INTERFERENCE AND CONTROL OF SHARPPOD MORNINGGLORY (*Ipomoea cordatotriloba* Dennstedt) IN GLYPHOSATE-RESISTANT COTTON

A Dissertation

by

GREGORY LEE STEELE

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

DOCTOR OF PHILOSOPHY

December 2004

Major Subject: Agronomy

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December 2004

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ABSTRACT

Interference and Control of

Sharppod Morningglory (*Ipomoea cordatotriloba* Dennstedt)

in Glyphosate-Resistant Cotton. (December 2004)

Gregory Lee Steele, B.S.; M.S., Texas A&M University

Chair of Advisory Committee: Dr. James M. Chandler

Sharppod morningglory is a perennial vine commonly found infesting croplands in Texas and the southeastern United States. Previous research regarding morningglory competition and control primarily focused on annual *Ipomoea*. Interference, control, and herbicide translocation of sharppod morningglory could differ from that of other morningglories because of differences in growth and resource allocation. Therefore, field and laboratory experiments were conducted from 2001 to 2004 to: 1) determine the effects of seed-propagated and root-sprouted sharppod morningglory on cotton economic value, yield, harvest efficiency, and fiber quality; 2) evaluate sharppod morningglory control with cotton herbicides, and determine the effect of diuron rates on glyphosate absorption and translocation; and 3) assess the impact of cotton herbicide program and cotton-corn rotation on weed species composition over three years.

A relatively large proportion of sharppod morningglory biomass was accumulated belowground during the first 8 wk of growth in the greenhouse. Consequently, up to 6 plants 10-m row^{-1} did not significantly reduce cotton lint yield. Sharppod morningglory density impacted color grade more than any other classification

parameter. Through combined effects on yield and quality, cotton lint value was reduced by approximately 85% in the presence of 8 sharppod morningglory 10 m^{-1}.

Glyphosate alone did not completely control sharppod morningglory. The use of glufosinate, bromoxynil, or a combination of glyphosate plus diuron provided acceptable control. Sharppod morningglory absorbed up to 75% of glyphosate when applied alone, but most glyphosate was retained in treated leaves and did not translocate well. Diuron decreased absorption, increased leaf retention, and inhibited glyphosate translocation to roots.

Rotation to corn and the use of preemergence herbicides in cotton improved control of grass and broadleaf weeds during the year of treatment. In the season following the 3-yr rotation, there were no lasting effects of crop rotation on density or control of grasses and broadleaves. However, hand-hoed and herbicide treated plots resulted in weed densities 2- to 3-fold lower than the untreated. Preemergence herbicides and/or crop rotation can reduce weed density and improve weed control, but these strategies must be employed long-term to reduce density of problematic weeds through depletion of the soil seedbank.

DEDICATION

God has made all things in my life possible. He has given me countless gifts and opportunities. He has blessed me with tremendous love through my family and the people in my life. Though I may not have always believed in myself, my parents provided me with enough faith and encouragement to accomplish most anything. I surely would have not gotten this far had it not been for them. More recently, my source of encouragement has come from my wife, Michelle and sons, Luke and Grant. As a parent, I strive to live up to the image that my children have of me. They have brought incredible joy to my life, and completely changed my perception of what really matters. Though I fail to recognize it at times, I owe so much to my wife. She has supported me emotionally, spiritually, and financially at times, throughout my education. She has given me the confidence and desire to attain this goal. I love you all dearly.

While completing this dissertation, I experienced the loss of one of the greatest men I have known. My Grandfather, Luther H. Neal II, has touched my life and the lives of many. He has been a role model to me throughout my life because of his compassion, his integrity, and his wisdom. I thank God for the time with him and all the joyous memories. I dedicate this dissertation to his memory.

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to the following individuals who have made my graduate research possible: Dr. Mike Chandler who has been my mentor for over six years, and taught me more than I often recognize; Dr. Scott Senseman for his support and guidance in the lab; and Dr. J. T. Cothren and Dr. D. D. Briske who have been my teachers and advisors during this program.

I would also like to recognize the individuals that have assisted me in my program and whose acquaintances have made this an enjoyable journey. I thank Dr. Chris Tingle, Dr. Audie Sciumbato, Dr. Jason Krutz, Mark Matocha, Brian Ottis, John O'Barr, Sam Willingham, and Luis Avila who have been great friends and have been part of a wonderful learning environment. I thank the student workers that have made the tedious tasks less of a burden: Derek Scasta, Justin Campbell, Jacob Powell, Paul Davis, Chris Hundley, Alaina Bilski, Kim Berger, and all the others that have come and gone over the years.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Sharppod morningglory is a member of the morningglory family, Convolvulaceae. Confusion regarding the correct taxonomic nomenclature for sharppod morningglory has arisen in recent years. Sharppod morningglory is reported as *Ipomoea trichocarpa var. trichocarpa* Ell. in previous botanical literature (Correll and Johnston 1979; Hatch et al. 1990; Mahler 1988), and is still listed as such by some sources (S. M. Tracy Herbarium 2002). Despite this, *I. cordatotriloba* Dennstedt (1810) was found to be the same biological population as *I. trichocarpa* Elliot (1817) (Austin 1988; Manitz 1983). As a result, sources (Austin 1988; USDA-NRCS 2002; WSSA 1989) now list *I. trichocarpa var. trichocarpa* Ell. as a synonym of the earliest binomial (*Ipomoea cordatotriloba var. cordatotriloba* Dennstedt).

Sharppod morningglory shares common morphological and biological features with other *Ipomoea spp.* Sharppod morningglory possesses a twining growth habit, similar to other related species. Leaf arrangement is alternate. Leaf shape is variable, typically cordate-ovate, and may be entire, 3- or 5-lobed. Sharppod morningglory stems and leaves may be glabrous or pubescent, but the presence of hispid-pilose pubescence on the sepals separates this variety from cotton morningglory [*I. cordatotriloba var.*

This dissertation follows the style and format of Weed Science.

torreyana (Gray) D. Austin] (Correll and Johnston 1979). The corolla is funnelform, lavender to purple-rose in color, and 3 to 5 cm in length (Mahler 1988).

Sharppod morningglory is a perennial vine with the ability to flower in the first year of its life cycle (Correll and Johnston 1979; Mahler 1988). Furthermore, research indicates that perennial shoot regeneration is possible within 2 to 3 wks of emergence. In field and growth chamber experiments, Dorneden (1986) reported 100% shoot regeneration with sharppod moringglory that had been detopped at 17 to 24 days after emergence. Apparently, multiple adventitious shoots arise from the severed main root of mature plants. Fresh sharppod morningglory seed germinate up to 39%. As with other Convolvulaceae, germination percent is increased with mechanical scarification (Dorneden 1986). The ability of sharppod morningglory to persist both vegetatively and by annual seed production creates challenges to the management of this weed.

Sharppod morningglory is generally distributed throughout the southeastern United States from North Carolina to Texas (USDA-NRCS 2002). The species now known as *I. cordatotriloba* is native to North America, and was first identified in the Carolinas in the early 1700s (Austin 1976; Dillenius 1732). The western range of sharppod morningglory is limited to east Texas, whereas cotton morningglory (*var. torreyana*) is found exclusively in the western portion of the state (Austin 1976). Sharppod morningglory is commonly found as a weed of economic importance in central and eastern Texas (Brown et al. 1987; Dorenden 1986; Savoy et al. 1993).

Hybridization between sharppod morningglory and other related species is quite common (Austin 1976; Elmore et al. 1990). In Texas, hybrids of cotton and sharppod morningglories occur at the mergence of their distributions. Subtle differences in sepal pubescence separate these hybrids from the pure varieties (Austin 1976). Furthermore, Austin (1976) states that hybridization between *I. cordatotriloba* and *I. lacuno*sa has been so widespread in history that pure populations of sharppod morningglory may be nonexistent. Thus, modern sharppod morningglory populations are likely hybrids of *I. cordatotriloba/I. lacunosa*. This outcrossing behavior is likely due to the inability of sharppod morningglory to self-pollinate. This is generally thought to be a primitive evolutionary trait typical of many perennial Convolvulaceae (Elmore et al. 1990).

Morningglories are among the most troublesome weeds in the cotton-producing region of the southern U. S. (Webster 2000, 2001). Although no data has been published regarding the competitive ability of sharppod morningglory, several researchers have evaluated competition of other morningglories with cotton. Tall morningglory (*Ipomoea purpurea*) densities of 16 plants 15 m^{-1} have reduced seed cotton yield as much as 75% (Buchanan and Burns 1971). Furthermore, research that evaluated competition of four *Ipomoea spp.* with cotton revealed that only 4 tall morningglory 15 m^{-1} of row significantly reduce cotton yield compared to the control (Crowley and Buchanan 1978). Results from these experiments suggest that competitiveness differed between species and could be ranked: tall morningglory > pitted morningglory (*Ipomoea lacunosa*) > ivyleaf morningglory (*I. hederacea var. hederacea*) = entireleaf morningglory (*I. hederacea var. integriuscula*. However, in these studies the authors concede that defoliation by rust could have resulted in diminished competitiveness of ivyleaf/entireleaf morningglory (Crowley and Buchanan 1978). Keeley et al. (1986)

reported that total crop loss occurred with one ivyleaf morningglory 2 m^{-1} of row. Moreover, researchers conclude from recent work that ivyleaf morningglory reduces cotton yield 6% for each plant 10 m^{-1}, up to 9 plants 10 m^{-1} (Rogers et al. 1996). Similarly, Wood et al. (1999) evaluated cotton yield with 0 to 12 ivyleaf morningglory 10 m^{-1} row, and reported 4 to 7% yield reductions for each weed 10 m^{-1} of row. In addition, several researchers have reported various soybean yield losses with entireleaf morningglory (Mosier and Oliver 1995), pitted morningglory (Norsworthy and Oliver 2002), and tall morningglory (Oliver et al. 1976).

Ipomoea spp. not only reduce crop yields through competition for common resources, but also by physically interfering with crop growth and harvest procedures (Buchanan and Burns 1971). Up to 24% reduction in harvest efficiency of mechanically picked cotton has been reported with 16 tall morningglory 15 m^{-1} of row. However, no density of pitted morningglory, ivyleaf morningglory, or entireleaf morningglory reduced harvest efficiency in this experiment (Crowley and Buchanan 1978). In contrast, others have reported that mechanical cotton harvest is prevented by 8 ivyleaf morningglory 10 m^{-1} (Rogers et al. 1996). Furthermore, 10 ivyleaf morningglory 10 m^{-1} prevented stripper harvest of cotton, despite no significant harvest efficiency reductions with lower weed densities (Wood et al. 1999).

The value of cotton is not only determined by yield weight, but is affected by fiber quality and other physical characteristics. The effect of morningglory density on cotton quality has been investigated with mixed results (Buchanan and Burns 1971; Crowley and Buchanan 1978; Rogers et al. 1996; Wood et al. 1999). Buchanan and

Burns (1971) reported that tall morningglory did not affect micronaire, length, strength, or uniformity, regardless of weed density. Likewise, Crowley and Buchanan (1978) concluded that quality was inconsistently affected by any density of the four morningglory species evaluated. Others have reported that morningglory density may detrimentally affect micronaire, strength, (Wood et al. 1999) and length (Rogers et al. 1996). Yield and quality have been used to determine the economic value of cotton in experiments with johnsongrass (Wood et al. 2002), but the reviewed literature does not provide a clear understanding of the relationship between morningglory density, cotton quality, and economic value of cotton.

Based on previous competition experiments with annual *Ipomoea*, it is hypothesized that moderate densities of sharppod morningglory will result in cotton yield reductions. Given its perennial growth form, seed-propagated sharppod morningglory will likely be less competitive compared to results with annual morningglories. The late season vegetative growth of sharppod morningglory will probably interfere with harvest operations and adversely affect lint quality, which impacts cotton economic value.

The literature is deficient in sharppod morningglory control data, and most reviewed treatments are somewhat outdated. Dorneden (1986) evaluated preemergence sharppod morningglory control with prometryn, fluometuron, cyanazine, propazine, atrazine, and linuron. Postemergence control was evaluated with oxyfluorfen, monosodium methyl arsonate (MSMA), or MSMA tankmixed with prometryn, cyanazine, fluometuron, or diuron. Results were variable between years, but generally, preemergence treatments of fluometuron controlled sharppod morningglory less than 60%. Postemergence treatments of MSMA were usually improved with the addition of residual herbicides, but MSMA applied alone resulted in no more than 55% sharppod morningglory control (Dorneden 1986). Others have reported up to 91% sharppod morningglory control with prometryn preemergence followed by methazole postemergence. Sharppod morningglory control was only 50 to 73% with prometryn alone in these studies (Savoy et al. 1993).

Few options were available for postemergence morningglory control in cotton before the mid-1990s (Paulsgrove and Wilcut 2001; Savoy et al. 1993). The advent of pyrithiobac provided the opportunity for excellent postemergence control of morningglories (Culpepper and York 1997, 2001; Paulsgrove and Wilcut 2001). Recent advances in biotechnology have led to the development of cotton lines tolerant to the herbicides bromoxynil (Stalker et al. 1988) and glyphosate (Nida et al. 1996). Glyphosate is a generally nonselective herbicide that inhibits amino acid synthesis. Specifically, glyphosate blocks the shikimate pathway by binding to the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) (Devine et al. 1993). Glyphosate controls a broad spectrum of weeds (Chachalis et al. 2001; Culpepper and York 2001; Ferrell and Witt 2002; Hoss et al. 2003; Krausz et al. 1996; Scott et al. 2002; Shaw and Arnold 2002; Wehtje and Walker 1997). Efficacy from glyphosate is variable between morningglory species (Chachalis et al. 2001; Wehtje and Walker 1997), and plant sizes (Hoss et al. 2003; Chachalis et al. 2001; Wehtje and Walker 1997). Surprisingly, seedling ivyleaf and palmleaf (*I. wrightii*) morningglories are less susceptible to glyphosate than later stages (Wehtje and Walker 1997). Conversely, four *Ipomoea spp*. demonstrated significant decrease in control when treatment was delayed from 2- to 4-leaf to 5- to 8-leaf stage (Chachalis et al. 2001).

Differences in absorption, translocation, and leaf characteristics have been attributed to differential herbicide susceptibility of morningglory species. Chachalis et al. (2001) concluded that differential herbicide susceptibility of ivyleaf, pitted, palmleaf, and smallflower (*Jacquemontia tamnifolia*) morningglories was not attributable to differences in their leaf structure or composition. Furthermore, absorption of ^{14}C-glyphosate differed among the same four species, although control of the weeds appeared unrelated to absorption and translocation (Wehtje and Walker 1997). Conversely, Norsworthy et al. (2001) attributed glyphosate tolerance in pitted morningglory to limited absorption, despite reports that ivyleaf morningglory absorbed more glyphosate than similar species (Wehtje and Walker 1997). Hoss et al. (2003) reported that ivyleaf morningglory translocated less glyphosate than other unrelated weeds. Glyphosate translocation was acropetal in ivyleaf morningglory, compared to basipetal translocation in the other species (Hoss et al. 2003). Moreover, problems understanding herbicide translocation can be exacerbated in perennial species. Herbicide movement could be affected by changes in relative sink strength of roots and shoots during establishment and growth of perennials. For instance, translocation of 2, 4 - D in field bindweed (*Convolvulus arvensis*) was found to be different between seedling and vegetatively-propagated plants, with a more acropetal shift in herbicide accumulation with increasing age (Agbakoba and Goodin 1969).

Decreased translocation of herbicide to the roots could allow persistence of perennial species like sharppod morningglory. Herbicide combinations also have the potential to detrimentally affect the efficacy of one or both of the components. Absorption and translocation of glyphosate was reduced when applied to pitted morningglory in combination with fomesafen (Starke and Oliver 1998). Fomesafen inhibits protoporphyrinogen oxidase, ultimately resulting in leaky cellular membranes and rapid (1-3 d) desiccation (Vencill 2002). In recent years, the herbicide diuron, has been applied postemergence directed and layby in combination with glyphosate to improve control of morningglories and other broadleaf weeds in cotton (Barber et al. 2003; Vencill 2003). When applied postemergence, diuron produces symptoms similar to fomesafen (Vencill 2002). The combination of glyphosate with diuron will result in greater weed desiccation than glyphosate alone. The increased dessication may inhibit glyphosate translocation to the roots and result in less than complete control.

Differential herbicide susceptibility is one of several factors that play a role in weed community composition. The repeated use of a particular herbicide or weed control measure has led to shifts in weed populations. Crop rotation has been employed to increase weed diversity, thereby preventing the dominance of a particular problem weed (Anderson et al. 1998). Ghosheh and Chandler (1998) reported that corn-cotton-corn rotation reduced johnsongrass density compared to continuous corn. However, the effect of crop rotation on weed communities is primarily due to the weed management practices associated with different crops (Doucet et al. 1999). Blackshaw et al. (1994) concluded that improved downy brome (*Bromus tectorum*) control in wheat rotations, compared to continuous wheat, was primarily due to the herbicides used in canola, lentils, and flax. Even without crop rotation, weed control practices alone have led to weed species shifts in soybean or corn (Buhler 1999).

The increasing reliance upon glyphosate in Roundup Ready® crops may reduce the beneficial effects of crop rotation for the control of certain weeds, and increase the occurrence of species more tolerant to glyphosate. Roundup Ready® varieties are the most popular among both conventional and transgenic cotton (Van Winkle 2002). Furthermore, Roundup® herbicide has become the largest selling agrichemical in the world (Magin 2003), and is used on73%, 57% and 13% of U. S. soybean, cotton, and corn acreage, respectively (Anonymous 2002). Although traditional corn herbicides are effective in controlling morningglories (Culpepper and York 1999; Johnson et al. 2000), programs consisting of glyphosate alone could negate the weed control benefits of rotating from cotton to corn, and lead to the proliferation of weeds inherently more tolerant to glyphosate. A tankmix of atrazine with single glyphosate applications has increased morningglory control from 39 to 90% (Johnson et al. 2000). Therefore, glyphosate tankmixes, rotation to conventional herbicide programs, and/or preemergence herbicides could improve long-term control of morningglories, compared to exclusive glyphosate use. To test the previously stated hypotheses, the objectives of this research are to: 1) determine the effects of seed-propagated and resprouted sharppod morningglory on cotton economic value, yield, harvest efficiency, and fiber quality; 2) evaluate sharppod morningglory control with cotton herbicides, and determine the effect of diuron rates on glyphosate absorption and translocation; 3) assess the impact of cotton herbicide program and cotton-corn rotation on weed species composition over three years.

CHAPTER II

GROWTH AND INTERFERENCE OF SHARPPOD MORNINGGLORY WITH COTTON

Introduction

Sharppod morningglory is a perennial vine, and a member of the morningglory family, Convolvulaceae. This weed is native to North America, and is generally distributed throughout the southeastern United States from North Carolina to Texas (USDA-NRCS 2002). In recent years, sharppod morningglory has become prevalent in row crops in south-central and southern Texas, and is listed as a noxious weed in Arizona (USDA, NRCS 2002). The regenerative ability of sharppod morningglory roots (Dorneden 1986) and the capacity to flower and produce seed in the first year of establishment (Correll and Johnston 1979; Mahler 1988) present a challenge to the management of this weed. However, little is known about the effect of sharppod morningglory growth on cotton yield. Since the majority of the research in this area addresses competition of annual morningglory species and is somewhat variable among those species, inferences about sharppod morningglory competitiveness based on these models are unreliable.

Morningglories are among the most troublesome weeds in the cotton-producing region of the southern U. S. (Webster 2000, 2001). Although no data has been published regarding the competitive ability of sharppod morningglory, several researchers have evaluated competition of other morningglories with cotton. Tall morningglory (*Ipomoea* *purpurea*) densities of 16 plants 15 m^{-1} have reduced seed cotton yield as much as 75% (Buchanan and Burns 1971). Furthermore, research that evaluated competition of four *Ipomoea spp.* with cotton revealed that only 4 tall morningglory 15 m^{-1} of row significantly reduce cotton yield compared to the control (Crowley and Buchanan 1978). Results from these experiments suggest that competitiveness differed between species, and could be ranked: tall morningglory > pitted morningglory (*Ipomoea lacunosa*) > ivyleaf morningglory (*I. hederacea var. hederacea*) = entireleaf morningglory (*I. hederacea var. integriuscula*. However, in these studies the authors concede that defoliation by rust could have resulted in diminished competitiveness of ivyleaf/entireleaf morningglory (Crowley and Buchanan 1978). Keeley et al. (1986) reported that total crop loss occurred with one ivyleaf morningglory 2 m^{-1} of row. Moreover, recent work concludes that ivyleaf morningglory reduces cotton yield 5.9% for each plant 10 m^{-1}, up to 8.7 plants 10 m^{-1} (Rogers et al. 1996). Similarly, Wood et al. (1999) evaluated cotton yield with 0 to 12 ivyleaf morningglory 10 m^{-1} row, and reported 3.8 to 6.9% yield reductions for each weed 10 m^{-1} of row. In addition, several researchers have reported various soybean yield losses with entireleaf morningglory (Mosier and Oliver 1995), pitted morningglory (Norsworthy and Oliver 2002), and tall morningglory (Oliver et al. 1976).

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Materials and Methods

Competition

Field research was conducted at the Texas A&M University Research Farm in Burleson County in 2002 and 2003. Treatments consisted of 0, 2, 4, 6, and 8 seed-propagated sharppod morningglory 10 m^{1} of row, and 0, 2, 4, and 6 sharppod morningglory 10 m^{-1} row, resprouted from mature roots. Experimental design was a randomized complete block. Plot size was 12.2 m in length by 4 rows, spaced 102 cm apart. Sharppod morningglory were evenly spaced in the center 10 m of the row, and transplanted directly beside the seed furrow. Approximately 1.1 m of weed-free buffer was maintained at the front and back of each plot. Likewise, the first row of each plot served as a weed-free buffer between adjacent plots. Treatments were replicated 3 times with a 4.6-m alley between replications.

Locally collected sharppod morningglory seed were sown in 118-ml paper cups filled with a 1:1 mixture of Ships Clay soil and potting mix on approximately the same day as cotton planting in the field. Sharppod morningglory were allowed to emerge in the greenhouse, thinned to 1 plant pot^{-1}, and transplanted in the field at the cotyledon growth-stage. Cotton planting was accomplished using a vacuum planter calibrated to deliver 143,000 seeds ha^{-1}. Cotton variety DPL 451 BR was planted in rows spaced 102 cm apart on approximately the first of May in both years. Approximately 30 d prior to planting, 112 kg ha^{-1} nitrogen, in the form of urea ammonium nitrogen, was injected into the rows and immediately incorporated. Standard irrigation and pest control procedures were employed in each year. Plots were maintained free of undesirable weeds by hand hoeing throughout the season. Weed emergence was monitored, and weeds removed in the seedling stage.

Similar methods were employed in perennial studies. However, sharppod moringglory were planted in 500-ml paper cups approximately 6 wk before cotton planting. At 4 wk after emergence, sharppod morningglory shoots were removed, and allowed to resprout from root buds. After resprouting, the entire root bundle was transplanted as described above.

When cotton achieved approximately 60 to 70% open bolls, a standard defoliation treatment of ethephon plus thidiazuron was applied across all plots. After adequate defoliation, the 1.1-m buffer areas were removed from the front and back of each plot. Seed cotton yield was determined from the center transplanted row of each plot using a one-row mechanical cotton picker. Cotton remaining on the plant or falling to the ground during harvest was collected by hand and used to calculate harvest efficiency. Harvest efficiency is described as the percentage of total cotton (mechanically and hand collected) that was mechanically picked. Lint yield was determined utilizing a 10-saw laboratory gin with a one-stage seed cleaner. Lint samples were collected and sent to the International Textile Center in Lubbock, TX for determination of fiber quality. A 3-yr average of cotton loan rate was used to estimate economic value as previously described (Wood et al. 2002). Total economic value was estimated for each treatment by multiplying loan rate by lint yield. In each year, dependent variables were analyzed by ANOVA, and combined across years where appropriate. Mean separation was used to describe the relationship between sharppod morningglory density and each dependent variable when there was a significant ($p \leq 0.05$) treatment effect.

Growth Analysis

Since growth rate and resource allocation can impact the competitiveness of weeds, growth of sharppod morningglory and ivyleaf morningglory were compared in greenhouse experiments. Experiments were conducted in a greenhouse at the Norman Borlaug Center for Southern Crop Improvement on the Texas A&M University campus. Locally collected sharppod morningglory seed and ivyleaf morningglory seed were sown in 15.2-cm pots filled with potting mix. A slow release fertilizer, 13-13-13, (500 mg) was incorporated into each pot prior to planting, and plants were watered to field capacity daily. The experimental design was completely randomized, with five replications. Experiments were repeated over years.

Five plants each of ivyleaf morningglory and sharppod morningglory were randomly sampled weekly for a period of 8 wk. Plants were partitioned into leaves, stem, and root. Excised plant parts were oven-dried at 32 C for 72 h before weighing. Leaf, stem, and root weights were used to calculate aboveground and belowground biomass, and root:shoot ratios of each species. All data were subjected to ANOVA and combined across experimental runs when appropriate. Mean separation and/or regression analysis were used to describe the relationship between dependent variables and plant age when there was a significant ($p \leq 0.05$) treatment effect.

Results and Discussion

Competition

All data in the seed-propagated experiments are presented separately by year. Cotton lint yield in 2002 ranged from 1229 to 926 kg ha^{-1} (Table 1). The only significant decrease in lint yield occurred with 8 plants ha^{-1}. Overall lint yields the following year were lower, and there were no significant differences at any sharppod morningglory density. This is in contrast to cotton yield reductions of 3.8 to 6.9% observed with each ivyleaf morningglory plant 10 m^{-1} (Wood et al. 1999). Furthermore, merely 2.7 tall morningglory (*Ipomoea purpurea*) plants 10 m^{-1} have been reported to significantly reduce cotton yield (Crowley and Buchanan 1978). This difference is probably attributable to the resource allocation pattern of the perennial sharppod morningglory, compared to the annual species.

Density had no effect on harvest efficiency in either year (Table 1). Harvest efficiencies were between 84 and 90% in 2002, and from 94 to 95% in 2003. Higher efficiency in 2003 could be attributed to less cotton present on the plants, indicated by the lower yields in that year. Compared to the literature, these results are not surprising. Most reports of reduced harvest efficiency have occurred with morningglory densities higher than those evaluated in our research. Up to 24% reduction in harvest efficiency

Table 1. The effect of seed-propagated sharppod morningglory density on cotton lint yield and harvest efficiency in 2002 and 2003.

Sharppod morningglory density	2002		2003	
	Yield[a]	Harvest efficiency[b]	Yield	Harvest efficiency
Plants $10m^{-1}$	kg ha^{-1}	%	kg ha^{-1}	%
0	1159 ab	87.4	722	94.8
2	1147 ab	88.0	728	94.9
4	1229 a	89.9	707	93.9
6	1198 ab	90.0	665	94.5
8	926 b	84.5	748	93.9

[a] Means followed by the same letter within a column are not significantly different according to Fisher's Protected LSD ($\alpha = 0.05$).

[b] Harvest efficiency is the percentage of total cotton yield that was mechanically picked.

has been reported with 10.7 tall morningglory plants 10 m^{-1} (Crowley and Buchanan 1978). Additionally, ivyleaf morningglory densities below 10 plants 10 m^{-1} did not affect stripper cotton harvest efficiency (Wood et al. 1999).

Fiber quality measurements reveal that sharppod morningglory density did not have a detrimental effect on micronaire in 2002 or 2003 (Figure 1). With the exception of 2 plants per 10 m of row in 2003, all other densities resulted in micronaire values in the base range. This means that micronaire did not result in any premiums or discounts applied to the base value of lint. Similarly, sharppod morningglory density had no effect on fiber length or fiber strength in either year (Figure 2a, 2b). Uniformity of fiber length was reduced with 2, 4, and 6 plants 10 m^{-1}. However, there was no difference in uniformity between 0 and 8 sharppod morningglory per 10 m of row (Figure 2c). Although morningglory effects on fiber quality are inconsistent in the literature, similar results have been reported with tall morningglory (Buchanan and Burns 1971).

Cotton lint classification and loan rate premiums and discounts were used to estimate lint value. Color grade was an important factor in final lint value. In 2002, 6 and 8 plants $10m^{-1}$ significantly increased color grade discounts, compared to the untreated (Figure 3). Only the highest density increased color grade discounts in the following year. This reflects the impact of sharppod morningglory contamination that was observed in the field. Sharppod morningglory that were present at harvest became entangled in the harvested seed cotton. This contamination led to lint staining that translated to lower color grade with the higher plant densities.

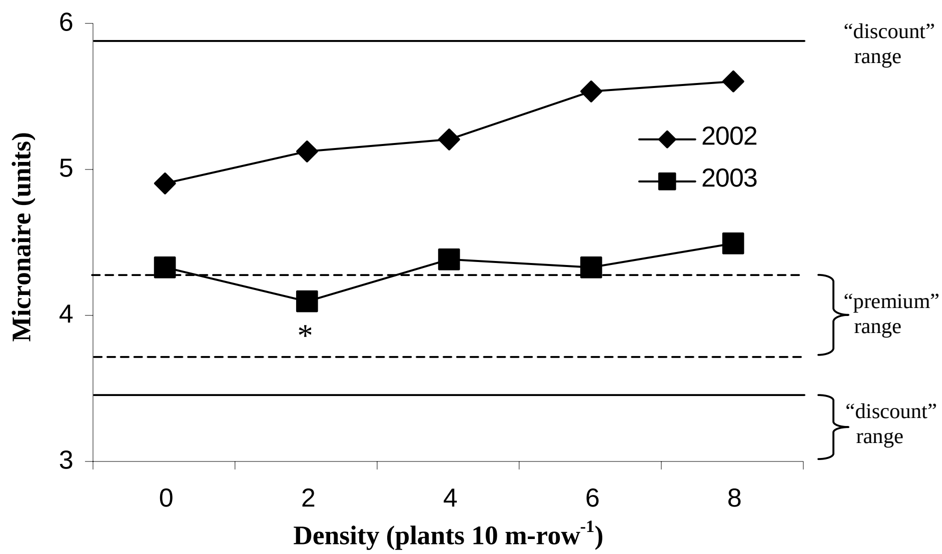

Figure 1. The effect of sharppod morningglory density on fiber fineness (micronaire) of cotton in 2002 and 2003. An asterik (*) denotes a significant difference in micronaire from the weed-free treatment in that year, according to Fisher's Protected LSD (α = 0.05).

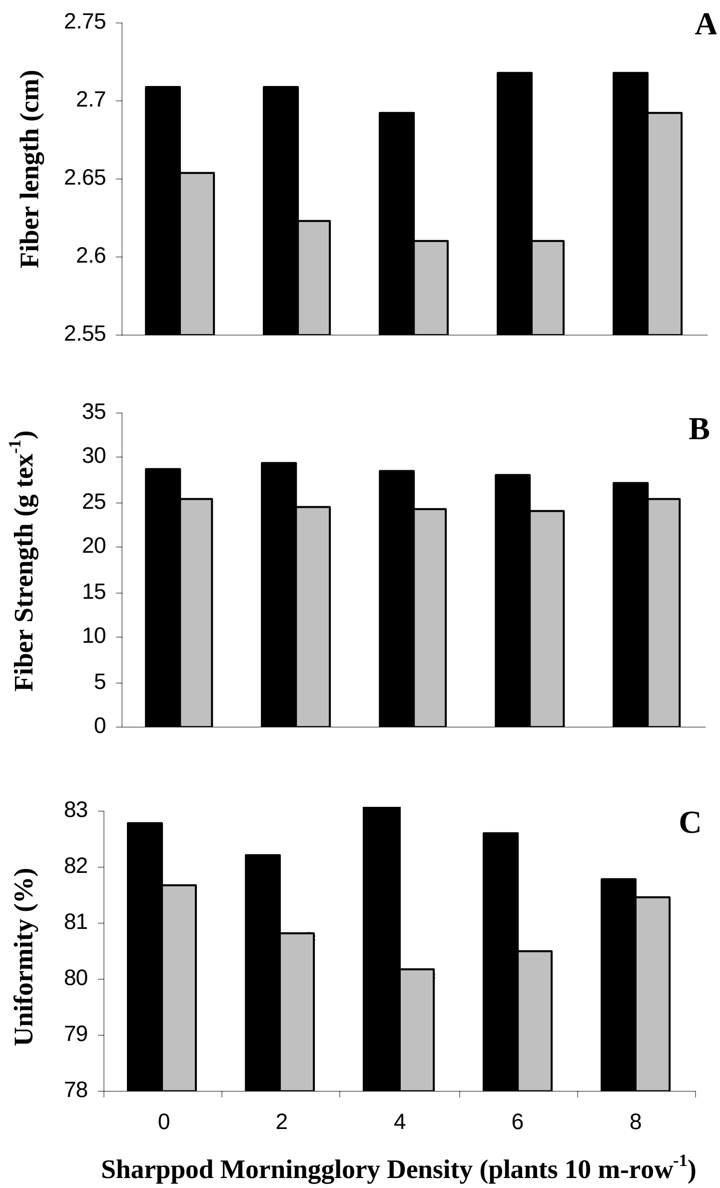

Figure 2. Fiber length (A), fiber strength (B), and fiber length uniformity (C) as a result of sharppod morningglory density in 2002 (dark bars) and 2003 (light bars). An asterik (*) indicates a significant difference from the weed-free treatment in that year, according to Fisher's Protected LSD ($\alpha = 0.05$).

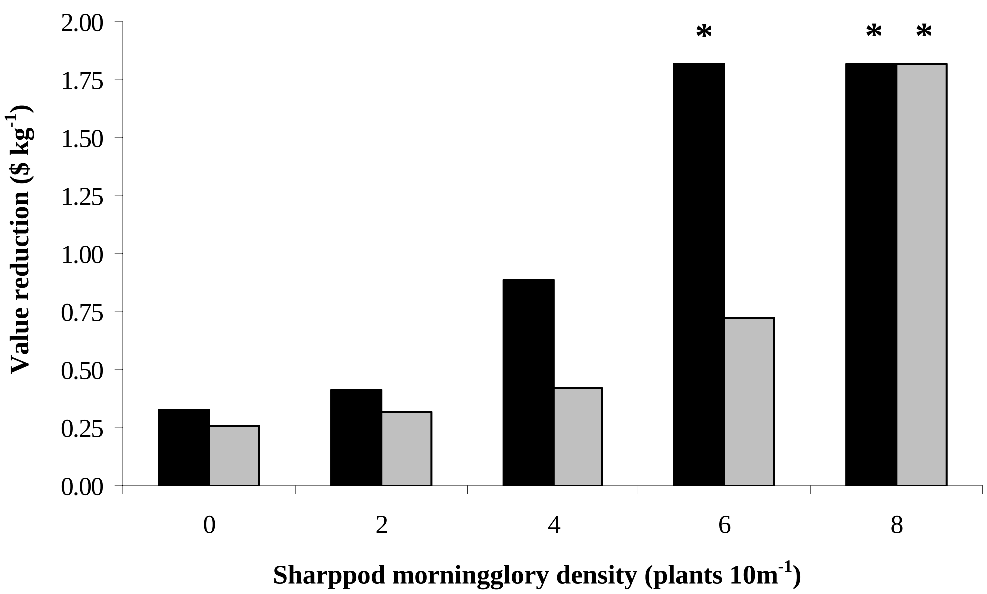

Figure 3. Cotton lint value reductions resulting from color grade discounts in 2002 (dark bars) and 2003 (light bars). An asterik (*) indicates a significant difference from the weed-free treatment in that year, according to Fisher's Protected LSD (α = 0.05).

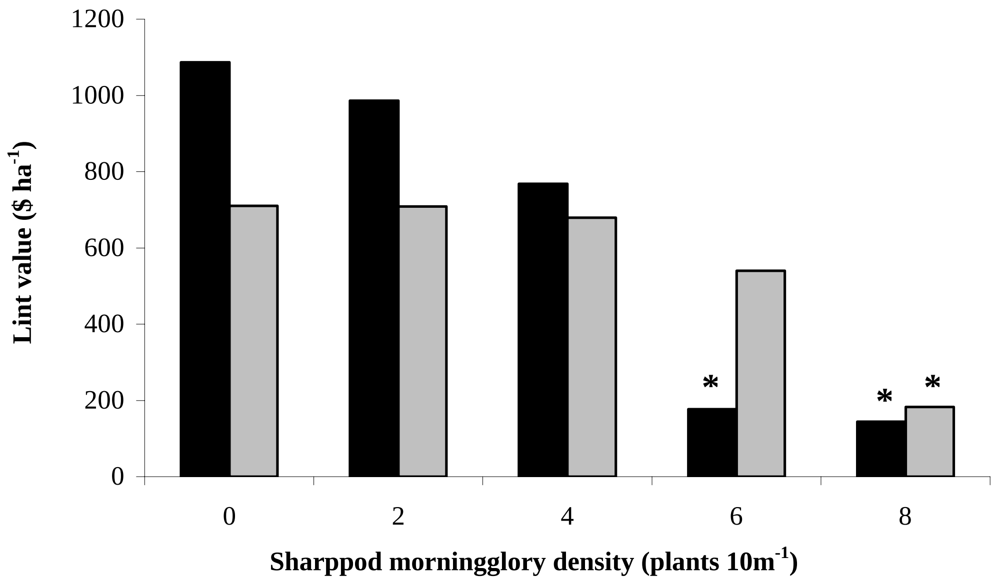

Figure 4. The effects of sharppod morningglory density on cotton lint value in 2002 (dark bars) and 2003 (light bars). An asterik (*) indicates a significant difference from the weed-free treatment in that year, according to Fisher's Protected LSD (α = 0.05).

In 2002, 6 and 8 sharppod morningglory 10 m^{-1} reduced lint value by $910 and $943 ha^{-1}, respectively (Figure 4). Lower overall yields in 2003 resulted in more moderate value reductions. Soil test the following year revealed that 2003 yields may have been limited by slight phosphorus deficiency, which reduced root production and subsequent water extraction later in the season. Only the highest density of sharppod morningglory significantly reduced value in 2003. These results are somewhat surprising considering the weak relationship between sharppod morningglory density and cotton yield. Similarly, individual fiber quality measurements alone do not seem to contribute to reductions in loan rate. Conclusions about sharppod morningglory competition based solely on these parameters would be misleading. However, using all these factors to calculate lint value results in a clearer picture of bottom-line effects of sharppod morningglory interference.

Sharppod morningglory plants, resprouted from roots, had no effect on cotton yield, harvest efficiency, or lint value (Table 2). Fewer densities were used in these experiments partly because of plant propagation problems in 2002, and partly due to an expected greater competitive ability of resprouted plants. It was hypothesized that the slow initial growth seen with seed-propagated plants could be increased if plants sprouted from established roots. Based on casual observations, resprouted plants appeared to accumulate more aboveground biomass than seed-propagated plants. However, at the densities evaluated, resprouted plants had no effect on any production parameter of cotton, including fiber quality (Table 3).

Table 2. Effect of resprouted sharppod morningglory density on lint yield, harvest efficiency, and lint price. Data were pooled for 2002 and 2003.

Sharppod morningglory density	Yield	Harvest efficiency[b]	Price
Plants 10 m^{-1}	kg ha^{-1}	%	\$ ha^{-1}
0	902[a]	92.7	9470
2	837	92.0	8308
4	851	92.0	8849
6	817	91.6	8353

[a] There were no significant differences in yield, harvest efficiency, and price among sharppod morningglory densities ($p \geq 0.05$).

[b] Harvest efficiency is the percentage of total cotton yield that was mechanically picked.

Table 3. Fiber quality as affected by resprouted sharppod morningglory density from 2002 to 2003.

Sharppod morningglory density	Micronaire	Length	Uniformity	Strength
Plants 10 m^{-1}	Units	cm	%	g tex^{-1}
0	4.4[a]	2.7	34.6	26.6
2	4.6	2.7	34.2	25.6
4	4.4	2.7	34.3	25.9
6	4.6	2.7	34.5	25.5

[a] There were no significant differences in micronaire, length, uniformity, and strength among sharppod morningglory densities ($p \geq 0.05$).

Growth Analysis

Greenhouse experiments were conducted to compare early season growth and biomass partitioning of sharppod morningglory with that of ivyleaf morningglory. Ivyleaf morningglory competition has been well documented, and a comparison would allow a better understanding of the effects of growth and biomass partitioning on sharppod morningglory competition in the field. Leaf dry weights of sharppod morningglory did not significantly increase beyond 4 wk after emergence (WAE), reaching a maximum of 974 mg at 8 WAE (Table 4). Maximum ivyleaf morningglory leaf weights were achieved by 4 WAE (1015 mg). Results were similar for stem weights, with sharppod morningglory reaching maximum of 761 mg at 8 WAE, and ivyleaf moringglory accumulating 1474 mg by 5 WAE. In contrast to aboveground biomass, sharppod morningglory partitioned a greater portion of resources to root growth. Sharppod moringglory root weights increased significantly every week, up to 7 WAE with root weights of 5209 mg by 8 WAE. Ivyleaf morningglory root weights did not increase beyond 4 WAE, and reached a maximum of only 423 mg at 6 WAE.

Due to artificial growth conditions, ivyleaf morningglory began flowering 3 WAE (Table 5). By 6 WAE, ivyleaf morningglory had partitioned 2271 mg of biomass into sexual reproductive structures. Consequently, ivyleaf morningglory leaves began senescing from 6 to 8 weeks, which explains the decline in leaf weight after 5 DAE. Sharppod morningglory did not initiate flowering during the experiment. Total plant biomass of sharppod morningglory increased weekly up to 7 WAE, reaching a maximum of 6507 mg at 8 WAE. In contrast, ivyleaf morningglory biomass did not increase

Table 4. Aboveground biomass of sharppod and ivyleaf morningglory partitioned into leaves, stems, and roots.

WAE[a]	Leaves[b]		Stems		Roots	
	SMG	IMG	SMG	IMG	SMG	IMG
	------------------ mg $plant^{-1}$ ------------------					
1	20 d[c]	79 d	7 e	20 e	12 g[c]	21 d
2	181 c	334 bc	67 d	259 d	97 f	116 c
3	379 b	495 ab	176 c	668 c	403 e	254 b
4	550 ab	1015 a	248 bc	1346 a	979 d	383 a
5	700 a	649 ab	467 a	1474 a	1897 c	365 a
6	690 a	444 ab	422 ab	1435 a	3249 b	423 ab
7	829 a	182 cd	469 ab	883 b	4623 a	383 a
8	974 a	24 e	761 a	856 b	5209 ab	343 a

[a] WAE, weeks after emergence; SMG, sharppod morningglory; IMG, ivyleaf morningglory.

[b] Actual data is presented. Log transformed data was used for analysis of variance and regression analysis.

[c] Means followed by the same letter within a column are not significantly different according to Fisher's Protected LSD (α=0.05).

Table 5. Reproductive structures and total biomass of sharppod and ivyleaf morningglory at 1 to 8 weeks after emergence in the greenhouse.

WAE[a]	Reproductive[b]		Total biomass	
	SMG	IMG	SMG	IMG
	------------------------------ mg plant^{-1} ------------------------------			
1	0	0 d	39 g	119 e
2	0	0 d	345 f	709 d
3	0	61 c	958 e	1417 c
4	0	415 b	1777 d	2744 a
5	0	1603 a	3064 c	2488 ab
6	0	2271 a	4361 b	2311 b
7	0	1868 a	6357 a	1448 c
8	0	1622 a	6507 a	1223 c

[a] WAE, weeks after emergence; SMG, sharppod morningglory; IMG, ivyleaf morningglory.

[b] Actual data is presented. Log transformed data was used for analysis of variance and regression analysis.

[c] Means followed by the same letter within a column are not significantly different according to Fisher's Protected LSD (α=0.05)

beyond 2744 mg at 4 WAE. Because of an accelerated shift from vegetative to reproductive growth, ivyleaf morningglory biomass actually decreased after 6 WAE

The differences in growth and biomass partitioning of sharppod and ivyleaf morningglories can be seen in a graphical representation of root:shoot ratios of the two species (Figure 5). Beginning at 2 WAE, sharppod morningglory partitions a relatively large amount of resources to root growth. Root:shoot ratio of sharppod moringglory continued to increase up to 7 WAE, and root growth slows by the eighth week. Conversely, ivyleaf morningglory root:shoot ratio decreased from 1 to 3 WAE, and remained below 1 through the eighth week. These results show that the apparent slow growth of sharppod morningglory seen in the field is a reflection of aboveground growth only. In fact, seed-propagated sharppod morningglory exhibits rapid growth during the first eight weeks of establishment. However, the majority of this growth takes place below ground. Because of the perennial nature of sharppod morningglory, establishment of roots and vegetative reproductive structures that ensure persistence are priorities for early growth.

Annual *Ipomoea*, like ivyleaf morningglory, are better competitors with cotton because of rapid aboveground growth, effectively competing for light during the critical first months of the season. Because sharppod morningglory concentrates its resources on root growth for the first 8 WAE, cotton yield is not drastically affected at moderate weed densities. The impact of belowground competition for resources is limited by cultural practices associated with cotton. Experiments were adequately fertilized with nitrogen, and irrigated as needed throughout both years. Aboveground competition by

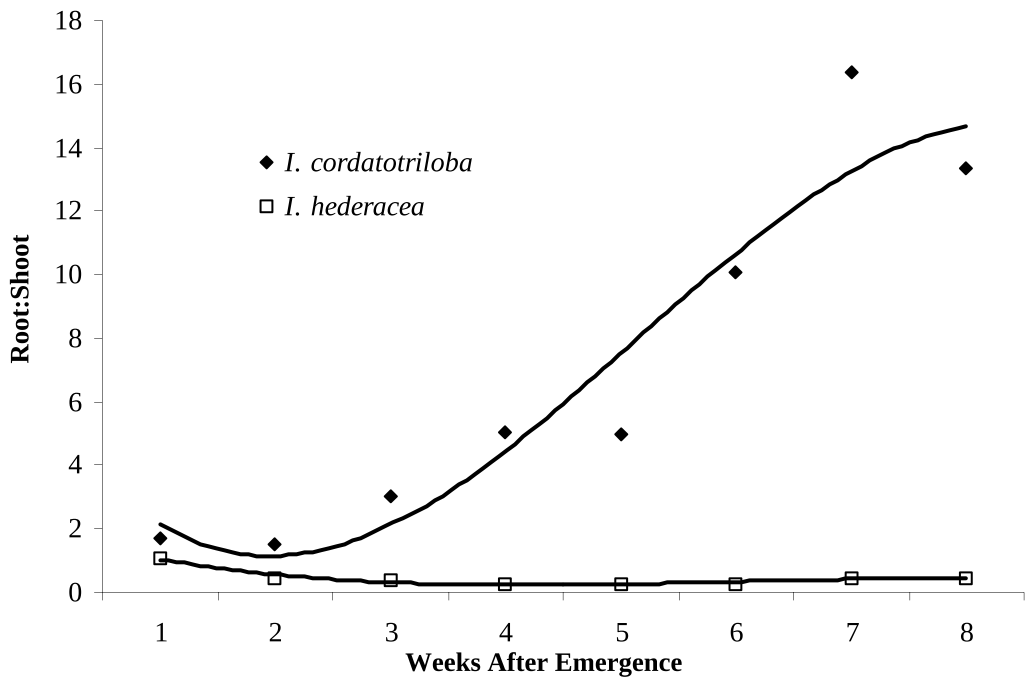

Figure 5. Actual and predicted root:shoot ratios of greenhouse-grown sharppod morningglory (♦); $\log Y=1.01+0.80x-0.30x^2+0.02x^3$) and ivyleaf morningglory (□); $\log Y=1.05+1.22x-0.18x^2+0.01x^3$).

sharppod morningglory after 8 weeks is tolerated, and corresponds to the 6- to 8-week weed-free period required by cotton (Zimdahl 1980; Tingle et al. 2003). Moreover, aboveground growth during the latter part of the season may contribute to increased trash content in the harvested cotton, and lead to grade reductions. This explains the contribution of color grade to value reductions, and the effect of high sharppod morningglory densities on total lint value, despite minor differences in yield.

CHAPTER III

SHARPPOD MORNINGGLORY CONTROL AND DIURON EFFECTS ON ABSORPTION AND TRANSLOCATION OF GLYPHOSATE

Introduction

Sharppod morningglory is a perennial vine distributed throughout the southeastern U. S. (USDA-NRCS 2002). This weed is commonly found infesting Central and Southern Texas cotton fields. *Ipomoea spp*. are listed as some of the most troublesome weeds in the cotton producing regions of the U. S. (Webster 2000, 2001). Moreover, the regenerative ability of sharppod morningglory roots (Dorneden 1986) and the capacity to flower and produce seed in the first year of establishment (Correll and Johnston 1979; Mahler 1988) present a challenge to the management of this weed.

The literature is deficient in sharppod morningglory control data, and most reviewed treatments are somewhat outdated. Dorneden (1986) evaluated preemergence sharppod morningglory control with prometryn, fluometuron, cyanazine, propazine, atrazine, and linuron. Postemergence control was evaluated with oxyflurofen, MSMA, or MSMA tankmixed with prometryn, cyanazine, fluometuron, or diuron. Results were variable between years, but generally, preemergence treatments of fluometuron controlled sharppod morningglory less than 60%. Postemergence applications of MSMA were usually improved with the addition of residual herbicides, but MSMA applied alone resulted in no more than 55% sharppod morningglory control (Dorneden 1986). Others have reported up to 91% sharppod morningglory control with prometryn preemergence followed by methazole postemergence. Whereas, sharppod morningglory control was only 50 to 73% with prometryn alone in these studies (Savoy et al. 1993).

Few options were available for postemergence morningglory control in cotton before the mid-1990s (Paulsgrove and Wilcut 2001; Savoy et al. 1993). The advent of pyrithiobac provided the opportunity for excellent postemergence control of morningglories (Culpepper and York 1997, 2001; Paulsgrove and Wilcut 2001). Recent advances in biotechnology have led to the development of cotton lines tolerant to the herbicides bromoxynil (Stalker et al. 1988) and glyphosate (Nida et al. 1996). Glyphosate is a generally nonselective herbicide that inhibits amino acid synthesis. Specifically, glyphosate blocks the shikimate pathway by binding to the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) (Devine et al. 1993). Glyphosate controls a broad spectrum of weeds (Chachalis et al. 2001; Culpepper and York 2001; Ferrell and Witt 2002; Hoss et al. 2003; Krausz et al. 1996; Scott et al. 2002; Shaw and Arnold 2002; Wehtje and Walker 1997). Efficacy from glyphosate is variable between morningglory species (Chachalis et al. 2001; Wehtje and Walker 1997), and plant sizes (Hoss et al. 2003; Chachalis et al. 2001; Wehtje and Walker 1997). Surprisingly, seedling ivyleaf and palmleaf (*I. wrightii*) morningglories are less susceptible to glyphosate than later stages (Wehtje and Walker 1997). Conversely, four *Ipomoea spp*. demonstrated significant decrease in control when treatement was delayed from 2- to 4-leaf to 5- to 8-leaf stage (Chachalis et al. 2001).

Differences in absorption, translocation, and leaf characteristics have been attributed to differential herbicide susceptibility of morningglory species. Chachalis et al. (2001) concluded that differential herbicide susceptibility of ivyleaf, pitted, palmleaf, and smallflower (*Jacquemontia tamnifolia*) morningglories was not attributable to differences in their leaf structure or composition. Absorption of ^{14}C-glyphosate differed among the same four species, although control of the weeds appeared unrelated to absorption and translocation (Wehtje and Walker 1997). Conversely, Norsworthy et al. (2001) attributed glyphosate tolerance in pitted morningglory to limited absorption, despite reports that ivyleaf morningglory absorbed more glyphosate than similar species (Wehtje and Walker 1997). Hoss et al. (2003) reported that ivyleaf morningglory translocated less glyphosate than other unrelated weeds. Glyphosate translocation was acropetal in ivyleaf morningglory, compared to basipetal translocation in the other species (Hoss et al. 2003). Moreover, problems understanding herbicide translocation can be exacerbated in perennial species. Herbicide movement could be affected by changes in relative sink strength of roots and shoots during establishment and growth of perennials. For instance, translocation of 2, 4 - D in field bindweed (*Convolvulus arvensis*) was found to be different between seedling and vegetatively-propagated plants, with a more acropetal shift in herbicide accumulation with increasing age (Agbakoba and Goodin 1969).

Decreased translocation of herbicide to the roots could allow persistence of perennial species like sharppod morningglory. Herbicide combinations also have the potential to detrimentally affect the efficacy of one or both of the components.

Absorption and translocation of glyphosate was reduced when applied to pitted morningglory in combination with fomesafen (Starke and Oliver 1998). Fomesafen inhibits protoporphyrinogen oxidase, ultimately resulting in leaky cellular membranes and rapid (1-3 d) desiccation (Vencill 2002). In recent years, the herbicide diuron, has been applied postemergence directed in combination with glyphosate to improve control of morningglories and other broadleaf weeds in cotton (Barber et al. 2003; Vencill 2003). When applied postemergence, diuron produces symptoms similar to fomesafen (Vencill 2002). Based on the reviewed literature, we hypothesize that combination of glyphosate with diuron will result in greater weed desiccation than glyphosate alone, and the increased desiccation may inhibit glyphosate translocation to the roots and result in less than complete control. Therefore, the objectives of this research were to evaluate sharppod morningglory control with cotton herbicides, and determine the effect of diuron on glyphosate absorption and translocation.

Material and Methods

Sharppod Morningglory Control

The efficacy of cotton herbicide treatments on two growth stages of sharppod morningglory was evaluated at the Texas A&M University Research Farm in Burleson County in 2002 and 2003. The experimental design was a randomized complete block. Treatments consisted of postemergence applications of glyphosate at 84 g ae ha^{-1}, pyrithiobac at 70 g ai ha^{-1}, pyrithiobac + glyphosate at 36 g ai ha^{-1} + 840 g ae ha^{-1}, trifloxysulfuron at 5.3 g ai ha^{-1}, glufosinate at 410 g ai ha^{-1}, bromoxynil at 560 kg ai ha^{-1}, MSMA + fluometuron at 2.24 + 1.12 kg ai ha^{-1}, glyphosate + diuron at 840 g ae ha^{-1} + 560 kg ai ha^{-1}, and a weedy check.

Sharppod morningglory was sown in the field using a tractor-mounted vegetable planter. Plots consisted of a single row of plants, 12.2 m long. Treatments were replicated 4 times, and a 4.6-m alley was maintained between replications. Planting date of 14- and 42-day-old plants was staggered so that both stages were present when herbicides were applied. Herbicide treatments as listed above were applied using a CO_2 powered backpack sprayer calibrated to deliver 187 L ha^{-1}. Data collection consisted of visual estimation of control as a function of visual biomass reduction, with 0% indicating no control, and 100% indicating complete control. Data were subjected to ANOVA, and means were separated according to Fisher's Protected LSD procedure when there was a significant ($p \leq 0.05$) treatment effect. Because of a significant treatment by year interaction, means are presented separately by year.

Diuron Effects on Absorption and Translocation of Glyphosate

Sharppod morningglory seed were sown in 3.8-cm diameter x 21-cm deep cones containing potting mix. Plants were grown in growth chambers with a 16-h photoperiod and 30 C day / 25 C night temperature regime. Plants were watered daily and fertilized weekly with a nutrient solution. Treatments for efficacy and absorption/translocation determinations were applied to sharppod morningglory plants approximately 21 d after emergence. This growth stage was used to simulate the size plants that are typically present when directed postemergence herbicide treatments are applied in the field. Treatments consisted of glyphosate applied alone at 840 g a.e. ha^{-1}, and glyphosate at

840 g ha^{-1} plus diuron at 420 and 840 g a.i. ha^{-1} applied in 93 L ha^{-1} of distilled water from a moving-boom spray chamber. The remaining spray solution was fortified with ^{14}C- phosphonomethyl labeled glyphosate, and four 1-μl aliquots (1.85 kBq μl^{-1}) were applied to the adaxial side of the youngest fully expanded mature leaf, immediately after herbicide application. Since most glyphosate translocation occurs within 3 d following application (Wyrill and Burnside 1976), treated leaves were excised 0.5 and 72 h after treatment, rinsed with 20 ml DI water to remove unabsorbed ^{14}C- glyphosate, then rinsed with 20 ml methanol to remove ^{14}C- glyphosate on the leaf cuticle. A 2-ml aliquot of the rinsate was added to 10 ml of scintillation cocktail. The remaining plant tissue was partitioned into four sections: treated leaf, tissue above treated leaf, tissue below treated leaf, and roots. Samples were oven-dried at 50 C for 72 h, ground, and a 100 mg subsample was combusted using a biological oxidizer. Radioactivity of oxidized and rinsate samples were quantified with liquid scintillation spectrometry, and used to calculate percent of applied ^{14}C glyphosate on the leaf surface, in the cuticle, and absorbed. Percent foliar absorption was calculated using the equation of Norsworthy et al. (2001). Total recovery of ^{14}C averaged 96%. Plants not receiving ^{14}C- treatment were maintained in growth chambers, and used for whole-plant efficacy determination of growth reduction. At 28 DAT plants were harvested, and samples were dried to determine whole plant biomass.

Plant growth, herbicide application, and liquid scintillation were accomplished in the laboratory, at Texas A&M University campus. Experimental design was completely randomized for both experiments. Treatments were replicated 3 times, and two experimental runs were conducted in the Summer and Fall of 2004. All data was subjected to ANOVA, and treatment means separated according to Fisher's Protected LSD at $P \leq 0.05$.

Results and Discussion

Sharppod Morningglory Control

In 2002, control of 10- to 20-cm and 30- to 60-cm sharppod morningglory with glyphosate was significantly improved with the addition of diuron (Table 6). Moreover, no other treatment exceeded the level of sharppod morningglory control attained with glyphosate + diuron. Bromoxynil efficacy was not evaluated in 2002 due to an application error. In 2003 glyphosate and glufosinate controlled 10- to 20-cm sharppod morningglory 10 to 13% better than the previous year. Although glyphosate + diuron was among the most efficacious treatments, providing 78% control, 10- to 20-cm sharppod morningglory control did not differ from glyphosate alone at 68%.

Glufosinate and bromoxynil were the only treatments that controlled 30- to 60-cm sharppod morningglory above 70%. Conversely, sharppod morningglory control was only 60% with glyphosate + diuron, and was no different than glyphosate alone. In both years, glufosinate provided at least 66% control of 30- to 60-cm sharppod morningglory. Although glyphosate + diuron efficacy was inconsistent on larger plants, 10-20 cm sharppod morningglory control ranged from 78 to 93% with this treatment from 2002 to 2003.

Table 6. Control of 10- to 20-cm and 30- to 60-cm sharppod morningglory in the field, 21 DAT.

Herbicide	Rate	2002		2003	
		10- to 20-cm	30- to 60-cm	10- to 20-cm	30- to 60-cm
	g ha^{-1}	-------------------------------- % --------------------------------			
Untreated	-	0 d[a]	0 d	0 d	0 c
Glyphosate	840	58 c	48 c	68 bc	58 b
Pyrithiobac	70	55 c	52 bc	63 c	62 b
Pyrithiobac + glyphosate	36 840	68 bc	64 abc	65 c	60 b
Trifloxysulfuron	5.3	76 abc	65 abc	63 c	58 b
Glufosinate	410	69 bc	66 ab	82 a	77 a
Bromoxynil	560	-	-	78 ab	73 a
MSMA + fluometuron	224 112	79 ab	61 bc	78 ab	63 b
Glyphosate + diuron	840 560	93 a	82 a	78 ab	60 b

[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD (α=0.05).

Table 7. Dryweight of sharppod morningglory grown in a growth chamber, as influenced by glyphosate and varying rates of diuron.

Herbicide	Rate	Dry weight
	G ha^{-1}	-------- mg --------
Glyphosate	840	1201
Glyphosate + diuron	840 420	968
Glyphosate + diuron	840 840	811
LSD		260[a]

[a] Treatment effect significant at $\alpha \leq 0.1$.

Diuron Effects on Absorption and Translocation of Glyphosate

There was a significant (p=0.06) treatment effect on sharppod morningglory dryweight in growth chamber experiments evaluating glyphosate alone and in combination with diuron at 420 g ha^{-1} and 840 g ha^{-1} (Table 7). The addition of diuron at 840 g ha^{-1} reduced sharppod morningglory biomass from 1206 to 811 mg, compared to glyphosate applied alone. This is in agreement with field data indicating an increase from 58 to 91% control of sharppod morningglory when diuron is tank-mixed with glyphosate.

Within 0.5 h after treatment, only 3 to 6% of applied ^{14}C-glyphosate had been absorbed, with no difference between treatments (Table 8). Although there were no differences in absorption or partitioning in the epicuticular matrix, significantly more glyphosate remained on the leaf surface when applied with diuron. The majority of applied ^{14}C-glyphosate had been absorbed by 72 h after treatment, when applied alone (Table 9). Mixture with 420 g ha^{-1} diuron reduced absorption from 75% to 38%, and resulted in significantly more ^{14}C on the leaf surface. As before, there were no differences in cuticular retention. In contrast, Norsworthy et al. (2001) reported only 6% absorption of glyphosate by pitted morningglory after 48 h. In our experiments, sharppod morningglory absorbed 6% of applied glyphosate within 30 min, and up to 75% by 72 hours after treatment. Furthermore, experiments with ivyleaf, palmleaf, pitted and smallflower morningglories revealed that only 25, 6, 6, and 9% of applied ^{14}C glyphosate was absorbed after 48 h (Wehtje and Walker 1997). In fact, absorption of glyphosate by sharppod morningglory is more similar to field bindweed, which is

Table 8. The effect of diuron on absorption of $^{14}C^{-}$glyphosate in treated leaves sampled 0.5 h after application[a].

Herbicide	Rate	Leaf surface	Cuticle	Absorbed
	g ha^{-1}	----------------------------------	%	----------------------------------
Glyphosate	840	88	6	6
Glyphosate + diuron	840 420	93	3	4
Glyphosate + diuron	840 840	95	2	3
LSD (α=0.05)		4	ns	ns

[a] Data presented as percent of applied ^{14}C-glyphosate.

Table 9. The effect of diuron on absorption of $^{14}C^{-}$glyphosate in treated leaves sampled 72 h after application[a].

Herbicide	Rate	Leaf surface	Cuticle	Absorbed
	g ha^{-1}	----------------------------------	%	----------------------------------
Glyphosate	840	19	6	75
Glyphosate + diuron	840 420	57	5	38
Glyphosate + diuron	840 840	41	5	54
LSD (α=0.05)		24	ns	26

[a] Data presented as percent of applied ^{14}C-glyphosate.

reported to absorb 46 to 49% glyphosate within 72 h (Sherrick et al. 1986). These differences in absorptivity may be partially attributed to differences in leaf structure and composition. The leaf cuticle is the primary barrier to herbicide penetration (Wanamarta and Penner 1989). Leaf surface structure, wax composition, and wax mass varies among annual *Ipomoea* (Chachalis et al. 2001). Furthermore, growing conditions can influence epicuticular wax deposition. Plants in our experiments were watered to field capacity daily. Since herbicide absorption generally increases with soil moisture content (Devine et al. 1993), this could have also contributed to the substantial amount of glyphosate absorbed in sharppod morningglory leaves.

Herbicide combination did not affect translocation of absorbed ^{14}C-glyphosate in plants harvested 0.5 h after treatment (Table 10). However, up to 16% absorbed glyphosate had translocated to the roots within 30 min, and approximately one third of ^{14}C was recovered in leaf and stem tissue below the treated leaf. By 72 hours after treatment, at least 87% of absorbed ^{14}C-glyphosate remained in the treated leaf (Table 11). The addition of 420 g ha^{-1} diuron significantly increased the retention of ^{14}C-glyphosate in the leaf. This difference must be attributed to decreased translocation, based on the pattern of absorption reported in Table 9. Although there were no differences in ^{14}C partitioning in above- and below-treated leaf parts, a greater percentage of ^{14}C-glyphosate was located in roots of plants treated with glyphosate alone. Moreover, there was no apparent increase in glyphosate translocation to roots of diuron-treated plants, from 0.5 to 72 h after treatment. Even with glyphosate alone, roots contained only 2% of absorbed glyphosate. In contrast, 14 to 18% of absorbed

Table 10. Distribution of absorbed ^{14}C-glyphosate 0.5 h after application, as affected by diuron.

Herbicide	Rate	Percent of absorbed ^{14}C			
		Treated leaf	Above treated leaf	Below treated leaf	Roots
	g ha^{-1}	------------------------------ % --------------------------			
Glyphosate	840	49	7	35	9
Glyphosate + diuron	840 420	58	7	27	8
Glyphosate + diuron	840 840	31	15	38	16
LSD (α=0.05)		ns			

Table 11. Distribution of absorbed ^{14}C-glyphosate 72 h after application, as affected by diuron.

Herbicide	Rate	Percent of absorbed ^{14}C			
		Treated leaf	Above treated leaf	Below treated leaf	Roots
	g ha^{-1}	------------------------------ % --------------------------			
Glyphosate	840	87	7	4	2
Glyphosate + diuron	840 420	95	3	2	< 1
Glyphosate + diuron	840 840	91	7	2	< 1
LSD (α=0.05)		7	ns	ns	1

glyphosate translocated to roots of field bindweed 72 h after treatment (Sherrick et al. 1986).

These results indicate that the limited susceptibility of sharppod morningglory to glyphosate observed in the field is not attributable to absorptivity. In fact, sharppod morningglory absorbs a much greater percentage of applied glyphosate than annual *Ipomoea* (Wehtje and Walker 1997; Norsworthy et al. 2001). Our results are more similar to those of Sherrick et al. (1986). However, sharppod morningglory absorbs as much as 19% more applied glyphosate than field bindweed. Although sharppod morningglory and field bindweed are both perennials with similar absorptivity, only 2% of absorbed glyphosate translocates to roots of sharppod morningglory, compared to 14% in field bindweed (Sherrick et al. 1986). In comparison, pitted morningglory is reported to translocate 25% of absorbed glyphosate to the roots (Starke and Oliver 1998). Our results are surprising considering that the majority of sharppod morningglory growth occurs belowground during the first few weeks after emergence (see Chapter II).

There are several possible explanations for the apparent contradiction in translocation of glyphosate to sharppod morningglory roots. At high concentrations, glyphosate may reduce photosynthetic electron transport by more than half (Munoz-Rueda et al. 1986, Devine et al. 1993). Normally this would be of little consequence since glyphosate does not accumulate at high concentrations in source tissues. However, in our experiments, 75% of applied glyphosate was absorbed, with the majority being retained in the treated leaf. This could potentially reduce translocation by limiting carbon fixation and sucrose synthesis (Geiger and Bestman 1990). Secondly, herbicide retention in treated tissue, and reduced translocation to the roots has been reported as a possible mechanism of resistance in *Lolium spp*. (Dinelli et al. 2004) and *Conyza canadensis* (Feng et al. 2004). In some of these experiments, glyphosate retention in treated leaves was 2- to 3-fold higher in resistant biotypes of *C. Canadensis.* Moreover, phloem loading and glyphosate export from treated leaves was slower than susceptible plants. By 48 h after treatment, glyphosate concentration in roots of resistant plants was 1/3 that of susceptible biotypes (Feng et al. 2004). Another possible scenario involves the interacton of calcium and magnesium salts with glyphosate, which impairs absorption in treated plants (Thelen et al. 1995). Although this antagonism occurs more commonly in spray solution, cations present on the leaf surface of *Abutilon theophrasti* and field bindweed can have similar effects (Hall et al. 2001). Furthermore, free cations in the leaf apoplast, and bound to cell wall components, may limit translocation by inhibiting entry of glyphosate into the symplast (Hall et al. 2001).

Results of our experiments do not indicate that sharppod morningglory is resistant to glyphosate. However, based on the findings of other researchers, complex physiological mechanisms may impact glyphosate translocation. From our results, we can conclude that glyphosate toxicity in sharppod morningglory may be partly influenced by retention in treated leaves and limited basipetal translocation.

Furthermore, we concluded that diuron improved visual control and reduced biomass of sharppod morningglory, but limited translocation of glyphosate to the roots. After 72 h, plants treated with glyphosate + diuron retained more ^{14}C glyphosate in treated leaves, and contained almost no ^{14}C in roots. Others have reported reductions in glyphosate translocation in combination with fomesafen (Starke and Oliver 1998). The inhibitory effects of diuron on glyphosate translocation is likely due to reduced carbon fixation and/or loss of membrane integrity. Diuron is an inhibitor of photosystem II in plants (Vencill 2002). One of the consequences of diuron activity is the cessation of carbon fixation within several hours (Devine et al. 1993), which reduces phloem transport. Moreover, the inhibition of photosystem II results in the formation of singlet oxygen (Vencill 2002). This leads to the subsequent peroxidation of membrane lipids, and reduced phloem transport through deterioration of the phloem transport system.

Increased efficacy of glyphosate combined with diuron in the field is partly due to aboveground desiccation resulting from the diuron component. Based on laboratory experiments, diuron reduced translocation of glyphosate, and resulted in the localization of glyphosate in treated leaves. Potentially, the diuron combination could increase glyphosate toxicity in aboveground tissues. Although our results suggest that diuron inhibits glyphosate translocation to the roots, it is unclear whether sharppod morningglory persistence is affected, compared to glyphosate alone. In fact, glyphosate did not achieve complete plant death in field experiments. Furthermore, translocation of glyphosate alone in sharppod morningglory was limited in our experiments. Based on these results, it is theorized that glyphosate concentration in sharppod morningglory roots, when applied at 840 g ae ha^{-1}, is inadequate for complete control. Neither glyphosate alone, nor glyphosate combined with diuron may prevent reestablishment of sharppod morningglory from roots in the following year. Therefore, field applications of diuron combined with 840 g ha^{-1} glyphosate positively influences sharppod morningglory control by improving foliar desiccation, despite reducing glyphosate translocation. Future research should address regrowth potential of sharppod morningglory with additional glyphosate rates, and the effect of diuron on translocation of higher rates of glyphosate.

CHAPTER IV

THE INFLUENCE OF COTTON HERBICIDE PROGRAM AND CROP ROTATION ON WEED CONTROL AND WEED SPECIES COMPOSITION

Introduction

Morningglories are among the most troublesome weeds in the cotton-producing region of the southern U. S. (Webster 2000, 2001). Until the 1990s, there were few options available for postemergence control of *Ipomoea spp.* in cotton. In recent times, pyrithiobac use and the development of glyphosate resistant cotton has provided an opportunity for postemergence morningglory control. However, efficacy from glyphosate alone is variable between morningglory species (Chachalis et al. 2001; Wehtje and Walker 1997) and plant sizes (Chachalis et al. 2001; Hoss et al. 2003; Wehtje and Walker 1997). For example, seedling ivyleaf and palmleaf (*I. wrightii*) morningglories are less susceptible to glyphosate than later stages (Wehtje and Walker 1997), and four *Ipomoea spp*. demonstrated significant decrease in control when treatment was delayed from 2- to 4-leaf to 5- to 8-leaf stage (Chachalis et al. 2001). Since differential herbicide susceptibility is one of several factors that play a role in weed species composition, continuous glyphosate use could lead to population shifts from more susceptible species to less susceptible species.

The repeated use of an herbicide or a management strategy associated with a given crop has led to decreased weed diversity and prevalence of less susceptible weeds. Crop rotation has been employed to increase weed diversity, thereby preventing the dominance of a particular problem weed (Anderson et al. 1998). Ghosheh and Chandler (1998) reported that corn-cotton-corn rotation reduced johnsongrass density compared to continuous corn. However, the effect of crop rotation on weed communities is primarily due to the weed management practices associated with different crops (Doucet et al. 1999). Blackshaw et al. (1994) concluded that improved downy brome (*Bromus tectorum*) control in wheat rotations, compared to continuous wheat, was primarily due to the herbicides used in canola, lentils, and flax. Even without crop rotation, weed control practices alone have led to weed species shifts in soybean or corn (Buhler 1999).

The increasing reliance upon glyphosate in glyphosate-resistant crops may reduce the beneficial effects of crop rotation for the control of certain weeds, and increase the occurrence of species more tolerant to glyphosate. Glyphosate-resistant varieties are the most popular among both conventional and transgenic cotton (Van Winkle 2002). Furthermore, Roundup® herbicide has become the largest selling agrichemical in the world (Magin 2003), and is used on 73%, 57% and 13% of U. S. soybean, cotton, and corn acreage, respectively (Anonymous 2002). Although traditional corn herbicides are effective in controlling morningglories (Culpepper and York 1999; Johnson et al. 2000), programs consisting of glyphosate alone could negate the weed control benefits of rotating from cotton to corn, and lead to the proliferation of weeds inherently more tolerant to glyphosate.

Fluometuron is commonly used preemergence in cotton for control of broadleaf weeds. Glyphosate applied following fluometuron has increased tall morningglory and entireleaf morningglory control compared to glyphosate alone (Scott et al. 2002). Pyrithiobac and trifloxysulfuron are effective options for postemergence control of morningglories in cotton (Burke and Wilcut 2004; Porterfield et al. 2002), and could increase morningglory control if tankmixed with glyphosate. Moreover, tankmixing atrazine with glyphosate has increased morningglory control in corn from 39 to 90% (Johnson et al. 2000). Glyphosate tankmixes, rotation to conventional herbicide programs, and/or preemergence herbicides could improve long-term control of morningglories, compared to exclusive glyphosate use. Therefore, the objectives of this research were to assess the impact of cotton herbicide program and cotton-corn rotation on weed control, weed species composition, and yield over a three-year period.

Materials and Methods

This experiment was conducted at the Texas A&M University Research Farm in Burleson County from 2001 to 2003. The study was established in an area with consistent and uniform weed pressure. Experimental design was a strip plot. The main plot consisted of crop rotation schemes, and cotton herbicide treatment comprised the subplots. Crop rotation schemes included 1) continuous Roundup Ready® cotton (RR cotton), 2) RR cotton – conventional corn – RR cotton, 3) RR cotton – RR corn – RR cotton. Herbicide treatments consisted of glyphosate applied to 1- to 2-leaf cotton and 4- to 8-cm weeds (EPOST) and to 3- to 4-leaf cotton and 10- to 20-cm weeds (POST) at 840 g ae ha^{-1}; pendimethalin at 1.12 kg ha^{-1} + fluometuron at 1.12 kg ha^{-1} applied preemergence, followed by (*fb*) glyphosate applied EPOST and POST at 840 g ae ha^{-1}; glyphosate at 840 g ae ha^{-1} applied EPOST, *fb* glyphosate at 840 g ae ha^{-1} + pyrithiobac at 70 g ha^{-1} applied POST; glyphosate at 840 g ae ha^{-1} applied EPOST, fb glyphosate at 840 g ae ha^{-1} + trifloxysulfuron at 7.8 g ha^{-1} applied POST; pendimethalin at 1.12 kg ha^{-1} + fluometuron at 1.12 kg ha^{-1} applied preemergence, followed by hand-hoeing (weed-free check); and no herbicide (weedy check). All herbicide applications were made with a tractor-mounted sprayer calibrated to deliver 187 L ha^{-1}. The herbicide treatments were only applied when plots were planted to cotton. All treatments rotated to RR corn received a single postemergence application of glyphosate at 840 g ae ha^{-1}. Conventional corn plots were treated with a preemergence application of 1.4 kg ha^{-1} atrazine + 1.1 kg ha^{-1} metolachlor, *fb* nicosulfuron at 37 g ha^{-1} + primisulfuron at 45 g ha^{-1} + prosulfuron at 45 g ha^{-1}, applied postemergence. Postemergence corn treatments were applied on April 25 and May 2, 2002.

Plot size was 12 m in length by 4 rows, spaced 102 cm apart. Treatments were replicated 4 times with a 4.6-m alley between replications. Cotton planting was accomplished using a vacuum planter calibrated to deliver 143,000 seed ha^{-1}. Cotton variety DPL 436 RR was planted in rows spaced 102 cm apart during approximately the first week of May. Corn varieties DK 697 (conventional) and RX 794 RR (Roundup Ready) were planted at a rate of 65,500 seed ha^{-1} on March 26, 2002 using similar equipment and methods. Standard irrigation and pest control procedures were employed in each year.

Visual weed control was evaluated approximately 8 weeks after cotton planting (approximately 21 days after early postemergence herbicide application). Weed counts were estimated by taking two, 930 cm^2 transects from the center two rows of each plot immediately prior to the early postemergence application. In each year, cotton yield was determined by mechanically picking the second row of each plot. Corn yield was estimated by hand harvesting 3 m from each of the center two rows. In year 4, the entire experiment was planted to corn and final weed counts were conducted on May 27. All data was subjected to analysis of variance to determine significance ($P \leq 0.05$) of main and subplots and all possible interactions. Weed control percentages that were subjected to arcsine transformation did not affect the results; therefore, untransformed data were used in the analysis. Weed counts were square root transformed prior to analysis, and then untransformed for presentation. Treatment differences were determined using the difference of least squares means procedure.

Results and Discussion

Weed Control

In 2001 Texas panicum control was at least 98%, regardless of herbicide treatment (Table 12). The following year Texas panicum control remained above 91% in continuous cotton treatments, with no differences between herbicide treatments. In 2002, continuous cotton and cotton rotated to glyphosate-resistant corn controlled Texas panicum better than with conventional corn, within each herbicide treatment. Interestingly, although corn herbicides were applied uniformly across all subplots, no weed control (untreated) in 2001 significantly reduced Texas panicum control the

Table 12. The effect of rotation and cotton herbicide program on Texas panicum control 8 weeks after cotton planting[a].

Herbicide treatment	Rate	2001	2002			2003
		Cot	Cot	CCC	CRC	Cot
	G ha^{-1}	---------------------------------%---------------------------------				
Untreated	-	0 d[b]	0 A c	64 A b	88 A b	0 d
Hand-hoed	-	100 a	100 A[c] a	80 B a	93 A ab	100 a
Glyphosate *fb*[d] glyphosate	840 *fb* 840	98 c	91 A b	76 B a	94 A ab	95 bc
Pendimethalin + fluometuron *fb* glyphosate *fb* glyphosate	1120 + 1120 *fb* 840 *fb* 840	99 b	95 A ab	81 B a	95 A ab	98 ab
Glyphosate *fb* glyphosate + pyrithiobac	840 *fb* 840 + 70	99 b	94 A ab	75 B a	90 A ab	97 bc
Glyphosate *fb* glyphosate + trifloxysulfuron	840 *fb* 840 + 7.8	98 c	96 A ab	74 B a	97 A a	94 c

[a] Cot, cotton monoculture; CCC, cotton-conventional corn-cotton rotation; CRC, cotton-glyphosate-resistant corn-cotton rotation.

[b] Means followed by the same lower case letter within a year and column are not significantly different as determined by the difference of least squares means at α=0.05.

[c] Means within a row and year followed by the same uppercase letter are not significantly different. Means within a column followed by the same lowercase letter are not significantly

[d] *fb*, followed by.

following year. This probably resulted from seedbank contributions of uncontrolled Texas panicum in 2001. In 2003 rotation had no effect on Texas panicum control. As in previous years when rotated to cotton, Texas panicum control was at least 94% in 2003. Pendimethalin + fluometuron *fb* two applications of glyphosate controlled Texas panicum better than glyphosate *fb* glyphosate + trifloxysulfuron.

Ivyleaf morningglory control was at least 90% among herbicide treatments in 2001 (Table 13). However, pendimethalin + fluometuron preemergence increased ivyleaf morningglory control with sequential glyphosate applications, and was more efficacious than pyrithiobac and trifloxysulfuron treatments. Results were similar for continuous cotton in 2002, but pendimethalin + fluometuron *fb* sequential glyphosate was the only herbicide treatment providing at least 90% ivyleaf morningglory control. There were no significant differences among subplots rotated to conventional or glyphosate-resistant corn. As with Texas panicum, ivyleaf morningglory control was only affected by herbicide treatment in 2003. Herbicide treatments controlled ivyleaf morningglory 73 to 88%. As before, pendimethalin + fluometuron *fb* sequential glyphosate outperformed all other herbicide treatments. Pyrithiobac tankmixed with glyphosate significantly improved control compared to glyphosate alone.

Sharppod morningglory control was similar to ivyleaf morningglory in 2001, with the highest herbicide input resulting in greatest control (Table 14). In both 2002 and 2003 there were significant main plot and subplot effects, and significant main plot x subplot interactions. As before, the pendimethalin + fluometuron treatment provided the highest sharppod morningglory control compared to other continuous cotton

Table 13. The effect of rotation and cotton herbicide program on ivyleaf/entireleaf morningglory control 8 weeks after cotton planting[a].

Herbicide treatment	Rate	2001	2002			2003
		Cot	Cot	CCC	CRC	Cot
	g ha^{-1}	------	------	%	------	------
Untreated	-	0 e[b]	0 B d[c]	79 A a	81 A a	0 e[b]
Hand-hoed	-	100 a	100 A a	86 B a	86 B a	100 a
Glyphosate *fb*[d] glyphosate	840 *fb* 840	90 d	76 A c	79 A a	77 A a	73 d
Pendimethalin + fluometuron *fb* glyphosate *fb* glyphosate	1120 + 1120 *fb* 840 *fb* 840	97 b	90 A b	88 A a	90 A a	88 b
Glyphosate *fb* glyphosate + pyrithiobac	840 *fb* 840 + 70	91 d	82 A bc	80 A a	81 A a	82 c
Glyphosate *fb* glyphosate + trifloxysulfuron	840 *fb* 840 + 7.8	92 c	79 B c	83 B a	90 A a	79 cd

[a] Cot, cotton monoculture; CCC, cotton-conventional corn-cotton rotation; CRC, cotton-glyphosate-resistant corn-cotton rotation.

[b] Means followed by the same lower case letter within a year and column are not significantly different as determined by the difference of least squares means at α=0.05.

[c] Means within a row and year followed by the same uppercase letter are not significantly different. Means within a column followed by the same lowercase letter are not significantly

[d] *fb*, followed by.

Table 14. The effect of rotation and cotton herbicide program on sharppod morningglory control 8 weeks after cotton planting[a].

Herbicide treatment	Rate	2001	2002			2003		
		Cot	Cot	CCC	CRC	Cot	CCC	CRC
	g ha^{-1}	---------------------------------------%	---------------------------------------					
Untreated	-	0 d[b]	0 B[c] e	95 A a	95 A a	0 A d	0 A e	0 A d
Hand-hoed	-	100 a	100 A a	95 A a	96 A a	100 A a	100 A a	100 A a
Glyphosate *fb*[d] glyphosate	840 *fb* 840	92 c	79 B d	94 A a	93 A a	71 B c	84 A cd	79 A c
Pendimethalin + fluometuron *fb* glyphosate *fb* glyphosate	1120 + 1120 *fb* 840 *fb* 840	97 b	94 A b	96 A a	96 A a	88 A b	91 A b	90 A b
Glyphosate *fb* glyphosate + pyrithiobac	840 *fb* 840 + 70	93 c	85 A c	95 A a	96 A a	86 A b	89 A bc	88 A b
Glyphosate *fb* glyphosate + tryfloxysulfuron	840 *fb* 840 + 7.8	93 c	83 B cd	95 A a	94 A a	85 A b	81 A d	86 A b

[a] Cot, cotton monoculture; CCC, cotton-conventional corn-cotton rotation; CRC, cotton-glyphosate-resistant corn-cotton rotation.

[b] Means followed by the same lower case letter within a year and column are not significantly different as determined by the difference of least squares means at α=0.05.

[c] Means within a row and year followed by the same uppercase letter are not significantly different.

[d] *fb*, followed by.

herbicide treatments in 2002. Sharppod morningglory control was at least 93% throughout both corn rotations. Furthermore, within sequential glyphosate and glyphosate *fb* glyphosate + trifloxysulfuron treatments, both conventional and glyphosate-resistant corn rotations resulted in higher sharppod morningglory control. In 2003, sequential glyphosate treatments that had been rotated to corn controlled sharppod morningglory better than treatments that had been in continuous cotton.

Palmer amaranth control was at least 92% across treatment combinations in all three years, and did not differ between herbicide treatments in 2001 (Table 15). In 2002 Palmer amaranth control was higher in sequential glyphosate treatments that had been rotated to either conventional or glyphosate-resistant corn. By 2003, there was no rotation effect, and Palmer amaranth control did not differ between herbicide treatments.

Weed Species Composition

Weed species that were sampled for density determination varied from year to year (Table 16). Therefore, all species were placed into three groups for analysis: grasses, morningglories, and other broadleaves. Because weed counts were conducted immediately prior to postemergence applications, grass density was lowest in the pendimethalin + fluometuron treatment (Table 17). Similar densities between the untreated and postemergence only treatments indicates that grass density was uniform across the trial. By 2002, grass density in the untreated continuous cotton treatments had almost tripled. As before, there were no differences in grass density between postemergence only herbicide treatments. In 2003, grass density in the untreated reached 242 plants m^{-2}, but was not significantly different from measurements in the

Table 15. The effect of rotation and cotton herbicide program on Palmer amaranth control 8 weeks after cotton planting[a].

Herbicide treatment	Rate	2001	2002			2003
		Cot	Cot	CCC	CRC	Cot
	g ha^{-1}	---%				---
Untreated	-	0 c[b]	0 A d	98 A a	98 A a	0 c[b]
Hand-hoed	-	100 a	100 A a[c]	98 A a	98 A a	100 a
Glyphosate *fb*[d] glyphosate	840 *fb* 840	99 d	92 B c	98 A a	98 A a	99 b
Pendimethalin + fluometuron *fb* glyphosate *fb* glyphosate	1120 + 1120 *fb* 840 *fb* 840	99 b	96 A b	98 A a	98 A a	99 b
Glyphosate *fb* glyphosate + pyrithiobac	840 *fb* 840 + 70	99 b	95 A bc	98 A a	98 A a	99 b
Glyphosate *fb* glyphosate + tryfloxysulfuron	840 *fb* 840 + 7.8	99 b	94 A bc	98 A a	98 A a	99 b

[a] Cot, cotton monoculture; CCC, cotton-conventional corn-cotton rotation; CRC, cotton-glyphosate-resistant corn-cotton rotation.

[b] Means followed by the same lower case letter within a year and column are not significantly different as determined by the difference of least squares means at α=0.05.

[c] Means within a row and year followed by the same uppercase letter are not significantly different.

[d] *fb*, followed by.

Table 16. Weed species observed from 2001 to 2004.

Grouping	2001	2002	2003	2004
Grasses	Texas panicum[a] Johnsongrass	Texas panicum Johnsongrass Junglerice	Texas panicum Johnsongrass Junglerice Red sprangletop	Texas panicum Johnsongrass Junglerice Red sprangletop
Morningglories	Entireleaf/ivyleaf morningglory Sharppod morningglory Tall morningglory	Entireleaf/ivyleaf morningglory Sharppod morningglory	Entireleaf/ivyleaf morningglory Sharppod morningglory	Entireleaf/ivyleaf morningglory Sharppod morningglory Tall morningglory
Other broadleaves	Palmer amaranth Smellmelon Common purslane	Palmer amaranth Smellmelon Common purslane	Palmer amaranth Smellmelon Common purslane Velvetleaf	Palmer amaranth Smellmelon Velvetleaf

[a] Texas panicum, *Panicum texanum*; johnsongrass, *Sorghum halapense*; junglerice, *Echinochloa colona*; red sprangletop, *Leptochloa filiformis*; entireleaf/ivyleaf morningglory, *Ipomoea hederacea*; sharppod morningglory, *Ipomoea cordatotriloba*; tall morningglory, *Ipomoea purpurea*; Palmer amaranth, *Amaranthus palmeri*; smellmelon, *Cucumis melo*; Common purslane, *Portulacca oleracea*; velvetleaf, *Abutilon theophrasti*.

Table 17. Density of grasses as influenced by crop rotation and cotton herbicide program.

Herbicide treatment	Rate	2001	2002			2003	2004
		Cot	Cot	CCC	CRC	Cot	Corn
	$g\ ha^{-1}$	-------------------------------		Plants m^{-2}		-------------------------------	
Untreated	-	57 a[b]	154 A a[c]	59 B a	35 B a	242 a[b]	154 a[b]
Hand-hoed	-	6 b	1 B c	35 A ab	27 A a	0 c	52 b
Glyphosate *fb*[d] glyphosate	840 *fb* 840	67 a	119 A ab	20 B b	23 B a	192 ab	69 b
Pendimethalin + fluometuron *fb* glyphosate *fb* glyphosate	1120 + 1120 *fb* 840 *fb* 840	9 b	1 B c	25 A ab	7 AB a	11 c	54 b
Glyphosate *fb* glyphosate + pyrithiobac	840 *fb* 840 + 70	90 a	88 A ab	62 A a	24 B a	138 b	63 b
Glyphosate *fb* glyphosate + tryfloxysulfuron	840 *fb* 840 + 7.8	54 a	83 A b	38 B ab	11 B a	156 b	67 b

[a] Cot, cotton monoculture; CCC, cotton-conventional corn-cotton rotation; CRC, cotton-glyphosate-resistant corn-cotton rotation.

[b] Means followed by the same lower case letter within a year and column are not significantly different as determined by the difference of least squares means at α=0.05.

[c] Means within a row and year followed by the same uppercase letter are not significantly different.

[d] *fb*, followed by.

sequential glyphosate treatment. However, results suggest that the previous treatments with glyphosate *fb* glyphosate + pyrithiobac and glyphosate *fb* glyphosate + trifloxysulfuron significantly reduced grass density. By 2004, grass density across all herbicide treatments were similar, and were significantly lower than the untreated.

Rotation had no effect on morningglory density in any year (Table 18). As with grasses, only the preemergence treatment showed a significant density reduction in 2001. Density in the untreated and postemergence treatments was uniform. Glyphosate *fb* glyphosate + trifloxysulfuron reduced morningglory density in 2002 compared to sequential glyphosate alone. However, this trend was not observed in subsequent years. As before, the only reduction in moringglory density in 2003 resulted from pendimethalin + fluometuron *fb* sequential glyphosate. By 2004, morningglory density with all herbicide treatments except glyphosate *fb* glyphosate + pyrithiobac was similar to the hand-hoed, and significantly lower than previously untreated plots.

Herbicide treatment effects on broadleaf weed density in 2001 and 2003 were similar to those observed with grasses and morningglories during 2001 (Table 19). However, glyphosate fb glyphosate + trifloxysulfuron was the only exclusive postemergence treatment that reduced broadleaf density in 2002. By 2004, all herbicide treatments, with the exception of the glyphosate + pyrithiobac treatment, reduced broadleaf weed density compared to the untreated. There were no differences in crop yield among herbicide treatments or between corn varieties in 2001 or 2002 (Table 20). Herbicide treatment did not affect seed cotton yield within each rotation in 2003. However, cotton plots that had been rotated to glyphosate-resistant corn the previous

Table 18. Density of moringglories as influenced by crop rotation and cotton herbicide program.

Herbicide treatment	Rate	2001	2002	2003	2004
	$g\ ha^{-1}$	----------------------	Plants m^{-2}	---------------------	
Untreated	-	21 a[a]	16 a	28 a	14 a
Hand-hoed	-	3 b	5 b	1 b	7 b
Glyphosate *fb*[b] glyphosate	840 *fb* 840	31 a	14 a	16 ab	6 b
Pendimethalin + fluometuron *fb* glyphosate *fb* glyphosate	1120 + 1120 *fb* 840 *fb* 840	4 b	3 c	6 b	5 b
Glyphosate *fb* glyphosate + pyrithiobac	840 *fb* 840 + 70	25 a	10 ab	15 ab	8 ab
Glyphosate *fb* glyphosate + tryfloxysulfuron	840 *fb* 840 + 7.8	22 a	6 bc	20 a	4 b

[a] Means followed by the same letter within a year and column are not significantly different as determined by the difference of least squares means at α=0.05.

[b] *fb*, followed by.

Table 19. Density of other broadleaf weeds as influenced by crop rotation and cotton herbicide program[a].

Herbicide treatment	Rate	2001	2002			2003	2004		
		Cot	Cot	CCC	CRC	Cot	Cot	CCC	CRC
	g ha^{-1}	Plants m^{-2}							
Untreated	-	24 a[b]	82 A a[c]	1 B a	0 B a	37 a[b]	6	4	1
Hand-hoed	-	0 b	3 A d	0 A a	1 A a	0 b	8	3	3
Glyphosate *fb* glyphosate	840 *fb* 840	21 a	50 A bc	0 B a	0 B a	49 a	2	1	6
Pendimethalin + fluometuron *fb* glyphosate *fb* glyphosate	1120 + 1120 *fb* 840 *fb* 840	1 b	2 A d	1 A a	1 A a	1 b	6	1	3
Glyphosate *fb* glyphosate + pyrithiobac	840 *fb* 840 + 70	16 a	56 A ab	0 B a	0 B a	35 a	4	2	3
Glyphosate *fb* glyphosate + tryfloxysulfuron	840 *fb* 840 + 7.8	27 a	33 A c	0 B a	0 B a	63 a	6	1	4
Average							5 A	2 B	3 AB

[a] Cot, cotton monoculture; CCC, cotton-conventional corn-cotton rotation; CRC, cotton-glyphosate-resistant corn-cotton rotation.

[b] Means followed by the same letter within a year and column are not significantly different as determined by the difference of least squares means at α=0.05.

[c] Means within a row and year followed by the same uppercase letter are not significantly different.

[d] *fb*, followed by.

Table 20. Cotton and corn yields from 2001 to 2003[a].

Herbicide treatment	Rate	2001	2002			2003		
		Cot	Cot	CCC	CRC	Cot	CCC	CRC
	g ha^{-1}	kg seed cotton ha^{-1}		Bushels ha^{-1}		------- kg seed cotton ha^{-1} -------		
Untreated	-	1701	740 b	306	252	0 b[b]	0 b	0 b
Hand-hoed	-	1751	1659 a	301	324	1975 B a	2986 A a	3526 A a
Glyphosate *fb* glyphosate	840 *fb* 840	2072	1714 a	320	319	1940 B a	2787 A a	3394 A a
Pendimethalin + fluometuron *fb* glyphosate *fb* glyphosate	1120 + 1120 *fb* 840 *fb* 840	2306	1973 a	321	314	2289 B a	2906 AB a	3515 A a
Glyphosate *fb* glyphosate + pyrithiobac	840 *fb* 840 + 70	1849	1801 a	309	333	2068 B a	2642 B a	3562 A a
Glyphosate *fb* glyphosate + tryfloxysulfuron	840 *fb* 840 + 7.8	2017	2205 a	345	296	2354 B a	2319 B a	3613 A a
Average yield		1949	-	319	306	-	-	-

[a] Cot, cotton monoculture; CCC, cotton-conventional corn-cotton rotation; CRC, cotton-glyphosate-resistant corn-cotton rotation.

[b] Means within a column followed by the same uppercase letter are not significantly different. Means within a row followed by the same lowercase letter are not significantly different as determined by the difference of least squares means at α=0.05.

[c] *fb*, followed by.

year yielded higher than continuous cotton within each herbicide treatment. Similarly, rotation to conventional corn increased yield within the hand-hoed and sequential glyphosate herbicide treatments. These results were probably more a function of differences in soil fertility, water use, and pathogen intensity between continuous cotton and corn-rotated plots.

With the exception of sharppod morningglory, rotation had no effect on weed control by 2003. This is probably due to the effectiveness of cotton herbicide treatments in that year. In general, weed control was good to excellent with all herbicide treatments, regardless of the previous year's rotation. Among these treatments, pendimethalin + fluometuron applied preemergence consistently improved weed control with sequential glyphosate application.

As with weed control, herbicide treatment had a significant effect on weed density, especially when rotated to cotton. However, there were no differences in control of any weed type among herbicide treatments by 2004. In fact, grass and morningglory densities in all herbicide treatments were no different than hand-hoed plots by 2004. Despite similarities in weed density between treated and untreated plots in 2001, all weed management options reduced grass and morningglory density 2- to 3-fold after only 3 yrs. Ghosheh and Chandler (1998) reported similar results with johnsongrass density after only 2 yr of herbicide treatment in corn. In contrast, Doucet et al. (1999) concluded that high weed densities in their research prevented weed density reductions after 10 yr of crop rotation and herbicide application.

Rotation generally reduced grass and broadleaf weed densities in 2002. Other broadleaf weeds were almost eliminated in both corn rotations during this year. However, rotation had no lasting effect on grass or morningglory density, but conventional corn-rotated plots had fewer broadleaf weeds present in 2004, compared to continuous cotton. Surprisingly, there were no major differences in weed control or density between conventional and glyphosate-resistant corn rotations. This suggests that earlier postemergence herbicide applications in corn, and shading may have been more important than the herbicide system for weed control and density reduction. Rotation and preemergence herbicides did not affect morningglory or grass density after three years in this experiment, despite density reductions and improved weed control in individual years. This is not surprising since weed density is influenced by the soil seedbank. A large and persistent seedbank could have buffered the effects of crop rotation on weed density (Doucet et al. 1999). Furthermore, morningglory seeds in particular possess dormancy mechanisms and require seed scarification to germinate (Eastin 1983; Holm and Miller 1972; Horak and Wax 1991). Egley and Chandler (1983) found that after 5.5 yr of burial, 10% of pitted morningglory seed remained germinable. It is likely, therefore, that the beneficial effects of crop rotation and preemergence herbicides may not be immediately reflected in weed density, but may be evident over several years. However, these results indicate that both rotation and preemergence herbicides improve weed control and reduce weed density in a given year, and could impact long-term weed management.

CHAPTER V

SUMMARY AND CONCLUSIONS

Sharppod morningglory is a perennial vine commonly found infesting croplands in Texas and the southeastern United States. Previous research regarding morningglory competition and control primarily focused on annual *Ipomoea*. Interference, control, and herbicide translocation of sharppod morningglory could differ from that of other morningglories because of differences in growth and resource allocation. Therefore, experiments were conducted in the field and laboratory from 2001 to 2004 in order to: 1) determine the effects of seed-propagated and root-sprouted sharppod morningglory on cotton economic value, yield, harvest efficiency, and fiber quality; 2) evaluate sharppod morningglory control with cotton herbicides, and determine the effect of diuron rates on glyphosate absorption and translocation; 3) assess the impact of cotton herbicide program and cotton-corn rotation on weed species composition over three years.

A relatively large proportion of sharppod morningglory biomass was accumulated belowground during the first 8 wk of growth in the greenhouse. Consequently, up to 6 plants 10-m row^{-1} did not significantly reduce cotton lint yield. Aboveground growth later in the growing season did not interfere with harvest operations, but did contaminate seed cotton. As a result, lint color grade was the cotton classification parameter most impacted by sharppod morningglory density, and resulted in significant discounts at high plant densities. Cotton lint value was reduced by approximately 85% in the presence of 8 sharppod morningglory 10 m^{-1}. Therefore, sharppod morningglory reduces economic value of cotton through cumulative effects on yield and lint quality.

Glyphosate alone did not completely control sharppod morningglory in the field. The use of glufosinate, bromoxynil, or a combination of glyphosate plus diuron provided acceptable control. In absorption and translocation experiments, sharppod morningglory absorbed up to 75% of applied glyphosate, but most glyphosate was retained in treated leaves and did not translocate well. Diuron decreased absorption of glyphosate, increased leaf retention of glyphosate, and inhibited glyphosate translocation to roots. However, glyphosate plus diuron is still a viable option for sharppod morningglory in the field because of improved aboveground control.

Rotation to corn and the use of preemergence herbicides in cotton improved control of grass and broadleaf weeds during the year of treatment. In the season following the 3-yr rotation, there were no lasting effects of crop rotation on density or control of grasses and broadleaves. However, when weeds were left uncontrolled for the 3-yr period, weed densities increased 2- to 3-times more than herbicide-treated plots. The use of preemergence herbicides and/or crop rotation can reduce weed density and improve weed control. The long-term employment of these strategies could lead to a reduction in density of problematic weeds through depletion of the soil seedbank.

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APPENDIX A

CLIMATIC CONDITIONS AT THE TEXAS A&M UNIVERSITY RESEARCH FARM IN BURLESON COUNTY, TX DURING THE 2001 GROWING SEASON

2001

Date	Air Temperature (°F)		Precipitation (in)	Relative Humidity (%)	
	Max	Min		Max	Min
3/1/2001	46	40	0.16	97	92
3/2/2001	53	46	1	97	89
3/3/2001	53	40	1.03	100	86
3/4/2001	68	38	0	100	33
3/5/2001	69	39	0	97	32
3/6/2001	67	41	0	96	40
3/7/2001	72	41	0	93	25
3/8/2001	62	48	0.44	96	72
3/9/2001	65	43	0	97	42
3/10/2001	69	41	0	96	57
3/11/2001	69	58	0.16	93	78
3/12/2001	80	50	0.86	97	25
3/13/2001	75	46	0	93	34
3/14/2001	64	50	0.83	96	70
3/15/2001	71	49	0	97	25
3/16/2001	65	41	0	82	37
3/17/2001	60	47	0	66	41
3/18/2001	56	45	0.11	90	57
3/19/2001	60	41	0	85	41
3/20/2001	65	37	0	97	38
3/21/2001	75	37	0	97	26
3/22/2001	78	48	0	100	37
3/23/2001	78	54	0	97	52
3/24/2001	72	49	0.11	97	63
3/25/2001	65	48	0	83	46
3/26/2001	63	46	0	71	42
3/27/2001	54	43	1.16	100	57
3/28/2001	51	45	0.16	100	96
3/29/2001	58	44	0.01	100	75
3/30/2001	61	40	0.05	100	72
3/31/2001	74	46	0	100	59
4/1/2001	78	49	0	100	54
4/2/2001	76	64	0	94	79
4/3/2001	82	71	0.03	97	72
4/4/2001	80	70	0	100	76
4/5/2001	83	69	0	97	60
4/6/2001	83	70	0	91	49
4/7/2001	80	65	0	97	67
4/8/2001	84	70	0	94	55

Date	Air Temperature (°F)		Precipitation (in)	Relative Humidity (%)	
	Max	Min		Max	Min
4/9/2001	85	71	0	96	59
4/10/2001	84	72	0	90	63
4/11/2001	75	61	0.05	84	51
4/12/2001	82	61	0.01	96	72
4/13/2001	86	64	0	97	67
4/14/2001	86	71	0	94	59
4/15/2001	90	70	0	96	54
4/16/2001	86	67	0	90	48
4/17/2001	70	53	0	87	35
4/18/2001	70	49	0	80	26
4/19/2001	77	51	0	93	64
4/20/2001	79	66	0	90	69
4/21/2001	86	65	0	96	53
4/22/2001	82	71	0	91	65
4/23/2001	76	59	0.15	96	68
4/24/2001	77	54	0	83	33
4/25/2001	80	46	0	96	28
4/26/2001	82	47	0	100	27
4/27/2001	81	48	0	97	38
4/28/2001	83	52	0	97	34
4/29/2001	84	51	0	93	44
4/30/2001	86	53	0	97	43
5/1/2001	89	66	0	91	51
5/2/2001	90	67	0	93	45
5/3/2001	89	70	0	90	46
5/4/2001	87	70	0.01	91	53
5/5/2001	86	63	1.65	93	65
5/6/2001	89	63	1.79	93	59
5/7/2001	86	63	0.17	93	53
5/8/2001	86	67	0.01	93	51
5/9/2001	86	64	0	97	46
5/10/2001	87	65	0.01	97	46
5/11/2001	88	66	0	93	45
5/12/2001	87	65	0.15	97	43
5/13/2001	88	65	0.01	97	46
5/14/2001	88	65	0	93	46
5/15/2001	87	63	0	96	45
5/16/2001	89	69	0	93	50
5/17/2001	89	73	0	90	52

Date	Air Temperature (°F)		Precipitation (in)	Relative Humidity (%)	
	Max	Min		Max	Min
5/18/2001	91	69	0	96	52
5/19/2001	89	71	0	97	54
5/20/2001	93	69	0.63	94	50
5/21/2001	88	62	0	87	47
5/22/2001	85	53	0	90	25
5/23/2001	89	53	0	93	25
5/24/2001	92	65	0	93	47
5/25/2001	86	63	0.43	87	37
5/26/2001	82	66	0.02	96	60
5/27/2001	91	68	0	97	52
5/28/2001	91	69	0.01	90	47
5/29/2001	93	73	0	96	49
5/30/2001	94	77	0.01	90	56
5/31/2001	93	72	0	91	41
6/1/2001	93	70	0	90	47
6/2/2001	96	77	0	90	48
6/3/2001	96	78	0	87	49
6/4/2001	96	75	0.08	88	49
6/5/2001	88	73	0.05	94	53
6/6/2001	88	72	0.01	94	55
6/7/2001	80	73	1.44	94	82
6/8/2001	77	73	1.99	97	90
6/9/2001	88	73	0	94	65
6/10/2001	90	73	0	94	55
6/11/2001	94	70	0	96	46
6/12/2001	95	75	0	94	49
6/13/2001	94	77	0	93	58
6/14/2001	94	81	0	85	60
6/15/2001	89	67	1.74	93	50
6/16/2001	93	71	0	94	47
6/17/2001	92	70	0	97	36
6/18/2001	91	67	0	93	41
6/19/2001	91	68	0	93	45
6/20/2001	91	70	0	93	45
6/21/2001	94	71	0.98	94	41
6/22/2001	91	70	0	97	49
6/23/2001	90	69	0	82	43
6/24/2001	91	72	0	84	43
6/25/2001	92	68	0	90	42

Date	Air Temperature (°F)		Precipitation (in)	Relative Humidity (%)	
	Max	Min		Max	Min
6/26/2001	93	73	0	90	51
6/27/2001	94	73	0	97	44
6/28/2001	94	74	0	94	44
6/29/2001	95	72	0	94	46
6/30/2001	93	74	0	94	50
7/1/2001	88	72	0.22	73*	
7/2/2001	92	71	0	73	
7/3/2001	93	71	0	74	
7/4/2001	94	72	0	75	
7/5/2001	95	73	0	76	
7/6/2001	96	74	0	77	
7/7/2001	95	76	0	77	
7/8/2001	96	74	0	76	
7/9/2001	97	75	0	76	
7/10/2001	97	75	0	76	
7/11/2001	96	75	0	75	
7/12/2001	98	73	0	75	
7/13/2001	98	77	0	76	
7/14/2001	97	76	0	76	
7/15/2001	97	77	0	77	
7/16/2001	98	76	0	77	
7/17/2001	99	74	0	76	
7/18/2001	99	77	0	77	
7/19/2001	99	76	0	77	
7/20/2001	100	76	0	77	
7/21/2001	101	74	0	75	
7/22/2001	101	72	0	74	
7/23/2001	101	74	0	76	
7/24/2001	100	74	0	76	
7/25/2001	101	76	0	77	
7/26/2001	96	77	1.46	77	
7/27/2001	95	76	0.01	77	
7/28/2001	97	78	0	78	
7/29/2001	98	78	0	78	
7/30/2001	98	77	0	77	
7/31/2001	99	76	0	77	

* average relative humidity

APPENDIX B

CLIMATIC CONDITIONS AT THE TEXAS A&M UNIVERSITY RESEARCH FARM IN BURLESON COUNTY, TX DURING THE 2002 GROWING SEASON

2002

Date	Air Temperature (°F) Max	Air Temperature (°F) Min	Precipitation (in)	Average Relative Humidity (%)
4/1/2002	78	48	0	58
4/2/2002	80	60	0	64
4/3/2002	65	57	0	51
4/4/2002	69	54	0	48
4/5/2002	74	56	0	52
4/6/2002	64	54	0.35	52
4/7/2002	76	54	0.58	63
4/8/2002	78	59	0.45	63
4/9/2002	74	57	0	60
4/10/2002	79	59	0	62
4/11/2002	82	57	0	62
4/12/2002	83	63	0.01	67
4/13/2002	82	60	0	65
4/14/2002	82	62	0	67
4/15/2002	84	68	0	69
4/16/2002	82	70	0.01	72
4/17/2002	87	70	0	72
4/18/2002	87	69	0	70
4/19/2002	86	70	0	70
4/20/2002	87	70	0	71
4/21/2002	86	71	0	72
4/22/2002	84	71	0	71
4/23/2002	86	69	0	71
4/24/2002	89	71	0	72
4/25/2002	78	66	0.04	68
4/26/2002	85	64	0	68
4/27/2002	88	72	0	72
4/28/2002	91	73	0	74
4/29/2002	93	72	0	74
4/30/2002	92	70	0	73
5/1/2002	93	73	0	73
5/2/2002	90	70	0	73
5/3/2002	79	63	0	68
5/4/2002	90	69	0	73
5/5/2002	92	73	0	74
5/6/2002	92	74	0	72
5/7/2002	92	74	0	74
5/8/2002	91	74	0	74
5/9/2002	92	73	0	74

Date	Air Temperature (°F)		Precipitation (in)	Average
	Max	Min		Relative Humidity (%)
5/10/2002	94	72	0	73
5/11/2002	92	74	0	73
5/12/2002	92	75	0	73
5/13/2002	79	57	0.07	58
5/14/2002	83	56	0	57
5/15/2002	88	51	0	62
5/16/2002	92	69	0	73
5/17/2002	79	64	0.01	69
5/18/2002	77	58	0	57
5/19/2002	78	50	0	53
5/20/2002	81	54	0	55
5/21/2002	85	50	0	58
5/22/2002	87	58	0	64
5/23/2002	89	65	0	67
5/24/2002	86	66	0	66
5/25/2002	92	64	0	70
5/26/2002	93	67	0.01	70
5/27/2002	92	68	0.02	70
5/28/2002	89	64	0.19	68
5/29/2002	82	64	0.59	68
5/30/2002	90	63	0	69
5/31/2002	88	68	0	69
6/1/2002	92	66	0	70
6/2/2002	93	66	0	71
6/3/2002	93	71	0	73
6/4/2002	95	73	0	74
6/5/2002	94	71	0	73
6/6/2002	95	71	0	72
6/7/2002	96	73	0.76	74
6/8/2002	95	73	0	75
6/9/2002	95	77	0.01	76
6/10/2002	96	76	0	76
6/11/2002	97	74	0	76
6/12/2002	96	74	0	75
6/13/2002	96	72	0	73
6/14/2002	95	73	0	73
6/15/2002	92	72	0	66
6/16/2002	85	67	1.01	70

Date	Air Temperature (°F)		Precipitation (in)	Average Relative Humidity (%)
	Max	Min		
6/17/2002	90	66	0	68
6/18/2002	92	68	0	69
6/19/2002	95	68	0	73
6/20/2002	95	73	0.13	75
6/21/2002	94	72	0	74
6/22/2002	94	70	0	69
6/23/2002	91	65	0	69
6/24/2002	89	69	0.11	72
6/25/2002	92	68	0.02	72
6/26/2002	-	-	0.16	-
6/27/2002	92	72	0	74
6/28/2002	90	74	0	74
6/29/2002	83	72	0.64	73
6/30/2002	90	72	0.2	75
7/1/2002	86	70	0.74	75
7/2/2002	88	73	0.18	74
7/3/2002	92	73	0	74
7/4/2002	91	75	0.06	75
7/5/2002	92	74	0	76
7/6/2002	94	71	0	74
7/7/2002	96	73	0	75
7/8/2002	96	74	0	76
7/9/2002	94	73	0.19	75
7/10/2002	93	72	0.01	74
7/11/2002	97	71	0	75
7/12/2002	97	73	0	75
7/13/2002	-	-	0.1	-
7/14/2002	77	69	3.18	71
7/15/2002	82	71	0.3	73
7/16/2002	80	73	0.88	74
7/17/2002	90	73	0.03	76
7/18/2002	92	73	0	77
7/19/2002	93	75	0	76
7/20/2002	-	-	0.01	-
7/21/2002	93	75	0	77
7/22/2002	94	73	0.01	-
7/23/2002	95	74	0	-
7/24/2002	96	74	0	76

Date	Air Temperature (°F)		Precipitation (in)	Average
	Max	Min		Relative Humidity (%)
7/25/2002	95	74	0	76
7/26/2002	94	75	0	76
7/27/2002	95	75	0	76
7/28/2002	96	76	0	77
7/29/2002	95	78	0	77
7/30/2002	96	76	0	76
7/31/2002	96	74	0	75
8/1/2002	96	72	0	74
8/2/2002	96	72	0	74
8/3/2002	101	72	0.02	74
8/4/2002	96	71	0.01	73
8/5/2002	96	71	0	73
8/6/2002	98	72	0	74
8/7/2002	100	76	0	75
8/8/2002	92	78	0	75
8/9/2002	96	75	0	75
8/10/2002	94	72	0	74
8/11/2002	95	71	0	73
8/12/2002	96	74	0.06	76
8/13/2002	94	75	0.01	76
8/14/2002	91	75	0.04	76
8/15/2002	76	69	3.47	71
8/16/2002	92	70	0	76
8/17/2002	95	76	0	78
8/18/2002	95	75	0	78
8/19/2002	94	75	0	77
8/20/2002	95	75	0	77
8/21/2002	95	76	0	77
8/22/2002	95	75	0.01	76
8/23/2002	95	74	0	76
8/24/2002	94	74	0	76
8/25/2002	96	74	0	76
8/26/2002	96	75	0	76
8/27/2002	92	75	0	75
8/28/2002	95	73	0	73
8/29/2002	94	70	0	70
8/30/2002	94	69	0	71
8/31/2002	96	71	0.01	74

APPENDIX C

CLIMATIC CONDITIONS AT THE TEXAS A&M UNIVERSITY RESEARCH FARM IN BURLESON COUNTY, TX DURING THE 2003 GROWING SEASON

2003

Date	Air Temperature (°F)		Precipitation (in)	Relative Humidity (%)
	Max	Min		Avg
3/1/2003	54	46	0.03	48
3/2/2003	60	50	0.01	51
3/3/2003	55	47	0.52	48
3/4/2003	59	48	0	51
3/5/2003	57	41	0.02	47
3/6/2003	64	36	0	42
3/7/2003	77	38	0	51
3/8/2003	65	50	0	54
3/9/2003	74	51	0	57
3/10/2003	75	47	0	55
3/11/2003	74	57	0	61
3/12/2003	78	64	0	67
3/13/2003	84	63	0.01	67
3/14/2003	80	54	0.01	61
3/15/2003	78	54	0	59
3/16/2003	78	60	0	60
3/17/2003	77	55	0.01	61
3/18/2003	67	54	0.4	57
3/19/2003	78	51	0	52
3/20/2003	64	51	0	52
3/21/2003	68	44	0	51
3/22/2003	62	46	0.12	50
3/23/2003	72	43	0	52
3/24/2003	77	51	0.01	58
3/25/2003	73	57	0.54	63
3/26/2003	66	53	0.05	56
3/27/2003	77	51	0.01	58
3/28/2003	63	48	0.01	51
3/29/2003	58	39	0	41
3/30/2003	65	33	0	40
3/31/2003	73	42	0	46
4/1/2003	76	50	0	56
4/2/2003	78	55	0	60
4/3/2003	77	61	0	64
4/4/2003	81	66	0	67
4/5/2003	84	67	0	68
4/6/2003	78	67	0.03	71
4/7/2003	84	65	0.01	67
4/8/2003	65	47	0	47

Date	Air Temperature (°F)		Precipitation (in)	Relative Humidity (%)
	Max	Min		Avg
4/9/2003	67	38	0	42
4/10/2003	74	36	0	47
4/11/2003	77	50	0	53
4/12/2003	82	52	0	57
4/13/2003	83	54	0	60
4/14/2003	83	59	0	63
4/15/2003	82	64	0	64
4/16/2003	86	65	0	65
4/17/2003	84	63	0.01	68
4/18/2003	84	66	0	67
4/19/2003	76	68	0.01	68
4/20/2003	75	63	0.01	64
4/21/2003	81	63	0	58
4/22/2003	73	58	0.13	59
4/23/2003	80	64	0.01	68
4/24/2003	91	71	0.01	70
4/25/2003	83	61	0	62
4/26/2003	85	57	0	61
4/27/2003	87	60	0	66
4/28/2003	83	62	0.01	66
4/29/2003	83	63	0	68
4/30/2003	85	66	0	70
5/1/2003	88	65	0.02	71
5/2/2003	87	63	0	70
5/3/2003	83	72	0	73
5/4/2003	86	74	0.01	74
5/5/2003	87	74	0.01	75
5/6/2003	87	76	0.02	75
5/7/2003	92	76	0.01	76
5/8/2003	M	M	0	-
5/9/2003	92	73	0	74
5/10/2003	90	73	0	74
5/11/2003	84	65	0.01	70
5/12/2003	77	67	0.06	63
5/13/2003	92	65	0	70
5/14/2003	92	72	0	74
5/15/2003	92	73	0	74
5/16/2003	95	69	0.43	74
5/17/2003	87	65	0.01	68

Date	Air Temperature (°F)		Precipitation (in)	Relative Humidity (%)
	Max	Min		Avg
5/18/2003	90	62	0	67
5/19/2003	94	70	0	73
5/20/2003	90	63	0	70
5/21/2003	80	63	0.03	65
5/22/2003	85	65	0.01	67
5/23/2003	88	65	0	68
5/24/2003	90	69	0	70
5/25/2003	87	67	0.01	70
5/26/2003	88	71	0.01	71
5/27/2003	85	69	0	67
5/28/2003	86	60	0	61
5/29/2003	94	60	0	65
5/30/2003	99	69	0	70
5/31/2003	98	70	0	70
6/1/2003	95	70	0	72
6/2/2003	94	74	0.05	74
6/3/2003	96	72	0	74
6/4/2003	85	69	0.25	72
6/5/2003	79	97	0.85	71
6/6/2003	84	98	0	70
6/7/2003	89	94	0	67
6/8/2003	86	98	0.01	69
6/9/2003	94	98	0	71
6/10/2003	91	77	0.01	76
6/11/2003	97	78	0	77
6/12/2003	94	68	0.75	73
6/13/2003	92	68	2	71
6/14/2003	89	67	0.21	72
6/15/2003	83	65	1.03	70
6/16/2003	88	71	0.03	72
6/17/2003	87	69	0	72
6/18/2003	89	70	0	72
6/19/2003	92	72	0	73
6/20/2003	93	72	0	74
6/21/2003	93	74	0	76
6/22/2003	95	75	0	77
6/23/2003	95	78	0.01	78
6/24/2003	93	76	0.01	78
6/25/2003	95	76	0.01	78

Date	Air Temperature (°F)		Precipitation (in)	Relative Humidity (%)
	Max	Min		Avg
6/26/2003	92	73	1.46	76
6/27/2003	90	73	0	73
6/28/2003	91	72	0	73
6/29/2003	91	73	0	73
6/30/2003	91	74	0	73
7/1/2003	93	75	0	75
7/2/2003	94	72	0	74
7/3/2003	92	74	0.33	74
7/4/2003	86	72	1.07	74
7/5/2003	88	74	0.02	74
7/6/2003	92	76	0.2	76
7/7/2003	90	73	0.12	75
7/8/2003	90	73	0.13	74
7/9/2003	90	73	0.19	75
7/10/2003	92	74	0.01	77
7/11/2003	91	70	1.42	75
7/12/2003	92	72	0.01	75
7/13/2003	93	75	0	76
7/14/2003	94	75	0	74
7/15/2003	85	75	0.08	74
7/16/2003	89	75	0.33	76
7/17/2003	93	74	0	75
7/18/2003	93	74	0	76
7/19/2003	91	75	0	75
7/20/2003	94	73	0	74
7/21/2003	96	76	0	76
7/22/2003	96	76	0	77
7/23/2003	87	71	0.16	75
7/24/2003	92	75	0	75
7/25/2003	93	73	0	75
7/26/2003	95	74	0	75
7/27/2003	94	74	0	75
7/28/2003	95	74	0	75
7/29/2003	96	73	0	75
7/30/2003	96	76	0	76
7/31/2003	96	75	0	75
8/1/2003	96	75	0	75
8/2/2003	96	75	0	76
8/3/2003	95	77	0	76

Date	Air Temperature (°F)		Precipitation (in)	Relative Humidity (%)
	Max	Min		Avg
8/4/2003	98	74	0	74
8/5/2003	97	75	0	76
8/6/2003	98	76	0	75
8/7/2003	103	76	0	76
8/8/2003	103	78	0.01	76
8/9/2003	94	76	0.01	75
8/10/2003	98	75	0.01	76
8/11/2003	93	69	0.73	73
8/12/2003	86	69	0.01	70
8/13/2003	89	68	0	70
8/14/2003	90	73	0.03	74
8/15/2003	95	73	0	75
8/16/2003	98	77	0	76
8/17/2003	97	75	0.01	76
8/18/2003	98	77	0.01	76
8/19/2003	97	75	0	76
8/20/2003	97	75	0	76
8/21/2003	98	72	2.12	75
8/22/2003	90	72	0	73
8/23/2003	94	74	0	74
8/24/2003	96	74	0.01	75
8/25/2003	96	76	0.01	76
8/26/2003	95	76	0.01	75
8/27/2003	96	75	0.01	76
8/28/2003	96	77	0	77
8/29/2003	95	76	0	76
8/30/2003	93	76	0	76
8/31/2003	79	74	1.48	75

APPENDIX D

SOURCES OF MATERIALS

Sources of Materials

Chapter II

MetroMix 200. The Scotts Company. 14111 Scottslawn Road. Marysville, OH 43041

John Deere Max-Emerge 1700. Deere and Company. One John Deere Place, Moline, Illinois 61265

Osmocote 13-13-13. Scotts-Sierra Horticultural Products Company. 14111 Scottslawn Road. Marysville, OH 43041

Chapter III

Planet Jr. Cole Planter Company. P.O. Box 2. 410 Hodges Avenue. Albany,GA 31702

MetroMix 200. The Scotts Company. 14111 Scottslawn Road. Marysville, OH 43041

Peter's General Purpose 20-20-20. The Scotts Company. 14111 Scottslawn Road, Marysville, OH 43041.

Roundup Weathermax. Monsanto Agricultural Company. 800 N. Lindberg Blvd. St. Louis, MO 63167.

Glyphosate-(phosphonomethyl-^{14}C). Sigma-Aldrich. 3050 Spruce St. St. Louis, MO 63103

Chapter IV

John Deere Max-Emerge 1700. Deere and Company. One John Deere Place, Moline, Illinois 61265

VITA

Gregory Lee Steele was born in Waco, Texas on August 4, 1975 to Sammy and Nancy Steele. Greg grew up and attended public school in Hillsboro, and graduated from Hillsboro High School in 1993. Greg received an Associate of Science degree from Hill College in 1995 before enrolling at Texas A&M University. In May of 1997 Greg earned a Bachelor's degree in Rangeland Ecology and Management. After a year of working and attending classes part time, he began to pursue a Master of Science degree in Agronomy, specializing in weed science. After completing his Master's degree in May of 2000, Greg accepted a position as a Research Associate with the Department of Soil and Crop Sciences. Over the next four years, Greg continued his education and research in pursuit of a doctorate. In December of 2004 Greg was awarded a Doctor of Philosophy degree in Agronomy.

Greg is a member of several organizations including the Weed Science Society of America, Southern Weed Science Society, and Texas Plant Protection Association. Greg has authored or co-authored 5 refereed journal articles, 16 published abstracts, and has received several research awards at the state and regional level. Greg remains employed with the Department of Soil and Crop Science and lives in College Station with his wife Michelle and sons, Luke and Grant.

Greg Steele's future mailing address is: 1302 East Franklin Street, Hillsboro, TX 76645.