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MOLECULAR BIOLOGY AND PHYSIOLOGY

Differential Genotypic Response to Exogenous IAA in Field-Grown Upland Cotton

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ABSTRACT

Indole-3-Acetic Acid (IAA) is a phytohormone, found to be abundant during the early stages of fiber development in cotton (*Gossypium hirsutum* L). When applied exogenously, it has been shown to increase fiber initiation; however, other effects are unknown. Therefore, genotypes differing in fiber length potential were placed in a field study to observe the effect of exogenous IAA on yield components and fiber properties. Field studies were conducted from 2008 to 2010 in College Station, TX. One boll per plant was treated with IAA at 4, 12, and 20 days post anthesis (dpa) to coincide with different phases of fiber development. Results showed a significant year interaction with IAA treatment and genotype. In 2009, the plants responded to IAA application. Bolls treated with IAA had increased lint percent due to increased fibers per seed. Genotypes with inherently longer fiber length were negatively affected by treatment with IAA, suggesting that a higher number of fibers per seed may decrease fiber length through competition. There was a genotype by IAA treatment interaction for lint percent, fibers per seed, fiber length, fiber elongation and seed index. However in 2008 and 2010 results were not consistent with 2009; possibly due to differences in environmental conditions. This research does indicate that genotypes differ in IAA sensitivity and suggests that previous work on IAA should be classified as genotype specific. Future work should include determining the amount of IAA that permeates and interacts with ovules to determine the most effective rate, form and application timing on yield components and fiber properties.

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Cotton is an important economic crop in the USA; therefore, increasing crop yield potential has been a major goal in cotton research for decades. More recently, there has been urgency among cotton researchers to improve fiber quality. Increased emphasis on fiber quality has been in large part prompted by new textile processing equipment that requires longer, stronger and more uniform fibers to operate at optimal efficiency rates (Foulk et al., 2009). In addition, the domestic textile industry, which traditionally consumed most of the US produced midgrade cotton, has dramatically declined. As a result, US cotton growers must now market their cotton in a competitive international arena with higher fiber quality standards than those of domestic textile mills.

Understanding the biological properties of cotton fiber is critical to improving fiber quality. Cotton fibers are elongated epidermal cells initiated on seed ovules. Development consists of four phases of growth: initiation, primary elongation, secondary wall formation and maturation (DeLanghe, 1986). These stages are influenced by environmental, genetic, physiological and biochemical factors and the combination of various fiber quality properties contribute to the overall economic value (Bradow and Davidonis, 2000). Fiber length, fiber strength and micronaire all contribute to spinnability and yarn strength (May, 1999). Fiber properties are not independent; rather they are interrelated based on developmental processes, length and rate of each phase and genetic background.

One possible area of improving fiber quality could be the enhancement of hormone activity, either by exogenous application, or by genetic improvement of endogenous production (John, 1994). Indole-3-acetic acid (IAA) is predominantly responsible for cell elongation, required for primary elongation in cotton fiber development (Birnbaum et al., 1974) and could be a regulatory factor in transitioning between primary and secondary wall thickening (Jasdanwala et al., 1977). IAA is highly concentrated in developing fibers during the first days of fiber elongation, and is found in significantly higher concentrations over a longer time period in longer staple cotton (Gokani and Thaker, 2002; John, 1994; Naithani et al., 1982; Seagull and Giavalis, 2004). *G. barbadense* has a 10x increase in IAA during fiber elongation compared to that of *G. hirsutum* (Gould et al., 2001). In addition, *G. barbadense* plants typically produce longer fiber than *G. hirsutum* plants. There may be a relationship between the amount of IAA present during primary elongation and final fiber length.

IAA is up-regulated during primary elongation and inhibited during secondary cell wall development, respectively. IAA has been shown to be predominant during primary elongation so secondary wall thickening starts only after IAA levels fall (Naithani et al. 1982). IAA oxidase, the major catabolic enzyme for IAA, has been demonstrated to be expressed predominantly during secondary cell wall development (Jasdanwala et al., 1977). Increased concentration of abscisic acid (ABA), another phytohormone, has been observed during formation of secondary cell wall development (Gould et al., 2001; Ruan, 2005). ABA inhibits fiber elongation; however, increased concentrations of IAA can overcome the inhibitory effects of ABA (Beasley and Ting, 1973).

John (1994) tried to change fiber properties by using transgenics as a means to increase IAA production and fiber quality. The maximum amount of IAA, however, was produced at 15 dpa, five days past peak elongation at 10 dpa (Naithani et al., 1982). Exogenous application of IAA has been a useful strategy to determine the hormone's impact on fiber initials and ovules. Seagull and Giavalis (2004) applied IAA and GA_3 to cotton bolls from cotton grown in a greenhouse. These hormones were applied, without the use of a surfactant, on reproductive pre-anthesis squares, white flowers, and small bolls at 1-5 dpa. Ovules were harvested from 0 to 5 dpa bolls, and fibers counted. Results indicated a 59% increase in fiber initials over the post-anthesis controls. They concluded that increasing IAA during the first 5 dpa could potentially increase fiber production by either increasing the proportion of epidermal cells that develop into fibers or inducing cell division, forming more epidermal cells.

Fiber development has been observed mainly in tissue culture, using the technique designed by Beasley and Ting (1974). In this and other studies, final fiber length was measured without ginning (Beasley and Ting, 1974; Seagull et al., 2000). There has been no investigation on how exogenous IAA affects high-volume instrumentation (HVI) measured traits. If IAA can increase the number of fibers produced (Seagull and Giavalis, 2004), and increase fiber length of short staple cotton (Gokani and Thaker, 2002), potential may exist to alter other fiber properties.

Therefore, the objective of this study was to determine the effect of exogenous IAA on fiber quality parameters in five genotypes differing in fiber length potential under field conditions. We hypothesized that exogenous IAA will have greater influence on genotypes with a reduced potential for fiber length. We also hypothesized that repeated exposure to supplemental IAA prevents or delays secondary wall thickening which could increase fiber length but reduce micronaire or strength.

MATERIALS AND METHODS

A field study was conducted on a Westwood silt loam, at the Texas Agrilife Research Farm near College Station, TX from 2008-2010 to evaluate the effect of IAA on five contrasting genotypes. TAM 94L-25 (Smith, 2003) is a breeding line chosen for its near-long staple length. TAM 94L-25-$M_{3:5}$-9469, (9469) TAM 94L-25-$M_{3:5}$-9505, (9505) and TAM 94L-25-$M_{3:5}$-9653 (9653) are sister lines selected from a chemically mutated population of TAM94L-25 developed in 2000 (Duncan et al., 2007). These mutant sister-lines were chosen due to significantly different potential fiber length, but otherwise maintain similar fiber traits. TAM B182-33 (B182-33) (Smith et al., 2009) an upland breeding line with fiber length often exceeding 34.9 mm was also chosen.

The experiment was arranged in a randomized complete block design with four replications. Entries were grown in single row plots, 1m x 12m in a furrow irrigated field. The experiments were planted on 25 April 2008, 4 May 2009 and 26 April 2010. Plots were overseeded and seedlings were thinned for uniformity to nine plants meter^{-1}. Irrigation was applied approximately every two weeks from first bloom to 5 nodes above white flower, if there was no rainfall in that time.

A 1.0 mg mL^{-1} IAA ($C_{10}H_9NO_2$, Sigma I-3750) stock solution was prepared by dissolving the appropriate amount of chemical in 1.0 mg mL^{-1} KOH, then diluting with H_2O (Seagull and Gialvalis, 2004). The stock solution was diluted to a working concentration of 0.1mg mL^{-1}, a higher concentration than Seagull and Giavalis (2004). The stock solution was prepared one time for use in 2008, but it was reconstituted weekly for use in 2009 and 2010.

One boll per plant, a total of ten plants per plot were treated to provide enough lint for fiber analysis. First position white flowers on the 1st, 2nd or 3rd fruiting branches were tagged and dated at early flowering in July of each year to represent 0 dpa. Ten drops of IAA solution were applied mid-morning, to tagged bolls, using a transfer pipette on 4, 12 and 20 dpa fruiting structures. IAA was applied directly to bolls at 4 dpa to coincide with end of initiation and the start of primary fiber elongation; at 12 dpa, to coincide with the start of secondary wall development, and at 20 dpa to coincide with the end of primary elongation. First position bolls, one per plant, on ten non-treated plants were chosen as experimental control units. Seagull and Giavalis (2004) reported that water and KOH had no effect when used as a control. Treated and control bolls were harvested by hand as soon as bolls opened to prevent weathering effects.

Seed cotton was processed on a laboratory saw gin. Lint percent was calculated as lint weight/seed cotton weight. Seed index was measured as the weight (grams) of 100 fuzzy seeds. Fiber samples were analyzed using HVI at the Fiber and Biopolymer Institute in Lubbock, TX. The HVI instrument measured fiber micronaire, length, strength, length uniformity, and elongation. Fibers per seed were estimated using the following equation: weight of fibers per seed divided by the average weight per fiber, where the average weight per fiber is the mean fiber length by mean linear density or micronaire. (Lewis et al., 2000; Worley et al., 1976). Data were analyzed using a pooled year analysis; significant interactions were present and individual years were analysed separately with SAS 9.2 (SAS institute, 2008). Means were separated using pairwise LSD comparisons at p=0.05.

RESULTS

The main effects of year, IAA treatment and genotype were significant for all measured traits except IAA on strength (p=0.067). There were significant year interactions with genotype and treatment (Table 1). Therefore results are reported for each year, rather than across years.

The year-by-treatment means for lint percent, seed index and fibers per seed are presented in Table 2. There were no significant responses to IAA in 2008 or 2010, except for a small increase in seed weight with IAA treatment in 2008. Genotypes expressed significant differences in these traits each year, but there were significant genotype-by-IAA interactions only in 2009. In that year, lint percent increased with IAA treatment in 9469, 9505, and Tam94L-25, but not in the other genotypes. Seed weight of all genotypes except 9469 decreased with IAA treatment. Fibers per seed of all genotypes increased with IAA treatment, but the magnitude of response differed among genotypes in 2009.

Genotypes expressed significant differences in all measured fiber properties each year (Table 3). There were significant responses to IAA for micronaire and length (2009, 2010); uniformity (2009); strength (2008, 2009) and elongation (2008, 2009, 2010). There were significant genotype-by-IAA interactions in 2008 for micronaire, strength, and elongation, and in 2009 for fiber length and elongation. Fiber length of the three genotypes with the longer control fiber lengths were decreased with IAA treatment in 2009, but length of the other genotypes were unaffected. No significant genotype-by-IAA interactions were observed in 2010 except in length uniformity. Line 9505 decreased in uniformity with IAA treatment. A decrease in length and increases in micronaire and elongation with IAA treatment were observed across genotypes in 2010.

Table 1. P-values for lint percent, HVI measured traits, seed index and estimated fibers per seed across years 2008-2010.

Effect	Lint Percent	Micronaire	Length	Uniformity	Strength	Elongation	Seed Index	Fibers seed^{-1}
Year	0.0173	<0.0001	<0.0001	<0.0001	0.0389	<0.0001	<0.0001	<0.0001
Genotype	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Year*Genotype	<0.0001	<0.0001	<0.0001	0.0001	0.0162	<0.0001	<0.0001	<0.0001
IAA	0.0116	<0.0001	0.0002	0.0325	0.0667	<0.0001	<0.0001	<0.0001
Year*IAA	<0.0001	<0.0001	<0.0001	0.0052	<0.0001	<0.0001	<0.0001	<0.0001
Genotype*IAA	0.0306	0.3852	<0.0001	0.1874	0.7846	<0.0001	0.0538	0.1079
Year*Genotype*IAA	0.0021	0.0084	0.0027	0.1204	0.0078	<0.0001	0.1526	0.0011

Table 2. Lint percent, seed index, and fibers per seed of five genotypes with and without IAA treatment in 2008, 2009 and 2010, and P-values of F-tests.

Genotype	IAA treatment	Lint percent			Seed weight			Fibers seed^{-1}		
		2008	2009	2010	2008	2009	2010	2008	2009	2010
					------------- g (100 seed)$^{-1}$ -------------					
9469†		39.7 b‡	41.9 a	39.4 b	10.1 d	9.8 b	10.1 c	14722 ab	20492 b	14003 a
9505§		35.4 fg	35.0 fgh	31.3 j	12.1 c	10.0 b	12.6 b	15101 a	21198 ab	16178 ab
9653¶		34.3 ghi	32.9 ij	35.6 efg	12.5 bc	10.5 b	12.1 b	14045 bc	22881 ab	13757 c
B182-33#		33.1 i	36.0 def	33.6 hi	13.7 a	11.6 a	13.7 a	13673 c	16657 c	14639 c
TAM 94L25		37.6 cd	38.5 bc	37.1 cde	12.9 b	10.4 b	12.3 b	15408 a	20577 b	14922 bc
P-value		<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	0.0100	<0.0001	<0.0001
	IAA	35.4	38.5 a	35.5	12.5 a	9.7 b	12.0	14487	24869 a	15258
	No IAA	36.6	35.3 c	35.3	12.1 b	11.2 a	12.3	14692	15852 b	15342
P-value		0.071	<0.0001	0.428	0.036	<0.0001	0.258	0.526	<0.0001	0.823
9469	IAA	38.3	45 a	39.3	10.3	9.8 cd	10.2	14554	24049 b	17620
9469	No IAA	41.0	38.8 cd	39.5	10.0	9.9 cd	10.0	14891	16935 d	16386
9505	IAA	35.0	37.5 c-g	30.6	12.3	8.9 d	12.4	14574	25751 b	15425
9505	No IAA	35.8	32.5 lmn	32	12.0	11.0 b	12.8	15629	16646 d	16932
9653	IAA	33.3	32 lmn	36	12.5	9.7 cd	12.2	13830	29721 a	13351
9653	No IAA	35.3	33.8 i-m	35.3	12.5	11.2 b	12.0	14259	16040 d	14163
B182-33	IAA	33.0	36.5 efg	34.3	14.0	10.9 b	13.7	14057	19848 c	14875
B182-33	No IAA	33.3	35.5 f-i	33	13.5	12.4 a	13.7	13288	13466 e	14404
TAM 94L25	IAA	37.7	41.3 b	37.5	13.2	9.3 cd	11.8	15421	24974 b	15016
TAM 94L25	No IAA	37.5	35.8 f-i	36.7	12.6	11.6 ab	12.7	15395	16180 d	14828
P-value		0.547	0.003	0.103	0.714	0.027	0.323	0.460	0.023	0.183

† TAM 94L-25-M$_{3:5}$-9469

‡ Within groups, means followed by the same letter do not differ at p=0.05 by independent pairwise comparisons (pdiff). Letters omitted where P(F)>0.05.

§ TAM 94L-25-M$_{3:5}$-9505

¶ TAM 94L-25-M$_{3:5}$-9653

 # TAM B182-33 ELS

DISCUSSION

Since genotypes had been chosen based on varying fiber quality properties (Clement et al., 2009), significance in all properties was expected. Fiber elongation was the only fiber trait that was altered by IAA treatment for three consecutive years. However, it was not consistent in the manner in which it was altered, significantly decreasing fiber elongation in 2008 and 2009 but increasing it in 2010 (Table 3); therefore the reason for the response across years is unclear. Though longer staple cotton has been found to have different rates and periods of developmental phases (Naithani et al., 1982) it can be speculated that IAA could have affected the period of overlap between primary elongation and secondary wall thickening. Or the variation may be due to environmental conditions that affect other fiber properties, since elongation measurements are inter-related with length and strength measurements (Benzina et al., 2007). Fiber strength increased in 2008, decreased in 2009, and did not respond to IAA in 2010.

Table 3. Fiber properties of five genotypes with and without IAA treatment in 2008, 2009 and 2010, and P-values of F-tests.

Genotype	IAA	Micronaire			Length			Uniformity			Strength			Elongation		
		2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010
					---------------- mm ----------------			---------------- % ----------------			------------- g tex-1 -------------			---------------- % ----------------		
9469†		4.4 b‡	3.8 a	4.2 c	30.0 d	29.0 bc	29.2 c	83.6 b	82.1 b	83.8 c	29.5 d	30.1 b	30.0 c	7.5 a	5.6 a	6.4 b
9505§		4.9 a	3.4 bc	4.5 b	25.7 e	25.1 d	24.4 d	82.3 c	77.3 c	82.4 d	31.0 c	27.8 b	29.9 c	7.0 b	5.3 a	6.6 a
9653¶		4.3 b	3.2 c	4.6 b	33.0 b	29.5 bc	32.0 b	82.9 bc	82.1 b	85.1 b	32.7 b	31.7 b	33.2 b	6.1 d	4.3 b	4.9 c
B182-33*		4.1 c	3.6 ab	4.0 d	36.3 a	34.0 a	35.1 a	85.3 a	84.3 a	86.6 a	35.6 a	36.1 a	36.1 a	4.7 e	4.6 b	5.0 c
TAM 94L25		4.8 a	3.6 ab	4.9 a	32.0 c	28.4 c	29.7 c	83.8 b	81.7 b	84.0 c	32.5 b	28.7 b	32.4 b	5.7 d	3.8 c	4.9 c
P-value		<0.0001	0.034	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.005	<0.0001	<0.0001	<0.0001	<0.0001
	IAA	4.5	3.0 b	4.6 a	32.0	28.4 b	29.7 b	83.8	80.8 b	84.2	33.1 a	29.3 b	31.9	5.3 b	4.5 b	5.7 a
	No IAA	4.5	4.0 a	4.3 b	31.8	30.0 a	30.5 a	83.4	82.2 a	84.6	31.4 b	32.4 a	32.7	7.0 a	4.9 a	5.4 b
P-value		0.295	<0.0001	<0.0001	0.068	<0.0001	0.007	0.178	0.017	0.168	<0.0001	0.031	0.096	<0.0001	0.003	0.009
9469	IAA	4.3 de	3.5	4.3	30.7	29.5 cde	29.0	84.1	82.1	84.2 cde	30.8 cde	29.9	29.5	6.3 c	5.3 ab	6.6
9469	No IAA	4.5 cd	4.0	4.2	29.7	28.6 de	29.2	83.2	82.1	83.4 e	28.3 f	30.4	30.5	8.7 a	5.8 a	6.1
9505	IAA	5.0 a	2.9	4.7	28.2	25.4 g	24.6	82.7	77.1	81.2 f	31.9 cde	24.8	30.3	5.6 d	4.9 bc	6.7
9505	No IAA	4.8 ab	3.9	4.4	27.7	24.6 g	24.4	81.9	77.5	83.6 de	30.1 e	30.9	29.6	8.3 a	5.6 a	6.6
9653	IAA	4.1 ef	2.9	4.9	33.0	28.1 ef	31.8	83.0	81.1	85.2 bc	33.8 b	29.7	32.6	5.2 de	4.0 de	5.0
9653	No IAA	4.5 cd	3.6	4.3	32.8	30.7 cde	32.5	82.9	83.1	85.0 cd	31.6 cde	33.7	33.7	7.1 b	4.6 cd	4.8
B182-33	IAA	4.0 f	3.1	4.1	36.3	32.1 b	34.8	84.9	82.9	86.8 a	34.7 b	35.9	36.1	5.0 ef	4.8 bc	5.0
B182-33	No IAA	4.2 ef	4.2	3.9	35.8	35.8 a	35.6	85.7	85.7	86.5 ab	36.4 a	36.4	36.1	4.4 g	4.4 cd	5.0
TAM 94L25	IAA	4.9 ab	3.0	5.0	32.0	27.3 f	29.0	84.2	80.8	83.5 e	34.4 b	26.6	31.2	4.6 fg	3.4 e	5.1
TAM 94L25	No IAA	4.7 bc	4.2	4.8	32.3	29.5 d	30.5	83.4	82.6	84.5 cde	30.5 de	30.8	33.7	6.9 b	4.2 d	4.7
P-value		0.019	0.207	0.084	0.505	<0.0001	0.344	0.277	0.463	0.024	<0.0001	0.234	0.233	<0.0001	0.023	0.443

†TAM 94L-25-$M_{3:5}$ -9469

‡Within groups, means followed by the same letter do not differ at p=0.05 by independent pairwise comparisons (pdiff). Letters omitted where P(F)>0.05.

§TAM 94L-25-$M_{3:5}$ -9505

Fiber length was hypothesized to increase with the IAA treatment; however, data from the 2009 and 2010 growing seasons indicated a decrease in fiber length with IAA treatment. The IAA-induced decrease in length in 2009 was accompanied by decreased length uniformity and large increase in fibers per seed, indicating that IAA treatment increased the number of shorter fibers. This negative response is contrary to the hypothesis that IAA would promote primary elongation. Although John (1999) reported no response in length, micronaire or strength when IAA levels were increased by overexpression of the iaaM/iaaH genes in transgenic cotton, one gene construct (iaaM/iaaH) did give a negative response to fiber length.

Fiber length was significantly reduced in TAM94L-25, 9653, and B182-33 by IAA (Table 3), in 2009. These genotypes have the highest fiber length potentials at 30.8, 32.0 and 35.9 mm, respectively. However, the applied IAA decreased these potentials by at least 1.2 mm to 29.4, 30.7 and 34.4mm. The shorter staple lines were not affected while the longer ones did in his study, conflicting to the findings of Gokani and Thaker (2002).

Fibers per seed increased in all genotypes while lint percent increased in the shorter fiber lines (9469 and 9505) and TAM 94L-25 in 2009. Clouvel et al. (1997) reported that fibers per seed can reach a threshold and start to have detrimental effects on fiber length; due to competition between fibers for resources. This may indicate a reason for the decrease in fiber length in the longer lines while an increase in lint percent could be the result of increased fibers per seed in the shorter lines.

Seed index is one component of lint percent; this is demonstrated by a highly significant negative correlation between seed index and lint percent ($r^2 = 0.33$; $P \leq 0.01$) and the trends for each were similar with IAA treatment for genotype and year (Table 2).

The strong interaction of IAA treatment with year may be due to seasonal differences in environmental conditions and growth stages of plants. The effectiveness of IAA treatment was much greater in 2009 than in the other two years. The years differed during the crucial fiber development stage; with 2009 being hot and dry compared with 2008 (Figure 1), while the 2010 growing season had more rainfall than 2008 or 2009 (Figure 2). Hotter temperatures can increase rates of metabolic processes and cause more rapid fiber development; shortening the time between fertilization and boll opening (Ehlig, 1986). Increased rainfall caused lower temperatures during fiber development (Figure 1) and perhaps greater shading due to cloud coverage. Cool temperatures can delay fiber initiation and early elongation (Haigler et al., 1991; Triplett 2000); while shading can result in decreased strength and micronaire due to limited photosynthetic capacity (Pettigrew, 2001). Future experiments focusing on the form, rate and timing of the IAA applications could elucidate the uncertainty across environments.

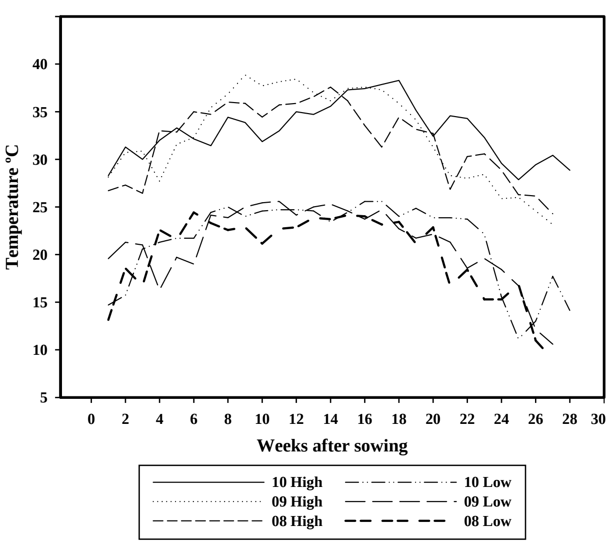

Figure 1. High and low temperatures for the weeks after sowing in 2008, 2009 and 2010. Crucial boll filling occurred during weeks 8-14.

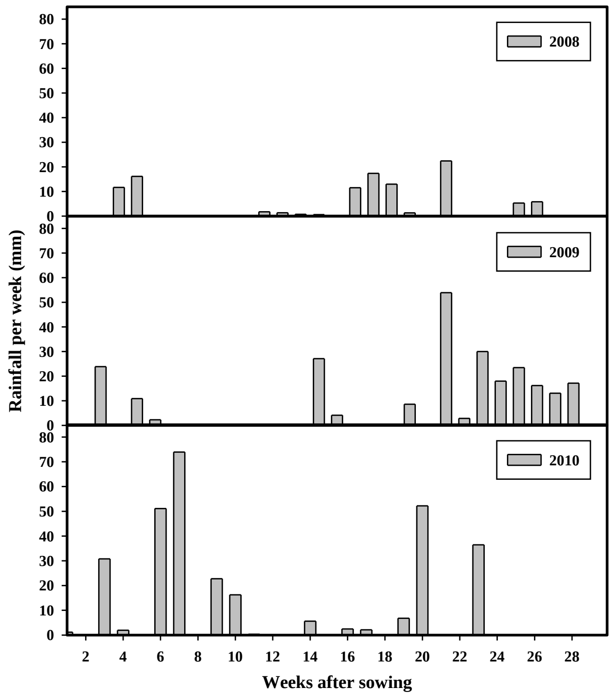

Figure 2. Rainfall per week during growing seasons; 2008, 2009, and 2010. Crucial boll filling occurred during weeks 8-14.

CONCLUSION

The purpose of this study was to take an agronomic approach to gain understanding about the effect of IAA on cotton fiber properties. It was hypothesized that exogenously applied IAA could positively affect initiation and primary elongation. This would be indirectly measured as fibers per seed or by HVI fiber properties such as fiber length. The increase in fibers per seed was confirmed in 2009, supporting Seagull and Giavalis (2004), that IAA enhances fiber initiation. In fact, in 2009 it was apparent that the increased fibres per seed created competition between fibers resulting in reduced fiber length (at least in longer-fibered genotypes), as well as reduced uniformity, micronaire and strength (Table 3). Applications of IAA at 12 and 20 dpa may have stimulated IAA oxidase production to further restrict fiber properties and also potentially reduced seed growth, which contributed to increased lint percentage (Table 2). However responses in 2008 and 2010 were not consistent, possibly due to environmental differences.

Future studies would benefit from experiments with concentration gradient and rate, since the amount of IAA that actually permeates into the boll and to ovules is unknown. The application at 4 dpa seems most effective, although form and rate may influence the timing. Knowing the amount that permeates the boll will help determine the rate necessary for efficacy. A synthetic auxin, NAA, maybe more suited for a field environment; since it appears to be more stable than IAA, making it easier to store (Barai et al., 2005). TAM 94L-25 appeared to be more sensitive to IAA for lint percent, fiber length, elongation, seed size, and fibers per seed, though not necessarily a positive response. However, it would be a genotype for future experiments with IAA to examine the effects on yield components and fiber properties. Due to differential genotype sensitivity, previous studies examining IAA may need to be revisited.

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