PHYSIOLOGICAL, GROWTH AND YIELD RESPONSES OF COTTON TO MEPPLUS AND MEPIQUAT CHLORIDE

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Abstract

An important objective for using plant growth regulators in cotton is to balance vegetative and reproductive growth and to improve lint yield. A 2-year field study was conducted to determine physiological and yield responses of cotton plants to foliar applications of MepPlus and Mepiquat Chloride (MC). Compared with the untreated control, application of MepPlus and MC efficiently reduced plant height, improved leaf photosynthetic rate, and numerically increased lint yield. MepPlus and MC had very similar effects on plant growth and most physiological parameters investigated in this study. However, MepPlus seems to be more efficient in improving photosynthate partitioning into fruits than MC, resulting in slightly higher yields from MepPlus application.

Introduction

Cotton (*Gossypium hirsutum* L.) is a perennial crop with an indeterminate growth habit, and is very responsive to environmental changes and management. Consequently, producers and researchers have long been interested in the use of plant growth regulators (PGRs) for adjusting plant growth and improving cotton yield (Oosterhuis and Egilla, 1996). Mepiquat Chloride (MC) has been the most successful and widely used PGR in US cotton production.

MepPlus is a new PGR from Micro Flo Company (Lakeland, FL), first tested in 1994 and registered in 1997. It consists of MC and the bacteria *Bacillus cereus*. Recent studies have indicated that applying MepPlus had similar effect on plant height control as applying MC. Additionally, MepPlus has been reported to improve leaf photosynthesis (Wells, 1997), dry matter partitioning (Oosterhuis et al., 1998), and lint yield (Parvin and Atkins, 1997; Wells, 1997) of field-grown cotton compared with both untreated control and MC-treated plants. Field studies were conducted at the two locations in Arkansas in 1997 and 1998 in order to compare MepPlus with MC for effects on growth and yield of cotton, and to investigate the physiological effect of MepPlus compared to MC on plant growth.

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Materials and Methods

Plant Culture

Field trials were conducted at the two locations: Clarkedale and Fayetteville, Arkansas in 1997 and 1998. At Clarkedale, the cotton cultivar Suregrow 125 was seeded on 7 May 1997 and 1998 at the Delta Branch Experimental Station. Rows were spaced 38 inches apart and oriented in a north-south direction. Each plot consisted of 4 rows, 50 feet in length.

At Fayetteville, cotton cultivar DPL 20 (1997) or Suregrow 125 (1998) were planted on 19 May 1997 and 15 May 1998 at the Arkansas Agricultural Research and Extension Center, University of Arkansas. Plots consisted of four rows, 16.5 feet in length, spaced 39 inches apart. Fields were hand thinned to 3 plants foot^{-1} row when seedlings had three true leaves. Weeds and insect control, fertilizer management and furrow irrigation were applied as needed according to the Arkansas cotton production recommendations.

Treatments

At both locations three treatments were used consisting of (1) an untreated control, (2) MepPlus, and (3) Mepiquat Chloride (MC). Experiments were arranged in a RCB design with six replications.

The timing and rate of applying PGRs at the two locations in 1997 and 1998 are given in Table 1. The PGRs were applied in 10 gallons of water acre^{-1} using a CO_2-pressurized backpack sprayer.

Measurements

The following physiological and yield parameters were determined:

- Plant height and the number of main-stem nodes;
- Plant growth analysis (leaf area, specific leaf weight, fruit sites, fruit shedding, dry matter accumulation and partitioning);
- Leaf net photosynthetic rate, stomatal conductance, inter-cellular CO_2 concentration, and transpiration rate;
- Leaf cell membrane integraty;
- Leaf nonstructural carbohydrate and mineral nutrient conc.;
- Leaf ATP content;
- ^{14}C-assimilate translocation from leaf to fruits;
- Boll retention and distribution in the plant canopy;
- Maturity;
- Lint yield and yield components;
- Fiber qualities (HVI).

Data were statistically analyzed by the ANOVA and LSD tests. Means were considered significant when $P \leq 0.05$.

Results and Discussion

Plant Growth

Plants receiving MepPlus and MC were significantly shorter than untreated control plants three (1997) or six weeks (1998) after the PGRs were applied (Table 2). However, there were no significant differences between MepPlus and MC. The number of main-stem nodes did not differ among treatments including MepPlus and MC. Therefore, the height/node ratios were similar for both PGR treated plants and much smaller than the control. This indicated that decreased plant height was mainly due to the shorter internode length rather than the decreased number of main-stem nodes.

Accumulation and Partitioning of Dry Matter

Plant growth analysis at 90 DAP indicated that there were no significant differences in the number of bolls and leaf area index among treatments although MepPlus and MC treatments had a numerically lower leaf area index than the control (data not shown). However, MepPlus and MC treated-plants exhibited significantly higher specific leaf weight (11-25%) than untreated control plants.

Among the three treatments, no significant differences were observed in total dry weight and fruit dry weight although the dry weights of stems and leaves for both PGR-treated plants were lower than the control. The fraction of fruit dry weight in total dry matter of the MepPlus treatment (41%) was significantly higher than that of both the control (33%) and the MC treatment (34%) (Oosterhus et al., 1998). This indicated that applying MepPlus improved partitioning of dry matter in plants compared to MC and the untreated control, and more assimilate was translocated into the fruits (squares and bolls) of MepPlus-treated plants.

Leaf Net Photosynthetic Rate

At 5 days after foliar application of MepPlus and MC to field-grown plants, both MepPlus- and MC-treated plants exhibited significantly higher single leaf photosynthetic rates than untreated control plants (Table 3). The increased leaf photosynthetic rate from MepPlus was related to increased specific leaf weifgt and a higher stomatal conductance. MepPlus treatment also resulted in a higher leaf transpiration rate than both the control and MC treatments, whereas intercellular CO_2 concentration was similar among treatments. No difference was observed in leaf photosynthesis between MepPlus and MC treatments.

Leaf Nonstructural Carbohydrate and ATP Concentrations

Under field conditions, the MepPlus and MC did not affect leaf hexose and sucrose concentrations (Fig. 1). However, MepPlus- and MC-treated plants had a significantly higher leaf starch concentration than untreated control plants although leaf starch content did not differ between MepPlus and MC treatments. Higher leaf starch concentrations for both PGR treatments were associated with a higher leaf net photosynthetic rate and a greater specific leaf weight (Table 3).

MepPlus- and MC-treated plants had significantly lower leaf ATP concentrations at 4 and 10 days after PGR application at the FF stage (Fig. 2). The correlation analysis among leaf photosynthetic rate, transpiration, ATP, and nonstructural carbohydrate concentrations indicated that there was no correlation between leaf ATP content and leaf photosynthetic rate or nonstructural carbohydrate concentration (Table 4).

^{14}C-assimilate Translocation

The $^{14}CO_2$ fixation of the subtending leaf of a 14-d-old young boll for the MepPlus-treated plants was higher than that of the control or the MC-treated plants (Table 5). However, there were no statistically differences in ^{14}C-assimilate translocation from the leaf to the subtended boll among the treatments although MepPlus- and MC-treated plants had numerically higher percentage of ^{14}C translocation into the boll than the control at 24 h after feeding.

Yield and Yield Components

In 1997 at Clarkedale, lint yield of the MC treatment was significantly decreased compared to the control, and the MepPlus treatment was numerically, but not significantly lower than the untreated control (Table 6). In 1998 lint yields of MepPlus and MC treatments were increased 49 and 11 lb./acre, respectively, compared to the untreated control although the differences were not statistically significant. Slightly decreased lint yields for both PGR treatments in 1997 might be associated with the extended growing season, because plants receiving growth retardants (MepPlus and MC) usually cutout earlier than the untreated control plants (Oosterhuis, et al., 1991) which may, therefore, have been able to continue to mature more late-season bolls in the extended favorable season than the MepPlus- and MC-treated plants.

In 1997 at Fayetteville, MepPlus treatment showed the highest, and MC lowest lint yield among the three treatments(Table 6). In 1998, MepPlus treatment had a significantly higher lint yield (18%) than the control. MepPlus treatments yielded 35 to 55 (in 1997) or 38 to 112 (in 1998) lb. lint/acre more than MC treatments in the two locations.

Of the three yield components, MepPlus and MC application increased the average boll weight, decreased lint percentage, and did not affect the number of bolls in 1997 (Table 6). In 1998, the yield components did not differ among treatments.

Analysis of plant mapping indicated that application of MepPlus increased the fraction of bolls located at Fruiting

Branches 1 to 3, and MC increase the fraction of bolls at Fruiting branches 4 to 6. Both PGRs decreased the fraction of bolls above Fruiting Branch 10 compared to the untreated control (data not shown). This supports the explanation of higher than expected yields in the untreated control due to more late-season bolls being matured in the extended growing season in 1997.

Fiber Quality

Both PGRs did not affect most fiber quality parameters measured except for fiber length (Table 7). Application of MepPlus and MC increased fiber length, especially the 2.5% span length.

Conclusions

Application of MepPlus and MC significantly decreased plant height, but had no effect on the number of main-stem nodes. MepPlus and MC also increased leaf stomatal conductance and net photosynthetic rate of field-grown cotton, and improved assimilate partitioning between vegetative and reproductive organs. MepPlus resulted in significantly more dry matter being partitioned into fruits. In 1997 lint yield was not significantly different between the two PGR treatments. MepPlus treatments yielded a 60 lb./acre higher lint yield than MC treatments and a 40 lb./acre higher yield than the untreated control averaged over both locations for two years. However, the increases in yields were not statistically significant ($P > 0.05$).

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Table 1. The timing and rates of MepPlus and MC treatments at two locations Clarkedale and Fayetteville in 1997 and 1998.

Treatment	1997	1998
	Clarkedale	
Control	No PGR	No PGR
MepPlus	4 oz./A at PHS	3 oz./A at PHS
	4 oz./A at PHS+9 d	6 oz./A at FF
	4 oz./A at FF	---
	4 oz./A at FF+9 d	---
MC	4 oz./A at PHS	3 oz./A at PHS
	4 oz./A at PHS+9 d	6 oz./A at FF
	4 oz./A at FF	---
	4 oz./A at FF+9 d	---
	Fayetteville	
Control	No PGR	No PGR
MepPlus	8 oz./A at PHS	4 oz./A at PHS
	8 oz./A at FF	8 oz./A at FF
MC	8 oz./A at PHS	4 oz./A at PHS
	8 oz./A at FF	8 oz./A at FF

Table 2. Effect of MepPlus and MC on plant height and main-stem nodes (MSN) of field-grown cotton in 1997 and 1998 (Clarkedale).[†]

Treatment	Plant height	MSN	Height/node
	(Inches)	(no. plant^{-1})	
		1997	
Control	36.7 a[‡]	20.7 a	1.77 a
MepPlus	27.0 b	20.3 a	1.33 b
MC	26.4 b	19.9 a	1.33 b
		1998	
Control	34.4 a	20.4 a	1.69 a
MepPlus	30.9 b	20.0 a	1.54 b
MC	29.2 b	19.5 a	1.50 b

[†] Measured 3 (1997) or 6 (1998) weeks after first PGR application.
[‡] Means with the same letter within a column are not significant ($P > 0.05$).

Table 3. Effects of MepPlus and MC application on leaf photosynthetic rate (Pn), intercellular CO_2 concentration (c_i), stomatal conductance (g_s) and transpiration rate (E) of cotton (Fayetteville).[†]

Treatment	Pn	c_i	g_s	E
	µmol CO_2 m^{-2} s^{-1}	ppm	cm s^{-1}	mol m^{-2} s^{-1}
Control	24.7 b[‡]	299 a	3.80 b	0.017 b
MepPlus	29.4 a	297 a	4.87 a	0.019 a
MC	28.1 a	294 a	3.90 b	0.017 b

[†] Means of two years (1997 and 1998).
[‡] Means with the same letter within a column are not significant ($P > 0.05$).

Table 4. Correlation coefficient (r) among leaf photosynthetic rate (Pn), transpiration rate (E), ATP, and nonstructural carbohydrate concentrations.

	ATP	Hexose	Sucrose	Starch	TNC
Pn	0.29	-0.77*	0.61*	0.81*	0.82*
E	-0.04	0.73*	-0.35	-0.68*	-0.65*
ATP		-0.23	-0.02	0.09	0.07
Hexose			-0.52	-0.89**	-0.86**
Sucrose				0.83*	0.87**
Starch					0.99***

*, **, and *** indicate significance at $P \leq$ 0.05, 0.01, and 0.001, respectively.

Table 5. Effects of MepPlus and MC application on $^{14}CO_2$ fixation and translocation from the loaf to the boll (Fayetteville, 1998).†

Treatment	$^{14}CO_2$ fixation	^{14}C translocation to the boll	
		6 hr	24 hr
	dpm mg^{-1} DW	------------------ % -------------------	
Control	2,630 b‡	33.6 a	60.7 a
MepPlus	3,498 a	26.8 a	76.7 a
MC	2,606 b	27.9 a	70.4 a

† The subtending sympodial leaf at the first position of MSN 10 was labeled with $^{14}CO_2$ when the boll at this position was 14 days old (10 days after PGR application).
‡ Means with the same letter within a column are not significant (P > 0.05).

Table 6. Effect of MepPlus and MC application on lint yield and yield components of field-grown cotton at Clarkedale and Fayetteville.

Treatment	Boll wt.	Boll no.	Ginning turnout	Lint yield	
				Clark.	Fayet.
	g boll^{-1}	no. m^{-2}	%	----- lbs acre^{-1} -----	
			1997		
Control	5.1 b†	78 a	39.8 a	1242 a	1110 a
MepPlus	5.8 a	73 a	38.4 b	1160ab	1133 a
MC	5.6 a	74 a	38.3 b	1125 b	1078 a
			1998		
Control	4.2 a	76 a	37.5 a	896 a	1012 b
MepPlus	4.3 a	79 a	38.2 a	945 a	1181 a
MC	4.1 a	77 a	37.9 a	907 a	1069ab

† Means with the same letter within a column and within a year are not significant (P > 0.05).

Table 7. Effect of MepPlus and MC application on fiber quality: micronaire (MIC), length (UHM), uniformity index (UI), strength (ST), and elongation (EL) in 1997 (Clarkedale).

Treatment	MIC	UHM	UI	ST	EL
		(in)	(%)	(g tax^{-1})	(%)
Control	4.48 a	1.18 b	83.7 a	29.7 a	6.78 a
MepPlus	4.55 a	1.21 a	84.3 a	29.7 a	6.63 a
MC	4.51 a	1.22 a	83.9 a	30.0 a	6.65 a

† Means with the same letter within a column are not significant (P > 0.05).

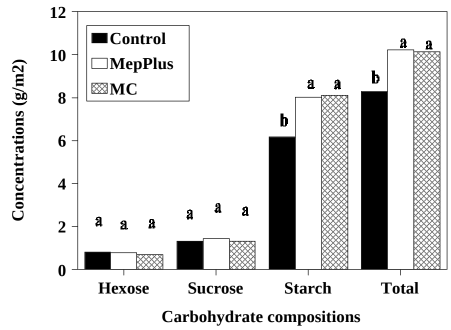

Figure 1. Effect of MepPlus and MC application on leaf nonstructural carbohydrate concentrations of field-grown cotton. Values are the mean of measurements 4 and 10 days after spraying at FF (Fayetteville, 1998).

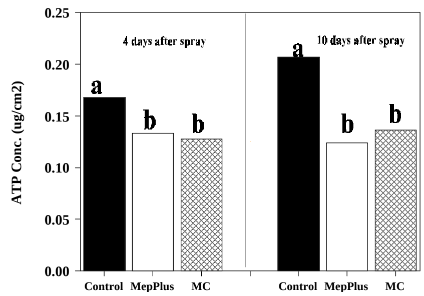

Figure 2. Effect of MepPlus and MC application at the FF stage on leaf ATP concentration of field-grown cotton (Fayetteville, 1998).