic response to mepiquat chloride could be explained by cotton cultivar choice or more specifically, maturity levels of cultivars chosen. Johnson and Pettigrew (2005) showed that yield can vary across different cultivar maturities when identical plant growth regulator rates and application times occur, regardless of growth stage. However, early research with mepiquat chloride using cotton cultivars that are not currently grown, indicated that cultivar selection should not affect mepiquat chloride application decisions (Cathey and Meredith Jr., 1988; York, 1983). Yield responses related to cotton maturity and plant growth regulator application may be further complicated by planting date. Late planted cotton would be expected to produce more vegetative growth, and therefore, respond favorably to plant growth regulator applications (Cathey and Meredith Jr., 1988; Johnson and Pettigrew, 2005).

Although mepiquat chloride applications have been evaluated with respect to different agronomic management factors (e.g., cultivar, planting date), testing mepiquat chloride applications in a conservation tillage system that includes non-inversion tillage, and a cover crop has not been extensively examined. Numerous studies have highlighted soil health benefits associated with using some form of conservation tillage in conjunction with a cover crop (Balkcom et al., 2013; Causarano et al., 2006; Franzluebbers, 2010; Schwab et al., 2002). One popular benefit associated with these systems, particularly for coarse-textured soils of the Southeast, is soil moisture conservation (Balkcom et al., 2006; Causarano et al., 2006). Minimizing surface tillage maintains crop residues and cover crop mulch on the soil surface, potentially increasing water infiltration and soil surface carbon, while decreasing soil evaporation, all of which enhance soil moisture conservation (Causarano et al., 2006). However, a potential negative consequence of increased soil moisture could be delayed cotton maturity (Balkcom et al., 2006). Benefits associated with increased surface residues may also affect fertilizer N application rates for subsequent crops. Greater fertilizer N rates have been suggested following cereal cover crop residues to offset potential N immobilization (Reiter et al., 2008). Plant growth characteristics should respond to mepiquat chloride applications under high soil moisture conditions and increased N rates, but yield effects are unknown. The hypothesis for this experiment is cotton grown in a conservation tillage system is more responsive to mepiquat chloride applications. Therefore, our objective was to compare six plant growth regulator strategies including with and without a late-season mepiquat chloride application on plant growth and cotton yield across two N rates in a conservation tillage system.

MATERIALS AND METHODS

Field experiments were conducted at Auburn University's Field Crops Unit at the E.V. Smith Research Center (EVS) (32°25'28.18"N, 85°53'25.39"W) near Shorter, AL and the Wiregrass Research and Extension Center (WREC) (31°21'26.35"N, 85°19'22.99"W) in Headland, AL across five site-years during the 2006 to 2008 growing seasons. Each experiment utilized a randomized complete block design with a split-plot treatment restriction and four replications. Main plots were two fertilizer N application rates (101 and 134 kg/ha) and subplots were six mepiquat chloride application strategies. Mepiquat chloride strategies were developed from product label directions and included: (1) no mepiquat chloride applied during the growing season; (2) a low mepiquat chloride rate applied multiple times during the growing season; (3) a high mepiquat chloride rate applied infrequently during the growing season; (4) no mepiquat chloride applied during the season except for a single, late-season intermediate application rate; (5) a low mepiquat chloride rate applied multiple times during the growing season that included a single, late-season intermediate mepiquat chloride application rate; and (6) a high mepiquat chloride rate applied infrequently during the growing season that included a single, late-season intermediate mepiquat chloride application rate. Split-plot treatment size was 3.7 m wide and 12.2 m long for each site-year.

Mepiquat chloride (Mepex® Gin Out™, DuPont, Wilmington, DE), was applied using an 11.4 L CO_2-pressurized backpack sprayer calibrated to deliver 140 L/ha using TeeJet® 8002 flat-fan nozzles (TeeJet Technologies, Wheaton, IL). Single application rates ranged from 12.3 g a.i./ha to 36.9 g a.i./ha. Application times, rates, and total product amounts applied across all strategies for each site-year are reported in Table 1.

Soil types and general soil fertility information for each site-year were reported in Table 2. Phosphorus, K, and lime were applied as necessary at each site-year prior to planting the rye (*Secale cereale*, L.) cover crop. Fertility additions, based on composite soil samples collected from ten soil probes (2.54 cm diam.) to 30 cm deep, ensured soil test ratings were considered "High" based on Auburn University soil test recommendations (Adams et al., 1994).

Table 1. Mepiquat chloride single application rates, totals, and application times across six different application strategies at the Wiregrass Research and Extension Center (WREC) in Headland, AL and the E.V. Smith Research Center (EVS) near Shorter, AL during the 2006 to 2008 growing seasons.

Location/Year	Application time (DAP[Z])	None	Low rate many applications	High rate few applications	Late season application		
					None	Low rate	High rate
		----------	----------	---------- g a.i. ha^{-1}	----------	----------	----------
WREC 2006	60		12.3			12.3	
	70		12.3	36.9		12.3	36.9
	80		12.3			12.3	
	89		12.3	36.9		12.3	36.9
	98				24.6	24.6	24.6
	Total	0	49.2	73.8	24.6	73.8	98.4
EVS 2007	63		12.3			12.3	
	71		24.6	36.9		24.6	36.9
	78		24.6			24.6	
	85		12.3			12.3	
	92				24.6	24.6	24.6
	Total	0	73.8	36.9	24.6	98.4	61.5
WREC 2007	52		12.3			12.3	
	64		12.3	36.9		12.3	36.9
	71		18.5			18.5	
	85				24.6	24.6	24.6
	Total	0	43.1	36.9	24.6	67.7	61.5
EVS 2008	61		12.3			12.3	
	68		12.3			12.3	
	76		18.5	36.9		18.5	36.9
	82		24.6			24.6	
	90		24.6	30.8		24.6	30.8
	104				24.6	24.6	24.6
	Total	0	92.3	67.7	24.6	116.9	92.3
WREC 2008	65		12.3			12.3	
	72		12.3			12.3	
	79		12.3	24.6		12.3	24.6
	87		18.5			18.5	
	93		18.5	24.6		18.5	24.6
	107				18.5	18.5	18.5
	Total	0	73.9	49.2	18.5	92.4	67.7

[Z] DAP, days after planting.

Table 2. Soil taxonomy and initial soil test values for five site-years during the 2006 to 2008 growing seasons at the Wiregrass Research and Extension Center (WREC) in Headland, AL and the E.V. Smith Research Center (EVS) near Shorter, AL.

Location/ Year	Soil series[Z]	Family	Soil pH	Mehlich 1 extractable			
				P	K	Mg	Ca
				------------------ mg/kg ------------------			
WREC 2006	Orangeburg sl	fine-loamy, kaolinitic, thermic Typic Kandiudults	6.0	27 (H)[Y]	77 (M)	93 (H)	637 (H)
EVS 2007	Marvyn ls	fine-loamy, kaolinitic, thermic Typic Kanhapludults	6.2	39 (H)	152 (H)	63 (H)	463 (H)
WREC 2007	Dothan fsl	fine-loamy, kaolinitic, thermic Plinthic Kandiudults	5.9	11 (L)	74 (M)	51 (H)	321 (H)
EVS 2008	Marvyn ls	fine-loamy, kaolinitic, thermic Typic Kanhapludults	5.7	40 (H)	120 (H)	84 (H)	598 (H)
WREC 2008	Orangeburg sl	fine-loamy, kaolinitic, thermic Typic Kandiudults	5.8	27 (H)	80 (M)	45 (H)	317 (H)

[Z] fsl, fine sandy loam; ls, loamy sand; sl, sandy loam

[Y] L, low; M, medium; H, high (soil test categories based on Alabama Experiment Station recommendations)

A rye cover crop, seeded at 101 kg/ha, was planted with a no-till grain drill in early November at each location, with the exception of the fall of 2005 at WREC when an oat (*Avena sativa*, L.) cover crop was planted. All cover crops were fertilized each spring (~mid-February) with 34 kg N/ha as ammonium nitrate to increase biomass production. The cover crop was chemically terminated each year with glyphosate (Roundup; Bayer Corp., Whippany, NJ) and rolled with a cover crop roller approximately three wk before anticipated cotton planting dates. Immediately prior to termination, aboveground cover crop dry matter samples (0.5 m^2 per plot) were collected from each plot, oven-dried at 55°C for 72 h and weighed to determine biomass production for each site-year (Fig. 1).

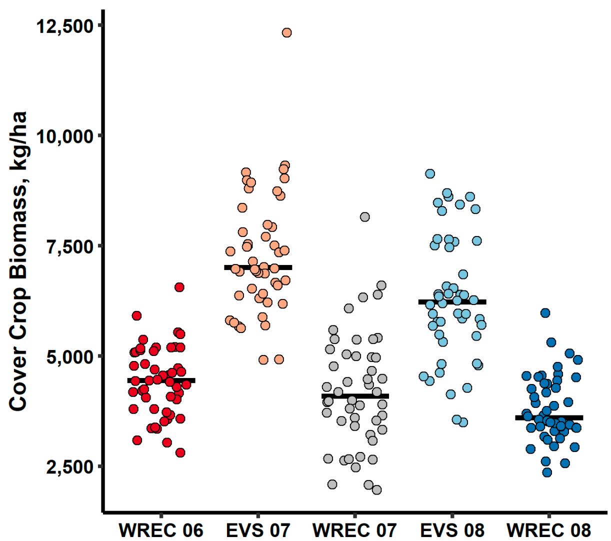

Figure 1. Cover crop biomass levels measured at termination across five site-years during the 2006 to 2008 growing seasons at the Wiregrass Research and Extension Center (WREC) and the E.V. Smith Research Center (EVS). The horizontal black line for each site-year combination represents the median, and the scatter points represent the variance of the observations around the median. (n=48 for all site-years).

All plots were in-row subsoiled with a KMC Ripper Stripper® (Kelly Manufacturing Company, Tifton, GA) equipped with rubber pneumatic tires behind each shank to minimize surface disruption, immediately prior to planting. Cotton planting dates were reported in Table 3. Cotton was seeded at 13.1 seeds/m in each trial. Application dates and rates for sidedress fertilizer N application rates, injected as 28% urea ammonium nitrate that also contained 5% sulfur are reported in Table 3. Prior to harvest aid application, plant heights, height to node ratios, and whole plant biomass samples were measured from all plots across each site-year (Table 3).

Table 3. Cultivar, planting date, sidedress date, plant sampling date, and harvest date for each site-year during the 2006 to 2008 growing seasons at the Wiregrass Research and Extension Center (WREC) in Headland, AL and the E.V. Smith Research Center (EVS) near Shorter, AL.

Location/Year	Cultivar	Planting	Sidedress	Plant Sampling	Harvest
WREC 2006	DP[Z] 455 BR	21 April	20 June	30 August	20 September
EVS 2007	DP 555 BR	8 May	12 June	10 September	1 October
WREC 2007	DP 555 BR	21 May	11 July	18 September	12 October
EVS 2008	DP 555 BR	9 May	6 June	29 September	13 October
WREC 2008	DP 555 BR	2 May	5 June	23 September	3 October

[Z] (Deltapine, Scott, MS)

Plant heights, measured from the soil surface to the terminal bud of the plant, were the average of 10 randomly selected plants within each plot. Nodes for each of the 10 randomly selected plants were counted when plant height measurements were collected to calculate height to node ratios. Whole plant biomass (bolls, leaves, stems) consisted of clipping the aboveground portion of all plants within a 1-m section of a non-harvest row from each plot. The collected plant material was dried at 55°C for 72 h and weighed to determine whole plant biomass production. The center two rows of each plot were harvested with a mechanical spindle picker equipped with a bag attachment system to obtain a seed cotton weight for each plot. Harvest dates are provided in Table 3. A subsample of seed cotton was collected from each plot weight sample and ginned in a 20-saw tabletop gin to determine lint turnout (%). Lint yields for each plot were determined by multiplying the lint percentage by the weight of the seed cotton and adjusting for the harvest area.

Data Analysis. Data were analyzed using linear mixed models procedures within SAS PROC GLIMMIX (SAS Institute Inc., Cary, NC). An initial analysis that included the independent variables (N rate and mepiquat chloride strategy) was performed on each dependent variable (plant height, height to node ratios, cotton biomass, and lint yield) to measure the effect of year and location as fixed effects. This initial analysis determined the extent of year and location interactions with treatments. Year was significant across all dependent variables, while location was only significant for plant height (data not shown). As a result, all subsequent analyses were performed by year. Location, fertilizer N application rate, mepiquat chloride treatment, and their interactions were treated as fixed effects, while block (N rate) and N rate * block (location) were considered random. In 2006, the experiment was only conducted at one location; therefore, the model was reduced to N rate, mepiquat chloride treatment, and the interaction between them as the fixed effect. The random effect was block (N rate). Comparisons among two or more treatment means were separated using the Tukey-Kramer method where a = 0.10.

RESULTS AND DISCUSSION

Cumulative rainfall received was 31% lower during the 2006 growing season and 25% lower during the 2007 growing season compared to the cumulative 30 yr normal rainfall total (1981-2010) (Fig. 2a and 2b). In comparison, rainfall received during the 2008 growing season was < 1% lower than the cumulative 30 yr normal.

Rainfall received during the 2006 and 2007 locations were similar with approximately between 500–600 mm of cumulative total rainfall (Fig. 2a and 2b). In contrast, cumulative rainfall was over 700 mm during the 2008 growing season at each location (Fig. 2a and 2b). As a result, total irrigation amounts applied were greater for the 2006 and 2007 growing seasons compared to 2008, except for the 2007 WREC location (Table 4). Despite less rainfall received at this location, the lack of additional irrigation required could be attributed to rainfall occurrence at critical growth stages compared to other similar drier site-years. Although below normal, 2007 cumulative rainfall amounts at WREC were more similar to the 30 yr normal compared to the other below normal site-years (Fig. 2a and 2b).

Table 4. Monthly and total overhead sprinkler irrigation applied during the 2006 to 2008 growing seasons at the Wiregrass Research and Extension Center (WREC) in Headland, AL and the E.V. Smith Research Center (EVS) near Shorter, AL.

Month	2006	2007		2008	
	WREC	EVS	WREC	EVS	WREC
	mm				
April	0	0	0	0	0
May	0	69	0	0	13
June	51	46	31	46	23
July	76	13	51	13	51
August	45	48	51	74	25
September	0	0	0	0	25
October	0	0	0	0	0
Total	172	176	133	133	137

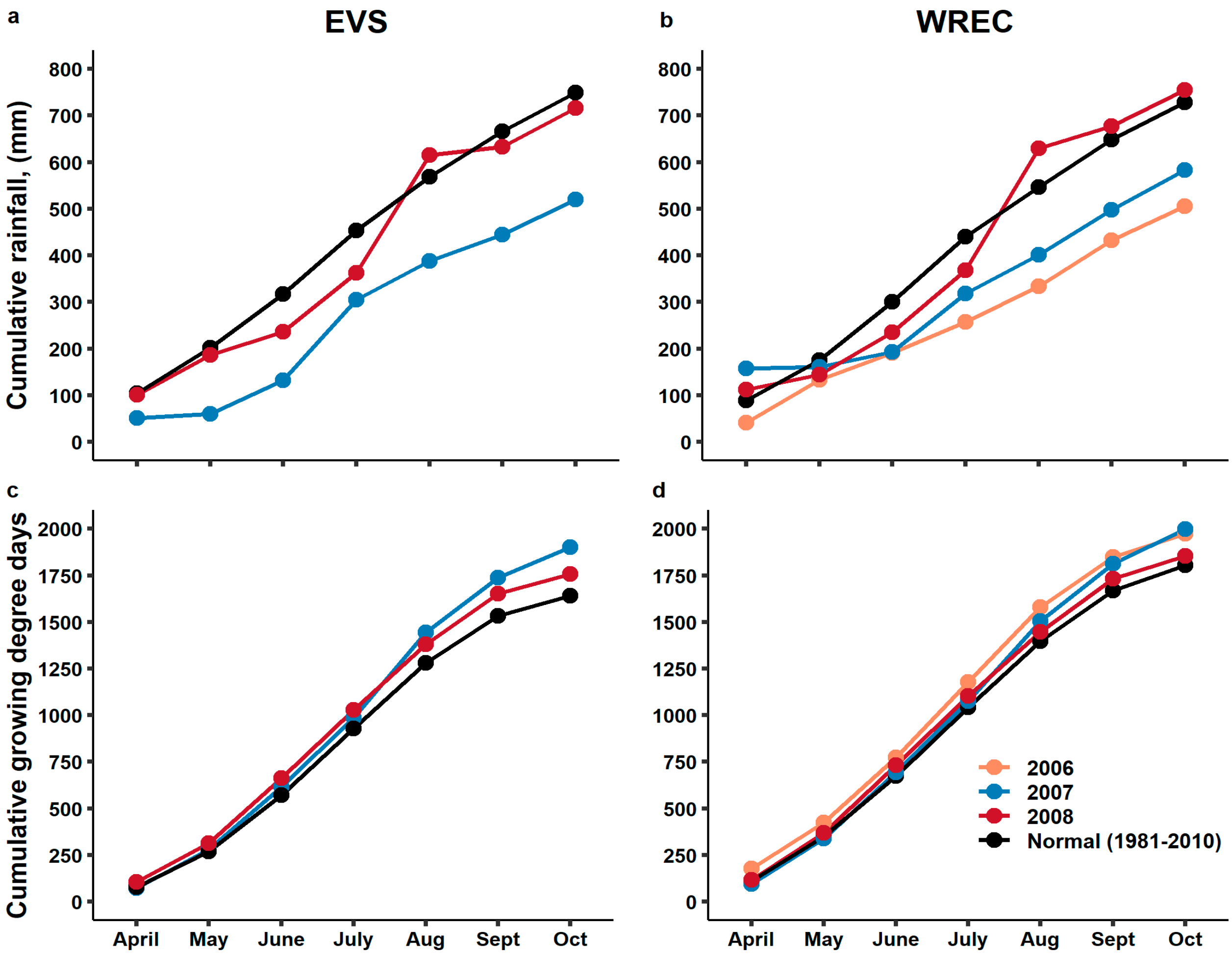

Figure 2. Cumulative rainfall measured at EVS (a) and WREC (b) and cumulative growing degree days measured at EVS (c) and WREC (d) during the 2006 to 2008 growing seasons compared to the cumulative normals (1981-2010) at each location.

Growing degree days (GDDs), sometimes referred to as "heat units", for each site-year were not dramatically different from the corresponding 30 yr normal GDDs (Fig. 2c and 2d). All site-years produced greater cumulative GDDs than the normal, despite the similarities. Observed deviations between site-year GDDs and 30 yr normal GDDs were most pronounced from Aug. until harvest (Fig. 2c and 2d). The greatest deviation between site-years and the normal was observed at EVS in 2007 (16%), WREC in 2007 (11%), and WREC in 2006 (10%) (Fig. 2c and 2d). Essentially, most site-years were warmer, particularly at the end of the season compared to the normal.

Plant Heights. A significant interaction (Pr > F = 0.0140) was observed between location and mepiquat chloride during the 2008 growing season (Table 5). In 2008, plant heights following each mepiquat chloride treatment were always greater at the EVS location compared to the WREC location, but the magnitude of the difference varied (data not shown). This difference among locations for plant heights was also illustrated by a significant location effect (Pr > F = <0.0001) observed in 2008 (Table 5). Plant heights at EVS were 22% greater than plant heights measured at WREC (Table 6). Although common agronomic management protocols were similar between locations, this difference between locations suggests that growing conditions and/or soil conditions promoted additional growth at EVS. For example, cover crop biomass averaged 64% greater at EVS compared to WREC (Fig. 1). In general, benefits associated with cover crops increase as the level of biomass increases (Balkcom et al., 2018). This increased surface biomass at EVS may have provided some short-term drought protection by improving efficiency of rainfall and/or irrigation that improved cotton growth compared to WREC. Fertilizer N application rate affected plant heights two out of three years (Table 5). In 2007, the greater fertilizer N application rate produced 3% taller plants, while the greater fertilizer N application rate produced ~5% taller plants in 2008 (Table 5).

Table 5. Degrees of freedom, F ratios, and P values from a general linear mixed model analysis for treatments within each site-year during the 2006 to 2008 growing seasons.

Year	Effect	df	Plant height		Height to node ratio		Whole plant biomass		Lint yield	
			F ratio	Prob > *F*	F ratio	Prob > *F*	F ratio	Prob > *F*	F ratio	Prob > *F*
2006	N rate (N)	1	0.73	0.4245	0.10	0.7637	1.95	0.2119	0.28	0.6010
	Mepiquat chloride (MC)	5	22.84	<0.0001	17.85	<0.0001	3.81	0.0087	6.26	0.0003
	N * MC	5	1.88	0.1283	2.20	0.0808	0.72	0.6161	2.40	0.0557
2007	Location (L)	1	1.00	0.3552	2.61	0.1576	17.35	0.0059	3.71	0.1025
	N rate (N)	1	3.81	0.0551	0.68	0.4408	5.40	0.0232	5.57	0.0562
	L * N	1	0.02	0.8874	0.05	0.8251	0.03	0.8540	0.05	0.8300
	Mepiquat chloride (MC)	5	14.96	<0.0001	7.95	<0.0001	1.05	0.3986	0.33	0.8903
	L * MC	5	1.62	0.1671	1.09	0.3728	1.44	0.2200	1.48	0.2089
	N * MC	5	0.40	0.8486	0.69	0.6360	0.50	0.7728	1.23	0.3072
	L * N * MC	5	1.55	0.1875	1.39	0.2422	0.78	0.5692	0.80	0.5571
2008	Location (L)	1	89.33	<0.0001	36.92	0.0009	0.32	0.5936	2.21	0.1878
	N rate (N)	1	12.49	0.0123	3.00	0.0878	2.47	0.1672	2.53	0.1625
	L * N	1	3.26	0.1210	2.29	0.1350	1.09	0.3358	0.03	0.8795
	Mepiquat chloride (MC)	5	19.10	<0.0001	6.89	<0.0001	0.61	0.6927	5.77	0.0002
	L * MC	5	3.13	0.0140	2.72	0.0270	0.38	0.8599	2.08	0.0798
	N * MC	5	0.72	0.6109	0.23	0.9470	0.28	0.9226	0.23	0.9458
	L * N * MC	5	1.28	0.2841	1.00	0.4270	0.90	0.4903	2.45	0.0435

Table 6. Plant heights, height to node ratio, biomass yield, and lint yield measured across location and nitrogen rate during the 2006 to 2008 growing seasons at the Wiregrass Research and Extension Center (WREC) in Headland, AL and the E.V. Smith Research Center (EVS) near Shorter, AL.

Year	Variable	Location		SED[Z]	SED 90% C.I.[Y]		N rate (kg/ha)		SED	SED 90% C.I.	
		EVS	WREC		Lower	Upper	100	134		Lower	Upper
2006	Plant height, (cm)	NA[X]					88.7 a[W]	93.1 a	4.9	-13.8	5.4
	Height to node ratio						4.36 a	4.43 a	0.22	-0.50	0.36
	Biomass yield, (kg/ha)						1394 a	1610 a	155	-518	85
	Lint yield, (kg/ha)						1810 a	1782 a	52	-61	115
2007	Plant height, (cm)	110.1 a	113.3 a	3.2	-9.5	3.0	110.0 b	113.4 a	1.7	-6.2	-0.5
	Height to node ratio	5.57 a	5.26 a	0.19	-0.06	0.68	5.38 a	5.44 a	0.07	-0.19	0.08
	Biomass yield, (kg/ha)	1203 b	1472 a	65	-395	-144	1263 b	1412 a	64	-256	-42
	Lint yield, (kg/ha)	1573 a	1725 a	79	-306	1	1600 b	1700 a	42	-180	-18
2008	Plant height, (cm)	148.1 a	121.1 b	2.9	21.4	32.6	131.6 b	137.7 a	1.7	-9.5	-2.8
	Height to node ratio	6.45 a	5.41 b	0.17	0.71	1.37	5.87 b	5.99 a	0.07	-0.23	-0.01
	Biomass yield, (kg/ha)	1725 a	1655 a	69	-169	307	1630 a	1750 a	75	-264	28
	Lint yield, (kg/ha)	2055 a	2005 a	33	-15	112	2007 a	2055 a	30	-107	11

[Z] Standard error of the difference between two means.

[Y] Confidence interval.

[X] Not applicable; only one location (WREC) was present during the 2006 growing season.

[W] Means within a row followed by the same letter are not different (*P* = 0.10).

Mepiquat chloride application affected plant heights across all three growing seasons (Table 5). Measured plant heights were shorter in 2006 and tended to increase each year (Fig. 3). The effect of mepiquat chloride application on plant heights was similar between the 2006 and 2007 growing seasons, although average plant heights for treatments varied between these years (Fig. 3). The tallest plants across treatments for the 2006 and 2007 growing seasons corresponded to the control and control + late season application (Fig. 3). Results for these treatments corresponded to the lowest total mepiquat chloride application rates (Table 1). No plant height differences were observed between the low and high mepiquat chloride rates or when a late season application was included with the low or high rates. As a result, any mepiquat chloride strategy adopted by the grower using either a low rate with frequent applications or a high rate with infrequent applications with or without the late season application was effective to reduce plant heights during the 2006 and 2007 growing seasons (Fig. 3). Despite taller plants, possibly associated with better growing conditions, the response to mepiquat chloride treatments in 2008 was similar to the previous two years. The low application rate applied frequently produced shorter plants compared to the other treatments, except the low rate treatment that included a late season application (Fig. 3). Plant height reductions associated with mepiquat chloride applications have been frequently observed across the U.S. Cotton Belt (Collins et al., 2017; Dodds et al., 2010; York, 1983), but no clear mepiquat chloride strategy can be determined from this experiment. Temporal variability among growing season conditions likely dictates effectiveness of mepiquat chloride strategy, regardless of the metric evaluated. Cumulative average rainfall indicated that growing conditions were better in 2008, which likely enhanced crop development and promoted a plant height response to mepiquat chloride. Managing plant height to optimize harvest is a primary advantage for using mepiquat chloride in cotton production (Collins et al., 2017).

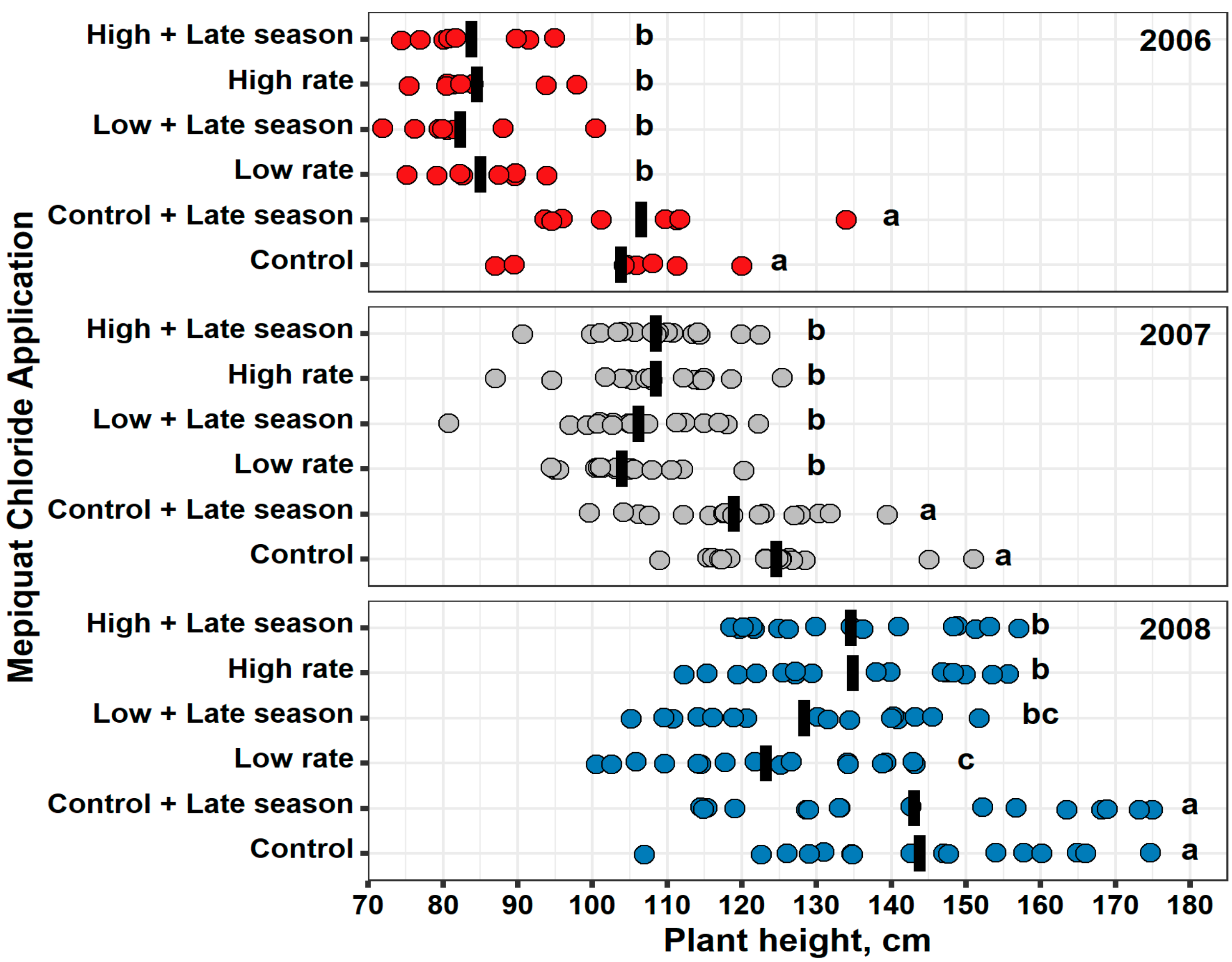

Figure 3. Plant heights measured prior to defoliation for each corresponding mepiquat chloride treatment for the 2006 to 2008 growing seasons. Vertical black bars represent the mean for each mepiquat chloride application, and the scatter points represent the variance of the observations around the mean. Different letters within each year represent mean separation using Tukey-Kramer where a = 0.10. (n=8 for 2006 and n=16 for 2007 and 2008).

Height to Node Ratio. Height to node ratios were affected by mepiquat chloride treatments across all three growing seasons, but interactions were observed during the 2006 and 2008 growing seasons (Table 5). In 2006, an interaction (Pr > F = 0.0808) between fertilizer N application rates and mepiquat chloride treatments indicated the effect of fertilizer N application rates on height to node ratios fluctuated across treatments, but fertilizer N application rates were not different from each other, regardless of treatment (data not shown). An interaction (Pr > F = 0.0270) was also observed between location and mepiquat chloride treatments in 2008 (Table 5). Height to node ratios for every mepiquat chloride treatment were greater at EVS compared to the corresponding treatment at WREC (data not shown). Height to node ratio differences observed between locations may be attributed to favorable growing conditions and not ineffectiveness of mepiquat chloride applications at EVS.

In 2008, a difference between height to node ratios was observed between the 100 and 134 kg/ha N rates (Table 5). Although small, the greater fertilizer N application rate produced a 2% greater height to node ratio compared with the lower fertilizer N application rate (Table 6). This difference also corresponded with the 2008 growing season that received higher average rainfall compared with the other growing seasons (Fig. 2a and 2b).

Mepiquat chloride treatments affected height to node ratios across all three growing seasons (Table 5). In 2006 and 2007, the greatest height to node ratio was observed for the control and the control with a late season application (Fig. 4). The low rate with frequent applications with or without a single late-season application produced equivalent height to node ratios compared to both high rates with infrequent applications for both years (Fig. 4). In 2007, an exception occurred where the control with a single late season application was equivalent to the high rate with infrequent applications that included a single late season application (Fig. 4). In 2008, both control treatments produced similar height to node ratios to both high rate, infrequent mepiquat chloride application treatments (Fig. 4). The low rate with frequent applications without the late season application produced the smallest height to node ratio, but this value was equivalent to the low rate that included the late season application in 2008 (Fig. 4). No clear strategy was identified that consistently minimized height to node ratios among mepiquat chloride strategies with and without a late season application. In 2006 and 2007, application of mepiquat chloride, regardless of application strategy, reduced height to node ratios. In 2008, the variable results across mepiquat chloride strategies corresponded to the wetter growing season. Nichols et al. (2003) reported height to node ratios were greatest for cotton not receiving mepiquat chloride, regardless of row spacings that ranged from 19-, 25-, 38-, and 76-cm.

Whole Plant Biomass. Whole plant biomass was affected by location and fertilizer N application rate during the 2007 growing season (Table 5). Whole plant biomass was 22% greater at WREC compared to plants at EVS (Table 6). Surprisingly, observed rainfall and cover crop biomass at WREC was less than that at EVS (Fig. 1, 2a, and 2b). Greater rainfall amounts with additional surface residue would be expected to promote additional cotton vegetative growth. Regardless of location, whole plant biomass following the 134 kg/ha N rate produced 12% larger plants compared to the 101 kg/ha N rate during the 2007 growing season (Table 6).

In 2006, whole plant biomass was affected by mepiquat chloride treatments at the WREC location (Table 5). The largest plants corresponded to no mepiquat chloride or only the single late season application with no additional mepiquat chloride applied previously (data not shown). However, the least whole plant biomass measured for this site-year was for the high mepiquat chloride rate that included the late season application (data not shown). Although minor differences were observed, evidence was not strong for a mepiquat chloride effect for whole plant biomass because only one site-year out of five produced any response.

Lint Yields. A three-way interaction (Pr > F = 0.0557) was observed between location, fertilizer N application rate, and mepiquat chloride treatments in 2008 (Table 5). At EVS, yields were greater than WREC for the low, frequent rate application and the high, infrequent application when 101 kg/ha N rate was applied (data not shown). In addition, EVS yields were also greater than WREC when the high, infrequent rate that included a late season application was applied for the 101 kg/ha N rate (data not shown). The yield differences across variables of the three-way interaction favored EVS compared to WREC and differed by approximately 200 kg/ha.

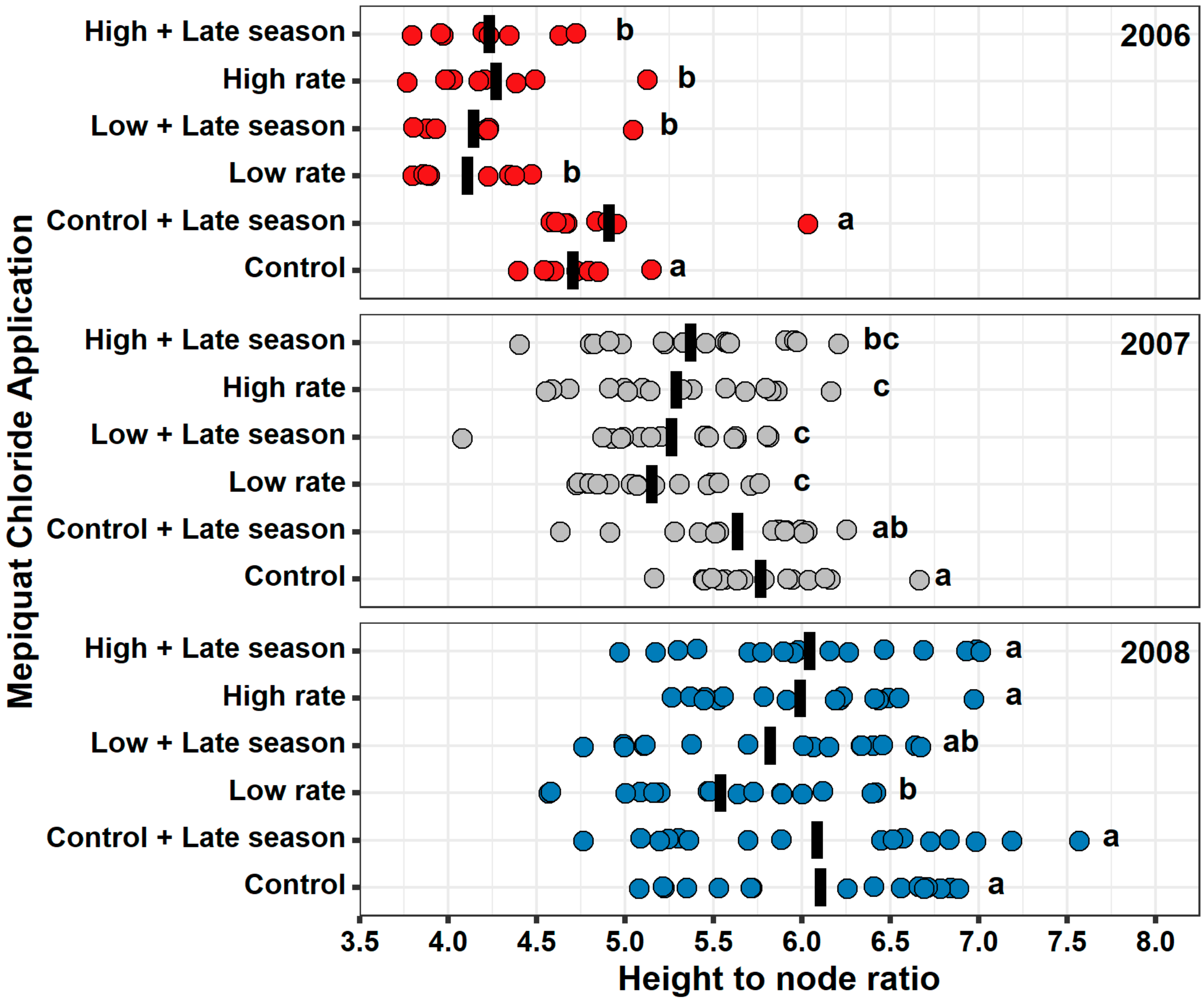

Figure 4. Height to node ratios measured prior to defoliation for each corresponding mepiquat chloride treatment for the 2006 to 2008 growing seasons. Vertical black bars represent the mean for each mepiquat chloride application, and the scatter points represent the variance of the observations around the mean. Different letters within each year represent mean separation using Tukey-Kramer where a = 0.10. (n=8 for 2006 and n=16 for 2007 and 2008).

Two-way statistical interactions that resulted in minimal agronomic significance associated with small yield changes were observed during the 2006 and 2008 growing seasons (Table 5). In 2006, the observed interaction (Pr > F = 0.0557) was between fertilizer N application rate and mepiquat chloride treatments. Lower yields were measured for the 134 kg/ha N rate compared to the 101 kg/ha N rate in the control treatment and the high rate plus the late season application (data not shown). No differences were observed between fertilizer N application rates across the remaining corresponding mepiquat chloride treatments for this single location. Lower yields for the higher fertilizer N application rate are plausible because the 134 kg/ha N rate could promote excess vegetative growth. However, excess vegetative growth following application of this rate when the high rate plus a late season mepiquat chloride application was applied does not seem probable, particularly when the control treatment with no mepiquat chloride responded similarly. In 2008, the observed interaction (Pr > F = 0.0798) was between location and mepiquat chloride treatments that indicated the yield response to mepiquat chloride treatments was not consistent across locations. Specifically, the low rate with infrequent applications that included the late season application produced 7% greater yields at EVS compared to the same treatment at WREC, while all other mepiquat chloride treatments produced similar yields between locations (data not shown).

In 2006, yields were affected by mepiquat chloride treatments (Table 5). However, the high rate and high rate plus the late season application were the only mepiquat chloride treatments that affected yields (Fig. 5). Yields following all mepiquat chloride treatments, including the control, averaged 16% greater than average yields of both high rate treatments. Yield following the high mepiquat chloride treatment was not different from that of any mepiquat chloride treatment that included the control, while yield following the high rate plus the late season application was different from that of all mepiquat chloride treatments, except the high mepiquat chloride treatment (Fig. 5).

In 2007, mepiquat chloride application did not affect yields, but differences across mepiquat chloride treatments were observed in 2008 (Table 5). In 2008, the yield response to mepiquat chloride was different compared to the responsive 2006 growing season (Fig. 5). For example, yield was lowest following application of the low rate with frequent applications but yield for this treatment was also similar to the control and control plus a late season mepiquat chloride treatment (Fig. 5). However, yield in the control treatments were also similar to that of the remaining mepiquat chloride treatments. The greatest yield measured across mepiquat chloride treatments in 2008 (low rate plus a late season application) was only 9% greater than the lowest-yielding treatment (low rate with no late season application). Despite these differences, yields across all application strategies only ranged 180 kg/ha from greatest to smallest in 2008 (Fig. 5).

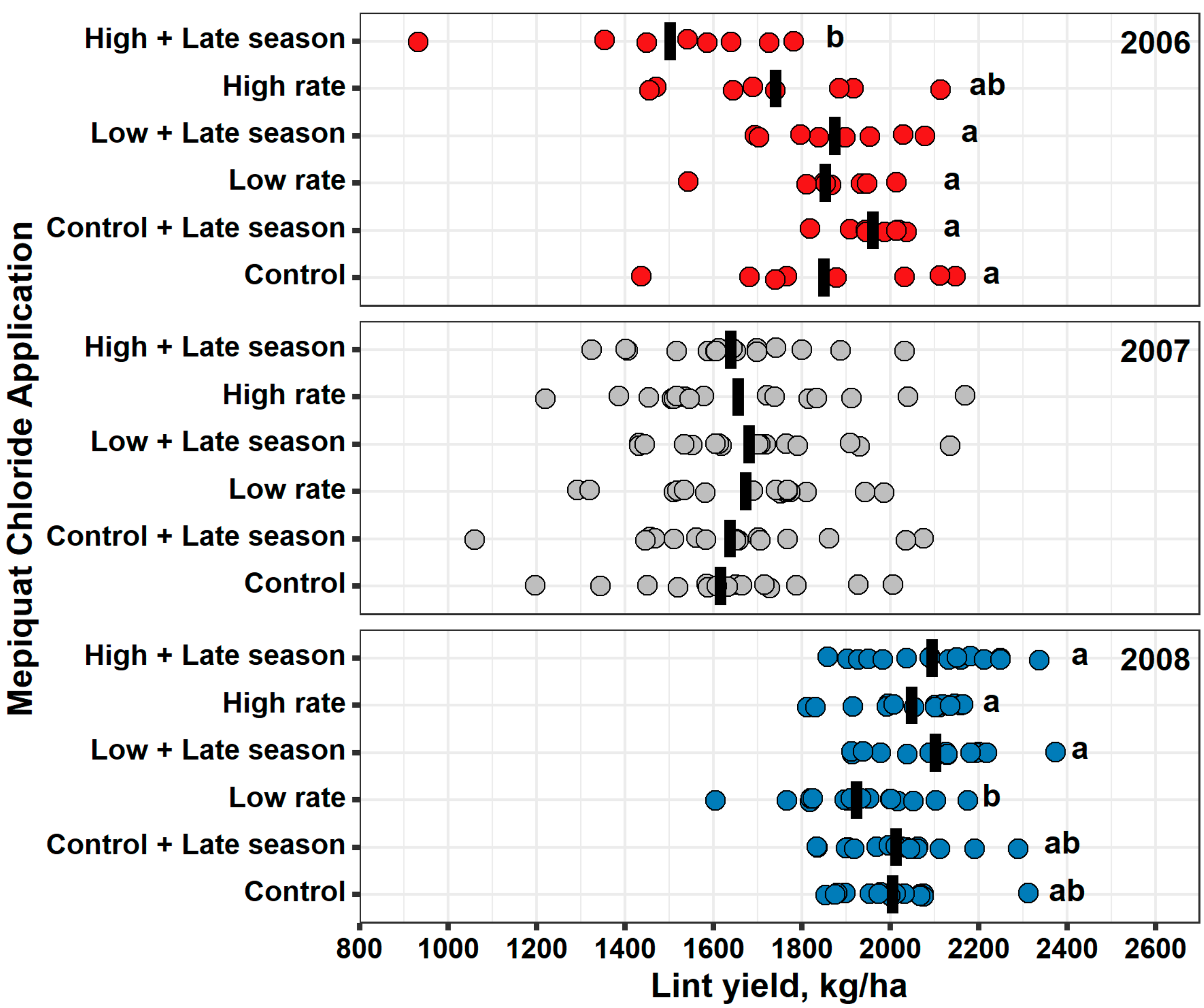

Figure 5. Lint yields measured for each corresponding mepiquat chloride treatment during the 2006 to 2008 growing seasons. Vertical black bars represent the mean for each mepiquat chloride application, and the scatter points represent the variance of the observations around the mean. Different letters within each year represent mean separation using Tukey-Kramer where a = 0.10. (n=8 for 2006 and n=16 for 2007 and 2008).

Nichols et al. (2003) reported a yield increase associated with mepiquat chloride application in one out of three years for ultra-narrow row cotton. Wilson et al. (2007) reported a 5% yield increase for mepiquat chloride, but this was also for narrow row cotton. Dodds et al. (2010) evaluated different mepiquat chloride formulations across Southwest, Mid-South, and Southeast regions of the U.S. Cotton Belt and reported no yield differences associated with any plant growth regulator treatments. Researchers across the different regions succinctly summarized that yield responses were “likely strongly linked to environment and management practices” (Dodds et al., 2010). Although end of season growing conditions were warmer than normal (Fig. 2c and 2d), evidence for any consistent yield advantage associated with a late season mepiquat chloride application was not evident in this experiment. Collins et al. (2017) reported no yield benefit of a late season mepiquat chloride application.

CONCLUSIONS

Two of the three growing seasons were drier than the 30 yr. normal, and cumulative GDDs were above the 30 yr. normal for all growing seasons. Despite the use of supplemental irrigation and conservation tillage with a cover crop, these growing conditions likely did not create environments conducive for excessive growth and the associated aggressive mepiquat chloride application strategies. Regardless of these growing conditions, parameters measured in this study were affected by fertilizer N application rate and mepiquat chloride applications. However, effects were variable and inconsistent across the three growing seasons examined. Interactions, primarily associated with differences between locations, were observed, but agronomic significance of these interactions was minimal.

These results generally agree with previous research that demonstrated mepiquat chloride can reduce plant heights and height to node ratios for cotton. However, variability among years that influenced the appropriate mepiquat chloride strategy was apparent. Mepiquat chloride applications reduced whole plant biomass at one out of five site-years, which indicated this effect was minimal. Lint yield response to mepiquat chloride applications was also variable across growing seasons, a response similarly noted in previously published research. Application strategies also affected yields inconsistently across growing seasons, illustrating how temporal environmental differences affect cotton response to mepiquat chloride. A direct comparison was not made between a conventional and conservation tillage system. However, our results do not indicate that cotton response to mepiquat chloride applications differs for cotton in a conservation system from traditional application strategies used for cotton managed with conventional tillage systems in previously published reports.

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DISCLAIMER

Mention of trade names and/or commercial products in this article are solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture, North Carolina State University, or Auburn University.

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