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AGRONOMY AND SOILS

Field Evaluation of Nitrophenolate Plant Growth Regulator (Chaperone) for the Effect on Cotton Lint Yield

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ABSTRACT

Reports in the literature have been inconsistent relative to enhanced yields from applications of Chaperone (Asahi Co., Ltd.; Nara Prefecture, Japan), a PGR containing the nitrophenolates sodium 5-nitroguaiacolate ($NaC_7H_6NO_4$) 1.25 g L^{-1}, sodium ortho-nitrophenolate ($NaC_6H_4NO_3$) 2.5 g L^{-1}, and sodium para-nitrophenolate ($NaC_6H_4NO_3$) 3.75 g L^{-1}. Two field studies were conducted to evaluate cotton yield response to foliar applications of Chaperone at early flowering. Study I was conducted in 2004 and 2005 at 28 locations in Texas, and assessed the commercially recommended rate of 0.43 g ai ha^{-1} compared with an untreated control. Study II was conducted at eight locations within Burleson County, Texas, from 2001 to 2005. The treatments consisted of Chaperone at 0.43 g ai ha^{-1}, 0.86 g ai ha^{-1}, and 1.72 g ai ha^{-1} compared with an untreated control. In Study 1, no differences in lint yield were observed between the Chaperone treatment and the untreated control. Regression analyses also failed to show a response from the Chaperone treatment at locations with lower lint yields relative to locations having higher lint yields. In Study 2, across all experiments, Chaperone at 1.72 g ai ha^{-1} increased lint yield by an average of 92 kg ha^{-1} (7.5%) over the untreated control lint yield of 1222 kg ha^{-1}. Chaperone applied in a single application at early flowering at 0.43 g ai ha^{-1} and 0.86 g ai ha^{-1} did not increase yield. Results of this research do not support the use of Chaperone in cotton at the current recommended rate.

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For decades plant growth regulators (PGRs) have been used to manage the growth of cotton plants, expedite maturity, and improve yield. One such PGR is Atonik (Asahi Co.,Ltd.; Nara Prefecture, Japan), a commercially available product containing the active ingredients, sodium 5-nitroguaiacolate ($NaC_7H_6NO_4$) 1.25 g L^{-1}, sodium ortho-nitrophenolate ($NaC_6H_4NO_3$) 2.5 g L^{-1}, and sodium para-nitrophenolate ($NaC_6H_4NO_3$) 3.75 g L^{-1}. These active ingredients, termed nitrophenolates, are found naturally in plants and stimulate plant growth by altering the activity of specific antioxidant enzymes, such as superoxide dismutase (SOD), catalase (CAT), and peroxidase (POX) (Djanaguiraman et al., 2004). These antioxidant enzymes are involved in the scavenging of reactive oxygen species (ROS), such as hydrogen peroxide (H_2O_2), hydroxyl (OH^-), and singlet oxygen (O_2^-) (Shanker et al., 2004). The ROS are able to attack polysaccharides, proteins, and nucleic acids (Matysik et al., 2002). Oxidative stress can occur when more ROS are produced than are metabolized (Dhindsa et al., 1981), so the ability to ameliorate or lessen the impact of ROS on the physiology and subsequent yield of the crop species is a desirable objective. Atonik has been used on various crops in more than 20 countries and was registered for pesticide use in cotton (*Gossypium hirsutum*), rice (*Oryza sativa*), and soybeans (*Glycine max*) in 1995 as ARYSTA-Exp-NP321 (Asahi Co.,Ltd.; Nara Prefecture, Japan). ARYSTA-Exp-NP321 has the trade name Chaperone, which was registered by the Environmental Protection Agency (EPA) with the patent pending in 2000. Chaperone was introduced into the cotton market in 2004, as a protein transport enhancer, and is currently the only agrochemical registered for cotton containing these nitrophenolates.

Recent reports have noted an increase in fruit set and yield of tomatoes with the application of nitrophenolates (Djanaguiraman et al., 2004). These authors attribute increases in fruit set and yield to higher activity of the antioxidant enzymes SOD, CAT, and POX, and auxin content. Increased yields as a result of nitrophenolate applications have also been reported for bell peppers (*Capsicum annuum*) (Csizinszky, 2001), tomato (*Lycopersicon escul-*

entum) (Djanaguiraman et al., 2004), and cotton (Bynum et al., 2004; Fernandez and Correa, 2005; Townsend, 2004; Oosterhuis and Brown, 2004). On the contrary, Robertson (2005) and Lemon et al. (2005) did not show significant cotton lint yield increases with the application of Chaperone.

Previous studies with nitrophenolates have shown increases in K, Ca, and Mg uptake by 23.5%, 22.2%, and 27.8%, respectively, in hydoponically-grown cotton (Guo and Oosterhuis, 1995). In addition, nitrophenolates were reported to increase the activity of nitrate reductase in chickpeas (*Cicer arietinum*) (Sharma et al., 1984) and to maintain higher petiole nitrate content over untreated plants for one to two weeks during early fruiting of cotton (Fernandez et al., 2003). Nitrophenolates also have been shown to increase photosynthesis up to 24.3% and decrease membrane leakage by 34.5% (Guo and Oosterhuis, 1995). Fernandez et al. (2002) reported decreased plant height and sympodial nodes, and an increase in percentage fruit retention and lint turnout on cotton treated with nitrophenolates. Enhancement of the above physiological parameters has the potential to ultimately contribute to lint yield.

The objective of this study was to determine the effect of a single application of Chaperone at early flowering on cotton lint yield under irrigated and dryland conditions. The experimental sites were located in major production regions in Texas and varied widely in climatic and edaphic characteristics.

METHODS AND MATERIALS

Study I. The study was conducted at 28 locations under both dryland and irrigated conditions across the major production regions in Texas. Study locations with cultivar, soil type and year are listed in Table 1.

The experimental design at each location was a randomized complete block with treatments replicated four times. Plot sizes ranged from 0.04 ha to 1.25 ha, depending upon location. Treatments consisted of Chaperone, a nitrophenolate-containing compound, at 0.43 g ai ha^{-1} applied at early flowering (5 to 6 flowers 8.3 m^{-1} of row; Anonymous, 1998), and an untreated control. Chaperone was applied with a small plot sprayer delivering 93.5 L ha^{-1}. The cotton cultivars, fertilization, insect control, weed control, growth management, and defoliation were standard for the respective locations.

Depending on location, plots were mechanically harvested using either a spindle-picker or stripper harvester. A 150- to 200-g sample of seed cotton was collected from each plot. These samples were ginned on a small laboratory gin, without cleaning, to determine lint percentage.

Study II. Study II was designed to evaluate three rates of Chaperone applied at early flowering. The study consisted of eight experiments conducted at the Texas Agricultural Experiment Station (TAES) in Burleson County, Texas, as follows: one in 2001 and 2003, and two in 2002, 2004, and 2005. The soil type for all experiments was a Weswood silt loam with a pH of 8.0 to 8.2. Cotton cultivars for each trial are listed in Table 2.

Treatments consisted of applying Chaperone at 0.43 g ai ha^{-1}, 0.86 g ai ha^{-1} or 1.72 g ai ha^{-1} at early flowering, and an untreated control. Chaperone was applied using an air-compressed small plot sprayer equipped with flat-fan nozzles spaced at 51 cm and calibrated to deliver 140 L ha^{-1}. The experiment was designed as a randomized complete block with treatments replicated four times. Plots were four rows each 1.1 m wide and 10 m long. Seed were planted with a vacuum planter and spaced 8 cm apart into conventionally prepared seedbeds.

The two center rows of each plot were harvested once with a spindle-picker modified for small-plot harvesting. A 150-g sample of harvested seed cotton was collected from each plot. The samples were ginned on a ten-saw, hand-fed laboratory gin without lint cleaning, and used to assess lint percentage and fiber properties. The ginned samples were subjected to HVI testing to determine micronaire, fiber length, uniformity index, and fiber strength (Sasser, 1981). Cotton grades would not be representative of cotton ginned commercially and therefore are not presented.

Both studies were analyzed similarly with lint yield data being subjected to analysis of variance using the mixed models procedure of the SAS (version 9.1.3; SAS Institute Inc.; Cary, NC) with treatments and locations as fixed effects and years and blocks as random effects. Interactions that contained a random variable were treated as random effects. Treatment sums of squares were partitioned to reflect the randomized complete block design of mixed models (McIntosh, 1983). The degrees of freedom were calculated using the Satterthwaite approximation (Satterthwaite, 1946). Simple linear regression was conducted on Study I yields using the regression procedure of the SAS to determine the relationship between treatments for cotton lint yield. A standard *t*-test was conducted to test the slope of the regression equation equal to one. In Study II, cotton lint yields were separated as appropriate using the Tukey-Kramer test at $P \leq 0.05$.

Table 1. Comparison of cotton lint yield response across two years and 28 locations to a single early flowering application of nitrophenolate (Chaperone)

County	Soil type	Cultivar	Year	Lint yield (kg ha^{-1}) [z] Application rate (g ai ha^{-1}) 0.43	0.0
Dryland locations					
Burleson	Weswood silt loam	DP 555 BR	2004	1253	1148
Burleson	Weswood silt loam	DP 555 BR	2005	734	722
Crosby	Pullman clay loam	FM 958	2004	1073	1058
Hill	Houston black clay	DP 436	2004	971	1074
Hill	Houston black clay	DP 424 B2R	2004	1188	1148
Navarro	Houston black clay	DP 436	2004	619	641
Nueces	Orelia fine bandy loam	DP 444 BR	2004	1313	1262
Nueces	Orelia fine bandy loam	FM 960 BR	2004	858	802
San Patricio	Victoria clay	DP 33 B	2004	1520	1571
Wharton	Lake Charles clay	DP 491	2004	909	942
Wharton	Lake Charles clay	DP 444 BR	2005	520	514
Wilbarger	Tillman clay loam	PM 2280 BR	2004	860	866
Combined				868	868
Irrigated Locations					
Burleson	Weswood silt loam	DP 555 BR	2004	1468	1373
Burleson	Weswood silt loam	DP 444 BR	2004	1073	1063
Burleson	Weswood silt loam	FM 800 B2R	2004	550	573
Burleson	Weswood silt loam	FM 800 B2R	2004	464	451
Burleson	Weswood silt loam	DP 449 BR	2005	1488	1468
Burlseson	Weswood silt loam	DP 449 BR	2005	1421	1373
Burleson	Weswood silt loam	DP 449 BR	2005	1627	1539
Crosby	Pullman clay loam	ST 4892 BR	2004	1951	1982
Dawson	Amarillo fine sandy loam	FM 989 R	2004	1275	1382
Hale	Pullman clay loam	ST 2448 R	2004	1347	1374
Hidalgo	Hidalgo fine sandy loam	FM 960 BR	2004	2200	1963
San Patricio	Victoria clay	DP 33 B	2004	1767	1706
Swisher	Pullman clay loam	FM 958	2004	1166	1159
Wharton	Lake Charles clay	DP 555 BR	2005	1430	1499
Wharton	Lake Charles clay	FM 832	2005	1228	1193
Wilbarger	Tillman clay loam	PM 2280 BR	2004	1172	1208
Combined				1353	1329
All locations				1195	1179

[z] According to the *F* test, yield response was not significant for the application of the recommended rate of nitrophenolate (Chaperone) in any year or location.

Table 2. Comparison of cotton lint yield response to a single early flowering application of different rates of nitrophenolate (Chaperone) from 2001 through 2005

Location	Year	Cultivar	Numerator DF	Denominator DF	Lint yield (kg ha^{-1}) [z]			
					Application rate (g ai ha^{-1})			
					0.0	0.43	0.86	1.72
Burleson	2001	DP 451 BR	3	6	1250 a	1341 a	1348 a	1394 a
Burleson	2002	DP 451 BR	3	12	1761 a	1757 a	1896 a	1770 a
Burleson	2002	DP 451 BR	3	12	1809 a	1891 a	1930 a	1939 a
Burleson	2003	DP 451 BR	3	9	1001 b	1094 ab	1136 ab	1272 a
Burleson	2004	FM 800 B2R	3	11.5	451 a	464 a	475 a	477 a
Burleson	2004	FM 800 B2R	3	9	573 ab	550 b	568 ab	634 a
Burleson	2005	DP 449 BR	3	9	1539 a	1627 a	1551 a	1579 a
Burleson	2005	DP 555 BR	3	12	1373 a	1421 a	1353 a	1457 a
Combined			3	92.5	1222 b	1268 ab	1282 ab	1314 a

[z] Means within a row followed by the same letter are not significantly different according to Tukey-Kramer ($P \leq 0.05$).

RESULTS

Study I. All data were pooled across locations because the location by treatment interaction was not significant (Table 3). The combined average lint yield for the Chaperone treatment was 1195 kg ha^{-1} and lint yield for the untreated check was 1179 kg ha^{-1}(Table 1). Lint yield of the cotton treated with Chaperone was not significantly different from the yield of the untreated control across all 28 locations.

Table 3. Partial analysis of variance for fixed effects and interactions on cotton lint yield

Source of variation	Numerator df	Denominator df	F value[z]
Study I			
Treatment	1	160	0.67
Location	27	160	86.79**
Treatment x location	27	160	0.60
Study II			
Treatment	3	92	2.75*
Location	7	92.8	254.58**
Treatment x location	21	92	0.54

[z] F values designated with ** and * are significantly different at the $P \leq 0.01$ and $P \leq 0.05$, respectively.

When the 12 dryland locations were analyzed separately from the irrigated locations, there were no significant differences between the lint yield of the Chaperone treatment (868 kg ha^{-1}) and the yield of the untreated control (868 kg ha^{-1}) (Table 1). Likewise, there were no significant yield differences between the Chaperone treatment (1353 kg ha^{-1}) and the untreated control (1329 kg ha^{-1}) when combined across 16 irrigated locations (Table 1).

To further address the yield potential issue (dryland versus irrigated production), a regression of the Chaperone treatment against the untreated control was conducted. Results indicated no difference across a broad range of lint yields with an r^2 of 0.89 (Fig. 1). The regression was not significant when tested against a slope equal to one. This indicated no response of the Chaperone treatment at locations with lower lint yields relative to locations having higher lint yields.

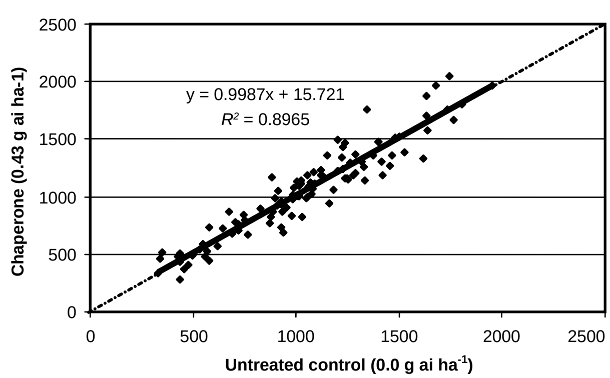

Figure 1. Relationship between nitrophenolate (Chaperone) application at 0.43 g ai ha^{-1} and the untreated control on cotton lint yield in 28 experiments in Texas against a slope equal to one. Applications were made at early flowering.

Study II. Lint yield data were pooled across locations because the treatment by location interaction was not significant. The combined analysis indicated no lint yield response of the Chaperone treatments when applied at 0.43 and 0.86 g ai ha^{-1}. Across locations, the yield response to the 1.72 g ai ha^{-1} rate of Chaperone ranged from 9 kg to 271 kg ha^{-1} above the untreated control (Table 2). The 1.72 g ai ha^{-1} rate of Chaperone increased average lint yield by 92 kg ha^{-1} (7.5%) over the untreated average lint yield of 1222 kg ha^{-1}.

DISCUSSION

Studies were conducted in the major cotton production regions in Texas to determine the ability of Chaperone to increase lint yields. Chaperone applied at a recommended rate of 0.43 and 0.86 g ai ha^{-1} at early flowering did not significantly increase cotton lint yield above the untreated control when tested across a wide range of environmental and edaphic conditions, cultivars, and yield potentials. Chaperone applied at a rate of 1.72 g ai ha^{-1} significantly increased cotton lint yields in Burleson County. Earlier reports claimed that Chaperone increased cotton lint yield by significantly increasing individual boll weights (Fernandez et al, 2003), increasing boll maturation period, and assisting in escape from cotton bollworm [*Heliocoverpa zea* (Boddie)] injury (Sheta and Mourad, 1982), increasing the number of harvested bolls per plant (Townsend, 2004), and increasing the number of seeds per boll (Fernandez and Correa, 2004). These previous reports on yield component enhancement were not confirmed with the findings of the present study. Yield analysis of the locations separated by dryland (non-irrigated) and irrigated failed to show a yield advantage under either production strategy. A yield response was observed at the 1.72 g ai ha^{-1} rate (twice the recommended label rate) and resulted in a net return of \$8.73 ha^{-1}, based on a loan value of \$0.24 kg^{-1}. This return for the yield response at the higher Chaperone rate was found only in Burleson County and should be explored at other locations to confirm the results for this high rate. The yield results of this research do not support the use of Chaperone at the current recommended rate.

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