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Improved Production Practices in a Double-Cropping System with Cotton (Gossypium Hirsutum) and Wheat (Triticum Aestivum)

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Improved production practices in a double-cropping system with cotton (*Gossypium hirsutum*) and wheat (*Triticum aestivum*)

By

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Improved production practices in a double-cropping system with Cotton (*Gossypium hirsutum*) and Wheat (*Triticum aestivum*)

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With the recent rise of wheat (*Triticum aestivum* L.) prices and the spike in cotton (*Gossypium hirsutum* L.) prices in 2011, a renewed interest in double-cropping cotton following wheat production occurred. Research was established to improve production practices of double-cropped cotton at three Mississippi locations, Starkville (2012-2013), Brooksville (2012-2013), and Stoneville (2013). Cotton following wheat has the potential to result in a higher return compared to soybeans; however, the financial risk associated with cotton is far greater than with soybeans. Growers should increase seeding rates by 20% when double-cropping cotton following wheat and burn the wheat stubble to maximize yield. No definitive N rate was observed to maximize yield; however, a normal rate full-season cotton is not recommended as high N rates delayed maturity and increased the potential yield loss.

DEDICATION

I would like to dedicate this research to my parents, Brett and Lisa Dixon. Throughout my education you have provided support and encouragement and for that I am thankful. Without your support I would not be where I am today. I would also like to dedicate this research to my late grandfather, Leslie Dixon. Afterall, growing up around his cotton farm gained my interest in agriculture.

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INTRODUCTION

Cotton (*Gossypium hirsutum* L.) use by man is believed to be at least 7,000 years old based upon pieces of cotton bolls and cloth found in Mexico (National Cotton Council 2012). By 3,000 BC, cotton was being cultivated and spun into cloth in Pakistan. In addition, cotton was planted in Florida as early as 1556 (National Cotton Council 2012). Due to the industrial revolution in England and the invention of the cotton gin in the United States, cotton became a very important crop and continues to contribute significantly to agriculture in many U.S. states and foreign countries (National Cotton Council 2012).

Cotton is an economically important crop throughout the world, as well as Mississippi. Cotton and it's by–products produced in 2012 in Mississippi were valued at $397,000,000 which ranked fifth in value of production behind corn (*Zea mays* L.), forestry, soybeans [*Glycine max* (L.) Merr.] and poultry (MDAC 2012). In the United States, annual revenue from cotton production exceeds $120 billion, which makes it the number one value-added crop in the U.S. (National Cotton Council 2012). All parts of the cotton fruit or fibers are utilized. The long fibers attached to the seed are the lint and are used to make cloth. The remaining short fuzz attached to the seed after ginning are called "linters" and provides cellulose to make plastics and explosives, padding for mattresses, furniture, automobile seats, and are also incorporated into high quality paper products.

Cotton seed are crushed for oil, meal and hulls (National Cotton Council 2012). Cottonseed oil is used for shortening, cooking oil and salad dressing. The meal and hulls can be used as feed and fertilizer (National Cotton Council 2012).

Cotton is a perennial plant that can reach heights of 4.6 to 6.1 m; however, as an agronomic crop, cotton typically reaches heights of 0.6 to 1.5 m given adequate moisture and nutrients. Growing temperatures for cotton range from 15.5°C to 37.7°C with an optimum temperature for growth and development ranging from 32.2°C to 35°C (Marois et al. 2007). Due to cotton's extensive root system, cotton is considered a drought tolerant plant. Root growth occurs rapidly until first bloom and begins to decline 90 days after planting (Marois et al. 2007). Five main growth stages have been described which include: germination and emergence, seedling establishment, leaf area and canopy development, flowering and boll development, and maturation (Jenkins et al., 1990). Cotton is a dicot therefore the seeds include two cotyledons and an embryo with the cotyledons containing food and energy for seed germination and early plant development. Cotton develops nodes above the cotyledons with the first sympodial branches typically occurring on node six or seven (Marois et al. 2007). Sympodial branches produce squares (flower buds) which will eventually grow into a flower. The first square is generally visible 35 days after planting with a bloom or flower appearing 21 days after the first square apprears (Ritchie et al. 2007). The flowering period typically lasts about six weeks (Ritchie et al. 2007). Due to cotton's indeterminate growth habit, it continues vegetative growth after reproductive growth begins (Silvertooth et al. 1999).

Growing degree days are commonly used to define the length of time required for cotton to reach a given growth stage. Because of the predictable pattern in which cotton grows related to temperature, the use of growing degree days are used to estimate the time it takes to reach a given developmental stage. Growing degree days are determined by summing the daily high and low temperatures and dividing that number by two. Sixty is then subtracted from the resulting number and the result is the number of growing degree day units that occur on any given day. Cotton growth and development ceases at temperatures below 60°F which is why this number is subtracted from the average daily temperature. This is often referred to as DD-60's. The number of DD-60's required to reach different stages of cotton development are presented in Table 1 (Marois et al. 2007).

Double-cropping Cotton following Wheat

In recent years wheat (*Triticum aestivum* L.) prices have risen and in turn wheat acreage has also risen in the Mid South. This has increased interest in double-cropping systems, including cotton, following wheat (Bagwell et al., 2007). Double-cropping refers to the practice of growing two subsequent crops in one year (Heatherly and Elmore, 2004). Historically, soybeans have been the primary crop grown following wheat production in the Mid South double-crop system (Baker 1987; Griffin et al., 1984; Rabb and Melville, 1984; Sanford 1982; Sanford et al., 1973). The length of the growing season in Mississippi combined with the eradication of the boll weevil, and the introduction of *Bacillus thuringiensis* (*Bt*) cotton varieties has made it more feasible to double crop cotton behind wheat (Bagwell et al., 2007).

Many factors should be considered when double-cropping cotton behind wheat. Cotton stand establishment after wheat harvest is of paramount importance (Bagwell et al., 2007). In order to establish an acceptable cotton plant population, good seed-soil contact with minimal seed bed disruption is needed. Obtaining good seed-soil contact can be difficult due to wheat straw left after harvest. In the Mid South, wheat harvest generally occurs 2 to 4 weeks later than normal cotton planting dates which exacerbates the need for timely cotton seeding following wheat harvest (Bagwell et al., 2007).

Stubble Management

There are several options a grower may utilize for wheat stubble management prior to planting a crop following wheat production. Burning wheat stubble and planting into stale seedbeds is commonly practiced by those that double crop cotton and soybean after wheat harvest. Burning wheat stubble may help improve seed-soil contact by removing most plant residue above the soil surface. Growers also commonly plant no-till directly into existing wheat straw. Leaving wheat straw intact will help conserve moisture; however, the presence of wheat stubble during planting makes it more difficult to get adequate seed-soil contact. Uniform distribution of wheat chaff and straw recycled during the combining process is essential for obtaining an adequate plant stand, since clumps or rows of straw and chaff could negatively affect the planter (Bagwell et al., 2007).

Seeding Rates

Little previous research is available regarding appropriate seeding rates for cotton planted into wheat stubble. It is generally recommended that cotton be seeded at 13 seeds $m^{-1}$of row for normal planted cotton (Buehring et al., 2009). In addition, limited previous research suggests increasing cotton seeding rates by 20% over normal planted cotton when planting into wheat stubble (Bagwell et al., 2007). In addition to stand establishment, another key component of successful cotton production following wheat is cotton maturity management. Several factors affect how quickly a cotton crop matures. Average time to maturity can vary greatly depending on variety of cotton planted. Cotton varieties can range from early, mid, and late maturing cultivars so variety selection can greatly affect the earliness of cotton planted following wheat production. Typically the greatest maturity span between early and late-maturing cotton varieties is approximately 14 days (MSU Cares IS1971). Planting early or early-mid maturing varieties as opposed to late maturing varieties can reduce the amount of growing degree days required to reach maturity. In addition, insect and weed pressure tends to increase throughout the growing season making it important to consider varieties that contain transgenic *Bt* technology that will provide protection from Lepidoptoran pests as well as herbicide resistant technology that will allow for effective weed management options (Bagwell et al., 2007). Plant population also affects maturity. Reduced plant populations can delay maturity as cotton will naturally attempt to add vegetative branches (Bagwell et al., 2007). Smith et al. (1979) also showed that low plant populations delayed maturity. However, Kerby et al. (1990) suggested that increasing plant density will delay maturity of full-season indeterminate cultivars due to reduced early season fruit retention.

Insect Management

Extensive scouting is necessary for double-crop cotton since the likelihood of increased insect pressure and damage could further delay maturity and reduce yield. The use of insecticide seed treatments for thrips (*Frankliniella occidentalis*) control is recommended; however, warm temperatures and adequate moisture should allow cotton to develop quickly and reduce the necessity of additional foliar oversprays for thrips control (Bagwell et al., 2007). Although cotton expressing the Bacillus thuringiensis (Bt) gene is very efficacious on most caterpillar pests attacking cotton, thourough scouting is still critical and occasional oversprays may still be warranted under high pressure (Bagwell et al., 2007; Sivasupramaniam et al., 2008). The tarnished plant bug, *Lygus lineolaris* (Palisot de Beavois), is the most economically important pest of cotton in Mississippi (Williams, 2013). Prior to 1995, the plant bug complex was mainly controlled by insecticide applications for other pests, but since the eradication of the boll weevil, *Anthonomus grandis grandis* (Boheman), and the wide-scale adoption of transgenic Bt cotton, those foliar insecticide applications for other pests have been reduced (Musser et al. 2007). In 2013, Mississippi averaged five applications per acre for a total cost of $60.44 per acre (Williams, 2013). It is critical to protect the fruit on double-cropped cotton to help ensure early maturity and optimum yields. Insect damage will only further delay maturity as the plant will try to add fruit in the upper portion of the canopy which adds more vegetative growth.

Weed Management

The use of a residual herbicide and intensive scouting for weeds is critical in double-cropped cotton. Cotton may take longer to reach full canopy when planted in wheat straw due to increased competition; therefore, it is important to manage weeds to prevent yield losses (Barber Personal Communication). Previous studies have estimated that with no physical or chemical control practices, weeds can cause up to a 34% yield loss worldwide for cotton (Oerke and Dehne 2004). With the recent rise in glyphosate-resistant *Amaranthus palmeri* (Palmer amaranth) and *Conyza canadensis* (Horseweed or Marestail) it is important that these weeds be completely controlled prior to cotton planting (Barber et al., 2013). Soil residual herbicides such as S-metolachlor may show reduced activity due to the presence of wheat straw; however, a rainfall event or sprinkler irrigation will help improve herbicide activity (Barber et al., 2013; Sims and Guethle, 1992). Not all existing vegetation may be controlled by burning wheat stubble; therefore, applications of paraquat or glufosinate may be required in a reduced tillage situation prior to planting (Barber et al., 2013).

Plant Growth Regulators

The most common plant growth regulator used in cotton is mepiquat chloride (Jost et al., 2006). Mepiquat chloride works by reducing gibberellic acid formation, which promotes cell division and expansion (Jost et. al., 2006 ; Taiz and Zeiger, 1998). Although match-head square applications of mepiquat chloride have become common, early bloom is the recommended target window when making initial mepiquat applications in cotton following wheat production. When applying plant growth regulators, the quicker the plant puts on nodes and starts to bloom the faster it will mature; therefore, mepiquat applications shouldn't be applied until bloom (Bagwell et al., 2007). For irrigated cotton under normal planting conditions, higher rates (8.9 to 13.4 oz ha^{-1}) are recommended at first bloom with subsequent applications two to three weeks later at a higher rate (Jost et al., 2005). However, some varieties may require higher application rates prior to bloom (Jost et al., 2005). For non-irrigated cotton under normal planting conditions, 8.9 oz ha^{-1} at first bloom should be safe to apply; however, subsequent applications depend on adequate rainfall and growth (Jost et al., 2005).

Nitrogen Management

Supplemental Nitrogen fertilizer affects lint yield and maturity. Excess Nitrogen can delay maturity and cause excess vegetative growth. Previous research has shown that 67 kg N ha^{-1} was adequate for maximum cotton yield when double cropping cotton behind wheat (Buehring, 2009). Barber et al. (2013) suggests that Nitrogen should be applied at two-thirds of a full-season rate (112 to 134 kg N ha^{-1}), and not to exceed 90 kg N ha^{-1} to avoid delayed maturity, issues with growth management, and troublesome defoliation for double-cropped cotton. Also, all Nitrogen should be applied prior to pinhead square, in order to limit late season growth and associated maturity delay (Barber et al., 2013).

Table 1.1 Estimated Average Number of Growing Degree Days to Reach Each Growth Stage in Cotton.

Event	DD-60s from Planting
Emergence (Stand Establishment)	45-130
First square	440-530
First flower	780-900
Peak Bloom	1350-1500
First open boll	1650-1850
Defoliation	1900-2600

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CHAPTER II

IMPACT OF COTTON AND SOYBEAN VARIETAL MATURITY PLANTED FOLLOWING WHEAT ON GROWTH, DEVELOPMENT, YIELD, AND ECONOMIC RETURNS

For the latter half of the 20th century, farmers have specialized in certain crops due to environmental constraints, economics, or infrastructure, which leads to the same crops being grown in a one or two year rotation. Short rotations are susceptible to problems such as: stagnant yields, soil degradation, and survival and adaption of pests and disease (Crookston, 1995; Zenter et al., 2001; Tanaka et al., 2002). However, a diversified cropping system can help reduce the risk of crop and economic losses from unpredictable weather and the economy as well as increase total income (Katsvairo et al., 2006).

Planting more than one crop in the same season, or double-cropping, offers producers potential advantages such as: increased cash flow resulting from better utilization of climate and land; reduced soil and water losses by having the soil covered with a plant canopy most of the year; and more intensive land use and utilization of machinery, labor, and capital investments (Heatherly and Hodges, 1998). Studies have shown that double-cropping can reduce soil loss compared to monocropping (Hairston et al., 1984; Mutchler and Greer, 1984; Wesley and Cooke, 1988). A major factor that has limited double-cropping is the requirement for careful and timely crop management to be more profitable than a monocrop system (Heatherly and Hodges, 1998).

Several factors are of importance when determining the economic feasibility of double-cropping. Spreading out fixed costs can help improve total farm income. Also, by double-cropping there is increased cash flow from the sale of wheat. Income from wheat harvest can then be put toward other crops grown instead of having to borrow money from the bank, which will reduce interest expenses and increase income (Heatherly and Hodges, 1998; Wesley and Cooke, 1988). The amount of wheat acres in the Mid-South can fluctuate greatly depending on price. However, when it comes to deciding whether to plant soybean following wheat, certain factors affect productivity including: harvest date of wheat and soil moisture for timely planting (Heatherly and Hodges, 1998). The planting date of soybean can have a significant affect on yield as studies have shown that yields decrease rapidly when planting after June 20 (Heatherly 1984; Kluse et al., 1976; Wesley and Cooke, 1988).

Net returns of irrigated double-cropped soybean have been shown to be slightly positive; however, economic returns on non-irrigated double-cropped soybean were negative (Heatherly and Hodges, 1998). Wesley et al. (1994a, 1995) determined that a wheat-soybean double-crop system is profitable when irrigation is available on clay soils in the Mid-South. Contrary to other studies, irrigated monocrop soybean planted no-till into standing wheat stubble has shown greater profits compared to a wheat-soybean double crop system; however, an irrigated wheat-soybean double crop system has shown greater profits compared to a monocrop soybean system when planted into burned wheat stubble (Wesley and Cooke, 1988). Previous research has reported that a cotton-wheat double crop system will work in areas with a long growing season and with adequate moisture from either rainfall or irrigation (Baker 1987).

Soybean and cotton maturity could play a major role in profitability as later maturing varieties might not receive enough heat units with the shorter growing season associated with a double-crop system. Studies have shown that late MG IV soybean provided the greatest yield and economic returns in a double-crop system when compared to MG III and MG V soybean (Kyei-Boahen and Zhang, 2006). Early maturing cotton varities are recommended due to the shorter growing season (Bagwell et al., 2007; Barber et al., 2013).

However, research on economics of cotton double-cropped following wheat production is lacking. Therefore, research was established to determine profitability of cotton and/or soybean following wheat production by tracking inputs throughout the year in order to determine returns above variable costs. In addition, the impact of varietal maturity, growth, and development, and yield in both cotton and soybean double-crop systems was examined.

Materials and Methods

Research was established at the R.R. Foil Plant Science Research Center in Starkville, MS (STK) and at the Black Belt Branch Experiment Station near Brooksville, MS (BR) in 2012 and 2013 as well as the Delta Research and Extension Center near Stoneville, MS (ST) in 2013 to determine the economic implications of cotton and soybean varietal maturity following wheat production.

Varieties

In 2012 six cotton varieties were evaluated including: DP 0912 B2RF (Monsanto Company, 800 N. Lindbergh Blvd., St. Louis, MO 63167); PHY 339 WRF (Dow AgroSciences LLC, 9330 Zionsville Road, Indianapolis, IN 46268); PHY 367 WRF (Dow AgroSciences); DP 1252 B2RF (Monsanto Company); PHY 499 WRF (Dow AgroSciences); ST 5288 B2F (Bayer CropScience, 2 TW Alexander Drive, Durham, NC 27709). Also, in 2012 six soybean varieties were planted which included: Asgrow 4632RR (Monsanto Company); Delta Grow 4670RR (Delta Grow Seed, 219 220 NW 2nd Street, England, AR 72046); Dyna-Gro 34RY46 (Crop Production Services, 3005 Rocky Mountain Avenue, Loveland, CO 80538); Asgrow 5332 (Monsanto Company); Armor 53-R15 (Armor Seed LLC, 2528 Alexander Dr,. Jonesboro, AR 72401); and Delta King 5563 (Delta King Seeds, P.O. Box 970, McGrory, AR 72101). In 2013, the same cotton varieties were evaluated. However, soybean varieties included: Asgrow 4632 RR (Monsanto Company); Delta Grow 4670 RR (Delta Grow Seed); Mor Soy 4629 (MFA Inc., 201 Ray Young Drive, Columbia, MO 65201); Asgrow 5332 RR (Monsanto Company); Armor 1316 (Armor Seed LLC); and Asgrow 5532 (Monsanto Company). Cotton seed treatmeants utilized in this study included: Acceleron N (Thiamethoxam + Pyraclostrobin + Ipconazole + Abamectin) on DP 0912 B2RF and DP 1252 B2RF; Avicta Complete (Thiamethoxam + Azoxystrobin + Fludioxonil + Mefenoxam + Myclobutanil + TCMTB + Abamectin) on PHY 339 WRF, PHY 367 WRF, and PHY 499 WRF; and Aeris + Trilex Advanced (Imidacloprid + Trifloxystrobin + Triadimenol + Metalaxyl + Ipconazole + Thiodicarb) for ST 5288 B2F.

Agronomic Management

Cotton was planted at a seeding rate of 128,000 seed ha^{-1} and soybean was planted at a seeding rate of 306,280 seeds ha^{-1} into standing wheat stubble in 2012 and into burned wheat stubble in 2013. Soybeans were inoculated with rhizobia prior to planting. Nitrogen was applied at 134 kg N ha^{-1} as 32% urea-ammonium nitrate (UAN) with a ground driven knife applicator in cotton. P_2O_5 and K_2O was applied at each location based on crop recommendations derived from soil test recommendations. Plot size consisted of four-97 cm rows which were 12.2 meters in length at Starkville and Brooksville, and four-102 cm rows which were 9.1 meters in length at Stoneville. The Starkville and Stoneville locations were irrigated as needed; whereas, the Brooksville location was rainfed only. Soil classifications were mapped as the following: the Starkville location was a Leeper silty clay loam (Fine, smectitic, nonacid, thermic Vertic Epiaquepts); the Brooksville location was a Brooksville silty clay (Fine, smectitic, thermic Aquic Hapluderts); and the Stoneville location a Bosket very fine sandy loam (Fine-loamy, mixed, active, thermic Mollic Hapludalfs). Each plot was scouted weekly for weed and/or insect pests. Pesticide and defoliation applications were applied as needed according to Mississippi State University Extension Service recommendations.

Data Collection

Data collection included the following: stand counts for cotton and soybean, plant height and total nodes at pinhead square as well as at first bloom for cotton, plant height and total nodes at 40 DAP (days after planting) and 65 DAP in soybeans during 2012 and in 2013 at 42 and 56 DAP, respectively, final plant height and total nodes for cotton and soybeans, nodes above cracked boll (NACB) for cotton, yield, fiber quality, and grain quality for each respective crop. Plant heights were measured from the soil level to the newest emerged leaf in cotton or newest unrolled trifoliate in soybean. The center two rows of each crop were harvested using either a cotton picker or combine (used to harvest soybean) modified for small plot research. Cotton at the Brooksville location in 2012 was not harvested. Fiber quality was obtained from 25 boll samples collected immediately prior to harvest that were analyzed by the fiber laboratory at the LSU AgCenter. Lint yield was calculated from lint percent determined from ginning for each individual plot. Grain quality was based on samples analyzed by the MS Grain Inspection Service in Stoneville, MS. In addition, all inputs and returns were documented for each crop and, net returns were calculated based on those inputs and returns. Wheat harvest dates, cotton and soybean planting dates, nitrogen application dates, and cotton and soybean harvest dates are given in Table 2.1.

Statistical Analysis

A randomized complete block design with four replications was utilized in all experiments. Two different maturity groups were utilized in each crop. Cotton maturity groups consisted of early and late varieties whereas soybean maturity groups consisted of MGIV and MGV varieties. Environment and maturity group were considered fixed effects and variety was considered a random effect. All data were analyzed using the Proc Glimmix procedure in SAS 9.3. Means were separated using Fisher's protected LSD at α=0.05. Data for each crop were analyzed by environment and maturity, since maturity group did not significantly affect any tested parameters except soybean quality, data for each crop were pooled across maturity groups with the exception of soybean quality. Analysis of variance p-values (Tables 2.2 and 2.3) are separated by crop.

Results and Discussion

Cotton Heights and Nodes 40 to 42 DAP

Cotton heights 40 to 42 DAP ranged from 28 to 46 cm, with the BR 2012 location having shorter plant heights (28 cm) compared to the other environments (Table 2.4). No differences were observed in cotton height 40 to 42 DAP between the BR 2013, ST 2013, STK 2012, or STK 2013 locations with cotton being 40 to 46 cm in height (Table 2.4). Cotton heights 40-42 DAP were dependent upon environment and varied little with the exception of the BR 2012 location. Cotton nodes 40 to 42 DAP ranged from 7 to 11, with cotton at the BR 2012 location having 7 nodes which was significantly less than cotton at other locations (Table 2.4). Cotton grown at ST 2013 produced 11 nodes which was significantly greater than the number of nodes at the BR 2012, BR 2013 or STK 2012 locations; however, node counts at these locations were not significantly different from the STK 2013 (Table 2.4) location. Cotton nodes also were dependent upon environment and varied little with the exception of ST 2013.

Soybean Heights and Nodes 40 To 42 DAP

Soybean heights 40 to 42 DAP ranged from 23 to 40 cm with plants at BR 2012 having shorter plant heights (23 cm), compared to the other environments (Table 2.4). No significant difference was observed between the BR 2012, BR 2013, ST 2013, or STK 2013 locations for soybeans. (Table 2.4). Soybean heights varied dependent upon environment and with the exception of the BR 2012 location, variation in height was minor. Soybean nodes 40 to 42 DAP ranged from 5.1 to 9.2, with plants at the BR 2012 location having 5.1 nodes, which was significantly less than other locations (Table 2.4). Plants grown at BR 2013 produced the most nodes with 9.2; however, those node counts were not significantly different from soybean plants at ST 2013 (Table 2.4). Soybean plants grown at STK 2013 had 8.4 nodes 40 to 42 DAP, which was significantly greater than node counts from the BR 2012 location, but significantly less than node counts from BR 2013 and not significantly different than counts from ST 2013 (Table 2.4). Soybean node counts varied dependent upon environment 40 to 42 DAP.

Cotton Heights, Nodes and NAWF 56 to 65 DAP

Cotton heights 56 to 65 DAP ranged from 68 to 93 cm with plants at BR 2013 being significantly taller (93 cm) compared to other environments (Table 2.4). No significant difference in cotton plant height was observed between the BR 2012, ST 2013, STK 2012, or STK 2013 locations; however, all were significantly shorter than cotton grown at BR 2013 (Table 2.4). Cotton heights 56 to 65 days varied dependent upon environment; however, with the exception of BR 2013, variation was minor. Cotton nodes 56 to 65 DAP ranged from 13 to 16, with cotton at ST 2013 and STK 2013 having significantly less nodes (13 and 14), respectively, than cotton at BR 2013. However, node counts at BR 2013 were not significantly different from those at BR 2012 and STK 2012 with plants at each location having 15 nodes (Table 2.4). Cotton node counts varied dependent upon environment 56 to 65 DAP. Cotton NAWF 56 to 65 DAP ranged from 5.7 to 7.7, with cotton at BR 2012 having 5.7 NAWF which was significantly less than NAWF counts at other locations (Table 2.4). No significant differences were observed with respect to NAWF for cotton grown at BR 2013, ST 2013, STK 2012, or STK 2013; however, cotton at these locations had significantly greater NAWF counts than cotton at BR 2012 (Table 2.4). Node above white flower was depended upon environment and varied little with the exception of the BR 2012 location 56 to 65 DAP. Typically you would expect to have 9 to 10 NAWF at first bloom under normal growing conditions (Edmisten, 1993). Lower NAWF counts could indicate stress is limiting growth whearas a higher NAWF could be the result of excess nitrogen or poor fruit retention (Edmisten, 1993).

Soybean Heights and Nodes 56 to 65 DAP

Soybean heights 56 to 65 DAP ranged from 56 to 70 cm with plants at STK 2013 having significantly shorter plants (56 cm) than plants at other locations (Table 2.4). No significant difference with respect to soybean plant height was observed between soybean plants at BR 2012, BR 2013, or ST 2013 (Table 2.4). However, soybean plants at these locations were significantly taller 56 to 65 DAP than those at STK 2013 (Table 2.4). Soybean heights 56 to 65 DAP were dependent upon environment and variation was minor with the exception of the STK 2013 location. Soybean nodes 56 to 65 DAP ranged from 12 to 16 with plants at BR 2012 having significantly more nodes at 16 compared to other environments (Table 2.4). No significant difference in soybean nodes was observed between soybeans grown at BR 2013, ST 2013, or STK 2013; however, soybean plants at these locations had significantly less nodes than soybean plants grown at BR 2012 (Table 2.4). Soybean node counts were dependent upon environment and varied little with the exeption of the BR 2012 location 56 to 65 DAP.

End of Season Cotton Heights, Nodes, and NACB

End of the season cotton heights ranged from 93 to 121 cm (Table 2.5). Cotton grown at STK 2012 (121 cm) was significantly taller than cotton grown at ST 2013 or STK 2013. No significant differences in end of the season cotton heights were observed between ST 2013 (97 cm), STK 2013 (93 cm), BR 2012 (111 cm), or BR 2013 (108 cm) (Table 2.5). Final cotton heights were dependent upon environment and variation was minor with the exception of the STK 2012 location. Cotton total nodes at the end of the season ranged from 17 to 21 with plants at BR 2013 and STK 2013 producing significantly less total nodes than other environments with 18 and 17 nodes, respectively (Table 2.5). Cotton at BR 2012 produced 21 nodes which was significantly greater than node counts from BR 2013, ST 2013, or STK 2013; however, these node counts were not significantly different from node counts at STK 2012 (Table 2.5). Cotton at ST 2013 had 20 nodes which was significantly greater than cotton node counts at BR 2013 or STK 2013, but significantly less than cotton node counts at BR 2012 (Table 2.5). Cotton grown under normal growing conditions typically has 20 to 24 nodes (Jenkins et al., 1990). Node above cracked boll counts indicate a delay in maturity whereas higher NACB counts lead to more heat units required to mature that plant. Typically it takes 50 heat units per NACB to mature each boll above the cracked boll (Dodds Personal Communication). Cotton NACB at the end of the season ranged from 3.9 to 8.3 with cotton at ST 2013 having significantly less NACB with 3.9 compared to other environments (Table 2.5). Cotton at BR 2013 and STK 2013 had 8.3 and 7.8 NACB, respectively, which was significantly greater than NACB counts for cotton at other locations (Table 2.5). Cotton at BR 2012 and STK 2012 had 5.9 and 6.3 NACB, respectively, which was significantly less than NACB counts from BR 2013 or STK 2013, but significantly greater than NACB counts from ST 2013 (Table 2.5). When NACB reaches four or lower it is considered safe to defoliate without yield loss from premature defoliation (Edmisten and Burmester, 1992). The lower NACB counts from cotton grown at the ST 2013 location could be due to an increased amount of heat units received in the Mississippi Delta region compared to the hills region.

End of Season Soybean Heights and Nodes

Soybean heights at the end of the season ranged from 64 to 82 cm (Table 2.5). Soybean grown at BR 2012 had the tallest plants at 82 cm; however, soybean heights at ST 2013 were similar at 76 cm (Table 2.5). Soybean grown at STK 2013 had the shortest plants at 64 cm; however, these heights were not significantly different than those from BR 2013 (71 cm) (Table 2.5). Soybean grown at BR 2013 and ST 2013 were not significantly different with respect to plant height at the end of the season (Table 2.5). Final soybean heights varied dependent upon environment. Soybean nodes at the end of the season ranged from 15 to 18 with node counts at BR 2012 being significantly greater with 18 nodes compared to the other environments (Table 2.5). No significant difference with repect to soybean nodes was observed between BR 2013, ST 2013, or STK 2013; however, node counts from these locations were significantly less than total nodes from soybeans plants at BR 2012 (Table 2.5). With the exception of the BR 2012 location, there was minor variation in final node counts which was dependent upon environment. Soybeans typically have final heights ranging from 79 to 119 cm with 16 to 25 nodes (Fischer, 1985).

Cotton Lint Yield

Cotton lint yields ranged from 681 to 1440 kg ha^{-1}. Cotton grown at STK 2013 produced 1440 kg ha^{-1} which was greater other environments (Table 2.5). Yields from cotton grown at BR 2013 and ST 2013 were 729 and 681 kg ha^{-1} respectively, which was significantly less than lint yields at other locations (Table 2.5). Lint yields from cotton at the STK 2012 location were 1040 kg ha^{-1} which was significantly greater than yields from BR 2013 or ST 2013, but significantly lower than yield from STK 2013 (Table 2.5). Lint yield varied dependent upon environment and growing conditions associated with those environments. Mississippi cotton in 2012 averaged 1,136 kg ha^{-1} and in 2013 set a record average yield of 1,377 kg ha^{-1} (USDA-NASS).

Fiber Quality

Cotton fiber strength was the only fiber quality property significantly affected by environment (Table 2.5). Fiber strength ranged from 30.9 to 34.6 g tex^{-1}. Cotton from BR 2012 had the lowest strength and cotton from BR 2013 had the greatest strength (Table 2.5). Although unaffected by maturity or environment, cotton fiber length ranged from 2.79 to 2.92 cm; fiber uniformity ranged from 66.7 to 84.0 %; and micronaire ranged from 4.6 to 5.0. No negative impacts to fiber quality parameters were observed and no price deductions would have been warranted.

Soybean Yield

Soybean yields ranged from 1210 to 2419 kg ha^{-1} (Table 2.5). Soybean grown at ST 2013 and STK 2013 produced 2083 and 2419 kg ha^{-1}, respectively, which was significantly greater than yields from soybean grown at BR 2012 or BR 2013 which produced 1546 and 1210 kg ha^{-1} respectively (Table 2.5). Soybean yield varied dependent upon environment, which could be attributed to irrigation since Stoneville and Starkville were irrigated whearas Brooksville was rainfed only. Soybean yields at ST 2013 and STK 2013 were comparable to yields of irrigated double-crop soybean in previous studies

(Wesley et al., 1994a,b). Mississippi had record soybean yields in 2012 and 2013 that averaged 3,024 kg ha^{-1} both years (USDA-NASS).

Grain Quality

An interaction between maturity group and environment existed for all soybean quality parameters (Table 2.6). Test weight ranged from 24 to 25 kg bu^{-1} with MG V soybean grown at STK 2013 having significantly greater test weight than MG V soybean grown at BR 2012, MG IV soybean grown at BR 2013, and both MG IV and MG V soybean grown at ST 2013 (Table 2.6). Moisture ranged from 11 to 18% with MG V soybean grown at BR 2012 having significantly higher moisture content at 18% compared to seed moisture content from other environments and maturity groups (Table 2.6). Damage ranged from 1.5 to 8.8% with MG V soybean grown at BR 2012 having significantly greater damage than soybean from other environments and maturity groups (Table 2.6). Splits ranged from 0.4 to 3.1 % with MG IV soybean grown at STK 2013 having a significantly greater percent splits than soybeans from other environments and maturity groups (Table 2.6). Mold damage ranged from 0.2 to 5.3 % with MG V soybean grown at BR 2012 having significantly greater mold damage compared to soybean from other environments and maturity groups (Table 2.6). No other significant differences were observed between environment and maturity groups with respect to mold damage (Table 2.6). The high damage from soybean at the BR 2012 location is mainly due from high mold damage that could be attributed to leaving the seed sealed in bags with a high moisture content for an extended period of time prior to testing.

Returns Above Variable Costs

Cotton and soybean profits above variable costs were calculated based on costs similar to those in Table 2.7 for each repective crop. Cotton profits above variable costs ranged from -63 to 1635 (\$ ha^{-1}) with standard deviations ranging from 279 to 573 (\$ ha^{-1}) (Fig. 2.1). Cotton producers in Mississippi received an average price of \$1.68 kg^{-1} in 2012 and \$1.71 kg^{-1} in 2013 (USDA-NASS). Soybean profits above variable costs ranged from 180 to 627 (\$ ha^{-1}) with standard deviations ranging from 142 to 309 (\$ ha^{-1}) (Fig. 2.2). Soybean growers in Mississippi received an average price of \$0.53 kg^{-1} in 2012 and \$0.48 kg^{-1} in 2013 (USDA-NASS). Non-irrigated soybean following wheat has the potential to be profitable contrary to the findings of Heatherly and Hodges (1998) and Wesley et al. (1994a,b; 1995) (Fig. 2.2). Based on these data, cotton following wheat has the potential to result in a much higher return over variable costs compared to soybean following wheat; however, the risks associated with cotton are far greater than soybean (Fig. 2.1 and 2.2). The returns over variable costs for cotton fluctuated far more than the returns for soybean (Fig. 2.1 and 2.2). These data reflect returns above variable costs; therefore, producers should take into account their fixed costs and make a decision on which crop would best fit their situation. Maturity group did not have an effect on growth or yield with the exception of soybean quality. Therefore, producers have the option to plant either a MG IV or MG V soybean and either an early or late maturing cotton variety and not see negative impacts with respect to plant growth, development, and yield. These findings differ from Kyei-Boahen and Zhang (2006) in that maturity group did not have a significant impact on yield or returns above variable costs.

Conclusion

Final cotton heights, nodes, and NAWF, and soybean heights and nodes varied dependent upon environment and were comparable to those parameters under normal growing conditions in a monocrop system. With the exception of the ST 2013 location, cotton showed potential for high returns following wheat, but the risk is also greater than soybean. Soybean following wheat is less risky when compared to cotton, but the potential returns are also lower. Although there were some significant differences, fiber quality was not negatively impacted from double cropping in any environment. With the exception of the BR 2012 location, variation in soybean quality was minor. Although no negative yield or profit impacts were observed from either a MG V soybean or late maturing cotton variety, later maturing varieties of either crop are not recommended due to the potential increased time needed to reach maturity, particularly with unpredicatable fall weather patterns that exist in the Mid-South. Returns above variable costs indicate that cotton following wheat in the Delta region may not be as feasible as soybean due to increased input costs associated with insecticide applications.

Table 2.1 Wheat harvest dates, planting dates, nitrogen application dates, and cotton or soybean harvest dates.

Crop	Environment	Wheat Harvest	Cotton/Soybean Planting	Nitrogen Application	Crop Harvest
Cotton	BR 2012	May 21, 2012	May 25, 2012	June 21, 2012	N/A
	BR 2013	June 18, 2013	June 21, 2013	July 29, 2013	October 29, 2013
	ST 2013	June 19, 2013	June 20, 2013	July 30, 2013	November 11, 2013
	STK 2012	June 1, 2012	June 4, 2012	July 23, 2012	Novemer 28, 2012
	STK 2013	June 12, 2013	June 14, 2013	July 29, 2013	November 7, 2013
———	———	———	———	———	———
Soybeans	BR 2012	May 21, 2012	May 25, 2012	N/A	October 10, 2012 (MG IV) October 16, 2012 (MG V)
	BR 2013	June 18, 2013	June 21, 2013	N/A	October 29, 2013
	ST 2013	June 19, 2013	June 20, 2013	N/A	November 11, 2013
	STK 2013	June 12, 2013	June 14, 2013	N/A	October 29, 2013

Table 2.2 Analysis of variance p-values for cotton heights and nodes 40-42 DAP[c]; heights, nodes and nodes above white flower 56-65 DAP[c]; final plant heights, nodes and nodes above cracked boll; lint yield; fiber length, uniformity and strength; and micronaire.

Source	Degrees of Freedom	Plant Height 40-42 DAP[c]	Plant Nodes 40-42 DAP[c]	Plant Height 56-65 DAP[c]	Plant Nodes 56-65 DAP[c]	NAWF[a] 56-65 DAP[c]	Final Plant Heights	Final Plant Nodes	NACB[b]	Lint Yield	Fiber Length	Fiber Uniformity	Fiber Strength	Micronaire
Maturity	1	0.6268	0.5211	0.3047	0.8361	0.2297	0.4574	0.7611	0.2573	0.0702	0.8285	0.3369	0.5816	0.1948
Environment	4 or 3[Ψ]	<.0001	<.0001	0.0003	0.0358	0.0023	0.0429	<.0001	<.0001	<.0001	0.8816	0.4569	<.0001	0.1394
Maturity x Environment	4 or 3[Ψ]	0.9325	0.7902	0.8314	0.8303	0.4016	0.2932	0.8546	0.2384	0.4408	0.9614	0.3684	0.4495	0.9209

[a] Nodes above white flower.

[b] Nodes above cracked boll.

[c] Days after planting.

[Ψ] Environment had 3 degrees of freedom for lint yield.

Table 2.3 Analysis of variance p-values for soybean heights and nodes 40-42 DAP[a]; heights and nodes 56-65 DAP[a]; final plant heights and nodes; yield; test weight, moisture, total damage, splits, and mold damage.

Source	Degrees of Freedom	Plant Height 40-42 DAP[a]	Plant Nodes 40-42 DAP[a]	Plant Height 56-65 DAP[a]	Plant Nodes 56-65 DAP[a]	Final Plant Heights	Final Plant Nodes	Yield	Test Weight	Moisture	Total Damage	Splits	Mold Damage
Maturity	1	0.2676	0.1369	0.7466	0.7848	0.1800	0.1465	0.1775	0.5206	0.0088	0.0152	0.1460	0.1137
Environment	3	<.0001	<.0001	0.0006	<.0001	0.0002	0.0045	0.0002	0.0504	<.0001	0.0149	0.0005	0.0415
Maturity x Environment	3	0.3484	0.0762	0.2586	0.5400	0.5778	0.0863	0.3271	0.0011	<.0001	0.0016	0.0402	0.0161

[a] Days after planting

Table 2.4 Plant heights and nodes at pinhead square and first bloom heights, nodes, and nodes above white flower as affected by environment[ab].

Crop	Environment	Plant Height 40-42 DAP[bc]	Total Nodes 40-42 DAP[bc]	Plant Height 56-65 DAP[bc]	Total Nodes 56-65 DAP[bc]	NAWF[bd]
		cm	#	cm	——— # ———	
Cotton	BR 2012	28 b	7 c	75 b	15 ab	5.7 b
	BR 2013	43 a	10 b	93 a	16 a	7.7 a
	ST 2013	46 a	11 a	69 b	13 b	6.9 a
	STK 2012	40 a	10 b	77 b	15 ab	7.1 a
	STK 2013	43 a	10 ab	68 b	14 b	7.2 a
Soybeans	BR 2012	23 b	5.1 c	70 a	16 a	--
	BR 2013	40 a	9.2 a	71 a	13 b	--
	ST 2013	39 a	8.6 ab	65 a	12 b	--
	STK 2013	37 a	8.4 b	56 b	12 b	--

[a] Data were pooled over maturity group within each crop as no interactions due to maturity group were observed.

[b] Means within a column for each respective crop followed by the same letter are not significantly different based on Fisher's protected LSD at $p \leq 0.05$.

[c] Days after planting.

[d] Nodes above white flower.

Table 2.5 End of season plant heights, nodes, nodes above cracked boll, and yield as affected by environment[a].

Crop	Environment	Final Height[b]	Final Nodes[b]	NACB[bc]	Yield[b]	Length[b]	Uniformity[b]	Strength[b]	Mic[b]
		cm	——— # ———		kg ha^{-1}	cm	%	g tex^{-1}	
Cotton	BR 2012	111 ab	21 a	5.9 b	--	2.90 a	84.0 a	30.9 d	4.9 a
	BR 2013	108 ab	18 c	8.3 a	729 c	2.87 a	84.0 a	34.6 a	4.6 a
	ST 2013	97 b	20 b	3.9 c	681 c	2.79 a	83.0 a	33.1 b	5.0 a
	STK 2012	121 a	21 ab	6.3 b	1041 b	2.92 a	66.7 a	32.0 c	4.6 a
	STK 2013	93 b	17 d	7.8 a	1440 a	2.84 a	83.5 a	33.6 b	4.8 a
Soybeans	BR 2012	82 a	18 a	--	1546 b	--	--	--	--
	BR 2013	71 bc	16 b	--	1210 b	--	--	--	--
	ST 2013	76 ab	16 b	--	2083 a	--	--	--	--
	STK 2013	64 c	15 b	--	2419 a	--	--	--	--

[a] Data were pooled over maturity group within each crop as no interactions due to maturity group were observed.

[b] Means within a column for each respective crop followed by the same letter are not significantly different based on Fisher's protected LSD at $p \leq 0.05$.

[c] Nodes above cracked boll.

Table 2.6 Soybean quality as affected by environment and maturity[a].

Environment	Maturity Group	Test Weight[b]	Moisture[b]	Damage[b]	Splits[b]	Mold Damage[b]
		kg bu^{-1}	%			
BR 2012	MG IV	24 ab	11 e	1.5 c	1.1 bc	0.2 b
--	MG V	24 c	18 a	8.8 a	0.7 c	5.3 a
BR 2013	MG IV	24 bc	16 b	3.2 bc	0.6 c	0.5 b
--	MG V	25 ab	16 b	4.5 b	0.4 c	0.3 b
ST 2013	MG IV	24 c	12 de	1.7 c	1.4 bc	0.8 b
--	MG V	24 bc	13 d	3.3 bc	1.3 bc	0.7 b
STK 2013	MG IV	24 ab	14 c	1.7 c	3.1 a	0.6 b
--	MG V	25 a	14 c	2.0 bc	1.6 b	0.4 b

[a] Data were pooled over variety within each maturity group as no interactions due to variety were observed.

[b] Means within a column followed by the same letter are not significantly different based on Fisher's protected LSD at $p \leq 0.05$.

Table 2.7 Summary of estimated costs and returns per acre Cotton, 8R-38” solid, conservation tillage B2RF variety, Non-Delta Area, Mississippi, 2014

Item	Unit	Price	Quantity	Amount	Your Farm
		dollars		dollars	
INCOME					
Cotton Lint	lb	0.78	750.0000	588.75	
Cotton Seed	lb	0.10	1125.0000	120.38	

TOTAL INCOME				709.13	
DIRECT EXPENSES					
HARVEST AIDS	acre	11.13	1.0000	11.13	
GINNING	acre	82.50	1.0000	82.50	
FERTILIZERS	acre	105.85	1.0000	105.85	
FUNGICIES	acre	20.00	1.0000	20.00	
HERBICIDES	acre	54.42	1.0000	54.42	
INSECTICIDES	acre	34.88	1.0000	34.88	
SEED/PLANTS	acre	32.40	1.0000	32.40	
TECHNOLOGY FEE	acre	67.05	1.0000	67.05	
GROWTH REGULATORS	acre	1.92	1.0000	1.92	
CUSTOM FERTILIZE	acre	7.50	1.0000	7.50	
ERADICATION FEE	acre	1.00	1.0000	1.00	
INSECT SCOUTING	acre	7.00	1.0000	7.00	
CUSTOM LIME	acre	24.00	1.0000	24.00	
HAND LABOR	hour	9.06	0.7840	7.11	
OPERATOR LABOR	hour	12.50	1.5254	19.06	
UNALLOCATED LABOR	hour	12.53	1.2203	15.30	
DIESEL FUEL	gal	3.30	16.9211	55.82	
REPAIR & MAINTENANCE	acre	33.84	1.0000	33.84	
INTEREST ON OP. CAP.	acre	8.74	1.0000	8.74	

TOTAL DIRECT EXPENSES				589.52	
RETURNS ABOVE DIRECT EXPENSES				119.61	
TOTAL FIXED EXPENSES				122.54	

TOTAL SPECIFIED EXPENSES				712.06	
RETURNS ABOVE TOTAL SPECIFIED EXPENSES				-2.93	

Note: Cost of production estimates are based on 2013 input prices. **Fertilization decisions should be based on soil tests**. (MSU Cares 2014 Budget Report 2013-01 p. 61)

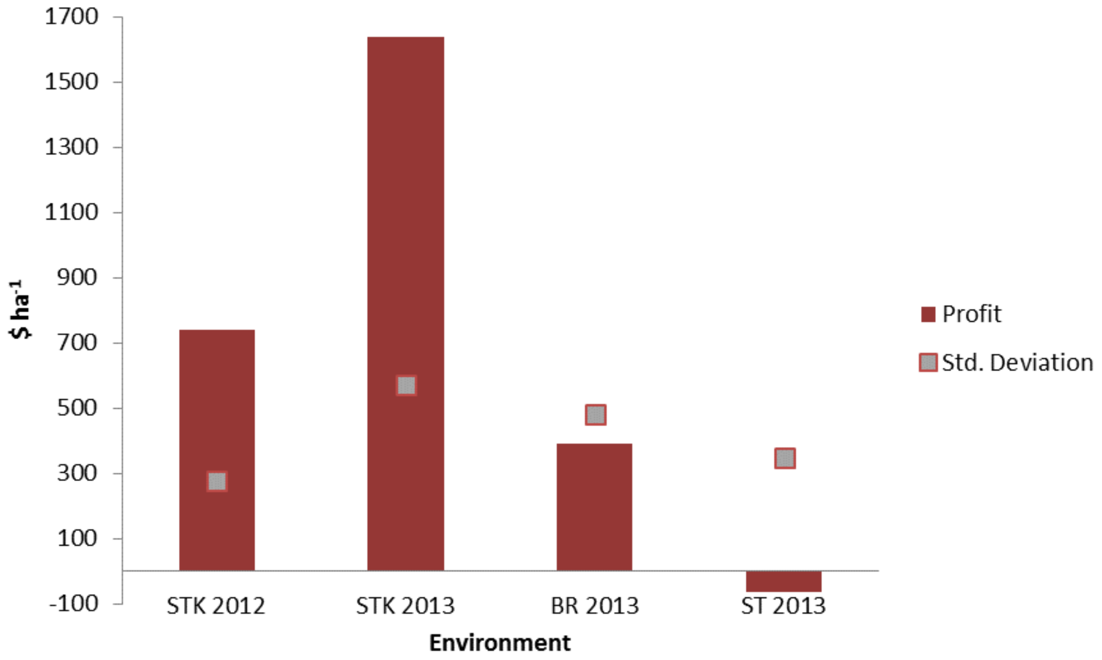

Figure 2.1 Cotton average profits with standard deviations ($ ha^{-1}) above variable costs as effected by environment.

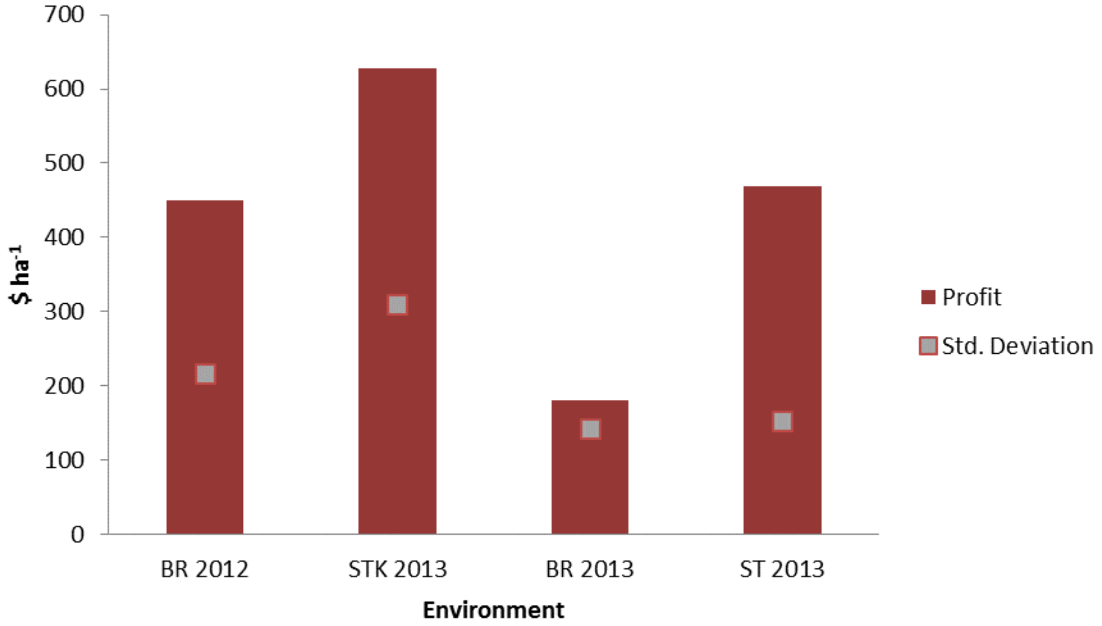

Figure 2.2 Soybean average profits with standard deviations ($ ha^{-1}) above variable costs as affected by environment.

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CHAPTER III

EVALUATION OF WHEAT STUBBLE MANAGEMENT AND COTTON SEEDING RATES FOLLOWING WHEAT PRODUCTION

Stubble Management

A primary decision when planting a crop following wheat production is determining how to manage wheat stubble after harvest. Residue management practices can influence soil loss (Hariston et al., 1894; Mutchler and Greer 1984) and factors that affect early season growth including: planting conditions, N immobilization, and phytotoxins from decomposing wheat straw (Hairston et al., 1987; Hicks et al., 1989). Burning, mowing, disking, and leaving the straw at harvest height are a few options producer's commonly utilize for managing wheat stubble. Planting directly into the existing stubble or no-tilling has been suggested as the optimum method of wheat stubble management when double-cropping cotton following wheat production (Bagwell et al., 2007). No-till will leave the most organic matter on the soil surface compared to other methods which can preserve moisture that can be beneficial for crop productivity when drought stress is likely. However, wheat straw may only be beneficial in conserving moisture on coarse textured soils compared to fine textured soils (Bond and Willis, 1971). Previous research has shown that wheat stubble height had no influence on lint yield. However, final cotton heights were significantly shorter in six and twelve inch stubble compared to stale seed beds or fields in which wheat stubble was burned prior to planting (Ferguson et al., 2008). A combine with a properly adjusted straw shredder or spreader set to spread the chaff uniformily may improve uniform stand establishment (Wesley, 1999a). In addition, weed control may be problematic when soybeans are planted into wheat straw (Sanford et al., 1973). Wheat straw can intercept herbicides, in turn decreasing efficacy as well as impairing cultivation equipment which has led many farmers to burn the straw (Kapusta, 1979; Sanford,1982; Sanford et al., 1973; Wesley and Cooke, 1988). Wesley and Cooke (1988) indicated that planting soybean no-till after burning wheat straw enhances net returns in the Mid-South. Further more, burning wheat straw may not result in long term effects on soil properties (Kelley and Sweeny, 1998).

Seeding Rates

Cotton seeding rates following wheat production are another factor to evaluate when double-cropping cotton following wheat. The additional costs associated with transgenic crops such as technology fees have increased input costs, and in turn, producers may reduce seeding rates as low as possible in order to optimize yield and increase profit (Pettigrew and Johnson, 2005). As with planting cotton early, double-cropped cotton following wheat production is also planted under risky conditions which adds complexity to the decision to lower or raise seeding rates as achieving an adequate stand is of paramount importance (Pettigrew 2002).

Low plant populations can cause delayed maturity (Bagwell et al., 2007). The recommended seeding rate for cotton planted under typical conditions is 128,000 seeds ha^{-1} (Buehring et al., 2009). However, cotton growers in Mississippi typically plant cotton seeds at 99,000 to 111,000 seeds ha^{-1} (Bridge et al., 1973). Bagwell et al. (2007) suggests increasing cotton seeding rates by 20% when planting into wheat stubble compared to seeding rates used when not double-cropping. Increased seeding rates facilitate adequate stand establishment and decreases the chance of delayed maturity. Also, with the shortened growing season associated with double-cropped cotton, it is important to have more first position fruiting structures due to the lack of heat units which are needed to mature second and third position fruiting strucures, hence the higher seeding rates (Barber Personal Communication). Jenkins et al. (1990) observed 90% of lint yield was obtained from fruiting positions one and two on sypodial branches which supports higher seeding rates based on increasing first position fruiting structures. However, Ball et al. (2000) reported no evidence to support greater seeding rates for double-cropped soybean. Additional studies have shown that lower seeding rates in early planted cotton should be avoided due to concerns of seed survival and uniform stand establishment (Pettigrew and Johnson, 2005). In addition, optimal plant density under stressful conditions has been observed to increase (Kerby et al., 1996).

Data is lacking on the interactions of wheat stubble management and seeding rates on cotton growth, development, and yield. Therefore, this research was established to evaluate the interactive effects of wheat stubble management and cotton seeding rates on cotton growth, development, and yield in a double-crop situation.

Materials and Methods

Studies were conducted at the R.R. Foil Plant Science Research Center in Starkville, MS and at the Black Belt Branch Experiment Station near Brooksville, MS in 2012 and 2013 to determine the effect of wheat stubble management and cotton seeding rates on cotton growth, development, and yield.

Agronomic Management

Plots consisted of four -97 cm rows that were 12.2 m in length. All treatments were replicated four times at each location. Stubble management techniques included: no-till planting into undisturbed wheat stubble (None); double disking followed by re-forming beds with a one-pass bedding implement (Re-bed); and burning stubble and planting without additional tillage (Burn). Delta and Pineland 0912 B2RF (Monsanto Company, 800 N. Lindbergh Blvd., St. Louis, MO 63167) was seeded at the following rates (planted seeds ha^{-1}): 49,400; 86,450; 123,500; and 160,550. Cotton seed treatment consisted of Acceleron N (Thiamethoxam + Pyraclostrobin + Ipconazole + Abamectin). Nitrogen was injected into the soil at 134 kg N ha^{-1} as 32% urea-ammonium nitrate (UAN) with a knife applicator. P_2O_5 and K_2O was applied at each location based on soil test recommendations for cotton at each location. Each plot was scouted with appropriate methodology on a weekly basis for weed and/or insect pests with all pesticide and defoliation applications applied according to Mississippi State University Extension Service recommendations. The Starkville location was irrigated as needed whereas the Brooksville location was rainfed only. Soil classifications were mapped as the following: the Starkville location was a Leeper silty clay loam (Fine, smectitic, nonacid, thermic Vertic Epiaquepts) and the Brooksville location was a Brooksville silty clay (Fine, smectitic, thermic Aquic Hapluderts. Wheat harvest dates, planting dates, nitrogen application dates, and cotton harvest dates are given in Table 3.1.

Data Collection

Data collection consisted of: stand counts; cotton height and total nodes at pinhead square; cotton height, total nodes and nodes above white flower (NAWF) at first bloom; height, nodes, and nodes above cracked boll (NACB) at harvest. Yield and fiber quality data were also collected. The center two rows of each plot were harvested with a cotton picker modified to harvest small plots and fiber quality was obtained from fiber collected from 25 hand collected boll samples collected immediately prior to harvest. Fiber quality was determined by High Volume Instrumentation (HVI) at the LSU AgCenter fiber testing labroratory. Lint yield was calculated from lint percent determined from ginning for each individual plot.

Statistical Analysis

Experiments were conducted using a split plot arrangement of treatments within a randomized complete plot design. Stubble management was the main plot and cotton seeding rate was the sub plot. All data were analyzed using the Proc Glimmix procedure in SAS 9.3. Means were separated using Fisher's protected LSD at α=0.05. Locations were treated as a random effect and data were pooled over experimental locations to allow for inferences about the treatments for a range of environments (Carmer et al., 1989; Dodds et al., 2010). No interactions between seeding rates and stubble management technique were present; however, each effect was independently significant for certain parameters. Analysis of variance p-values for first bloom heights, first bloom nodes, first bloom NAWF, final heights, final nodes, NACB and lint yields are given in Table 3.2.

Results and Discussion

Stand Emergence

Seeding rate significantly affected percent emergence at all dates stand counts were taken (Table 3.2). Stubble management only significantly affected percent emergence 11 to 12 DAP and 17 to 19 DAP (Table 3.2). Although unaffected by stubble management technique, percent emergence ranged from 39 to 47% 9 to 10 DAP (Table 3.3). Emergence based on cotton seeding rate ranged from 35 to 60% 9 to 10 DAP (Table 3.3). A cotton seeding rate of 49,400 seed ha^{-1} resulted in significantly greater plant emergence (60%) 9 to 10 DAP compared to all other seeding rates (Table 3.3). Emergence based on stubble management technique ranged from 37 to 50% 11 to 12 DAP. Stand counts 11 to 12 DAP indicated cotton planted into burned wheat stubble (50%) and cotton planted directly into standing wheat stubble (45%) resulted in significantly greater plant emergence than cotton planted into land that was re-bedded prior to planting (Table 3.3). Emergence based on seeding rate ranged from 38 to 60% 11 to 12 DAP with a seeding rate of 49,400 seed ha^{-1} resulting in significantly greater emergence (60%) compared to all other seeding rates (Table 3.3). Although unaffected by stubble management, emergence 13 to 14 DAP ranged from 60 to 62% (Table 3.3). Stand counts based on seeding rate indicated a seeding rate of 49,400 seed ha^{-1} resulted in significantly greater emergence (77%) compared to all other seeding rates 13 to 14 DAP (Table 3.3). Emergence based on stubble management technique ranged from 50 to 58% 17 to 19 DAP (Table 3.3). Cotton planted into burned wheat stubble resulted in significantly greater emergence (58%) compared to cotton that was planted into land re-bedded prior to planting 17 to 19 DAP (Table 3.3). Cotton planted directly into standing wheat stubble was not significantly different from that planted into burned wheat stubble or cotton that was planted into land re-bedded prior to planting 17 to 19 DAP (Table 3.3). Emergence based on seeding rate 17 to 19 DAP ranged from 47 to 70% with a seeding rate of 49,400 seed ha^{-1} again resulting in significantly greater emergence (70%) than all other seeding rates (Table 3.3). Reduced percent emergence could be attributed to wheat residue allelopathy as previous studies have observed up to a 21% reduction in cotton emergence depending on variety (Hicks et al., 1989). Furthermore, with increasing cotton seeding rates, a reduction in plant emergence has been observed possibly due to increased competition (Barber Personal Communication).

First Bloom Heights, Nodes, and NAWF

Cotton height at first bloom ranged from 66 to 68 cm with plants having 15 nodes regardless of wheat stubble management technique or cotton seeding rate. Stubble management significantly affected NAWF at first bloom (Table 3.4). Cotton grown on land that was re-bedded prior to planting had 6.7 NAWF at first bloom, which was significantly greater than cotton grown where no wheat stubble management was performed which had 6.4 NAWF (Table 3.4). Wheat stubble that was burned prior to cotton planting resulted in cotton with 6.6 NAWF at first bloom which was not significantly different than cotton grown where no wheat stubble management was performed or where land was re-bedded prior to cotton planting (Table 3.4). These results indicate that the greatest vegetative growth at first bloom occurred where land was re-bedded prior to cotton planting. Although significant differences did exist, they were minor. Cotton grown under normal conditions typically has 9 to 10 NAWF at first bloom (Edmisten, 1993). Lower NAWF counts could indicate stress is limiting growth whearas higher NAWF counts could be the result of excess nitrogen or poor fruit retention (Edmisten, 1993).

End of Season Height, Nodes and NACB

Seeding rates affected total nodes; however, both seeding rate and wheat stubble management both affected NACB, lint yield, and fiber strength (Table 3.5). Although unaffected by either wheat stubble management or cotton seeding rate, end of the season cotton height ranged from 88 to 91 cm (Table 3.5). Total nodes were unaffected by stubble management practice; however, total nodes were affected by cotton seeding rates and ranged from 19 to 20 at seeding rates of 49,400 and 160,550 seed ha^{-1}, respectively (Table 3.5). Cotton seeding rates of 49,400 seed ha^{-1} resulted in significantly greater total nodes at the end of the season than cotton seeding rates of 123,500 or 160,550 seed ha^{-1}. Total cotton nodes following seeding rates of 49,400 seed ha^{-1} were not significantly different from total cotton nodes from a seeding rate of 86,450 seed ha^{-1} (Table 3.5). Total nodes at the end of the season increased as seeding rates decreased; however, differences were minute. Nodes above cracked boll were affected by wheat stubble management practice and cotton seeding rate. Nodes above cracked boll ranged from 6.9 at a seeding rate of 123,500 seed ha^{-1} to 7.6 at seeding rates of 49,400 and 86,450 seed ha^{-1} (Table 3.5). Cotton seeding rates of 123,500 seed ha^{-1} resulted in the least amount of NACB; however, NACB counts at this seeding rate were not significantly different than NACB counts following cotton seeding rates of 160,550 seed ha^{-1} (Table 3.5). The two lower seeding rates of 49,400 seed ha^{-1} and 86,450 seed ha^{-1} resulted in the largest delay in maturity; however, NACB counts from these seeding rates were not significantly different from NACB counts following seeding rates of 160,550 seed ha^{-1} which tends to agree with previous research (Bagwell et al. 2007) (Table 3.5). Wheat stubble management affected NACB and counts ranged from 6.9 where cotton was planted into burned wheat stubble to 7.6 where cotton was planted into land re-bedded prior to planting (Table 3.5). Cotton planted into burned wheat stubble had significantly lower NACB than cotton planted into standing wheat stubble or land that had been re-bedded prior to planting (Table 3.5). Cotton planted into standing wheat stubble and land that had been re-bedded prior to planting resulted in delayed maturity, compared to cotton planted into burned wheat stubble. When NACB reaches four or lower it is considered safe to defoliate without yield loss from premature defoliation (Edmisten and Burmester, 1992).

Yield

Lint yield was affected by wheat stubble management and seeding rate (Table 3.5). Cotton lint yields ranged from 766 to 892 kg ha^{-1} with cotton planted into burned wheat stubble having significantly greater yields than cotton planted into standing wheat stubble which are similar to previous results observed in soybeans following wheat (Wesley and Cooke 1988); however, contrary to the finding of Bagwell et al. (2007) who suggest planting no-till directly into wheat stubble. However, lint yield from cotton planted into standing wheat stubble was not significantly different from cotton planted into land that had been re-bedded prior to planting (Table 3.5). Cotton lint yields ranged from 750 to 944 kg ha^{-1} depending on seeding rate (Table 3.5). Cotton seeding rates of 160,550 seed ha^{-1} resulted in significantly greater lint yields than cotton planted at all other seeding rates which is similar to results from previous research (Table 3.5) (Bagwell et al. 2007; Bednarz et al., 2000; Franklin et al., 2000; Pettigrew and Johnson 2005; Siebert et al., 2006; Siebert and Stewart 2006).

Fiber Quality

Fiber length was unaffected by cotton seeding rate or stubble management practice with fiber lengths ranging from 2.82 to 2.84 cm which would not warrant price deductions. Uniformity was significantly affected by stubble management and fiber strength was significantly affected by stubble management and seeding rate (Table 3.5) contrary to the finding of Baker (1987). Cotton planted into land that was re-bedded prior to planting had significantly greater uniformity at 83.8% than cotton planted into burned wheat stubble which had 83.4% uniformity (Table 3.5). Although significant differences did exist, all stubble management techniques resulted in high levels of uniformity. Cotton planted into standing wheat stubble as well as land that was re-bedded prior to planting had significantly greater strength than cotton planted into burned wheat stubble (Table 3.5). Seeding rates of 49,400 and 123,500 resulted in significantly greater fiber strength than fiber strength of cotton planted at a seeding rate of 86,450 seed ha^{-1}; however, fiber strength was similar for cotton planted at 49,400, 123,500, and 160,550 seed ha^{-1} (Table 3.5). Fiber strength was affected by both stubble management and seeding rate; although there were significant differences between treatments, these differences were minor. Micronaire was unaffected by cotton seeding rate or wheat stubble management practice and ranged from 4.8 to 4.9 which would not warrant price deductions (Table 3.5). Fiber quality data agree with Smith and Varvil (1982), who found that double-cropped cotton did not result in detrimental effects on fiber quality.

Conclusion

In conclusion, as seeding rates increased, percent emergence decreased. Additionally cotton planted into burned wheat stubble resulted in greater emergence compared to cotton planted into land that was re-bedded prior to planting. Cotton height at first bloom or the end of the season was unaffected by either stubble management or seeding rate. Based on yield data, growers should increase seeding rates by 20% compared to monocropped cotton when double-cropping cotton following wheat production, and burn the wheat stubble prior to planting to maximize yield. Although it did not reduce yield, disking the wheat stubble and re-bedding is not recommended due increased input costs and risk of moisture loss.

Table 3.1 Wheat harvest dates, planting dates, nitrogen application dates, and cotton harvest dates.

Environment	Wheat Harvest	Cotton/Soybean Planting	Nitrogen Application	Cotton Harvest
BR 2012	May 21, 2012	May 25, 2012	June 21, 2012	N/A
BR 2013	June 18, 2013	June 21, 2013	July 29, 2013	October 29, 2013
STK 2012	June 1, 2012	June 4, 2012	July 23, 2012	Novemer 28, 2012
STK 2013	June 12, 2013	June 14, 2013	July 29, 2013	November 7, 2013

Table 3.2 Analysis of variance p-values for percent emergence 9 to 19 days after planting, first bloom heights, first bloom nodes, first bloom nodes above white flower, final heights, final nodes, nodes above cracked boll and lint yields.

Source	Degrees of Freedom	9 to 10 DAP	11 to 12 DAP	13 to 14 DAP	17 to 19 DAP	First Bloom Heights	First Bloom Nodes	First Bloom NAWF	Final Heights	Final Nodes	NACB	Lint Yield	Fiber Length	Fiber Uniformity	Fiber Strength	Micronaire
Stubble Management	2	0.2647	0.0012	0.6246	0.0226	0.2346	0.3230	0.0233	0.4174	0.2660	0.0219	0.0364	0.2281	0.0256	0.0215	0.5300
Seeding Rate	3	0.0046	<.0001	<.0001	<.0001	0.9673	0.3153	0.3500	0.8483	0.0306	0.0274	0.0075	0.4202	0.0718	0.0310	0.1640
Stubble Management x Seeding Rate	6	0.9521	0.8836	0.1206	0.8952	0.5348	0.6050	0.8513	0.9357	0.9401	0.9986	0.7656	0.8026	0.2280	0.7080	0.8596

Table 3.3 Cotton percent emergence 9-19 days after planting based on stubble management and seeding rate[a].

Stubble Management	Seeding Rate	9 to 10 DAP[bc]	11 to 12 DAP[bc]	13 to 14 DAP[bc]	17 to 19 DAP[bc]
	seed ha^{-1}	%			
Burn		46 a	50 a	62 a	58 a
None		47 a	45 a	60 a	53 ab
Re-bed		39 a	37 b	60 a	50 b
	49400	60 a	60 a	77 a	70 a
	86450	40 b	40 b	56 b	49 b
	123500	40 b	38 b	54 b	48 b
	160550	35 b	38 b	54 b	47 b

[a] Data were pooled across experimental locations and years.
[b] Means within a column followed by the same letter are not significantly different based on Fisher’s protected LSD at $p \leq 0.05$.
[c] Days after planting.

Table 3.4 Cotton height, total nodes and nodes above white flower at first bloom (56 to 65 days after planting) as affected by stubble management and seeding rate[a].

Stubble Management	Seeding Rate	Height[b]	Node[b]	NAWF[bc]
	seed ha^{-1}	cm	#	
Burn	--	68 a	15 a	6.6 ab
None	--	67 a	15 a	6.4 b
Re-bed	--	66 a	15 a	6.7 a
--	49400	67 a	15 a	6.6 a
--	86450	67 a	15 a	6.6 a
--	123500	67 a	15 a	6.5 a
--	160550	68 a	15 a	6.4 a

[a] Data were pooled across experimental locations and years.

[b] Means within a column grouped with alike treatments (stubble management or seeding rate) followed by the same letter are not significantly different based on Fisher's protected LSD at $p \leq 0.05$.

[c] Node above white flower.

Table 3.5 End of season cotton height, nodes, nodes above cracked boll, lint yield, and fiber quality based on stubble management and seeding rate[a].

Stubble Management	Seeding Rate	Height[b]	Nodes[b]	NACB[bc]	Lint Yield[b]	Fiber Length[b]	Fiber Uniformity[b]	Fiber Strength[b]	Mic[b]
	seed ha^{-1}	cm	———— # ————		kg ha^{-1}	cm	%	g tex^{-1}	
Burn	--	88 a	20 a	6.9 b	892 a	2.82 a	83.4 b	31.6 b	4.8 a
None	--	91 a	20 a	7.5 a	766 b	2.82 a	83.5 ab	32.2 a	4.8 a
Re-bed	--	91 a	20 a	7.6 a	824 ab	2.84 a	83.8 a	32.1 a	4.9 a
--	49400	91 a	20 a	7.6 a	785 b	2.84 a	83.8 a	32.1 a	4.8 a
--	86450	90 a	20 ab	7.6 a	750 b	2.82 a	83.5 a	31.6 b	4.8 a
--	123500	89 a	19 b	6.9 b	831 b	2.84 a	83.6 a	32.3 a	4.9 a
--	160550	89 a	19 b	7.1 ab	944 a	2.82 a	83.4 a	31.6 ab	4.9 a

[a] Data were pooled across experimental locations and years.

[b] Means within a column grouped with alike treatments (stubble management or seeding rate) followed by the same letter are not significantly different based on Fisher's protected LSD at $p \leq 0.05$.

[c] Nodes above cracked boll

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CHAPTER IV

EVALUATION OF NITROGEN APPLICATION RATES AND PLANT GROWTH REGULATOR ON COTTON FOLLING WHEAT PRODUCTION

Nitrogen

Nitrogen fertilizer has the greatest impact on lint yield, earliness, and fiber quality in both dryland and irrigated cotton production; however, it is often not used efficiently by the crop even though it is often provided in high quantities (Hunt et al., 1998; Hutmacher et al., 2004). Due to recent increases in fertilizer price and increased volatility in the fertilizer market, more efficient N fertilizer use is needed (USDA-ERS, 2012). Nitrogen fertilizer is essential for cotton production; however, determining how much to apply is important in order to obtain proper vegetative growth without causing excess vegetative growth which can lead to boll rot and hard lock (Marois et al., 2011). In addition, cotton Nitrogen fertilizer needs may be affected by several factors including: residual Nitrogen fertilizer, soil Nitrogen transformations and dynamics, field history and previous crop growth, increasing yields and production technology, and environmental conditions (Howard et al., 2001).

Cotton height, total number of nodes, delayed maturity and lint yield are factors that N application rates have been shown to influence (Main et al., 2013). Increased cotton height and total nodes can delay maturity, by increasing the time required to mature uppermost fruit on the plant (Main et al., 2013). Previous research indicates boll weight is maximized following Nitrogen application rates of 134 kg N ha^{-1}. However, Nitrogen fertilizer application rates greater than 67 kg N ha^{-1} may not significantly increase lint yield. Increased yields following increased Nitrogen fertilizer rates was mainly due to increased boll numbers (Koziara et al., 2005). In addition, double-cropped cotton yield following wheat production was maximized when 67 kg N ha^{-1} was applied (Buehring, 2009). Additional research has also suggested similar results in that 23 kg N ha^{-1} per bale of expected yield is adequate to maximize yield (Main et al., 2013).

Plant Growth Regulator

Plant growth regulators (PGR's) are commonly used to improve square and boll retention, and manage vegetative and reproductive growth (Albers and Schnakenberg, 1994; Dodds et al., 2010). Reductions in cotton height and total number of mainstem nodes have been observed from applications of PGR's (Dodds et al., 2010; Kerby et al., 1998; Pettigrew and Johnson,2005). Contrary to these findings, (Zhao and Ooserhuis, 1999; Zhao and Oosterhuis, 2000) showed number of mainstem nodes were not affected by PGR applications. Limiting vegetative growth is critical because shading of the lower canopy from excessive vegetative growth may increase fruit shed (Dunlap, 1945).

Mepiquat chloride was the first plant growth regulator to make a significant impact in cotton production and is still used today. It is an anti-gibberellin which reduces the natural production of gibberellin in the plant that reduces cell growth. Reduced cellular growth, elongation, and division helps direct the energy from vegetative growth toward boll development and retention (Albers and Schnakenberg, 1994). Cotton yield responses to mepiquat chloride applications has been inconsistent (Dodds et al., 2010). Previous research has indicated increased cotton yield following application of mepiquat chloride (Cathey and Meredith, 1988; Kerby, 1985; Kerby et al., 1998; York, 1983a). Although Ebelhar et al., 1996 found an increasing yield response to applications of mepiquat chloride, the slight increase in yield would offer little economic benefit once application costs were factored in. In contrast, research has shown no yield response following mepiquat chloride application (Boman and Westerman, 1994; Kerby et al., 1986; Zhao and Oosterhuis, 2000) and yield reductions following PGR application have also been observed in other research (Cathey and Merideth, 1988; York, 1983a; York, 1983b; Zhao and Oosterhuis, 2000). Although increased earliness is a purported benefit from applications of mepiquat chloride, results are inconsistent (Boman and Westerman, 1994; Cathey and Merideth, 1988; Dodds et al., 2010; Kerby, 1985; Kerby et al., 1986; York, 1983a; York, 1983b).

Little published previous research exists on the interactive effects of Nitrogen rate and mepiquat chloride application on cotton growth, development, and yield of cotton grown following wheat production. Therefore, this research was conducted to determine the interactive effects of N fertilizer application and PGR application on cotton growth, development, and yield for cotton grown following wheat production.

Materials and Methods

Studies were conducted at the R.R. Foil Plant Science Research Center in Starkville, MS (STK) and at the Black Belt Branch Experiment Station near Brooksville, MS (BR) in 2012 and 2013 as well as the Delta Research Extension Center near Stoneville, MS (ST) in 2013 to determine the effect of Nitrogen application rate and plant growth regulator application on cotton growth, development, and yield.

Agronomic Management

Plots consisted of four-97 cm rows that were 12.2 meters in length in Starkville and Brooksville and four-102 cm rows that were 9.1 meters in length in Stoneville. Cotton variety DP 0912 B2RF (Monsanto Company, 800 N. Lindbergh Blvd., St. Louis, MO 63167) was planted 2 cm deep at 128,000 seed ha^{-1} into standing wheat stubble during 2012 and burned wheat stubble during 2013. Cotton seed treatment consisted of Acceleron N (Thiamethoxam + Pyraclostrobin + Ipconazole + Abamectin). Nitrogen application rates used in this study included : 0, 34, 67, 101, and 134 kg N ha^{-1}. Nitrogen was applied at pinhead square as 32% urea-ammonium nitrate (UAN) using a ground driven knife applicator. Mepiquat chloride (Mepex, Nufarm Americas Inc., 150 Harvester Drive, Burr Ridge, IL 60527) application rates consisted of (kg ai ha^{-1}) 0, 0.04 at pinhead square followed by 0.05 at first bloom, or a single application of 0.05 at first bloom. Each plot was scouted with appropriate methodology on a weekly basis for weed and/or insect pests with all pesticide and defoliation applications applied according to Mississippi State University Extension Service recommendations. P_2O_5 and K_2O was applied uniformly at each location based on soil test recommendations. The Starkville and Stoneville locations were irrigated as needed whereas the Brooksville location was dryland. Soil classifications were mapped as the following: the Starkville location was a Leeper silty clay loam (Fine, smectitic, nonacid, thermic Vertic Epiaquepts); the Brooksville location was a Brooksville silty clay (Fine, smectitic, thermic Aquic Hapluderts); and the Stoneville location a Bosket very fine sandy loam (Fine-loamy, mixed, active, thermic Mollic Hapludalfs). Wheat harvest dates, planting dates, nitrogen application dates, and cotton harvest dates are given in Table 4.1.

Data Collection

Data collection consisted of: stand counts; cotton height, and total nodes at pinhead square; cotton height, total nodes, and nodes above white flower (NAWF) at first bloom; cotton height, total nodes, and nodes above cracked boll (NACB) at harvest. Yield and fiber quality data were also collected. The center two rows of each plot were harvested using a spindle picker modified to harvest small plots. Fiber quality was obtained by a high volume instrument (HVI) from fiber collected from 25 hand collected boll samples immediately prior to harvest. Lint yield was calculated from lint percent determined from ginning for each individual plot.

Statistical Analysis

Experiments were conducted using a three (PGR rate- 0, 0.04 at pinhead square fb 0.05 at first bloom, or 0.05 kg ai ha^{-1} at first bloom) X five (N-rate- 0, 34, 67, 101, or 134 kg N ha^{-1}) factor factorial arrangement of treatments in a randomized complete block design with four replications. Previous researchers have used a similar statistical approach utilizing a factorial arrangement of treatments in a randomized complete block design (Bond et al., 2008; Dodds et al., 2010; Ottis et al., 2004; Walker et al., 2008). Data were analyzed by environment, N rate, and PGR application rate. Data were initially regressed on N rate and the most complex nonsignificant ($p>0.05$) model terms were removed sequentially and the model was refit until a satisfactory model was obtained. Previous researchers have utilized a smililar approach (Golden et al. 2006). All statistical analyses were conducted using the Proc Mixed procedure in SAS 9.3. Analysis of variance p-values for first bloom heights, first bloom nodes, first bloom nodes above white flower, final heights, final nodes, nodes above cracked boll, and lint yields are given in Table 4.2.

Results and Discussion

First Bloom Heights, Nodes, and NAWF

The overall model as affected by N rate for all data collected at first bloom including: cotton height, total nodes, and NAWF was non-linear; however, only the STK 2012 location resulted in a significant quadratic coefficient for first bloom cotton heights and NAWF (Tables 4.2, 4.3, 4.4, and 4.5). The linear and non-linear coefficients were significantly greater for the STK 2012 location compared to other environments for first bloom cotton heights and NAWF (Tables 4.2, 4.3, and 4.5). Cotton grown at the STK 2012 location also had a significantly greater linear coefficient compared to other environments for total nodes at first bloom (Table 4.4). Cotton height at first bloom was maximized (68 cm) with 119 kg N ha^{-1} and NAWF was greatest (7.3) with 100 kg N ha^{-1} at the STK 2012 location (Tables 4.3 and 4.5). First bloom data varied little within environment across all N rates.

End of Season Heights, Nodes, and NACB

The overall model for end of season cotton heights and total nodes as affected by N rate was non-linear, and the model for NACB as affected by N rate was linear (Table 4.2). All environments resulted in a significant quadratic coefficient for end of season cotton heights; however, BR 2013 was the only environment to result in a non-significant linear coefficient (Table 4.6). Cotton heights at the BR 2013 location were maximized (76 cm) with 48 kg N ha^{-1}; heights at the ST 2013 location were maximzed (80 cm) with

91 kg N ha^{-1}; and heights at the STK 2013 location were maximized (77 cm) with 81 kg N ha^{-1} (Table 4.6). Cotton heights at the BR 2012 and STK 2012 locations did not reach a maximum height within the tested N rates (Table 4.6). Again, the overall model for end of season total nodes was non-linear; however, only the BR 2013, ST 2013, and STK 2013 locations resulted in a significant quadratic coefficient with respect to total nodes (Table 4.2 and 4.7). Total nodes at the BR 2013 location were maximized (16.7) with 69 kg N ha^{-1}; total nodes at the ST 2013 location were maximized (17.4) with 113 kg N ha^{-1}; and total nodes at the STK 2013 location were maximized (17.3) with 88 kg N ha^{-1} (Table 4.7). All environments resulted in a significant linear coefficient for end of the season total nodes (Table 4.7). Final cotton heights and total nodes both followed quadratic trends, which indicates heights were positively linear; however, at higher N rates, end of season cotton height and total nodes started to decline with the exception of the BR 2012 and STK 2012 locations. Data for NACB resulted in an overall linear model which is similar to previous observations (Main et al., 2013), although the BR 2013 and ST 2013 locations resulted in a non-significant linear coefficient (Table 4.2 and 4.8). Data for NACB resulting in a linear trend indicates that as N rate increased, so did the number of NACB which in turn resulted in delayed maturity. End of the season data displayed slightly more variation within each environment; however, these results are not shown graphically.

Yield

Mepiquat chloride application had no effect on lint yield with the exception of the STK 2013 location and application of 0.05 kg ai ha^{-1} mepiquat chloride. No yield response has been previously reported (Boman and Westerman, 1994; Kerby et al., 1986;

Zhao and Oosterhuis, 2000). These results are contrary to those of Bagwell et al. (2007) who found that PGR applications should be delayed until first bloom; however, PGR's should be applied on a field to field basis and based on plant growth and development not strictly on growth stage of the plant. The use of PGRs can lead to indirect benefits such as managing plant height which can lead to more consistent control from herbicides and insecticides and may eliminate the need for multiple pesticide applications. Lint yield for the BR 2013, ST 2013, STK 2012, and STK 2013 (0 and 0.04 + 0.05 kg ai ha^{-1} mepiquat chloride) locations as affected by N rate followed an overall linear model, whereas lint yields from the STK 2013 (0.05 kg ai ha^{-1} mepiquat chloride) location followed an overall non-linear model as affected by N rate, mepiquat chloride application, and environment that was maximized at 67 kg N ha^{-1} (Tables 4.2 and 4.9 and Fig. 4.1). This environment and PGR rate interaction with respect to lint yield based on N rate is consistent with the findings of Buehring (2009) who found that 67 kg ha^{-1} is adequate to maximize yield of double-cropped cotton; however, yields at other environments were not maximized at 67 kg N ha^{-1}. Lint yield from cotton grown at STK 2013 (0 and 0.04 + 0.05 kg ai ha^{-1}) resulted in a non-significant linear coefficient; however, all other environments had a significant linear coefficient (Table 4.9 and Fig. 4.1). Lint yields for the ST 2013 and STK 2012 locations were both positively sloped and yield increased at a rate of 2.3 and 4.6 kg of lint per kg of N applied, respectively (Table 4.9 and Fig. 4.1). The BR 2013 location resulted in a negative linear slope that decreased at a rate of 1.9 kg of lint per kg of N applied (Table 4.9 and Fig. 4.1). The negatively sloped linear trend for the BR 2013 location could be influenced by the late planting date. In 2013, the ST 2013 location was planted the day before the BR 2013 location which could cause the smaller slope coefficient which in turn indicates reduced yields compared to the STK 2012 and STK 2013 locations at higher N application rates.

Conclusion

Lint yields for the most part were never maximized within the tested N rates. Overall, results from this study were variable and highly dependent upon the environment as the environment significantly affected all parameters measured. Lint yield data do not indicate a definitive N rate to maximize cotton lint yield following wheat production; however, a full N rate for normal planted cotton would not be recommended as NACB steadily increased with each N rate increase, again which further delayed maturity and increased the potential for yield loss due to the unpredictability of weather during harvest. Lint yield was not affected by PGR application rate, although it is not recommended to eliminate PGR’s altogether.

Table 4.1 Wheat harvest dates, planting dates, nitrogen application dates, and cotton harvest dates.

Environment	Wheat Harvest	Cotton Planting	Nitrogen Application	Cotton Harvest
BR 2012	May 21, 2012	May 25, 2012	June 21, 2012	N/A
BR 2013	June 18, 2013	June 21, 2013	July 29, 2013	October 29, 2013
ST 2013	June 19, 2013	June 20, 2013	July 30, 2013	November 11, 2013
STK 2012	June 1, 2012	June 4, 2012	July 23, 2012	Novemer 28, 2012
STK 2013	June 12, 2013	June 14, 2013	July 29, 2013	November 7, 2013

Table 4.2 Analysis of variance p-values for first bloom heights, first bloom nodes, first bloom nodes above white flower, final heights, final nodes, nodes above cracked boll, and lint yields.

Source	Degrees of Freedom	First Bloom Heights	First Bloom Nodes	First Bloom NAWF[c]	Final Heights	Final Nodes	NACB[d]	Lint Yield[a]	Lint Yield[b]
Env	4 or 3 or 1Ψ	<.0001	0.0003	<.0001	<.0001	0.0047	<.0001	<.0001	<.0001
Pix rate	2 or 1∞	<.0001	<.0001	<.0001	<.0001	<.0001	0.0246	--	--
Pix rate x Env	7 or 6 or 1	--†	--	--	--	--	--	--	--
Linear N-rate	1	0.0016	0.0188	0.0024	<.0001	<.0001	<.0001	--	0.0029
Linear N-rate x Env	4 or 3 or 1	<.0001	<.0001	<.0001	<.0001	--	<.0001	--	--
Linear N-rate x Pix rate	2	--	--	--	--	--	--	--	--
Linear N-rate x Pix rate x Env	7 or 6 or 1	--	--	--	--	--	--	<.0001	--
Quadratic N-rate	1	--	--	0.0381	0.0086	--	--	--	0.0021
Quadratic N-rate x Env	4 or 3 or 1	0.0006	0.0036	0.0001	--	<.0001	--	--	--
Quadratic N-rate x Pix rate	2	--	--	--	--	--	--	--	--
Quadratic N-rate x Pix rate x Env	7 or 6 or 1	--	--	--	--	--	--	--	--

[a] Represents lint yields with 0 kg ai and 0.04 + 0.05 kg ai ha^{-1} mepiquat chloride.

[b] Represents lint yields with 0.05 kg ai ha^{-1} mepiquat chloride.

[†] Was not significant in the final model.

[c] Nodes above white flower.

[d] Nodes above cracked boll

Ψ Environment had 4 degrees of freedom for first bloom heights, first bloom nodes, first bloom NAWF, final heights, final nodes, and NACB; 3 degrees of freedom for Lint yield[a] and; 1 degree of freedom for lint yield[b].

∞.Pix rate had 2 degrees of freedom for first bloom heights, first bloom nodes, first bloom NAWF, final heights, final nodes, NACB, and Lint yield[a] and; 1 degree of freedom for lint yield[b].

Table 4.3 Coefficients for first bloom heights as affected by environment.

Environment	Intercept	Linear	Quadratic
		Coefficient†	
BR 2012	55.1968	0.09354‡	-0.00037‡
Std. Error	2.3019	0.05794	0.000463
BR 2013	67.0042	0.04186‡	-0.00054‡
Std. Error	4.6886	0.1320	0.000866
ST 2013	64.5156	-0.01326‡	0.000185‡
Std. Error	2.6580	0.06690	0.000535
STK 2012	43.7476	0.4596	-0.00216
Std. Error	2.3023	0.05872	0.000470
STK 2013	60.9689	-0.01251‡	0.000084‡
Std. Error	2.3071	0.05884	0.000469

† Where Y = first bloom heights (cm) and x= N rate (kg N ha^{-1}).

‡ Coefficient is not significantly different from zero.

Table 4.4 Coefficients for first bloom nodes as affected by environment.

Environment	Intercept	Linear	Quadratic
	——————Coefficient†——————		
BR 2012	13.6143	0.004696‡	0.000011‡
Std. Error	0.2406	0.007141	0.000057
BR 2013	15.6208	-0.00814‡	0.000032‡
Std. Error	0.5580	0.01627	0.000107
ST 2013	13.3029	-0.00145‡	5.291E-6‡
Std. Error	0.2778	0.008246	0.000066
STK 2012	12.7556	0.04925	-0.00024‡
Std. Error	0.2406	0.007236	0.000058
STK 2013	13.6564	0.008065‡	-0.00005‡
Std. Error	0.2413	0.007248	0.000058

† Where Y = first bloom nodes and $x^{=}$ N rate (kg N ha^{-1}).

‡ Coefficient is not significantly different from zero.

Table 4.5 Coefficients for nodes above white flower at first bloom as affect by environment.

Environment	Intercept	Linear	Quadratic
	Coefficient†		
BR 2012	5.7273	-0.00104‡	0.000034‡
Std. Error	0.1746	0.005761	0.000046
BR 2013	7.4549	-0.00061‡	0.000017‡
Std. Error	0.4281	0.01270	0.000083
ST 2013	6.1500	0.009963‡	-0.00007‡
Std. Error	0.1954	0.006440	0.000051
STK 2012	5.3027	0.04441	-0.00025
Std. Error	0.1692	0.005650	0.000045
STK 2013	6.9224	0.000919‡	1.572E-6‡
Std. Error	0.1698	0.005659	0.000045

† Where Y = first bloom NAWF and x= N rate (kg N ha^{-1}).

‡ Coefficient is not significantly different from zero.

Table 4.6 Coefficients for final heights as affected by environment.

Environment	Intercept	Linear	Quadratic
	Coefficient†		
BR 2012	61.4237	0.2610	-0.00069
Std. Error	2.5983	0.03686	0.000265
BR 2013	74.2947	0.05913‡	-0.00069
Std. Error	3.2840	0.04771	0.000265
ST 2013	75.6348	0.1121	-0.00069
Std. Error	2.9877	0.03841	0.000265
STK 2012	51.8955	0.3976	-0.00069
Std. Error	2.5991	0.03686	0.000265
STK 2013	73.6012	0.1002	-0.00069
Std. Error	2.6065	0.03706	0.000265

† Where Y = final heights (cm) and x= N rate (kg N ha^{-1}).

‡ Coefficient is not significantly different from zero.

Table 4.7 Coefficients for final nodes as affected by environment.

Environment	Intercept	Linear	Quadratic
	——Coefficient†——		
BR 2012	17.3474	0.02212	0.000029‡
Std. Error	0.2913	0.005533	0.000049
BR 2013	16.0439	0.02212	-0.00018
Std. Error	0.3585	0.005533	0.000046
ST 2013	16.3378	0.02212	-0.00011
Std. Error	0.3311	0.005533	0.000051
STK 2012	15.7456	0.02212	0.000089‡
Std. Error	0.2917	0.005533	0.000049
STK 2013	16.4396	0.02212	-0.00014
Std. Error	0.2931	0.005533	0.000049

† Where Y = final nodes and x= N rate (kg N ha^{-1}).

‡ Coefficient is not significantly different from zero.

Table 4.8 Coefficients for nodes above cracked boll at the end of the season as affected by environment.

Environment	Intercept	Linear
	Coefficient†	
BR 2012	1.3908	0.02047
Std. Error	0.3108	0.003123
BR 2013	7.6333	-0.00461‡
Std. Error	0.4191	0.004416
ST 2013	2.5404	0.004944‡
Std. Error	0.3589	0.003606
STK 2012	3.6606	0.01733
Std. Error	0.3114	0.003123
STK 2013	6.9728	0.01019
Std. Error	0.3130	0.003164

† Where Y = end of season NACB and x= N rate (kg N ha^{-1}).

‡ Coefficient is not significantly different from zero.

Table 4.9 Coefficients for lint yields as affected by environment and PGR rate.

Environment	Intercept	Linear	Quadratic
	———Coefficient†———		
BR 2013	588.85	-1.8637	--
Std. Error	67.3958	0.7267	--
ST 2013	674.36	2.2938	--
Std. Error	56.6090	0.5933	--
STK 2012	598.20	4.6458	--
Std. Error	49.1164	0.5139	--
STK 2013[a]	1460.47	-1.0088‡	--
Std. Error	57.6370	0.6421	--
STK 2013[b]	1362.15	12.6997	-0.1063
Std. Error	100.75	3.5319	0.02822

† Where Y = lint yield (kg ha^{-1}) and x = N rate (kg N ha^{-1}).

‡ Coefficient is not significantly different from zero.

[a] Represents yields with 0 kg ai and 0.04 + 0.05 kg ai ha^{-1} mepiquat chloride.

[b] Represents yields with 0.05 kg ai ha^{-1} mepiquat chloride.

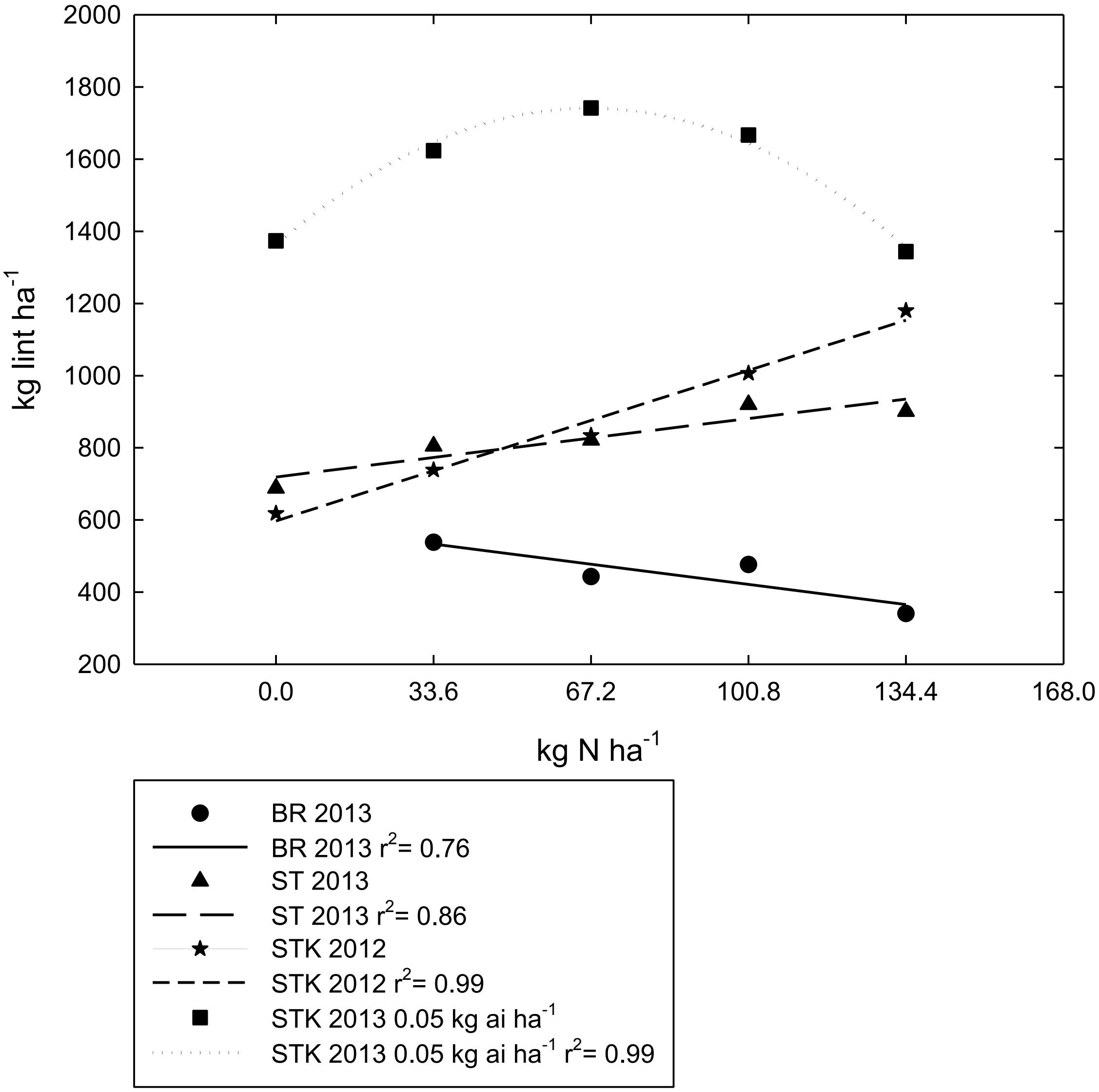

Figure 4.1 Lint yields as affected by environment, N rate, and PGR rate and their interations at Starkville in 2012 (STK 2012) and Brooksville (BR 2013), Stoneville (ST 2013), and Starkville (STK 2013) in 2013.

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