MATURITY ELONGATION OF MID-SEASON UPLAND COTTON VARIETIES THROUGH THE USE OF PYRACLOSTROBIN AND AZOXYSTROBIN FUNGICIDES

A Thesis

by

JOHN DAVID ROCCONI

Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Chair of Committee,	J. Tom Cothren
Committee Members,	Tom Isakeit
	James Starr
Head of Department,	David D. Baltensperger

May 2014

Major Subject: Agronomy

ABSTRACT

Cotton (*Gossypium hirsutum L.*) is subject to stress and yield reducing factors throughout the growing season. The loss of Delta and Pine Land 555 Bollgard® Roundup Ready® (DPL 555 BR) cotton in September 2009 removes a variety from the commercial market that proved to be a useful tool for farmers. This true full-season variety gave producers in regions of the U.S. Cotton Belt, where long growing season windows are established, the opportunity to take full advantage of extended growing days until harvest. The potential to delay the maturity of a mid-full season upland cotton variety, to that of the established full season variety, DPL 555 BR, may be possible through the determent of stress with fungicides.

A two-year field study was conducted at the Texas AgriLife Research Farm in Burleson County in 2008 and 2009. The study evaluated the impact of pyraclostrobin, Headline®, and azoxystrobin, Quadris®, fungicides and their effect on yield and maturity after application to a mid-full season upland cotton variety, Stoneville 4554 Bollgard II® Roundup Ready Flex® (STV 4554 B2RF). These fungicides, along with commercially available tank-mix compounds, were applied to the study area at two defined growth stages: Early Bloom (EB), and Early Bloom +14 days (EB+14). Data analyzed over the years of both studies indicated statistical and numerical differences for fungicidal treatments.

Statistical differences were noted in measurements throughout the years of both Study 1 and Study 2. Final plant mapping measurements and fiber properties for both

studies failed to show improvements of increased nodes or plant height, as well as the measurements obtained from HVI analysis, due to the additions of either pyraclostrobin or azoxystrobin compounds. Combining these strobilurin fungicides with the labeled compounds of mepiquat chloride or mepiquat chloride did not yield results detrimental to plant characteristics measured in these studies. The treatment timing of EB+14 that contained the pyraclostrobin compound increased lint yield versus the untreated control by 213 kg ha^{-1}.

DEDICATION

This thesis is dedicated to my beautiful wife and best friend, Robin, whose love, support, and friendship made it possible for me to complete this degree.

ACKNOWLEDGMENTS

I would first like to thank God, through whom all things are made possible, for blessing me with such a rich life and the ability to complete this task.

I would like to recognize and extend appreciation to the following members of my graduate committee for their support and mentorship: Dr. Tom Cothren, committee chair; Dr. Tom Isakeit, member; Dr. Jim Starr, member. Their assistance, encouragement, and support are greatly appreciated.

Recognition is given to my beautiful wife Robin and loving parents, Charles and Judy Rocconi, for their unconditional and continuous support, encouragement, and love.

Special appreciation is given to my committee chair, advisor, and mentor, Dr. Tom Cothren, for his advice, moral example, support, and generosity.

Recognition is also extended to my co-workers and peers. I would also like to thank all of the student workers of the Crop Physiology and Production Team for the countless hours spent providing aid with this project.

Finally I would like to extend gratitude to Dr. Joshua Bynum, Dr. Robert Lemon, Dr. Scott Senseman, Dr. Randy Boman, Dr. Byron Burson, and Dr. Brad Minton for their advice and friendship through this endeavor.

Difficult tasks in life can be made much easier by the people around you who offer their friendship, love, support, advice, and encouragement. To those mentioned on this page, “thanks”, and I am forever grateful.

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

Page

1. INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is a cash crop for farmers in the Southern United States. Cotton is a perennial, sub-tropical, and indeterminate maturing plant. Cotton is primarily the world's major fiber used in almost half of all textiles, apart from the seed also being used as a source of food (Sharma and Bambawale, 2008). Through breeding and selection cotton has been developed into cultivars that are managed for their yield potential within a single growing season. After harvest of seed cotton has been completed, the plants are destroyed through mowing, tillage, or chemical destruction.

Cotton production acreage has been reduced significantly throughout the United States over the last four years, except in Texas (D. Albers, personal communication, April 1, 2008). Subsequently the need to produce large amounts of fiber for export throughout the world must now be met on an all-time historically low amount of acreage (Boman, 2010).

The remaining acres of cotton production throughout the south and in Texas have been primarily occupied by one cultivar, Delta and Pine Land 555 BGRR (DPL 555). DPL 555 is the staple among growers in regions that have the potential to grow a full-season variety which can maximize lint yield potentials by reducing stress that is induced at varying periods (D. Albers, personal communication, April 1, 2008).

DPL *555* is the historical leader for production acres planted to cotton and is considered the marker, within the maturity scale, of true full-season varieties. This variety was among the first cultivars released with Bollgard I Roundup Ready® technology genetics. In the fourth quarter of 2007, Monsanto Company, the proprietary owner of this variety and genetic modification, was notified by the Environmental Protection Agency (EPA) that the Bollgard I gene would not have its label renewed as of September 2009 (Golden, 2009).

Ongoing breeding programs of the major companies, who release germplasm for commercial availability have failed thus far to produce a replacement for this variety. The loss of this cultivar has spurred the investigation and research for a replacement to fill, in maturity and yield potential, the void created in the market. Through their entire life cotton plants are subjected to a variety of stresses (Cothren, 1999). Plants have the ability to adapt to stress in various ways, such as reorienting leaves in response to high light intensity, osmotic adjustment and changes in the metabolic processes (Cothren, 1999). DPL *555* contained the growth potential to endure fruit loss from drought and insect damage and still maintain high yields.

1.1 Literature Review

1.1.1 NAWF and Maturity

Cotton plants progress towards maturity based on environmental conditions to which they are exposed, and not necessarily to the number of calendar days (Silvertooth, 1995). Cotton growth proceeds from vegetative to reproductive stages, with a linear increase in heat unit accumulation (Fry, 1983). Nodes above white flower (NAWF) is used as a monitoring system for the growth of a cotton plant. A NAWF value gives an insightful measurement of the growth status of the crop from mid- to late- season (Oosterhuis, 1991). NAWF and heat units are highly correlated in linear fashion to the relative maturity of a cotton plant (Bourland *et al*., 2001). The NAWF value is related to variation in canopy photosynthesis, which implies that growth activity of the crop can be assessed by monitoring nodes above white flower (Bourland *et al*., 1992). The uppermost first position white flower is often used to describe the balance between fruit set and rate of terminal growth (Bourland *et al*., 2001). White flowers located in the first position on sympodia, grow progressively closer to the apex as the plant nears maturity (Oosterhuis, 1991).

Nodes above white flower can be used to calculate the maturity and length of time until harvest of cotton crops (Bourland *et al*., 1992). The appearance of white flowers in the apex is indicative of flower cessation and is precluded by termination of nodal extension; this event is known as cutout (Guinn, 1979). The point at which this occurs is set at NAWF=5 and is therefore noted as the last effective flower population (Bourland *et al*., 1992), as well as being an indication that the crop is mature at this point. Several factors affect the growth, maturity, and yield of commercially available cotton varieties: extreme temperatures (Reddy *et al*., 1999; Zhao *et al*., 2005); moisture deficits (Pettigrew, 2004); poor fertility (Hake *et al*., 1989b); drought stress (Guinn, 1982; Hake *et al*., 1992; McMichael, 1979a; McMichael and Jordan, 1973); and pathogenic pressure during key growth stages (Stewart *et al*., 2001). In order to achieve full maturity and maximize yield potential, abiotic and biotic stress found in production field environments must be monitored and managed throughout the growing season.

1.1.2 Strobilurin Fungicides

Plant diseases are of significant concern in crop production due to the intimate relationship between plant health and the welfare of people, animals, and the environment (Brimner and Boland, 2003). Sales of the strobilurin and related fungicides totaled approximately $620 million in 1999, which represented over 10% of the global fungicide market (Bartlett *et al.*, 2002).

Cotton is affected by a number of foliar diseases viz., *Alternaria macrospora* (leaf spot), *Myrothecium roridum* (leaf spot), *Cercospora gossypina* (leaf spot) and *Colletotrichum gossypii* (Anthracnose: pink boll rot or seedling disease) (Sharma and Bambawale, 2008). The strobilurins are an important class of agricultural fungicides, the discovery of which was inspired by a group of natural fungicidal derivatives of *β*-methoxy-acrylic acid (Bartlett *et al.*, 2002). Strobilurins are natural substances isolated mainly from mushrooms (basidiomycetes) (Balba, 2007). This class of fungicide inhibits the respiration of fungal mycoflora found in many environments (Gullino *et al.*, 2000).

The breakdown of organic molecules (i.e. sugars, fats, proteins) provides energy for the survival of living systems (Leroux, 1996). Through the destruction of sugars, fats, and proteins, energy is regenerated and captured through the phosphorylation of inorganic substances in order to store energy in the form of chemical bonds. The pathway for capture of this stored energy is through respiration (Waard *et al.*, 1993). The strobilurins bind to one specific site in the mitochondria, the quinol oxidation (Q_o)

site (or ubiquinol site) of cytochrome b and thereby stops electron transfer between cytochrome b and cytochrome c. This disruption of electron transfer halts reduced nicotinamide adenine dinucleotide (NADH) oxidation and adenosine triphosphate (ATP) synthesis (Balba, 2007) . The presence of the electron transport chain and the need for respiration under high heat conditions in cotton fields has led to the investigation of strobilurin fungicide's potential action on plant physiology and its impact in production settings.

1.1.3 Strobilurin and Plant Physiological Interaction

After the launching of strobilurins, and with the evolution of this group of chemical products, the concept of disease control gained new perspectives, especially when considering the advantages obtained by the action of positive physiological effects on plants (Venancio *et al*., 2003). Ammerman *et al.*, (2000) stated that the most important contribution provided by the pyraclostrobin molecule to agriculture is derived from its wide range of fungicidal activity. During the last decade of intense research on the fungicidal properties of strobilurins, the evidence for their direct influence in physiological processes of plants that were not infected or threatened by pathogens was strengthened (Venancio *et al*., 2003). Apart from its fungicidal effect, the strobilurin BAS 490F was found to induce physiological and developmental alterations in wheat (*Triticum aestivum*) (Grossmann and Retzlaff, 1997).

As noted previously, the strobin fungicides directly inhibit respiration by acting in the mitochondria on the quinol oxidation (Q_o) site (or ubiquinol site) of cytochrome b (Balba, 2007; Bartlett *et al*., 2002; Gullino *et al*., 2000). Pyraclostrobin, a fungicide of the strobilurins group acts by inhibiting mitochondrial respiration by blocking the transfer of electrons in the III complex (bc1) of electron flow for mitochondria (Ammerman *et al.*, 2000). Since the bc1 complex persists in all eucaryotae, at least one partial inhibition in the transportation of electrons would also be expected in plant cells after absorbing the fungicide (Venancio *et al.*, 2003). Although the strobilurins' effects in plants have been studied for more than seven years, there is no evidence of any direct interaction of pyraclostrobin with enzymes of receptor systems other than mitochondrial respiration (Koehle *et al.*, 2003)

Retardation of senescence by strobin fungicides in plant tissue has been shown in previous research (Koehle *et al.*, 2003). The rate reduction in desiccation and maturity of a plant species has received attention in recent years. After exposing wheat leaf discs to pyraclostrobin for 48 hours, the loss of chlorophyll, measured as a parameter of the progression of senescence, was inhibited by an increasing concentration of pyraclostrobin (Grossmann and Retzlaff, 1997).

Unfavorable environmental stress stimulates the formation of radicals, especially of reactive oxygen and increases the oxidative potential in plant tissues (Bartosz, 1997). Active oxygen species (AOS) have been proposed as a central component of plant adaptation to both biotic and abiotic stresses (Dat *et al.*, 2000). Resistant plants respond to oxidative stress with an increase in the activity of antioxidative enzymes, such as superoxide dismutase, catalases, and peroxidases (Larson, 1997). Zhang *et al.* (2010) stated that azoxystrobin does not affect the chlorophyll content in winter wheat, however it application delayed the increase of AOS, the delaying the senescence of wheat and prolonging the duration of flag leaf photosynthesis.

Harsh environments that are encountered during plant growth may be deterred by the use of a strobin fungicide. Koehle *et al.* (2003) stated that winter barley (*Hordeum vulgare*) treated with pyraclostrobin showed less visual symptoms than the untreated control. When the activity of peroxidases in the flag leaf was evaluated, the plants treated with pyraclostrobin showed almost double enzymatic activity, which can contribute to stress tolerance (Koehle *et al*., 2003). The most remarkable change was the inhibition of ethylene biosynthesis by the reduction of the activity of ACC synthase (Koehle *et al*., 2003). Together with the increase in endogenous auxin, this change in hormonal balance would explain the retarded senescence of leaves and enhancement in the tolerance to stress (Koehle *et al*., 2003). Also pyraclostrobin stimulated the levels of ABA, and the authors believe that this might favor tolerance to cold and adaptation to conditions of water shortage (Venancio *et al*., 2003). The proper timing, in crucial stress periods within a crop's life, is key for the benefits of this compounds activity to deter stress (Waard *et al*., 1993). However, the toxicity and the pollution generated by fungicides cannot be neglected. The toxic effect of a given pesticide on seeds depends on its distribution, persistence, metabolism, its active form, and its concentration (Petit *et al*., 2012).

1.1.4 Timing of Fungicide Application

Cotton is most susceptible to stress during periods of fruiting and high water needs (McMichael and Jordan, 1973). A cotton crop is most sensitive to deficit replacement of water when this stress is imposed during the flowering period (Cetin and

Bilgel, 2002). Evapotranspiration, water loss through the plant and from the soil, for cotton in a production field is approximately 0.25 inches of water a day during the first two weeks of the blooming period (Iersel and Oosterhuis, 1995). As water availability in the soil profile decreases, stress increases in a linear relationship within the plant (McMichael *et al.*, 1973). Loss of larger fruiting structures proves to be more detrimental to a plant's ability to compensate for the reproductive loss due to either water stress or insect pressure (Stewart *et al.*, 2001).

Although the flowering period has been firmly established as the greatest time of moisture need within a cotton growing season, many times the pathogenic pressure in this time window is overlooked. Seed formation, and thus lint yield potential, is most vulnerable during the bloom stage (Osekre *et al.*, 2009). Fusarium hardlock of cotton, associated with *Fusarium verticilliodes*, is the failure of the fiber to fluff as the boll opens at maturity (Osekre *et al.*, 2009). Some insect species have been associated with hardlock; notable among these are thrips (*Franklinella bispinosa* and *Franklinella occidentalis*) and stink bugs (*Nezara viridula*) (Osekre *et al.*, 2009). Thrips are hypothesized to increase hardlock by carrying *Fusarium* to the flowers or creating entrance wounds in the course of feeding; and these wounds can then serve as points for *Fusarium* to infect. Stink bugs can also contribute to hardlock by direct feeding on developing seed, often transmitting microorganisms in the process (Bell, 1999). Species in the family Pentatomidae are some of the most important crop pests, and they also are important transmitters of many different pathogens in the crop production world. Economic losses are difficult to calculate due to the minimum amount of information known on the exact volume of pathogen inoculums being carried by these species (Butt and Brownbridge, 1997). Knowledge of potential stressing agents within the growing season is crucial for optimal placement of a stress alleviating compound. Paul *et al.* (2011) found in their investigation, that one cannot recommend fungicides when foliar disease is low. At least part of the reason that calendar-based fungicide application is not profitable is apparently the very low yield response in disease-free environments (≈0.13 Mg ha^{-1}) (Weisz *et al.*, 2010).

1.2 Objectives

The primary objective of these studies was to determine the potential for foliar application of strobilurin containing fungicides to delay maturity of upland cotton varieties and whether this translates to a potential for improving lint yield. The practice of mixing commercially compatible compounds has been widely adopted by cotton farmers to reduce production costs associated from several applications made to a production field. Mixing of the strobilurin compounds with commonly applied products over these timings was included solely for the purpose of confirming or negating any potential impacts on an actively growing cotton crop.

These studies will help determine the benefit, if observed, as well as the appropriate timing of strobilurin containing fungicides on cotton in south central Texas, in order to optimize lint yield and fiber quality. Results from this study should aid in broadening the understanding of the use of these compounds and their effects on cotton production.

2. MATERIALS AND METHODS

A two-year study was conducted in 2008 and 2009 to determine the benefits and appropriate timing of strobilurin compounds in south central Texas. In both years, field plots were located at the Texas A&M AgriLife Research Farm in Burleson County, Texas. Field plots were located in the Brazos River Bottom on a Weswood silt loam (fine-silty, mixed, superactive, thermic, Udifluventic Halpustepts), having a pH of 8.2.

Plots were plowed and received deep tillage before being bedded on 1.11-m centers. Fertilization consisted of 135 kg ha^{-1} of urea ammonium nitrate (UAN) applied in furrow. In both years, cv. Stoneville 4554 B2RF (STV 4554 B2RF) was seeded at 128,440 plants ha^{-1}, using a John Deere 1700 MaxEmerge Plus vacuum planter. In 2008 and 2009 plots were planted on April 9 and April 11, respectively. Plots were four 1.11-m rows that were 10.66 m in length. Low pressure furrow irrigation was applied as needed at approximately 7.5 cm of water, with each irrigation. The crop was managed by recommendations made for local production to prevent disease, control insects, and manage weed populations. The only physiologically needed mepiquat chloride application was applied following extension recommendations shortly after the pinhead square growth stage of development in both years. It was applied uniformly across the two study areas, in year one and two.

In both years, plots were arranged as a randomized complete block design with four replications. There were ten total treatments applied to the STV 4554 B2RF variety. STV 4554 B2RF was planted through the entire field, while the ten treatments were replicated and kept separate by fungicidal compound in order to reduce contamination. Study 1 contained all compounds and combinations being compared and incorporated with the pyraclostrobin compound (Headline®). Study 2 contained the same compounds and combinations of Study 1, while using the azoxystrobin containing fungicide (Quadris®). All treatment applications were made as a foliar spray with 93.7 L ha^{1} of water using a compressed air small plot sprayer equipped with Tee Jet® (Spraying Systems Inc.) XR 8002 VS flat fan nozzles at 51-cm spacing. The respective treatments are listed in Table 1 for Study 1, while the treatments for Study 2 are listed in Table 2. The compounds used in this study were commercially available and labeled fungicides applied at recommended rates.

Of the four rows, plant growth data was only obtained from row one or four, and rows two and three were machine-harvested using a John Deere 9910 high drum, two-row spindle picker, to determine lint yield. Weather data was obtained from a nearby USDA weather station.

Prior to harvest aid application, ten plants per plot were removed and plant mapped to determine final height, total number of nodes, and final NAWF, if present. Height measurements were taken from the cotyledonary node to the terminal of the plant. Total and first fruiting nodes were determined from the cotyledonary node to the terminal of the plant, with the cotyledonary node considered as node zero.

A tank-mix of thidiazuron (Dropp SC®) (0.15 kg ha^{-1}), thidiazuron/ diuron (Ginstar EC®) (0.07 L ha^{-1}), and ethephon/ cyclanilide (Finish Pro 6®) (1.75 L ha^{-1}) was applied to the plot area when the cotton plots reached 60% open boll load. Harvest aid

Table 1. Treatment identification for pyraclostrobin comparisons (Study 1), 2008-2009.

	Application Specifications†		
Treatment	**-Active Ingredient[£]-**	**-Applied Rate[µ]-**	**-Timing of Application§-**
1. Untreated Control (UTC)	N/A	N/A	N/A
2. Pyraclostrobin (Headline®)	252.8	290.2	EB
3. Mepiquat Chloride (Compact®)	4.194	117.4	EB
4. Glyphosate (Roundup WM®)	660	1608	EB
5. Pyraclostrobin	252.8	290.2	EB
Mepiquat Chloride	4.194	117.4	
6. Pyraclostrobin	252.8	290.2	EB
Glyphosate	660	1608	
7. Pyraclostrobin	252.8	290.2	EB+14
8. Pyraclostrobin	252.8	290.2	EB+14
Mepiquat Chloride	4.194	117.4	
9. Pyraclostrobin	252.8	290.2	EB+14
Glyphosate	660	1608	
10. Pyraclostrobin	252.8	290.2	EB, EB+14

† All compounds were delivered in a water/solution volume of 93.55 L ha^{-1}

§ EB= Early bloom treatment, defined as appearance of first flower in plant canopy
EB+14= Early bloom +14 days after Early Bloom (EB) treatment

[£] Active Ingredient (A.I.) given in gram liter^{-1}

[µ] Applied Rate given in mL ha^{-1}

Table 2. Treatment identification for azoxystrobin comparisons (Study 2), 2008-2009.

	Application Specifications†		
Treatment	**-Active Ingredient[£]-**	**-Applied Rate[µ]-**	**-Timing of Application§-**
1. Untreated Control (UTC)	N/A	N/A	N/A
2. Azoxystrobin (Quadris®)	252.8	290.2	EB
3. Mepiquat Chloride (Compact®)	4.194	117.4	EB
4. Glyphosate (Roundup WM®)	660	1608	EB
5. Azoxystrobin	252.8	290.2	EB
Mepiquat Chloride	4.194	117.4	
6. Azoxystrobin/Glyphosate	252.8	290.2	EB
Glyphosate	660	1608	
7. Azoxystrobin	252.8	290.2	EB+14
8. Azoxystrobin/Mepiquat Chloride	252.8	290.2	EB+14
Mepiquat Chloride	4.194	117.4	
9. Azoxystrobin	252.8	290.2	EB+14
Glyphosate	660	1608	
10. Azoxystrobin	252.8	290.2	EB, EB+14

† All compounds were delivered in a water/solution volume of 93.55 L ha^{-1}

§ EB= Early bloom treatment, defined as appearance of first flower in plant canopy
EB+14= Early bloom +14 days after Early Bloom (EB) treatment

[£] Active Ingredient (A.I.) given in gram $liter^{-1}$

[µ] Applied Rate given in mL ha^{-1}

chemicals were applied with 93.5 L ha^{-1} of water using a compressed air small plot sprayer with Tee Jet® (Spraying Systems Inc.) XR 8002 VS flat fan nozzles at 51-cm nozzle spacings.

In both years, the two middle rows were machine picked 14 DAT with defoliant compounds. Seed cotton yields were determined, and 150-g sub-samples were collected from each plot for ginning to determine percent turnout and lint yield. Each sample was ginned using a ten-saw hand-fed, portable gin. After ginning, 50-g fiber samples from each plot were subjected to High Volume Instrument (HVI) classing at the International Textile Center in Lubbock, Texas. Classification was based on physical attributes: micronaire, length, strength, uniformity. Micronaire is a measure of fiber fineness and is influenced by moisture, temperature, plant nutrients, sunlight, nutrition, and extremes in plant or boll population. Fiber length is determined by the length of the longest one half of the fibers in the sample. Length is based on the variety of cotton and is influenced by the plant's exposure to extreme temperatures, water stress, and nutrient deficiencies. The uniformity of length is also measured in a sample by a ratio of mean length and the upper half mean length of the fiber. Fiber strength is measured as the force required to break a bundle of fibers one tex (weight in grams of 1,000 m of fiber) in size.

Results from HVI classing were utilized to calculate the Commodity Credit Corporation (CCC) loan value for each treatment. These monetary values were retained in standard units.

Statistical analysis was conducted on all appropriate data presented in this document. The data sets were analyzed using SAS® 9.2 statistical software (SAS, 2007-

2008). Data was subjected to the General Linear Model Procedure with degrees of freedom estimated using the Satterthwaite approximation (Satterthwaite, 1946). Means were separated using the Tukey-Kramer procedure to determine statistical differences at the 5% significance level. Linear regression analysis was conducted using the Regression Procedure at the 0.1 level (*Pr>f*). Data for 2008 and 2009 were combined over years in the absence of year x treatment interaction.

3. RESULTS AND DISCUSSION

3.1 Timing of Fungicide and Tank Mix Applications

Cotton, a native of tropical regions, requires warm days and relatively warm nights for optimum growth and development (Gibson and Joham, 1968). In both 2008 and 2009, temperatures during the early portion of the growing season were cooler than the seven-year average. After the pinhead square growth stage, in 2008, temperature and heat units began to reach levels greater than the seven-year average (Figure 1). Daily HU accumulation in 2008 started slower compared to the seven-year average, but began to plateau approximately 50 DAP, and remained fairly constant and at a higher level for the remainder of the growing season (Figure 1). Daily HU accumulation in 2009 (Figure 2) did not begin to plateau until 70 days after planting, while the value of heat units maintained a larger scale of accrual . Calendar dates, number of days following planting, and HU accumulations corresponding to the two designated nodal stages and the initiated treatments are found in Table 3. Prior to the first bloom growth stage, the plot area received uniform cultural treatments that were consistent with local recommendations. With the exception of growth regulators and insecticides, which must be applied above the plant, all compounds were delivered underneath the crop with the use of a Redball^{TM} 420 Lay-By Hooded Sprayer. At first bloom, application of fungicide and compatible compound treatments were initiated. Under optimal conditions, cotton plants should possess a minimum of eight sympodia at first bloom (Bourland *et al*., 1992). In both years of the study, the average NAWF value at early bloom (EB) was

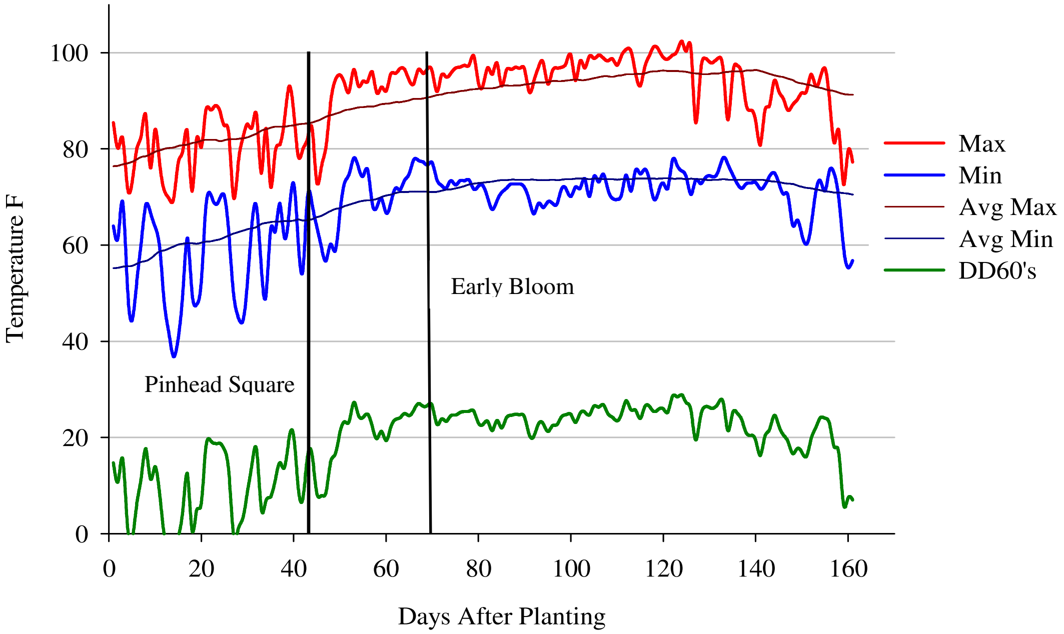

Figure 1. Historical weather averaged over seven years, maximum and minimum temperatures throughout the growing season and the corresponding accumulated heat units, 2008

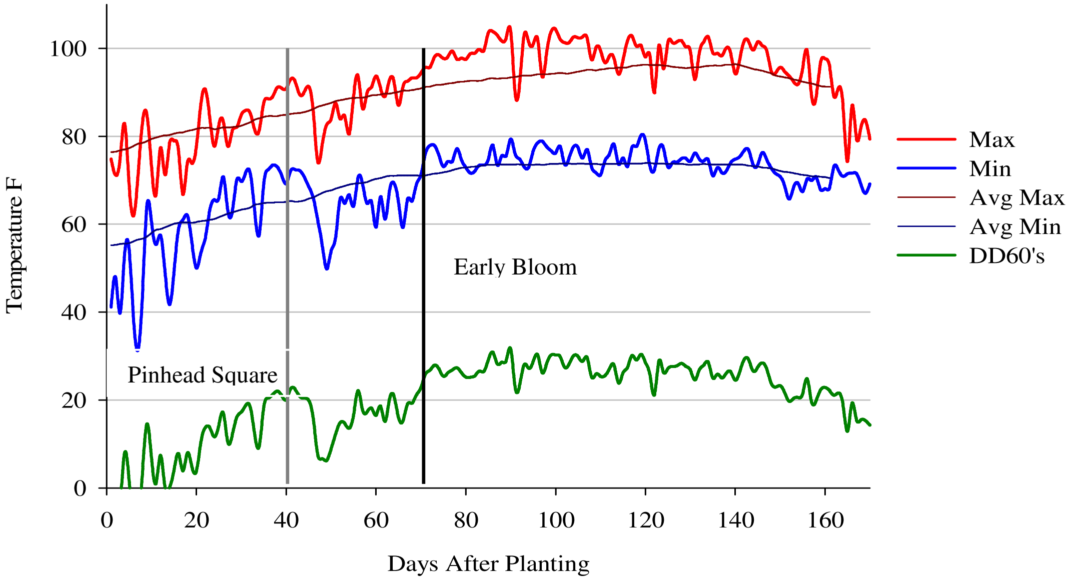

Figure 2. Historical weather averaged over seven years, maximum and minimum temperatures throughout the growing season and the corresponding accumulated heat units, 2009.

Table 3. Date of fungicide application and accumulated heat units at each corresponding application, 2008-2009.

Study 1 and 2 Treatments	Growth Parameters											
	—EB 2008—			—EB+14 2008—			—EB 2009—			—EB+14 2009—		
	Date	DAP‡	HU§	Date	DAP‡	HU§	Date	DAP‡	HU§	Date	DAP‡	HU§
1	17-Jun	70	1103	1-Jul	84	1428	20-Jun	71	1154	4-Jul	85	1540
2	17-Jun	70	1103	1-Jul	84	1428	20-Jun	71	1154	4-Jul	85	1540
3	17-Jun	70	1103	1-Jul	84	1428	20-Jun	71	1154	4-Jul	85	1540
4	17-Jun	70	1103	1-Jul	84	1428	20-Jun	71	1154	4-Jul	85	1540
5	17-Jun	70	1103	1-Jul	84	1428	20-Jun	71	1154	4-Jul	85	1540
6	17-Jun	70	1103	1-Jul	84	1428	20-Jun	71	1154	4-Jul	85	1540
7	17-Jun	70	1103	1-Jul	84	1428	20-Jun	71	1154	4-Jul	85	1540
8	17-Jun	70	1103	1-Jul	84	1428	20-Jun	71	1154	4-Jul	85	1540
9	17-Jun	70	1103	1-Jul	84	1428	20-Jun	71	1154	4-Jul	85	1540
10	17-Jun	70	1103	1-Jul	84	1428	20-Jun	71	1154	4-Jul	85	1540

‡ DAP corresponds to days after planting.

§ HU refers to accumulated heat units from planting when growth parameter was reached to initiate treatment.
1103 vs 1154 for EB in 2008 and 2009, respectively.
1154 vs 1540 for EB+14 in 2008 and 2009 respectively.

approximately ten. Fourteen days after the initial application of treatments, the second application of compounds were imposed on the plot area. HU accumulation from planting to the first flower growth stage was slightly dissimilar between years, thus resulting in a difference between initiations of treatment applications (Table 3). Once the applications were initiated, EB+14 parameters were rigorously followed for final application of treatments in both studies. Once 60% of the open boll maturity was reached in the untreated plot, harvest aid compounds were applied and harvest was initiated 14DAT with defoliants.

3.2 Study 1 Plant Height at Harvest

Final plant heights were determined by the end-of-season plant mapping of Study 1 (Table 4). Plant heights, for the treatment set of pyraclostrobin compounds, yielded a mean of 66.44 cm with a coefficient of variance equivalent to 7.89. Though statistically significant in analysis, this range of 7.67 cm is considered of non-importance over production scale agronomics.

Within Study 1, the untreated control was not statistically different in height from the pyraclostrobin applications made at the early bloom or early bloom +14 treatments. The tandem application of pyraclostrobin at EB and EB+14 was numerically taller than the untreated control over the study and was taller than treatment with pyraclostrobin at EB+14.

Table 4. Final plant heights at harvest (Study 1), 2008-2009.

		Plant Height†
		2 Year
Treatment	Timing of Application	height (cm) $plant^{-1}$
1. Untreated Control (UTC)	N/A	70.3 ab§
2. Pyraclostrobin (Headline®)	EB	68.6 b
3. Mepiquat Chloride (Compact®)	EB	71.6 ab
4. Glyphosate (Roundup WM®)	EB	68.2 b
5. Pyraclostrobin/Mepiquat Chloride	EB	68.7 b
6. Pyraclostrobin/Glyphosate	EB	66.9 b
7. Pyraclostrobin	EB+14	66.6 b
8. Pyraclostrobin/Mepiquat Chloride	EB+14	70.7 ab
9. Pyraclostrobin/Glyphosate	EB+14	68.4 b
10. Pyraclostrobin	EB, EB+14	74.2 a
Pr > f ‡		*0.0001*

† Final plant heights were taken from ten consecutive plants in one of the outer two rows of the four row plot, which were unharvested.

§ Plant height values within a single column followed by the same letter are not different at a 0.1 probability level.

‡ Probability of the ANOVA.

The comparisons of mepiquat chloride containing applications yielded nonsignificant results. Treatment three, with mepiquat chloride at EB, was numerically taller than the applications of mepiquat chloride at EB plus pyraclostrobin or EB+14 DAT in combination with pyraclostrobin, but was not found statistically different.

Glyphosate treatment comparisons for height yielded no separation in the final analysis. The numerical range was 1.46 cm over the course of the study. The glyphosate control application, applied at EB, was found to be in the middle of the observed range for treatments containing glyphosate.

3.3 Plant Nodes at Harvest

Final total plant nodes were determined by end-of-season plant mapping (Table 5). Total plant nodes for Study 1, in 2008, averaged 20.19 nodes plant^{-1} across treatments with a coefficient of variance equivalent to 9.12. In 2009, the mean total node value was 18.67 with a variance of 5.59. With the 2009 year, higher heat experienced by the plot area, coupled with longer periods without measurable rainfall, imposed a different growing environment than for 2008. These measurements were analyzed independently due to high levels of interaction between year and treatment (Table 5).

The first year of Study 1 showed statistical difference when comparing the UTC to the corresponding pyraclostrobin compound treatments. The application of pyraclostrobin at EB+14 had a statistically higher value compared to pyraclostrobin at EB and treatment ten, of two applications of the fungicide. No significant difference

Table 5. Final total nodes and NAWF pre-harvest measurement (Study 1), 2008–2009.

		End of Season Plant Measurement†			
		2008	2009	2008	2009
		Nodes		NAWF	
Treatment	Timing of Application	——— plant^{-1}———		——— plant^{-1}———	
1. Untreated Control (UTC)	N/A	22.50 a	18.30 ab	1.07 ab	1.07 ab
2. Pyraclostrobin	EB	19.45 cde	18.85 ab	1.25 a	1.00 ab
3. Mepiquat Chloride	EB	19.80 bcd	18.75 ab	0.82 abc	0.30 c
4. Glyphosate	EB	16.82 e	19.00 ab	0.30 d	1.32 a
5. Pyraclostrobin Mepiquat Chloride	EB	17.55 de	18.15 ab	0.82 abc	0.72 abc
6. Pyraclostrobin Glyphosate	EB	20.60 abc	19.50 a	1.00 ab	0.82 abc
7. Pyraclostrobin	EB+14	21.2 abc	17.55 b	0.47 cd	1.00 ab
8. Pyraclostrobin Mepiquat Chloride	EB+14	22.20 ab	19.00 ab	0.65 bcd	0.82 abc
9. Pyraclostrobin Glyphosate	EB+14	22.15 ab	19.47 a	0.47 dc	0.82 abc
10. Pyraclostrobin	EB, EB+14	19.65 bcd	18.12 ab	1.00 ab	0.30 c
Pr > f ‡		*.0041*	*.0907*	*.0088*	*.0635*

†Nodes and NAWF values within a single column followed by the same letter are not different at a 0.1 probability level.

‡ Probability of the ANOVA

was shown between the UTC and the strobin compound, treatment seven. In 2009, the UTC was not significantly adjusted from application of pyraclostrobin at EB, EB+14, or the sequential application at EB and EB+14. The growing conditions of year two produced shorter plants, on average, within Study 1.

The mepiquat chloride comparisons in 2008, between the application of mepiquat chloride at EB and the early bloom applications in combination with pyraclostrobin at EB or EB+14 showed no difference for total plant nodes. Mepiquat chloride applied at EB did separate with a lower numerical value for total plant nodes than pyraclostrobin with mepiquat chloride at EB+14. Year two of the study showed no statistical differences between the mepiquat chloride treatments for total plant nodes.

Glyphosate applications in combination with pyraclostrobin at EB and also at EB+14 DAT led to more nodes, statistically, than their comparison treatment of glyphosate alone at EB in 2008. The early bloom application, in the first year of study one, had the lowest value and statistical classification among this study's treatments. These treatments containing the glyphosate compound, in 2009, showed no statistical separation in total final node counts prior to harvest (Table 5).

3.4 Study 1 Final NAWF

The node above white flower (NAWF) measurement was included for verification of potential effects on maturity (Table 5). A NAWF value gives an insightful measurement of the growth status of the crop from mid- to late- season (Oosterhuis, 1991). The fewer the nodes above the upper most first position white flower, the more mature a crop is observed to be. Oosterhuis found that the expected flowering interval between a reproductive structure on a node and another reproductive structure at the same position, but one branch higher, would be three days. The NAWF measurement for Study 1 was analyzed by year due to the interaction of treatment x year. The mean of NAWF for all treatments in 2008 was 0.78 white flowers per plant at prior to defoliation application. The variance for this year was 43.98. In the second year of Study 1, the mean NAWF value was 0.80. The variance was 57.14. The low mean values of these two years, in Study 1, show a small difference in total white flowers present prior to harvest.

In 2008 for final NAWF, the untreated control and pyraclostrobin applied at either EB or at both EB followed by a second application at EB+ 14 were not significantly separated. The application of pyraclostrobin at EB yielded the highest numerical value for NAWF. The application of pyraclostrobin alone, at the early bloom growth stage, yielded lower numerical values as compared to the untreated control. In year two of Study 1, pyraclostrobin containing treatments applied at EB or EB+14 were not statistically different from the UTC for final NAWF. The double application of the pyraclostrobin treatment was statistically lower for final NAWF than the untreated control, showing a value of 0.30 NAWF versus 1.32 NAWF for the untreated control.

The 2008 and 2009 comparison of mepiquat chloride, applied as a single compound, versus in combination with pyraclostrobin did not separate statistically. The potentially detrimental effects of tank mixing these compounds proved to be of no consequence on the NAWF measurement.

In the first year of Study 1, glyphosate applied at EB yielded the lowest numerical value for the node above white flower parameter. Glyphosate and pyraclostrobin applied in combination at early bloom yielded a higher NAWF value than the glyphosate applied alone at EB. This value did not differ from the later application at the fourteen days after early bloom application of pyraclostrobin with glyphosate.

Treatment results for NAWF did not align across years. Factors contributing to these confounding results are attributed to higher temperature in 2009 and the reduction of in-season rainfall. The variance in abiotic stress, between the growing seasons, had a larger effect on the results of this particular measurement. The NAWF assessment is an indicator of season long duration of stress and growing conditions.

3.5 Study 1 Yield Parameters

The analysis of yield parameters; seed cotton ha^{-1}, lint turnout percentage, and lint yield ha^{-1}, resulted in insignificant treatment x year interaction. Thus data was combined over the years that Study 1 was conducted (Table 6). The mean values for the data points of seed cotton ha^{-1}, lint turnout percentage, and lint yield ha^{-1} for the two years of Study 1 were 2337.2, 41.65, and 975 respectively. The seed cotton results maintained a coefficient of variance showed a value of 12.97. Lint turnout percentage had a *c.v.* 2.93 over the two years of Study 1. The range for lint turnout percentage, 1.7% difference, was extremely narrow, and was typified by numerically higher values than the values for this trait found in commercial ginning. Lint yield ha^{-1} preserved a variance of 14.16 over both years.

Table 6. Lint yield as affected by pyraclostrobin treatments (Study 1), 2008-2009.

		Yield Parameters		
Treatment	**Timing of Application**	**—seed cotton yield kg ha^{-1}—**	**—lint turnout percentage—**	**—lint yield kg ha^{-1}—**
1. Untreated Control	N/A	2019 b†	41.1 d	831 b
2. Pyraclostrobin	EB	2239 ab	41.1 d	919 ab
3. Mepiquat Chloride	EB	2388 a	41.2 cd	987 a
4. Glyphosate	EB	2370 a	41.5 bcd	984 a
5. Pyraclostrobin Mepiquat Chloride	EB	2311 ab	42.7 a	988 a
6. Pyraclostrobin Glyphosate	EB	2401 a	41.3 cd	994 a
7. Pyraclostrobin	EB+14	2457 a	42.6 ab	1044 a
8. Pyraclostrobin Mepiquat Chloride	EB+14	2316 ab	41.0 d	954 ab
9. Pyraclostrobin Glyphosate	EB+14	2481 a	42.3 abc	1053 a
10. Pyraclostrobin	EB, EB+14	2390 a	41.7 bcd	996 a
Mean		*2337.2*	*41.7*	*975*
Pr > f ‡		*.0157*	*.0597*	*.0261*
c.v.		*12.97*	*2.93*	*14.16*

† Yield parameter values within a single column followed by the same letter are not different at a 0.1 probability level.
‡ Probability of the ANOVA.

In comparing seed cotton ha^{-}1, the treatments containing pyraclostrobin showed significantly higher yield values for the treatments applied during the later growth stage, EB+14, than the untreated control with the exception of the pyraclostrobin and mepiquat chloride combination at EB. Pyraclostrobin at EB did not separate significantly from the UTC, although it was numerically higher. Lint turnout percentage for the UTC was numerically and statistically alike with the early bloom application of pyraclostrobin and the sequential application of pyraclostrobin at EB followed by an additional treatment at EB+14. Pyraclostrobin applied at EB+14 was statistically higher compared to the untreated control in turnout percentage. Lint yield ha^{-1}, however, the untreated control one was not pointedly different from the early bloom application of pyraclostrobin at EB. Treatments with pyraclostrobin at EB+14 and pyraclostrobin at EB followed by an additional application at EB+14 were found to be statistically greater than the untreated control.

Treatments containing mepiquat chloride showed no statistical differences in comparison to the untreated control, relative to seed cotton returns. The mepiquat chloride treatment alone was numerically higher than the applications containing the pyraclostrobin mixture with the growth regulator, mepiquat chloride. Turnout percentage showed statistical differences between treatments, although the actual values ranged from 41.1% to 42.7%. This small difference in range showed that the turnout percentage for the UTC was separated from the values returned for the pyraclostrobin and mepiquat chloride applied at EB, with the combination treatment having a higher value. Separation was not apparent between the later growth stage application with pyraclostrobin at EB+14, the UTC. The mepiquat chloride application at EB, pyraclostrobin and mepiquat chloride applied at EB, and pyraclostrobin with mepiquat chloride applied at EB+14 did not statistically separate for the measurement of final lint yield.

Glyphosate comparisons applied through differing timings yielded the highest level of recorded seed cotton yields within the two years of the study. The evaluation of glyphosate applied at EB, was not statistically altered from the application of this compound in conjunction with pyraclostrobin of Study 1. Values for the glyphosate treatments did not disperse in the measurement of lint turn out and final lint yield.

3.6 Study 1 Major Fiber Properties

Significant year x treatment interaction was not observed for micronaire values, fiber length, fiber strength, and fiber uniformity (Table 7). High Volume Instrument (HVI) classing, at the International Textile Center in Lubbock, Texas was performed on the lint 150 gram samples from Study 1 in both years of the testing. The fiber measurements analyzed for Study 1 showed statistical significance, except for the micronaire values, but failed to show statistical separation where numerical significance was noted.

Strength, measured in g tex^{-1}, also showed statistical significance in analysis. Statistical separation was not apparent between the untreated control and pyraclostrobin applied at EB, EB+14 or the application in tandem at EB followed by EB+14 DAT within Study 1. Within the mepiquat chloride comparisons for strength, again no separation was noted between the mepiquat chloride applied alone at EB, pyraclostrobin

Table 7. Major fiber properties from pyraclostrobin treatments (Study 1), 2008-2009.

		High Volume Instrument Testing†			
		Strength	**Length**	**Micronaire**	**Uniformity**
Treatment	**Timing of Application**	**—g tex^{-1}—**	**–100ths of an inch–**	**—value—**	**—percent—**
1. Untreated Control	N/A	30.28 a	1.07 a	4.90	82.27 a
2. Pyraclostrobin	EB	30.36 a	1.08 a	4.93	82.15 a
3. Mepiquat Chloride	EB	29.43 a	1.07 a	4.98	82.28 a
4. Glyphosate	EB	29.76 a	1.07 a	4.95	82.71 a
5. Pyraclostrobin/Mepiquat Chloride	EB	30.03 a	1.06 a	4.95	82.32 a
6. Pyraclostrobin/Glyphosate	EB	29.83 a	1.08 a	4.87	82.53 a
7. Pyraclostrobin	EB+14	30.03 a	1.08 a	4.98	82.76 a
8. Pyraclostrobin/Mepiquat Chloride	EB+14	29.66 a	1.07 a	4.98	82.83 a
9. Pyraclostrobin/Glyphosate	EB+14	29.95 a	1.06 a	4.90	82.62 a
10. Pyraclostrobin	EB, EB+14	30.21 a	1.07 a	5.06	82.10 a
Pr > f ‡		*.0001*	*.0006*	*.2286*	*.0001*

† HVI values within a single column followed by the same letter are not different at a 0.1 probability level.
‡ Probability of the ANOVA.

and mepiquat chloride applied at EB, or pyraclostrobin with mepiquat chloride at EB+14. The comparison of glyphosate applied at EB with pyraclostrobin and glyphosate applied at EB or at the timing of EB+14 resulted in the absence of statistical separation.

The length factor, measured in 100^{ths} of an inch, showed statistical significance. Although significance was noted in the model, the length values of the untreated control paralleled to treatments of pyraclostrobin applications at EB, pyraclostrobin applied at EB+14, and the application of pyraclostrobin at EB then followed again at EB+14 did not separate statistically. Measurements for mepiquat chloride applied at EB, the combination of mepiquat chloride with pyraclostrobin at EB, and the treatment of mepiquat chloride in conjunction with pyraclostrobin at EB+14 failed to yield statistical separation in analysis. Glyphosate application at EB was not statistically separated from the application of pyraclostrobin and glyphosate at either timing of EB or EB+14.

Micronaire values for Study 1 resulted in a *p-value* of .2286. Results at this level were statistically classified together, though insignificant, at this level of confidence. The untreated control versus comparisons with pyraclostrobin applied at EB, the application of pyraclostrobin at EB+14, or pyraclostrobin applied at both EB and then followed by EB+14 DAT yielded no statistical significance and a minute numerical separation. The comparisons made between applications containing pyraclostrobin and mepiquat chloride versus the EB application of mepiquat chloride alone were insignificant. Treatments containing glyphosate yielded no statistical significance or numerical separation for the micronaire fiber property measurement. These comparisons were made between the application of glyphosate at EB, pyraclostrobin and glyphosate applied at EB, and pyraclostrobin and glyphosate in combination applied at EB+14 in both years of the study.

Uniformity of the samples processed for the untreated control failed to show statistical separation when compared to the pyraclostrobin compounds applied as a standalone application, though statistically significant. This measurement maintained the same results for the applications being compared to the mepiquat chloride compound. The percentage of uniformity for glyphosate applied at EB, in conjunction with pyraclostrobin at EB, and tank-mixed with pyraclostrobin at EB+14 was statistically similar as previously discussed on this point of data collection.

3.7 Study 2 Plant Heights at Harvest

Final plant heights were determined by the end-of-season plant mapping of Study 2 (Table 8). Statistical separation, in the absence of treatment x year interaction, was noted. Plant heights, for the treatment set containing azoxystrobin compounds yielded a mean value of 66.92cm and a coefficient of variance value of 7.63. The numerical range, from 61cm to 72.54cm, for treatment means returned was 11.54cm.

The double application of azoxystrobin, contained in treatment ten at EB and EB+14, resulted in a significantly higher value for height than for the untreated control in Study 2. The treatment of azoxystrobin at early bloom and the treatment of azoxystrobin at early bloom +14DAT did not separate from the UTC.

Table 8. Final plant heights at harvest (Study 2), 2008-2009.

Treatment	Timing of Application	Plant Height†
		2 Year
		height (cm) $plant^{-1}$
1. Untreated Control (UTC)	N/A	61.2 d§
2. Azoxystrobin (Quadris®)	EB	64.1 cd
3. Mepiquat Chloride (Compact®)	EB	72.4 a
4. Glyphosate (Roundup WM®)	EB	68.7 abc
5. Azoxystrobin/Mepiquat Chloride	EB	70.9 ab
6. Azoxystrobin/Glyphosate	EB	67.9 abc
7. Azoxystrobin	EB+14	66.3 bcd
8. Azoxystrobin/Mepiquat Chloride	EB+14	63.9 cd
9. Azoxystrobin/Glyphosate	EB+14	66.9 bc
10. Azoxystrobin	EB, EB+14	66.6 bc
Pr > f ‡		*0.0001*

† Final plant heights were taken from ten consecutive plants in one of the outer two rows of the four row plot, which were not harvested.

§ Plant height values within a single column followed by the same letter are not different at a 10% probability level.

‡ Probability of the ANOVA.

The comparison of mepiquat chloride and its combination with azoxystrobin for an early bloom application were not statistically different. The later application of these compounds in combination, treatment eight, had a lower value in height than its non-mixed application, treatment three.

Glyphosate in combination with azoxystrobin, treatment six, was not statistically separated in final plant height measurement. Treatment nine, the combination of azoxystrobin and glyphosate at the EB+14 growth stage, was significantly shorter in plant stature at the final plant height measurement than its evaluation with the application of glyphosate alone at EB.

3.8 Study 2 Plant Nodes at Harvest

Final total plant nodes were determined by end-of-season plant mapping (Table 9). Total plant nodes for Study 2, in 2008-2009, averaged 19.37 nodes plant^{-1} across treatments with a coefficient of variance equivalent to 6.75. Statistical significance was not detected in these measurements. The analysis yielded $Pr > f$ at 0.2902.

Numerical differences were noted within the comparison of the untreated control, treatment one 18.67 nodes plant^{-1}, and the applications of azoxystrobin at EB with 18.71 nodes plant^{-1}, the application of azoxystrobin at EB+14 18.82 nodes plant^{-1}, and the sequential application of azoxystrobin at EB and then EB+14 19.62 nodes plant^{-1}. These values were not of statistical power or significance.

The treatments, within Study 2, that contained comparisons of mepiquat chloride applications in combination with azoxystrobin were numerically similar in their values. Statistical differences were nullified by the elevated $Pr>f$ analysis.

Table 9. Final node counts at harvest (Study 2), 2008-2009.

Treatment	Timing of Application	Final Nodes† 2 Year nodes plant^{-1}
1. Untreated Control (UTC)	N/A	18.67
2. Azoxystrobin (Quadris®)	EB	18.71
3. Mepiquat Chloride (Compact®)	EB	20.17
4. Glyphosate (Roundup WM®)	EB	19.85
5. Azoxystrobin/Mepiquat Chloride	EB	20.10
6. Azoxystrobin/Glyphosate	EB	19.62
7. Azoxystrobin	EB+14	18.82
8. Azoxystrobin/Mepiquat Chloride	EB+14	19.66
9. Azoxystrobin/Glyphosate	EB+14	18.53
10. Azoxystrobin	EB, EB+14	19.62
Pr > f ‡		*.2902*

† Final node counts were taken from ten consecutive plants in one of outer two rows of the plot, which were not harvested.

‡ Probability of the ANOVA.

The glyphosate application at EB, in treatment four, was separated from the value observed for the EB+14 application of azoxystrobin with glyphosate numerically. Those numerical values were 19.85 nodes plant^{-1} versus 18.53 nodes plant^{-1}, respectively. The glyphosate alone application at EB, in treatment four, was similar to the combination of azoxystrobin with glyphosate application at EB, in treatment six. These, again, were not significantly significant.

The evaluation of azoxystrobin, and its combination with commercially applied compounds, yielded results of insignificance within the realm of total plant nodes prior to defoliation. Statistical significance was not present in this measurement and numerical values had a range of 1.64 nodes plant^{-1}.

3.9 Study 2 Final NAWF

The node above white flower (NAWF) measurement was included for verification of potential effects on maturity with applications of azoxystrobin (Table 10). Significant year x treatment interaction was absent for the analysis, thus the combination of the years for analysis. The NAWF measurements of Study 2 were not statistically different. The evaluation of results yielded a probability level higher than 0.1, *Pr>f* was 0.1551. Numerical differences were noted.

In Study 2, the untreated control, treatment one, had a NAWF value of 1. This treatment related to the application of azoxystrobin at EB, the application of azoxystrobin at EB+14, or the tandem application of azoxystrobin at EB and then

Table 10. Final node above white flower (Study 2), 2008-2009.

		NAWF†
		2 Year
Treatment	**Timing of Application**	**——NAWF plant^{-1}——**
1. Untreated Control (UTC)	N/A	1.00
2. Azoxystrobin (Quadris®)	EB	0.62
3. Mepiquat Chloride (Compact®)	EB	0.37
4. Glyphosate (Roundup WM®)	EB	0.62
5. Azoxystrobin/Mepiquat Chloride	EB	0.87
6. Azoxystrobin/Glyphosate	EB	0.50
7. Azoxystrobin	EB+14	1.00
8. Azoxystrobin/Mepiquat Chloride	EB+14	0.75
9. Azoxystrobin/Glyphosate	EB+14	0.50
10. Azoxystrobin	EB, EB+14	0.75
Pr > f ‡		*.1551*

† NAWF counts were taken from ten consecutive plants in one of the two rows of the 4 row plot, which were not harvested.

‡ Probability of the ANOVA.

applied at EB+14 were not statistically different or significant. The range was 1 NAWF to 0.62 for the lowest numerical value with the application of azoxystrobin at EB.

With the growth regulator, mepiquat chloride, comparisons for the final NAWF varied numerically, but failed to yield statistical significance. The mepiquat chloride alone application at EB retained the lowest numerical value for NAWF, but was not significantly different or significant from the application of azoxystrobin with mepiquat chloride at EB and the treatment azoxystrobin and mepiquat chloride at EB+14.

The glyphosate application treatments produced a numerical range across this measurement that yielded insignificance statistically. No statistical significance was proven among the application of glyphosate at EB, azoxystrobin with glyphosate, as well as the EB+14 application of azoxystrobin with glyphosate in combination.

3.10 Study 2 Yield Parameters

The yield parameters were in insignificant. The data was evaluated over the years that Study 2 was conducted (Table 11). The mean values for seed cotton ha^{-1}, lint turnout percentage, and lint yield ha^{-1} for Study 2 were 2056, 41.5, and 947, respectively. The modeling of the yield parameters returned a value of statistical insignificance.

As shown in Table 11, the mean value for seed cotton returns pertaining to the untreated control, treatment 1, was not significantly different from the azoxystrobin applied at EB, EB+14, or the tandem application of azoxystrobin at EB and then followed at EB+14. Numerically, within these comparisons, the treatment containing

Table 11. Lint yield as affected by azoxystrobin treatments (Study 2), 2008-2009.

		Yield Parameters		
Treatment	**Timing of Application**	**–seed cotton yield kg ha^{-1}–**	**–lint turnout percentage–**	**–lint yield kg ha^{-1}–**
1. Untreated Control (UTC)	N/A	2297	41.37	947
2. Azoxystrobin (Quadris®)	EB	2373	42.00	998
3. Mepiquat Chloride (Compact®)	EB	2490	41.50	1031
4. Glyphosate (Roundup WM®)	EB	2297	41.62	957
5. Azoxystrobin Mepiquat Chloride	EB	2312	41.87	966
6. Azoxystrobin/Glyphosate Glyphosate	EB	2297	41.62	954
7. Azoxystrobin	EB+14	2281	41.37	940
8. Azoxystrobin Mepiquat Chloride	EB+14	2158	41.37	896
9. Azoxystrobin/Glyphosate Glyphosate	EB+14	2264	41.37	934
10. Azoxystrobin	EB, EB+14	2268	41.87	949
Pr > f ‡		*.7448*	*.3922*	*.7560*

‡ Probability of the ANOVA.

azoxystrobin at EB yielded the highest mean for the seed cotton measurement. The treatment of azoxystrobin at EB, the later application of azoxystrobin at EB+14, as well as the dual application of azoxystrobin at EB and EB+14 were numerically separated for lint turn out percentage and final lint yield. These values had no statistical significance.

Mepiquat chloride applied at EB compared with the treatments containing azoxystrobin compounds applied at EB and EB+14 showed similar results as those discussed previously within Study 2, which was statistical insignificance. Seed cotton yield for the mepiquat chloride at EB application yielded the highest numerical yield, but was not statistically different from the azoxystrobin with mepiquat chloride applied at EB or this combination applied at EB+14. Lint turnout percentage and final lint yield were not separated statistically for these combinations and comparisons.

The glyphosate combinations in Study 2 showed insignificance statistical probability in their comparisons for seed cotton yield. Glyphosate applied at EB and the combination of azoxystrobin with glyphosate at EB was numerically equivalent for seed cotton yield. Azoxystrobin and glyphosate applied at EB+14 was numerically smaller than its glyphosate comparison of glyphosate applied alone at EB. Lint turnout percentage and final lint yield values were not different for any of the treatments.

3.11 Study 2 Major Fiber Properties

Significant year x treatment interaction was not observed for micronaire values, fiber length, fiber strength, and fiber uniformity; therefore, data was combined for the two years of Study 2 (Table 12). High Volume Instrument (HVI) classing, at the International Textile Center in Lubbock, Texas was performed on the lint 150-gram

Table 12. Major fiber properties from azoxystrobin treatments (Study 2), 2008-2009.

		High Volume Instrument Testing†			
		Strength	**Length**	**Micronaire**	**Uniformity**
Treatment	**Timing of Application**	**–g tex^{-1}–**	**–100^{ths} of an inch–**	**—value—**	**—percent–**
1. Untreated Control (UTC)	N/A	31.06 a	1.10 a	5.07	82.61 a
2. Azoxystrobin (Quadris®)	EB	31.12 a	1.10 a	5.12	82.73 a
3. Mepiquat Chloride (Compact®)	EB	31.05 a	1.10 a	5.05	83.06 a
4. Glyphosate (Roundup WM®)	EB	30.76 a	1.09 a	5.12	83.03 a
5. Azoxystrobin/Mepiquat Chloride	EB	31.32 a	1.11 a	5.11	83.35 a
6. Azoxystrobin/Glyphosate	EB	31.18 a	1.10 a	5.02	82.93 a
7. Azoxystrobin	EB+14	30.82 a	1.10 a	5.03	83.27 a
8. Azoxystrobin/Mepiquat Chloride	EB+14	31.26 a	1.10 a	4.98	83.12 a
9. Azoxystrobin/Glyphosate	EB+14	31.07 a	1.09 a	5.03	83.26 a
10. Azoxystrobin	EB, EB+14	31.12 a	1.10 a	4.92	83.20 a
Pr > f ‡		*.0001*	*.0022*	*.3223*	*.0001*

† HVI values within a single column followed by the same letter are not different at a 0.1 probability level.

‡ Probability of the ANOVA.

samples from Study 2 in both years of the study. The fiber measurements analyzed over the two years of Study 2 showed statistical significance, except for the micronaire values, but failed to show separation where significance was noted.

Strength, measured in g tex^{-1}, showed statistical significance in its analysis. Statistical separation was absent between the untreated control and the application of azoxystrobin at EB, azoxystrobin at EB+14, or the dual application of azoxystrobin at EB and then EB+14. The mepiquat chloride application at EB for strength yielded no statistical separation form the treatment of azoxystrobin with mepiquat chloride at EB or this combination at EB+14. Glyphosate comparisons yielded the same results as the treatment combinations discussed previously for fiber strength. Statistical separation was not found between glyphosate at EB, azoxystrobin with glyphosate at EB, or azoxystrobin with glyphosate at EB+14.

The length factor, measured in 100$^{\text{ths}}$ of an inch, showed statistical significance. Though significance was noted in the model for length, the values of the untreated control paralleled to the treatments of azoxystrobin applications at early bloom and the following application fourteen days later did not separate. Observations for the mepiquat chloride application at EB and the combination of azoxystrobin with mepiquat chloride at EB or EB+14 failed to yield statistical separation. Glyphosate applied at EB did not separate statistically from the applications of azoxystrobin and glyphosate applied at EB or EB+14. A narrow range of 0.01one hundredths of an inch was yielded.

Micronaire values for Study 2 failed to display statistical strength in the evaluation of the treatments imposed within this study. The probability of data resulted in $Pr > f$ as 0.3233. The untreated control versus its comparison to the treatments of azoxystrobin at EB, azoxystrobin at EB+14, and the sequential application of azoxystrobin at EB and EB+14 yielded had numerical differences in a small range of 0.2. This micronaire value analysis returned results of the same statistical no significance within the application of azoxystrobin with mepiquat chloride at EB or this same combination of compounds at EB+14 in Study 2. The application of glyphosate at EB showed no statistical significance as with the application of azoxystrobin and glyphosate at EB or at the timing of EB+14 for effects on micronaire. These compounds were contained in treatments four, six, and nine in both years of the study, respectively.

Uniformity of the samples processed for the untreated control failed to show statistical separation when compared to the azoxystrobin compounds applied as a standalone application at EB and EB+14. This data point maintained the same results for the applications being compared to the mepiquat chloride treatment at EB and the combination of azoxystrobin and mepiquat chloride at EB and EB+14. The percentage of uniformity for glyphosate applied at EB, in combination with azoxystrobin at EB and EB+14 was statistically significant, but did not separate in the analysis.

4. CONCLUSIONS

4.1 Study 1 Conclusions

According to the analysis of Study 1, final plant measurements conducted in 2008 and 2009 were statistically different among treatments. The scale of the differences, and their occurrence throughout the treatments, were not sound evidence of maturity being lengthened due to pyraclostrobin being applied, as compared to the untreated control. The effects of tank mixing glyphosate, or mepiquat chloride, with pyraclostrobin did not prove detrimental to the growth measurements of the cotton in this study.

Within the yield parameters, the application of pyraclostrobin at EB and the treatment at EB+14 ten did separate themselves from the comparison with the untreated control. This separation was statistically significant in seed cotton yields, as well as final lint yield ha^{-1}. The differences in final lint yield 213 kg ha^{-1} of the application with pyraclostrobin at EB+14 compared to the untreated control is considered significant. The scale of separation between the sequential applications of pyraclostrobin at EB and EB+14 with the untreated control was shown to be 65 kg ha^{-1}. The comparisons between glyphosate and mepiquat chloride treatments were statistically the same as their combination treatments including pyraclostrobin.

HVI analysis of fiber samples from Study 1 showed significance in 3 categories. Though significance was proven, statistical separation was not present. No derogatory affects were observed with tank mixing of glyphosate or the growth regulator, mepiquat chloride. Differences observed within Study 1, based on monetary returns, would differ solely on lint kg ha^{-1} harvested. The cotton cultivar STV 4554B2RF was not lengthened in maturity due to the application of pyraclostrobin and the blanket application of pyraclostrobin, with lack of disease pressure, is not recommended for the stewardship and longevity of activity with this chemistry.

4.2 Study 2 Conclusions

Statistical differences were observed for final plant measurements within the treatments containing comparisons with azoxystrobin. These differences, though significant, did not prove to lengthen maturity of the STV 4554B2RF plants. The data, within these measurements, was proven statistically significant, but not relevant to production practices due to the small numerical differences from the UTC. Tank mixing azoxystrobin with glyphosate and mepiquat chloride yielded results that were not detrimental to the growth parameters measured in this study.

The yield parameters for Study 2 showed the absence of statistical power. Numerical comparisons displayed small scalar differences between the untreated control and the treatments containing azoxystrobin within Study 2. Glyphosate and mepiquat chloride tank mixes proved to be of no consequence on final lint kg ha^{-1}.

The fiber analysis of treatments from Study 2 maintained statistical significance, though separation was not observed in the classification of results. The azoxystrobin treatments did not separate from the untreated control in lint analysis. The combination of the herbicide, glyphosate, and the growth regulator mepiquat chloride did not prove detrimental to these fiber measurements.

REFERENCES

Ammerman E., G. Lorenz, K. Schelberger, B. Mueller, R. Kirstgen, and H. Sauter. 2000. Pests and diseases. British Crop Protection Council, BCPC. Brighton, England.

Balba H. 2007. Review of strobilurin fungicide chemicals. J. Env. Sci. Health, Part. B. Pesticides, food contaminants, and agricultural wastes. 42:441-451.

Bartlett D.W., J.M. Clough, J.R. Godwin, A.A. Hall, M. Hamer, B. Parr-Dobrzanski. 2002. The strobilurin fungicides. Pestic. Sci. 58:649-662.

Bartosz G. 1997. Oxidative stress in plants. Acta Physiol. Plant. 19:47-64.

Bell A.A. 1999. Diseases of cotton. p. 553-593. *In* C.W. Smith and J.T. Cothren (eds.) Cotton: Origin, History, Technology, and Production. John Wiley and Sons, Inc. New York.

Boman R. (ed.) 2010. Harvester comparisons: stripper versus picker, Bayer CropScience Southwest Reg. Technol. Conf. 10-12 Feb. 2009., San Antonio, TX.

Bourland F.M., D.M. Oosterhuis, N.P. Tugwell. 1992. Concept for monitoring the growth and development of cotton plants using main-stem node counts. J. Prod. Agric. 5(4):532-537.

Bourland F.M., N.R. Benson, E.D. Vories, N.P. Tugwell, D.M. Danforth. 2001. Measuring maturity of cotton using nodes above white flower. J. of Cotton Sci. 5:1-8.

Brimner T.A., G.J. Boland. 2003. A review of the non-target effects of fungi used to biologically control plant diseases. Agric. Ecosyst. Environ. 100:3-16.

Butt T.M., M. Brownbridge. 1997. Fungal pathogens of thrips. p. 399-434. *In* T. Lewis (ed.) Thrip as Crop Pests. CAB International, Wallingford, UK

Cetin O., L. Bilgel. 2002. Effects of different irrigation methods on shedding and yield of cotton. Agric. Manag. Water Qual. 54:1-15. DOI: 10.1016/s0378-3774(01)00138-x.

Cothren, J.T. 1999. Physiology of the cotton plant. p. 207-268. *In* C.W. Smith and J.T. Cothren (eds.) Cotton: Origin History, Technology, and Production. John Wiley & Sons, Inc. New York.

Dat J., S. Vandenabeele, E. Vranova, M. van Montagu, D. Inze, F. Van Breusegem. 2000. Dual action of the active oxygen species during plant stress responses. Cell. Mol. Life Sci. 57:779-95.

Fry K.E. 1983. Heat unit calculations in cotton crop and insect models. USDA-ARS Advances in Agricultural Technology – ATT-W-23.

Gibson, J.R. and H.E. Joham. 1968. Influence of night temperature on growth and development of cotton (*Gossypium hirsutum* L.). Fruiting and boll development. Agron. J., 60:292-295.

Golden P. 2009. Race for acres: end of triple nickel. Southern Farmer. Farm Progress, 8 January, p. 6.

Grossmann K., G. Retzlaff. 1997. Bioregulatory effects of the fungicidal strobilurin kresoxim-methyl in wheat (*triticum aestivum*). Pestic. Sci.50:11-20.

Guinn G. 1979. Hormonal relations in flowering, fruiting and cut-out. P. 265-276. *In* J. McD. Stewart (ed.) Cotton physiology – A treatise, Sect. 1. Part 2. Flowering, fruiting, and cutout. Proc. Beltwide Cotton Prod. Res. Conf., Phoenix, AZ. 7-11 January. Natl. Cotton Council, Memphis, TN.

Guinn G. 1982. Causes of square and boll shedding in cotton. USDA Technical Bulletin. 1672:1-22.U.S. Gov. Print. Office, Washington, DC.

Gullino M.L., P. Leroux, C.M. Smith. 2000. Uses and challenges of novel compounds for plant disease control. Crop Prot. 19:1-11.

Hake K., F. Carter, J. Mauney, N. Namken, J. Heitholt, T. Kerby, B. Pettigrew. 1992. Square rentention. *In Cotton Physiology Today*. 3 (6).

Hake K.D., T. Kerby, W. McCarty. 1989b. Effect of cold weather on yield and quality. *In Cotton Physiology.* Natl. Cotton Council, Technical Services, Memphis, TN.

Iersel M.W., D.M Oosterhuis. 1995. Diurnal water relations of expanding and full-sized cotton fruits and subtending leaves. Plant, Cell and Environ. 18:807-812.

Jenkins J.N., J.C. McCarty. 1995. Useful tools in managing cotton production: end of season plant maps. Technical Bulletin M. A. F. E. Station (ed.), Office of Agricultural Communications, Mississippi State University, Starksville. pp. 1-24.

Koehle H., K. Grossmann, T. Jabs, M. Gerhard, W. Kaiser, J. Glaab, U. Conrath, K. Seehaus, S. Herms. 2003. Physiological effects of the strobilurin fungicide F500 on plants. Agron. J. 23: 1287-1292.

Larson R.A. 1997. Natrually occuring antioxidants. Lewis Publishers, CRC Press LLC, Boca Raton, New York.

Leroux P. 1996. Recent developments in the mode of action of fungicides. Pestic. Sci. 47:191-197.

McMichael B.L., W.R. Jordan 1973. Abscission processes in cotton: introduction by plant water deficit. Agron. J. 65:202-204.

McMichael B.L. 1979. The influence of water stress on flowering and fruiting in cotton. p. 301-302. *In* J. McD. Stewart (ed.) Cotton physiology – A treatise, Sect.1 Part 2. Flowering, fruiting, and cutout. Proc. Beltwide Cotton Prod. Res. Phoenix, AZ. 7-11 January. Natl. Cotton Council, Memphis, TN.

Oosterhuis D.M. 1991. Growth and development of the cotton plant, p. 1-24. *In* W.N. Miley and D.M. Ooserthuis (eds.) Nitrogen Nutrition in Cotton: Practical Issues. Proceedings Southern Branch Workshop for Practicing Agronomists. American Society of Agronomy, Madison, WI.

Osekre E.A., D.L. Wright, J.J. Marois, J. Funderburk. 2009. Flower-inhabiting frankliniella thrips (thysanoptera: thripidae), pesticides, and fusarium hardlock in cotton. J. Econ. Entomol. 102:887-96.

Paul P.A., V. Madden, C.A. Bradley, A.E. Robertson, G.P. Munkvold, G. Shaner, K.A. Wise, D.K. Malvick, T.W. Allen, A. Gybauskas, P. Vincelli, P. Esker. 2011. Meta-analysis of yield response of hybrid field corn to foliar fungicides in the U.S. corn belt. Phytopathology. 101:1122-1132.

Petit, A-N, F. Fontaine, P. Vatsa, C. Clément, N. Vaillant-Gaveau. 2012. Fungicide impacts on photosynthesis in crop plants. Photosynth. Res. 111:315-326.

Pettigrew W.T. 2004. Physiological consequences of moisture deficit stress in cotton. Crop Sci. 44:1265-1272.

Reddy K.R., G.H. Davidonis, A.S. Johnson, B.T. Vinyard. 1999. Temperature regime and carbon dioxide enrichment alter cotton boll development and fiber properties. Agron. J. 91:851-858.

SAS Institute. 2007-2008. The SAS System for Windows - Release 9.2, SAS Institute Inc. Cary, NC.

Sharma O.P., O.M.Bambawale. 2008. Integrated management of key diseases of cotton and rice, p. 271-297. *In* A. Ciancio and K.G. Mukerji (eds.) Integrated Management of Diseases Caused by Fungi, Phytoplasma and Bacteria. Springer. Netherlands.

Satterthwaite, F.E. 1946. An approximate distribution of estimates of variance components. Biometrics 2: 110-114.

Silvertooth J.C. (1995) Crop monitoring and management for Pima cotton.p.88-89. *In* P. Dugger and D. ritcher (eds.) Proc.Beltwide Cotton Conf. San Antonio, TX. 4-7 Jan. 1995. Natl. Cotton Council, Memphis, TN.

Stewart S.D., M.B. Layton, M.R. Williams, D. Ingram, W. Maily. 2001. Response of cotton to prebloom square loss. J. of Econ. Entomol. 94:388-396.

Venancio W.S., M.A.T. Rodrigues, E. Begliomini, N.L. de Souza. 2003. Physiological effects of strobilurin fungicides on plants. Ag. Sci. Eng. 9:59-68.

Waard M.A., S.G. Georgopoulos, D.W. Hollomon, H. Ishii, P. Leroux, N.N. Ragsdale, F.J. Schwinn. 1993. Chemical control of plant diseases: problems and prospects. Annu. Rev. of Phytopathol. 31:403-421. DOI:10.1146/annurev.py.31.090193.002155.

Weisz, R., C. Cowger, G. Ambrose, A. Gardner. 2010. Multiple mid-atlantic field experiments show no economic benefit to fungicide application when fungal disease is absent in winter wheat. Phytopathology. 101:323-333.

Zhang Y.J., X. Zhang, C.J. Chen, M.G. Zhou, H.C. Wang. 2010. Effects of fungicides JS399-19, azoxystrobin, tebuconazloe, and carbendazim on the physiological and biochemical indices and grain yield of winter wheat. Pestic. Biochem. Physiol. 98:151-157.

Zhao D., K.R. Reddy, V.G. Kakani, S. Koti, W. Gao. 2005. Physiological causes of cotton fruit abscission under conditions of high temperature and enhanced ultraviolet-B radiation. Physiol. Plant. 124:189-199.

APPENDIX A

2008 WEATHER DATA - BURLESON COUNTY, TX

Date	Max.	Min.	Max.	Min.	DD60's
	°C		°F		Daily
9-Apr	24.44	19.33	76	66.8	11.4
10-Apr	28.89	17.72	84	63.9	14.0
11-Apr	24.94	15.28	76.9	59.5	8.2
12-Apr	21.89	8.94	71.4	48.1	-0.3
13-Apr	20.94	5.33	69.7	41.6	-4.3
14-Apr	20.83	2.67	69.5	36.8	-6.9
15-Apr	25.06	4.78	77.1	40.6	-1.2
16-Apr	26.39	9.89	79.5	49.8	4.7
17-Apr	28.61	16.39	83.5	61.5	12.5
18-Apr	21.78	10.06	71.2	50.1	0.7
19-Apr	27.83	8.72	82.1	47.7	4.9
20-Apr	26.83	11.28	80.3	52.3	6.3
21-Apr	31.11	19.89	88	67.8	17.9
22-Apr	31.17	21.44	88.1	70.6	19.4
23-Apr	31.67	20.33	89	68.6	18.8
24-Apr	31.11	20.94	88	69.7	18.9
25-Apr	29.33	21.22	84.8	70.2	17.5
26-Apr	28.22	16.72	82.8	62.1	12.5
27-Apr	21.00	9.89	69.8	49.8	-0.2
28-Apr	24.94	7.22	76.9	45	1.0
29-Apr	27.89	6.78	82.2	44.2	3.2
30-Apr	29.56	11.22	85.2	52.2	8.7
1-May	29.17	18.17	84.5	64.7	14.6
2-May	30.56	19.89	87	67.8	17.4
3-May	23.83	12.94	74.9	55.3	5.1
4-May	29.06	9.67	84.3	49.4	6.8
5-May	22.28	17.33	72.1	63.2	7.7
6-May	26.28	17.06	79.3	62.7	11.0
7-May	27.17	20.39	80.9	68.7	14.8
8-May	29.94	16.44	85.9	61.6	13.8
Date	Max.	Min.	Max.	Min.	DD60's

	———°C———		———°F———		Daily
9-May	33.89	19.17	93	66.5	19.8
10-May	31.00	22.67	87.8	72.8	20.3
11-May	25.83	15.94	78.5	60.7	9.6
12-May	26.67	12.67	80	54.8	7.4
13-May	27.78	21.06	82	69.9	16.0
14-May	29.00	20.22	84.2	68.4	16.3
15-May	22.83	17.72	73.1	63.9	8.5
16-May	24.61	15.33	76.3	59.6	8.0
17-May	26.89	13.72	80.4	56.7	8.6
18-May	32.00	15.67	89.6	60.2	14.9
19-May	34.61	14.89	94.3	58.8	16.6
20-May	35.22	19.17	95.4	66.5	21.0
21-May	34.28	22.72	93.7	72.9	23.3
22-May	33.28	23.72	91.9	74.7	23.3
23-May	35.83	25.61	96.5	78.1	27.3
24-May	33.94	24.61	93.1	76.3	24.7
25-May	34.50	23.50	94.1	74.3	24.2
26-May	34.44	24.28	94	75.7	24.9
27-May	35.56	20.39	96	68.7	22.4
28-May	33.11	19.94	91.6	67.9	19.8
29-May	33.83	20.94	92.9	69.7	21.3
30-May	33.33	19.28	92	66.7	19.4
31-May	35.28	20.33	95.5	68.6	22.1
1-Jun	35.39	22.11	95.7	71.8	23.8
2-Jun	35.94	21.94	96.7	71.5	24.1
3-Jun	35.83	23.06	96.5	73.5	25.0
4-Jun	34.61	23.78	94.3	74.8	24.6
5-Jun	34.22	25.44	93.6	77.8	25.7
6-Jun	35.83	25.33	96.5	77.6	27.1
7-Jun	35.39	25.17	95.7	77.3	26.5
8-Jun	35.94	24.83	96.7	76.7	26.7
9-Jun	35.61	25.06	96.1	77.1	26.6
10-Jun	33.28	23.11	91.9	73.6	22.8
11-Jun	35.17	22.44	95.3	72.4	23.9
12-Jun	34.94	22.11	94.9	71.8	23.4
13-Jun	35.39	23.00	95.7	73.4	24.6
Date	Max.	Min.	Max.	Min.	DD60's

	°C		°F		Daily
14-Jun	36.00	22.50	96.8	72.5	24.7
15-Jun	36.11	23.00	97	73.4	25.2
16-Jun	36.33	23.00	97.4	73.4	25.4
17-Jun	36.39	23.06	97.5	73.5	25.5
18-Jun	37.39	22.00	99.3	71.6	25.5
19-Jun	34.28	22.39	93.7	72.3	23.0
20-Jun	34.00	22.39	93.2	72.3	22.8
21-Jun	36.06	21.00	96.9	69.8	23.4
22-Jun	35.28	19.67	95.5	67.4	21.5
23-Jun	36.61	20.67	97.9	69.2	23.6
24-Jun	33.94	21.61	93.1	70.9	22.0
25-Jun	35.72	22.11	96.3	71.8	24.1
26-Jun	35.83	22.61	96.5	72.7	24.6
27-Jun	36.11	22.61	97	72.7	24.9
28-Jun	36.00	22.61	96.8	72.7	24.8
29-Jun	35.83	22.17	96.5	71.9	24.2
30-Jun	33.22	20.72	91.8	69.3	20.6
1-Jul	34.50	19.17	94.1	66.5	20.3
2-Jul	36.11	20.39	97	68.7	22.9
3-Jul	36.67	19.89	98	67.8	22.9
4-Jul	34.17	20.56	93.5	69	21.3
5-Jul	35.67	20.39	96.2	68.7	22.5
6-Jul	36.00	20.33	96.8	68.6	22.7
7-Jul	36.11	22.06	97	71.7	24.4
8-Jul	36.61	22.00	97.9	71.6	24.8
9-Jul	37.50	21.17	99.5	70.1	24.8
10-Jul	34.56	22.28	94.2	72.1	23.2
11-Jul	36.83	22.11	98.3	71.8	25.1
12-Jul	36.00	23.22	96.8	73.8	25.3
13-Jul	37.39	21.17	99.3	70.1	24.7
14-Jul	37.11	23.50	98.8	74.3	26.6
15-Jul	37.50	22.83	99.5	73.1	26.3
16-Jul	37.17	23.78	98.9	74.8	26.9
17-Jul	36.83	22.00	98.3	71.6	25.0
18-Jul	37.06	20.94	98.7	69.7	24.2
19-Jul	36.33	20.83	97.4	69.5	23.5
Date	Max.	Min.	Max.	Min.	DD60's

	————°C————		————°F————		Daily
20-Jul	37.50	21.44	99.5	70.6	25.1
21-Jul	38.17	23.67	100.7	74.6	27.7
22-Jul	37.94	21.78	100.3	71.2	25.8
23-Jul	35.44	24.22	95.8	75.6	25.7
24-Jul	33.94	23.78	93.1	74.8	24.0
25-Jul	36.11	24.33	97	75.8	26.4
26-Jul	37.44	23.06	99.4	73.5	26.5
27-Jul	38.50	20.83	101.3	69.5	25.4
28-Jul	38.11	21.78	100.6	71.2	25.9
29-Jul	37.22	22.72	99	72.9	26.0
30-Jul	37.06	22.17	98.7	71.9	25.3
31-Jul	37.50	25.39	99.5	77.7	28.6
1-Aug	37.94	24.78	100.3	76.6	28.5
2-Aug	39.11	24.11	102.4	75.4	28.9
3-Aug	37.94	23.39	100.3	74.1	27.2
4-Aug	38.17	21.39	100.7	70.5	25.6
5-Aug	29.72	23.06	85.5	73.5	19.5
6-Aug	35.22	22.67	95.4	72.8	24.1
7-Aug	37.11	23.28	98.8	73.9	26.4
8-Aug	36.72	23.56	98.1	74.4	26.3
9-Aug	36.78	23.44	98.2	74.2	26.2
10-Aug	37.17	24.22	98.9	75.6	27.3
11-Aug	35.67	25.67	96.2	78.2	27.2
12-Aug	30.00	24.89	86	76.8	21.4
13-Aug	35.28	23.72	95.5	74.7	25.1
14-Aug	36.28	22.67	97.3	72.8	25.1
15-Aug	35.28	22.11	95.5	71.8	23.7
16-Aug	31.67	22.67	89	72.8	20.9
17-Aug	31.11	22.72	88	72.9	20.5
18-Aug	29.89	22.78	85.8	73	19.4
19-Aug	27.11	22.06	80.8	71.7	16.3
20-Aug	31.11	22.50	88	72.5	20.3
21-Aug	31.67	23.50	89	74.3	21.7
22-Aug	34.56	23.89	94.2	75	24.6
23-Aug	33.33	22.78	92	73	22.5
24-Aug	32.44	21.44	90.4	70.6	20.5

APPENDIX B

2009 WEATHER DATA - BURLESON COUNTY, TX

Date	Max.	Min.	Max.	Min.	DD60's
	———^{o}C———		———^{o}F———		Daily
11-Apr	19.28	13.00	66.7	55.4	1.1
12-Apr	25.22	14.17	77.4	57.5	7.5
13-Apr	21.78	9.56	71.2	49.2	0.2
14-Apr	25.72	5.39	78.3	41.7	0.0
15-Apr	26.06	9.44	78.9	49	4.0
16-Apr	24.94	14.89	76.9	58.8	7.8
17-Apr	19.28	16.11	66.7	61	3.9
18-Apr	23.33	16.67	74	62	8.0
19-Apr	23.22	13.22	73.8	55.8	4.8
20-Apr	25.39	10.00	77.7	50	3.9
21-Apr	30.78	11.94	87.4	53.5	10.5
22-Apr	32.56	13.83	90.6	56.9	13.8
23-Apr	28.94	17.39	84.1	63.3	13.7
24-Apr	25.39	18.67	77.7	65.6	11.7
25-Apr	28.11	18.89	82.6	66	14.3
26-Apr	28.50	21.56	83.3	70.8	17.1
27-Apr	25.39	17.22	77.7	63	10.4
28-Apr	27.39	17.17	81.3	62.9	12.1
29-Apr	27.83	21.17	82.1	70.1	16.1
30-Apr	29.39	20.94	84.9	69.7	17.3
1-May	29.94	22.11	85.9	71.8	18.9
2-May	29.56	21.94	85.2	71.5	18.4
3-May	27.44	17.06	81.4	62.7	12.1
4-May	27.44	14.22	81.4	57.6	9.5
5-May	30.89	20.67	87.6	69.2	18.4
6-May	31.39	22.44	88.5	72.4	20.5
7-May	31.72	23.06	89.1	73.5	21.3
8-May	32.83	22.78	91.1	73	22.1
9-May	32.72	21.72	90.9	71.1	21.0
10-May	32.72	20.67	90.9	69.2	20.1
11-May	33.89	22.33	93	72.2	22.60
Date	Max.	Min.	Max.	Min.	DD60's

	°C		°F		Daily
12-May	33.56	22.44	92.4	72.4	22.40
13-May	31.94	22.33	89.5	72.2	20.85
14-May	32.28	21.56	90.1	70.8	20.45
15-May	32.94	20.33	91.3	68.6	19.95
16-May	29.94	18.94	85.9	66.1	16.00
17-May	23.50	16.11	74.3	61	7.65
18-May	25.50	13.00	77.9	55.4	6.65
19-May	28.11	9.89	82.6	49.8	6.20
20-May	28.83	12.17	83.9	53.9	8.90
21-May	30.89	13.83	87.6	56.9	12.25
22-May	28.83	18.78	83.9	65.8	14.85
23-May	29.28	18.17	84.7	64.7	14.70
24-May	26.94	19.28	80.5	66.7	13.60
25-May	31.72	17.83	89.1	64.1	16.60
26-May	34.28	21.44	93.7	70.6	22.15
27-May	30.17	20.67	86.3	69.2	17.75
28-May	32.17	18.17	89.9	64.7	17.30
29-May	32.89	18.39	91.2	65.1	18.15
30-May	34.28	15.17	93.7	59.3	16.50
31-May	32.78	19.06	91	66.3	18.65
1-Jun	31.72	16.17	89.1	61.1	15.10
2-Jun	33.78	19.78	92.8	67.6	20.20
3-Jun	33.56	20.72	92.4	69.3	20.85
4-Jun	30.56	18.39	87	65.1	16.05
5-Jun	32.94	15.11	91.3	59.2	15.25
6-Jun	33.61	18.67	92.5	65.6	19.05
7-Jun	34.06	18.44	93.3	65.2	19.25
8-Jun	34.06	20.61	93.3	69.1	21.20
9-Jun	34.67	21.78	94.4	71.2	22.80
10-Jun	35.39	24.50	95.7	76.1	25.90
11-Jun	35.39	25.50	95.7	77.9	26.80
12-Jun	36.67	25.50	98	77.9	27.95
13-Jun	36.94	24.28	98.5	75.7	27.10
14-Jun	36.50	22.83	97.7	73.1	25.40
15-Jun	36.72	23.50	98.1	74.3	26.20
16-Jun	37.44	23.50	99.4	74.3	26.85
Date	Max.	Min.	Max.	Min.	DD60's

	————°C————		————°F————		Daily
17-Jun	36.39	25.11	97.5	77.2	27.35
18-Jun	36.56	23.72	97.8	74.7	26.25
19-Jun	36.39	22.72	97.5	72.9	25.20
20-Jun	37.11	22.00	98.8	71.6	25.20
21-Jun	37.17	22.28	98.9	72.1	25.50
22-Jun	37.67	23.00	99.8	73.4	26.60
23-Jun	37.50	23.06	99.5	73.5	26.50
24-Jun	39.72	23.72	103.5	74.7	29.10
25-Jun	39.89	25.56	103.8	78	30.90
26-Jun	39.44	23.00	103	73.4	28.20
27-Jun	38.72	24.22	101.7	75.6	28.65
28-Jun	39.11	24.22	102.4	75.6	29.00
29-Jun	39.94	26.33	103.9	79.4	31.65
30-Jun	32.00	24.39	89.6	75.9	22.75
1-Jul	33.39	23.78	92.1	74.8	23.45
2-Jul	39.50	22.78	103.1	73	28.05
3-Jul	38.56	22.78	101.4	73	27.20
4-Jul	38.28	24.78	100.9	76.6	28.75
5-Jul	38.94	25.83	102.1	78.5	30.30
6-Jul	34.17	26.06	93.5	78.9	26.20
7-Jul	37.22	25.33	99	77.6	28.30
8-Jul	39.89	24.83	103.8	76.7	30.25
9-Jul	40.17	24.56	104.3	76.2	30.25
10-Jul	38.94	25.39	102.1	77.7	29.90
11-Jul	38.50	23.11	101.3	73.6	27.45
12-Jul	38.50	23.94	101.3	75.1	28.20
13-Jul	39.22	25.33	102.6	77.6	30.10
14-Jul	39.11	25.22	102.4	77.4	29.90
15-Jul	39.22	23.89	102.6	75	28.80
16-Jul	39.11	25.00	102.4	77	29.70
17-Jul	36.33	22.78	97.4	73	25.20
18-Jul	37.89	22.06	100.2	71.7	25.95
19-Jul	37.50	21.78	99.5	71.2	25.35
20-Jul	35.94	23.61	96.7	74.5	25.60
21-Jul	36.83	24.44	98.3	76	27.15
22-Jul	36.50	25.67	97.7	78.2	27.95
Date	Max.	Min.	Max.	Min.	DD60's

	———°C———		———°F———		Daily
23-Jul	34.50	23.11	94.1	73.6	23.85
24-Jul	36.28	23.94	97.3	75.1	26.20
25-Jul	38.72	22.83	101.7	73.1	27.40
26-Jul	39.33	25.28	102.8	77.5	30.15
27-Jul	38.06	25.39	100.5	77.7	29.10
28-Jul	38.17	26.78	100.7	80.2	30.45
29-Jul	36.67	26.11	98	79	28.50
30-Jul	36.83	22.89	98.3	73.2	25.75
31-Jul	32.17	22.44	89.9	72.4	21.15
1-Aug	38.17	25.06	100.7	77.1	28.90
2-Aug	35.17	25.17	95.3	77.3	26.30
3-Aug	38.56	22.78	101.4	73	27.20
4-Aug	38.50	23.33	101.3	74	27.65
5-Aug	38.61	23.39	101.5	74.1	27.80
6-Aug	38.78	23.83	101.8	74.9	28.35
7-Aug	37.94	23.89	100.3	75	27.65
8-Aug	37.39	23.50	99.3	74.3	26.80
9-Aug	33.83	24.56	92.9	76.2	24.55
10-Aug	37.22	23.78	99	74.8	26.90
11-Aug	38.61	23.56	101.5	74.4	27.95
12-Aug	39.22	23.67	102.6	74.6	28.60
13-Aug	37.22	21.67	99	71	25.00
14-Aug	37.17	22.72	98.9	72.9	25.90
15-Aug	36.83	22.06	98.3	71.7	25.00
16-Aug	37.83	22.28	100.1	72.1	26.10
17-Aug	37.11	23.33	98.8	74	26.40
18-Aug	34.56	23.78	94.2	74.8	24.50
19-Aug	36.39	24.11	97.5	75.4	26.45
20-Aug	38.72	24.89	101.7	76.8	29.25
21-Aug	38.61	24.89	101.5	76.8	29.15
22-Aug	37.56	23.06	99.6	73.5	26.55
23-Aug	38.61	23.06	101.5	73.5	27.50
24-Aug	38.11	24.61	100.6	76.3	28.45

APPENDIX C

CROP PRODUCTION PRODUCTS USED IN 2008 COTTON STUDY

The following products were used at the rates indicated for the designated weeds or pest.

Preplant

Broadleaf weeds and annual grasses	Treflan® 4EC – trifluralin: 1.86 L ha^{-1} α,α,α-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-tolidine

Early Season

Thrips (*Thrips tabaci*)	Temik® 15G – aldicarb: 5.61 kg ha^{-1} [2-methyl-2-(methylthio)propionaldehyde 0-(methylcarbamoyl)]
	Bidrin® 8 – dicrotophos: 0.29 L ha^{-1} Dimethyl phosphate of 3-hydroxy-*N*,*N*-Dimethyl-*cis*-crotonamide
Annual grasses	Dual® II – metolachlor: 1.17 L ha^{-1} 2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-Methoxy-1-methylethyl)acetamide
	Caparol® 4L – prometryn: 2.34 L ha^{-1} 2,4-bis(isopropylamino)-6-methylthio)-*S*-triazine
Broadleaf weeds (primarily *Ipomoea* sp.)	Roundup WeatherMax® – glyphosaste: 1.61 L ha-1 N-(phosphonomethyl)glycine
Grasses (primarily *Sorghum halepense*)	Fusilade® DX – fluazifop-P-butyl: 0.88 L ha^{-1} Butyl (*R*)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoate
Cotton Fleahopper (*Pseudatomoscelis seriatus*)	Orthene® 90S acephate: 0.22 L ha-1 (O,S-Dimethyl acetylphosphoramidiothioate)

Plant Growth Regulator	Pentia® – mepiquat pentaborate: 0.58 L ha^{-1} N,N-dimethylpiperidiniurn pentaborate
Harvest Aids	Dropp® 50WP – thidiazuron: 0.11 kg ha^{-1} N-phenyl-N-1,2,3-thiadiazol-5-urea
	Def® – tribufos: 1.75 L ha^{-1} *S*,*S*,*S*-tributyl phosphorotrithioate
	Prep – ethephon: 1.55 L ha-1 (2-chloroethyl) phosphonic acid

APPENDIX D

CROP PRODUCTION PRODUCTS USED IN 2009 COTTON STUDY

The following products were used at the rates indicated for the designated weeds or pest.

Preplant

Broadleaf weeds and annual grasses	Treflan® 4EC – trifluralin: 1.86 L ha^{-1} α,α,α-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-tolidine

Early Season

Thrips (*Thrips tabaci*)	Temik® 15G – aldicarb: 5.61 kg ha^{-1} [2-methyl-2-(methylthio)propionaldehyde 0-(methylcarbamoyl)]
	Bidrin® 8 – dicrotophos: 0.29 L ha^{-1} Dimethyl phosphate of 3-hydroxy-*N*,*N*-Dimethyl-*cis*-crotonamide
Annual grasses	Dual® II – metolachlor: 1.17 L ha^{-1} 2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-Methoxy-1-methylethyl)acetamide
	Caparol® 4L – prometryn: 2.34 L ha^{-1} 2,4-bis(isopropylamino)-6-methylthio)-*S*-triazine
Broadleaf weeds (primarily *Ipomoea* sp.)	Roundup WeatherMax® – glyphosaste: 1.61 L ha-1 N-(phosphonomethyl)glycine
Grasses (primarily *Sorghum halepense*)	Fusilade® DX – fluazifop-P-butyl: 0.88 L ha^{-1} Butyl (*R*)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoate
Cotton Fleahopper (*Pseudatomoscelis seriatus*)	Trimax® imidicloprid: 0.11 L ha-1 1-[(6-Chloro-3-pyridinyl)methyl]-*N*-nitro-2-imidazolidinimine

Mid- to Late Season

Cotton Aphid (Aphis gossypii) and Whitefly ( )	Provado 1.6F – imidicloprid: 0.18 L ha-1 1-[(6-chloro-3-pryidinyl)methyl]-*N*-nitro-2-imidazolidinimine
Plant Growth Regulator	Pentia® – mepiquat pentaborate: 0.58 L ha^{-1} N,N-dimethylpiperidiniurn pentaborate
Harvest Aids	Dropp® SC – thidiazuron: 0.15 kg ha^{-1} N-phenyl-N-1,2,3-thiadiazol-5-urea
	Ginstar® – thidiazuron/diuron: 0.07 L ha^{-1} N-phenyl-N'-1,2,3-thidiazol-5-ylurea, 3-(3,4-dichlorophenyl)-1,1-dimethylurea
	Finish Pro 6® – ethephon: 1.55 L ha^{1} (2-chloroethyl) phosphonic acid, cyclanilide 1-(2,4-dichlorophenlyaminocarbonyl)-cyclopropane carboxylic acid