Multiyear Study of the Effects of Kinetin and Other Plant Growth Hormones on Yield, Agronomic Traits, and Allelochemicals of Cotton

Paul A. Hedin* and Jack C. McCarty, Jr.

Crop Science Research Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Mississippi State, Mississippi 39762-5367

In recent years, a number of plant growth hormones including the synthetic cytokinin, kinetin, have been evaluated for their effects on yield and agronomic traits of various crop plants. In a series of tests conducted from 1986 to 1992, kinetin was evaluated using foliar sprays applied to cotton (*Gossypium hirsutum* L.) plants in an attempt to improve yield, agronomic traits, and content of allelochemicals in the bud. For comparison, tests were conducted using kinetin riboside, indoleacetic acid, and gibberellic acid. The effects of these plant growth hormones were near zero over the 6 year period, although, in some individual tests, statistically significant differences in yield were obtained. No multiyear trends were evident. Kinetin and gibberellic acid appeared to increase bud gossypol, an established cotton allelochemical, in some years. Overall, these growth hormones appeared to be marginally effective at best for increasing yields and allelochemicals as tested.

Keywords: *Plant growth regulators; cytokinins; cotton yield*

INTRODUCTION

In recent years, a number of kinetin-based commercial plant growth regulator preparations have been evaluated for their effects on yield and agronomic traits of various crop plants. Cytokinins were discovered as a result of efforts to find factors that would stimulate plant cells to divide, and subsequently they were shown to affect various plant processes. The synthetic cytokinin, kinetin, was identified by Miller et al. (1955) as a result of its ability to stimulate cell division. Kinetin is not naturally occurring but results from heat-induced degradation of DNA. The basis for foliar application of cytokinins to field plants is inferred from the improved growth of plants in cytokinin-containing solutions. Cytokinins may not always be active unless other hormones are present. However, cytokinins alone can often evoke a variety of physiological, metabolic, biochemical, and developmental processes when applied to plants. A detailed description of the roles of cytokinins in plant growth can be found in a review chapter by Taiz and Zeiger (1991) and in publications by Weaver (1972) and Elliott (1982).

Guinn (1986) reviewed the known hormonal relationships associated with growing cotton *Gossypium hirsutum* L.) plants. Cytokinins can either inhibit or promote abscission depending on time and site of application and can promote the ability of an organ to compete for metabolites. Guinn (1986) reported that exogenous applications of cytokinins may promote, rather than retard, abscission unless applied directly to the abscission zone. Retained bolls, however, tended to contain more cytokinin.

The use of bioregulators on cotton has been investigated extensively, and the literature has been cited in several of our previous papers (Hedin et al., 1984, 1988a,b; McCarty et al., 1987; McCarty and Hedin, 1989; Hedin and McCarty, 1991). The focus of this study is to report on our recent results with kinetin and two other plant growth hormones and to compare these results with previous ones to establish whether there are helpful trends. Results from previous field tests using foliar sprays showed that kinetin and two commercial kinetin formulations tended to increase yield of cotton, pest resistance, and yield of four allelochemicals: gossypol, condensed tannins, flavonoids, and anthocyanins (Hedin et al., 1988a; McCarty et al., 1987; McCarty and Hedin, 1989). These allelochemicals have been shown to be toxic to the tobacco budworm [*Heliothis virescens* (F.)], a major pest of cotton, and therefore could be associated with yield (Hedin et al., 1984, 1988a,b).

MATERIALS AND METHODS

1986–1992 Bioregulator Field Tests. The field tests were conducted each year on the North Farm at Mississippi State University using two commercial cotton cultivars, Stoneville 213 (ST-213) and Deltapine 50 (DPL-50). The cotton was planted each year about May 1 in single-row [0.97 × 12.8 m (W × L)] plots. Insects were controlled all season with fenvalerate (DuPont Agricultural Products, Wilmington, DE) and Cythion (American Cyanamid, Princeton, NJ). The plant growth regulator formulations were applied each year at three rates (zero, low, high; see Table 1 for rates) to plants whose squares were "match head" in size on about July 10 and 24. Each compound was handled as a separate randomized complete block experiment with five replications.

The timing of applications and rates were in general those recommended by previous investigators or the provider (Hedin et al., 1988a,b). Two rates, with the second application generally 3-fold higher, were used to improve the likelihood that a response would be elicited. The rates and numbers of applications were as follows: kinetin; 1.8 × 2 and 6.2 × 2 g ha^{-1}, kinetin riboside, 3.7 × 2 and 17.3 × 2 g ha^{-1}; gibberellic acid (GA_3) 1.8 × 2 and 6.2 × 2 g ha^{-1}; and indole-3-acetic acid (IAA), 1.8 × 2 and 6.2 × 2 g ha^{-1}. Each compound was weighed and dissolved in 5–10 mL of H_2O. One milliliter each of Span 80 and Tween 80 was then added. The solutions were made up to 1.25 L with water just before use. They were

* Author to whom correspondence should be addressed.

Table 1. Summary of Percent Changes in Yield and Agronomic Traits of Cotton Treated with Kinetin and Other Naturally Occurring Plant Growth Regulators[a-c]

				change, %				
				yield				
year	cultivar	compound	control yield, kg/ha	low	high	lint %	boll size	seed index
1986	ST-213	kinetin	1374	+6.4	+4.1			
1988	DPL-50	kinetin	1397	+1.9	+9.5	−1.2	0.0	−1.0
1989	DPL-50	kinetin	1212	−17.7*	−4.0	−1.3	0.0	+1.0
1990	DPL-50	kinetin	1528	+2.8	+5.0	−0.1	+6.4	+4.4
1991	DPL-50	kinetin	1399	−10.5*	−5.7	+0.2	+3.5	
1991	DES-119	kinetin	1447	+10.5*	+9.5*	−0.2	+4.0	
av			1393	−1.1	+3.1	−0.8	+2.8	+1.5
1986	ST-213	gibberellic acid	1076	+23.2*	−1.9			
1986	ST-213	indole acetic acid	1112	−8.5	+4.1			
1988	DPL-50	kinetin riboside	1397	+1.6	−1.0	−0.2	+1.8	+1.0
1989	DPL-50	kinetin + IAA	1212	+7.1	−12.9*	−0.4	+5.3	0.0

[a] Numbers followed by an asterisk are statistically significant at the 5% level. [b] Rates and numbers of applications: kinetin, 1.8 × 2 and 6.2 × 2 g ha^{-1}; kinetin riboside, 3.7 × 2 and 17.3 × 2 g ha^{-1}; gibberellic acid, 1.8 × 2 and 6.2 × 2 g ha^{-1}; indoleacetic acid, 1.8 × 2 and 6.2 × 2 g ha^{-1}. [c] Percent change in lint percent, boll size, and seed index from the control for high rate only. Change in lint percent is reported as numerical change.

Table 2. Summary of Percent Changes of Allelochemicals in Squares (Buds) of Cotton Treated with Kinetin and Other Naturally Occurring Plant Growth Regulators[a,b]

			gossypol		tannins, %		flavonoids, %	
year	cultivar	compound	low	high	low	high	low	high
1986	ST-213	kinetin	+15.4	+7.7	−8.4	−4.0	−4.0	−1.0
1988	DPL-50	kinetin	+4.1*	+2.0	+6.1	+3.2	−1.4	−0.5
1989	DPL-50	kinetin	−3.3*	−3.3*	−1.3	−12.5	+0.9	−3.7
1991	DPL-50	kinetin	+8.1*	−5.4	+2.1	+9.2	+5.4	+2.7
1991	DES-119	kinetin	0.0	+6.3*			−5.2	−3.0
av			+4.9	+1.5	−0.3	−0.8	−0.9	−1.1
1986	ST-213	gibberellic acid	0.0	0.0	+13.5*	−5.4*	+5.4	−3.1
1986	ST-213	indoleacetic acid	+16.7*	+8.3*	+8.0	−4.0	+7.2	+1.0
1988	DPL-50	kinetin riboside	−6.1*	−2.0	+2.3	+15.0	−3.2	−13.9*
1989	DPL-50	kinetin + IAA	0.0	0.0	+1.8	−0.3	+3.7	+3.2

[a] Numbers followed by an asterisk are statistically significant at the 5% level. [b] See footnote *b*, Table 1, for rates.

applied with a CO_2-pressurized backpack sprayer delivering 203 L/ha at 207 kPa of pressure. For allelochemical analyses, plant material (terminal leaves and squares) was collected on about July 31 and August 14 and placed in the freezer (−20 °C) until processed.

The plots were machine harvested one time for yield determination on about September 30. A defoliant (in recent years, Dropp, NOR-Am. Chemical Co., Wilmington, DE) was applied if required for efficient harvesting. Prior to machine harvest, 25 open bolls were hand harvested from each plot, weighed, and ginned to determine boll size, lint percentage, and seed index. Seed index is the weight in grams of 100 fuzzy seeds. The lint percentage determined was used in calculating lint yields.

Procurement of Bioregulators. Kinetin (6-furfurylaminopurine), kinetin riboside, IAA and GA_3 (gibberellic acid) were procured from Sigma Chemical Co., St. Louis, MO.

Analysis of Allelochemicals. Plant tissue [ca. 25 terminal leaves and 25 squares (buds)] from each replication was collected, freeze-dried, and ground prior to allelochemical analysis. Analysis of allelochemicals (gossypol, tannin, anthocyanin, flavonoid) was conducted following the procedures described by Hedin et al. (1988a).

Statistical Procedures. Data obtained from the various analyses and measurements were subjected to the analysis of variance, and least significant differences (lsd) values were calculated according to SAS (1985) methods.

RESULTS AND DISCUSSION

Table 1 presents a summary of changes in yields and agronomic traits of cottons treated with kinetin and two other plant growth hormones during the period from 1986 to 1991. Table 2 presents a summary of changes of three cotton plant allelochemicals for insects (gossypol, condensed tannins, and flavonoids) in the cottons treated with kinetin and the other growth hormones during the same period. This information was compiled from statistically analyzed data. It must be conceded that experimental conditions (i.e., rates, number of applications, cultivars, climate) varied over the several year period. While this may limit the ability to make rigorous comparisons, obvious efficacy would nevertheless be apparent.

Over the total study period from 1982 to 1992 on bioregulators, the average lint yield of controls was 1400 kg ha^{-1} and the average lint percent (percent lint in seed cotton), boll size (grams per boll), and seed index (grams per 100 seeds) were 39.2, 5.3, and 10.1, respectively. The average contents of bud allelochemicals of controls during the same period were as follows: gossypol, 0.32%; tannins, 11.99%; and flavonoids, 1.78%.

The results in Table 1 indicate that the effects of kinetin, kinetin riboside, IAA, and GA_3 on yield were near zero over the 6 year period (1986−1991) with one possible exception (GA_3 at the lower level only). GA_3 is known to effect an internode elongation, but it was not evident at harvesting. In a few instances, there were statistically significant changes in yield, but these isolated differences were not sustained at both levels or over the duration of the tests, and no multiyear

trends were evident. Because the tests were carried out at at least two levels, and because tests using 1,1-dimethylpiperdinium chloride (PIX) always exhibited internode shortening (McCarty and Hedin, 1994), there is little reason to believe the tests were flawed within the perspective of their constitution. The candidate compounds also did not substantially affect the levels of lint percent, boll size, or seed index (Table 1).

Kinetin appeared to increase square (bud) gossypol in 1986 and 1988, but these increases were not sustained in succeeding years (Table 2). GA_3 appeared to increase square gossypol substantially in 1986 at the lower level only. Indole-3-acetic acid alone gave mixed results in 1986, and a mixture of kinetin and IAA had no effect in 1989. Kinetin riboside appeared to increase tannins in 1988, but it had no effect on the more important allelochemical, gossypol (Table 2). None of the other compounds substantially affected tannins and flavonoids.

In summary, although these growth hormones were applied in a culturally convenient and presumably acceptable manner, they did not appear to be effective for increasing yields or allelochemicals in these tests at this location. In other environments, the effects may have been more favorable.

ACKNOWLEDGMENT

We thank Moderia Petty, Randall McPherson, and Russ Hayes for technical assistance.

LITERATURE CITED

Elliott, M. C. The Regulation of Plant Growth. In *Plant Growth Regulator Potential and Practice*; Thomas, T. H., Ed.; BCPC Publications: London, 1982; pp 57–98.

Guinn, G. Hormonal Relations During Reproduction. In *Cotton Physiology, Number One, The Cotton Foundation Reference Book* Series; Mauney, J. R., McD. Stewart, J., Eds.; The Cotton Foundation, Memphis, TN, 1986; pp 113–136.

Hedin, P. A.; McCarty, J. C., Jr. Effects of Kinetin Formulations on Allelochemicals and Agronomic Traits of Cotton. *J. Agric. Food Chem.* **1991**, *39*, 549–553.

Hedin, P. A.; Jenkins, J. N.; McCarty, J. C., Jr.; Mulrooney, J. E.; Parrott, W. L.; Borazjani, A.; Graves, C. H., Jr.; Fuller, T. H. Effects of 1,1-Dimethylpeperdinium Chloride on the Pests and Allelochemicals of Cotton and Pecan. In *Bioregulators: Chemistry and Uses*; Ory, R. L., Rittig, F. R., Eds.; ACS Symposium Series 257; American Chemical Society: Washington, DC, 1984; pp 171–191.

Hedin, P. A.; Jenkins, J. N.; Thompson, A. C.; McCarty, J. C., Jr.; Smith, D. H.; Parrott, W. L.; Shepherd, R. L. Effects of Bioregulators on Flavonoids, Insect Resistance, and Yield of Seed Cotton. *J. Agric. Food Chem.* **1988a**, *36*, 1055–1061.

Hedin, P. A.; McCarty, J. C., Jr.; Jenkins, J. N. Effects of CCC and PIX Related Bioregulators on Gossypol, Protein, Yield and Seed Properties of Cotton. *J. Miss. Acad. Sci.* **1988b**, *33*, 49–57.

McCarty, J. C., Jr.; Hedin, P. A. Effects of Bioregulators on Allelochemicals, Proteins, and Agronomic Traits of Cotton. *Miss. Agric. For. Exp. Stn. Res. Rep.* **1989**, *14*, 1–5.

McCarty, J. C., Jr.; Hedin, P. A. Effects of 1,1-Dimethylpiperidinium Chloride on the Yields, Agronomic Traits, and Allelochemicals of Cotton (*Gossypium hirsutum* L.), a Nine Year Study. *J. Agric. Food Chem.* **1994**, preceding paper in this issue.

McCarty, J. C., Jr.; Jenkins, J. N.; Hedin, P. A.; Shepherd, R. L.; Parrott, W. L. The Effects of Plant Growth Regulators on Cotton Yield in Two Environments. *Miss. Agric. For. Exp. Stn. Res. Rep.* **1987**, *12*, 1–4.

Miller, C. O.; Skoog, F.; von Saltza, M. H.; Strong, F. M. Kinetin, a Cell Division Factor from Deoxyribonucleic Acid. *J. Am. Chem. Soc.* **1955**, *77*, 1392.

SAS. *SAS User's Guide: Statistics*, version 5 ed.; SAS Institute: Cary, NC, 1985; 956 pp.

Taiz, L.; Zeiger, E. Cytokinins. In *Plant Physiology*; Taiz, L., Zeiger, E., Eds.; Benjamin/Cummings: Redwood City, CA, 1991; pp 452–472.

Weaver, R. J. *Plant Growth Substances in Agriculture*; Freeman: San Francisco, 1972; pp 99–103.

Received for review September 16, 1993. Revised manuscript received January 3, 1994. Accepted July 21, 1994.[⊗] Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

[⊗] Abstract published in *Advance ACS Abstracts,* September 1, 1994.