EFFECT OF WEED MANAGEMENT ON FRUITING POSITION AND YIELD OF

ROUNDUP READY FLEX COTTON

Except where reference is made to the work of others, the work described in this thesis is my own or was done in collaboration with my advisory committee. This thesis does not include proprietary or classified information.

____
John Kade Haas

Certificate of Approval:

C. Dale Monks
Professor
Agronomy and Soils

Michael G. Patterson, Chair
Professor
Agronomy and Soils

David B. Weaver
Professor
Agronomy and Soils

David H. Teem
Professor
Agronomy and Soils

Stephen L. McFarland
Dean
Graduate School

EFFECT OF WEED MANAGEMENT ON FRUITING POSITION AND YIELD OF ROUNDUP READY FLEX COTTON

John Kade Haas

A Thesis

Submitted to

the Graduate Faculty of

Auburn University

in Partial Fulfillment of the

Requirements for the

Degree of

Master of Science

Auburn, Alabama
August 7, 2006

EFFECT OF WEED MANAGEMENT ON FRUITING POSITION AND YIELD OF

ROUNDUP READY FLEX COTTON

John Kade Haas

____
Signature of Author

____
Date of Graduation

VITA

John Kade Haas, son of Bill Haas and Michelle Page Haas, was born November 10, 1980, in Huntsville, Alabama. He graduated from Madison County High School in May 1999. He attended Snead State Community College in Boaz, Alabama, for two years, and entered Auburn University in August of 2001. He graduated with a Bachelor of Science degree in Agronomy and Soils (Science Option) in December 2003. In January 2004, he entered Graduate School at Auburn University where he was appointed to a Graduate Research Assistantship and Graduate Teaching Assistantship. He received a Master of Science degree in Agronomy and Soils (Weed Science) in August, 2006.

THESIS ABSTRACT

EFFECT OF WEED MANAGEMENT ON FRUITING POSITION AND YIELD OF

ROUNDUP READY FLEX COTTON

John Kade Haas

Master of Science, August 7, 2006
(B.S., Auburn University, 2003)

50 Typed Pages

Directed by Michael G. Patterson

Roundup Ready Flex cotton was commercially available in 2006 and growers need production information about this new technology. Field trials were conducted at the Prattville Experiment Field, Prattville, AL and the Field Crops Unit, Shorter, AL in 2005 to evaluate the influence of 10 weed management systems on fruiting position and yield of Roundup Ready Flex Cotton (*Gossypium hirsutum* L.). Individual treatments consisted of glyphosate (Roundup Weather Max) at a rate of 1.0 kg ai/ha either alone, with a preemergence herbicide (PRE), or as a tank mix with other postemergence (POST) herbicides. Glyphosate applications were made at weed growth stages of 5 to 7.6 cm, 10 to15.2 cm, and 17.8-22.8 cm for Treatments 1, 2, and 3 respectively. Glyphosate was tank-mixed with acephate (Orthene) and mepiquat chloridide (Pix) for Treatment 4. Treatment 5 consisted of fluometuron (Cotoran) applied PRE followed by (fb) glyphosate

+ pyrithiobac (Staple) fb glyphosate at a weed heights of 5-7.6 cm. Treatment 6 received fluometuron + pyrithiobac PRE fb glyphosate at 5-7.6 cm tall weeds. Treatment 7 applications included glyphosate fb trifloxysulfuron (Envoke) + nonionic surfactant (NIS) fb glyphosate when weeds reached 5-7.6 cm. Treatment 8 received glyphosate + pyrithiobac fb trifloxysulfuron + NIS fb glyphosate at weed heights of 5-7.6 cm. Applications for treatment 9 included glyphosate + metolachlor (Dual Magnum) fb trifloxysulfuron + NIS at 5-7.6 cm tall weeds. Treatment 10 consisted of pendimethalin (Prowl) PRE fb glyphosate when weed reached a height of 5-7.6 cm. Plots consisted of four rows 7.7 m in length with 91 cm between rows. Treatments were applied in 140 L/ha and replicated four times. Box mapping (fruiting position) was obtained from 3m of the middle right row of each plot. Significant treatment differences for weed control were obtained for grasses (50% *Digitaria* spp. and 50% *Eleusine indica* (L.) Gaertn, *Ipomoea hederacea* var. *intergriuscula* Gray, and *Amaranthus spinosus* L. The numerically highest seed cotton yields were obtained with Treatment 6 at FCU (2665 kg ha^{-1}) and Treatment 5 at PEF (2921 kg ha^{-1}). Treatment 3, where glyphosate application was delayed until weeds reached 17.8-22.8 cm in height, had lower yields caused by a reduction in boll number and boll weight at the lower nodes. Some compensation occurred because cotton produced more bolls at higher nodes. The addition of pyrithiobac to glyphosate fb trifloxysulfuron tended to adversely affect yield and fruiting at both trial locations. Fluometuron PRE fb glyphosate did not adversely affect yield or fruiting position.

ACKNOWLEDGEMENTS

The author wishes to express his love and appreciation to his parents, Bill and Page Haas, for their support and encouragement during graduate school. He would like to express his thanks to his mother for assisting in editing of this manuscript and his father for all the words of encouragement. He would also like to express his thanks to Dr. Mike Patterson, Dr. David Teem, Dr. David Weaver, Dr. Dale Monks, Dr. Edzard van Santen, Dr. Steven Noffsinger, Mr. Buford Murphy, Mr. Don Moore, and Mr. Bobby Durbin. The author would like to thank these men for the guidance they provided, not only in his academic career but also in life. He would also like to express his appreciation to the faculty and staff of the Agronomy and Soils Department for making this experience an enjoyable one. Finally, he would like to express his love and thanks to his family and friends for their encouragement they provided during his studies.

Style manual or journal used Weed Technology: Journal of the Weed Science Society of America.

Computer software used Microsoft Word, The SAS System for Windows v 9.1, and Agriculture Research Manager.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

EFFECT OF WEED MANAGEMENT ON FRUITING POSITION AND YIELD OF ROUNDUP READY FLEX COTTON[1]

John Kade Haas[2]

Abstract. Roundup Ready Flex cotton was commercially available in 2006 and growers need production information about this new technology. Field trials were conducted at the Prattville Experiment Field (PEF), Prattville, AL and the Field Crops Unit (FCU), Shorter, AL in 2005 to evaluate the influence of 10 weed management systems on fruiting position and yield of Roundup Ready Flex Cotton (*Gossypium hirsutum* L.). The numerically highest seed cotton yields were obtained with Treatment 6 at FCU (2665 kg ha^{-1}) and Treatment 5 at PEF (2921 kg ha^{-1}). Treatment 6 received a single PRE application of fluometuron + pyrithiobac fb a single application of glyphosate at a weed height of 5 to 7.6cm. This treatment provided > 90% weed suppression throughout the growing season. Early season weed competition was eliminated with the PRE application, which provided the cotton time to produce and set bolls. Treatment 5 consisted of fluometuron PRE fb POT applications of glyphosate + pyrithiobac fb

[1] Received for publication _______________, and in revised form _____________.

[2] Grad. Res. Assist., Dept. Agron. and Soils and Alabama Agric. Exp. Stn., Auburn Univ., Auburn, AL 36849-5412

Corresponding author's e-mail: haasjoh@auburn.edu

glyphosate at weed heights of 7.6 cm and 15 cm. This treatment yielded significantly more than all other treatments at PEF (Table 3). Treatment 3 was the lowest yielding treatment at FCU (1673 kg ha^{-1}), whereas Treatment 10 had the lowest yield at PEF (1857 kg ha^{-1}). Treatment 3 received two POT applications of glyphosate when weeds were at a height of 17.7 to 22.8 cm. The delayed applications had a significant effect on seed cotton yield which is probably due to weed competition causing plants to not produce bolls on lower and middle nodes. Treatment 10 produced the lowest yield of all treatments for the study at PEF with a seed cotton yield of 1875 kg ha^{-1} and was significantly lower than our standard Treatment 1. Treatment 10 consisted of pendimethalin applied PRE and one POT application of glyphosate when weeds were 7.6 cm tall. Since Treatment 10 provided > 80% control of the weeds present, yield loss can be attributed to mid and late season weed competition.

The standard (Treatment 1) received three applications of glyphosate applied POT to weeds 2.5 to 10 cm tall and ranked 2nd at both locations. Treatment 3 at FCU ranked 10th due to delayed weed control (17.7 to 22.8 cm tall) and high weed pressure; while at PEF, it ranked 3rd due to reduced overall weed pressure. Treatment 8, which received glyphosate + pyrithiobac fb trifloxysulfuron fb glyphosate, ranked 8th at FCU and 9th at PEF in overall yield due to possible sulfonylurea injury. Trifloxysulfuron showed the same effect on Treatments 7 and 9 at FCU. Since herbicide application was made on the same date, injury was possibly due to sulfonylurea injury. Treatment 10 received pendimethalin PRE and one application of glyphosate at weed heights of 5 to 7.6 cm and ranked 10th overall due to poor late season weed control.

INTRODUCTION

Traditionally, weed management in cotton has been achieved by using herbicides in both preemergence and postemergence directed applications. Prior to 1980, most cotton was grown under conventional tillage systems, with in-season mechanical cultivation and postemergence herbicides for weed management following crop establishment. In the 1940s, herbicidal oils were applied to small weeds and the base of the cotton plant for weed control. Diuron was introduced in 1951 for control of broadleaf weeds and was the first selective herbicide in cotton. In 1961, trifluralin was brought onto the market for the control of grasses and small seeded broadleaf weeds in cotton. Fluometuron, released in 1963, became the dominant preemergence herbicide in the Southeastern U.S. and virtually ended manual weed control. By 1996, 80% of cotton in the Southeast was treated with fluometuron.

In 1997, Monsanto Company (St. Louis, MO) released Roundup Ready[3] cotton, which introduced the technology for cotton to tolerate postemergence applications of glyphosate up to the four leaf stage. The introduction of this technology provided growers with a potential tool for a weed management system that relies solely on postemergent herbicides, without the necessity for preemergence herbicides or mechanical cultivation. However, this technology has limiting factors that do not allow a total POT management system. Glyphosate applications POT on Roundup Ready cotton can only be applied up

[3] Roundup Ready is a trademark of Monsanto Company, St. Louis, MO 63189

to the four-leaf development stage. Postemergence directed spray (PDS) applications are made throughout the remainder of the growing season. During the POT application window, at least ten days and two nodes of growth are required between applications according to the manufacturer's label. When applied beyond the four-leaf stage, glyphosate can cause abnormal flowers with stunted filaments and anthers that do not release pollen. The result is a lack of pollination and boll abortion, resulting in potential yield loss.

The narrow application window prompted Monsanto to construct a new promoter and combine it with the gene already in commercial production. The new generation cotton, Roundup Ready Flex[4], can tolerate multiple applications of glyphosate POT throughout the growing season without interfering with male flower development and causing boll abortion. Thus, the POT application of glyphosate to Roundup Ready Flex cotton is not limited to early growth stages and can be used throughout the growing season. There are no restrictions on timing of applications. With this new technology, the potential to manage weeds with a total POT system is now more feasible.

LITERATURE REVIEW

Cotton Production. Cotton [*Gossypium hirsutum* L. # GOSHI] was being grown in Alabama by the mid to late 1700s with approximately 1.62 million hectares of cotton grown in the state by 1914 (Mitchell, 1996). Cotton is currently planted on more total land area than any other row crop in Alabama acreage and comprised over 5.67 million hectares of cropland in the United States in 2005 (USDA). Producers in Alabama harvested more than 220,000 hectares of cotton in 2005, yielding 848,000 bales (USDA).

[4] Roundup Ready Flex is a trademark of Monsanto Company, St. Louis, MO 63189

The total value of cotton harvested in Alabama in 2005 was $201 million (U.S.D.A. 2005).

Weed Management. Herbicide programs for cotton producers in the Southeastern U.S. often begin with applications of multiple herbicides applied preplant incorporated (PPI) and/or preemergence (PRE) at planting followed by (fb) a postemergence over-the-top (POT) herbicide and concluded with a soil applied POST-directed spray herbicide (Culpepper and York, 1998; Faircloth et al., 2001; Jordan et al., 1997). Prior to 1980, most cotton was grown using conventional tillage systems with in-season mechanical cultivation and postemergence herbicides for weed management following crop establishment. In the 1940s, herbicidal oils were applied to small weeds and the base of the cotton plant for weed control. Diuron was introduced in 1951 for control of broadleaf weeds and was the first selective herbicide in cotton. In 1961, trifluralin was brought onto the market for the control of grasses and small seeded broadleaf weeds in cotton. Fluometuron, released in 1963, became the dominant preemergence herbicide and virtually ended manual weed control. By 1996, 80% of cotton in Alabama was treated with fluometuron (Patterson, 2005). Although these herbicides improved weed management in cotton, trifluralin and fluometuron did not provide season-long control (Culpepper and York, 1998).

While growers prefer to apply herbicides such as fluometuron, MSMA (monosodium acid methanearsonate), and DMSA (disodium acid methanearsonate) POT to cotton, these herbicides have been shown to cause excessive crop injury, delayed maturity, and yield reductions (Byrd and York, 1987; Culpepper and York, 1998; Faircloth et al., 2001; Pankey et al., 2004). Crop injury is not the only problem associated with traditional weed management programs. Post-directing herbicides to small cotton is a very time-consuming task (York et al., 2004) and specialized spray equipment is needed to make applications.

Glyphosate and Roundup Ready Cotton. Glyphosate, formulated as a monoisopropylamine salt, was developed by Monsanto Company in 1970. Glyphosate became commercially available in 1974 under the trade name Roundup® (Franz et al., 1997). This herbicide is the most widely labeled agricultural chemical product in U.S. history and the only herbicide to be named by Farm Chemicals magazine as one of the top ten products to have the greatest effect on agriculture in the last 100 years (Franz et al., 1997; Monsanto, 2005).

Glyphosate effectively controls a broad spectrum of weeds from annual and perennial grasses to broadleaf weeds and is also noted as an environmentally benign herbicide (Culpepper et al., 2004; Franz et al., 1997). Glyphosate, which binds to the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSP synthase) in the shikimate acid pathway of plants, is generally considered a nonselective herbicide (McCloskey et al., 2004). By binding to the EPSP synthase and forming an EPSPS-shikimate-3-phosphate-glyphosate complex, glyphosate inhibits the biosynthesis of the aromatic amino acids phenylalanine, tyrosine, and tryptophan, which are responsible for protein production and plant growth (McCloskey et al., 2004; Viator et al., 2003). Non-transgenic plants treated with glyphosate cannot produce the aromatic amino acids needed to survive (McCloskey et al., 2004).

Glyphosate is most well known to the cotton industry for use in Roundup Ready® (RR) cotton. Introduced in 1997 by Monsanto Company, RR cotton has redefined weed management in cotton production and has been readily accepted by growers across the Southeast (Croon et al., 2005; York et al., 2004). Roundup Ready® cotton confers its tolerance to glyphosate with a glyphosate tolerant EPSPS gene. This tolerance was achieved by introducing into the cotton plant a cloned gene for 5-enolpyruvylshikimate-3-phosphate synthase from *Agrobacterium* spp. strain CP4, which is naturally less sensitive to inhibition of glyphosate (Jones and Snipes, 1999; Nida et al., 1996).

Roundup Ready® cotton has provided producers with a broad spectrum of weed control options, more flexibility in crop rotations, the ability to farm more hectares of land, and the ability to control weeds more economically and in a more environmentally friendly manner (Jones and Snipes, 1999; May et al., 2004; Stewart et al., 2001). Ward et al. (Ward et al., 2002) state that the glyphosate resistance technology may also enhance the benefits of conservation tillage, while Wilcut et al. (1996) state that the greatest benefit gained with RR cotton is the convenience of POT applications to small cotton without crop injury. Roundup Ready cotton is labeled for foliar POT applications up to the 4-leaf stage. However, there are additional restrictions on the POT applications made on the young cotton. Producers are restricted to only two POT applications, and within that restriction, they must also allow ten days and two nodes of growth between applications (May et al., 2004). Beyond the 4-leaf stage, producers can make postemergence-directed sprays, which minimizes glyphosate contact with leaf tissue (Pline-Srnic et al., 2004).

Problems with Roundup Ready Technology: Roundup Ready cotton has changed the way weed management is conducted in cotton. However, the application window in which producers have to make POT applications of glyphosate limits the utility of topical applications of glyphosate, which may be necessary for in-row weed control (Matthews et al., 1998). Studies conducted in California from 1997 to 2001 determined over-the-top applications of glyphosate past the 4-leaf stage would cause significant injury, resulting in yield loss (Duvall et al., 2005). The injury caused to the cotton when POT applications were made past the 4-leaf stage was due to the lack of expression of the promoter and EPSPS gene in male flower tissue (Pline et al., 2002b). The lack of gene expression caused abnormal flowers with stunted filaments and anthers that do not release the pollen. The lack of pollination, which resulted in boll abortion, resulted in yield loss (McCloskey et al., 2004).

The restrictions that exist on Roundup Ready® cotton in regard to the proper application timing of glyphosate appear to be correlated with fruit shedding that takes place when applications are made past the 4-leaf stage (Jones and Snipes, 1999). Jones and Snipes reported plant mapping data revealed there was a decrease from 50 to 20% in boll retention at early-season fruiting sites when glyphosate applications were delayed to the six-leaf stage (1999). Edenfield et al. (2005) reported when a glyphosate application was made past the six-leaf stage, first position boll retention was reduced by 25%. This study also showed a 14-19% reduction in yield when applied beyond the 12-leaf stage when compared to the non-treated cotton. This is pertinent information since the number of cotton fruiting structures is positively correlated with lint yield and is one of the most important traits related to the amount of lint produced (Stewart et al., 2005; Wu et al., 2005). While boll abscission due to glyphosate typically occurs in the first and second fruiting positions of lower fruiting branches, studies have shown that cotton will compensate by producing bolls at higher nodes and fruit on positions further out on the plant (Jones et al., 1996). However, research has shown that the greatest portion of yield occurs on main-stem nodes 9-16, with nodes above 16 contributing little to overall yield (Jenkins et al., 1990). According to Jones and Snipes (1999), late season compensation may cause a delay in harvest and a decrease in yield if the season is not long enough for compensatory growth.

Roundup Ready Flex Cotton: Due to the impact of boll abortion in RR cotton and the narrow application window, Monsanto was prompted to address this problem with the development of a new glyphosate resistant genetic construct (McCloskey et al., 2004). The construct consists of a new promoter combining the commercialized EPSP synthase gene with the current commercial promoter and EPSP synthase gene combination ((McCloskey et al., 2004; Pline-Srnic et al., 2004). Croon et al. (2005) describes Roundup Ready Flex cotton as Event MON 88913, Roundup Ready Flex cotton utilizes a *cp4* EPSPS gene sequence that encodes for the CP4 EPSPS protein. This is the same protein that is expressed in Roundup Ready cotton. The increased level of glyphosate resistance was achieved through the use of improved promoter sequences which regulate the expression of the *cp4* EPSPS coding sequence (Croon et al., 2005).

The Roundup Ready Flex technology offers an increased margin of crop safety because of increased tolerance to glyphosate during cotton fruiting. The technology extends the herbicide application window for POT application from emergence through layby, which is the critical period for control of economically damaging weeds (Croon et al., 2005). Roundup Ready Flex® cotton has shown excellent tolerance to topical applications of glyphosate up to the 14-leaf stage with rates which are three times the recommended rate (Keeting et al., 2004). May et al. (2004) states that extending the reproductive resistance to glyphosate later in the crop development stage and resistance to higher rates will provide growers with more options in the use of glyphosate. Roundup Ready Flex® cotton was released in spring 2006. Monsanto Company research shows the following benefits are expected from RR Flex: season-long application options, combination of glyphosate with other chemicals, no specialized spray equipment, enhanced crop safety, herbicide applications determined by weed stage of development instead of cotton development, and no waiting periods between applications (Croon et al., 2005).

RESEARCH OBJECTIVES

The primary objective of this research was to determine the optimal period to apply glyphosate to Roundup Ready Flex cotton, based on weed growth stage instead of cotton growth stage. A second objective was to determine if delayed applications would cause boll abortions on the plant and, if so, what nodes and positions would be affected. The research consisted of ten herbicide treatments, applied as a glyphosate-only system, or as glyphosate mixed with other agriculture chemicals. Determining when to apply glyphosate based on weed growth stage could mean that a producer would not have the narrow application window associated with Roundup application based on cotton growth stage. Another benefit of timing applications based on weed size and competition would reduce wasted trips across a field.

MATERIALS AND METHODS

Field trials were conducted in 2005 on Alabama Agricultural Experiment Stations at the E.V. Smith Research Center (Field Crops Unit, FCU) located near Shorter, Alabama and at the Prattville Agriculture Research Unit (Prattville Experiment Field, PEF) located in Prattville, Alabama. The soil at FCU was a Norfolk sandy loam (fine-loamy, kaolinitic, thermic, Typic Kandiudults) with organic content of 1.2% and pH of 6.0. The soil at PEF was a Lucedale fine sandy loam (fine-loamy, siliceous, Paleudults) with organic content of 1.0% and pH of 6.1. Conventional tillage practices were followed at both locations and plots were fertilized and limed according to Auburn University soil test recommendations. Trials at both locations were planted on April 25, 2005. Plots received irrigation throughout the season at the FCU location and none at the PEF location (rainfall and irrigation amounts provided in Fig. 1). Plots at both locations consisted of four rows, spaced 91 cm apart and 7.7 m in length. The genotype of glyphosate-tolerant (Roundup Ready Flex®) cotton planted at both locations was experimental MON 730001G. In-furrow treatments, fertilization and insect control were conducted as recommended by Alabama Cooperative Extension System. Herbicide applications were made using a CO_2- pressurized tractor mounted sprayer at both locations. The spray equipment was equipped with 8 flat-fan nozzles, 11002 tips, on 45-cm spacing at FCU and 50-cm spacing at PEF. All herbicides were applied in water solution with a carrier volume of 140L/ha at pressures of 165 to 310 kPa depending on spray equipment.

A treatment list is shown in Table 1. Three herbicides were used alone or in combination as a PRE treatment directly following planting: fluometuron (1.4 kg ai ha^{-1}), pendimethalin (1.1 kg ai ha^{-1}), and pyrithiobac (0.07 kg ai ha^{-1}). Glyphosate (1.0 kg ai ha^{-1}), metolachlor (1.1 kg ai ha^{-1}), pyrithiobac (0.07 kg ai ha^{-1}), and trifloxysulfuron (0.007 kg ai ha^{-1}) were used alone or as a combination for the POT treatments. The POT treatments were applied based on various growth stages of weeds: 2.5 cm to 10 cm, 5.0

cm to 7.6 cm, 10 cm to 15.2 cm, and 17.2 cm to 22.8 cm. For the purpose of this study, we have designated Treatment 1 as our standard treatment for Roundup Ready Flex cotton.

Each trial was set up in a randomized complete block design with ten treatments in four replications. Data collected included visual weed control ratings (scale of 0 to 100 where 0 = no control, 100 = complete control) at 14 days after each application, crop injury rated 14 days after application using the scale 0 = no injury and 100 = complete death (Frans et al., 1986), and box mapping was conducted on each plot at the end of the growing season after defoliation and before harvest according to Jenkins et al. (1990). To perform the box mapping, plants from 3m of the right middle row were removed from each plot. Box mapping data included boll count and boll weight, which was collected from first, second, and third positions on nodes 5 through 21 (McCarty et al. 1975). Seed cotton yield was also determined for both trials. At FCU, only the center two rows were harvested, and at PEF, all four rows were harvested.

Agriculture Research Manager (ARM 7) was used to organize treatment information and preliminary data. Data were then exported into SAS program for analysis. Q-Q plots were used to check the normality assumption. This is a particular concern for weed control data expressed as percent control. The normality assumption was found not to be violated. Weed control, seed cotton yield, boll number per 3-m row and boll weight per 3-m row were initially analyzed across locations using mixed models procedures as implemented in the SAS procedure MIXED (Little et al., 2006). Location, treatment, node number, and position and all their interactions were treated as fixed effects and block and its interaction with fixed effects were treated as random. Nearest neighbor adjustments based on residuals to reduce treatment variances for seed cotton yield was used. Statistical significance of seed cotton yield differences within location among treatments were assessed using Fisher's protected LSD test at the 5% level. Treatment effects on boll number and boll weight in relation to node position were evaluated using up to 5th order polynomial regression. An additional term was included in the model if the coefficient of determination improved by at least 10% as suggested by Draper and Smith (1998).

RESULTS

WEED CONTROL

Visual Weed Ratings. Late season (August) visual ratings were analyzed across locations, except for AMASP (*Amaranthus spinosus* L.), which was present only at FCU. Location by treatment interactions were not significant (P = 0.05) for CASOB (*Cassia obtusifolia* L.), IPOHG (*Ipomoea hederacea* var. *intergriuscula* Gray), and GRASS (50% *Digitaria* spp. and 50% *Eleusine indica* (L.) Gaertn.) (Table 2). No significant differences ($P \geq 0.45$) were observed for CASOB but treatment effects were significant for AMASP, IPOHG, and GRASS. At FCU, Treatment 5, consisting of fluometuron PRE fb POT applications of glyphosate + pyrithiobac fb glyphosate provided 80% control for AMASP, which was significantly less than other treatments (Fig. 2) Although analysis showed treatment differences in weed control for IPOHG, control was ≥ 80% for all treatments. No significant visual crop injury was observed due to delayed applications of glyphosate or tank-mix partners.

COTTON YIELD RESPONSE TO TREATMENTS

Analysis of variance indicated that the location × treatment interaction for seed cotton yield was highly significant ($P < 0.001$, data not shown). Nearest neighbor adjustments based on using residuals as covariates reduced the LSD by over 50%, resulting in a significant gain in precision (Table 3). The numerically highest seed cotton yields were obtained with Treatment 6 at FCU (2665 kg ha^{-1}) and Treatment 5 at PEF (2921 kg ha^{-1}). Treatment 6 received a single PRE application of fluometuron + pyrithiobac fb a single application of glyphosate at a weed height of 5 to 7.6cm. This treatment provided > 90% weed suppression throughout the growing season. Early season weed competition was eliminated with the PRE application, which provided the cotton time to produce and set bolls. Treatment 5 consisted of fluometuron PRE fb POT applications of glyphosate + pyrithiobac fb glyphosate at weed heights of 7.6 cm and 15 cm. This treatment yielded significantly more than all other treatments at PEF (Table 3). Treatment 3 was the lowest yielding treatment at FCU (1673 kg ha^{-1}), whereas Treatment 10 had the lowest yield at PEF (1857 kg ha^{-1}). Treatment 3 received two POT applications of glyphosate when weeds were at a height of 17.7 to 22.8 cm. The delayed applications had a significant effect on seed cotton yield which is probably due to weed competition causing plants to not produce bolls on lower and middle nodes. Treatment 10 produced the lowest yield of all treatments for the study at PEF with a seed cotton yield of 1875 kg ha^{-1} and was significantly lower than our standard Treatment 1. Treatment 10 consisted of pendimethalin applied PRE and one POT application of glyphosate when weeds were 7.6 cm tall. Since Treatment 10 provided > 80% control of the weeds present, yield loss can be attributed to mid and late season weed competition.

The standard (Treatment 1) received three applications of glyphosate applied POT to weeds 2.5 to 10 cm tall and ranked 2nd at both locations. Treatment 3 at FCU ranked 10th due to delayed weed control (17.7 to 22.8 cm tall) and high weed pressure; while at PEF, it ranked 3rd due to reduced overall weed pressure. Treatment 8, which received glyphosate + pyrithiobac fb trifloxysulfuron fb glyphosate, ranked 8th at FCU and 9th at PEF in overall yield due to possible sulfonylurea injury. Trifloxysulfuron showed the same effect on Treatments 7 and 9 at FCU. Since herbicide application was made on the same date, injury was possibly due to sulfonylurea injury. Treatment 10 received pendimethalin PRE and one application of glyphosate at weed heights of 5 to 7.6 cm and ranked 10th overall due to poor late season weed control.

Location × treatment × node × position 4-way interaction for both number of bolls and boll weight per 3-m row was highly significant ($P < 0.001$; data not shown) in a combined analysis. Two steps were taken to make the data amenable to interpretation: (1) position was dropped as a classification variable from the analysis and node totals were used instead in the analysis, and (2) a separate analysis was conducted for each location. Thus the model was simplified to include main effects for treatment and nodes plus the treatment × node interaction term, which was highly significant at both locations for both boll number and boll weight. ($P < 0.001$, Table 4). The effect of treatments was modeled using up to 5th order polynomial regression. Given that 12 df (degrees of freedom) were available, maximum model df accounted for less than half of available df. R^2 improvement by 10% rule of thumb provided by Draper and Smith (1998) was used to justify the inclusion of higher order polynomial coefficients in the model (Figures 3 and 4; Tables 5 and 6).

Seed Cotton Yield at FCU. Seed cotton yields decreased as applications were delayed and fewer treatments were applied from Treatment 1 to 3 (Table 3). Herbicides were applied when weeds were on the average 5 cm, 12.5 cm, and 20 cm tall for Treatments 1, 2, and 3 respectively. Treatment 1 yielded 2490 kg ha^{-1} of seed cotton, Treatment 2 yielded 2336 kg ha^{-1}, and Treatment 3 had a significant lower yield of 1673 kg ha^{-1} of seed cotton. Treatment 4 received only one application of glyphosate + acephate and one application of glyphosate + mepiquat chloride during the growing season and yielded 2150 kg ha^{-1} of seed cotton. Yield in Treatment 5 was 2469 kg ha^{-1} of seed cotton and had three applications which included fluometuron PRE, glyphosate + pyrithiobac for the first POT application at 5 to 7.6 cm tall weeds, which provided more residual control and a final glyphosate application at 15 cm tall weeds. A yield of 1876 kg ha^{-1} was harvested from Treatment 7 which received two applications of glyphosate and one application of trifloxysulfuron. This was significantly lower than yields for Treatments 1, 2, 5, and 6. Treatments 8 (2039 kg ha^{-1}) and 9 (2081 kg ha^{-1}) showed similar yields. This reduction in yield could possibly be explained by the application of trifloxysulfuron, which can be potentially injurious to young cotton (Koger et al., 2005). Treatment 8 could also have been affected by the application of glyphosate + pyrithiobac fb trifloxysulfuron which is known to be an injurious combination for cotton (Porterfield et al., 2002). Cotton yielded 2120 kg ha^{-1} of seed cotton receiving only one POT application of glyphosate during the growing season. Weed competition could have caused the plants not to produce an adequate number of bolls (Brar and Gill, 1983) .

Box mapping at FCU. Treatments 1, 2, and 3 showed a pattern of boll loss at lower nodes as treatments were delayed based on weed growth stage (Figure 3, Table 5). The response to Treatment 1 consisting of three POT applications of glyphosate at 2.5 to 10 cm weeds, could be modeled as a 2nd order polynomial ($R^2 \geq 0.86$). The seed cotton yield from this treatment was 2490 kg ha^{-1}, with the majority of yield contributed by nodes 7 through 15. The early applications prevented any yield loss due to boll abortion because, weeds were controlled at an early stage and allowed the cotton to produce and set bolls. Treatment 2 ($R^2 \geq 0.88$) and 3 ($R^2 \geq 0.92$) required a 5th order polynomial for adequate fit (Figure 3, Tables 4 and 5). Treatment 2 received only two applications of glyphosate at 10 to 15 cm weed growth stage. This treatment yielded 2336 kg ha^{-1} which was distributed on the lower and upper portion plant with a decline in boll number and weight with nodes 8 through 12 possibly due to weed competition. A noticeable affect was the drop in boll number and boll weight on the middle portion of the plant. Early season weed competition possibly had an effect on the lower nodes and plants did not produce the boll number nor the weight of bolls compared with Treatment 1. Plants in Treatment 2 compensated for the loss of bolls at lower nodes by producing bolls at nodes 12 and higher. Treatment 3 also received two later applications of glyphosate when weeds were taller (17.7 to 22.8 cm). This treatment yielded only 1673 kg ha^{-1} of seed cotton which was significantly lower than Treatments 1 and 2. The delayed treatment had a significant effect on boll number and boll weight on nodes 5 through 11. Plants in Treatment 3 produced a much higher number of bolls on nodes 12 through 15 which was possibly related to intense weed competition in the early stages of cotton plant development. The delayed weed control resulted in reduced numbers and weights of bolls at the lower and middle nodes resulting in the lower yields (Buchanan and Burns, 1971). Response to Treatment 4 could be modeled using a 3rd order polynomial ($R^2 \geq 0.83$). This treatment is similar to Treatment 1 in that the glyphosate + acephate (1st application) and the glyphosate + mepiquat chloride (2nd application) were applied when weeds were 2.5 to 10 cm tall. It yielded 2150 kg ha^{-1} of seed cotton and was significantly lower than Treatments 5 and 6 and significantly higher than Treatment 3.

Treatment 5 ($R^2 \geq 0.85$) and Treatment 6 ($R^2 \geq 0.61$) could be modeled as a 4th order polynomial and 2nd order polynomial respectively. Both treatments received a PRE application of fluometuron while Treatment 6 had the addition of pyrithiobac with the fluometuron as a PRE. Treatment 5 received a POT application of glyphosate + pyrithiobac at a weed height of 7.6 cm fb glyphosate at 15 cm weeds. Treatment 6 received only one application of glyphosate when weeds were 7.6 cm tall following the PRE application. Boll number and boll weight for Treatment 5 remained nearly constant between nodes 7 to node 16. The response to Treatment 6 was similar to that for Treatment 1 (early application). The absence of early season weed competition allowed the plants to set bolls across the lower and middle portion of the plant.

Boll response to Treatment 7 can be modeled using a 3rd order polynomial ($R^2 \geq 0.82$). This treatment received glyphosate fb trifloxysulfuron + NIS fb glyphosate when weeds were 5 to 7.6 cm in height. No boll reduction was evident although boll number and boll weight were greater at higher nodes than most other treatments. This is possibly due to the effect trifloxysulfuron sometimes has on young cotton. This treatment did not adversely effect boll production on the lower nodes; however it did cause the plants to produce a greater number of bolls on the upper portion of the plant. Treatment 8 ($R^2 \geq$

0.77) required a 3rd order polynomial for adequate fit. Treatment 8 received an initial application of glyphosate + pyrithiobac fb trifloxysulfuron + NIS fb glyphosate, all timed at 5 to 7.6 cm tall weeds. This treatment had an adverse effect on boll number and boll weight across all nodes. The applications of glyphosate + pyrithiobac fb trifloxysulfuron tended to reduce boll weights. While the cotton tried to compensate for the loss of the bolls on nodes 5 through 11 with more bolls on nodes 12 through 15, it could not produce the boll weight needed to produce optimum yield possibly due to rainfall conditions later in the growing season. Treatment 9 ($R^2 \geq 0.88$) box mapping data was modeled as a 5th order polynomial. Applications made POT included glyphosate + metolachor fb trifloxysulfuron + NIS at a weed height of 5 to 7.6 cm. Boll number and boll weight are linear from nodes 7 to 15. Treatment 10 response was modeled as a 4th order polynomial ($R^2 \geq 0.76$). The two applications made to this treatment were pendimethalin PRE fb glyphosate at 5 to 7.6 cm tall weeds. This treatment resulted in low boll counts and boll weights at nodes 5-13. Plants did not compensate for boll loss as much as other treatments. This could be an effect of receiving only one POT application of glyphosate throughout the entire growing season resulting in a lack of weed control. The plants in this treatment tended to set fewer bolls at all nodes due to the weed competition in the second half of the growing season.

Seed Cotton Yield at PEF. Treatments 1 through 3 did not show a decreasing yield trend as found at FCU (Table 3). Overall weed pressure was lower at PEF than at FCU. Yields did not differ significantly among the three treatments, averaging 2382 kg ha^{-1} of seed cotton. Treatment 4 yielded 2175 kg ha^{-1} of seed cotton and was significantly different from Treatment 1. Treatment 5 provided the highest yield, possibly due to higher boll set in the upper nodes. Treatments 6 yielded 2304 kg ha^{-1} of seed cotton and received one PRE application of fluometuron + pyrithiobac and one POT application of glyphosate with 7.6 cm tall weeds. Treatments 7 to 9 received an application of trifloxysulfuron along with applications of glyphosate. The average yield for these treatments was 2215 kg ha^{-1}. Treatment 8 did yield significantly less than treatment 7. The herbicide sequence of glyphosate + pyrithiobac fb trifloxysulfuron in Treatment 8 possibly damaged the young cotton.

Box mapping at PEF. Treatment 1 data could be modeled as a 2nd order polynomial ($R^2 \geq 0.86$) (Fig 4, Table 6). Applications for treatment 1 consisted of three POT applications of glyphosate applied at 2.5 to 10 cm tall weeds. Box mapping showed the greatest portion of the 2472 kg ha^{-1} yield coming from nodes 7 to 15 with boll number and boll weight dropping off after node 15. Although the number of bolls produced on the lower portion of the plant was not extremely high, high boll weight compensated for the low boll count. Treatments 2 ($R^2 \geq 0.90$) and 3 ($R^2 \geq 0.92$) required a 5th order polynomial for adequate fit. Treatment 2 and 3 each received two applications of glyphosate with treatment 2 being applied at weeds 10 to 15 cm tall and treatment 3 applications being made at taller weeds (17.7 to 22.8 cm). Treatment 2 yielded 2315 kg ha^{-1} of seed cotton with the most yield coming from nodes 7 to 11. This treatment showed a similar pattern of not producing as many bolls, but producing bolls with higher weights. The box mapping data for Treatment 3 shows that plants in this treatment produced a greater amount of bolls and heavier bolls in the top portion of the plants on nodes 9 to 14. Data shows that plants compensated for early season boll loss from the delayed herbicide applications by producing heavy bolls on the top portion of the plant. The response to

Treatment 4 could be modeled as a 3rd order polynomial ($R^2 \geq 0.83$). This treatment is not statistically different from treatments 2 and 3 with a yield of 2175 kg ha^{-1} of seed cotton. Applications of glyphosate + acephate (1st application) and glyphosate + mepiquat chloride (second application) were made when weeds were at a height of 2.5 to 10 cm tall. Boll weight and boll numbers resemble the distribution of data for Treatment 3 in that bolls were set on nodes 9 to 14. The absence of a third postemergence application in Treatment 4 allowed for competition from mid to late season weeds. Treatment 5 (R2 $\geq$ 0.85) required a 4th order polynomial for adequate fit. Treatment 5 yielded the highest of all treatments in the study with a seed cotton yield of 2921 kg ha^{-1}. This treatment consisted of PRE application of fluometuron and two POT applications of glyphosate + pyrithiobac (5 to 7.6 cm weeds) fb glyphosate alone when weeds were 10 to 15 cm tall. The box mapping data was distributed across nodes 7 to 16 with a rise at nodes 8 to 13. As with previous results, boll number was low and boll weight large, implying that cotton plants produced heavier bolls. Weed competition was not a concern in this treatment due to the residual control provided by the fluometuron and the pyrithiobac, also delaying the last application of glyphosate until weeds reached an intermediate height helped in giving season-long control.

Treatment 6 could be modeled as a 2nd order polynomial ($R^2 \geq 0.61$). Treatment 6 received a PRE application of fluometuron + pyrithiobac fb glyphosate POT at a weed height of 5 to 7.6 cm tall weeds. Yield for Treatment 6 was 2304 kg ha^{-1}. Boll number and boll weight data was very consistent across all nodes. There was no significant decline in boll number or boll weight from nodes 7 to16. Treatments 7 ($R^2 \geq 0.82$) and 8 ($R^2 \geq 0.77$) required a 3rd order polynomial for adequate fit. Treatment 7 received three

POT applications which included glyphosate fb trifloxysulfuron fb glyphosate all at a weed height of 5 to 7.6 cm. Yield for Treatment 7 (2326 kg ha^{-1}) did not significantly differ from any other treatment with the exception of treatments 5, 8, and 10. Boll numbers and boll weights were lower across all nodes than any other treatment. However, boll distribution across the plant was consistent with an average of 10 bolls at each node and boll weight of 35g. Treatment 8 received the same treatment at 5 to 7.6 cm tall weeds except pyrithiobac was added to the first application of glyphosate. The yield for Treatment 8 was 2044 kg ha^{-1} which was the second lowest yield at PEF. This can possibly be explained as an adverse response to the use of both pyrithiobac and trifloxysulfuron in the same treatment. Box mapping showed that yield was from nodes 8 through 16. Treatment 9 data could be modeled as a 5^{th} order polynomial ($R^2 \geq 0.88$). Glyphosate + metolachlor fb trifloxysulfuron was applied POT at 5 to 7.6 cm tall weeds. This treatment produced a higher number of bolls on the middle and upper portions of the plants on nodes 11 to 17 and yielded 2275 kg ha^{-1} of seed cotton. Treatment 10 ($R^2 \geq 0.76$) data required a 4^{th} degree polynomial for adequate fit. This treatment consisted of a PRE application of pendimethalin and one POT application of glyphosate when weeds were 5-7.6 cm tall. Treatment 10 yielded significantly less than other treatments at PEF with a seed cotton yield of 1857 kg ha^{-1}. Boll number and boll weight were low across all nodes. Bolls were mainly produced on nodes 7 to 12 with a steady decline on the upper portions of the plants.

CONCLUSIONS

All herbicide treatments provided > 80% late season control of all weed species at both locations. Treatment 5 for AMASP control at FCU was significantly lower than other treatments, however this treatment still provided above 80% control. The standard treatment of three POT applications of glyphosate at 2.5 to 10 cm tall weeds provided excellent weed control throughout the growing season and ranked 2nd in yield at both locations. Treatment 3 at FCU, which consisted of two POT applications of glyphosate at weed heights of 17.7 to 22.8 cm, had a significantly lower yield than treatments in which applications were made at an earlier weed growth stage. Rankings revealed lower yields at both locations with the mixture of glyphosate alone or tank-mixed with pyrithiobac fb trifloxysulfuron when compared to the standard. The PRE application of pendimethalin fb one application of glyphosate at 5 to 7.6 cm tall weeds resulted in greatly reduced seed cotton yield at PEF due to poor late season weed control (Buchanan and Burns, 1970).

Box mapping data from FCU revealed that delaying applications of glyphosate resulted in a lower number of bolls on nodes 5 to 12. This had a significant effect on yield for Treatment 3 where applications were delayed until weeds reached a height of 17.7 to 22.8 cm. Data also shows that the application of a PRE herbicide works well with Roundup Ready Flex where more than one POT application of glyphosate is applied. Although boll counts and boll weights varied at different nodes due to treatment, our research showed similar results to Mann et al. (1997), that when the growing season permits cotton will often compensate for the reduction at lower nodes by producing bolls at higher nodes.

Post over the top applications of glyphosate applied to weeds before they reach 17 cm in height was found to be a feasible weed control program with Roundup Ready Flex cotton. Given the application timing flexibility of the new generation cotton, producers will now be able to make applications based on weed growth instead of cotton stage. This will offer growers season long application options, the ability to combine glyphosate with other agriculture chemicals, and present the possibility of no post-directed layby applications.

Table 1. Treatments applied at Field Crops Unit and Prattville Experiment Field.[a]

Treatment	Components[b]	Weed growth stage	Rate	Application dates FCU[c]	Application dates PEF
		cm	kg a.i./ha		
1	Glyphosate	5 - 7.6	1	25-May-05	16-May-05
	Glyphosate	5 - 7.6	1	9-Jun-05	14-Jun-05
	Glyphosate	2.5 - 10	1	18-Jul-05	18-Jul-05
2	Glyphosate	10 - 15	1	7-Jun-05	26-May-05
	Glyphosate	10 - 15	1	7-Jul-05	29-Jun-05
3	Glyphosate	17.7 - 22.8	1	9-Jun-05	14-Jun-05
	Glyphosate	17.7 - 22.8	1	18-Jul-05	18-Jul-05
4	Glyphosate + Acephate	2.5 - 10	1 + 0.336	9-Jun-05	14-Jun-05
	Glyphosate + M.C.	2.5 - 10	1+ 0.224	7-Jul-05	29-Jun-05
5	Fluometuron	PRE	1.41	25-Apr-05	25-Apr-05
	Glyphosate + Pyrithiobac	5 - 7.6	1.0 + 0.07	7-Jun-05	26-May-05
	Glyphosate	10 - 15	1	7-Jul-05	29-Jun-05

continued

Table 1. continued.

Treatment	Components	Weed growth stage	Rate	Application dates FCU	PEF
6	Fluometuron + Pyrithiobac	PRE	1.41 + 0.07	25-Apr-05	25-Apr-05
	Glyphosate	5 - 7.6	1	9-Jun-05	14-Jun-05
7	Glyphosate	5 - 7.6	1	25-May-05	16-May-05
	Trifloxysulfuron + NIS	5 - 7.6	0.007 + 0.25% v/v	9-Jun-05	14-Jun-05
	Glyphosate	5 - 7.6	1	18-Jul-05	18-Jul-05
8	Glyphosate + Pyrithiobac	5 - 7.6	1 + 0.05	25-May-05	16-May-05
	Trifloxysulfuron + NIS	5 - 7.6	0.007 + 0.25% v/v	9-Jun-05	14-Jun-05
	Glyphosate	5 - 7.6	1	18-Jul-05	18-Jul-05
9	Glyphosate + Metolachlor	5 - 7.6	1 + 1.1	25-May-05	16-May-05
	Trifloxysulfuron + NIS	5 - 7.6	0.007 + 0.25% v/v	9-Jun-05	14-Jun-05
10	Pendimethalin	PRE	1.1	25-Apr-05	25-Apr-05
	Glyphosate	5 - 7.6	1	25-May-05	16-May-05

[a]Abbreviations: NIS, non-ionic surfactant; PRE, preemergence; M.C., mepiquat chloride.

[b]Glyphosate was applied postemergence over-the-top of the crop canopy.

Table 2. Probability values from the analysis of variance for visual weed control ratings (P< 0.05).

		Weed species			
Source	df	CASOB	GRASS	IPOHG	AMASP
		P-values			
Location	1	0.004	0.144	0.096	†
Treatment	9	0.465	0.011	0.048	<0.001
Loc*Trt	9	0.060	0.093	0.152	†
		Variance estimates			
Exp. Error	54	14.56	8.83	25.40	7.29

† Not applicable because AMASP was present only at the E.V. Smith location. (df for error = 27).

[a]AMASP (*Amaranthus spinosus* L.), CASOB (*Cassia obtusifolia* L.), IPOHG (*Ipomoea hederacea* var. *intergriuscula* Gray), and GRASS (50% *Digitaria* spp. and 50% *Eleusine indica* (L.) Gaertn.).

Table 3. Unadjusted treatment least squares means for seed cotton yield from ANOVA and nearest neighbor analysis (NNA) adjusted means.

	Field Crops Unit				Prattville Experiment Field			
	LS mean		Rank		LS mean		Rank	
Trt	Unadj.	NNA	Unadj.	NNA	Unadj.	NNA	Unadj.	NNA
	----- kg ha^{-1} ----				----- kg ha^{-1} ----			
1	2381	2490	3	2	2418	2472	3	2
2	2349	2336	4	4	2360	2315	4	5
3	1608	1673	10	10	2556	2360	2	3
4	2149	2150	5	5	2109	2175	9	8
5	2610	2469	2	3	3144	2921	1	1
6	2708	2665	1	1	2225	2304	5	6
7	1928	1876	9	9	2120	2326	8	4
8	1971	2039	8	8	2178	2044	6	9
9	2076	2081	7	7	2174	2275	7	7
10	2088	2120	6	6	1797	1857	10	10
$LSD_{0.05}$[a]	788	266			788	266		

[a]Combined analysis performed.

Table 4. Probability values from the analysis of variance for boll number and boll weight.

			Field Crops Unit		Prattville Experiment Field	
Source	NumDF	DenDF	Number	Weight	Number	Weight
Trt	9	27	0.0380	0.0267	0.4952	0.1099
Node	13	39	≤ 0.0001	≤ 0.0001	≤ 0.0001	≤ 0.0001
Trt*Node	117	351	≤ 0.0001	≤ 0.0001	0.0029	0.0137

Table 5. Field Crops Unit. Regression coefficients and coefficient of determination from the polynomial regression of boll number and boll weight on node number.

	Intercept		Linear		Quadratic		Cubic		4th order		5th order		
Trt	Estim.	SE	Estim.	SE	Estim.	SE	Estim.	SE	Estim.	SE	Estim.	SE	R^2
Boll number per 3-m row													
1	-8.7	4.7	5.5	0.9	-0.3	0.04							0.86
2	-761.1	139.9	399.0	72.3	-77.9	14.20	7.25	1.33	-0.322	0.060	0.005	0.0010	0.88
3	-488.4	101.6	278.9	52.5	-59.1	10.31	5.90	0.97	-0.277	0.044	0.005	0.0008	0.95
4	22.5	8.7	-4.4	2.6	0.6	0.24	-0.02	0.01					0.88
5	-77.4	26.0	34.3	10.6	-4.8	1.52	0.30	0.09	-0.007	0.002			0.90
6	-19.8	5.7	6.7	1.1	-0.3	0.05							0.75
7	16.6	12.0	-3.6	3.6	0.7	0.33	-0.03	0.01					0.87
8	46.9	16.9	-14.7	5.0	1.7	0.46	-0.06	0.01					0.77
9	-399.6	126.0	211.6	65.1	-41.3	12.78	3.87	1.20	-0.174	0.054	0.003	0.0009	0.88
10	-30.6	32.2	20.0	13.1	-3.5	1.89	0.26	0.11	-0.01	0.002			0.76
Boll weight per 3-m row													
1	-45.9	17.3	22.8	3.2	-1.1	0.14							0.88
2	-2715.5	439.1	1428.1	226.8	-279.9	44.56	26.14	4.18	-1.166	0.188	0.020	0.0033	0.90
3	-1752.3	479.9	991.9	247.9	-208.4	48.70	20.57	4.57	-0.954	0.206	0.017	0.0036	0.92
4	72.9	41.3	-15.1	12.3	2.2	1.13	-0.09	0.03					0.83
5	-365.1	113.3	163.1	46.2	-23.2	6.65	1.44	0.40	-0.033	0.009			0.85
6	-55.1	23.8	20.8	4.5	-0.9	0.19							0.61
7	92.2	47.7	-22.7	14.2	3.2	1.31	-0.12	0.04					0.82
8	83.0	39.0	-27.1	11.6	3.3	1.07	-0.11	0.03					0.78
9	-1291.3	384.5	688.3	198.6	-135.5	39.02	12.79	3.66	-0.578	0.165	0.010	0.0029	0.90
10	-142.4	110.0	88.9	44.9	-15.5	6.46	1.12	0.39	-0.03	0.008			0.78

Table 6. Prattville Experiment Field. Regression coefficients and coefficient of determination from the polynomial regression of boll number and boll weight on node number.

	Intercept		Linear		Quadratic		Cubic		4th order		5th order		
Trt	Estim.	SE	Estim.	SE	Estim.	SE	Estim.	SE	Estim.	SE	Estim.	SE	R^2
Boll number per 3-m row													
1	-323.9	69.6	165.2	36.0	-31.3	7.1	2.85	0.66	-0.125	0.030	0.0021	0.0005	0.91
2	-114.4	44.6	45.9	18.2	-6.0	2.6	0.34	0.16	-0.007	0.003			0.66
3	-22.1	4.6	6.4	0.9	-0.3	0.0							0.80
4	-18.1	3.0	5.1	0.6	-0.2	0.0							0.87
5	-38.8	10.0	12.5	3.0	-0.9	0.3	0.02	0.01					0.82
6	-91.6	24.0	37.2	9.8	-4.9	1.4	0.28	0.09	-0.006	0.002			0.85
7	-74.9	25.9	30.2	10.6	-4.0	1.5	0.23	0.09	-0.005	0.002			0.77
8	-18.6	3.6	5.6	0.7	-0.2	0.0							0.84
9	-84.9	24.6	37.7	10.0	-5.5	1.4	0.35	0.09	-0.008	0.002			0.85
10	-19.3	9.9	7.8	2.9	-0.6	0.3	0.02	0.01	0.02	0.008			0.71
Boll weight per 3-m row													
1	-1248.8	370.6	623.3	191.4	-114.8	37.6	10.18	3.53	-0.435	0.159	0.0072	0.0028	0.82
2	-513.8	194.0	204.3	79.2	-26.7	11.4	1.50	0.69	-0.031	0.015			0.64
3	-91.4	15.7	25.7	3.0	-1.1	0.1							0.85
4	-82.1	12.1	22.6	2.3	-0.9	0.1							0.89
5	-165.2	47.8	52.7	14.3	-3.9	1.3	0.09	0.04					0.78
6	-421.6	88.9	173.1	36.3	-23.2	5.2	1.34	0.32	-0.028	0.007			0.85
7	-331.1	106.1	134.4	43.3	-17.9	6.2	1.03	0.38	-0.022	0.008			0.69
8	-73.2	16.3	22.5	3.1	-0.9	0.1							0.80
9	-318.1	89.4	139.3	36.5	-19.8	5.2	1.24	0.32	-0.028	0.007			0.88
10	-100.2	24.3	37.1	7.2	-3.2	0.7	0.08	0.02	0.08	0.019			0.88

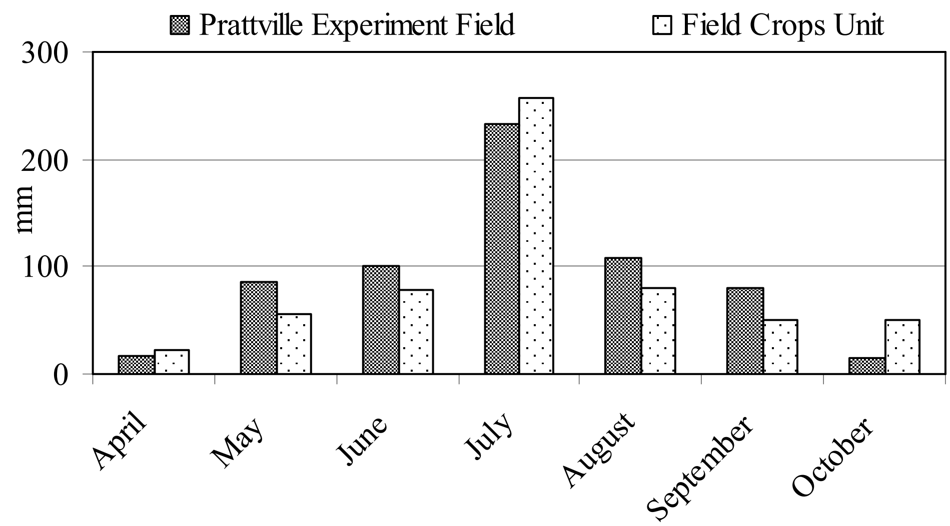

Figure 1. Total monthly rainfall and irrigation (for FCU) for the 2005 crop year.

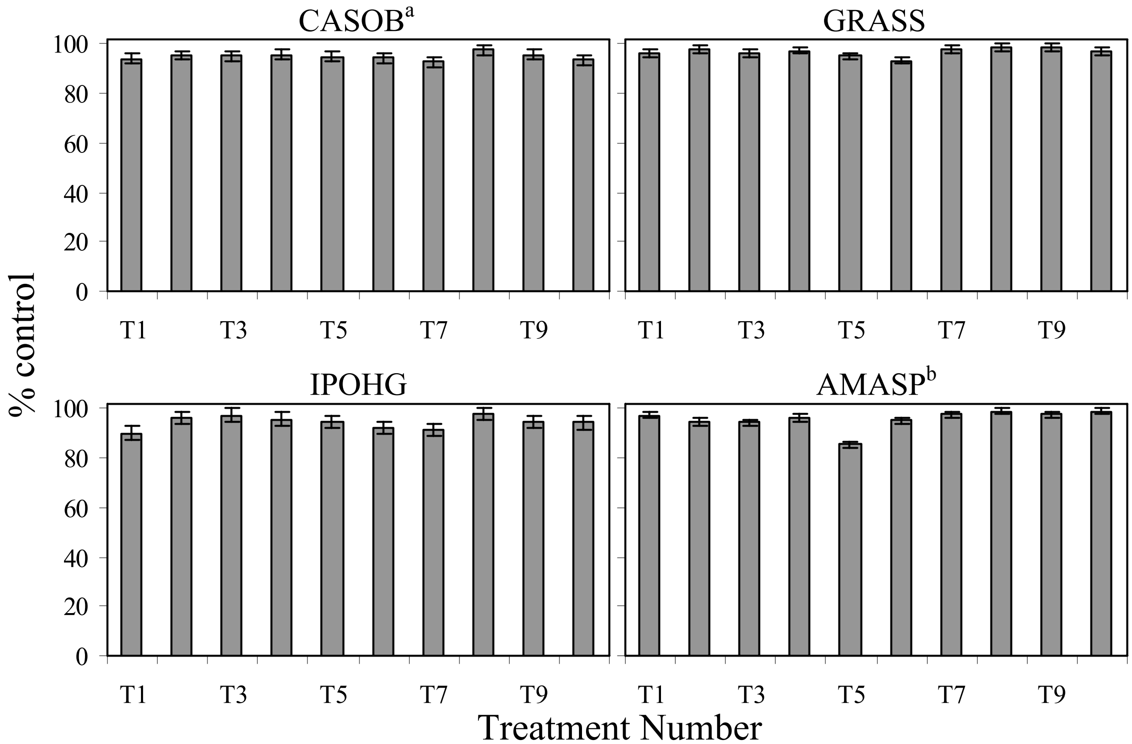

Figure 2. Visual weed control ratings for Field Crops Unit and Prattville Experimental Field.[c]

[a]AMASP (*Amaranthus spinosus* L.), CASOB (*Cassia obtusifolia* L.), IPOHG (*Ipomoea hederacea* var. *intergriuscula* Gray), and GRASS (50% *Digitaria* spp. and 50% *Eleusine indica* (L.) Gaertn.).

[b]AMASP present only at FCU.

[c]Treatments combined over locations.

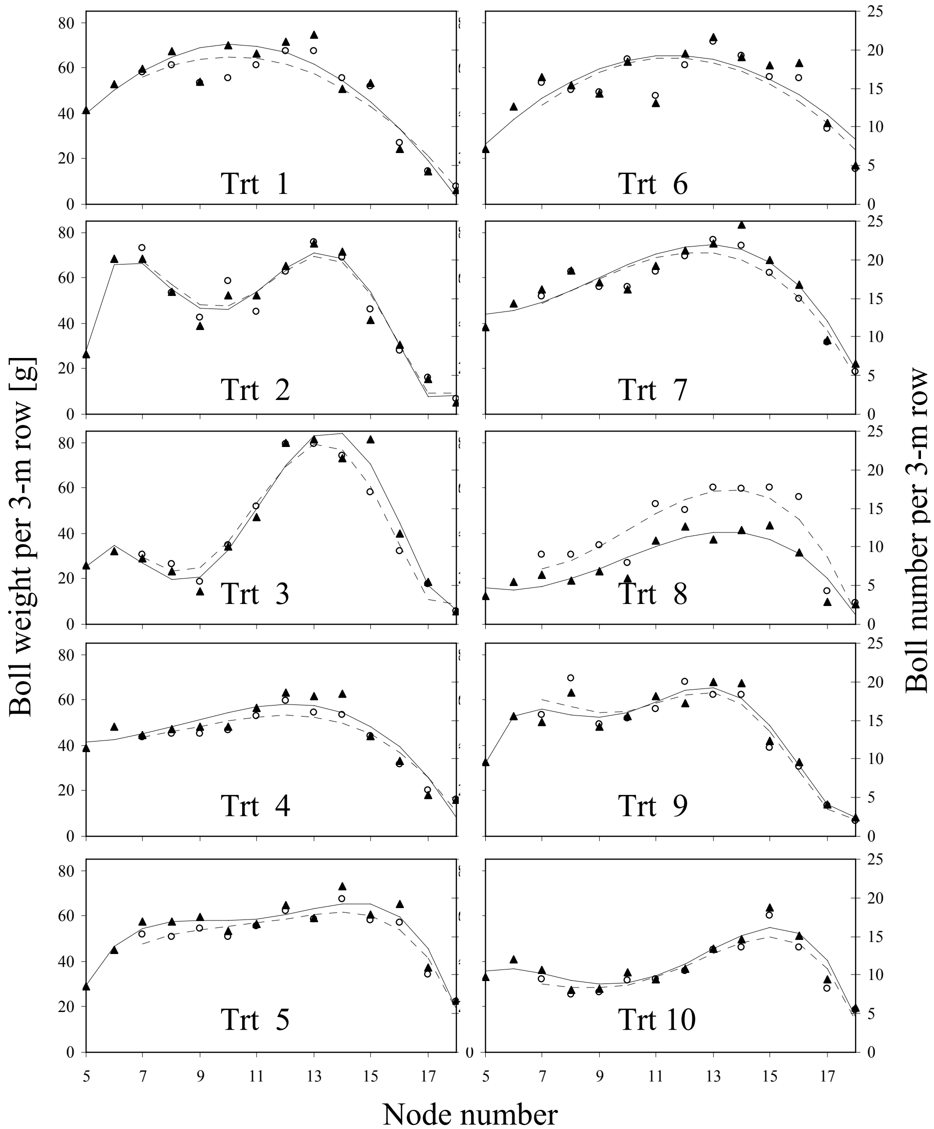

Figure 3. FCU. Regression of boll number (open circles, dashed line) and boll weight (triangles, solid line) on node number. Regression coefficients, associated standard errors, and coefficients of determination are given in Table 5.

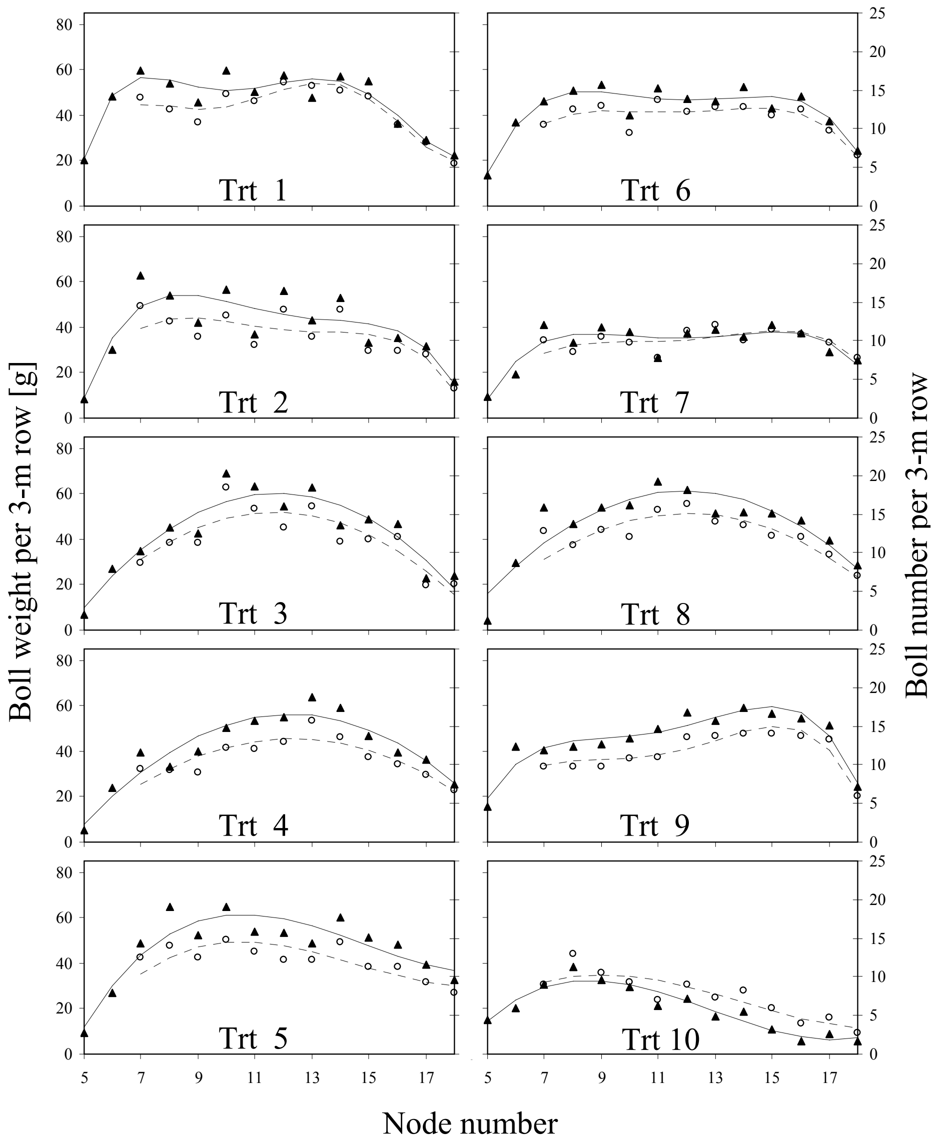

Figure. 4 . Prattville Experiment Field. Regression of boll number (open circles, dashed line) and boll weight (triangles, solid line) on node number. Regression coefficients, associated standard errors, and coefficients of determination are given in Table 6.

LITERATURE CITED

Brar, H.S., and H.S. Gill. 1983. Studies on the critical period of crop weed competition in cotton Gossypium hirsutum. Indian Journal of Ecology 10:248-253.

Buchanan, G.A., and E.R. Burns. 1970. Influence of weed competition on cotton. [not specified]. Weed Sci. 18:149-54.

Buchanan, G.A., and E.R. Burns. 1971. Weed competition in cotton. 2. Cocklebur and redroot pigweed. Weed Science. 19:580-2.

Byrd, J.D., and A.C. York. 1987. Interaction of fluometuron and MSMA with sethoxydim and fluazifop. Weed Science 35:270-276.

Croon, K.A., R.A. Ihrig, J.W. Mullins. 2005. Roundup Ready Flex cotton technology. Proc., Beltwide Cotton Conference. 1:69.

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

Culpepper, A.S., T.M. Webster, A.C. York, R.M. Barentine, and B.G. Mullinix, Jr. 2004. Glyphosate/MSMA mixtures in glyphosate-resistant cotton (*Gossypium hirsutum*). Journal of Cotton Science 8:124-129.

Duvall, T.M., E. Hoffman, R.N. Vargas, S.D. Wright, L. Banuelos. 2005. A comparison of Roundup Ready and Roundup Ready Flex cotton systems. Proc., Beltwide Cotton Conference. 1: 2877-2878.

Draper, N.R. and H. Smith. 1998. Applied Regression Analysis. Wiley, New York.

Edenfield, M.W., B.J. Brecke, D.L. Colvin, J.A. Dusky, and D.G. Shilling. 2005. Effect of glyphosate and MSMA application timing on weed control, fruiting patterns, and yield in glyphosate-resistant cotton. Weed Technology 19:224-230.

Faircloth, W.H., M.G. Patterson, C.D. Monks, and W.R. Goodman. 2001. Weed management programs for glyphosate-tolerant cotton (Gossypium hirsutum). Weed Technology 15:544-551.

Frans R. E., R. Talbert, D. Marx, H. Crowley. 1986. Experimental design and techniques for measuring and analyzing plant responses to weed control practices. Pages 37-38 in N. D. Camper, ed. Research Methods in Weed Science. 3rd ed. Champaign, IL: Southern Weed Science Society.

Franz, J.E., M.K. Mao, and J.A. Sikorski. 1997. Glyphosate: A Unique Global Herbicide., p. 6-16, *In* A. C. Society., ed., Washington, DC.

Jenkins, J.N., J.C. McCarty, and W.L. Parrott. 1990. Effectiveness of fruiting sites in cotton: Yield. Crop Science 30:365-369.

Jones, M.A., and C.E. Snipes. 1999. Tolerance of transgenic cotton to topical applications of glyphosate. Journal of Cotton Science 3:19-26.

Jones, M.A., R. Wells, and D.S. Guthrie. 1996. Cotton response to seasonal patterns of flower removal: I. Yield and fiber quality. Crop Science 36:633-638.

Jordan, D., M. McClelland, A. Kendig, and R. Frans. 1997. Monosodium methanearsonate influence on broadleaf weed control with selected postemergence-directed cotton herbicides. Journal of Cotton Science 1:72-75.

Keeting, J.W., B.L. Joy, J.D. Everitt, L.L. Lyon, and P.A. Dotray. 2004. Application Timings and Rates in Roundup Ready Flex Cotton. Texas Agriculture Experiment Station.

Koger, C.H., A.J. Price, K.N. Reddy. 2005. Weed control and cotton response to combinations of glyphosate and trifloxysulfuron. Weed Science 19: 113-121.

Little, R.C., G.A. Milliken, W.W. Stroup, R. D. Wolfinger, O. Schabenberger. 2006. SAS for Mixed Models, 2nd Edition. SAS Institute, Cary, NC.

Mann, J.E., S.G. Turnipseed, M.J. Sullivan, P.H. Adler, J.A. DuRant, and O.L. May. 1997. Effects of early season loss of flower buds on yield, quality, and maturity of cotton in South Carolina. J. Econ. Entomol. 90:1324-1331.

Matthews, S.G., G.N. Rhodes, T.C. Mueller, R.M. Hayes. 1998. Effects of Roundup Ultra on Roundup Ready cotton. Proc., Beltwide Cotton Conference. 1: 850.

May, O.L., A.S. Culpepper, R.E. Cerny, C.B. Coots, C.B. Corkern, J.T. Cothren, K.A. Croon, K.L. Ferreira, J.L. Hart, R.M. Hayes, S.A. Huber, A.B. Martens, W.B. McCloskey, M.E. Oppenhuizen, M.G. Patterson, D.B. Reynolds, Z.W. Shappley, J. Subramani, T.K. Witten, A.C. York, and B.G. Mullinix, Jr. 2004. Transgenic cotton with improved resistance to glyphosate herbicide. Crop Science 44:234-240.

McCarty, W., J.N. Jenkins, and J.C. McCarty. 1975. Using Plant Mapping to evaluate Cotton Harvest. Mississippi State University Extension Service.

McCloskey, W.B., K.O. Adu-Tutu, and T.V. Hicks. 2004. Roundup Ready Flex cotton: Glyphosate tolerance and weed management 2002-2003. University of Arizona and Monsanto Company, Tucson, AZ and Fountain Hills, AZ.

Mitchell, C. *A Pictorial History of Alabama Agriculture: From Cotton Fields to Catfish*. 2004, Alabama Cooperative Extension System: Auburn University.

Monsanto. 2005. Backgrounder: History of Monsanto's Glyphosate Herbicides. [Online] http://www.monsanto.com/monsanto/content/products/productivity/roundup/back_history.pdf (posted June 2005; verified May 23, 2006).

Nida, D.L., K.H. Kolacz, R.E. Guehler, W.R. Deaton, W.R. Schuler, T.A. Armstrong, M.L. Taylor, C.C. Ebert, G.J. Rogan, S.R. Padgette, and R.L. Fuchs. 1996. Glyphosate-tolerant cotton: genetic characterization and protein expression. Journal of Agricultural and Food Chemistry 44:1960-1966.

Pankey, J.H., J.L. Griffin, B.R. Leonard, D.K. Miller, R.G. Downer, and R.W. Costello. 2004. Glyphosate-insecticide combination effects on weed and insect control in cotton. Weed Technology 18:698-703.

Patterson, M.G. 2005. Personal Communication, Auburn University.

Pline-Srnic, W.A., K.L. Edmisten, J.W. Wilcut, R. Wells, and J.L. Thomas. 2004. Effect of glyphosate on fruit retention, yield, and fiber quality of glyphosate resistant cotton. Journal of Cotton Science 8:24-32.

Pline, W.A., R. Viator, J.W. Wilcut, K.L. Edmisten, J. Thomas, and R. Wells. 2002b. Reproductive abnormalities in glyphosate-resistant cotton caused by lower CP4-EPSPS levels in the male reproductive tissue. Weed Science 50:438-447.

Porterfield, D., J.W. Wilcut, S.D. Askew. 2002. Weed management with CGA-362622, fluometuron, and prometryn in cotton. Weed Science 50: 642-647.

Stewart, A.M., A.C. York, A.S. Culpepper, and P.R. Vidrine. 2005. Response of glyphosate-resistant cotton to pre-harvest glyphosate application. Journal of Cotton Science 9:110-114.

Stewart, S.D., M.B. Layton, M.R. Williams, D. Ingram, and W. Maily. 2001. Response of cotton to prebloom square loss. Journal of Economic Entomology 94:388-396.

USDA. National Ag. Statistics Service On-Line. [Online] www.nass.usda.gov/ (posted 5/22/2006).

Viator, R.P., S.A. Senseman, and J.T. Cothren. 2003. Boll abscission responses of glyphosate-resistant cotton (Gossypium hirsutum) to glyphosate. Weed Technology 17:571-575.

Ward, C.W., A. Flanders, O. Isengildina, and F.C. White. 2002. Efficiency of alternative technologies and cultural practices for cotton in Georgia. Agbioforum 5:10-13.

Wilcut, J.W., H.D. Coble, A.C. York, and D.W. Monks. 1996. The niche for herbicide-resistant crops in U.S. agriculture. p. 213-230. *In* S.O. Duke (ed.) Herbicide-resistant crops: Agricultural, environmental, economic, regulatory, and technical aspects. CRC Press, Boca Raton, FL.

Wu, J., J.N. Jenkins, J.C. McCarty, and C.E. Watson. 2005. Comparisons of two statistical models for evaluating boll retention in cotton. Agronomy Journal 97:1291-1294.

York, A.C., A.S. Culpepper, D.T. Bowman, and O.L. May. 2004. Performance of Glyphosate-tolerant Cotton Cultivars in Official Cultivar Trials. The Journal of Cotton Science 8:261-270.