The *Journal of Cotton Science 23:161–167 (2019)*
http://journal.cotton.org, © The Cotton Foundation 2019

AGRONOMY AND SOILS

Upland Cotton Growth and Yield Response to Enhanced Inputs Across the Mid-south and Southeast Cotton Belt

Todd A. Spivey, W. Hunter Frame, Darrin M. Dodds, Andrea S. Jones,
Keith L. Edmisten, David Jordan, and Randy Wells*

ABSTRACT

In addition to cost of seed and agrichemicals, cotton growers are often enticed to apply additional inputs in the quest for plant health. It is not known, however, whether these additional inputs are cost effective. The objectives of this study were to evaluate current extension recommendations compared to several additional inputs on yield and economic gain. In addition, differences in plant populations, plant heights and thrips damage were assessed. Additional inputs included enhanced soil fertility, in-furrow and foliar fungicides, in-furrow insecticide, and late foliar applied potassium. Each of the inputs was included as an individual treatment, a combined treatment with all five inputs, and a control treatment based on each state's extension recommendations in the trial. Each treatment was included at both an early and late planting date from 2014 through 2016 in Missouri, Mississippi, North Carolina, and Virginia. No additional inputs increased fiber yield or economic gain significantly compared to the controls. Plant populations and plant heights at five weeks after planting (WAP) were not influenced by inputs except for a reduction in plant population of the 150% fertility treatment when compared to local extension recommendations in 2016. Thrips injury rating at three WAP was reduced by treatments including the in-furrow insecticide compared to the control in two of three years in both North Carolina and Virginia The data indicate that these additional inputs are for use under specific circumstances or thresholds and should not be used as a blanket agronomic treatment in the name of plant health.

Much advancement in cotton production has led to an increase in cost of production. Agrichemical, fertilizer, and seed costs have increased 35, 93, and 551 % since 1995, respectively (USDA-ERS, 2016a). The introduction of plant incorporated protectants and herbicide tolerance through biotechnological modification has increased ease of production while continuing the trend of escalating seed cost (Culpepper and York, 1998; Nida et al., 1996; USDA-ARS, 2000). Since 1996, the adoption of both *Bacillus thuringiensis* (Bt) cotton and herbicide-tolerant cotton has steadily increased to approximately 84% and 90% of planted hectares, respectively (USDA-ERS, 2016b). Although initially simplifying the management of the cotton bollworm (tobacco budworm, *Heliothis virescens* F. and cotton bollworm, *Helicoverpa zea* B.) and weed complexes, these technologies have shown recent downfalls including the selection for Bt-resistant bollworms in sweet corn with similar Cry toxins to those used in cotton cultivars, as well as a number of herbicide-resistant weed species (Culpepper, 2006; Dively et al., 2016; Norsworthy et al., 2012). Due to the diminishing control of cotton bollworm, the presence of herbicide-resistant weeds, and the threat of selecting for future herbicide-resistance, growers are forced to include more costly chemical control options than were needed 10 to 15 years ago (Collins and Reisig, 2016; Norsworthy et al., 2012).

Along with the increasing costs of seed and chemicals, which are largely out of the control of the producer, growers are often enticed to include additional inputs by many sectors of the cotton industry. These additional inputs are often exten-

---

T.A. Spivey, Americot, Inc., 582 S. Pleasant Coates Road, Benson, NC 27504; W.H. Frame, Tidewater Agricultural Research and Extension Center, Virginia Tech , 6321 Holland Road , Suffolk, VA 23437; D.M. Dodds, Plant and Soil Sciences Department, Mississippi State University, Dorman Hall, 138, Mississippi State, MS 39762l; A.S. Jones, PhytoGen Cottonseed / Corteva Agriscience, 759 South Walnut, Steele, MO 63877; K.L. Edmiston, D. Jordan, and R. Wells*, Crop and Soil Sciences Department, North Carolina State University, Williams Hall, Box 7620, Raleigh, NC 27695.
*Corresponding author: randy_wells@ncsu.edu

sion recommended practices under certain environmental conditions or when specific symptoms are observed. These inputs include enhanced soil fertility, in-furrow foliar fungicides, in-furrow insecticides, foliar applied fungicides, and late foliar applied potassium. In-furrow fungicide provides added protection against the cotton seedling disease complex above what is already achieved with the seed treatment fungicides which are present on the overwhelming majority of planted acres (Keonning and Collins, 2016). An in-furrow insecticide on top of insecticidal seed treatments has been recommended to improve and prolong the management of early season thrips populations in upland cotton in the southeastern United States (US) Cotton Belt (Reisig, 2016). The application of foliar fungicides is intended to prevent leaf spot and boll rot caused by fungal pathogens in conditions conducive to disease development (Syngenta Crop Protection, 2017). Potassium, is utilized by cotton throughout the growing season (Pettigrew, 2008), but the majority of utilization occurs during boll development and plays a vital role in cotton fiber elongation (Pettigrew, 2008; Snider and Oosterhuis, 2015). These inputs are presented to the growers as inexplicit ways to promote plant health even when the recommended conditions and symptoms are not present. Therefore, research was conducted to observe these representative inputs, regardless of present environmental conditions or plant symptoms, for effects on cotton growth and yield compared to current state extension recommendations. In addition, the monetary impacts of these inputs were analyzed for profitability.

MATERIALS AND METHODS

Experiments were conducted at Lee Farm at the Fisher Delta Research Center in Portageville, MO; the Upper Coastal Plain Research Station in Rocky Mount, NC; and the Tidewater Agriculture Research and Extension Center in Suffolk, VA from 2014 through 2016; the R.R. Foil Plant Science Research Station in Starkville, MS in 2015; and the Black Belt Experiment Station in Brooksville, MS in 2016. Cultivar Phytogen 499WRF (Dow AgroScience, Indianapolis, IN) was seeded at a rate of 8.1 seed m^{-1} row (106,447seed ha^{-1}) in Missouri in 76 cm row spacing; 10.7 seed m^{-1} row (111,458 seed ha^{-1}) in 96 cm row spacing in Mississippi; 9.8 seed m^{-1} row (108,160 seed ha^{-1}) in 91 cm row spacing in North Carolina; and 11.2 seed m^{-1} row (121,939 seed ha^{-1}) in 91 cm row spacing in Virginia. Plots at all locations were 12.2 m in length and four rows wide.

A total of seven treatments were included in this study (Table 1), with a control treatment of base extension recommendations from the state in regard to all aspects of production including fertility and pest management (Dodds, 2017; Edmisten, 2016; Frame et al., 2016; Univ. of Missouri, 2017). Five fertilizer and agrichemical inputs were chosen to include in this study to represent the varying options that are presented to growers as practices to improve plant health. These inputs include a 150% soil fertility program, in-furrow fungicide, in-furrow insecticide, early season foliar fungicide, and late season foliar potassium fertilization (Table 1). All treatments were managed with these base recommendations with the exception of the additional input(s) in question. The soil fertility input, 150% soil fertility, consisted of 150% of the soil test recommended rates of nitrogen (N), phosphorus (P), and potassium (K). The additional 50% of N, P, and K was applied to the surface of the soil prior to planting each spring. The in-furrow fungicide input, mefenoxam (Ridomil Gold SL, Syngenta Crop Protection, Greensboro, NC), was applied in-furrow, at-planting at a rate of 106 ml ha^{-1}. Imidacloprid (Admire Pro, Bayer Crop Science, Research Triangle Park, NC), the in-furrow insecticide, was applied in-furrow, at-planting at a rate of 672 ml ha^{-1}. Although the use of imidacloprid in-furrow is currently an extension-recommended practice on cotton planted in the southeast United States (US), the input was chosen for inclusion in this study based on resistance of tobacco thrips (*Frankliniella fusca*) to the neonicotinoid class of insecticides in the Mid-South and the declining efficacy of the neonicotinoids on tobacco thrips in the Southeast (Huseth et al., 2016). A foliar fungicide, azoxystrobin (Syngenta Crop Protection, 2017), was applied at a rate of 438 ml ha^{-1} at the three to four leaf stage and again at a rate of 584 ml ha^{-1} at matchhead square. The final input consisted of a series of weekly potassium nitrate (KNO_3, 13-0-44) foliar applications of 11.2 kg ha^{-1} (4.9 kg K ha^{-1}) each during the first five weeks of bloom for a total of 56 kg ha^{-1} (24.6 kg K ha^{-1}). Each of the five additional inputs was included as an individual treatment and in a high-input treatment consisting of all five inputs together, treated at the same rate and timing as each of the individual treatments.

Table 1. Treatments and inputs used in experiments in Missouri, Mississippi, North Carolina, and Virginia from 2014-2016

Treatment	Product	Trade Name	Rate	Application Timing	Manufacturer
1) Base Ext. Rec.	-	-	-	-	-
2) Base+ 150% Soil Fertility	N, P, K	-	1.5x soil test	Preplant	-
3) Base+ In-Furrow Fungicide	mefenoxam	Ridomil Gold SL	106 ml ha^{-1}	At-Planting	Syngenta Crop Protection
4) Base+ In-Furrow Insecticide	imidacloprid	Admire Pro	672 ml ha^{-1}	At-Planting	Bayer Crop Science
5) Base+ Foliar Fungicide	azoxystrobin	Quadris	438 ml ha^{-1}	3-4 Leaf Stage	Syngenta Crop Protection
			584 ml ha^{-1}	Match Head Square	
6) Base+ Foliar Fertilizer	KNO_3	-	11.2 kg ha^{-1} (56 kg ha^{-1})	Weeks of Bloom 1-5	-
7) Base+ High Input	Inputs 2-6	-	-	-	-

Each treatment was included at two planting dates each year. Early planting ranged from 27 April to 8 May in Missouri, 9 May to 11 May in Mississippi, 9 May to 15 May in North Carolina, and from 9 May to 24 May in Virginia. Late planting ranged from 24 May to 30 May in Missouri, 7 June to 8 June in Mississippi, 25 May to 2 June in North Carolina, and 23 May to 10 June in Virginia.

Plant populations were determined in all locations except Missouri 2014. Plant populations were determined by counting individual plants from three m from each of the two center rows in Missouri, North Carolina, and Virginia and from four m from each of the two center rows in Mississippi. Visual thrips (order Thysanoptera) injury ratings were assigned to each plot at three weeks after planting (WAP). Thrips injury ratings were based on a one to five scale in which a rating of one indicates no visible injury, and a rating of five indicates severe injury or plant death (Faircloth et al., 2001). Plant heights were also measured of five plants in each plot at five WAP across all locations with the exception of Missouri 2014. Five plants from the center two rows were measured from the soil surface to the terminal bud (Grimes and Yamada, 1982).

The two center rows of each plot were machine (spindle) harvested from late October through early November in all locations and seasons. Seedcotton samples from each plot (~500 g) were ginned to determine lint percentage, with the exception of locations in Mississippi. Virginia seedcotton was ginned with a 10-saw Continental Eagle gin without lint cleaners. North Carolina seedcotton was ginned with a Continental 12-saw gin without lint cleaners. Missouri samples were processed on a 20-saw Continental gin with a seed cotton cleaner and one-stage lint cleaner (Continental Gin, Birmingham, AL).

Seedcotton yield was converted to lint yield based on the lint percentage from each individual plot, ranging from 35 to 45% in Missouri, 41 to 50% in North Carolina, and 40 to 48% in Virginia. Seedcotton yield in Mississippi was converted to lint yield based on a lint percentage of 40%.

Data was analyzed as a split block design blocked by plant date, with early and late planting date corresponding to separate sections of the field. Within each plant date, input treatments were arranged as a randomized complete block design with a total of seven treatments and four replications in Mississippi, North Carolina, and Virginia, and three replications in Missouri. Treatments were randomized independently within each block at each location and year. Plant date and input treatments were considered fixed effects and location, year, and replications were considered random effects. Data was subjected to analysis of variance using the PROC GLM in SAS 9.4 (SAS Institute Inc., Cary, North Carolina) with corrected error terms for fixed and random effects and means were separated using Dunnett's Procedure ($\alpha = 0.05$) for a pairwise comparison of each input with the local extension recommendations (Carmer et al, 1989; Moore and Dixon, 2015).

RESULTS AND DISCUSSION

The three-way interaction of year, plant date, and input was significant for plant populations. When analyzed by year, however, the two-way interaction of plant date and input was not significant in any year. At the time plant populations were calculated, only the 150% soil fertility, in-furrow fungicide, in-furrow insecticide had been applied. When pooled across all locations, plant populations of any treatment did not differ when compared to local extension recommendations in 2014 and 2015 (Table 2). In 2016, plant populations were lower in plots treated with 150% soil fertility. Plant date only influenced plant populations in 2014 (Table 2). The increased populations of late planted cotton is most likely due to increased soil and air temperatures at planting for more optimal germination conditions.

When pooled across all locations and years, plant heights measured at five WAP did not differ due to input (Table 2). Plant date did, however, influence plant heights as late planted cotton had greater plant heights at five WAP than did early planted cotton. The increased plant heights observed in late planted cotton is most likely related to an increased rate of vegetative development due to increased temperatures and more optimum growing conditions during germination and early development compared to environmental conditions observed around early planted cotton. Wells and Meredith (1984a) found that vegetative dry matter produced at approximately 50 days after planting in response to a late-April planting was less than 80% of that produced by a mid-May planting date.

The three-way interaction location, year, and plant date was significant for visual thrips injury so that data was not pooled across location for analysis. Visual thrips injury ratings were taken in Missouri only in 2016 and no differences were observed by input or by plant date (Table 3). In Mississippi, the two-way interaction of year and plant date was significant. No differences were observed by input for either early or late planted cotton, with the exception of late planted cotton in 2015 in which the in-furrow fungicide reduced visual thrips injury rating compared to local extension recommendations. There is no biological reasoning for the reduction of thrips injury due to the use of an in-furrow fungicide. It is more probable that a vigor response to the in-furrow fungicide was realized, resulting in a lower visual injury rating. All injury ratings of the late planted cotton were low and the reduction of injury rating due to the use of an in-furrow fungicide was minor.

Populations of tobacco thrips range in susceptibility to neonicotinoid insecticides in the Southeast. Despite this, the practice of using a neonicotinoid in-furrow insecticide in addition to neonicotinoid insecticidal seed treatment is effective in most areas (Huseth et al., 2016; Reisig, 2016). In-furrow insecticide treatments in early planted cotton in North Carolina reduced visual thrips injury compared to the local extension recommendations (Table 3). Interestingly, the high-input treatment, which includes the in-furrow insecticide applications did not significantly reduce thrips injury in the early planted cotton. In late planted cotton in 2014, the opposite situation was observed. The high-input treatment had reduced thrips injury compared to base recommendations while the in-furrow insecticide alone showed no response. In 2014 and 2016 in Virginia, both the in-furrow insecticide alone and the high-input treatment reduced visual thrips injury compared to the base recommendations (Table 3). Visual thrips injury ratings in Virginia were only taken for early planted cotton. Planting date has previously been shown to have a significant effect on thrips abundance in late-planted cotton. Thrips infestations are usually reduced in later planted than in a timely planted crop, possibly due to the amount of alternate hosts available at the time of emergence (Parajulee et al., 2006; Parrella & Lewis, 1997).

The two-way interaction of year and plant date within location was significant for cotton lint yield so that each location was analyzed separately, except for Virginia which only had early planting dates. In Missouri and North Carolina, early planting resulted in increased lint yields in 2014 and 2015 (Table 4) but did not influence cotton lint yields in 2016. For all remaining locations and years, early planting resulted in 244 to 1090 kg ha^{-1} greater fiber yield compared to late planted cotton. It is possible that this reduction in yield for late planted cotton occurred due to a reduction in season length and observed heat units for late planted cotton compared to early planted cotton as was previously observed by O'Berry et al. (2008).

With no significant interactions concerning the main effect of inputs, lint yields were pooled across all locations and years (Table 5). Fiber yield response to inputs, whether individual or the high input, was at best 59 kg ha^{-1} and non-significant as compared to local base recommendations. This lack of yield response was consistent with the absence of conditions requiring these inputs. The cost of each input, including the high-input treatment, along with the increase in lint yield needed to cover the cost of each treatment (breakeven lint target) is presented in Table 5. The cost for individual inputs ranged from 20 to 120 \$ ha^{-1} for the in-furrow fungicide and the 150% soil fertility inputs, respectively. The high-input treatment required over 300 \$ ha^{-1} in added costs. Since no significant yield increase was realized from any additional inputs beyond the base recommendations for each state, none of the treatments would have covered the cost of the inputs in the environments encountered during this study.

Table 2. Influence of input treatments and cotton planting date on plant populations and plant heights measured at 5 weeks after planting in Missouri, Mississippi, North Carolina, and Virginia from 2014 to 2016

INPUT	Plant Populations			Plant Height
	2014	2015	2016	
	plants ha^{-1}			cm
Base Ext. Rec.	92662	108722	100452	22.95
Base+ 150% Soil Fertility	92687	109251	89930[z]	23.45
Base+ In-Furrow Fungicide	87757	112086	94095	23.09
Base+ In-Furrow Insecticide	100756	111977	96182	23.81
Base+ Foliar Fungicide	95137	110784	98378	23.23
Base+ Foliar Fertilizer	90222	114633	95942	22.84
Base+ High Input	86075	112108	99437	23.15
MSD[y]	ns	ns	7472	ns
Plant Date				
Early	75386 b[x]	109357	93154	21.19 b
Late	108983 a	113373	99536	25.86 a
LSD	6111	ns	ns	0.49

[z] Comparison of input means to base extension recommendations is significant according to Dunnett's procedure at α=0.05.

[x] Minimum Significant Difference for comparing inputs to base extension recommendations.

[y] Means followed by the same letter within each column and effect are not significantly different according to Fisher's Protected LSD at p ≤ 0.05.

Table 3. Influence of input treatments and cotton planting date on visual thrips injury rating at three weeks after planting in Missouri, Mississippi, North Carolina, and Virginia from 2014 to 2016

INPUT	Missouri	Mississippi			North Carolina			Virginia	
		Early	Late		Early	Late			
	2014-2016	2014-2016	2015	2016	2014-2016	2014	2015-2016	2014,2016	2015
	Thrips Injury Rating (1-5)								
Base Ext. Rec.	2.0	2.6	2.0	2.0	2.5	2.3	1.5	2.1	1.4
Base+ 150% Soil Fertility	2.3	2.5	2.0	1.5	2.9	2.5	1.9	2.0	1.5
Base+ In-Furrow Fungicide	2.7	2.6	1.0[z]	2.0	2.2	2.8	1.5	1.8	1.5
Base+ In-Furrow Insecticide	2.3	2.5	1.8	1.0	1.3[z]	1.5	1.6	1.3[z]	1.5
Base+ Foliar Fungicide	2.5	2.2	1.8	1.5	2.5	2.5	1.4	1.9	1.5
Base+ Foliar Fertilizer	2.3	2.4	1.3	1.3	2.7	2.3	1.5	1.8	1.4
Base+ High Input	2.5	2.3	1.3	1.5	1.9	1.4[z]	1.8	1.2[z]	1.6
MSD	ns	ns	0.8	ns	0.6	0.9	ns	0.3	ns
Plant Date									
Early	2.8								
Late	2.0								
LSD	ns								

[z] Comparison of input means to base extension recommendations is significant according to Dunnett's procedure at α=0.05.

Table 4. Influence of cotton planting date on lint yield in Missouri, Mississippi, North Carolina, and Virginia from 2014 to 2016

Plant Date	Missouri			Mississippi		North Carolina			Virginia
	2014	2015	2016	2015	2016	2014	2015	2016	2014-2016
	lint yield (kg ha^{-1})								
Early	1270 a[z]	1531 a	1530	2490 a	1511 a	2047 a	1148 a	772	1401 a
Late	510 b	1098 b	1318	1400 b	812 b	1340 b	904 b	715	1026 b
LSD	116	115	ns	199	119	231	89	ns	47

[z] Means followed by the same letter within each column are not significantly different according to Fisher's Protected LSD at $p \leq 0.05$.

Table 5. Cotton lint yield response to additional inputs along with cost of each input treatment and the lint yield gain above base extension recommendations required to cover the cost of each input (breakeven lint gain)

Input	Lint Yield kg ha^{-1}	Input Cost[†z] \$ ha^{-1}	Breakeven Lint Target[y] kg ha^{-1}
Base Extension Recommendations	1238	-	-
Base+ 150% Soil Fertility	1283	119.93	78
Base+ In-Furrow Fungicide	1242	17.93	12
Base+ In-Furrow Insecticide	1252	29.54	19
Base+ Foliar Fungicide	1251	105.30	68
Base+ Foliar Fertilizer	1263	65.16	42
Base+ High Input	1297	337.90	219
MSD[x]	ns	-	-

[z] Cost of inputs are based on prices obtained January 2016 in North Carolina. The cost of each input does not include application cost.

[y] Breakeven lint target based on cotton lint price of \$1.54 kg^{-1} (\$0.70 lb^{-1}).

[x] Minimum Significant Difference for comparing inputs to base extension recommendations.

As previously discussed, each of the inputs included in this study are extension-recommended practices but only under certain environmental conditions, or when pest thresholds are an issue. Based on the data contained herein, it is not recommended that producers use any of these inputs as plant health treatments when not specifically recommended by local extension guidelines. Although the logistics of a field study makes it impossible to evaluate every non-extension-based recommendation presented to producers, it is imperative that producers consider each recommendation based on sound data to prevent an unnecessary reduction of net returns in the name of plant health.

REFERENCES

Carmer, S.G., W.E. Nyquist, and W.M. Walker. Least Significant differences for combined analyses of experiments with two- or three-factor treatment designs. Agron. J. 81:665-672.

Culpepper, A.S. 2006. Glyphosate-induced weed shifts. Weed Tech. 20:277-281.

Culpepper, A.S., and A.C. York. 1998. Weed management in glyphosate-tolerant cotton. J. Cotton Sci. 2:174-185.

Collins, G.D., and D. Reisig. 2016. Managing Bollworms in Bt Cotton through season's end. North Carolina Coop. Ext. Service. https://cotton.ces.ncsu.edu/2016/08/managing bollworms-in-bt-cotton-through-seasons-end/. (accessed 12 Feb. 2017).

Dively, G.P., P.D. Venugopal, and C. Finkenbinder. 2016. Field-evolved resistance in corn earworm to Cry proteins expressed by transgenic sweet corn. PLoS ONE. doi:10.1371/journal.pone.0169115.

Dodds, D.M. 2017. Mississippi State Extension: Cotton. Mississippi Extension. http:// extension.msstate.edu/agriculture/crops/cotton.

Edmisten, K.L. 2016. 2016 Cotton Information. AG-417. Raleigh, NC: North Carolina Coop. Ext. Service.

Faircloth, J. C., J.R. Bradley, J.W. Van Duyn, and R.L. Groves. 2001. Reproductive success and damage potential of tobacco thrips and western flower thrips on cotton seedlings in a greenhouse environment. J. Agric. and Urban Entomol. 18:179-185.

Frame, W.H., D.A. Herbert, H. Mehl, C. Cahoon, M.S. Reiter, and M. Flessner. 2016. Virginia Cotton Production Guide 2016. AREC-123. Blacksburg, VA: Virginia Coop. Ext.

Grimes, D.W., and H. Yamada. 1982. Relation of cotton growth and yield to minimum leaf water potential. Crop Sci. 22:134-139.

Huseth, A.S., T.M. Chappell, K. Langdon, S.C. Morsello, S. Martin, J.K. Greene H. Ames Herbert, A.L. Jacobson, F.P.F. Reay-Jones, T. Reed, D.D. Reisig, P.M. Roberts, R. Smith and G.G. Kennedy. 2016. *Frankliniella fusca* resistance to neonitoctinoid insecticides: an emerging challenge for cotton pest management in the eastern United States. Pest Manag. Sci. 72:1934-1945.

Keonning, S., and G. Collins. 2016. Disease management in cotton. p.75-83. *In* K. Edmisten (Ed.) 2016 Cotton Information. Publ. AG-417. Raleigh, NC: North Carolina Coop. Ext. Serv.

Moore, K.J., and P.M. Dixon. 2015. Analysis of combined experiments revisited. Agron. J. 107:763-771.

Nida, D.L., K.H. Kolacz, R.E. Buehler, W.R. Deaton, W.R. Schuler, T.A. Armstrong, et al. 1996. Glyphosate-tolerant cotton: Genetic characterization and protein expression. J. Agric. Food Chem. 44:1960-1966.

Norsworthy, J.K., S.M. Ward, D.R. Shaw, R.S. Llewellyn, R.L. Nichols, T.M. Webster, et al. 2012. Reducing the risks of herbicide resistance: Best management practices and recommendations. Weed Sci. 60(sp1):31-62.

O'Berry, N.B., J.C. Faircloth, K.L. Edmisten, G.D. Collins, A.M. Stewart, A.O. Abaye, et al. 2008. Plant population and planting date effects on cotton (Gossypium hirsutum L.) growth and yield. J. of Cotton Sci. 12:178-187.

Parajulee, M. N., R.B. Shrestha, and J.F. Leser. 2006. Influence of tillage, planting date, and bt cultivar on seasonal abundance and within-plant distribution patterns of thrips and cotton fleahoppers in cotton. Int. J. of Pest Manag. 52: 249-260.

Parrella, M. P., and T. Lewis. 1997. Integrated pest management (IPM) in field crops. p. 595-614. In T. Lewis (Ed.), Thrips as crop pests. New York, NY: CAB International.

Pettigrew, W.T. 2008.Potassium influences on yield and quality production for maize, wheat, soybean, and cotton. Physiol. Plant. 133:670-681.

Reisig, D. 2016. Managing insects on cotton. p.130-147. *In* K. Edmisten (Ed.) 2016 Cotton Information. Publ. AG-417. Raleigh, NC: North Carolina Coop. Ext. Serv.

Snider, J.L., and D.M. Oosterhuis. 2015. Physiology. p.339-400. *In* D.D. Fang and R.G. Percy (Eds.), Cotton: Second edition. Agronomy Monograph No.57. Madison, WI, American Society of Agronomy.

Syngenta Crop Protection. 2017. Quadris fungicide label. SCP 1098B-L2S 1116. Greensboro, NC, Syngenta Crop Protection.

Univ. of Missouri. 2017. Missouri Crop Resource Guide: Cotton. University of Missouri Extension. http://crops.missouri.edu/cotton/.

[USDA-ARS] U.S. Department of Agriculture-Agronomic Research Service. 2000. Bt Cotton and management of the tobacco budworm-bollworm complex. U.S. Department of Agriculture-Agronomic Research Service. ARS-154.

[USDA-ERS] U.S. Department of Agriculture-Economic Research Service. 2016a. Commodity costs and returns. U.S. Department of Agriculture. https://www.ers.usda.gov/data-products/commodity-costs-and-returns/commodity-costs-and-returns/# Recent Costs and Returns: Cotton (accessed 10 Feb. 2017).

[USDA-ERS] U.S. Department of Agriculture-Economic Research Service. 2016b. Recent trends in GE adoption. U.S. Department of Agriculture. https://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us/recent-trends-in-ge adoption/. (accessed 10 Feb. 2017).

Wells, R., and W.R. Meredith, Jr. 1984. Comparative growth of obsolete and modern cotton cultivars. I. Vegetative Dry Matter Partitioning. Crop Sci. 24:858-862.