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Weed Management Programs for Dicamba- and 2,4-D Tolerant Cotton

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WEED MANAGEMENT PROGRAMS FOR DICAMBA- AND 2,4-D TOLERANT COTTON

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ABSTRACT

To evaluate weed management programs in cotton tolerant to dicamba and 2,4-D, field experiments were conducted in 2011, 2012 and 2013 at the Edisto Research and Education Center near Blackville, South Carolina. The studies addressing herbicide programs in cotton tolerant to dicamba consisted of different herbicide combinations sprayed at different timings. Some programs included a PRE with multiple POST applications and some did not include a PRE and were POST only. In each study, the dicamba herbicide treatments provided excellent control (95 to 100%) of Palmer amaranth and pitted morningglory throughout the growing season, which reduced competition and protected overall yields. Control of large crabgrass was more variable between studies. Treatments applied at PRE and POST 1 resulted in high seed cotton yields because the cotton plants did not have any competition at the critical growing stage of cotton, 8 – 10 weeks after planting. There was no crop injury observed from applications of dicamba or 2,4-D. The studies addressing herbicide programs in cotton tolerant to 2,4-D included PRE and POST treatments, and excellent control of Palmer amaranth was observed by all treatments in each study, with the exception of a no PRE and glyphosate alone POST 1 and 2 herbicide program having 88% control. In 2011 and 2012, 2,4-D choline plus glyphosate and glufosinate provided excellent control of pitted morningglory, and in 2013 the herbicides provided a range of 80 to 95% control. In 2011 and 2012, yields were high across all treatments due to adequate weed control and growing conditions. Yield was extremely low in 2013 because of excessive early rainfall events, water-soaked fields, and late planting dates.

In greenhouse experiments evaluating the control of grass species at various height intervals with combinations of dicamba, glyphosate, 2,4-D, and glufosinate combinations using three different nozzle types, large crabgrass and broadleaf signalgrass were controlled at heights from 5 to 20 cm; at 41 cm grasses were not controlled as effectively. At 41 cm percent controls ranged from 71 to 75% for large crabgrass and 84 to 89% for broadleaf signalgrass. There was no significant difference in efficacy between nozzle types.

BIOGRAPHY

Colton Heath Sanders is the son of Mr. Sidney Ansel Sanders and Mrs. Angela Hudson Sanders of Olar, South Carolina, and the brother to Miss Sydney Jane Sanders and Mrs. Stephanie Sanders Mills. He was raised in Barnwell County, South Carolina. He received an education in the Barnwell County public school system and graduated from Barnwell High School in 2007.

Colton received the Bachelor of Science degree in Applied Economics and Statistics with an emphasis in Agribusiness from Clemson University in Clemson, South Carolina, in May of 2011. He was accepted into the Clemson University graduate degree program in the spring of 2012 to pursue the Master of Science degree in Plant and Environmental Sciences. Colton worked as a Graduate Research Assistant at the Edisto Research and Education Center in Blackville, South Carolina, where he performed research in the field of Weed Science in cotton. His graduate program is coordinated by Dr. Michael W. Marshall.

Colton hopes to become an employee in the Cooperative Extension Service of Clemson University in South Carolina. He is engaged to Miss Whitney Lauren Cook of Barnwell, South Carolina, and has plans to wed in the spring of 2015.

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CHAPTER ONE
REVIEW OF LITERATURE

HISTORY OF COTTON

Origin and Industry of Cotton

In the United States, cotton, *Gossypium hirsutum* L., has been grown since 1621 (Smith, 1995). It is not known exactly when cotton was first discovered. *Gossypium hirsutum* L. is known as upland cotton, which is the major species of cotton grown in the United States. The most important fiber crop is cotton, and is grown mainly in tropical and subtropical areas (Oerke, 2005). The most common use, and also the most important use, is the fiber. The fiber, or lint, is used for making cotton cloth. The linters are the short fibers on the seed and are used in making plastics, explosives, paper products, cushions, and other products. Cottonseed is used to make oil, meal, and hulls. The meal and hulls are used in feeding livestock, poultry, or fish and can also be used as fertilizer. Cottonseed oil is used for cooking oil and shortening. The cotton industry in the United States impacts the economy greatly by means of the producers' purchase of supplies and services, which stimulates business for factories and enterprises. The annual production, processing, handling, and harvesting of cotton generates tremendous business activity. Cotton production stimulates business revenues in the United States economy at approximately $1.9 billion annually (National Cotton Council, 2014), making it the leading cash crop in the country. It is no surprise that cotton is used more than any other fiber in the world.

Cotton grows in subtropical areas where it has a long growing season before exposed to low temperatures and frost. The United States, Uzbekistan, the People's Republic of China, and India grow most of the world's cotton. In the United States, there are 17 major cotton producing states: Alabama, Arkansas, Arizona, California, Florida, Georgia, Kansas, Louisiana, Mississippi, Missouri, New Mexico, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. In those states, farmers all use similar methods in growing cotton. One difference in their methods is whether they use a reduced tillage system or conventional tillage system. When cotton first became domesticated, it was grown in a conventional tillage system because of the lack of technologies. Farmers have new alternatives to maximize profits because of new production practices and new technologies in seed genetics (Ward et al. 2002). A major driving force for new developments has been the need to effectively and efficiently manage weeds.

Cotton Production Methods

Farmers have moved away from tillage because of herbicide-resistant crops and the ability to broadly control weeds with chemicals versus machinery. A result of reducing tillage has been that they are no longer disturbing the seed bank. Refraining from tilling leaves a cover of litter from the previous crop, that helps prevent many weed seeds from germinating in the field by preventing sunlight from directly reaching the ground. Conservation tillage, or minimum tillage, is done by using special equipment that plants the cotton seed through the debris covering the soil surface. The previous method of conventional tillage was performed by using a disk harrow or plow to disk the land into rows and forming raised seed beds for planting. Studies have been done on both tillage systems to determine the efficiency and profits. One study in South Georgia in 1999 showed that production was greater using transgenic varieties of cotton in conservation tillage systems (Ward et al. 2002).

Farmers have always battled pests in crops, especially weeds. The methods used in controlling these weeds have changed a great deal over the years. “Such practices include crop rotation, row spacing, seeding rate, planting date, fertilization, tillage, water management, weed-free crop seed, field sanitation, and varieties/cultivars”, Walker and Buchanan, 1981. Rotation of crops caused it to be difficult for weeds to grow on land that was rotated between grain, grass, and cultivated crops, such as cotton. Crop rotation declined in the 1940’s because of the introduction of new and increased use of herbicides. Later, crop rotation included rotating both crops and herbicides that proved to be effective in controlling weeds as well as increasing production.

Studies have been done to look at different row spacing and its impact on weed control as well as the seeding rates of crops. Decreasing the row spacing of crops can increase the canopy cover that will shade out weeds that grow between rows. Also, the seeding rate of crops can reduce weed competition. Decreased row spacing in soybeans led to high yields and less weeds (Wax and Pendleton, 1968). There has been some work done with cotton and the response from row spacing. “Cotton planted in 53 cm rows produced maximum yields with as little as 6 weeks of weed-free maintenance; with wider row spacing (79 and 106 cm) the first 10 and 14 weeks had to be weed free for maximum yields”, Walker and Buchanan, 1981. Planting rows closer and having higher plant populations can contribute more than just controlling weeds; it can decrease evaporation, increase efficient water use, and increase the energy available to the crop.

Today, herbicides are heavily relied upon for managing weeds. Chemical control is used to control weeds before weeds emerge by the use of pre-emergence (PRE) herbicides applied to the soil before the crop emerges. Pre- and post-emergence (POST) herbicides are necessary to control weeds effectively in cotton (Wilcut et al., 1997). Pre-emergence herbicides do not provide season-long control of weeds. These pre-emergence herbicides control initial flushes of weeds, alleviating stress on the early crop by reducing competition for water and nutrients. In order to achieve good control of weeds using herbicides, farmers must have a well-planned herbicide program in place. Cotton fields will have more than one weed species, such as broadleaf weeds and grasses, as well as sedges. In conventional and transgenic cotton, it is not wise to rely heavily on one herbicide or mode of action. Many studies have been, and continue to be, performed on testing herbicide programs in cotton. Some findings have indicated that a soil-applied herbicide is the most important. When fomesafen was included in a soil-applied herbicide program, yield was not improved by post-directed herbicides (Wilcut et al., 1997). It is beneficial to have a post-directed herbicide combination in cotton to continue to have good weed control and avoid losses during harvest. “The data suggest that post-directed herbicides are important components of currently large-seeded broadleaf weeds and perennial sedges and for increasing cotton yield in the Southeast”, Wilcut et al., 1997.

It is understood that weeds can decrease yields of cotton by competing for light, water, and nutrients. Many studies have examined the impacts of weeds on yield, but only a few have determined the impact of weeds on harvest efficiency. Most cotton is harvested with a spindle picker and packed into a module. The module is then taken to the cotton gin for the ginning process. Recently, cotton pickers have developed into wrapping cotton into round bales, which are similar to hay bales. This decreases labor expenses and saves time because there is no need in packing the cotton into modules. Farmers know how troublesome weeds can become at the time of harvest. One study noted variable harvesting efficiency depending on weed density. Weed-free plots had an average harvest time of 79 min/ha and the plots with the highest weed density increased to 90 min/ha (Smith et al., 2000). They also noticed a significant increase in harvest stoppages (74 to 183 min/ha) due to large Palmer amaranth (*Amaranthus palmeri* S. Wats.) lodged in the picker heads (Smith et al., 2000).

TECHNOLOGIES IN COTTON

Bromoxynil and Sulfonylurea Resistant Cotton

Technologies in cotton have had a large impact on improving pest control. “Until 1995, cotton was the only major agronomic crop in the United States without a selective post-emergence herbicide registered for control of annual broadleaf weeds that did not cause significant crop injury or yield reductions”, Paulsgrove et al., 2005. The development of bromoxynil-resistant cotton and pyrithiobac for use in all cotton varieties provided broadleaf weed control. Most difficult annual broadleaf weeds are controlled by both bromoxynil and pyrithiobac; however, the herbicides alone in cotton do not control the entire spectrum of annual broadleaf weeds (Paulsgrove et al., 2005). Another early development in cotton was resistance to the herbicide sulfonylurea. Sulfonylurea herbicides are inhibitors of the acetolactate synthase enzyme in plants, also known as an ALS inhibitor. This herbicide is not registered for applications to cotton under the five-leaf stage. Few studies were conducted to differentiate cotton's response to sulfonylurea herbicides at growth stages. One study did show that applications of trifloxysulfuron, a sulfonylurea herbicide, at the five-leaf stage to be beneficial. (Richardson et al., 2007).

Bt Cotton

Along with weeds, insects are a problem pest in cotton and cause yield losses. Bollworm, *Helicoverpa zea*, and tobacco budworms, *Heliothus virescens*, are a couple of the main lepidopteran pests of cotton beacause, they are capable of feeding on and damaging meristematic tissue and reproductive structures (pre-floral buds, blooms, and bolls). In 1996, transgenic cotton containing a gene from the bacterium *Bacillus thuringiensis* (Bt) was released that proved to be very beneficial to cotton farmers. This Bt cotton worked by producing proteins toxic and specific to caterpillar pests, such as bollworms and tobacco budworms. Although there were moderately high adoption costs and restrictions for Bt cotton; the interest was prevalent in the late 1990's (Marra et al., 2001). Advanced Bt technology (multiple Bt genes) is used today by farmers on most acres of cotton in the United States, and herbicide-resistant traits are paired with the in-plant insecticide traits most cotton varities currently offered.

Glyphosate Resistant Cotton

Genetically modified crops have become extremely popular over the years, especially since the introduction of glyphosate-resistant crops. Glyphosate is the active ingredient in Roundup® herbicide. In 1997, glyphosate resistant cotton was released, and, by 2001, 56% of cotton hectares planted in the United States were planted using a glyphosate-tolerant variety. The mode of action for glyphosate targets an enzyme that can only be found in plants and certain bacteria (Dill, 2005). Glyphosate inhibits the enzyme, 5-enolpyruylskikimic acid-3-phosphate (EPSPS) synthase (Steinrücken and Amrhein, 1980). Since its release, there has been a copious amount of research performed in looking at the efficiency of glyphosate-based herbicide programs in glyphosate-resistant cotton. Seed cotton yield and net returns were highest for the postemergence-only programs (Faircloth et al., 2001). Many farmers relied heavily on glyphosate-resistant technology in cotton and other crops and did not use any other herbicides. However, it was still recommended to use a pre-emergence or soil-applied herbicide to control early weeds that could cause yield loss before glyphosate could be safely applied. The first resistant weeds were discovered almost 10 years after glyphosate resistant crops were introduced (Culpepper et al., 2006). This was due predominately to the over reliance on one herbicide mode of action, and, now, many farms struggle with resistant weeds, especially Palmer amaranth.

Glufosinate-Resistant Cotton

The latest transgenic herbicide trait in cotton was released in 2004, and it is resistant to the herbicide glufosinate. Glutamine synthetase is the enzyme that catalyzes conversion of glutamic acid and ammonia into glutamine; glutamine synthetase is inhibited by Glufosinate (Gardner et al., 2006). It is similar to glyphosate in that they are both non-selective herbicides. Glufosinate-resistant cotton was developed from the insertion of a gene that came from the fungus *Streptomycyes viridochromogenes*. The timing of applications is important for glufosinate to be highly successful in controlling weeds, and many studies have shown optimal control when combined with a residual pre-emergence herbicide program. PRE herbicides provided greater control of *Amaranthus* species after POST 1 of a glufosinate application and 1 week after the late-post (LPOST) glufosinate application (Gardner et al., 2006). The reason this technology never became popular with growers was because of the marginal control of many annual grasses as well as Palmer amaranth, especially without the use of pre-emergence herbicides.

DEVELOPMENT OF HERBICIDE-RESISTANT WEEDS

Palmer Amaranth Resistant Biotypes

One of the major problems that occurred after the introduction of transgenic crops with resistance to herbicides was the development of resistance to herbicides by weeds. The most troublesome weed in cotton is Palmer amaranth, and several resistant biotypes have appeared in the last 8 years (Heap, 2014). Palmer amaranth can grow in dry and very hot days that aren't favorable for cotton (Culpepper et al., 2006). It is an annual broadleaf weed that can grow 2 m tall and cause major yield losses in crops due to those characteristics. Palmer amaranth has a rapid growth rate and can negativly affect crop yield by out competing for light, water, and nutrients (Rowland et al., 1999). Palmer amaranth produces hundreds of thousands of seeds per plant that have the ability to remain dormant in the soil for several years. This contributes to it being such a troublesome pest. Because of this high reproductive capability, cotton producers can have 99% control of Palmer amaranth in the field and experience field-wide reinfestation from the surviving 1%within a couple of years. Also, if 1% of Palmer amaranth plants are resistant to the herbicides used, the hundreds of thousands of seeds that the surviving plants produce will be herbicide-resistant offspring.

The introduction of transgenic cotton was intended to aid in controlling pests, such as weeds. The herbicide resistant crop was so successful in controlling weeds and not causing significant injury to the crop that there was a large increase in hectares of transgenic cotton. Along with the increase in hectares was the increase in reliance on glyphosate to control the problem weed or weeds. There are biotypes of Palmer amaranth resistant to dinitroaniline herbicides, ALS-inhibitors, and glyphosate. Dinitroaniline herbicides mainly control grasses, but have also been used to control broadleaf weeds. Dinitroaniline herbicides enter the plants by the roots and emerging shoots, and are more phytotoxic to the emerging shoots (Appleby and Valverde, 1989).

Acetolactate synthase inhibiting herbicides, also known as ALS-inhibitors, are used widely in cotton to control many problem weeds. Herbicides that are ALS inhibitors stop protein synthesis that leads to termination of the cell division and kills the plant (Sprague et al., 1997). These herbicides were first used in small grains for control of broadleaf weeds; more applications of ALS inhibitor herbicides were applied to Palmer amaranth after the release of resistant cotton. Many weed species became resistant to ALS-inhibiting herbicides over the years and caused widespread concerns (Sprague et al., 1997). Palmer amaranth was one species that developed biotypes resistant to ALS-inhibitors. This was such a concern because these herbicides were widely used, required low application rates, were tremendously safe to crops, and were part of a few herbicides at the time that persisted in the soil.

The most recent development of resistant biotypes of Palmer amaranth, also the biggest concern, is glyphosate-resistant Palmer amaranth. Glyphosate-resistant cotton cultivars have been the most popular cultivars used, and the technology remains broadly used. After the development of glyphosate-resistant cotton, growers in Georgia used a monoculture system of glyphosate only herbicide programs to control Palmer amaranth and other weeds (Culpepper et al., 2006). This over-reliance has led to selection of glyphosate-resistant Palmer amaranth. In 2004, a cotton grower in Georgia was unable to control Palmer amaranth with glyphosate, which was later confirmed to be resistant. There was no controlling the spread of glyphosate-resistant Palmer amaranth, mainly because, shortly after the first discovery, many more were being reported in Georgia. Additionally, pollen from Palmer amaranth is known to spread rapidly over a large area, and pollen from resistant plants has also facilitated the spread of resistant biotypes. Currently, glyphosate-resistant Palmer amaranth biotypes have been confirmed in most of the Southeast. Over the years, Palmer amaranth has proven itself to be one of the worst weeds in cotton, not only because of the yield losses it can cause, but because of the ability to develop biotypes resistant to herbicides used in controlling this pest. The outbreak of these herbicide-resistant biotypes has led to more research and work in developing new transgenic cotton to control these resistant Palmer amaranth biotypes.

AUXIN HERBICIDES

2,4-D and Dicamba Herbicides

The selective herbicide 2,4-D, used for broadleaf weed control, has been around since the 1940's and is still in use today. This herbicide, 2,4-D, as well as many other auxin herbicides, was first described as a plant growth regulator. Dicamba is another auxin herbicide with a similar mode of action as 2,4-D. These herbicides are registered for use in agricultural and non-agricultural settings, such as homeowner's lawn. The growth regulator herbicides are recommended for POST applications to control broadleafs in grass crops such as, wheat, sorghum, corn, rice, pastures, and sugar cane (Praczyk et al., 2012). Auxin herbicides work by causing uncontrolled cell divison in vascular tissue which is caused by abnormal increases in cell wall growth. Broadleaf weeds in aquatic sites can also be controlled with 2,4-D. Many growers of corn and sorghum use auxin herbicides to control broadleaf weeds like Palmer amaranth, particularly suspected populations of glyphosate-resistant Palmer amaranth and other weeds that can be problematic in corn and sorghum. Timely applications of 2,4-D can succefully control species from the Amaranthaceae family such as, Redroot pigweed (*Amaranthus retroflexus*) and common waterhemp (*Amaranthus rudis* L.) (Craigmyle et al., 2013). Exposure of cotton to these auxin herbicides is detrimental to the crop. Because these herbicides are highly volatile, the main way cotton is exposed is through drift from nearby pastures. One study determined the effect on yield and growth of cotton from simulated drift of 2,4-D and dicamba, and discovered that the cotton was affected more by 2,4-D amine than dicamba (Everitt and Keeling, 2009). The large increase in herbicide-resistant biotypes of weeds, especially glyphosate-resistant Palmer amaranth, has led to more work in developing new transgenic cotton.

UPCOMING TECHNOLOGIES IN COTTON

Cotton Tolerant to Dicamba and 2,4-D

Traits are currently being developed that includes resistance to 2,4-D applied at pre-plant, PRE, and POST for corn, soybean, and cotton hybrids (Craigmyle et al., 2013). There is also work being done in the development of dicamba tolerance in cotton and soybeans. These two new transgenic technologies will be very beneficial in controlling herbicide-resistant Palmer amaranth. The current herbicide resistance technologies will be expanded by the dicamba resistance trait (Behrens et al., 2007). Both will keep the glyphosate-resistant trait in cotton and include resistance to glufosinate and the new trait with tolerance to 2,4-D or dicamba. Farmers will be able to control grasses and broadleaves with glyphosate and glufosinate, and 2,4-D or dicamba will help control the weeds resistant to glyphosate. Another benefit of this new technology will be the addition of two new modes of action in herbicide programs for cotton. Dicamba can be used as a preplant, preemergence, and postemergence herbicide. However, with any cotton variety it is always best to have a well-planned program to manage weeds. As stated earlier, tillage and crop rotation help considerably in controlling weeds, especially in conjunction with herbicides. One of the most important ways to not only control weeds but to control the weeds ability to develop more resistant biotypes is to have applications of herbicides with different modes of action. Combining the dicamba- or 2,4-D-resistant genes with the glyphosate and glufosinate resistance genes can possibly prevent the presence of dicamba- or 2,4-D-resistant weeds (Behrens et al., 2007). It is likely that both 2,4-D and dicamba will effectively control the currently most troublesome weed in cotton, glyphosate-resistant Palmer amaranth.

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CHAPTER TWO

EVALUATION OF DICAMBA-BASED HERBICIDE PROGRAMS IN DICAMBA-TOLERANT COTTON

ABSTRACT

The prevalance of herbicide-resistant biotypes over the last couple of decades is due to reliance on one single herbicide mode of action for weed management. The major troublesome herbicide-resistant weed in row-crop production in the southern United States is Palmer amaranth. New herbicide-tolerant technologies are being developed with multiple modes of action to control these resistant weeds. Field experiments were conducted to determine the efficacy of dicamba-based herbicide programs in dicamba-tolerant cotton at the Edisto Research and Education Center in 2012 and 2013 near Blackville, SC. In each study, the dicamba-based herbicide treatments provided excellent control of broadleaf weeds (Palmer amaranth and pitted morningglory) with percent control being greater than 90%. The treatments with dicamba, glyphosate, and glufosinate provided excellent control which reduced competition and protected overall yields. Treatments applied PRE and POST 1 included high yields because of low to no competition from weeds.

INTRODUCTION

The selection of herbicide-resistant weeds, which was caused by the reliance on a single herbicide mode of action, began not long after the introduction of glyphosate-tolerant crops. After the development of glyphosate-resistant cotton, growers in the Southeast utilized a monoculture system of glyphosate only herbicide programs applied topically over the top multiple times each season to manage Palmer amaranth and other weeds (Culpepper et al., 2006).

In cotton, Palmer amaranth causes significant yield losses due to its rapid growth rate, prolific seed production, and its ability to aggressively compete with the crop for water and nutrients (Culpepper et al., 2006). Palmer amaranth not only leads to yield losses, but it increases the cost of production and impedes on harvest efficiency and loss of cotton yield. This weed developed resistance to several groups of herbicides, including dintitroanilines, ALS-inhibitors, and glyphosate in South Carolina (Heap, 2014). Cultivars of glyphosate-tolerant cotton have been a popular choice among growers since its introduction in 1997 and still are commonly used today. However, glyphosate-resistant biotypes of Palmer amaranth have spread rapidly since their initial discovery in 2006. This has led to researchers to develop new trait technology in cotton with tolerance to alternative herbicides.

Currently, cotton cultivars are being developed and tested that are tolerant to topical applications of dicamba herbicide. Without this trait, cotton is very sensitive to dicamba. Cotton had some losses (1.3%) from dicamba vapor drift exposure and higher losses (3.9%) from particle drift exposures (Egan et al., 2014). Dicamba is a synthetic auxin herbicide that is selective for broadleaf weed control and has been used in grass crops including pastures, corn, grain sorghum, and wheat for control of broadleaf weeds. This herbicide, dicamba, when applied at the correct rate and timing is effective in controlling glyphosate-resistant biotypes of Palmer amaranth. Current herbicide-resistance technologies will enhance and be extended due to the new dicamba-resistance technology (Behrens et al., 2007).

This new cotton trait technology, Bollgard II XtendFlex™, with tolerance to the herbicides dicamba, glufosinate, and glyphosate is currently being developed by Monsanto Company. This technology will also contain Genuity® Bollgard II® system, which provides protection against lepidopteran insect pests. The key to the stacked herbicide trait system will be the opportunity to use several modes of action at planting (preemergence) and after crop emergence (postemergence) to reduce the likelihood of promoting resistance to herbicides. In South Carolina, the use of dicamba and glufosinate will provide control of ALS- and glyphosate-resistant biotypes of Palmer amaranth and other potential resistant broadleaf weed species. The rotation of herbicides will be allowed due to the dicamba –resistance trait combined with glyphosate and glufosinate resistance traits, and will significantly control herbicide-resistant weeds (Behrens et al., 2007).

Dicamba-tolerant cotton has not been released to farmers yet due to pending regulatory approval by the USDA and EPA. Because this technology is new, very little research has been conducted on the efficacy of these dicamba-based herbicide programs on herbicide-resistant Palmer amaranth in cotton. Therefore, research was initiated to evaluate dicamba-based herbicide combinations on control of herbicide-resistant Palmer amaranth and other significant weeds and their effects on cotton growth and yield.

MATERIALS AND METHODS

Field experiments were conducted at the Edisto Research and Education Center located near Blackville, South Carolina, from 2011 to 2013. The soil types for the 2012 trials were a Varina sandy loam (0-10% slope, fine, kaolinitic, thermic Plinthic Paleudults), with 1.8% organic matter and pH of 6.4, and a Dothan sandy loam (0-15% slope, fine-loamy, kaolinitic, thermic Plinthic Kandiudults), with 1.2% organic matter and pH of 6.2. In 2013, a Dothan sandy loam was identified for all three trials. Cotton was seeded in all experiments at three seeds per row 0.3 m using a four-row Almaco cone plot planter. The cotton variety '6H_S26695' was planted at each trial. All crop production practices, such as fertilizing, defoliation, and insect control, followed recommended methods for cotton production in South Carolina (Jones et al., 2013).

Experimental design consisted of a randomized complete block design, and plots were four rows with 97-cm row spacing. Treatments were replicated four times. In 2012, the plots were 10.67 meters in length, and, in 2013, plots were 7.62 meters in length. The middle two rows were treated leaving the outside two rows as untreated controls. Each field was naturally infested with a mixed population of glyphosate-resistant and susceptible Palmer amaranth (*Amaranthus palmeri* S. Wats.), pitted morningglory (*Ipomoea lacunosa* L.), and large crabgrass (*Digitaria sanguinalis*). Where population pressure was low, Palmer amaranth seed was spread in the plot areas. Treatments were applied using a backpack sprayer with a four-nozzle boom and nozzle spacing of 48.26 centimeters. The nozzle type used was Turbo TeeJet® 11002 Induction Flat fan Spray tips with an operation pressure of 234 kPa at a spray volume of 140 L/ha. These nozzles were selected due to the production of large ultra-coarse spray droplets which minimizes potential for spray drift.

STUDY 1

Two trials, CT 112 and CT 2313, were conducted in 2012 and 2013, respectively. The first trial (CT 112) in Study 1 was planted on 15 June 2012 in prepared strip-tilled seed beds. The other trial (CT 2313) was planted in conventionally-tilled seed beds on 29 May 2013. The study included 14 treatments. In Study 1, two sets of postemergence (POST) herbicides were applied (Table 2-1).

In CT 112, the POST 1 applications (early application timing A) were sprayed on 11 July 2012, which was 26 days after planting (DAP) (9:35 AM EDT; temperature of 30.8°C; 67.9% RH; average wind speed of 1.3 KPH; soil was wet with a temperature of 27°C; cloud cover of 40%) when weeds (Palmer amaranth, pitted morningglory, and large crabgrass ranged from 5 to 10 cm in height. The POST 2 applications (late application timing B) were sprayed on 20 July 2012, 35 DAP (2:45 PM EDT; temperature of 36°C; 51.2% RH; average wind speed of 3.3 KPH; soil was dry with a temperature of 36.8°C; cloud cover of 10%) when weeds (Palmer amaranth, pitted morningglory, and large crabgrass) ranged from 15 to 25 cm in height.

In CT 2313, the POST 1 applications (application A) were sprayed on 21 June 2013 at 23 DAP (3:00 PM EDT; temperature of 35°C; average wind speed of 1.9 KPH; 44% RH; soil was dry with a temperature of 36.2°C; 0% cloud cover) when weed sizes ranged from 5 to 10 cm in height. The POST 2 applications (application B) were sprayed on 5 July at 37 DAP (9:00 AM EDT; temperature of 31.2°C; average wind speed of 1.6

KPH; 66.3% RH; soil was wet with temperature of 28.7°C; 90% cloud cover) when weed sizes ranged from 15 to 20 cm in height.

STUDY 2

This study (CT 1113) included a single trial that was planted in conventionally-tilled seed beds on 29 May 2013. The trial included 13 treatments with four replications (Table 2-2). An untreated control was included. The study included five separate application timings: PRE (A), early POST (B), mid-POST (C), late POST (D), and a Layby POST directed (E) of diuron and MSMA (Table 2-2). Acetochlor (Warrant) was applied at 1.26 kg ai/ha. Glufosinate (Liberty) was applied at 0.59 kg ai/ha. Diuron was applied at 1.12 kg ai/ha. Monosodium acid Methanearsonate (MSMA) was applied at 2.24 kg ai/ha. Dicamba (Clarity) was applied at 1.12 kg ai/ha. Glyphosate (Roundup PowerMax) was applied at 0.75 kg ai/ha. Fomesafen (Reflex) was applied at 0.28 kg ai/ha. Pyrithiobac sodium (Staple LX) was applied at 0.07 kg ai/ha.

The PRE (A) applications were made shortly after planting on 29 May 2013 (10:00 AM EDT; temperature of 28°C; 52.1% RH; average wind speed of 2.7 KPH; soil was dry with temperature of 27.7°C; 25% cloud cover). The early POST (B) applications were sprayed on 21 June at 23 DAP (3:00 PM EDT; temperature of 35°C; 44%RH; average wind speed of 1.9 KPH; soil was dry with temperature of 36.2°C; 0% cloud cover) when weed sizes ranged from 5 to 10 cm in height. The mid-POST applications (C) were sprayed on 5 July, 37 DAP (9:00 AM EDT; temperature of 31.2°C; 66.3% RH; average wind speed of 1.6 KPH; soil was wet with temperature of 28.7°C; 90% cloud cover) when weed sizes ranged from 8 to 13 cm in height. Late POST applications (D) were sprayed on 17 July, 49 DAP (2:00 PM EDT; temperature of 38.8°C; 56.4% RH; average wind speed 1.7 KPH; soil was wet with temperature of 36°C; 20% cloud cover) when weed sizes ranged from 10 to 15 cm in height. The Layby POST directed application (E) was sprayed on 5 August, 68 DAP (3:00 PM EDT; temperature of 34.1°C; 48.4% RH; average wind speed of 1.4 KPH; soil was wet with temperature at 33°C; 35% cloud cover) when weed sizes ranged from 8 to 20 cm in height.

STUDY 3

Two trials, CT 1412 and CT 2213, were conducted in 2012 and 2013, respectively. The first trial (CT 1412) was planted in conventionally-tilled seed beds on 19 June 2012. The second trial (CT 2213) was planted in conventionally-tilled seed beds on 29 May 2013. Each trial in the study had 12 treatments with four replications. An untreated control was included. Study 3 consisted of five different preemergence (PRE) herbicide combinations followed by several different POST combinations (Table 2-3).

In CT 1412, all PRE applications (A) were made immediately following planting on 19 June 2012 (3:00 PM EDT; temperature was 33.8°C; 35.3% RH; average wind speed of 1.1 KPH; soil was dry with a temperature of 37.7°C; 10% cloud cover). The POST 1 (B) applications were applied on 12 July 2012 at 23 DAP (9:00 AM EDT; temperature of 25.2°C; 81.4% RH; average wind speed of 1.1 KPH; soil was wet with temperature of 26.5°C; 100% cloud cover) when weeds were 7.6 to 12.7 cm in height. The POST 2 (C) application was sprayed on 1 August 2012 at 43 DAP (10:00 AM EDT; temperature of 26.7°C; 79.1% RH; average wind speed of 1.4 KPH; soil was wet with temperature of 28.2°C; 100% cloud cover) when weeds ranged from 8 to 15 cm in regrowth height.

In CT 2213, the PRE applications (A) were sprayed after planting on 29 May 2013 (10:00 AM EDT; temperature of 28°C; average wind speed of 2.7 KPH; 52.1% RH; soil was dry with a temperature of 27.7°C; 25% cloud cover). The POST 1 applications (application B) were sprayed at 23 DAP on 21 June 2013 (3:00 PM EDT; temperature of 35°C; average wind speed of 1.9 KPH; 44% RH; soil was dry with a temperature of 36.2°C; 0% cloud cover) when weeds ranged from 8 to 10 cm in height. The POST 2 application (application C) was sprayed on 5 July at 37 DAP (9:00 AM EDT; temperature of 31.2°C; average wind speed of 1.6 KPH; 66.3% RH; soil was wet with temperature of 28.7°C; 90% cloud cover) when weed sizes ranged from 8 to 10 cm in regrowth height.

Data collected included percent visual weed control ratings, weed counts in plots, crop injury, and seed cotton yield. Percent visual crop injury and weed control ratings were taken on a scale of 0-100%, with 0% indicating no effect on cotton and 0% for weed control indicating no effect on weed populations in the treated area and 100% for complete weed control or complete crop death. Weed count data were determined by randomly tossing a 0.45-m quadrat (square made from plastic pipe) in the plots and counting each weed species within the quadrat.

In Study 1, visual ratings of weed control data of each plot were gathered 2 weeks after A application (2 WAA) and 2 weeks after B applications (2WAB). Weed counts for Study 1 were collected 2 WAB. In Study 2, percent weed control was collected 3 WAA, 3 WAB, 3 WAC, 4 WAD, 3 WAE, and weed counts were gathered at 3 WAE. Percent weed control ratings were collected for Study 3 at 3 WAA, 3 WAB, 2 WAC, and weed counts were gathered on 2 WAC.

The two middle rows of each plot were harvested using a two-row spindle picker. Trial CT 112 was harvested on 15 January 2013. Trial CT 1412 was harvested on 15 January 2013. Trial CT 2213 was harvested on 11 December 2013. Trial CT 2313 was harvested on 11 December 2013. Trial CT 1113 was harvested on 11 December 2013. All plots were harvested and weighed in kilograms per plot, and plot weights were converted to kilograms per hectare.

Data for percent weed control, weed counts, and cotton harvest data were subjected to ANOVA using the PROC GLM procedure of SAS (version 9.3; SAS Institute Inc., Cary, NC.). Herbicide treatments and years (where studies were repeated in time) were treated as fixed effects. Means were separated using Fisher's Protected LSD at $p \leq 0.05$. When year and treatment interactions were found to be significant, data were presented by year.

RESULTS AND DISCUSSION

STUDY 1

Percent weed control and population data from Study 1 showed significant interactions between treatment and years; therefore, data are presented by year for control ratings and weed counts by species (Table 2-4 to 2-6). Palmer amaranth control at 2 WAA resulted in significant differences between treatments for 2012 but not in 2013 (Table 2-7a). The glufosinate-only treatment provided fair (70%) control of Palmer amaranth in 2012, but, in 2013, control of Palmer amaranth with glufosinate was excellent (98%). Similar results were observed by Merchant et al. (2013), where they observed Palmer amaranth control of 74% using glufosinate. The glufosinate plus acetochlor POST provided 83% control of Palmer amaranth in 2012, and 100% control in 2013. At the 2 WAB observations the opposite results were noted, with more variation between treatments and poorer control of Palmer amaranth in 2013 than in 2012 (Table 2-7b). Glufosinate alone provided poor (52%) control in 2013 and better (84%) control in 2012. Also, glufosinate plus acetochlor POST was 62% and 94% in 2012 and 2013, respectively. Population counts of Palmer amaranth indicated that glufosinate applied at the A timing had the most Palmer amaranth than in any other treatments in 2012 (Table 2-7a). The glufosinate-based treatments, except for glufosinate plus dicamba sprayed at the B timing in 2013 resulted in higher weed population counts of 6-8 plants; while the same treatments sprayed in 2012 averaged only 0 to 1 plants m^2. The differences observed in the glufosinate treatments from 2012 to 2013 could be a result of weather factors, including humidity and/or temperature at time of application.

At 2 WAA, pitted morningglory showed significant differences between treatments in 2012 but not for 2013 (Table 2-8a). The glufosinate alone treatment provided 71 and 98% control of pitted morningglory in 2012 and 2013, respectively. Merchant et al. (2013) reported excellent control of pitted morningglory when glufosinate was mixed with an auxin herbicide. Counts of pitted morningglory also showed a significantly higher number of pitted morningglory plants with glufosinate alone in 2012. The 2 WAB ratings indicated good to excellent control of pitted morningglory in 2012 and 2013 for all treatments (Table 2-8b). Glufosinate plus acteochlor provided control of pitted morningglory in 2013 of 87% and 99% in 2012. No pitted morningglory weeds were detected in treatments that received glufosinate with dicamba in 2013.

Control ratings and population counts for large crabgrass had significant differences among treatments applied at the POST 1 timing in both years (Table 2-9a). Glufosinate applied alone in 2012 resulted in only 71% control of large crabgrass and 83% control in 2013. In 2013, glufosinate plus dicamba provided 73% control of large crabgrass; however, in 2012, large crabgrass control provided 93%. At 2 WAB, significant differences in treatments by year were expressed (Table 2-9b). In 2012, all treatments were similar, with the exception of glufosinate alone which provided 79% control of large crabgrass. However, in 2013 all treatments provided less than 53% control of large crabgrass. The population counts did not match up to the control ratings (2 WAB) in 2013.

The year by treatment interaction was not significant for cotton yield; therefore, data were combined for Study 1 (Table 2-10). The plots treated with glufosinate generally had lower yields compared with those without glufosinate herbicide (Table 2-11). These yield data match with the percent control ratings of all three weed species. The treatments that included glufosinate alone had more weeds and resulted in lower yields of 823 and 633 kg/ha for the POST 1 and POST 2 applications, respectively. Yields from the treatments that were applied at the POST 2 timing were lower than those sprayed at POST 1, which was caused by weeds competing with the cotton longer into the growing season before they were controlled.

STUDY 2

Ratings for percent control of and counts for Palmer amaranth resulted in some significant differences in treatments in Study 2 (Table 2-12). At the 3 WAA timing, treatments that did not include acetochlor or dicamba generally had a lower overall percent Palmer amaranth control (Table 2-13a). However, treatments without acetochlor and dicamba did provide acceptable control, ranging from 85 to 95% control. There were no significant differences among treatments at the 3 WAB (Table 2-13a). The 3 WAC timing resulted in differences between treatments, but the lowest percent control was 93% which was sprayed with glufosinate (Table 2-13b). At 4 WAD, good control was observed across all treatments, with the exception of 87% control for a treatment of dicamba and glyphosate. Johnson et al. (2010), discovered that combinations of dicamba and glyphosate provided 30 to 65% greater control of glyphosate-resistant palmer amaranth. At 3 WAE, similar results were observed, with all treatments expressing good control, except for the 88% in dicamba plus acetochlor PRE and dicamba plus glyphosate POST 2 (Table 2-13c). The reason for this slightly lower percent control could have been the timing. Palmer amaranth might have grown slightly larger than the recommended height to control the weed in between the PRE and MidPOST timings. Counts agreed with the Palmer amaranth percent controls and the untreated control having a count of 12 plants m^2.

All treatments included significantly different results for percent control data and population counts of pitted morningglory (Table 2-14). At 3 WAA, there were not any treatments that had excellent control, but small differences were noted in the fomesafen plus diuron treatments (Table 2-15a). However, dicamba plus acetochlor provided 77% control, and another dicamba plus acetochlor recorded 92% control. At 3 WAB, all treatments provided a minimum of 92% control of Palmer amaranth. At 3 WAC, all treatments had good control of morningglory, with the glufosinate treatment being the lowest at 93% (Table 2-15b). At 4 WAD, the treatment of acetochlor applied at PRE followed by glufosinate applied at POST 2 resulted in with a lower rating of 87%. At 3 WAE, only two treatments had less than 90% (83 and 88%) control of pitted morningglory (Table 2-15c). All treatments received the same herbicides prior to this rating, but controls were different due to some weeds exceeding the recommended size for optimum control compared to earlier in the growing season. Counts of pitted morningglory populations were low for all treatments with a population count of 11 plants m^2 for the untreated control.

Percent control ratings and counts for large crabgrass had some significant differences (Table 2-16). The 3 WAA timing included differences in treatments; the treatments that included fomesafen plus diuron had lower percent controls than other treatments (Table 2-17a). The 3 WAB timing resulted in all treatments having good control of greater than 90%. At 3 WAC, all treatments had similar results with controls greater than 93% (Table 2-17b). The 4 WAD timing had significant differences in treatments; glufosinate plus dicamba applied at POST 2 provided poor (80%) control of large crabgrass. At 3 WAE, the same treatment was less than all other treatments, with 72% control and 5 plants m^2 observed (Table 2-17c). Dicamba and glufosinate in combination do not provide great control of grass species like large crabgrass. There have been many reports of decreased control of grasses and broadleaves when glufosinate is mixed with a growth regulator herbicide (Craigmyle et al., 2013). Population count data matched with the percent control ratings; 13 plants m^2 were observed in the untreated control and a majority of the treatments had fairly low populations of weeds.

Yields of seed cotton in Study 2 had significantly different results by treatments (Table 2-18). The treatment that had the least percent control of Palmer amaranth and pitted morningglory also resulted in a low yield of only 212 kg/ha (Table 2-19). Most other treatments had similar seed cotton yield results.

STUDY 3

Only one rating (Palmer amaranth 3 WAA) did not have interactions between treatment and years, but all other data are presented by years (Table 2-20 to 2-22). Treatments containing one application of fomesafen PRE provided a minimum of 80% control of Palmer amaranth (Table 2-23a). At 3 WAB, glyphosate alone provided poor control at 59 and 85% control in 2012 and 2013, respectively. This could have been due to higher populations of glyphosate-resistant Palmer amaranth in 2012 than in 2013.

Other treatments had good control (90%) of Palmer amaranth during both years. At 2 WAC, the glyphosate only treatment had significant differences in percent control in both years; 50% in 2012 and 75% in 2013 (Table 2-23b). Counts of Palmer amaranth populations complemented the percent control ratings, with the glyphosate only treatment leaving 15 and 7 plants m^2 in 2012 and 2013, respectively. All other treatments had less than 2 plants m^2.

There were some significantly different treatments for ratings and counts of morningglory control (Table 2-24a). In 2012, fomesafen and dicamba applied at the PRE timing had great control of pitted morningglory. In 2013, fomesafen and dicamba applied at PRE resulted in control of pitted morningglory that ranged from 80 to 92%. At 3 WAB, 70% control of morningglory was observed with glyphosate alone and no PRE in 2012; however, the same treatment provided 97% control in 2013. All other treatments provided greater than 93% control of pitted morningglory in both years. At 2 WAC, results were similar to those observed from the 3 WAB timing; glyphosate alone provided 73% control of pitted morningglory in 2012 and 93% control in 2013 (Table 2-24b). All other treatments had excellent control of morningglory. These results were similar to Faircloth et al. (2001), who reported that glyphosate applied at two POST provided poor control (less than 67%) of pitted morningglory. Estimates of weed populations included a plant count of 10 plants m^2 in 2012 for the glyphosate only treatment, and the other treatments had 2 or less plants m^2.

In 2012, there were no differences among treatments for control of large crabgrass at 3 WAA, with the exception of the treatments that did not receive a PRE treatment

(Table 2-25a). In 2013, there were significant differences, with controls ranging from 80 to 95% and 0% for the no PRE treatments. The glufosinate plus dicamba treatments in 2013 resulted in lower large crabgrass control ratings (70 and 77%). In 2013, the glyphosate plus dicamba plus acetochlor applied POST 1 and glufosinate and acetochlor applied POST 2 provided only 23% control of large crabgrass (Table 2-25b). Results did not match research of Everman et al. (2007), who reported that glufosinate improved late-season control of large crabgrass and Palmer amaranth. All other treatments that received glyphosate and dicamba at POST 1 resulted in better control of large crabgrass (98 to 100%); while other treatments had fair to good control (85 to 100%). Estimates of large crabgrass populations did not correlate with the visual percent control ratings. This could have been due to a dense population which made it difficult to distinguish in exact number of plants.

There was no interaction of treatment by years for cotton yield (Table 2-26); therefore, yield data were combined over years. Dicamba PRE, followed by glufosinate plus acetochlor POST 1 and POST 2, had a yield of 705 kg/ha (Table 2-27). Similarly, no PRE, followed by glyphosate sprayed at POST 1 and POST 2, also resulted in 705 kg/ha. Dicamba applied at PRE, followed by glyphosate and dicamba applied at POST 1, followed by glufosinate plus acetochlor POST 2, produced the best cotton yield of 1226 kg/ha.

CONCLUSION

In each study, the dicamba-based treatments provided good to excellent control of mixed populations of Palmer amaranth and pitted morningglory throughout the growing season, which reduced competition and protected overall yields. Treatments applied at the PRE and POST 1 timings protected yields because cotton plants did not have any competition during the early growth stages. The first 8 to 10 weeks after cotton emergence is critical to be kept weed free for higher yields, after that period, yield is not affected by weeds (Walker and Buchanan, 1981). In Study 1, treatments sprayed at POST 1 resulted in higher yields than those sprayed at POST 2. Treatments that included glufosinate in Studies 1 and 2 had the lowest percent control of weeds and reduced yields. Dicamba combined with glyphosate provided better control of all weed species. We attribute our results to the glyphosate controlling the grass species and dicamba having good activity on broadleaf weeds, especially glyphosate-resistant Palmer amaranth. Our studies demonstrated the performance of potential herbicide programs for this new transgenic cotton technology with tolerance to dicamba, glyphosate, and glufosinate. This new trait technology will provide cotton producers with the option to use many modes of actions in sequence or concurrently to control species that already have developed resistance to herbicides and will also help forestall the selection of new resistant biotypes.

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Table 2-1. Treatments and rates applied to cotton from study 1 in 2012 and 2013 near Blackville, SC.

TRT. NO.	Treatment Name	Timing	Rate/unit	
1	Glyphosate	A	0.75	kg ae/ha
	Dicamba	A	1.12	kg ae/ha
2	Glyphosate	A	0.75	kg ae/ha
	Dicamba	A	1.12	kg ae/ha
	Acetochlor	A	1.26	kg ai/ha
3	Glufosinate	A	0.59	kg ai/ha
	Dicamba	A	1.12	kg ae/ha
	Acetochlor	A	1.26	kg ai/ha
4	Glufosinate	A	0.59	kg ai/ha
	Dicamba	A	1.12	kg ae/ha
5	Glufosinate	A	0.59	kg ai/ha
6	Glufosinate	A	0.59	kg ai/ha
	Acetochlor	A	1.26	kg ai/ha
7	Glyphosate	A	0.75	kg ae/ha
	Glufosinate	A	0.59	kg ai/ha
8	Glyphosate	B	0.75	kg ae/ha
	Dicamba	B	1.12	kg ae/ha
9	Glyphosate	B	0.75	kg ae/ha
	Dicamba	B	1.12	kg ae/ha
	Acetochlor	B	1.26	kg ai/ha
10	Glufosinate	B	0.59	kg ai/ha
	Dicamba	B	1.12	kg ae/ha
	Acetochlor	B	1.26	kg ai/ha
11	Glufosinate	B	0.59	kg ai/ha
	Dicamba	B	1.12	kg ae/ha
12	Glufosinate	B	0.59	kg ai/ha
13	Glufosinate	B	0.59	kg ai/ha
	Acetochlor	B	1.26	kg ai/ha
14	Glyphosate	B	0.75	kg ae/ha
	Glufosinate	B	0.59	kg ai/ha

A. Timing A is POST 1 (11 July 2012 and 21 June 2013)
B. Timing B is POST 2 (20 July 2012 and 5 July 2013)

Table 2-2. Treatment applied to cotton from Study 2 in 2013 near Blackville, SC.

	Timing and combinations							
TRT. Number	A		B		C		D	
1	Acetochlor		Glufosinate				Glufosinate	
2	Dicamba	Acetochlor	Dicamba	Glufosinate			Glufosinate	
3	Acetochlor				Glufosinate			
4	Dicamba	Acetochlor			Dicamba	Glufosinate		
5	Acetochlor		Glyphosate				Glyphosate	
6	Dicamba	Acetochlor	Dicamba	Glyphosate			Glyphosate	
7	Acetochlor	Dicamba	Glyphosate				Dicamba	Glyphosate
8	Acetochlor				Glyphosate			
9	Dicamba	Acetochlor			Dicamba	Glyphosate		
10	Untreated Check							
11	Fomesafen	Diuron	Glyphoste	Acetochlor			Glyphosate	Acetochlor
12	Fomesafen	Diuron	Glufosinate	Acetochlor			Glufosinate	Acetochlor
13	Fomesafen	Diuron	Glyphosate	Pyrithiobac sodium			Glyphosate	Acetochlor

- ❖ All Treatments received a Layby POST application of Diuron and MSMA on 5 August 2013.
- ❖ Diuron was applied at 1.12 kg ai/ha.
- ❖ MSMA was applied at 2.24 kg ai/ha.
- ❖ PRE (A) was applied on 29 May 2013
- ❖ POST 1 (B) was applied on 21 June 2013
- ❖ POST 2 (C) was applied on 5 July 2013
- ❖ POST 3 (D) was applied on 17 July 2013
- ❖ Layby POST (E) was applied on 5 August 2013

Table 2-3. Treatments applied to cotton from Study 3 in 2012 and 2013 near Blackville, SC

TRT. Number	Timing	Treatment Combinations		
	A		Fomesafen	
1	B	Glyphosate	Dicamba	
2	B	Glyphosate	Dicamba	Acetochlor
3	B	Glufosinate	Acetochlor	
4	B	Glufosinate	Dicamba	
	A		Dicamba	
5	B	Glyphosate	Dicamba	
6	B	Glyphosate	Dicamba	Acetochlor
7	B	Glufosinate	Acetochlor	
8	B	Glufosinate	Dicamba	
	A		No PRE	
9	B	Glyphosate	Dicamba	
10	B	Glyphosate	Dicamba	Acetochlor
11	B	Glufosinate	Acetochlor	
12	B	Glyphosate		
	C	Glyphosate		

- ❖ Treatments 1-11 all received a Late Post application (C) of Glufosinate and Acetochlor.
- ❖ Glufosinate was applied at 0.59 kg ai/ha and Acetochlor applied at 1.26 kg ai/ha
- ❖ PRE (A) was applied on 19 June 2012 and 29 May 2013
- ❖ POST 1 (B) was applied on 12 July 2012 and 21 June 2013
- ❖ POST 2 (C) was applied on 1 August 2012 and 5 July 2013

Table 2-4. Analysis of Variance for Palmer amaranth counts, 2 weeks after application A, and 2 weeks after application B in Study 1

	Palmer amaranth Count					Palmer amaranth 2 WAA				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	97	822.2448980				97	12234.69388			
Rep	5	52.3333333	10.4666667	2.81	0.0233	5	795.386905	159.077381	2.52	0.0383
Treatment	13	195.3877551	15.0298273	4.03	<.0001	13	4113.265306	316.405024	5	<.0001
Year	1	4.9115646	4.9115646	1.32	0.2551	1	1214.306973	1214.306973	19.20	<.0001
Treat * Year	13	327.4455782	25.1881214	6.76	<.0001	13	2000.871599	153.913200	2.43	0.0095
Error	65	242.1666667	3.725641			65	4110.86310	63.24405		

	Palmer amaranth 2 WAB				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	97	18111.47959			
rep	5	1237.5	247.5	3.86	0.004
Treatment	13	8828.827	679.1405	10.61	<.0001
year	1	129.3367	129.3367	2.02	0.1601
trt*year	13	4906.378	377.4137	5.89	<.0001
Error	65	4162.5	64.03846		

- DF = degrees of freedom

Table 2-5. Analysis of Variance for pitted morningglory counts, 2 weeks after application A, and 2 weeks after application B in Study 1

	pitted morningglory Count					pitted morningglory 2 WAA				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	97	783.5510204				97	6710.459184			
Rep	5	33.101195	6.6202381	2.07	0.0804	5	337.053571	67.410714	2.13	0.0733
Treatment	13	202.0620748	15.5432365	4.86	<.0001	13	1083.014456	83.308804	2.63	0.0053
year	1	17.8784014	17.8784014	5.59	0.021	1	1875.191327	1875.191327	59.14	<.0001
Treat * Year	13	266.3477891	20.4882915	6.71	<.0001	13	1076.892007	82.837847	2.61	0.0055
Error	65	207.8154762				65	2060.863095			

	pitted morningglory 2 WAB				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	97	4017.602041			
Rep	5	204.910714	40.982143	1.85	0.1162
Treatment	13	910.565476	70.043498	3.16	0.0011
year	1	139.477041	139.477041	6.28	0.0147
Treat * Year	13	1184.034864	91.079605	4.1	<.0001
Error	65	1443.005952	22.2000092		

- DF = degrees of freedom

Table 2-6. Analysis of Variance for large crabgrass counts, 2 weeks after application A, and 2 weeks after application B in Study 1.

	large crabgrass Count					large crabgrass 2 WAA				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	97	822.2448980				97	52812.5			
Rep	5	52.3333333	10.4666667	2.81	0.0233	5	1601.33929	320.26786	1.7	0.1465
Treatment	13	229.9761905	17.6904762	4.75	<.0001	13	15569.15391	1197.62722	6.37	<.0001
year	1	4.9115646	4.9115646	1.32	0.2551	1	12834.375	12834.375	68.24	<.0001
Treat*year	13	327.4455782	25.1881214	6.76	<.0001	13	13467.1131	1035.93178	5.51	<.0001
Error	65	242.1666667	3.725641			65	12225.74405	188.08837		

	large crabgrass 2 WAB				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	97	84270.40816			
Rep	5	4065.625	813.125	3.88	0.0039
Treatment	13	15817.53827	1216.73371	5.81	<.0001
year	1	42444.06888	42444.06888	202.62	<.0001
Treat*year	13	11124.68112	855.7447	4.09	<.0001
Error	65	13615.625			

- DF = degrees of freedom

Table 2-7a. Mean percent control and population counts of Palmer amaranth (AMAPA) after application of selected postemergence herbicides in cotton near Blackville, SC during 2012 and 2013 (Study 1) [a].

TRT. #	POST 1 (A) [c] TREATMENT	Rates (kg ai/ha) or (kg ae/ha) [b]	2 WAA [d] 2012		2 WAA [d] 2013		Counts 2 WAB [d] 2012		Counts 2 WAB [d] 2013	
			---------% Control------				# AMAPA/m^2			
1	Glyphosate + Dicamba	0.75 + 1.12	95	abc	100	a	0	b	0	b
2	Glyphosate + Dicamba + Acetochlor	0.75 +1.12 + 1.26	96	abc	100	a	0	b	0	b
3	Glufosinate + Dicamba + Acetochlor	0.59 + 1.12 +1.26	88	bcde	98	ab	2	b	0	b
4	Glufosinate + Dicamba	0.59 + 1.12	91	abcde	100	a	2	b	0	b
5	Glufosinate	0.59	70	h	98	ab	7	a	0	b
6	Glufosinate + Acetochlor	0.59 + 1.26	83	defg	100	a	2	b	0	b
7	Glyphosate + Glufosinate	0.75 + 0.59	93	abcd	100	a	1	b	0	b

[a] Means within a column followed by the same letter are not different according to Fisher's Protected LSD at p≤0.05.
[b] Active ingredients correspond to Acetochlor and Glufosinate and Active equivalent corresponds to Glyphosate and Dicamba.
[c] POST 1 was sprayed when Palmer amaranth was 5 to 10 cm tall.
[d] WAA = weeks after application timing A (POST 1). WAB = weeks after application timing B (POST 2).

Table 2-7b. Mean percent control and population counts of Palmer amaranth (AMAPA) after application of selected postemergence herbicides in cotton near Blackville, SC during 2012 and 2013 (Study 1) [a].

TRT. #	POST 2 (B) [c] TREATMENT	Rates (kg ai/ha) or (kg ae/ha) [b]	2 WAB [d] 2012		2 WAB [d] 2013		Counts 2 WAB 2012		Counts 2 WAB 2013	
			-----------% Control-------				# AMAPA/m^2			
8	Glyphosate + Dicamba	0.75 + 1.12	99	ab	100	a	0	b	0	b
9	Glyphosate + Dicamba + Acetochlor	0.75 +1.12 + 1.26	99	ab	100	a	0	b	0	b
10	Glufosinate + Dicamba + Acetochlor	0.59 + 1.12 +1.26	96	ab	95	abc	1	b	1	b
11	Glufosinate + Dicamba	0.59 + 1.12	94	abc	98	ab	2	b	2	b
12	Glufosinate	0.59	84	cde	52	g	1	b	6	a
13	Glufosinate + Acetochlor	0.59 + 1.26	94	abc	62	fg	0	b	8	a
14	Glyphosate + Glufosinate	0.75 + 0.59	90	abc	73	ef	1	b	8	a

[a] Means within a column followed by the same letter are not different according to Fisher's Protected LSD at p≤0.05.
[b] Active ingredients correspond to Acetochlor and Glufosinate and Active equivalent corresponds to Glyphosate and Dicamba.
[c] POST 2 was sprayed when Palmer amaranth was at 15 to 25 cm heights.
[d] WAB = weeks after application timing B (POST 2).

Table 2-8a. Mean percent control and population counts of pitted morningglory (IPOLA) after application of selected postemergence herbicides in cotton near Blackville, SC during 2012 and 2013 (Study 1) [a].

TRT. #	POST 1 (A) [c] TREATMENT	Rates (kg ai/ha) or (kg ae/ha) [b]	2 WAA [d] 2012	2 WAA [d] 2013	Counts 2 WAB [d] 2012	Counts 2 WAB [d] 2013
			--------% Control----		# IPOLA/m^2	
1	Glyphosate + Dicamba	0.75 + 1.12	93 abcd	100 a	1 c	1 c
2	Glyphosate + Dicamba + Acetochlor	0.75 +1.12 + 1.26	94 abcd	100 a	1 c	0 c
3	Glufosinate + Dicamba + Acetochlor	0.59 + 1.12 +1.26	91 bcd	100 a	1 c	0 c
4	Glufosinate + Dicamba	0.59 + 1.12	91 bcd	100 a	1 c	0 c
5	Glufosinate	0.59	71 f	98 ab	11 a	0 c
6	Glufosinate + Acetochlor	0.59 + 1.26	83 e	100 a	5 b	1 c
7	Glyphosate + Glufosinate	0.75 + 0.59	89 cde	98 ab	2 bc	1 c

[a] Means within a column followed by the same letter are not different according to Fisher's Protected LSD at $p \leq 0.05$.
[b] Active ingredients correspond to Acetochlor and Glufosinate and Active equivalent corresponds to Glyphosate and Dicamba.
[c] POST 1 was sprayed when pitted morningglory was at 5 to 10 cm heights.
[d] WAA = weeks after application timing A(POST 1). WAB = weeks after application timing B(POST 2).

Table 2-8b. Mean percent control and population counts of pitted morningglory (IPOLA) after application of selected postemergence herbicides in cotton near Blackville, SC during 2012 and 2013 (Study 1) [a].

TRT. #	POST 2 [c] TREATMENT	Rates (kg ai/ha) or (kg ae/ha) [b]	2 WAB [d] 2012		2 WAB [d] 2013		Counts 2 WAB 2012		Counts 2 WAB 2013	
			-------% Control-----				# IPOLA/m^2			
8	Glyphosate + Dicamba	0.75 + 1.12	96	ab	100	a	1	c	0	c
9	Glyphosate + Dicamba + Acetochlor	0.75 +1.12 + 1.26	100	a	100	a	0	c	0	c
10	Glufosinate + Dicamba + Acetochlor	0.59 + 1.12 +1.26	99	ab	100	a	0	c	0	c
11	Glufosinate + Dicamba	0.59 + 1.12	95	ab	100	a	1	c	0	c
12	Glufosinate	0.59	96	ab	93	abc	1	c	2	bc
13	Glufosinate + Acetochlor	0.59 + 1.26	99	ab	87	c	0	c	4	b
14	Glyphosate + Glufosinate	0.75 + 0.59	98	ab	93	abc	0	c	2	bc

[a] Means within a column followed by the same letter are not different according to Fisher's Protected LSD at p≤0.05.
[b] Active ingredients correspond to Acetochlor and Glufosinate and Active equivalent corresponds to Glyphosate and Dicamba.
[c] POST 2 was sprayed when pitted morningglory was at 15 to 20 cm heights.
[d] WAB = weeks after application timing B(POST 2).

Table 2-9a. Mean percent control and population counts of large crabgrass (DIGSA) after application of selected postemergence herbicides in cotton near Blackville, SC during 2012 and 2013 (Study 1) [a].

TRT. #	POST 1 [c] TREATMENT	Rates (kg ai/ha) or (kg ae/ha) [b]	2 WAA [d] 2012		2 WAA [d] 2013		Counts 2 WAB [d] 2012		Counts 2 WAB [d] 2013	
			---------% Control--------				# DIGSA/m^2			
1	Glyphosate + Dicamba	0.75 + 1.12	97	a	98	a	0	b	0	b
2	Glyphosate + Dicamba + Acetochlor	0.75 +1.12 + 1.26	95	a	87	abcd	0	b	0	b
3	Glufosinate + Dicamba + Acetochlor	0.59 + 1.12 +1.26	90	ab	90	abc	2	b	0	b
4	Glufosinate + Dicamba	0.59 + 1.12	93	ab	73	bcdef	2	b	0	b
5	Glufosinate	0.59	71	cdef	83	abcde	7	a	0	b
6	Glufosinate + Acetochlor	0.59 + 1.26	91	ab	87	abcd	2	b	0	b
7	Glyphosate + Glufosinate	0.75 + 0.59	95	a	93	ab	1	b	0	b

[a] Means within a column followed by the same letter are not different according to Fisher's Protected LSD at p≤0.05.
[b] Active ingredients correspond to Acetochlor and Glufosinate and Active equivalent corresponds to Glyphosate and Dicamba.
[c] POST 1 was sprayed when large crabgrass was at 5 to 10 cm heights.
[d] WAA = weeks after application timing A(POST 1). WAB = weeks after application timing B(POST 2)

Table 2-9b. Mean percent control and population counts of large crabgrass (DIGSA) after application of selected postemergence herbicides in cotton near Blackville, SC during 2012 and 2013 (Study 1) [a].

TRT. #	POST 2 [c] TREATMENT	Rates (kg ai/ha) or (kg ae/ha) [b]	2 WAB [d] 2012	2 WAB [d] 2013	Counts 2 WAB 2012	Counts 2 WAB 2013
			-----------% Control-------		# DIGSA/m^2	
8	Glyphosate + Dicamba	0.75 + 1.12	96 abc	20 i	0 b	0 b
9	Glyphosate + Dicamba + Acetochlor	0.75 +1.12 + 1.26	99 ab	28 hi	0 b	0 b
10	Glufosinate + Dicamba + Acetochlor	0.59 + 1.12 +1.26	94 abc	47 fgh	1 b	1 b
11	Glufosinate + Dicamba	0.59 + 1.12	89 abc	15 i	2 b	2 b
12	Glufosinate	0.59	79 bcd	38 ghi	1 b	6 a
13	Glufosinate + Acetochlor	0.59 + 1.26	99 ab	53 efg	0 b	8 a
14	Glyphosate + Glufosinate	0.75 + 0.59	100 a	52 efgh	1 b	8 a

[a] Means within a column followed by the same letter are not different according to Fisher's Protected LSD at p≤0.05.
[b] Active ingredients correspond to Acetochlor and Glufosinate and Active equivalent corresponds to Glyphosate and Dicamba.
[c] POST 2 was sprayed when large crabgrass was at 15 to 20 cm heights.
[d] WAB = weeks after application timing B(POST 2).

Table 2-10. Analysis of Variance for cotton yield data in Study 1.

	Yield Analysis				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	97	45573999.61			
Rep	5	3531787.3	706357.46	9.61	<.0001
Treatment	13	2071016.23	159308.94	2.17	0.0211
Year	1	34077684.45	34077684.45	463.84	<.0001
Treat*year	13	1149156.83	88396.68	1.2	0.2975
Error	65	4775428.35	73468.13		

- DF = degrees of freedom

Table 2-11. Mean cotton yield after application of selected postemergence herbicides near Blackville, SC during 2012 and 2013 (Study 1) [a].

TRT. #	TREATMENT	Rates (kg ai/ha) or (kg ae/ha) [b]	Seed cotton yield	
			---------kg/ha------	
1	Glyphosate + Dicamba	0.75 + 1.12	1001	ab
2	Glyphosate + Dicamba + Acetochlor	0.75 +1.12 + 1.26	1166	a
3	Glufosinate + Dicamba + Acetochlor	0.59 + 1.12 +1.26	866	bc
4	Glufosinate + Dicamba	0.59 + 1.12	757	bc
5	Glufosinate	0.59	823	bc
6	Glufosinate + Acetochlor	0.59 + 1.26	670	c
7	Glyphosate + Glufosinate	0.75 + 0.59	896	abc
8	Glyphosate + Dicamba	0.75 + 1.12	854	bc
9	Glyphosate + Dicamba + Acetochlor	0.75 +1.12 + 1.26	627	c
10	Glufosinate + Dicamba + Acetochlor	0.59 + 1.12 +1.26	773	bc
11	Glufosinate + Dicamba	0.59 + 1.12	879	abc
12	Glufosinate	0.59	633	c
13	Glufosinate + Acetochlor	0.59 + 1.26	635	c
14	Glyphosate + Glufosinate	0.75 + 0.59	759	bc

[a] Means within a column followed by the same letter are not different according to Fisher's Protected LSD at p≤0.05.
[b] Active ingredients correspond to Acetochlor and Glufosinate and Active equivalent corresponds to Glyphosate and Dicamba.

Table 2-12. Analysis of Variance for Palmer amaranth counts, 3 weeks after application A, 3 weeks after application B, 3 weeks after application C, 4 weeks after application D, and 3 weeks after application E.

Palmer amaranth Count

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	38	413.0769231			
Treat.	12	365.7435897	30.4786325	15.81	<.0001
Rep.	2	1.0769231	0.5384615	0.28	0.7587
Error	24	46.2564103	1.9273504		

Palmer amaranth 3 WAA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	38	24826.92308			
Treat.	12	24310.25641	2025.8547	122.34	<.0001
Rep.	2	119.23077	59.61538	3.6	0.0429
Error	24	397.43590	16.55983		

Palmer amaranth 3 WAB

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	38	26847.43590			
Treat.	12	26597.4359	2216.45299	231.8	<.0001
Rep.	2	20.51282	10.25641	1.07	0.3579
Error	24	229.48718	9.56197		

Palmer amaranth 3 WAC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	38	27008.97436			
Treat.	12	26858.97436	2238.24786	361.21	<.0001
Rep.	2	1.28205	0.64103	0.1	0.9021
Error	24	148.71795	6.19658		

Palmer amaranth 4 WAD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	38	25939.74359			
Treat.	12	25223.07692	2101.92308	75.38	<.0001
Rep.	2	47.4359	23.71795	0.85	0.4396
Error	24	669.23077	27.88462		

Palmer amaranth 3 WAE

Source		Sum of Squares	Mean Square	F Value	Pr > F
Total	38	25624.69231			
Treat.	12	24991.02564	2082.58547	81.05	<.0001
Rep.	2	16.66667	8.33333	0.32	0.7261
Error	24	616.66667			

- DF = degrees of freedom

Table 2-13a. Mean percent control of Palmer amaranth (AMAPA) after application of selected herbicides in cotton near Blackville, SC during 2013 (Study 2) [a].

TRT. #	PRE (A) [c] Treatment	Rates (kg ai/ha) or (kg ae/ha) [b]	3 WAA [d]		POST 1 (B) [c] Treatment	Rates (kg ai/ha) or (kg ae/ha) [b]	3 WAB [d]	
			% Control				% Control	
1	Acetochlor	1.26	95	ab	Glufosinate	0.59	98	a
2	Dicamba + Acetochlor	1.12 + 1.26	98	a	Dicamba + Glufosinate	1.12 + 0.59	100	a
3	Acetochlor	1.26	92	abc			95	a
4	Dicamba + Acetochlor	1.12 + 1.26	95	ab			100	a
5	Acetochlor	1.26	93	ab	Glyphosate	0.75	95	a
6	Dicamba + Acetochlor	1.12 + 1.26	92	abc	Dicamba + Glyphosate	1.12 + 0.75	100	a
7	Dicamba + Acetochlor	1.12 + 1.26	92	abc	Glyphosate	0.75	97	a
8	Acetochlor	1.26	97	ab			98	a
9	Dicamba + Acetochlor	1.12 + 1.26	92	abc			97	a
10	Untreated check		0	d			0	b
11	Fomesafen + Diuron	0.28 + 1.12	85	c	Glyphosate + Acetochlor	0.75 + 1.26	97	a
12	Fomesafen + Diuron	0.28 + 1.12	90	bc	Glufosinate + Acetochlor	0.59 + 1.26	100	a
13	Fomesafen + Diuron	0.28 + 1.12	95	ab	Glyphosate + Pyrithiobac sodium	0.75 + 0.07	97	a

[a] Means within a column followed by the same letter are not different according to Fisher's Protected LSD $p \leq 0.05$.
[b] Acitive ingredients correspond to acetochlor, fomesafen, and diuron. Active equivalent corresponds to dicamba.
[c] PRE was sprayed at planting and earlyPOST was sprayed when Palmer amaranth was at 5 to 10 cm heights.
[d] WAA = weeks after application timing A. WAB = weeks after application timing B.

Table 2-13b. Mean percent control of Palmer amaranth (AMAPA) after application of selected postemergence herbicides in cotton near Blackville, SC during 2013 (Study 2) [a].

TRT. #	POST 2 [C] [c] Treatment	Rates (kg ai/ha) or (kg ae/ha) [b]	3 WAC [d]	POST 3(D) [c] Treatment	Rates (kg ai/ha) or (kg ae/ha) [b]	4 WAD [d]
			% Control			% Control
1			100 a	Glufosinate	0.59	98 ab
2			100 a	Glufosinate	0.59	95 abc
3	Glufosinate	0.59	93 c			93 abc
4	Dicamba + Glufosinate	1.12 + 0.59	100 a			92 abc
5			98 ab	Glyphosate	0.75	90 bc
6			100 a	Glyphosate	0.75	97 ab
7			98 ab	Dicamba + Glyphosate	1.12 + 0.75	100 a
8	Glyphosate	0.75	98 ab			93 abc
9	Dicamba + Glyphosate	1.12 + 0.75	95 bc			87 c
10			0 d			0 d
11			97 abc	Glyphosate + Acetochlor	0.75 + 1.26	93 abc
12			100 a	Glufosinate + Acetochlor	0.59 + 1.26	100 a
13			98 ab	Glyphosate + Acetochlor	0.75 + 1.26	95 abc

[a] Means within a column followed by the same letter are not different according to Fisher's Protected LSD at $p \leq 0.05$.
[b] Active ingredients correspond to Glufosinate and Acteochlor. Active equivalent corresponds to Dicamba and Glyphosate.
[c] POST 2 was sprayed at Palmer amaranth sizes of 7 to 12 cm heights and POST 3 was sprayed at Palmer amaranth sizes of 10 to 15 cm heights.
[d] WAC = weeks after application timing C. WAD = weeks after application timing D.

Table 2-13c. Mean percent control and population counts of Palmer amaranth (AMAPA) after application of selected postemergence herbicides in cotton near Blackville, SC during 2013 (Study 2) [a].

TRT. #	POST 4 [E] [b] Treatment	Rates (kg ai/ha)	3 WAE [c]		Counts 3 WAE	
			% Control		# AMAPA/m^2	
1	Diuron + MSMA	1.12 + 2.24	97	ab	1	bc
2	Diuron + MSMA	1.12 + 2.24	95	ab	1	bc
3	Diuron + MSMA	1.12 + 2.24	90	b	2	bc
4	Diuron + MSMA	1.12 + 2.24	93	ab	1	bc
5	Diuron + MSMA	1.12 + 2.24	90	b	3	b
6	Diuron + MSMA	1.12 + 2.24	95	ab	1	bc
7	Diuron + MSMA	1.12 + 2.24	100	a	0	c
8	Diuron + MSMA	1.12 + 2.24	90	b	2	bc
9	Diuron + MSMA	1.12 + 2.24	88	b	2	bc
10	Diuron + MSMA	1.12 + 2.24	0	c	12	a
11	Diuron + MSMA	1.12 + 2.24	93	ab	2	bc
12	Diuron + MSMA	1.12 + 2.24	100	a	0	c
13	Diuron + MSMA	1.12 + 2.24	97	ab	1	bc

[a] Means within a column followed by the same letter are not different according to Fisher's Protected LSD $p \leq 0.05$.
[b] POST 4 directed was sprayed when Palmer amaranth was 7 to 20 cm heights.
[c] WAE = weeks after application timing E.

Table 2-14. Analysis of Variance for pitted morningglory counts, 3 weeks after application A, 3 weeks after application B, 3 weeks after application C, 4 weeks after application D, and 3 weeks after application E.

	pitted morningglory Count					pitted morningglory 3 WAA				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	38	335.0769231				38	21343.58974			
Treat.	12	291.7435897	24.3119658	13.81	<.0001	12	19926.92308	1660.57692	30.93	<.0001
Rep.	2	1.0769231	0.5384615	0.31	0.7393	2	128.20513	64.10256	1.19	0.3204
Error	24	42.2564103	1.7606838			24	1288.46154	53.68590		

	pitted morningglory 3 WAB					pitted morningglory 3 WAC				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	38	26047.43590				38	27208.97436			
Treat.	12	25747.4359	2145.61966	176.94	<.0001	12	27108.97436	2259.0812	595.63	<.0001
Rep.	2	8.97436	4.48718	0.37	0.6946	2	8.97436	4.48718	1.18	0.3236
Error	24	291.02564	12.12607			24	91.02564	3.79274		

	pitted morningglory 4 WAD					pitted morningglory 3 WAE				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F		Sum of Squares	Mean Square	F Value	Pr > F
Total	38	26676.92308				38	26174.35897			
Treat.	12	26293.58974	2191.13248	138.57	<.0001	12	25241.02564	2103.4188	61.81	<.0001
Rep.	2	3.84615	1.92308	0.12	0.886	2	116.66667	58.33333	1.71	0.2014
Error	24	379.48718	15.81197			24	816.66667	34.02778		

- DF = degrees of freedom

Table 2-15a. Mean percent control of pitted morningglory (IPOLA) after application of selected herbicides in cotton near Blackville, SC during 2013 (Study 2) [a].

TRT. #	PRE (A) [c] Treatment	Rates (kg ai/ha) or (kg ae/ha) [b]	3 WAA [d]		POST 1 (B) [c] Treatment	Rates (kg ai/ha) or (kg ae/ha) [b]	3 WAB [d]	
			% control				% Control	
1	Acetochlor	1.26	78	bcd	Glufosinate	0.59	93	bc
2	Dicamba + Acetochlor	1.12 + 1.26	87	abcd	Dicamba + Glufosinate	1.12 + 0.59	97	abc
3	Acetochlor	1.26	83	abcd			93	bc
4	Dicamba + Acetochlor	1.12 + 1.26	92	a			100	a
5	Acetochlor	1.26	80	abcd	Glyphosate	0.75	97	abc
6	Dicamba + Acetochlor	1.12 + 1.26	77	cd	Dicamba + Glyphosate	1.12 + 0.75	95	abc
7	Dicamba + Acetochlor	1.12 + 1.26	88	abc	Glyphosate	0.75	97	abc
8	Acetochlor	1.26	85	abcd			93	bc
9	Dicamba + Acetochlor	1.12 + 1.26	90	ab			92	c
10	Untreated check		0	e			0	d
11	Fomesafen + Diuron	0.28 + 1.12	75	d	Glyphosate + Acetochlor	0.75 + 1.26	100	a
12	Fomesafen + Diuron	0.28 + 1.12	77	cd	Glufosinate + Acetochlor	0.59 + 1.26	97	abc
13	Fomesafen + Diuron	0.28 + 1.12	75	d	Glyphosate + Pyrithiobac sodium	0.75 + 0.07	98	ab

[a] Means within a column followed by the same letter are not different according to Fisher's Protected LSD p≤0.05
[b] Acitive ingredients correspond to Acetochlor, fomesafen, and diuron. Active equivalent corresponds to Dicamba.
[c] PRE was sprayed at planting and POST 1 was sprayed when pitted morningglory was at 5 to 10 cm heights.
[d] WAA = weeks after application timing A. WAB = weeks after application timing B.

Table 2-15b. Mean percent control of pitted morningglory (IPOLA) after application of selected postemergence herbicides in cotton near Blackville, SC during 2013 (Study 2) [a].

TRT. #	POST 2 [C] [c] Treatment	Rates (kg ai/ha) or (kg ae/ha) [b]	3 WAC [d]		POST 3(D) [c] Treatment	Rates (kg ai/ha) or (kg ae/ha) [b]	4 WAD [d]	
1			100	a	Glufosinate	0.59	98	a
2			100	a	Glufosinate	0.59	98	a
3	Glufosinate	0.59	93	d			87	b
4	Dicamba + Glufosinate	1.12 + 0.59	100	a			95	a
5			100	a	Glyphosate	0.75	100	a
6			100	a	Glyphosate	0.75	97	a
7			100	a	Dicamba + Glyphosate	1.12 + 0.75	98	a
8	Glyphosate	0.75	97	bc			97	a
9	Dicamba + Glyphosate	1.12 + 0.75	95	cd			95	a
10			0	e			0	c
11			100	a	Glyphosate + Acetochlor	0.75 + 1.26	100	a
12			100	a	Glufosinate + Acetochlor	0.59 + 1.26	98	a
13			98	ab	Glyphosate + Acetochlor	0.75 + 1.26	97	a

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

[b] Active ingredients correspond to Glufosinate and Acteochlor. Active equivalent corresponds to Dicamba and Glyphosate.

[c] POST 2 was sprayed at pitted morningglory sizes of 7 to 12 cm heights and POST 3 was sprayed at pitted morningglory sizes of 10 to 15 cm heights.

[d] WAC = weeks after application timing C. WAD = weeks after application timing D.

Table 2-15c. Mean percent control and population counts of pitted morningglory (IPOLA) after application of selected postemergence herbicides in cotton near Blackville, SC during 2013 (Study 2) [a].

TRT. #	POST 4 [E] [b] Treatment	Rates (kg ai/ha)	3 WAE [d]		Counts 3 WAE	
			% Control		# IPOLA/m^2	
1	Diuron + MSMA	1.12 + 2.24	97	abc	1	bc
2	Diuron + MSMA	1.12 + 2.24	98	ab	0	bc
3	Diuron + MSMA	1.12 + 2.24	83	d	2	b
4	Diuron + MSMA	1.12 + 2.24	93	abc	2	bc
5	Diuron + MSMA	1.12 + 2.24	97	abc	0	c
6	Diuron + MSMA	1.12 + 2.24	88	cd	2	bc
7	Diuron + MSMA	1.12 + 2.24	98	ab	0	bc
8	Diuron + MSMA	1.12 + 2.24	93	abc	1	bc
9	Diuron + MSMA	1.12 + 2.24	90	bcd	1	bc
10	Diuron + MSMA	1.12 + 2.24	0	e	11	a
11	Diuron + MSMA	1.12 + 2.24	100	a	0	bc
12	Diuron + MSMA	1.12 + 2.24	95	abc	1	bc
13	Diuron + MSMA	1.12 + 2.24	95	abc	1	bc

[a] Means within a column followed by the same letter are not different according to Fisher's Protected LSD $p \leq 0.05$
[b] POST 4 directed was sprayed when pitted morningglory was 7 to 20 cm heights.
[d] WAE = weeks after application timing E.

Table 2-16. Analysis of Variance for large crabgrass counts, 3 weeks after application A, 3 weeks after application B, 3 weeks after application C, 4 weeks after application D, 3 weeks after application E.

	large crabgrass Count					large crabgrass 3 WAA				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	38	615.2307692				38	27239.74359			
Treat.	12	473.2307692	39.4358974	7.04	<.0001	12	25906.41026	2158.86752	40.9	<.0001
Rep.	2	7.5384615	3.7692308	0.67	0.5197	2	66.66667	33.33333	0.63	0.5404
Error	24	134.4615385	5.6025641			24	1266.66667	52.77778		

	large crabgrass 3 WAB					large crabgrass 3 WAC				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	38	26689.74359				38	27507.69231			
Treat.	12	26306.41026	2192.20085	145.01	<.0001	12	27357.69231	2279.80769	395.17	<.0001
Rep.	2	20.51282	10.25641	0.68	0.5169	2	11.53846	5.76923	1	0.3827
Error	24	362.82051	15.11752			24	138.46154	5.76923		

	large crabgrass 4 WAD					large crabgrass 3 WAE				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F		Sum of Squares	Mean Square	F Value	Pr > F
Total	38	27466.66667				38	29026.92308			
Treat.	12	26383.33333	2198.61111	50.94	<.0001	12	25860.25641	2155.02137	17.97	<.0001
Rep.	2	47.4359	23.71795	0.55	0.5843	2	288.46154	144.23077	1.2	0.3179
Error	24	1035.89744	43.16239			24	2878.20513	119.92521		

- DF = degrees of freedom

Table 2-17a. Mean percent control of large crabgrass (DIGSA) after application of selected herbicides in cotton near Blackville, SC during 2013 (Study 2) [a].

TRT. #	PRE (A) [c] Treatment	Rates (kg ai/ha) or (kg ae/ha) [b]	3 WAA [d]		POST 1 (B) [c] Treatment	Rates (kg ai/ha) or (kg ae/ha) [b]	3 WAB [d]	
			% Control				% Control	
1	Acetochlor	1.26	100	a	Glufosinate	0.59	98	ab
2	Dicamba + Acetochlor	1.12 + 1.26	95	abc	Dicamba + Glufosinate	1.12 + 0.59	97	ab
3	Acetochlor	1.26	100	a			100	a
4	Dicamba + Acetochlor	1.12 + 1.26	98	ab			90	c
5	Acetochlor	1.26	100	a	Glyphosate	0.75	97	ab
6	Dicamba + Acetochlor	1.12 + 1.26	87	bc	Dicamba + Glyphosate	1.12 + 0.75	97	ab
7	Dicamba + Acetochlor	1.12 + 1.26	93	abc	Glyphosate	0.75	97	ab
8	Acetochlor	1.26	98	ab			100	a
9	Dicamba + Acetochlor	1.12 + 1.26	100	a			100	a
10	Untreated check		0	d			0	d
11	Fomesafen + Diuron	0.28 + 1.12	85	bc	Glyphosate + Acetochlor	0.75 + 1.26	98	ab
12	Fomesafen + Diuron	0.28 + 1.12	85	bc	Glufosinate + Acetochlor	0.59 + 1.26	97	ab
13	Fomesafen + Diuron	0.28 + 1.12	92	abc	Glyphosate + Pyrithiobac sodium	0.75 + 0.07	93	bc

[a] Means within a column followed by the same letter are not different according to Fisher's Protected LSD p≤0.05.
[b] Acitive ingredients correspond to Acetochlor, fomesafen, and diuron. Active equivalent corresponds to Dicamba.
[c] PRE was sprayed at planting and POST 1 was sprayed when large crabgrass was at 5 to 10 cm heights.
[d] WAA = weeks after application timing A. WAB = weeks after application timing B.

Table 2-17b. Mean percent control of large crabgrass (DIGSA) after application of selected postemergence herbicides in cotton near Blackville, SC during 2013 (Study 2) [a].

TRT. #	POST 2 [C] [c] Treatment	Rates (kg ai/ha) or (kg ae/ha) [b]	3 WAC [d]		POST 3(D) [c] Treatment	Rates (kg ai/ha) or (kg ae/ha) [b]	4 WAD [d]	
			% Control				% Control	
1			100	a	Glufosinate	0.59	97	a
2			100	a	Glufosinate	0.59	97	a
3	Glufosinate	0.59	98	a			93	a
4	Dicamba + Glufosinate	1.12 + 0.59	93	b			80	b
5			100	a	Glyphosate	0.75	98	a
6			100	a	Glyphosate	0.75	92	a
7			100	a	Dicamba + Glyphosate	1.12 + 0.75	100	a
8	Glyphosate	0.75	100	a			97	a
9	Dicamba + Glyphosate	1.12 + 0.75	100	a			97	a
10			0	c			0	c
11			100	a	Glyphosate + Acetochlor	0.75 + 1.26	100	a
12			98	a	Glufosinate + Acetochlor	0.59 + 1.26	98	a
13			100	a	Glyphosate + Acetochlor	0.75 + 1.26	100	a

[a] Means within a column followed by the same letter are not different according to Fisher's Protected LSD p≤0.05.
[b] Active ingredients correspond to Glufosinate and Acteochlor. Active equivalent corresponds to Dicamba and Glyphosate.
[c] POST 2 was sprayed at weed sizes of 7 to 12 cm heights and POST 3 was sprayed at weed sizes of 10 to 15 cm heights.
[d] WAC = weeks after application timing C. WAD = weeks after application timing D.

Table 2-17c. Mean percent control and population counts of large crabgrass (DIGSA) after application of selected postemergence herbicides in cotton near Blackville, SC during 2013 (Study 2)[a].

TRT. #	POST 4 [E][b] Treatment	Rates (kg ai/ha) or (kg ae/ha)	3 WAE[c]		Counts 3 WAE	
			% Control		# DIGSA/m^2	
1	Diuron + MSMA	1.12 + 2.24	95	a	0	c
2	Diuron + MSMA	1.12 + 2.24	95	a	2	bc
3	Diuron + MSMA	1.12 + 2.24	92	a	2	bc
4	Diuron + MSMA	1.12 + 2.24	72	b	5	b
5	Diuron + MSMA	1.12 + 2.24	97	a	0	c
6	Diuron + MSMA	1.12 + 2.24	88	ab	4	b
7	Diuron + MSMA	1.12 + 2.24	98	a	0	c
8	Diuron + MSMA	1.12 + 2.24	90	ab	3	bc
9	Diuron + MSMA	1.12 + 2.24	92	a	2	bc
10	Diuron + MSMA	1.12 + 2.24	0	c	13	a
11	Diuron + MSMA	1.12 + 2.24	100	a	0	c
12	Diuron + MSMA	1.12 + 2.24	97	a	1	bc
13	Diuron + MSMA	1.12 + 2.24	100	a	0	c

[a] Means within a column followed by the same letter are not different according to Fisher's Protected LSD p≤0.05.
[b] POST 4 directed was sprayed when large crabgrass was 7 to 20 cm heights.
[c] WAE = weeks after application timing E.

Table 2-18. Analysis of Variance for cotton yield data in Study 2.

Source	Yield Analysis				
	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	38	14285649.04			
Treat.	12	9120307.449	760025.621	3.6	0.0037
Rep.	2	98759.31	49379.655	0.23	0.7932
Error	24	5066582.28	211107.59		

- DF = degrees of freedom

Table 2-19. Mean cotton yield after application of selected postemergence herbicides in cotton near Blackville, SC during 2013 (Study 2) [a].

TRT. NO.	Yield	
	Kg/ha	
1	1340	abc
2	1270	abc
3	1411	abc
4	847	cd
5	1199	abc
6	1411	abc
7	917	bcd
8	917	bcd
9	212	de
10	0	e
11	1693	a
12	1622	ab
13	988	abc

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

Table 2-20. Analysis of Variance for Palmer amaranth counts, 3 weeks after application A, 3 weeks after application B, and 2 weeks after application C in study 3.

	Palmer amaranth Count					Palmer amaranth 3 WAA				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	83	912.2380952				83	177223.8095			
Treatment	11	729.0952381	66.2813853	62.29	<.0001	11	164923.8095	14993.0736	113.69	<.0001
Rep.	5	3.3958333	0.6791667	0.64	0.6714	5	994.6181	198.9236	1.51	0.2023
year	1	1.5089286	1.5089286	1.42	0.2388	1	1416.6915	1416.6915	10.74	0.0018
Treat*year	11	119.7172619	10.8833874	10.23	<.0001	11	2635.3919	239.5811	1.82	0.0732
Error	55	58.5208333	1.0640152			55	7253.2986	131.8782		

	Palmer amaranth 3 WAB					Palmer amaranth 2 WAC				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	83	7378.571429				83	11066.66667			
Treatment	11	5607.142857	509.74026	101.76	<.0001	11	9873.809524	897.619048	461.63	<.0001
Rep.	5	30.729167	6.145833	1.23	0.309	5	9.722222	1.944444	1	0.4265
year	1	339.508929	339.508929	67.77	<.0001	1	77.777778	77.777778	40	<.0001
Treat*year	11	1125.669643	102.333604	20.43	<.0001	11	998.412698	90.764791	46.68	<.0001
Error	55	275.520833	5.00947			55	106.94444	1.94444		

- DF = degrees of freedom

Table 2-21. Analysis of Variance for pitted morningglory counts, 3 weeks after application A, 3 weeks after application B, and 2 weeks after application C in study 3.

	pitted morningglory Count					pitted morningglory 3 WAA				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	83	419.6666667				83	163358.0357			
Treatment	11	208.8095238	18.982684	16.59	<.0001	11	159629.4643	14511.7695	561.47	<.0001
Rep.	5	6.2222222	1.2444444	1.09	0.3777	5	303.4722	60.6944	2.35	0.0529
year	1	0.7777778	0.7777778	0.68	0.4133	1	1135.8135	1135.8135	43.95	<.0001
Treat.*year	11	140.9126984	12.8102453	11.19	<.0001	11	867.7579	78.8871	3.05	0.003
Error	55	62.9444444	1.14444444			55	1421.5278	25.846		

	pitted morningglory 3 WAB					pitted morningglory 2 WAC				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	83	3770.238095				83	3100.892857			
Treatment	11	2098.809524	190.800866	45.69	<.0001	11	2122.321429	192.938312	68.52	<.0001
Rep.	5	9.895833	1.979167	0.47	0.7941	5	36.805556	7.361111	2.61	0.0343
year	1	339.508929	339.508929	81.3	<.0001	1	12.003968	12.003968	4.26	0.0437
Treat.*year	11	1092.33631	99.303301	23.78	<.0001	11	774.900794	70.445527	25.02	<.0001
Error	55	229.6875	4.176136			55	154.861111	2.815657		

- DF = degrees of freedom

Table 2-22. Analysis of Variance for large crabgrass counts, 3 weeks after application A, 3 weeks after application B, and 2 weeks after application C in study 3.

	large crabgrass Count					large crabgrass 3 WAA				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	83	912.2380952				83	169673.8095			
Treat.	11	729.0952381	66.2813853	62.29	<.0001	11	164959.5238	14996.3203	343.19	<.0001
Rep	5	3.3958333	0.6791667	0.64	0.6714	5	48.7847	9.7569	0.22	0.951
Year	1	1.5089286	1.5089286	1.42	0.2388	1	1233.3581	1233.3581	28.23	<.0001
Treat*year	11	119.7172619	10.8833874	10.23	<.0001	11	1028.8442	93.5313	2.14	0.0321
Error	55	58.5208333	1.0640152			55	2403.2986	43.6963		

	large crabgrass 3 WAB					large crabgrass 2 WAC				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	83	6450.892857				83	26958.03571			
Treat.	11	1558.035714	141.63961	3.75	0.0005	11	5793.75	526.704545	6.93	<.0001
Rep	5	64.0625	12.8125	0.34	0.8868	5	40.451389	8.090278	0.11	0.9904
Year	1	830.580357	830.580357	22.01	<.0001	1	9078.000992	9078.000992	119.5	<.0001
Treat*year	11	1922.693452	174.790314	4.63	<.0001	11	7867.534722	715.230429	9.41	<.0001
Error	55	2075.520833	37.736742			55	4178.29861	75.96907		

- DF = degrees of freedom

Table 2-23a. Mean percent control of Palmer amaranth (AMAPA) after application of selected herbicides in cotton near Blackville, SC during 2012 and 2013 (Study 3) [a].

TRT. #	PRE (A) [c] Treatment	Rates (kg ai/ha) or (kg ae/ha) [b]	3 WAA [d] 2012/2013	POST 1 (B) [c] Treatment	Rates (kg ai/ha) or (kg ae/ha) [b]	3 WAB [d] 2012	3 WAB [d] 2013
			% Control			-----% Control------	
1	Fomesafen	0.28	99 a	Glyphosate + Dicamba	0.75 + 1.12	100 a	100 a
2	Fomesafen	0.28	95 ab	Glyphosate + Dicamba + Acetochlor	0.75 + 1.12 + 1.26	99 a	100 a
3	Fomesafen	0.28	96 ab	Glufosinate + Acetochlor	0.59 + 1.26	100 a	100 a
4	Fomesafen	0.28	80 c	Glufosinate + Dicamba	0.59 + 1.12	98 a	100 a
5	Dicamba	1.12	85 bc	Glyphosate + Dicamba	0.75 + 1.12	100 a	100 a
6	Dicamba	1.12	94 ab	Glyphosate + Dicamba + Acetochlor	0.75 + 1.12 + 1.26	100 a	100 a
7	Dicamba	1.12	96 ab	Glufosinate + Acetochlor	0.59 + 1.26	99 a	100 a
8	Dicamba	1.12	96 ab	Glufosinate + Dicamba	0.59 + 1.12	100 a	100 a
9	No PRE		0 d	Glyphosate + Dicamba	0.75 + 1.12	100 a	100 a
10	No PRE		0 d	Glyphosate + Dicamba + Acetochlor	0.75 + 1.12 + 1.26	90 b	100 a
11	No PRE		0 d	Glufosinate + Acetochlor	0.59 + 1.26	93 b	100 a
12	No PRE		0 d	Glyphosate	0.75	59 d	85 c

[a] Means within a column followed by the same letter are not different according to Fisher's Protected LSD at $p \leq 0.05$.
[b] Active ingredients correspond to Fomesafen, Glufosinate and Acetochlor. Active equivalent corresponds to Glyphosate and Dicamba.
[c] PRE was sprayed at planting. POST 1 was sprayed when Palmer amaranth was 7 to 12 cm heights.
[d] WAA = weeks after application timing A. WAB = weeks after application timing B.

Table 2-23b. Mean percent control and population counts of Palmer amaranth (AMAPA) after application of selected postemergence herbicides in cotton near Blackville, SC during 2012 and 2013 (Study 3) [a].

TRT. #	POST 2 [C] [c] Treatment	Rates (kg ai/ha) or (kg ae/ha) [b]	2 WAC [d] 2012	2 WAC [d] 2013	Counts 2 WAC 2012	Counts 2 WAC 2013
			-----% Control-----		# AMAPA/m^2	
1	Glufosinate + Acetochlor	0.59 + 1.26	100 a	100 a	0 d	1 cd
2	Glufosinate + Acetochlor	0.59 + 1.26	100 a	100 a	0 d	2 c
3	Glufosinate + Acetochlor	0.59 + 1.26	100 a	100 a	0 cd	0 cd
4	Glufosinate + Acetochlor	0.59 + 1.26	100 a	100 a	0 cd	2 c
5	Glufosinate + Acetochlor	0.59 + 1.26	100 a	100 a	0 d	1 cd
6	Glufosinate + Acetochlor	0.59 + 1.26	100 a	100 a	0 d	1 cd
7	Glufosinate + Acetochlor	0.59 + 1.26	100 a	98 a	0 cd	1 cd
8	Glufosinate + Acetochlor	0.59 + 1.26	100 a	100 a	1 cd	0 cd
9	Glufosinate + Acetochlor	0.59 + 1.26	100 a	100 a	2 c	0 cd
10	Glufosinate + Acetochlor	0.59 + 1.26	100 a	100 a	1 cd	0 cd
11	Glufosinate + Acetochlor	0.59 + 1.26	100 a	100 a	0 d	0 cd
12	Glyphosate	0.75	50 c	75 b	15 a	7 b

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

[b] Active ingredients correspond to Glufosinate and Acetochlor. Active equivalent corresponds to Glyphosate.

[c] POST 2 was sprayed when Palmer amaranth was at 7 to 15 cm heights.

[d] WAC = weeks after application timing C.

Table 2-24a. Mean percent control and population counts of pitted morningglory (IPOLA) after application of selected postemergence herbicides in cotton near Blackville, SC during 2012 and 2013 (Study 3) [a].

TRT. #	PRE (A) [c] Treatment	Rates (kg ai/ha) or (kg ae/ha) [b]	3 WAA [d] 2012	3 WAA [d] 2013	POST 1 (B) [c] Treatment	Rates (kg ai/ha) or (kg ae/ha) [b]	3 WAB [d] 2012	3 WAB [d] 2013
			-------% Control---				--------% Control-------	
1	Fomesafen	0.28	99 a	82 cd	Glyphosate + Dicamba	0.75 + 1.12	100 a	100 ab
2	Fomesafen	0.28	98 a	85 bcd	Glyphosate + Dicamba + Acetochlor	0.75 + 1.12 + 1.26	100 a	100 ab
3	Fomesafen	0.28	98 a	92 ab	Glufosinate + Acetochlor	0.59 + 1.26	99 ab	100 ab
4	Fomesafen	0.28	96 a	83 cd	Glufosinate + Dicamba	0.59 + 1.12	100 ab	100 ab
5	Dicamba	1.12	99 a	92 ab	Glyphosate + Dicamba	0.75 + 1.12	95 cde	100 ab
6	Dicamba	1.12	99 a	80 d	Glyphosate + Dicamba + Acetochlor	0.75 + 1.12 + 1.26	99 ab	100 ab
7	Dicamba	1.12	93 ab	87 bcd	Glufosinate + Acetochlor	0.59 + 1.26	100 a	100 ab
8	Dicamba	1.12	98 a	88 ab	Glufosinate + Dicamba	0.59 + 1.12	100 a	100 ab
9	No PRE		0 e	0 e	Glyphosate + Dicamba	0.75 + 1.12	98 abc	100 ab
10	No PRE		0 e	0 e	Glyphosate + Dicamba + Acetochlor	0.75 + 1.12 + 1.26	93 e	100 ab
11	No PRE		0 e	0 e	Glufosinate + Acetochlor	0.59 + 1.26	94 de	100 ab
12	No PRE		0 e	0 e	Glyphosate	0.75	70 f	97 bcd

[a] Means within a column followed by the same letter are not different according to Fisher's Protected LSD at p≤0.05

[b] Active ingredients correspond to Fomesafen, Glufosinate and Acetochlor. Active equivalent corresponds to Glyphosate and Dicamba.

[c] PRE was sprayed at planting. POST 1 was sprayed when pitted morningglory was 7 to 12 cm heights.

[d] WAA = weeks after application timing A. WAB = weeks after application timing B.

Table 2-24b. Mean percent control and population counts of pitted morningglory (IPOLA) after application of selected postemergence herbicides in cotton near Blackville, SC during 2012 and 2013 (Study 3) [a].

TRT. #	POST 2 [C] [c] Treatment	Rates (kg ai/ha) or (kg ae/ha) [b]	2 WAC [d] 2012	2 WAC [d] 2013	Counts 2 WAC 2012	Counts 2 WAC 2013
			-----% Control-----		-------# IPOLA/m^2 ------------	
1	Glufosinate + Acetochlor	0.59 + 1.26	100 a	100 a	0 c	0 c
2	Glufosinate + Acetochlor	0.59 + 1.26	100 a	100 a	0 c	0 bc
3	Glufosinate + Acetochlor	0.59 + 1.26	100 a	100 a	1 bc	1 bc
4	Glufosinate + Acetochlor	0.59 + 1.26	100 a	98 ab	0 bc	0 bc
5	Glufosinate + Acetochlor	0.59 + 1.26	100 a	100 a	0 bc	0 bc
6	Glufosinate + Acetochlor	0.59 + 1.26	100 a	98 ab	0 bc	2 b
7	Glufosinate + Acetochlor	0.59 + 1.26	100 a	98 ab	0 bc	0 bc
8	Glufosinate + Acetochlor	0.59 + 1.26	100 a	98 ab	0 bc	1 bc
9	Glufosinate + Acetochlor	0.59 + 1.26	100 a	97 b	1 bc	1 bc
10	Glufosinate + Acetochlor	0.59 + 1.26	100 a	100 a	0 c	1 bc
11	Glufosinate + Acetochlor	0.59 + 1.26	100 a	98 ab	0 c	1 bc
12	Glyphosate	0.75	73 d	93 c	10 a	1 bc

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

[b] Active ingredients correspond to Glufosinate and Acetochlor. Active equivalent corresponds to Glyphosate.

[c] POST 2 was sprayed when pitted morningglory was at 7 to 15 cm heights.

[d] WAC = weeks after application timing C

Table 2-25a. Mean percent control of large crabgrass (DIGSA) after application of selected postemergence herbicides in cotton near Blackville, SC during 2012 and 2013 (Study 3) [a].

TRT. #	PRE (A) Treatment	Rates (kg ai/ha) or (kg ae/ha)	3 WAA 2012	3 WAA 2013	POST 1 (B) Treatment	Rates (kg ai/ha) or (kg ae/ha)	3 WAB 2012	3 WAB 2013
			-------% Control--------				-----------% Control--------	
1	Fomesafen	0.28	99 a	80 f	Glyphosate + Dicamba	0.75 + 1.12	100 a	98 ab
2	Fomesafen	0.28	98 ab	92 abcde	Glyphosate + Dicamba + Acetochlor	0.75 + 1.12 + 1.26	99 ab	98 ab
3	Fomesafen	0.28	99 a	82 ef	Glufosinate + Acetochlor	0.59 + 1.26	98 ab	90 bcd
4	Fomesafen	0.28	99 a	93 abcd	Glufosinate + Dicamba	0.59 + 1.12	99 ab	77 ef
5	Dicamba	1.12	99 a	83 def	Glyphosate + Dicamba	0.75 + 1.12	98 ab	98 ab
6	Dicamba	1.12	100 a	85 cdef	Glyphosate + Dicamba + Acetochlor	0.75 + 1.12 + 1.26	98 ab	98 ab
7	Dicamba	1.12	99 a	95 abc	Glufosinate + Acetochlor	0.59 + 1.26	99 ab	85 de
8	Dicamba	1.12	100 a	88 bcdef	Glufosinate + Dicamba	0.59 + 1.12	98 ab	70 f
9	No PRE		0 g	0 g	Glyphosate + Dicamba	0.75 + 1.12	98 ab	92 bcd
10	No PRE		0 g	0 g	Glyphosate + Dicamba + Acetochlor	0.75 + 1.12 + 1.26	93 abcd	87 cde
11	No PRE		0 g	0 g	Glufosinate + Acetochlor	0.59 + 1.26	90 bcd	97 abc
12	No PRE		0 g	0 g	Glyphosate	0.75	100 ab	100 ab

[a] Means within a column followed by the same letter are not different according to Fisher's Protected LSD at p≤0.05

[b] Active ingredients correspond to Fomesafen, Glufosinate and Acetochlor. Active equivalent corresponds to Glyphosate and Dicamba.

[c] PRE was sprayed at planting. POST 1 was sprayed when large crabgrass was 7 to 12 cm heights.

[d] WAA = weeks after application timing A. WAB = weeks after application timing B.

Table 2-25b. Mean percent control and population counts of large crabgrass (DIGSA) after application of selected postemergence herbicides in cotton near Blackville, SC during 2012 and 2013 (Study 3) [a].

TRT. #	POST 2 [C] [c] Treatment	Rates (kg ai/ha) or (kg ae/ha) [b]	2 WAC [d] 2012		2 WAC [d] 2013		Counts 2 WAC 2012		Counts 2 WAC 2013	
			-----% Control------				---------# DIGSA/m^2----------			
1	Glufosinate + Acetochlor	0.59 + 1.26	100	a	90	abcd	0	d	1	cd
2	Glufosinate + Acetochlor	0.59 + 1.26	100	a	97	ab	0	d	2	c
3	Glufosinate + Acetochlor	0.59 + 1.26	100	a	78	de	0	cd	0	cd
4	Glufosinate + Acetochlor	0.59 + 1.26	100	a	75	e	0	cd	2	c
5	Glufosinate + Acetochlor	0.59 + 1.26	100	a	93	abc	0	d	1	cd
6	Glufosinate + Acetochlor	0.59 + 1.26	99	a	93	abc	0	d	1	cd
7	Glufosinate + Acetochlor	0.59 + 1.26	100	a	80	cde	0	cd	1	cd
8	Glufosinate + Acetochlor	0.59 + 1.26	100	a	58	f	1	cd	0	cd
9	Glufosinate + Acetochlor	0.59 + 1.26	100	a	88	abcde	2	c	0	cd
10	Glufosinate + Acetochlor	0.59 + 1.26	100	a	23	g	1	cd	0	cd
11	Glufosinate + Acetochlor	0.59 + 1.26	100	a	87	abcde	0	d	0	cd
12	Glyphosate	0.75	100	a	83	bcde	15	a	7	b

[a] Means within a column followed by the same letter are not different according to Fisher's Protected LSD at p≤0.05
[b] Active ingredients correspond to Glufosinate and Acetochlor. Active equivalent corresponds to Glyphosate.
[c] POST 2 was sprayed when large crabgrass was at 7 to 15 cm heights.
[d] WAC = weeks after application timing C.

Table 2-26. Analysis of Variance for cotton yield data in Study 3.

	Yield Analysis				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	83	17424881.43			
Treatment	11	1424518.481	129501.68	0.7	0.729
Rep.	5	3451216.575	690243.315	3.75	0.0054
year	1	397707.693	397707.693	2.16	0.1471
Treat.*year	11	2038506.286	185318.753	1.01	0.4518
Error	55	10112932.39	183871.5		

- DF = degrees of freedom

Table 2-27. Mean cotton yield after application of selected postemergence herbicides in cotton near Blackville, SC during 2012 and 2013 (Study 3) [a].

TRT. NO.	Yield	
	Kg/ha	
1	945	ab
2	856	ab
3	1035	ab
4	962	ab
5	1226	a
6	895	ab
7	705	b
8	930	ab
9	1078	ab
10	838	ab
11	975	ab
12	705	b

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

CHAPTER THREE

EVALUATION OF 2,4-D BASED HERBICIDE PROGRAMS IN 2,4-D TOLERANT COTTON

ABSTRACT

The use of transgenic crops has grown drastically over the past couple of decades. Many agronomic crops, such as cotton, soybeans, and corn, produced today are tolerant to glyphosate. Glyphosate-tolerant crops were introduced in 1997, and, about six years later, glyphosate-resistant Palmer amaranth was confirmed in Georgia. Glyphosate-resistant weeds arose from reliance on repeated applications of glyphosate alone to control weeds in crops. New transgenic traits for herbicide tolerance have been developed, and evaluations of stacked traits and concurrent use of multiple herbicides have provided insight into management of glyphosate-resistant weeds. Field experiments were conducted in 2011, 2012, and 2013 at the Edisto Research and Education Center near Blackville, SC, to determine the efficacy of 2,4-D-based herbicide programs in cotton tolerant to 2,4-D, glyphosate, and glufosinate. The treatments provided excellent control (> 93%) of multiple weed species (Palmer amaranth, pitted morningglory, and large crabgrass) and resulted in high cotton yields (> 2171 kg/ha). This new trait has the potential to be successfully used in controlling problem weeds in cotton.

INTRODUCTION

The use of genetically modified crops has risen significantly over the years. In 2001, 56% of the USA cotton hectares were planted in glyphosate-resistant cotton (Owen and Zelaya, 2005). Because weed control programs have relied almost exclusively on glyphosate to manage weeds for almost two decades, it was inevitable that the intense and sustained selection pressure would lead to the development of glyphosate-resistant weed biotypes.

The most troublesome weed in cotton is Palmer amaranth (*Amaranthus palmeri* S. Watts) not only because of its resistance to glyphosate but its rapid growth rate, prolific seed production and highly competiveness (Culpepper at al., 2006). After the discovery of glyphosate-resistant biotypes of Palmer amaranth, control has been very difficult with labeled herbicides available to producers. Palmer amaranth has previously developed resistance to other herbicides as well, including the dintitroanilines and ALS-inhibitors (Heap, 2014). The over reliance on glyphosate has led to rapid spread of resistant Palmer amaranth biotypes throughout the southern United States and is causing huge economic losses in these crops. Palmer amaranth not only leads to yield losses, but it increases the costs of production and impedes on the harvesting of cotton. Currently, Monsanto and Dow AgroSciences are developing new transgenic cotton varieties with tolerance to other herbicides that would control glyphosate-resistant Palmer amaranth.

A new transgenic cotton being researched and developed is one that is tolerant to 2,4-D. This herbicide is most commonly used in grass crops and has been around since the mid 1940’s to control broadleaf weeds (Bayley et al., 1992). The herbicide, 2,4-D, is a selective herbicide for broadleaf weed control and is categorized as a synthetic auxin herbicide. These auxinic herbicides cause abnormal increases in cell wall growth that leads to uncontrolled cell division in vascular tissue. Timely applications of 2,4-D can succefully control species from the Amaranthaceae family such as, Redroot pigweed (*Amaranthus retroflexus*) and common waterhemp (*Amaranthus rudis* L.) (Craigmyle et al., 2013). Dow AgroSciences has developed a new formulation of 2,4-D called 2,4-D choline that is significantly less volatile than previous formulations and will be premixed with glyphosate and marketed as Enlist Duo™. Enlist Duo™ is a prepackaged mixture of 0.19 kg ai/L of 2,4-D choline and 0.2 kg ae/L of glyphosate. This will provide farmers with new modes of action in cotton for weed control programs.

This new combination of 2,4-D choline and glyphosate, along with soil residual herbicides, will be beneficial in managing herbicide-resistant weeds. This new technology will facilitate control of the multiple biotypes of resistant Palmer amaranth and help delay or prevent the development of more resistant biotypes. Dow AgroSciences has not released this new cotton technology to growers due to pending regulatory approval by the USDA and EPA. Because this technology is new, very little research has been conducted on the efficacy of 2,4-D-based herbicide programs on herbicide-resistant Palmer amaranth in cotton. Therefore, research was initiated to evaluate 2,4-D-based herbicide combinations on herbicide-resistant Palmer amaranth and their effects on cotton growth and yield.

MATERIALS AND METHODS

Field experiments were conducted at Edisto Research and Education Center in Blackville, South Carolina, to determine the efficacy of 2,4-D based herbicide programs. Three studies were conducted on a Varina sandy loam (0-10% slope, fine, kaolinitic, thermic Plinthic Paleudults) during 2011-2013. The cotton variety 'pDAB4468' was planted in all three years. Cotton was seeded at 10 seed per meter of row using a four-row Almaco cone plot planter on a strip-tilled seed bed, and rows were spaced 96.5 centimeters. Experimental design was a randomized complete block of four row plots with four replications. All field maintenance processes, such as fertilizing, defoliation, and insect control, were followed according to recommended production practices for cotton in South Carolina (Jones et al., 2013). The middle two rows represented the treated area and outside rows were used as an untreated control. Treatments (16) (Tables 3.1-3.3) were applied using a backpack sprayer with a four-nozzle boom and nozzle spacing of 48 cm. Turbo TeeJet® Induction Flat Spray tips (11002 size) were used with an operation pressure of 234 kPa and a spray volume of 140 L/ha.

STUDY 1

In Study 1, cotton was planted on 25 May 2011, and plot dimensions were 4 rows by 11m long. Treatments were applied at the PRE (A), POST 1 (B), and POST 2 (C) stages, and all plots, with the exception of the untreated controls, were sprayed with a Layby POST directed (D) (Table 3.1). The PRE herbicides were applied after planting on 25 May (2:30 PM EDT; temperature of 43.2°C; average wind speed of 1.4 KPH; 30.7% RH; soil was dry with a temperature of 35.8°C; 40% cloud cover). The POST 1 treatments were sprayed 13 days after planting (DAP) on 7 June (8:15 AM EDT; temperature of 29°C; average wind speed of 3.7 KPH; 67.3% RH; soil was dry with a temperature of 29.1°C; 20% cloud cover) when weed sizes ranged from 5 to 10 cm in height. The POST 2 treatments were sprayed 33 DAP on 27 June (1:45 PM EDT; temperature of 33°C; 47.1% RH; soil was dry with a temperature of 40.7°C; 5% cloud cover) when weed sizes ranged from 8 to 13 cm in regrowth height.

STUDY 2

In Study 2, cotton was planted on 15 June 2012, and plot dimensions were four rows by 9 m in length. Plots were treated with a PRE herbicide followed by POST 1 and POST 2 combinations (B and C) [Table 3.2]. The PRE was applied at planting on 21 June (10:00 AM EDT; temperature of 27.1°C; 45.7% RH; average wind speed of 3.5 KPH; soil was dry with a temperature of 26.5°C; 0% cloud cover). The POST 1 treatments (B) were sprayed 20 DAP on 11 July 2012 (10:30 AM EDT; temperature of 29.9°C; 66.9% RH; average wind speed of 2.2 KPH; soil was wet with a temperature of 29.2°C; 5% cloud cover) when weed sizes ranged from 5 to 10 cm in height. The POST 2 combinations (C) were sprayed 45 DAP on 5 August 2012 (9:30 AM EDT; temperature of 27.6°C; 77% RH; average wind speed of 1.1 KPH; soil was dry with a temperature of 26.9°C; 75% cloud cover) when weed sizes ranged from 10 to 15 cm in height.

STUDY 3

In Study 3, cotton was planted on 21 June, and plots dimensions were 4 rows by 11 m long. Plots were treated with a PRE herbicide following planting and followed up with two postemergence herbicide combinations (B; POST1 and C; POST2) at different rates (Table 3.3). All plots, except for the untreated controls, were treated with a PRE (A) on 15 June 2013 (1:30 PM EDT; temperature of 29.2°C; 45.7% RH; average wind speed of 3.4 KPH; soil was wet with temperature of 28.2°C; 20% cloud cover). The POST 1 (B) treatments were applied 26 DAP on 11 July 2013 (10:30 AM EDT; temperature of 32.6°C; 57.8% RH; average wind speed of 1.7 KPH; soil was wet with temperature of 28.8°C; 30% cloud cover) when weed sizes ranged from 5 to 10 cm in height. The POST 2 combinations (C) were sprayed 47 DAP on 1 August 2013 (2:45 PM EDT; temperature of 34.1°C; 58.2% RH; average wind speed of 3.8 KPH; soil was dry with temperature of 34.4°C; 30% cloud cover) when weed sizes ranged from 10 to 15 cm in height.

Data collected included visual ratings of percent control of weeds, estimates of weed populations in plots, crop injury, and seed cotton yield. Ratings for crop injury and percent controlwere taken on a scale of 0-100%, with 0% indicating no effect on cotton or weed populations, respectively, in the treated area and 100% indicating crop death or complete weed control, respectively. Estimates of weed population were collected. Weed count data were determined by randomly tossing a 0.45-m quadrat (square made from plastic pipes) in the plots and counting each weed species within the quadrat. . Three weed species focused on in the experiments were: Palmer amaranth, pitted morningglory (*Ipomoea lacunose* L.), and large crabgrass (*Digitaria sanguinalis* L.). Cotton was harvested using a two-row spindle picker, and the middle two treated rows were harvested.

Visual ratings of control were collected for Study 1 at 2 weeks after A application (2 WAA), 3 WAB, and 4 WAC. No estimates of weed density were collected for this test. Cotton was harvested on 11 November 2011 and weighed in kg per plot. Visual ratings of weed control for Study 2 were gathered at 4 WAA, 5 WAB, and 2 WAC. Estimates of the weed population were collected on 2 WAC. Cotton was harvested on 11 December 2012 and weighed in kg per plot. In Study 3, visual ratings of control were collected at 3 WAA, 4 WAB, and 4 WAC. Estimates of weed density were gathered on 4 WAC. Cotton was harvested on 15 January 2013 and weighed in kg per plot. Harvest weights for each plot for the three test trials were then converted into kg per hectare.

Ratings of weed control, estimates of weed density, and cotton yield data were subjected to ANOVA using the PROC GLM procedure in SAS (SAS Institute Inc. Cary, NC), with herbicide treatment as the main effect and replication as the random effect. Means of significant main effects were separated using Fisher's Protected LSD at $p \leq 0.05$.

RESULTS AND DISCUSSION

STUDY 1

At 2 WAA, no significant differences were observed with treatments receiving a PRE application. (Table 3-4). At 3 WAB, treatments of glyphosate and glufosinate alone demonstrated 84 and 87% control, respectively, of Palmer amaranth (Table 3-5a). The other treatments provided control of greater than 93%, with a majority of treatments at 100% control. At 4 WAC (Table 3-5b), glyphosate alone provided the poorest control (88%) of Palmer amaranth. The addition of 2,4-D choline to glyphosate or glufosinate increased control of Palmer amaranth to 98-100% (Table 3-5b), suggesting synergism or improved control through additive control of Palmer amaranth. However, some researchers have found antagonism when mixing auxin herbicides with glyphosate or glufosinate (Craigmyle et al., 2013).

All treatments at each evaluation for pitted morningglory control had significant differences (Table 3-6). Treatments that included a PRE at planting provided excellent control of pitted morningglory, whereas treatments without a PRE had 0% control (Table 3-7a). Control of pitted morningglory with glyphosate alone at POST 1 (B) was 84%. There were significant differences among the treatments at 3WAC; however, all treatments provided 99 to 100% control (Table 3-7b).

There were significant differences in treatments for large crabgrass control (Table 3-8). At 2 WAA, control of large crabgrass was 100% across all treatments that included a PRE herbicide in the program (Table 3-9a). Differences were observed among the two treatments that did not receive a PRE herbicide and included glufosinate at POST 1.

Glufosinate alone had 84 % and 2,4-D choline mixed with glufosinate had 81% and 95 % control of large crabgrass without a PRE being used. The treatments that included glyphosate had better control of large crabgrass. At 4 WAC, all treatments provided 93% or better control of large crabgrass (Table 3-9b). The glufosinate alone treatment provided 93% control of large crabgrass, while all other treatments provided greater than 96% control. Our results were similar to those reported by Johnson et al. (2010) who noticed late-season control of large crabgrass and Palmer amaranth when glufosinate was applied.

Fomesafen plus pendimethalin at PRE followed by 2,4-D choline plus glyphosate at POST 1 and POST 2 was significantly lower than 2,4-D choline plus glufosinate at POST 1 and POST 2 without a PRE treatment (Table 3-10). Treatments of 2,4-D choline plus glufosinate without a PRE had high yields of 2993 and 2849 kg/ha (Table 3-11). There was no significant crop injury resulting from herbicide applications to cotton (data not shown).

STUDY 2

Estimates for control and density of Palmer amaranth for Study 2 resulted in some significant differences between treatments (Table 3-12). At 4 WAA, all treatments that included fomesafen demonstrated at least 91% control of Palmer amaranth (Table 3-13a). At 3 WAB, the treatment without a POST herbicide showed poor control (43%) of Palmer amaranth. At 2 WAC, all treatments that received a POST herbicide showed greater than 94% control of Palmer amaranth. Estimates of the weed population trended with the visual control ratings in all treatments, except for the untreated having 1 plant m^2 or less (Table 3-13b).

The population counts and visual percent control for pitted morningglory had a lot of variability between treatments (Table 3-14). Treatments prior to 4 WAA were sprayed with fomesafen, and significant differences in control of pitted morningglory (from 83 to 100%) were observed between treatments (Table 3-15a). At 3 WAB, treatments that included 2,4-D at POST 1 provided 94 to 99% control of pitted morningglory; however, in treatments without 2,4-D, control declined to 85 to 89%. In a similar study, Merchant et al., 2013 found that the control of pitted morningglory increased when auxinic herbicide was mixed with glufosinate rather than sprayed alone (Merchant et al., 2013). At 2 WAC, control of pitted morningglory was greater than 90% with all treatments containing 2,4-D choline and glyphosate combinations (Table 3-15b). The combination of 2,4-D plus glyphosate with glufosinate added at POST 2 had 91% control, and the same treatment at POST 1, when combined with pyrithiobac sodium instead of glufosinate, had 97% control. Glyphosate applied alone provided the lowest control (89%) of pitted morningglory. Estimates of pitted morningglory density trended with visual ratings of percent control.

Significant differences were observed between treatments for large crabgrass control ratings and population counts; however all treatments provided excellent control (> 90%) (Table 3-16). All treatments except for the untreated were treated with fomesafen at plant (PRE) and provided controls ranging from 68 to 100% (Table 3-17a). At 3 WAB, most treatments provided good control of large crabgrass, except for the PRE with no POST 1 treatment. At 2 WAC, all treatments that were sprayed at POST 1 and POST 2 provided excellent control of large crabgrass (Table 3-17b). All counts for the treated treatments had less than 1 plant m^2, and the untreated plots averaged 6 or 9 plants m^2.

There was not any significant difference in cotton yield across all treatments (Table 3-18). Cotton yield ranged from 1234 to 2057 kg/ha for treatments that included POST applications (Table 3-19).

STUDY 3

Control ratings and population estimates for Palmer amaranth in Study 3 showed significant differences; however there was excellent control across all treatments (Table 3-20). All fomesafen PRE treatments provided greater than 97% control of Palmer amaranth (Table 3-21a). All treatments provided 97 to 100% Palmer amaranth control at 4 WAB and 4 WAC (Table 3-21b). Estimates of Palmer amaranth density trended with percent control data, with 15 plants m^2 for the untreated control and all other treatments at 0 plants m^2. These results are not similar to those observed by Merchant et al. (2013) who reported that Palmer amaranth was not controlled by any of the auxin herbicides or glufosinate.

Significant differences among the treatments were observed with the Pitted morningglory percent control ratings and population counts; and the PRE of fomesafen was applied across all treatments (3-22). Treatment results for 3 WAA were similar (72 to 83%) (Table 3-23a), providing evidence that fomesafen PRE does not control pitted morningglory. At 4 WAB, control improved to 82 to 95%. Metolachlor followed by glufosinate provided excellent control of pitted morningglory (95%). Glufosinate plus 2,4-D choline resulted in lower control (82%). Other studies have reported that auxin herbicides mixed with glufosinate provided excellent control of morningglory species (Merchant et al., 2013). At 4 WAC, metolachlor plus glufosinate applied POST 1 provided 95% control of pitted morningglory followed by 2,4-D choline plus glyphosate applied at POST 2 that provided 92% control (Table 3-23b). Glufosinate applied at POST 1 provided 88% control of pitted morningglory. Subsequently, control of pitted morningglory increased to 95% after 2,4-D choline plus glyphosate was applied at POST 2. Estimates of pitted morningglory density did not correspond to the visual control ratings because all control ratings were less than complete control, and counts had 0 plants m^2.

Treatment differences were observed for large crabgrass control and population counts, especially after the POST 1 applications (Table 3-24). There were no significant differences, with the exception of the untreated, in treatments at 3 WAA **(**Table 3-25a). At 4 WAB, 2,4-D choline plus glyphosate or glufosinate did not control large crabgrass as well as acetochlor and metolachlor because all treatments containing acetochlor and metolachlor controlled crabgrass greater than 98%. Similar to Craigmyle et al. (2013), who observed a decrease in large crabgrass control when glufosinate was mixed with 2,4-D compared to glufosinate alone. At 4 WAC, control of large crabgrass was excellent (95%) across all treatments (Table 3-25b). Estimates of weed density trended with visual control data with counts of less than 1 plant m^2 counts across all treatments and 16 plants m^2 in the untreated control.

There were significant differences in cotton yield for Study 3 (Table 3-26). However, the cotton yields were low across the study due to excessive rainfall amounts in 2013, which hindered our planting date (Figure 3-1). Cotton yields ranged from 0 to 647 kg/ha.

CONCLUSION

In each study, all treatments provided excellent (94– 100 %) control of Palmer amaranth, with the exception of an herbicide program with no pre-emergence material and glyphosate applied alone twice post-emergence providing unacceptable (88%) control. In the studies from 2011 and 2012 treatments that consisted of 2,4-D choline at POST 1 had excellent control of pitted morningglory. In 2013, the results could have been lower due to excessive rainfall and cooler, cloudy days between rainfall events. After POST 2 all treatment combinations of 2,4-D choline, glyphosate, and glufosinate provided excellent control of large crabgrass including treatments that did not receive a PRE. In 2011 and 2012, all treatments that included a POST application resulted in excellent seed cotton yield. This experiment provided a well representation of this new transgenic cotton with tolerance to dicamba, glyphosate, and having great control of a broad spectrum of troublesome weeds. These new transgenic cotton technologies will provide producers with the opportunities to use herbicides with multiple modes of actions to control existing herbicide-resistant weeds and forestall the development of new resistant biotypes of weeds.

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Table 3-1. Herbicide treatments and rates applied to cotton from Study 1 in 2011 near Blackville, SC

TRT. NO.[a]	PRE	RATE[b]	POST1	RATE[b]	POST2	RATE[b]
1	No PRE		Glyphosate	0.75	Glyphosate	0.75
2	No PRE		Glufosinate	0.59	Glufosinate	0.59
3	No PRE		2,4-D choline + Glyphosate	0.80	2,4-D choline + Glyphosate	0.80
4	No PRE		2,4-D choline Glufosinate	1.40 0.59	2,4-D choline Glufosinate	1.40 0.59
5	No PRE		2,4-D choline + Glyphosate	0.80	2,4-D choline Glufosinate	1.40 0.59
6	No PRE		2,4-D choline Glufosinate	1.40 0.59	2,4-D choline + Glyphosate	0.80
7	No PRE		2,4-D choline + Glyphosate Glufosinate	0.80 0.59	2,4-D choline + Glyphosate Glufosinate	0.80 0.59
8	No PRE		2,4-D choline + Glyphosate Metolachlor	0.80 0.15	2,4-D choline + Glyphosate	0.80
9	No PRE		2,4-D choline + Glyphosate Pyrithiobac sodium	0.80 0.07	2,4-D choline + Glyphosate	0.80
10	Fluometuron Pendimethalin	1.12 0.53	2,4-D choline + Glyphosate	0.80	2,4-D choline + Glyphosate	0.80
11	Fluometuron Pendimethalin	1.12 0.53	2,4-D choline + Glyphosate	0.80	2,4-D choline + Glyphosate	0.80
12	Fomesafen Pendimethalin	0.28 0.53	2,4-D choline + Glyphosate	0.80	2,4-D choline + Glyphosate	0.80
13	Fomesafen Pendimethalin	0.28 0.53	2,4-D choline + Glyphosate	0.80	2,4-D choline + Glyphosate	0.80
14	Fluometuron Pendimethalin	1.12 0.53	2,4-D choline Glufosinate	1.40 0.59	2,4-D choline Glufosinate	1.40 0.59
15	Fomesafen Pendimethalin	0.28 0.53	2,4-D choline Glufosinate	1.40 0.59	2,4-D choline Glufosinate	1.40 0.59
16	Untreated					

[a] All treatments except #16 were sprayed with a Layby Post (D) of Diuron at 1.12 kg ai/ha and MSMA at 2.24 kg ai/ha.
[b] Rate = kg ai/ha or kg ae/ha.

Table 3-2. Treatments and rates applied to cotton from Study 2 in 2012 near Blackville, SC

TRT. No.[a]	POST1	Rate[b]	POST2	Rate[b]
		kg/ha		kg/ha
1	Untreated Control			
2	2,4-D choline + Glyphosate	0.49	2,4-D choline + Glyphosate	0.49
3	2,4-D choline + Glyphosate	0.65	2,4-D choline + Glyphosate	0.65
4	2,4-D choline + Glyphosate Glufosinate	0.65 0.59	2,4-D choline + Glyphosate	0.65
5	2,4-D choline + Glyphosate Glufosinate	0.65 0.59	Glufosinate	0.59
6	2,4-D choline + Glyphosate Glufosinate	0.65 0.59	2,4-D choline + Glyphosate Glufosinate	0.65 0.59
7	2,4-D choline + Glyphosate Metolachlor	0.65 1.06	2,4-D choline + Glyphosate Glufosinate	0.65 0.59
8	2,4-D choline + Glyphosate Acetochlor	0.65 1.26	2,4-D choline + Glyphosate Glufosinate	0.65 0.59
9	2,4-D choline + Glyphosate Pyrithiobac sodium	0.65 0.04	2,4-D choline + Glyphosate Glufosinate	0.65 0.59
10	2,4-D choline + Glyphosate Acetochlor	0.65 1.26	2,4-D choline + Glyphosate	0.65
11	2,4-D choline Acetochlor	1.34 1.26	2,4-D choline	1.34
12	Glyphosate	0.75	Glyphosate	0.75
13	Glufosinate	0.59	Glufosinate	0.59
14	Glufosinate Acetochlor	0.59 1.26	Glyphosate	0.75
15	Glufosinate Acetochlor	0.59 1.26	Glufosinate	0.59
16	Check			

[a] Treatments 2 through16 all received a PRE (A) application of fomesafen at 0.28 Kg ai/ha after planting.
[b] Herbicide rate = kg ai/ha or kg ae/ha.

Table 3-3. Treatments and rates applied to cotton from Study 3 in 2013 near Blackville, SC

Timing and Combinations (kg ai/ha or kg ae/ha)				
TRT. No. [a]	B[b]	Rates	C	Rates
		kg/ha		kg/ha
1	Untreated Control			
2	2,4-D choline + Glyphosate	1.21	2,4-D choline + Glyphosate	1.21
3	2,4-D choline + Glyphosate	1.61	2,4-D choline + Glyphosate	1.61
4	2,4-D choline + Glyphosate Glufosinate	1.61 0.59	2,4-D choline + Glyphosate	1.61
5	Glufosinate	0.59	2,4-D choline + Glyphosate	1.61
6	2,4-D choline + Glyphosate	1.61	Glufosinate	0.59
7	2,4-D choline + Glyphosate Glufosinate	1.61 0.59	Glufosinate	0.59
8	2,4-D choline + Glyphosate	1.61	2,4-D choline + Glyphosate Glufosinate	1.61 0.59
9	2,4-D choline + Glyphosate	1.61	2,4-D choline + Glyphosate Glufosinate	1.61 0.59
10	Metolachlor Glufosinate	1.06 0.59	2,4-D choline + Glyphosate	1.61
11	Acetochlor Glufosinate	1.26 0.59	2,4-D choline + Glyphosate	1.61
12	2,4-D choline + Glyphosate Acetochlor	1.61 1.26	2,4-D choline + Glyphosate	1.61
13	2,4-D choline Glufosinate	1.61 0.59	2,4-D choline Glufosinate	1.61 0.59
14	Glyphosate	0.75	Glyphosate	0.75
15	Glufosinate	0.59	Glufosinate	0.59
16	Acetochlor Glufosinate	1.26 0.59	Glyphosate	0.75

[a]Treatments 2 – 16 all received a PRE (A) application of Fomesafen at 0.28 Kg ai/ha.
[b]Timing B is POST 1 and Timing C is POST 2.

Table 3-4. Analysis of Variance for Palmer amaranth 2 weeks after application A, 3 weeks after application B, and 4 weeks after application C in Study 1.

	Palmer amaranth 2 WAA					Palmer amaranth 3 WAB				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	23	0				63	32694.58727			
Rep.	3	0	0	0	1	3	342.985589	114.32853	2.065	0.1182
Treatment	5	0	0	0	1	15	29860.5402	1990.70268	35.961	0.0001
Error	15	0	0			45	2491.061475	55.356922		

	Palmer amaranth 4 WAC				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	63	37649.60938			
Rep.	3	32.421875	10.807292	1	0.4016
Treatment	15	37130.85938	2475.390625	229.048	0.0001
Error	45	486.328125	10.807292		

- DF = degrees of freedom

Table 3-5a. Mean percent control of Palmer amaranth after application of selected postemergence herbicides in cotton near Blackville, SC during 2011 (Study 1) [a]

	PRE (A)[e]			POST 1 (B)		
TRT. #	Treatment	Rates (kg ai/ha)	2 WAA[b]	Treatment	Rates (kg ai/ha) or (kg ae/ha)[d]	3 WAB[b]
			% Control			% Control
1	No PRE		0 b	Glyphosate	0.75	84 c
2	No PRE		0 b	Glufosiante	0.59	87 c
3	No PRE		0 b	2,4-D choline + glyphosate	0.8	93 bc
4	No PRE		0 b	2,4-D choline + glufosinate	1.4 + 0.59	100 a
5	No PRE		0 b	2,4-D choline + glyphosate	0.8	98 ab
6	No PRE		0 b	2,4-D choline + glufosinate	1.4 + 0.59	99 ab
7	No PRE		0 b	(2,4-D choline + glyphosate) + glufosinate	0.8 + 0.59	100 a
8	No PRE		0 b	(2,4-D choline + glyphosate) + metolachlor	0.8 + 0.15	100 a
9	No PRE		0 b	(2,4-D choline + glyphosate) + pyrithiobac sodium	0.80 + 0.07	100 a
10	Fluometuron + Pendimethalin	1.12 + 0.53	100 a	2,4-D choline + glyphosate	0.8	100 a
11	Fluometuron + Pendimethalin	1.12 + 0.53	100 a	2,4-D choline + glyphosate	0.8	100 a
12	Fomesafen + Pendimethalin	0.28 + 0.53	100 a	2,4-D choline + glyphosate	0.8	100 a
13	Fomesafen + Pendimethalin	0.28 + 0.53	100 a	2,4-D choline + glyphosate	0.8	100 a
14	Fluometuron + Pendimethalin	1.12 + 0.53	100 a	2,4-D choline + glufosinate	1.4 + 0.59	100 a
15	Fomesafen + Pendimethalin	0.28 + 0.53	100 a	2,4-D choline + glufosinate	1.4 + 0.59	100 a
16	Untreated Check		0 b	Untreated Check		0 d

[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at a $p \leq 0.05$.
[b] WAA = weeks after application timing a. WAB = weeks after application timing b.
[d] Active ingredients correspond to Glufosinate, metolachlor, pyrithiobac sodium. Active equivalent corresponds to Glyphosate and 2,4-D choline.
[e] PRE was sprayed at planting. POST 1 was sprayed when Palmer amaranth was at 5 to 10 cm heights.

Table 3-5b. Mean percent control and population counts of Palmer amaranth after application of selected postemergence herbicides in cotton near Blackville, SC during 2011 (Study 1) [a]

TRT. #	POST 2 [C] Treatment	Rates (kg ai/ha) or (kg ae/ha)[c]	4 WAC[b]
			% Control
1	Glyphosate	0.75	88 c
2	Glufosinate	0.59	94 b
3	2,4-D choline + glyphosate	0.8	98 ab
4	2,4-D choline + glufosinate	1.4 + 0.59	100 a
5	2,4-D choline + glufosinate	1.4 + 0.59	100 a
6	2,4-D choline + glyphosate	0.8	100 a
7	(2,4-D choline + glyphosate) + glufosinate	0.8 + 0.59	100 a
8	2,4-D choline + glyphosate	0.8	100 a
9	2,4-D choline + glyphosate	0.8	100 a
10	2,4-D choline + glyphosate	0.8	100 a
11	2,4-D choline + glyphosate	0.8	100 a
12	2,4-D choline + glyphosate	0.8	100 a
13	2,4-D choline + glyphosate	0.8	100 a
14	2,4-D choline + glufosinate	1.4 + 0.59	100 a
15	2,4-D choline + glufosinate	1.4 + 0.59	100 a
16	Untreated Check		0 d

[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at a p≤0.05.
[b] WAC = weeks after application timing C.
[c] Active ingredients correspond to Glufosinate,. Active equivalent corresponds to Glyphosate and 2,4-D choline.

Table 3-6. Analysis of Variance for pitted morningglory 2 weeks after application A, 3 weeks after application B, and 4 weeks after application C in Study 1.

	pitted morningglory 2 WAA					pitted morningglory 3 WAB				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	19	0				63	36274.60938			
Rep.	3	0	0	0	1	3	141.796875	47.265625	3.943	0.014
Treatment	4	0	0	0	1	15	35593.35938	2372.890625	197.941	0.0001
Error	12	0	0			45	539.453125	11.987847		

	pitted morningglory 4 WAC				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	63	37462.10938			
Rep.	3	1.171875	0.390625	1	0.4016
Treatment	15	37443.35938	2496.223958	6390.334	0.0001
Error	45	17.578125	0.390625		

- DF = degrees of freedom

Table 3-7a. Mean percent control of pitted morningglory after application of selected postemergence herbicides in cotton near Blackville, SC during 2011 (Study 1) [a]

TRT. #	PRE (A)[e] Treatment	Rates (kg ai/ha)	2 WAA[b]	POST 1 (B) Treatment	Rates (kg ai/ha) or (kg ae/ha)[d]	3 WAB[c]
			% Control			% Control
1	No PRE		0 b	Glyphosate	0.75	84 d
2	No PRE		0 b	Glufosiante	0.59	90 c
3	No PRE		0 b	2,4-D choline + glyphosate	0.8	96 ab
4	No PRE		0 b	2,4-D choline + glufosinate	1.4 + 0.59	100 a
5	No PRE		0 b	2,4-D choline + glyphosate	0.8	96 ab
6	No PRE		0 b	2,4-D choline + glufosinate	1.4 + 0.59	98 ab
7	No PRE		0 b	(2,4-D choline + glyphosate) + glufosinate	0.8 + 0.59	98 ab
8	No PRE		0 b	(2,4-D choline + glyphosate) + metolachlor	0.8 + 0.15	96 ab
9	No PRE		0 b	(2,4-D choline + glyphosate) + pyrithiobac sodium	0.80 + 0.07	100 a
10	Fluometuron + Pendimethalin	1.12 + 0.53	95 a	2,4-D choline + glyphosate	0.8	95 b
11	Fluometuron + Pendimethalin	1.12 + 0.53	95 a	2,4-D choline + glyphosate	0.8	98 ab
12	Fomesafen + Pendimethalin	0.28 + 0.53	95 a	2,4-D choline + glyphosate	0.8	98 ab
13	Fomesafen + Pendimethalin	0.28 + 0.53	96 a	2,4-D choline + glyphosate	0.8	96 ab
14	Fluometuron + Pendimethalin	1.12 + 0.53	95 a	2,4-D choline + glufosinate	1.4 + 0.59	99 ab
15	Fomesafen + Pendimethalin	0.28 + 0.53	95 a	2,4-D choline + glufosinate	1.4 + 0.59	99 ab
16	Untreated Check		0 b	Untreated Check		0 e

[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at a p≤0.05.
[b] WAA = weeks after application timing a.
[c] WAB = weeks after application timing b
[d] Active ingredients correspond to Glufosinate, metolachlor, pyrithiobac sodium. Active equivalent corresponds to Glyphosate and 2,4-D choline.
[e] PRE was sprayed at planting. POST 1 was sprayed when pitted morningglory was at 5 to 10 cm heights.

Table 3-7b. Mean percent control of pitted morningglory after application of selected postemergence herbicides in cotton near Blackville, SC during 2011 (Study 1) [a]

TRT. #	POST 2 [C][d] Treatment	Rates (kg ai/ha) or (kg ae/ha)[c]	4 WAC[b]
			% Control
1	Glyphosate	0.75	100 a
2	Glufosinate	0.59	100 a
3	2,4-D choline + glyphosate	0.8	100 a
4	2,4-D choline + glufosinate	1.4 + 0.59	100 a
5	2,4-D choline + glufosinate	1.4 + 0.59	100 a
6	2,4-D choline + glyphosate	0.8	100 a
7	(2,4-D choline + glyphosate) + glufosinate	0.8 + 0.59	100 a
8	2,4-D choline + glyphosate	0.8	100 a
9	2,4-D choline + glyphosate	0.8	100 a
10	2,4-D choline + glyphosate	0.8	100 a
11	2,4-D choline + glyphosate	0.8	100 a
12	2,4-D choline + glyphosate	0.8	100 a
13	2,4-D choline + glyphosate	0.8	99 b
14	2,4-D choline + glufosinate	1.4 + 0.59	100 a
15	2,4-D choline + glufosinate	1.4 + 0.59	100 a
16	Untreated Check		0 c

[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at a $p \leq 0.05$.
[b] WAC = weeks after application timing C.
[c] Active ingredients correspond to Glufosinate. Active equivalent corresponds to Glyphosate and 2,4-D choline.
[d] POST 2 was sprayed when pitted morningglory were at 7 to 12 cm heights.

Table 3-8. Analysis of Variance for large crabgrass 2 weeks after application A, 3 weeks after application B, and 4 weeks after application C in Study 1.

	large crabgrass 2 WAA					large crabgrass 3WAB				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	23	0				63	35582.08704			
Rep.	3	0	0	0	1	3	508.532636	169.510879	1.773	0.1658
Treatment	5	0	0	0	1	15	30771.74612	2051.449741	21.46	0.0001
Error	15	0	0			45	4301.80828	95.59574		

	large crabgrass 4WAC				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	63	32659.4023			
Rep.	3	282.652831	94.21761	1.616	0.199
Treatment	15	29752.46106	1983.497404	34.012	0.0001
Error	45	2624.288412	58.31752		

- DF = degrees of freedom

Table 3-9a. Mean percent control of large crabgrass after application of selected herbicides in cotton near Blackville, SC during 2011 (Study 1) [a]

	PRE (A)[d]			POST 1 (B)		
TRT. #	Treatment	Rates (kg ai/ha)	2 WAA[b]	Treatment	Rates (kg ai/ha) or (kg ae/ha)[c]	3 WAB[b]
			% Control			% Control
1	No PRE		0 b	Glyphosate	0.75	99 a
2	No PRE		0 b	Glufosiante	0.59	84 bc
3	No PRE		0 b	2,4-D choline + glyphosate	0.8	99 a
4	No PRE		0 b	2,4-D choline + glufosinate	1.4 + 0.59	81 c
5	No PRE		0 b	2,4-D choline + glyphosate	0.8	96 ab
6	No PRE		0 b	2,4-D choline + glufosinate	1.4 + 0.59	95 abc
7	No PRE		0 b	(2,4-D choline + glyphosate) + glufosinate	0.8 + 0.59	100 a
8	No PRE		0 b	(2,4-D choline + glyphosate) + metolachlor	0.8 + 0.15	100 a
9	No PRE		0 b	(2,4-D choline + glyphosate) + pyrithiobac sodium	0.80 + 0.07	100 a
10	Fluometuron + Pendimethalin	1.12 + 0.53	100 a	2,4-D choline + glyphosate	0.8	100 a
11	Fluometuron + Pendimethalin	1.12 + 0.53	100 a	2,4-D choline + glyphosate	0.8	100 a
12	Fomesafen + Pendimethalin	0.28 + 0.53	100 a	2,4-D choline + glyphosate	0.8	100 a
13	Fomesafen + Pendimethalin	0.28 + 0.53	100 a	2,4-D choline + glyphosate	0.8	100 a
14	Fluometuron + Pendimethalin	1.12 + 0.53	100 a	2,4-D choline + glufosinate	1.4 + 0.59	100 a
15	Fomesafen + Pendimethalin	0.28 + 0.53	100 a	2,4-D choline + glufosinate	1.4 + 0.59	100 a
16	Untreated Check		0 b	Untreated Check		0 d

[a]Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at a $p \leq 0.05$.
[b]WAA = weeks after application timing A. WAB = weeks after application timing B
[c] Active ingredients correspond to Glufosinate, metolachlor, pyrithiobac sodium. Active equivalent corresponds to Glyphosate and 2,4-D choline.
[d] PRE was sprayed at planting. POST 1 was sprayed when large crabgrass was at 5 to 10 cm heights.

Table 3-9b. Mean percent control of large crabgrass after application of selected postemergence herbicides in cotton near Blackville, SC during 2011 (Study 1) [a]

TRT. #	POST 2 [C][d] Treatment	Rates (kg ai/ha) or (kg ae/ha)[c]	4 WAC[b]
			% Control
1	Glyphosate	0.75	99 ab
2	Glufosinate	0.59	93 c
3	2,4-D choline + glyphosate	0.8	100 a
4	2,4-D choline + glufosinate	1.4 + 0.59	96 bc
5	2,4-D choline + glufosinate	1.4 + 0.59	99 abc
6	2,4-D choline + glyphosate	0.8	100 a
7	(2,4-D choline + glyphosate) + glufosinate	0.8 + 0.59	100 a
8	2,4-D choline + glyphosate	0.8	100 a
9	2,4-D choline + glyphosate	0.8	100 ab
10	2,4-D choline + glyphosate	0.8	100 ab
11	2,4-D choline + glyphosate	0.8	100 a
12	2,4-D choline + glyphosate	0.8	100 a
13	2,4-D choline + glyphosate	0.8	100 a
14	2,4-D choline + glufosinate	1.4 + 0.59	100 a
15	2,4-D choline + glufosinate	1.4 + 0.59	100 a
16	Untreated Check		0 d

[a]Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at a p≤0.05.
[b]WAC = weeks after application timing C.
[c] Active ingredients correspond to Glufosinate. Active equivalent corresponds to Glyphosate and 2,4-D choline.
[d] POST 2 was sprayed when large crabgrass was at 7 to 12 cm heights.

Table 3-10. Analysis of Variance for cotton yield in Study 1.

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Total	63	28503051.32			
Rep.	3	220735.2391	73578.41303	0.326	0.8063
Treatment	15	18137761.54	1209184.103	5.364	0.0001
Error	45	10144554.54	225434.5454		

- DF = degrees of freedom

Table 3-11. Mean cotton yield after application of selected postemergence herbicides in cotton near Blackville, SC during 2011 (Study 1) [a]

TRT. NO.	Cotton Yield	
	Kg/ha	
1	2533	ab
2	2697	ab
3	2387	ab
4	2993	a
5	2531	ab
6	2849	ab
7	2467	ab
8	2420	ab
9	2359	ab
10	2564	ab
11	2495	ab
12	2774	ab
13	2171	b
14	2774	ab
15	2915	ab
16	299	c

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

Table 3-12. Analysis of Variance for Palmer amaranth counts, 4 weeks after application A, 3 weeks after application B, and 2 weeks after application C in Study 2.

	Palmer amaranth 4 WAA					Palmer amaranth 3 WAB				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	47	28086.97917				47	27931.25			
Rep.	2	1.041667	0.520833	1	0.3798	2	12.5	6.25	1.8	0.1827
Treatment	15	28070.3125	1871.354167	3593	0.0001	15	27814.58333	1854.305556	534.04	0.0001
Error	30	15.625	0.520833			30	104.166667	3.472222		

	Palmer amaranth 2 WAC					Palmer amaranth Count				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	47	28125				47	604.8125			
Rep.	2	0	0	0	1	2	0	0	0	1
Treatment	15	28125	1875	0	1	15	603.479167	40.231944	905.219	0.0001
Error	30	0	0			30	1.333333	0.044444		

- DF = degrees of freedom

Table 3-13a. Mean percent control of Palmer amaranth after application of selected herbicides in cotton near Blackville, SC during 2012 (Study 2) [a]

TRT. #	PRE (A)[e] Treatment	Rates (kg ai/ha)	4 WAA[b]	POST 1 (B)[e] Treatment	Rates (kg ai/ha) or (kg ae/ha)[d]	3 WAB[c]
			% Control			% Control
1	Untreated		0 e	Untreated		0 d
2	Fomesafen	0.28	100 a	2,4-D choline + Glyphosate	0.49	100 a
3	Fomesafen	0.28	100 a	2,4-D choline + Glyphosate	0.65	100 a
4	Fomesafen	0.28	99 ab	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	98 ab
5	Fomesafen	0.28	98 b	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	99 ab
6	Fomesafen	0.28	98 b	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	100 a
7	Fomesafen	0.28	99 ab	(2,4-D choline + Glyphosate) + Metolachlor	0.65 + 1.06	100 a
8	Fomesafen	0.28	100 a	(2,4-D choline + Glyphosate) + Acetochlor	0.65 + 1.06	100 a
9	Fomesafen	0.28	100 a	(2,4-D choline + Glyphosate) + Pyrithiobac sodium	0.65 + 0.04	100 a
10	Fomesafen	0.28	100 a	(2,4-D choline + Glyphosate) + Acetochlor	0.65 + 1.26	100 a
11	Fomesafen	0.28	100 a	2,4-D choline + Acetochlor	1.34 + 1.26	100 a
12	Fomesafen	0.28	91 d	Glyphosate	0.75	95 b
13	Fomesafen	0.28	95 c	Glufosinate	0.59	96 ab
14	Fomesafen	0.28	100 a	Glufosinate + Acetochlor	0.59 + 1.26	100 a
15	Fomesafen	0.28	100 a	Glufosinate + Acetochlor	0.59 + 1.26	100 a
16	Fomesafen	0.28	93 d	Check		43 c

[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at a p≤0.05.
[b] WAA = weeks after application timing a.
[c] WAB = weeks after application timing b
[d] Active ingredients correspond to Glufosinate, Metolachlor, Pyrithiobac sodium, and Acetochlor. Active equivalent corresponds to 2,4-D choline and Glyphosate.
[e] PRE was sprayed at planting and POST 1 was sprayed when Palmer amaranth was at 5 to 10 cm heights.

Table 3-13b. Mean percent control and population counts of Palmer amaranth after application of selected postemergence herbicides in cotton near Blackville, SC during 2012 (Study 2) [a]

TRT. #	POST 2 (C)[d] Treatment	Rates (kg ai/ha) or (kg ae/ha)[c]	2 WAC[b]	Counts 2 WAC
			% Control	Plants m^2
1	Untreated		0 c	5.0 a
2	2,4-D choline + Glyphosate	0.49	100 a	0 c
3	2,4-D choline + Glyphosate	0.65	100 a	0 c
4	2,4-D choline + Glyphosate	0.65	100 a	0 c
5	Glufosinate	0.59	100 a	0 c
6	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	100 a	0 c
7	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	100 a	0 c
8	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	100 a	0 c
9	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	100 a	0 c
10	2,4-D choline + Glyphosate	0.65	100 a	0 c
11	2,4-D choline	1.34	100 a	0 c
12	Glyphosate	0.75	94 b	1 b
13	Glufosinate	0.59	100 a	0 c
14	Glyphosate	0.75	100 a	0 c
15	Glufosinate	0.59	99 a	0 c
16	Check		0 c	0 c

[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at a $p \leq 0.05$.
[b] WAC = weeks after application timing C.
[c] Active ingredient corresponds to Glufosinate. Active equivalent corresponds to 2,4-D choline and Glyphosate.
[d] POST 2 was sprayed when Palmer amaranth was at 7 to 12 cm heights.

Table 3-14. Analysis of Variance for pitted morningglory counts, 4 weeks after application A, 3 weeks after application B, 2 weeks after application C in Study 2.

	pitted morningglory 4 WAA					pitted morningglory 3 WAB				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	44	2077.777778				47	23897.91667			
Rep.	2	101.111111	50.555556	1.049	0.3635	2	501.041667	250.520833	8.518	0.0012
Treatment	14	627.777778	44.84127	0.931	0.54	15	22514.58333	1500.972222	51.037	0.0001
Error	28	1348.888889	48.174603			30	882.291667	29.409722		

	pitted morningglory 2 WAC					pitted morningglory Count 2 WAC				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	47	24099.47917				47	362.666667			
Rep.	2	19.791667	9.895833	0.252	0.7792	2	0.041667	0.020833	0.079	0.9247
Treatment	15	22899.47917	1526.631944	38.806	0.0001	15	354.666667	23.644444	89.131	0.0001

- DF = degrees of freedom

Table 3-15a. Mean percent control of pitted morningglory after application of selected herbicides in cotton near Blackville, SC during 2012 (Study 2) [a]

	PRE (A)[e]			POST 1 (B)[e]		
TRT. #	Treatment	Rates (kg ai/ha)	4 WAA[b]	Treatment	Rates (kg ai/ha) or (kg ae/ha)[d]	3 WAB[c]
			% Control			% Control
1	Untreated		0 h	Untreated		0 f
2	Fomesafen	0.28	96 bc	2,4-D choline + Glyphosate	0.49	95 abc
3	Fomesafen	0.28	95 c	2,4-D choline + Glyphosate	0.65	94 a-d
4	Fomesafen	0.28	96 bc	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	96 ab
5	Fomesafen	0.28	95 c	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	97 a
6	Fomesafen	0.28	96 bc	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	95 abc
7	Fomesafen	0.28	95 c	(2,4-D choline + Glyphosate) + Metolachlor	0.65 + 1.06	97 a
8	Fomesafen	0.28	100 a	(2,4-D choline + Glyphosate) + Acetochlor	0.65 + 1.06	99 a
9	Fomesafen	0.28	99 ab	(2,4-D choline + Glyphosate) + Pyrithiobac sodium	0.65 + 0.04	97 a
10	Fomesafen	0.28	95 c	(2,4-D choline + Glyphosate) + Acetochlor	0.65 + 1.26	94 a-d
11	Fomesafen	0.28	96 bc	2,4-D choline + Acetochlor	1.34 + 1.26	96 ab
12	Fomesafen	0.28	89 de	Glyphosate	0.75	89 bcd
13	Fomesafen	0.28	85 fg	Glufosinate	0.59	85 d
14	Fomesafen	0.28	83 g	Glufosinate + Acetochlor	0.59 + 1.26	87 cd
15	Fomesafen	0.28	86 ef	Glufosinate + Acetochlor	0.59 + 1.26	85 d
16	Fomesafen	0.28	91 d	Check		46 e

[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at a p≤0.05.
[b] WAA = weeks after application timing a.
[c] WAB = weeks after application timing b
[d] Active ingredients correspond to Glufosinate, Metolachlor, Pyrithiobac sodium, and Acetochlor. Active equivalent corresponds to 2,4-D choline and Glyphosate.
[e] PRE was sprayed at planting and POST 1 was sprayed when pitted morningglory was at 5 to 10 cm heights.

Table 3-15b. Mean percent control and population counts of pitted morningglory after application of selected postemergence herbicides in cotton near Blackville, SC during 2012 (Study 2) [a]

TRT. #	POST 2 (C)[d] Treatment	Rates (kg ai/ha) or (kg ae/ha)[c]	2 WAC[b]	Counts 2 WAC	
			% Control	Plants m2	
1	Untreated		0 d	11	a
2	2,4-D choline + Glyphosate	0.49	96 a	1	defg
3	2,4-D choline + Glyphosate	0.65	98 a	1	defg
4	2,4-D choline + Glyphosate	0.65	99 a	1	efg
5	Glufosinate	0.59	96 a	0	fg
6	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	95 ab	4	abcdef
7	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	95 ab	1	defg
8	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	99 a	0	g
9	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	91 bc	8	ab
10	2,4-D choline + Glyphosate	0.65	95 ab	7	abc
11	2,4-D choline	1.34	95 ab	5	abcde
12	Glyphosate	0.75	89 c	6	abcd
13	Glufosinate	0.59	96 a	2	cdefg
14	Glyphosate	0.75	95 ab	3	bcdefg
15	Glufosinate	0.59	98 a	2	bcdefg
16	Check		0 d	11	a

[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at a p≤0.05.
[b] WAC = weeks after application timing C.
[c] Active ingredient corresponds to Glufosinate. Active equivalent corresponds to 2,4-D choline and Glyphosate.
[d] POST 2 was sprayed when pitted morningglory was at 7 to 12 cm heights.

Table 3-16. Analysis of Variance for large crabgrass counts, 4 weeks after application A, 3 weeks after application B, and 2 weeks after application C in Study 2.

	large crabgrass 4 WAA					large crabgrass 3 WAB				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	47	28036.97917				44	4307.777778			
Rep.	2	2769.791667	1384.895833	12.796	0.0001	2	154.444444	77.222222	1.251	0.3018
Treatment	15	22020.3125	1468.020833	13.564	0.0001	14	2424.444444	173.174603	2.805	0.0098
Error	30	3246.875	108.229167			28	1728.888889	61.746032		

	arge crabgrass 2 WAC					large crabgrass Count 2 WAC				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	47	28074.47917				47	725.25			
Rep.	2	4.166667	2.083333	0.385	0.684	2	0.125	0.0625	0.135	0.8741
Treatment	15	27907.8125	1860.520833	343.481	0.0001	15	711.25	47.416667	102.523	0.0001

- DF = degrees of freedom

Table 3-17a. Mean percent control of large crabgrass after application of selected herbicides in cotton near Blackville, SC during 2012 (Study 2) [a]

TRT. #	PRE (A)[e] Treatment	PRE (A)[e] Rates (kg ai/ha)	4 WAA[b]	POST 1 (B)[e] Treatment	Rates (kg ai/ha) or (kg ae/ha)[d]	3 WAB[c]
			% Control			% Control
1	Untreated		0 e	Untreated		0 d
2	Fomesafen	0.28	98 ab	2,4-D choline + Glyphosate	0.49	96 ab
3	Fomesafen	0.28	98 ab	2,4-D choline + Glyphosate	0.65	96 ab
4	Fomesafen	0.28	96 bc	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	96 ab
5	Fomesafen	0.28	98 ab	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	98 ab
6	Fomesafen	0.28	98 ab	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	96 ab
7	Fomesafen	0.28	100 a	(2,4-D choline + Glyphosate) + Metolachlor	0.65 + 1.06	100 a
8	Fomesafen	0.28	100 a	(2,4-D choline + Glyphosate) + Acetochlor	0.65 + 1.06	100 a
9	Fomesafen	0.28	100 a	(2,4-D choline + Glyphosate) + Pyrithiobac sodium	0.65 + 0.04	100 a
10	Fomesafen	0.28	100 a	(2,4-D choline + Glyphosate) + Acetochlor	0.65 + 1.26	100 a
11	Fomesafen	0.28	100 a	2,4-D choline + Acetochlor	1.34 + 1.26	100 a
12	Fomesafen	0.28	98 ab	Glyphosate	0.75	98 ab
13	Fomesafen	0.28	94 c	Glufosinate	0.59	96 ab
14	Fomesafen	0.28	96 bc	Glufosinate + Acetochlor	0.59 + 1.26	95 b
15	Fomesafen	0.28	100 a	Glufosinate + Acetochlor	0.59 + 1.26	99 ab
16	Fomesafen	0.28	68 d	Check		20 c

[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at a $p \leq 0.05$.
[b] WAA = weeks after application timing a.
[c] WAB = weeks after application timing b
[d] Active ingredients correspond to Glufosinate, Metolachlor, Pyrithiobac sodium, and Acetochlor. Active equivalent corresponds to 2,4-D choline and Glyphosate.
[e] PRE was sprayed at planting and POST 1 was sprayed when large crabgrass was at 5 to 10 cm heights.

Table 3-17b. Mean percent control of large crabgrass after application of selected postemergence herbicides in cotton near Blackville, SC during 2012 (Study 2) [a]

TRT. #	POST 2 (C)[d] Treatment	Rates (kg ai/ha) or (kg ae/ha)[c]	2 WAC[b]	Counts 2 WAC
			% Control	Plants m[2]
1	Untreated		0 c	9.0 a
2	2,4-D choline + Glyphosate	0.49	100 a	0 c
3	2,4-D choline + Glyphosate	0.65	99 ab	0 c
4	2,4-D choline + Glyphosate	0.65	100 a	0 c
5	Glufosinate	0.59	100 a	0 c
6	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	100 a	0 c
7	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	100 a	0 c
8	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	100 a	0 c
9	(2,4-D choline + Glyphosate) + Glufosinate	0.65 + 0.59	100 a	0 c
10	2,4-D choline + Glyphosate	0.65	100 a	0 c
11	2,4-D choline	1.34	100 a	0 c
12	Glyphosate	0.75	100 a	0 c
13	Glufosinate	0.59	98 b	1 b
14	Glyphosate	0.75	100 a	0 c
15	Glufosinate	0.59	100 a	0 c
16	Check		0 c	6.0 a

[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at a p≤0.05.
[b] WAC = weeks after application timing C
[c] Active ingredient corresponds to Glufosinate. Active equivalent corresponds to 2,4-D choline and Glyphosate.
[d] POST 2 was sprayed when large crabgrass was at 7 to 12 cm heights.

Table 3-18. Analysis of Variance for cotton yield in Study 2.

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Total	47	76.97579			
Rep.	2	3.463856	1.731928	1.712	0.1976
Treatment	15	43.16883	2.877922	2.845	0.0072
Error	30	30.3431	1.011437		

- DF = degrees of freedom

Table 3-19. Mean cotton yield after application of selected postemergence herbicides in cotton near Blackville, SC during 2012 (Study 2) [a]

TRT. NO.	Cotton Yield	
	Kg/ha	
1	534	d
2	1679	ab
3	2057	ab
4	1660	ab
5	1983	ab
6	1759	ab
7	1676	ab
8	1568	ab
9	1234	bcd
10	1541	ab
11	1422	abc
12	1554	ab
13	1358	abc
14	1507	ab
15	1754	ab
16	708	cd

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

Table 3-20. Analysis of Variance for Palmer amaranth counts, 3 weeks after application A, 4 weeks after application B, and 4 weeks after application C in Study 3.

	Palmer amaranth 3 WAA					Palmer amaranth 4 WAB				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	63	36680.85938				63	46625			
Rep.	3	4.296875	1.432292	0.508	0.679	3	50	16.666667	1.935	0.1374
Treatment	15	36549.60938	2436.640625	863.695	0.0001	15	46187.5	3079.166667	357.581	0.0001
Error	45	126.953125	2.821181			45	387.5	8.611111		

	Palmer amaranth 4 WAC					Palmer amaranth Count 4 WAC				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	63	69585.9375				63	115.4375			
Rep.	3	7.8125	2.604167	0.652	0.5858	3	0.3125	0.104167	0.51	0.6773
Treatment	15	69398.4375	4626.5625	1158.652	0.0001	15	105.9375	7.0625	34.592	0.0001
Error	45	179.6875	3.993056			45	9.1875	0.204167		

- DF = degrees of freedom

Table 3-21a. Mean percent control of Palmer amaranth after application of selected postemergence herbicides in cotton near Blackville, SC during 2013 (Study 3) [a]

	PRE (A)[e]			POST 1 (B)[e]		
TRT. #	Treatment	Rates (kg ai/ha)	3 WAA[b]	Treatment	Rates (kg ai/ha) or (kg ae/ha)[d]	4 WAB[c]
			% Control			% Control
1	Fomesafen	0.28	0 c	Untreated Control		0.0 c
2	Fomesafen	0.28	100 a	2,4-D choline + Glyphosate	1.21	100 a
3	Fomesafen	0.28	100 a	2,4-D choline + Glyphosate	1.61	100 a
4	Fomesafen	0.28	100 a	(2,4-D choline + Glyphosate) + Glufosinate	1.61 + 0.59	100 a
5	Fomesafen	0.28	100 a	Glufosinate	0.59	98 ab
6	Fomesafen	0.28	100 a	2,4-D choline + Glyphosate	1.61	100 a
7	Fomesafen	0.28	98 b	(2,4-D choline + Glyphosate) + Glufosinate	1.61 + 0.59	97 b
8	Fomesafen	0.28	100 a	2,4-D choline + Glyphosate	1.61	100 a
9	Fomesafen	0.28	100 a	2,4-D choline + Glyphosate	1.61	100 a
10	Fomesafen	0.28	100 a	Metolachlor + Glufosinate	1.06 + 0.59	100 a
11	Fomesafen	0.28	100 a	Acetochlor + Glufosinate	1.26 + 0.59	100 a
12	Fomesafen	0.28	100 a	(2,4-D choline + Glyphosate) + Acetochlor	1.61 + 1.26	100 a
13	Fomesafen	0.28	100 a	2,4-D choline + Glufosinate	1.61 + 0.59	100 a
14	Fomesafen	0.28	100 a	Glyphosate	0.75	98 ab
15	Fomesafen	0.28	100 a	Glufosinate	0.59	97 b
16	Fomesafen	0.28	100 a	Acetochlor + Glufosinate	1.26 + 0.59	100 a

[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at a $p \leq 0.05$.
[b] WAA = weeks after application timing a.
[c] WAB = weeks after application timing b
[d] Active ingredient corresponds to Glufosinate, Metolachlor, and Acetochlor. Active equivalent corresponds to 2,4-D choline and Glyphosate.
[e] POST 1 was sprayed when Palmer amaranth was at the 5 to 10 cm heights.

Table 3-21b. Mean percent control of Palmer amaranth after application of selected postemergence herbicides in cotton near Blackville, SC during 2013 (Study 3) [a]

TRT. #	POST 2 (C)[d] Treatment	Rates (kg ai/ha) or (kg ae/ha)[c]	4 WAC[b]	Counts 4 WAC
			% Control	Plants m^{2}
1			0 b	15 a
2	2,4-D choline + Glyphosate	1.21	100 a	0 b
3	2,4-D choline + Glyphosate	1.61	100 a	0 b
4	2,4-D choline + Glyphosate	1.61	100 a	0 b
5	2,4-D choline + Glyphosate	1.61	100 a	0 b
6	Glufosinate	0.59	100 a	0 b
7	Glufosinate	0.59	100 a	0 b
8	(2,4-D choline + Glyphosate) + Glufosinate	1.61 + 0.59	100 a	0 b
9	(2,4-D choline + Glyphosate) + Glufosinate	1.61 + 0.60	100 a	0 b
10	2,4-D choline + Glyphosate	1.61	100 a	0 b
11	2,4-D choline + Glyphosate	1.61	100 a	0 b
12	2,4-D choline + Glyphosate	1.61	100 a	0 b
13	2,4-D choline + Glufosinate	1.61 + 0.59	100 a	0 b
14	Glyphosate	0.75	100 a	0 b
15	Glufosinate	0.59	100 a	0 b
16	Glyphosate	0.75	100 a	0 b

[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at a $p \leq 0.05$.
[b] WAC = weeks after application timing C.
[c] Active ingredient corresponds to Glufosinate. Active equivalent corresponds to 2,4-D choline and Glyphosate.
[d] POST 2 was sprayed when Palmer amaranth was at the 10 to 15 cm heights.

Table 3-22. Analysis of Variance for pitted morningglory counts, 3 weeks after application A, 4 weeks after application B, and 4 weeks after application C in Study 3.

	pitted morningglory 3 WAA					pitted morningglory 4 WAB				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	63	34298.4375				63	27534.96165			
Rep.	3	4.6875	1.5625	0.319	0.8115	3	19.493273	6.497758	0.176	0.9122
Treatment	15	34073.4375	2271.5625	463.979	0.0001	15	25852.35809	1723.490539	46.634	0.0001
Error	45	220.3125	4.895833			45	1663.110286	36.958006		

	pitted morningglory 4 WAC					pitted morningglory Count 4 WAC				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	63	64683.98438				63	3873.336255			
Rep.	3	91.796875	30.598958	3.133	0.0347	3	312.165866	104.055289	2.768	0.0525
Treatment	15	64152.73438	4276.848958	437.949	0.0001	15	1869.642206	124.642814	3.316	0.0009
Error	45	439.453125	9.765625			45	1691.528182	37.589515		

- DF = degrees of freedom

Table 3-23a. Mean percent control of pitted morningglory after application of selected postemergence herbicides in cotton near Blackville, SC during 2013 (Study 3) [a]

	PRE (A)[e]			POST 1 (B)[e]		
TRT. #	Treatment	Rates (kg ai/ha)	3 WAA[b]	Treatment	Rates (kg ai/ha) or (kg ae/ha)[d]	4 WAB[c]
			% Control			% Control
1	Fomesafen	0.28	0 c	Untreated Control		0 d
2	Fomesafen	0.28	78 ab	2,4-D choline + Glyphosate	1.21	88 abc
3	Fomesafen	0.28	72 b	2,4-D choline + Glyphosate	1.61	83 c
4	Fomesafen	0.28	78 ab	(2,4-D choline + Glyphosate) + Glufosinate	1.61 + 0.59	85 bc
5	Fomesafen	0.28	78 ab	Glufosinate	0.59	88 abc
6	Fomesafen	0.28	75 ab	2,4-D choline + Glyphosate	1.61	88 abc
7	Fomesafen	0.28	72 b	(2,4-D choline + Glyphosate) + Glufosinate	1.61 + 0.59	83 c
8	Fomesafen	0.28	75 ab	2,4-D choline + Glyphosate	1.61	87 bc
9	Fomesafen	0.28	83 a	2,4-D choline + Glyphosate	1.61	93 ab
10	Fomesafen	0.28	82 ab	Metolachlor + Glufosinate	1.06 + 0.59	95 a
11	Fomesafen	0.28	80 ab	Acetochlor + Glufosinate	1.26 + 0.59	93 ab
12	Fomesafen	0.28	83 a	(2,4-D choline + Glyphosate) + Acetochlor	1.61 + 1.26	90 abc
13	Fomesafen	0.28	77 ab	2,4-D choline + Glufosinate	1.61 + 0.59	82 c
14	Fomesafen	0.28	77 ab	Glyphosate	0.75	90 abc
15	Fomesafen	0.28	77 ab	Glufosinate	0.59	88 abc
16	Fomesafen	0.28	72 b	Acetochlor + Glufosinate	1.26 + 0.59	88 abc

[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at a $p \leq 0.05$.
[b] WAA = weeks after application timing a.
[c] WAB = weeks after application timing b
[d] Active ingredient corresponds to Glufosinate, Metolachlor, and Acetochlor. Active equivalent corresponds to 2,4-D choline and Glyphosate.
[e] PRE was sprayed at planting and POST 1 was sprayed when pitted morningglory was at the 5 to 10 cm heights

Table 3-23b. Mean percent control of pitted morningglory after application of selected postemergence herbicides in cotton near Blackville, SC during 2013 (Study 3) [a]

TRT. #	POST 2 (C) [d] Treatment	Rates (kg ai/ha) or (kg ae/ha) [c]	4 WAC [b]	Counts 4 WAC
			% Control	Plants m^2
1			0 d	11.0 a
2	2,4-D choline + Glyphosate	1.21	90 abc	0 b
3	2,4-D choline + Glyphosate	1.61	80 c	0 b
4	2,4-D choline + Glyphosate	1.61	87 abc	0 b
5	2,4-D choline + Glyphosate	1.61	95 a	0 b
6	Glufosinate	0.59	82 bc	0 b
7	Glufosinate	0.59	80 c	0 b
8	(2,4-D choline + Glyphosate) + Glufosinate	1.61 + 0.59	90 abc	0 b
9	(2,4-D choline + Glyphosate) + Glufosinate	1.61 + 0.60	93 a	0 b
10	2,4-D choline + Glyphosate	1.61	92 ab	0 b
11	2,4-D choline + Glyphosate	1.61	93 a	0 b
12	2,4-D choline + Glyphosate	1.61	88 abc	0 b
13	2,4-D choline + Glufosinate	1.61 + 0.59	82 bc	0 b
14	Glyphosate	0.75	90 abc	0 b
15	Glufosinate	0.59	88 abc	0 b
16	Glyphosate	0.75	92 ab	1 b

[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at a $p \leq 0.05$.
[b] WAC = weeks after application timing C.
[c] Active ingredient corresponds to Glufosinate. Active equivalent corresponds to 2,4-D choline and Glyphosate.
[d] POST 2 was sprayed when pitted morningglory was at the 10 to 15 cm heights.

Table 3-24. Analysis of Variance for large crabgrass counts, 3 weeks after application A, 4 weeks after application B, and 4 weeks after application C in Study 3.

	large crabgrass 3 WAA					large crabgrass 4 WAB				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	63	38524.60938				63	55425			
Rep.	3	13.671875	4.557292	1.065	0.3735	3	3.125	1.041667	0.115	0.9512
Treatment	15	38318.35938	2554.557292	596.927	0.0001	15	55012.5	3667.5	403.145	0.0001
Error	45	192.578125	4.279514			45	409.375	9.097222		

	large crabgrass 4 WAC					large crabgrass 4 WAC				
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	DF	Sum of Squares	Mean Square	F Value	Pr > F
Total	63	69696.48438				63	2006.467701			
Rep.	3	1.171875	0.390625	0.413	0.7446	3	24.581467	8.193822	1.871	0.148
Treatment	15	69652.73438	4643.515625	4907.643	0.0001	15	1784.834688	118.988979	27.173	0.0001
Error	45	42.578125	0.946181			45	197.051545	4.378923		

- DF = degrees of freedom

Table 3-25a. Mean percent control of large crabgrass after application of selected postemergence herbicides in cotton near Blackville, SC during 2013 (Study 3) [a]

TRT. #	PRE (A) [e] Treatment	Rates (kg ai/ha)	3 WAA [b]	POST 1 (B) [e] Treatment	Rates (kg ai/ha) or (kg ae/ha) [d]	4 WAB [c]
			% Control			% Control
1	Fomesafen	0.28	0 b	Untreated Control		0 e
2	Fomesafen	0.28	83 a	2,4-D choline + Glyphosate	1.21	83 cd
3	Fomesafen	0.28	80 a	2,4-D choline + Glyphosate	1.61	75 d
4	Fomesafen	0.28	82 a	(2,4-D choline + Glyphosate) + Glufosinate	1.61 + 0.59	85 cd
5	Fomesafen	0.28	92 a	Glufosinate	0.59	82 cd
6	Fomesafen	0.28	87 a	2,4-D choline + Glyphosate	1.61	87 bcd
7	Fomesafen	0.28	87 a	(2,4-D choline + Glyphosate) + Glufosinate	1.61 + 0.59	90 abc
8	Fomesafen	0.28	87 a	2,4-D choline + Glyphosate	1.61	83 cd
9	Fomesafen	0.28	85 a	2,4-D choline + Glyphosate	1.61	88 abc
10	Fomesafen	0.28	88 a	Metolachlor + Glufosinate	1.06 + 0.59	98 ab
11	Fomesafen	0.28	82 a	Acetochlor + Glufosinate	1.26 + 0.59	100 a
12	Fomesafen	0.28	90 a	(2,4-D choline + Glyphosate) + Acetochlor	1.61 + 1.26	98 ab
13	Fomesafen	0.28	83 a	2,4-D choline + Glufosinate	1.61 + 0.59	85 cd
14	Fomesafen	0.28	90 a	Glyphosate	0.75	90 abc
15	Fomesafen	0.28	90 a	Glufosinate	0.59	80 cd
16	Fomesafen	0.28	97 a	Acetochlor + Glufosinate	1.26 + 0.59	98 ab

[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at a p≤0.05.
[b] WAA = weeks after application timing a.
[c] WAB = weeks after application timing b
[d] Active ingredient corresponds to Glufosinate, Metolachlor, and Acetochlor. Active equivalent corresponds to 2,4-D choline and Glyphosate.
[e] PRE was sprayed at planting and POST 1 was sprayed when large crabgrass was at the 5 to 10 cm heights.

Table 3-25b. Mean percent control of large crabgrass after application of selected postemergence herbicides in cotton near Blackville, SC during 2013 (Study 3) [a]

TRT. #	POST 2 (C) [d] Treatment	Rates (kg ai/ha) or (kg ae/ha) [c]	4 WAC [b]	Counts 4 WAC
			% Control	Plants m[2]
1	Untreated		0 c	16 a
2	2,4-D choline + Glyphosate	1.21	100 a	0 b
3	2,4-D choline + Glyphosate	1.61	100 a	0 b
4	2,4-D choline + Glyphosate	1.61	100 a	0 b
5	2,4-D choline + Glyphosate	1.61	100 a	0 b
6	Glufosinate	0.59	100 a	0 b
7	Glufosinate	0.59	100 a	0 b
8	(2,4-D choline + Glyphosate) + Glufosinate	1.61 + 0.59	100 a	0 b
9	(2,4-D choline + Glyphosate) + Glufosinate	1.61 + 0.60	100 a	0 b
10	2,4-D choline + Glyphosate	1.61	100 a	0 b
11	2,4-D choline + Glyphosate	1.61	100 a	0 b
12	2,4-D choline + Glyphosate	1.61	100 a	0 b
13	2,4-D choline + Glufosinate	1.61 + 0.59	95 b	1 b
14	Glyphosate	0.75	100 a	0 b
15	Glufosinate	0.59	97 ab	0 b
16	Glyphosate	0.75	100 a	0 b

[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at a $p \leq 0.05$.
[b] WAC = weeks after application timing C.
[c] Active ingredient corresponds to Glufosinate. Active equivalent corresponds to 2,4-D choline and Glyphosate.
[d] POST 2 was sprayed when large crabgrass was at the 10 to 15 cm heights.

Table 3-26. Analysis of Variance for cotton yield in Study 3.

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Total	63	18290097.96			
Rep.	3	1447773.975	482591.3251	2.389	0.0812
Treatment	15	7753336.167	516889.0778	2.559	0.0076
Error	45	9088987.817	201977.507		

- DF = degrees of freedom

Table 3-27. Mean cotton yield after application of selected postemergence herbicides in cotton near Blackville, SC during 2013 (Study 3) [a]

TRT. NO.	Cotton Yield	
	kg/ha	
1	0	d
2	7	bcd
3	647	a
4	7	bcd
5	0	d
6	7	bcd
7	49	a-d
8	6	bcd
9	0	d
10	0	d
11	49	a-d
12	0	d
13	433	a
14	4	cd
15	300	ab
16	79	abc

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

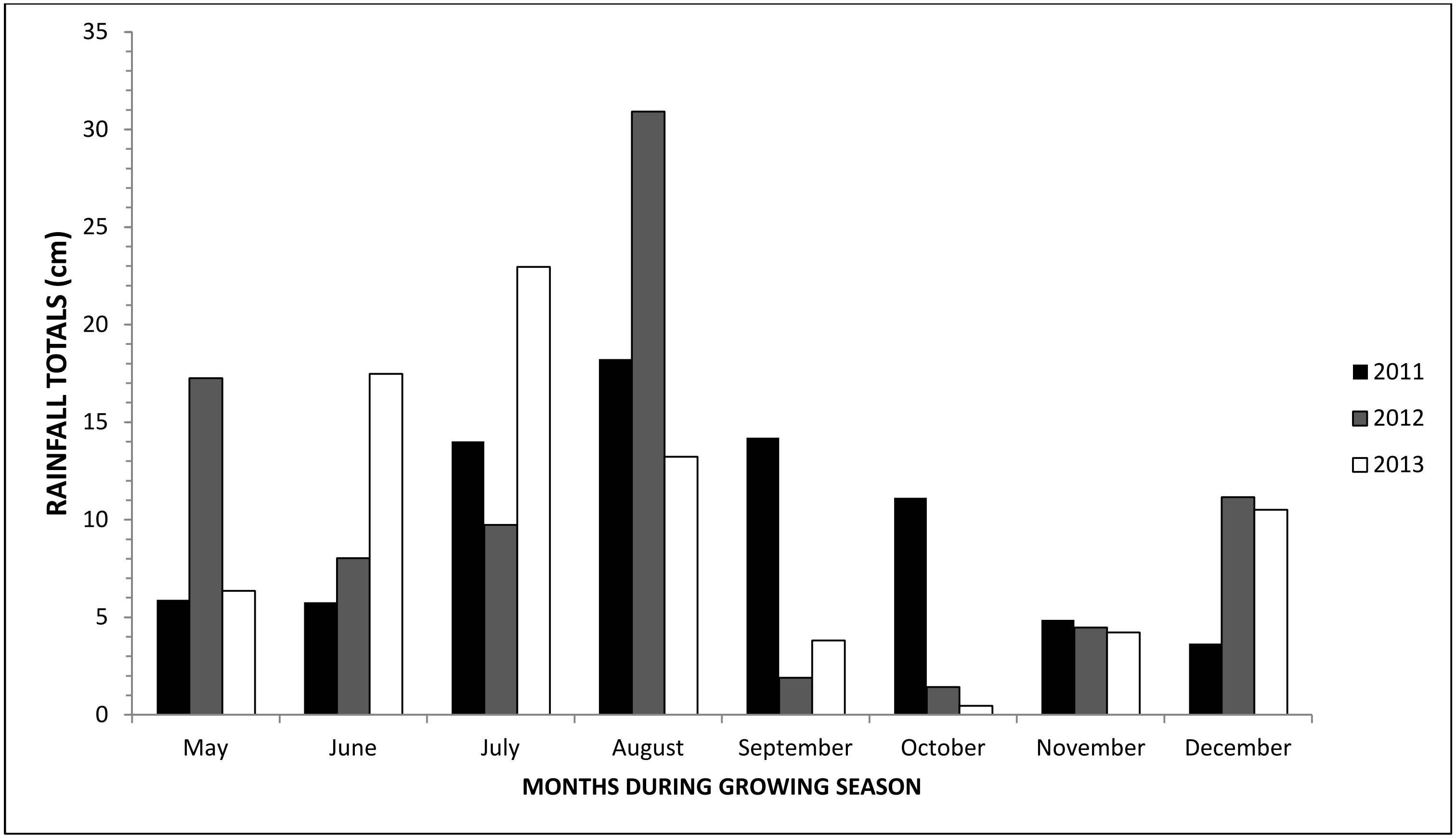

Figure 3-1. Monthly precipitations during the growing season of cotton in 2011, 2012, and 2013 at Edisto Research and Education Center near Blackville, SC

CHAPTER FOUR

EFFECT OF SELECTED SPRAY NOZZLES ON THE EFFICACY OF GLYPHOSATE, DICAMBA, 2,4-D, AND GLUFOSINATE ON SELECTED GRASS WEEDS

ABSTRACT

Previous research has shown that auxinic herbicides tank mixed with glyphosate or glufosinate can antagonize or reduce the efficacy of glyphosate or glufosinate on grass species. A replicated greenhouse experiment was conducted at Edisto Research and Education Center in Blackville, South Carolina, in 2013 to determine the effect of glyphosate, dicamba, 2,4-D, and glufosinate mixtures on selected grass weeds using three different nozzle types. Large crabgrass [*Digitaria sanguinalis* (L.) Scop.] and broadleaf signalgrass [*Urochloa platyphylla* (Nash) R.D. Webster] were treated at heights of 5, 10, 20, and 41 cm. All treatments combinations provided excellent control of both grass species ranging from 5 to 20 cm in height. At the 41 cm height, efficacy declined significantly in both species, with control of large crabgrass at 41 cm in height ranging from 71 to 75% and control of broadleaf signalgrass at 41 cm ranging from 84 to 89%.

INTRODUCTION

New transgenic crops are being developed with tolerance to combinations of 2,4-D, dicamba, glufosinate, and glyphosate. This new technology will provide growers with the ability to apply herbicides with up to three different modes of actions without affecting the growth of the crop. Glyphosate-resistant Palmer amaranth is the main reason for this new development. Palmer amaranth is the most troublesome weed today in cotton and soybean because of the difficulty to control it with existing herbicides. Other weeds common in cotton are morningglory species and grass species such as large crabgrass (*Digitaria sanguinalis*), broadleaf signalgrass [*Urochloa platyphylla* (Munro ex C. Wright) R.D. Webster], goosegrass [*Eleusine indica* (L.) Gaertn.], and Texas panicum [*Urochloa texana* (Buckl.) R. Webster].

Dicamba and 2,4-D are auxinic herbicides that are selective for control of broadleaf weeds in grass crops. These herbicides will be beneficial in controlling Palmer amaranth in cotton that is transformed to tolerate broadcast applications of these materials. Broadleaf weeds that are common in cotton can be effectively controlled with auxinic herbicides and will be recommended with a PRE and to combine with glufosinate and glyphosate (Merchant et al., 2013). However, there are other weeds besides Palmer amaranth in cotton such as grasses. The auxinic herbicides that will be used in the new transgenic cotton varieties are not effective on controlling grass species. Therefore, this cotton technology will be used in combination ("stacked") with tolerance to glyphosate and glufosinate, which will help growers control a large spectrum of weeds.

There is the concern that mixing the auxin herbicides with glyphosate and glufosinate can have a negative effect on controlling grass weeds. Previous research has shown that mixing auxin herbicides with glyphosate and glufosinate have negative effects on controlling grasses (Flint and Barrett, 1989; Culpepper et al., 2001). Several studies have looked at combinations of glyphosate and 2,4-D or dicamba on grass species such as johnsongrass (*Sorghum halepense* L.), large crabgrass, texas panicum, and broadleaf signalgrass. The results of these experiments demonstrated that glyphosate toxicity to johnsongrass was decreased when mixed with 2,4-D or dicamba (Flint and Barrett, 1989). Flint and Barrett also found that the absorption and translocation of glyphosate in johnsongrass was reduced by 2,4-D or dicamba in the spray mixture. An experiment by Culpepper et al., 2001, found that large crabgrass did not show visible effects from 2,4-DB applied alone, and no interaction was observed between glyphosate and 2,4-DB. The study by Merchant et al., 2013, confirmed that the auxinic herbicides did not control the two grass species (Texas panicum and broadleaf signalgrass). They determined that glufosinate was effective in controlling the grasses. Control of Texas panicum with glufosinate plus dicamba was similar to control by glufosinate alone. The 2,4-D and 2,4-DB reduced the toxicity of glufosinate on Texas panicum and broadleaf signalgrass (Merchant et al., 2013).

Dicamba and 2,4-D exhibit relatively high volatility, meaning that these herbicides can vaporize and drift out of the target area being sprayed into a nearby non-target area which may contain a sensitive crop or other non-target plants. Growers can reduce the potential for drift when spraying these auxin herbicides by using certain nozzle types that produce larger, coarse droplets instead of fine, driftable droplets. These nozzle types hinder complete coverage of herbicides on target weeds, but, because these chemicals are able to translocate through the plants, they work well in the larger droplet sizes. Despite that seemingly workable solution, this can cause problems with growers who desire to spray herbicides or other pesticides, such as glufosinate, which require smaller droplet sizes, with auxinic herbicides.

Previous work with these auxin herbicides used in combination glyphosate and glufosinate has yielded controversial findings regarding control of grasses. Therefore, an experiment was initiated to determine the effects of auxinic herbicides combined with glyphosate and glufosinate on control of selected grass weeds when applied with three different nozzle types.

MATERIALS AND METHODS

A replicated greenhouse experiment was conducted at Edisto Research and Eduction Center in Blackville, South Carolina, in the fall/winter of 2013 to determine the effect of various combinations of glyphosate, dicamba, 2,4-D, and glufosinate (Table 4.1) on large crabgrass and broadleaf signalgrass using three different nozzle types. . Herbicides were sprayed on weeds at 5, 10, 20, and 41 cm in height. An untreated control was maintained for both grass species.

The experimental design was a randomized complete block design with four replications. Each grass species was seeded into 11 by 11 cm square pots and thinned to 3 plants per pot in the greenhouse. Pots were divided into three groups for each species and a nozzle type used. Within each group, applications were made according to the heights of the grasses.

All treatments were sprayed using a backpack sprayer and three different nozzle types (TeeJet® Flatfan 8002, Turbo TeeJet® Induction Flat Spray 11002, and TurboDrop® Asymmetric DualFan 11002) at a pressure calibrated to the equivalent of 15 gal/a.

Trials were labeled as GH 213 (first trial for large crabgrass), GH 313 (first trial for broadleaf signalgrass), GH 214 (second trial for large crabgrass), and GH 314 (second trial for broadleaf signalgrass). Treatments were applied to GH 213 and GH 313 for each designated height on the same days. Treatments for the 5, 10, 20, and 41 cm heights were sprayed on 12 August, 5 September (replanted), 14 August, and 22 August 2013, respectively.

Trials GH 214 and 314 were planted several days apart to stagger the spray dates. In trial GH 214, treatments for the 5, 10, 20, and 41 cm heights were applied on 2, 3, 8, and 22 October 2013, respectively. In trial GH 314, treatments for the 5, 10, 20, and 41 cm heights were applied on 30 September, 2, 7, and 15 October 2013, respectively.

At 28 days after treatment, biomass weights were gathered for each experimental unit by clipping the grass species from each pot, placing the clippings in oven driers, and weighing the dried samples after a minimum of 7 days. Weights were converted into a percent of the untreated to represent a percent control using the formula:

$$\text{\% Weed Control} = [1 - \frac{Weight\ treated\ plants}{Weight\ untreated\ plants}]\ x\ 100\%$$

This protocol was repeated as each weed height was achieved.

Data for percent control of large crabgrass and broadleaf signalgrass were analyzed over trials using JMP Pro 10 software (SAS Institute Inc. 2014). Treatments and trials were the fixed effects. When there was not an interaction between treatments and trials, data was combined over trials. Means were separated using the student's t-test at a $p \leq 0.05$ significance level.

RESULTS AND DISCUSSION

LARGE CRABGRASS

There was no interaction between treatment and trials (Table 4-2), so data are presented with trials combined. Control of large crabgrass was excellent at 5, 10, and 20 cm (Figure 4-1). When large crabgrass reached the 41 cm height, percent control was low (71 to 85%), but there was no significant difference among the means. There was no significant difference among nozzle types because the nozzles applied the same rate but in different droplet sizes, and the herbicides' ability to translocate throughout the plant. The auxinic herbicides did not seem to antagonize glyphosate or glufosinate because of the excellent control observed for heights ranging from 5 to 20 cm. Similar to other research results, 2,4-DB applied alone did not show any visual effects on large crabgrass, and an interaction of glyphosate by 2,4-DB was not observed (Culpepper et al., 2001).

BROADLEAF SIGNALGRASS

There was not an interaction in treatment by trial for broadleaf signalgrass (Table 4-3), so trials were combined. Treatment by height did have a significant interaction; therefore, data were analyzed separately by heights (Figure 4-2 to 4-5). No interaction was observed among the three different nozzle types, so data for nozzles were combined. At 5 and 10 cm heights, all treatments provided excellent control of broadleaf signalgrass (Figures 4-2 and 4-3). At the 20 cm height, there were differences between treatments of glyphosate plus dicamba (98%) and glufosinate plus 2,4-D (96%), although both treatments provided excellent control (Figure 4-4). There were no significant differences observed at the 41 cm heights (Figure 4-5). In the two treatments that contained 2,4-D, control was lower than those with dicamba, with glyphosate plus 2,4-D being the lowest at 84% control. The percent control of broadleaf signalgrass ranged from 84 to 89% for 41 cm heights.

CONCLUSION

At heights less than 41 cm, large crabgrass and broadleaf signalgrass were controlled easily. There was no significant difference in treatments by height for large crabgrass. There was a difference in treatment by height for broadleaf signalgrass at the 20 cm height, with the treatment of glufosinate plus 2,4-D being the lowest at 96% control. The 2,4-D plus glufosinate treatment did not provide great control of both species at 41 cm heights with controls ranging from 71 to 75% for large crabgrass and 84 to 89% for broadleaf signalgrass. There were no interactions between nozzles. The results provide evidence that glyphosate or glufosinate will control large crabgrass and broadleaf signalgrass at heights ranging from 5 cm to 20 cm when mixed with auxin herbicides.

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Table 4-1. Treatment combinations for each height of large crabgrass and broadleaf signalgrass in greenhouse trials in 2013.

TRT. No.	Herbicides and Rates (Kg ai/ha)		Growth Stage
1	Untreated		
2	Glyphosate	0.75	
	Dicamba	1.12	
3	Glyphosate	0.75	
	2,4-D	1.12	5 cm
4	Glufosinate	0.59	
	Dicamba	1.12	
5	Glufosinate	0.59	
	2,4-D	1.12	
1	Untreated		
2	Glyphosate	0.75	
	Dicamba	1.12	
3	Glyphosate	0.75	
	2,4-D	1.12	10 cm
4	Glufosinate	0.59	
	Dicamba	1.12	
5	Glufosinate	0.59	
	2,4-D	1.12	
1	Untreated		
2	Glyphosate	0.75	
	Dicamba	1.12	
3	Glyphosate	0.75	
	2,4-D	1.12	20 cm
4	Glufosinate	0.59	
	Dicamba	1.12	
5	Glufosinate	0.59	
	2,4-D	1.12	
1	Untreated		
2	Glyphosate	0.75	
	Dicamba	1.12	
3	Glyphosate	0.75	
	2,4-D	1.12	41 cm
4	Glufosinate	0.59	
	Dicamba	1.12	
5	Glufosinate	0.59	
	2,4-D	1.12	

Table 4-2. Analysis of Variance for large crabgrass.

Source	DF	Sum of Squares	F	P > F
Treatment	3	221.5911	0.3767	0.7698
Trial	1	3450.0026	17.5969	<.0001
Height	3	48625.049	235.6057	<.0001
Nozzle	2	111.703	0.8119	0.4449
Treat*Trial	3	86.8411	0.1476	0.9312
Treat*Height	9	306.523	0.4951	0.8777
Treat*Nozzle	6	183.526	0.4446	0.8487

- DF = degrees of freedom

Table 4-3. Analysis of Variance for broadleaf signalgrass.

Source	DF	Sum of Squares	F	P > F
Treatment	3	136.59853	1.175	0.319
Trial	1	750.57231	19.3692	<.0001
Height	3	8015.1041	159.4112	<.0001
Nozzle	2	20.3126	0.606	0.5461
Treat*Trial	3	117.87294	1.0139	0.3865
Treat*Height	9	375.8548	2.4918	0.009
Treat*Nozzle	6	148.4027	1.4758	0.1854

- DF = degrees of freedom

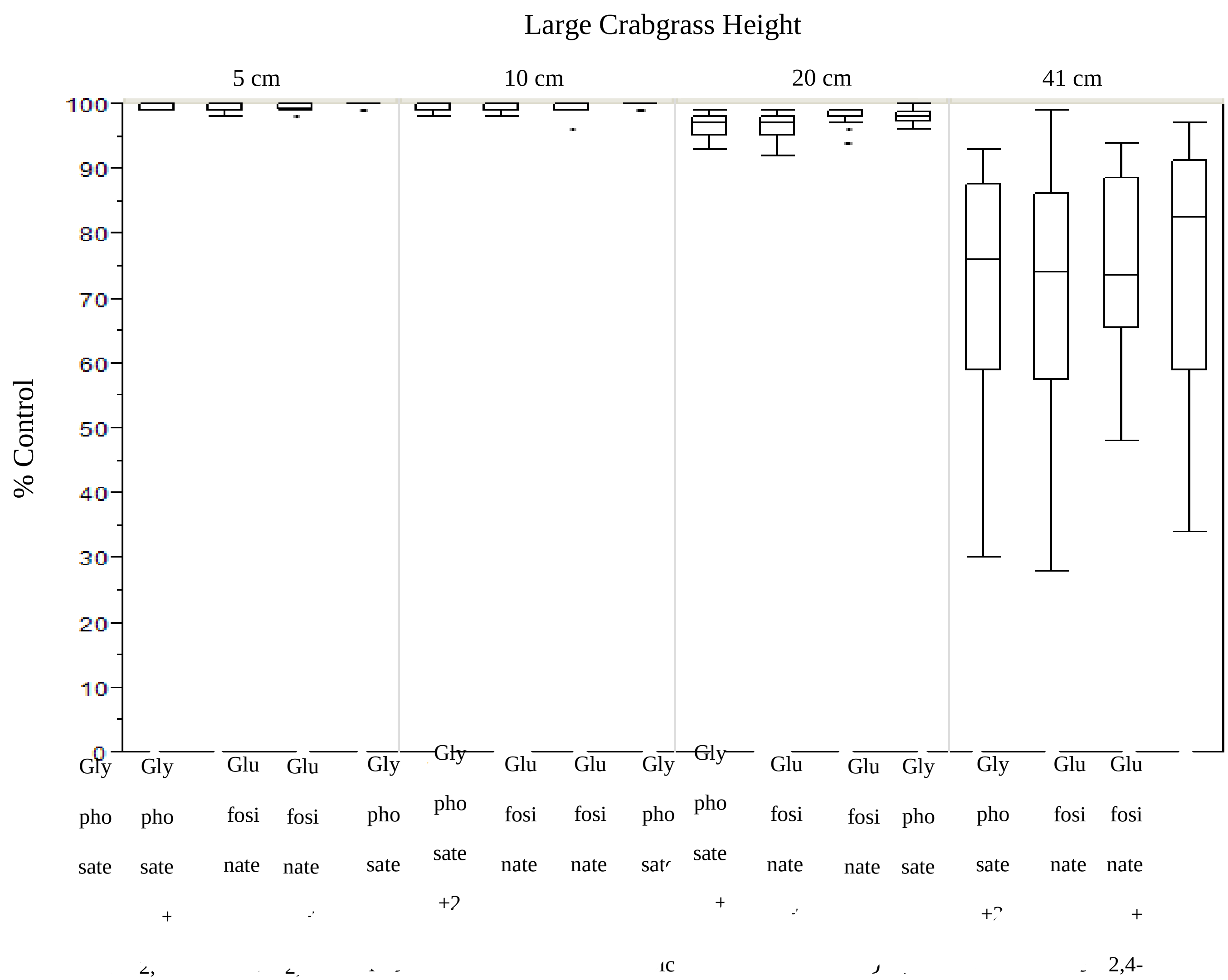

Figure 4-1. Large crabgrass percent control averaged across trials and nozzles for each height from greenhouse experiment conducted in 2013 near Blackville, SC.

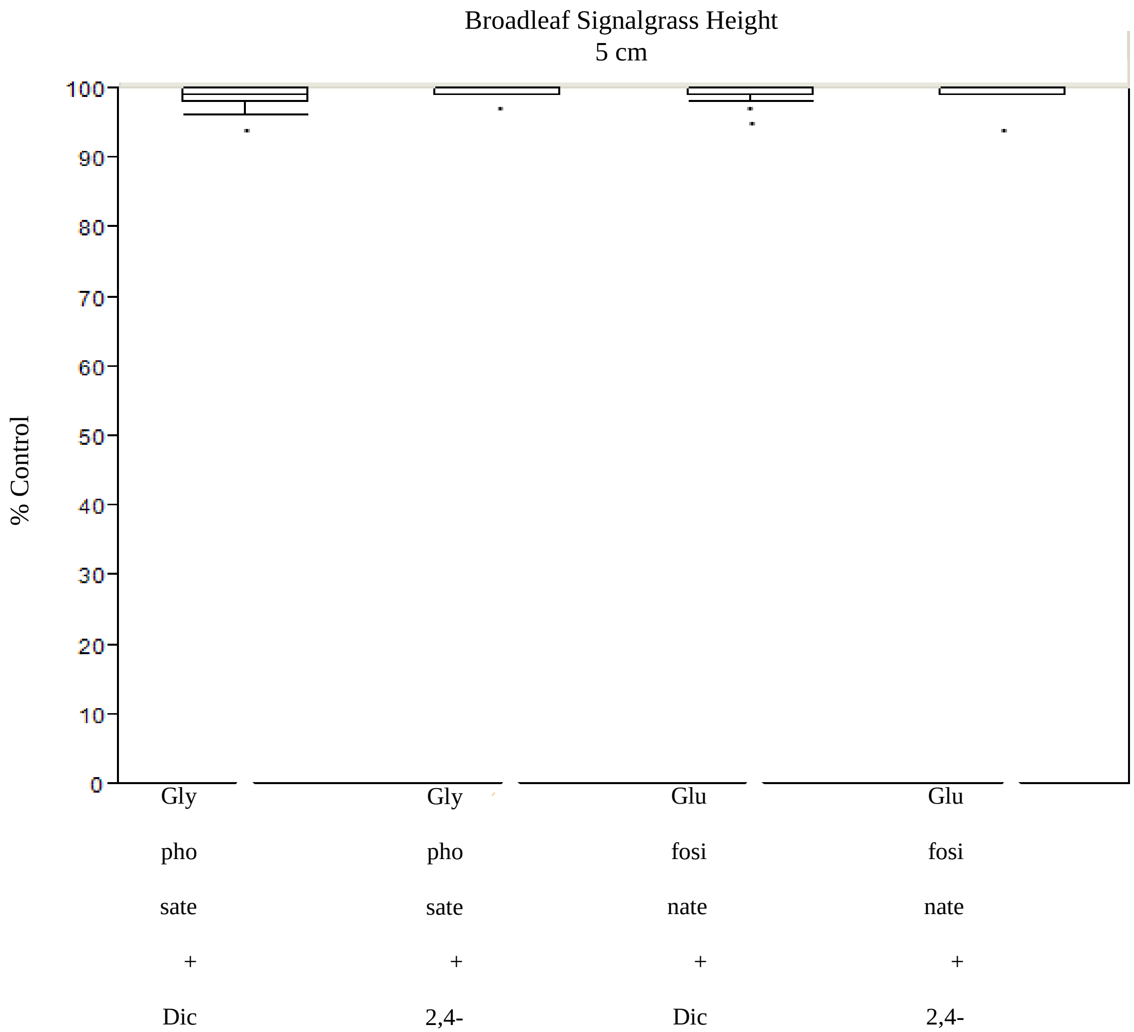

Figure 4-2. Broadleaf signalgrass percent control at 5 cm height averaged across both trials and nozzles as affected by selected herbicides in greenhouse experiments in 2013 near Blackville, SC.

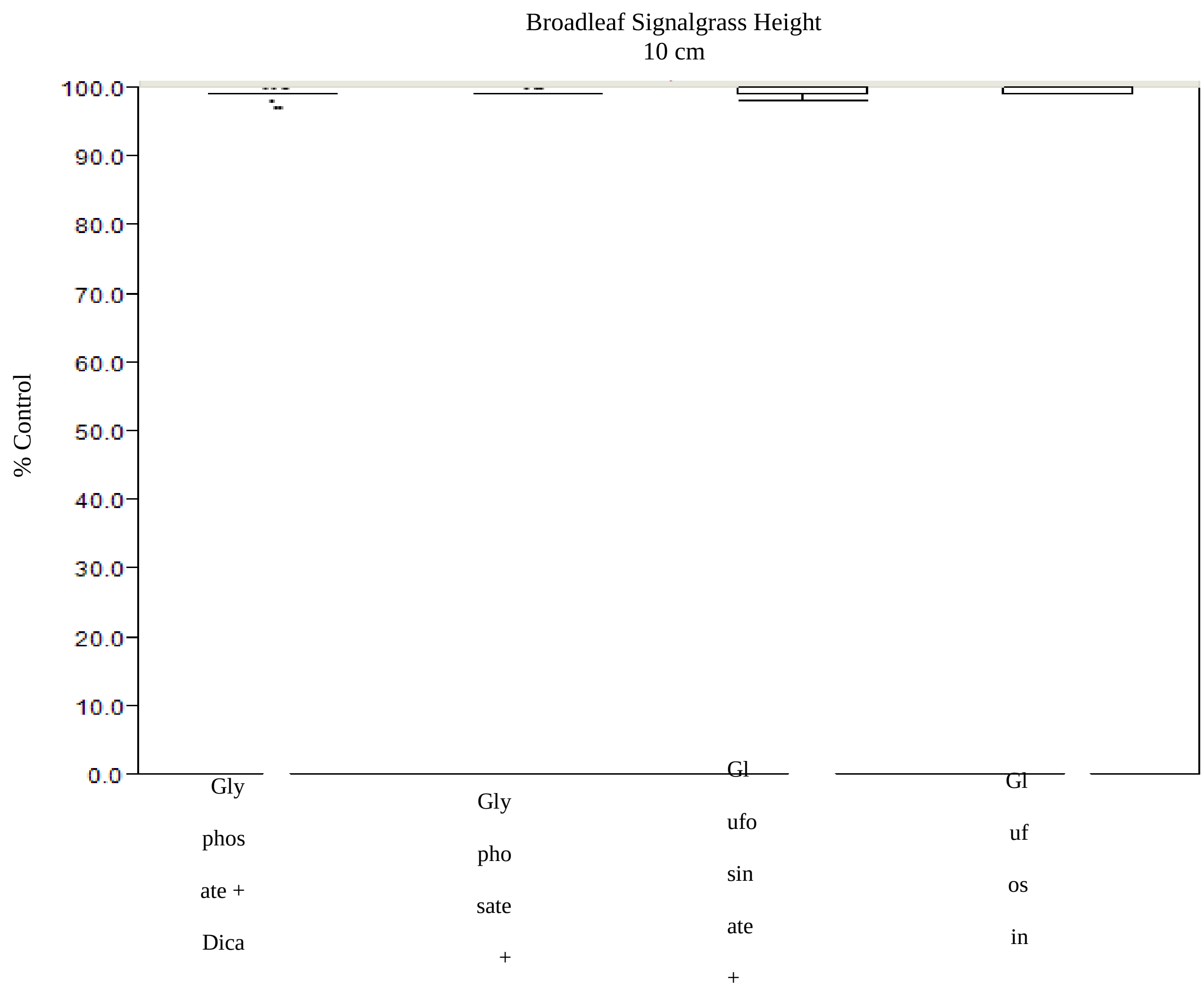

Figure 4-3. Broadleaf signalgrass percent control at 10 cm height averaged across both trials and nozzles as affected by selected herbicides in green house experiments in 2013 near Blackville, SC.

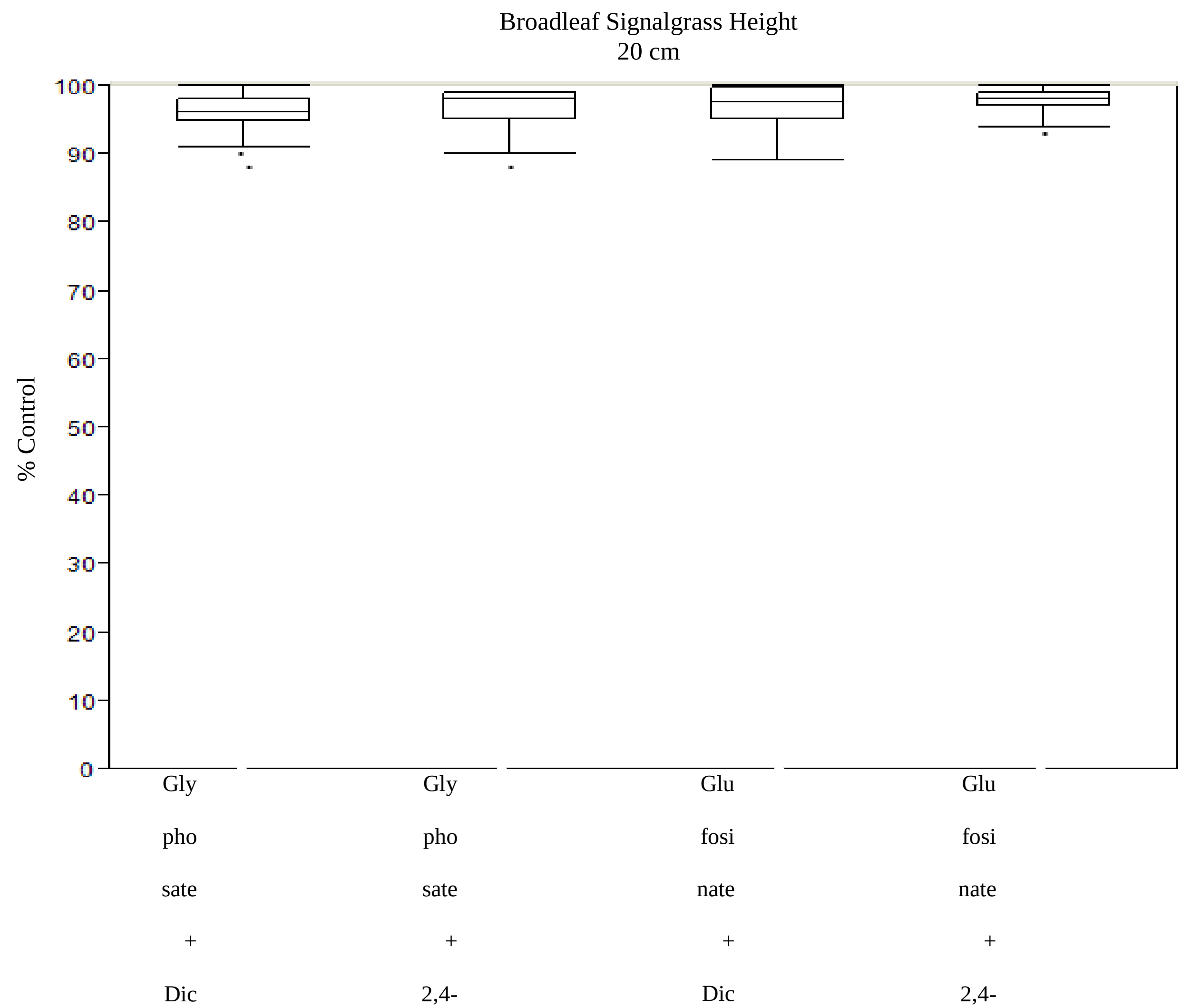

Figure 4-4. Broadleaf signalgrass percent control at 20 cm height averaged across both trials and nozzles as affected by selected herbicides in greenhouse experiments in 2013 near Blackville, SC.

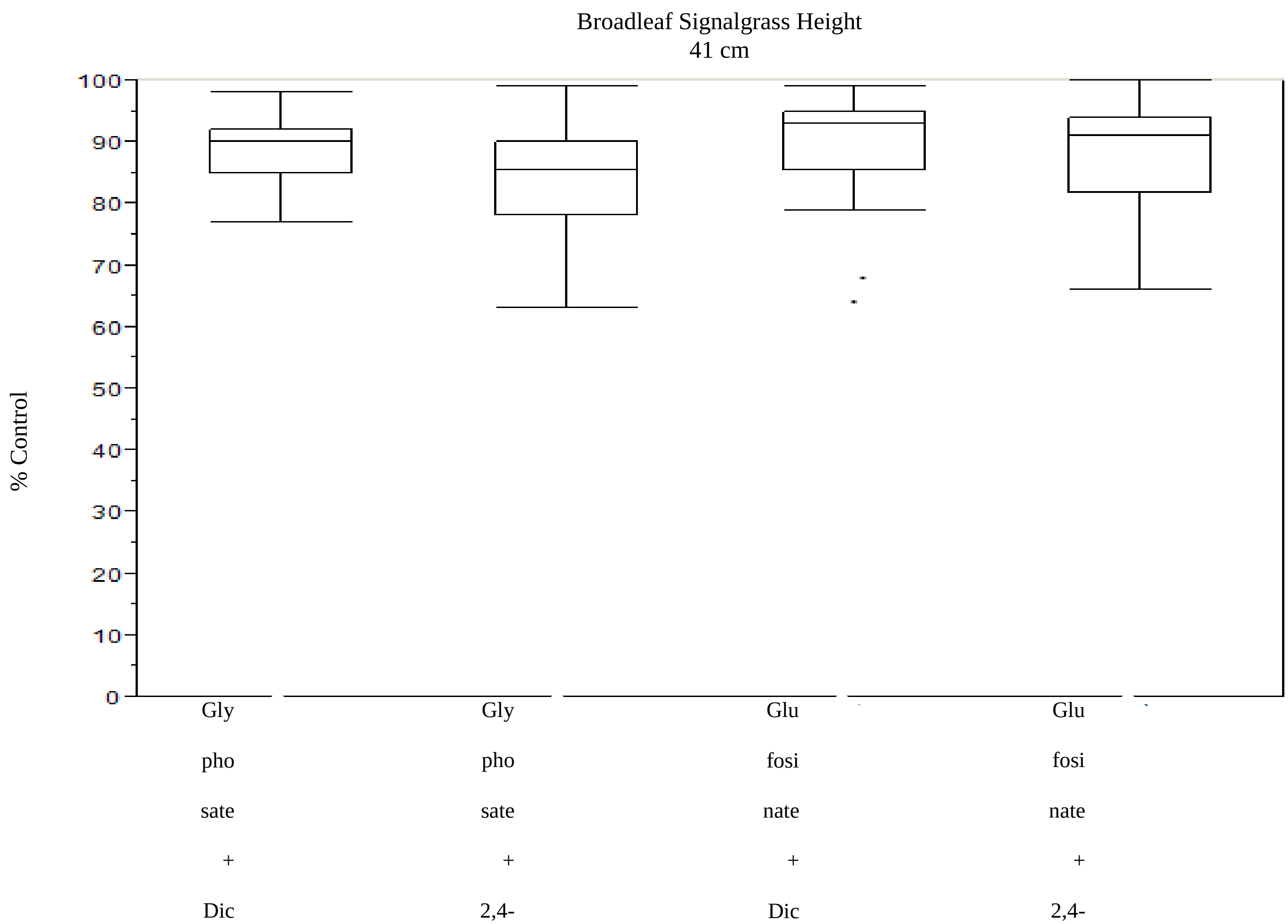

Figure 4-5. Broadleaf signalgrass percent control at 41 cm height averaged across both trials and nozzles as affected by selected herbicides in greenhouse experiments in 2013 near Blackville, SC.