Management of Glyphosate Resistant Palmer Amaranth in Liberty Link® Soybeans

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DEDICATION

I would like to dedicate this paper to my mother, Lacee Jacobs Mallard and father, Alan Mallard. They have showed me the way through life. My mother introduced me to the great outdoors by gardening and just the general work in the family garden. My mother has pushed me to pursue my dreams of a master's degree by encouraging me every step of the way. My father taught me the valuable lessons of love what you do and do your job great. He taught me to do the best that I could; that way I could enjoy the fruits of my labor. Without their encouragement and dedication to keeping on the road less traveled, I would not have been in this moment of my life.

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ABSTRACT

Soybeans (*Glycine max L.)* have been the main crop planted in West Tennessee for many years but glyphosate resistance in palmer amaranth (*Amaranthus palmeri*) or pigweed is becoming a problem.

A field study was conducted during the 2009 growing season to study glyphosate resistant palmer amaranth management in Liberty Link® soybeans and the damage caused by different herbicide rates of glufosinate (Ignite 280®) and mixtures of glufosinate with Cadet or Flexstar. Five herbicide treatments were applied when soybeans were at the third trifoliate stage. A randomized complete block design with three replications was used. The test was rated for soybean injury and pigweed control at five days and ten days after herbicide application.

There were significant differences ($P < 0.0001$) among treatments for soybean injury. The treatments with the lowest percentage of damage to the soybean plants were: Ignite 280® at 22, 29 and 44 ounces per acre. Treatments in which Ignite 280® was mixed with Cadet® or Flexstar® produced significantly ($P < 0.05$) more injury in soybean plants in this study. The amount of damage to the soybean plant from herbicide could impact the yield potential of the crop.

There were significant differences ($P < 0.0001$) among herbicide treatments for pigweed control in this trial. On day 5 after application, the lowest percentage of pigweed control pigweeds was Ignite 280® at 22 ounces per acre with 63.3% control. The best control came from the Ignite 280® at 44 ounces per acre with a control rating of 92% at 5 days after treatment. On day 10 after application, Ignite 280® at 22 ounces per acre had

the lowest ($P < 0.05$) control rating (78%) of all treatments. The rest of the treatments were not significantly different from each other. Ignite 280® at 29, Ignite 280® 29 + Cadet® and Ignite 280® 29 + Flexstar® all had pigweed control ratings of 97.7% and Ignite 280® at 44 ounces controlled the pigweed at 99%.

The results of this study indicate that the best product and rate to use in the control of glyphosate resistant pigweed is Ignite 280® at 29 ounces per acre. This produced no significant damage to the Liberty Link soybean crop while controlling the rapidly growing palmer amaranth within 10 days of application. The 44 ounce rate of Ignite also controlled the pigweed with little or no damage to the soybeans, but the label on Ignite 280® states that only 44 ounces per acre can be used per growing season. Therefore, using 44 ounces at once would limit the producer to applying this product only once and having to rely on another product to control later emerging pigweed. Using glufosinate to control palmer amaranth in Liberty Link soybeans provides another alternative for producers who must deal with this difficult weed. Producers must keep up with new technologies in integrated weed management if they are to control glyphosate-resistant pigweed as well as other herbicide-resistant weeds.

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Chapter I - Introduction

Glycine max, soybean, is a legume that is native to East Asia. *G. max* is an annual plant that is used for the oil found in the seed. Like most other legumes, soybeans achieve nitrogen fixation by creating a symbiotic relationship with the bacterium *Bradyrhizobium japonicum*. The average number of days from planting to harvest of soybeans is 80 to 120 days and soybean plants will reach an average height of 1 m. Soybeans have been genetically modified to have resistance to glyphosate and glufosinate herbicides. The first GMO (genetically modified organisms) soybean plants were planted in the United States in 1996 (Liu, 1997). Since then, producers have seen a steady increase in the use of these GMO plants. According to the End of Year Producers Crop survey from the small grain specialist Bob Williams of the University of Tennessee (personal communication, 2009), 83.3% of soybeans grown in West Tennessee in 2003 were GMO. In 2004, 95.5% of soybeans were GMO and in 2005, 97.8% of soybeans were GMO. After 2005, data were no longer broken down into GMO and conventional soybeans, because of the high percentage of GMO soybeans. The majority of the GMO soybean varieties were genetically modified to have resistance to the herbicide glyphosate. With over 90% of soybeans in West Tennessee being glyphosate-resistant GMO plants, more and more glyphosate is being sprayed to control weeds. Some weeds are building up resistance to glyphosate and can cause big problems for producers (Liu, 1997). In 1997, about 8% of all soybeans cultivated for the commercial market in the United States were genetically modified. In 2006, the figure was 89%. As with other "Roundup Ready" crops (crops genetically modified to be resistant to glyphosate),

concern was expressed over damage to biodiversity (Liu, 1997). However, the RR (Roundup Ready) gene has been bred into so many different soybean cultivars that the genetic modification itself has not resulted in any decline of genetic diversity (Sneller, 2003).

According to the National Agricultural Statistics Service, there were 51,500 acres of corn, 24,800 acres of upland cotton and 117,000 acres of soybeans harvested in Gibson County, TN in 2008 (NASS, 2009). Soybean acreage was more than double that of corn, the next most important crop in Gibson County. In 2008, the average yield of soybeans in Gibson County was 30.5 bushels per acre. This produced 3,568,500 bushels for the county. The average price per bushel in 2008 was $8.75 (Chuck Danhower, UT Extension Specialist, personal communication, 2009). This means Gibson County farmers had the potential to make $31,224,375 from soybean production in 2008, ignoring price variation due to low seed quality or contracts.

Glyphosate resistance is growing in West Tennessee and every year more and more acres are affected by resistant weeds. The extensive use of glyphosate is causing this problem and producers are going to have to start thinking about other means of controlling problem weeds. One such problem weed is palmer amaranth (*Amaranthus palmeri)*. When palmer amaranth is resistant, the highest recommended rate of glyphosate will not even slow the growth of this weed. Palmer amaranth is not only resistant to glyphosate, but also to ALS inhibitors (acetolactate synthase) and other herbicides (Sprague et al., 1997).

Palmer amaranth, also called pigweed, is a very hard weed to control in soybean production fields. Palmer amaranth is a rapidly growing plant that has the potential to

reduce yields. The seedlings can emerge from March to September, so one blanket treatment of herbicide will not cover that time span and control all pigweed that emerge. Once pigweeds become resistant to different herbicides, these weeds become harder and harder to control. Palmer amaranth is known to have built up resistance to triazine, urea and now glyphosate herbicides (Steckel, 2003). The female plants can produce hundreds of thousands to a million seeds per plant, therefore control is vital for optimum crop production.

Objectives

The objectives of this study were to:

1. Determine the effect of glufosinate herbicide, alone and in mixtures, on Liberty Link soybean plants.
2. Determine the effectiveness of glufosinate herbicide, alone and in mixtures, in controlling palmer amaranth.

Chapter II – Literature Review

Genus Amaranthus

The amaranth family has 865 species but only nine are commonly found in Tennessee. The nine species (all in the genus *Amaranthus)* can be broken down into three different groups by growth and flowering habits (Steckel, 2003).

Group one consists of tall, upright pigweeds that are monoecious (the plant has both male and female flowers). This group includes: redroot pigweed (*Amaranthus retroflexus*), smooth pigweed (*A. hybridus*) and green amaranth (*A. gracilis*). All of these pigweeds are found in abundance in West Tennessee.

Group two amaranths consist of tall, upright, dioecious (male and female flowers on separate plants) pigweeds. This group includes: common waterhemp (*A. rudis*), palmer amaranth (*A. palmeri*) and tall waterhemp (*A. tubercuatis*). The waterhemps are commonly found around Mississippi River bottoms in Tennessee. Palmer amaranth originated in the Midwest but has recently migrated to Tennessee. These plants are very competitive with crops because of upright, branching growth habit. Palmer is the most competitive and rapidly growing species of the pigweeds (Steckel, 2003) and has become the most troublesome weed in row crops in West Tennessee (Steckel, 2007). Palmer amaranth has 65% more biomass at 2 weeks after emergence than *A. retroflexus, A. hybridus, A. ridus, A. spinosus,* and *A. albus* (Sellers et al. 2003). Flowering stems of *A. palmeri* are the longest of the pigweeds, ranging from 1 to 2 feet in length. The petioles are typically longer than the leaf blades. The leaves of palmer amaranth plants are wider than that of its close cousin, waterhemp. The later leaves may have an occasional watermark (white or red v-shaped variegation) and the backs of leaves are usually waxy.

Palmer amaranth can grow as fast as one inch per day, which makes it a very aggressive weed in row crops. The female plant can produce 500,000 to 1,000,000 seeds per plant, which can reduce yields in soybean crops by as much as 43% with weed densities at less than 1.5 plants per foot of row (Holshouser, 2008). According to University of Tennessee, soybean seeding rate on no-till 20 inch rows, should produce 6 to 8 soybean plants per foot of row (Flinchum, 2001). Adding the aggressive *A. palmeri* could greatly affect yield potential.

Group three amaranths consist of prostrate growing pigweeds that are also monoecious (Steckel, 2003). This group includes: spiny amaranth (*A. spinosus*), tumble pigweed (*A. albus*) and prostrate pigweed (*A. blitoides*). Of these, spiny amaranth is the most common in West Tennessee, but all are found here. Tumble pigweed and prostrate pigweed are commonly found around the edges of fields and pastures.

Glyphosate

Glyphosate is a herbicide that is sold under several different names, including Roundup®, Touchdown® and Glyphomax®, trademarks of Monsanto Company, Syngenta Group Company, and Dow AgroSciences LLC, respectively. This herbicide controls a broad spectrum of weeds in agriculture and is a simple weed management tool in glyphosate resistant crop varieties. Its mode of action is a non-selective, systemic herbicide. On the other hand, it is used repeatedly and is often the only herbicide used for weed management in some fields. As a result, some weeds have built up tolerance to glyphosate and are no longer controlled by this herbicide (Garhan, 2008). The use of a single product weed management tool can result in resistant weeds (Garhan, 2008) and it

is apparent that overuse of glyphosate has caused glyphosate resistance in palmer amaranth.

Glufosinate

Glufosinate or glufosinate-ammonium, is a herbicide with the following chemical makeup: (monoammonium 2-amino-4(hydroxymethylphosphinyl) butanoate) (Cox, 1996). Its mode of action is to inhibit the activity of the enzyme glutamine synthetase (Cox, 1996). Glutamine synthetase is involved in the synthesis of the amino acid glutamine. Glufosinate is a rapid action post emergence herbicide for use in glufosinate tolerant Liberty Link® soybeans.

Control of Palmer Amaranth

Amaranthus palmeri, palmer amaranth, is becoming a very hard weed to control in cotton and soybean production fields. Palmer amaranth, also known as pigweed, is building up resistance to glyphosate herbicides (York, 2007). Glyphosates are the main weed control chemicals used in West Tennessee. Proper weed management requires rotation of chemicals along with crop rotation in each field. Soybean farmers are concerned about pigweed because most use Roundup Ready soybeans in their fields. Soybean producers could be most affected by yield loss due to palmer amaranth. This pigweed has the potential to reduce soybean yields by 17-68% in field experiments (Bensch et al., 2003). Producers are asking why glyphosates herbicides are not killing their pigweed anymore. Over the last decade, pigweeds in Tennessee have become a major weed pest in row crops and pastures (Steckel, 2003).

Pigweed seedlings emerge from March to September; therefore, one blanket treatment of preplant or post emergence herbicide treatment for pigweed control will not work due to the long window of emergence. Planting earlier in the spring allows for higher yields, but has also extended the time that weeds must be controlled. One pigweed per 20 foot of row could reduce yield by 7% or one pigweed per square yard could reduce yield by as much as 50% (York, 2007). The cooler weather usually slows growth of row crops and reduces their ability to shade out the weeds under the crop.

There are some new weed control technologies with multiple herbicides that are waiting for approval from the USDA. Some of the area producers are dusting off their hooded sprayers, to revert back to older herbicides that cannot be applied post emergence. The Natural Resources Conservation Service is also becoming aware of pigweed's threat to conservation tillage. As producers turn to tillage to control pigweed, new problems with erosion control may surface (Robinson, 2009). Certain types of pigweeds have or are evolving resistance to triazine and urea herbicides such as Atrazine, Princep, Cotoran and Direx. These pigweed genotypes are present in Tennessee but they are not widespread (Steckel, 2003). Ten years ago, palmer amaranth developed a resistance to the ALS (acetolactate synthase) inhibiting herbicides such as: Scepter®, Staple®, Steadfast® and Classic® (Steckel, 2007). The ALS inhibiting herbicides were being used heavily in soybean fields at that time. Since 2007, palmer amaranth has shown resistance to diphenyl ether and to dinitroanaline herbicides such as Treflan and Prowl (Steckel, 2007). Weed control of palmer amaranth has become difficult because of its resistance to all commonly used herbicides. In 2007, there were 12 fields in three counties in West Tennessee that contained glyphosate resistant pigweed (Steckel, 2007).

The University of Tennessee's recommendations for herbicides to use in soybeans are: Dual®, Prowl®, Spartan®, Glyphosate, Reflex®, Blazer®, Cobra® and Treflan® (Steckel, 2003). Of these, Dual (active ingredient metolachlor) is the only one to which palmer amaranth has not shown resistance. There is some urgency to find a solution to fight palmer amaranth in soybeans in West Tennessee. The Liberty Link System® in soybeans adds another dimension to solving the problem of glyphosate resistant pigweed by incorporating the use of a glufosinate herbicide.

Liberty Link Soybeans

Liberty Link® Soybeans have been genetically modified to withstand glufosinate. The first glufosinate tolerant soybeans were commercially planted in 2009. Glufosinate tolerance is added to soybean plants by incorporating either the *pat* (phosphinothricin-acetyltranserfase) or the *bar* (bialaphos resistance) genes, which are the codes for enzymes that inactivate the glufosinate by acetylation (Mullner et al., 1993). Liberty Link Soybeans are just another step in the direction of using technology to try and help with the weed management programs by genetically modifying soybean plants.

Chapter III – Materials and Methods

Plot Design

Field experiments were initiated in the 2009 growing season on the farm of Scotty Barnett, located in Gibson County, Tennessee. This research paper summarizes the results from the 2009 growing season. A randomized complete block design (Figure 1) with three blocks was utilized in this experiment. Five herbicide treatments were tested. Each plot was 30 feet long by 6.67 feet wide. The total plot size was 0.0138 acres with border rows around the entire trial. Soybeans used in this test were Stine 49LA02 a type of Liberty Link Soybean. The soybeans were seeded on a no-till seed bed on 20 inch centers.

Rep 1	Rep 2	Rep 3
101-Ignite 280 at 22 oz. rate	**201**- Ignite 280 at 29 oz. rate	**301**- Ignite 280 at 29 oz. + Flexstar 16 oz. rate
102- Ignite 280 at 29 oz. rate	**202**- Ignite 280 at 44 oz. rate	**302**- Ignite 280 at 29 oz. + Cadet 0.6 oz. rate
103- Ignite 280 at 44 oz. rate	**203**- Ignite 280 at 29 oz. + Cadet 0.6 oz. rate	**303**- Ignite 280 at 44 oz. rate
104- Ignite 280 at 29 oz. + Cadet 0.6 oz. rate	**204**- Ignite 280 at 29 oz. + Flexstar 16 oz. rate	**304**- Ignite 280 at 22 oz. rate
105- Ignite 280 at 29 oz. + Flexstar 16 oz. rate	**205**- Ignite 280 at 22 oz. rate	**305**- Ignite 280 at 29 oz. rate

Figure 1: Diagram of research plot design

Treatments and Procedures

The five herbicide treatments used in this trial were 1) Ignite 280® at 22 ounces per acre, 2) Ignite 280® at 29 ounces per acre, 3) Ignite 280® at 44 ounces per acre, 4) Ignite 280® at 29 ounces per acre plus Cadet® 0.6 ounces per acre, 5) Ignite 280® 29 ounces per acre plus Flexstar® 16 ounces per acre. Ignite 280® is a glufosinate, Cadet® is fluthiacet-methyl and Flexstar® is sodium salt of fomesafen. The 22 ounce rate of glufosinate in treatment 1 is the low label rate for Ignite 280®. The 29 ounce rate in treatment 2 is the high label rate for Ignite 280® (Glufosinate) 2-amino-4-(hydoxymethylphosphinyl) butanoic acid (LSU, 2008). Treatment three was 44 ounces per acre of glufosinate. The 44 ounce rate is not on the label but it is the total amount of Ignite 280® that is allowed to be sprayed on Liberty Link® soybeans in one growing season. Treatment four was 29 ounces per acre of glufosinate plus 0.6 ounces per acre of Cadet® (Fluthiacet-methyl) [[2-Chloro-4-Fluoro-5-[(tetrahydro-3-oxo-1*H*,3*H*-[1,3,4]thiadiazolo[3,4-α]pyridazin-1-ylidene)amino]phenyl]thino]-methyl ester (EPA, 1999). The 0.6 ounce rate of Cadet® is the high label rate. Treatment five was 29 ounces per acre of glufosinate plus 16 ounces per acre of Flexstar® (Sodium salt of fomesafen) 5-[2-chloro-4-(trifluoromethyl)phenoxy]-N-(methylsofonyl)-2-nitrobenzamide (L.S.U., 2008).

Timing of Herbicide Application

Herbicides were applied when soybeans were at the three trifoliate stage. The three trifoliate stage is when there are three true leaves on the plant. The treatments were sprayed over the top using a CO_2 backpack sprayer to ensure that only the plot was sprayed. This application took place on July 16, 2009 under the direction of Dr. Larry Steckel of the Department of Plant Sciences, University of Tennessee.

Data Collection

Data on soybean injury and pigweed control were collected five days and ten days after herbicide application. On both data collection days, the soybeans were rated for herbicide injury using a scale of 0 to 100% damage, with 0 being no damage and 100% being dead. Only the middle two rows of the four rows in each plot were used for rating. The damage was rated according to leaf burn and stunting of the plants. Outside of the test plots were control plants that had not been sprayed and ratings were based on the check plants. Pigweed control by the herbicide treatments was rated on a scale of 0 to 100% control with 100% being total control of pigweed. Pigweed control was determined by counting the number of dead pigweed plants and dividing by the number of live plus dead plants to calculate the percentage of control.

Statistical Analysis

Data collected during the 2009 growing season were analyzed using the ANOVA procedure of Statistical Analysis Software (SAS). Data from each date of collection were analyzed separately. Means for each treatment were separated using Tukey's Studentized Range Test ($P \leq 0.05$).

Chapter IV – Results

There were significant differences ($P < 0.0001$) among herbicide treatments for both soybean injury and pigweed control rated 5 and 10 days after application (Table 1).

Soybean Injury

At both 5 and 10 days after treatment, there was no noticeable damage to soybean plants treated with Ignite 280® at 22 (treatment 1) and 29 (treatment 2) ounces per acre (Table 2, Figure 2). Five days after application, soybeans treated with Ignite 280® at 44 ounces per acre (treatment 3) showed slight injury with a mean of 1% (Table 2), but this was not significantly different ($P < 0.05$) from the lower rates of application (Treatments 1 and 2). By 10 days after treatment, no visible damage to soybeans was observed in this treatment. The Ignite 280® mixtures with Cadet® at 0.6 ounces per acre and Flexstar® at 16 ounces per acre caused the highest amount of soybean damage. The Cadet® mixture (Treatment 4) produced the most damage followed by Flexstar® (Treatment 5) (Figure 2, Table 2). Treatment 4 was significantly different ($P < 0.05$) from treatment 5 at both rating times (Table 2). Both mixtures caused significantly ($P < 0.05$) more injury than glufosinate (Ignite 280®) alone. Although the soybeans recovered somewhat by 10 days after treatment (treatment 4 dropped from 35.7% to 20.0% damage and treatment 5 dropped from 17.3% to 9.0% damage), both herbicide mixtures still caused more damage than the three treatments of glufosinate alone. This injury could translate into reduced soybean yields.

Pigweed Control

At 5 days after treatment, pigweed control was lowest in Treatment 1 (Ignite 280® at 22 ounces per acre) with only 63.3% of the pigweeds controlled (Table 2, Figure 3). Treatment 2 (Ignite 280® at 29 ounces per acre), Treatment 4 (Ignite plus Cadet), and Treatment 5 (Ignite plus Flexstar) all had significantly ($P < 0.05$) better control than Treatment 1, with mean control ratings of 81.0% to 82.3%. Ignite 280® at 44 ounces per acre (Treatment 3) had the highest pigweed control rating with a mean of 92%. At 10 days after treatment, Treatments 2, 3, 4, and 5 were not significantly different ($P < 0.05$) from each other, but did give significantly better control than Treatment 1 (Ignite at 22 ounces per acre). Mean pigweed control ratings for treatment 2, 3, 4, and 5 ranged from 97.7% to 99.0%. The mean rating for Treatment 1 was only 78%, which is not high enough to control pigweed. Therefore, any of the treatments with 29 ounces or more per acre of Ignite appear to be adequate for controlling pigweeds.

Table 1: Summary of ANOVA results for soybean injury rating and control of pigweed 5 and 10 days after herbicide application

	Soybean Injury Rating (%)		Pigweed Control Rating (% plants killed)	
ANOVA Results	After 5 days	After 10 Days	After 5 days	After 10 days
Mean Square	742.8	234.6	323.2	241.0
F Value	152.6	391.0	46.6	219.1
Pr > F	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Table 2: Mean soybean injury ratings and mean ratings for control of pigweed 5 and 10 days after herbicide application.

	Soybean Injury Rating (%)		Pigweed Control Rating (% plants killed)	
Treatment	After 5 days	After 10 Days	After 5 days	After 10 days
Ignite 280® 22 oz./A	0.0c*	0.0c	63.3c	78.0b
Ignite 280® 29 oz./A	0.0c	0.0c	82.3b	97.7a
Ignite 280® 44 oz./A	1.0c	0.0c	92.0a	99.0a
Ignite 280® 29 oz. + Cadet® 0.6 oz./A	35.7a	20.0a	81.7b	97.7a
Ignite 280® 29 oz. + Flexstar® 16 oz./A	17.3b	9.0b	81.0b	97.7a

*Within each rating time, treatments with the same letter are not significantly different according to Tukey's test (P < 0.05)

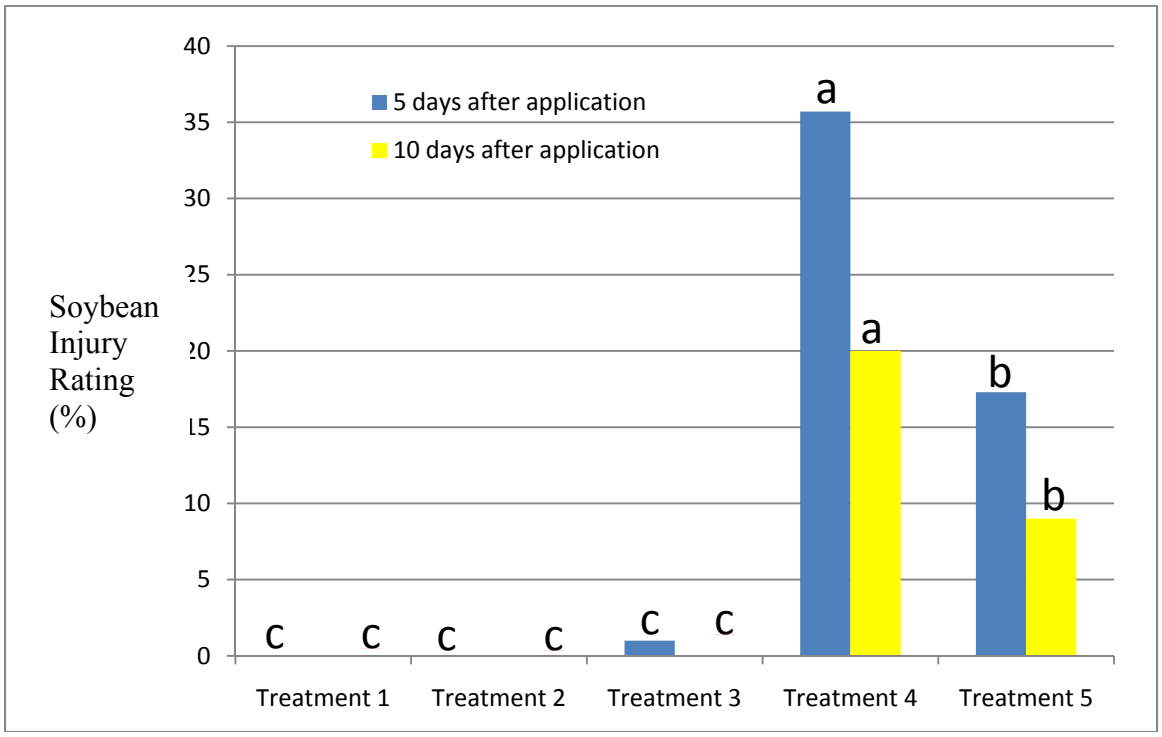

Figure 2: Soybean injury from herbicide treatments

Within each rating time, means with the same letter are not significantly different according to Tukey's test ($P < 0.05$)

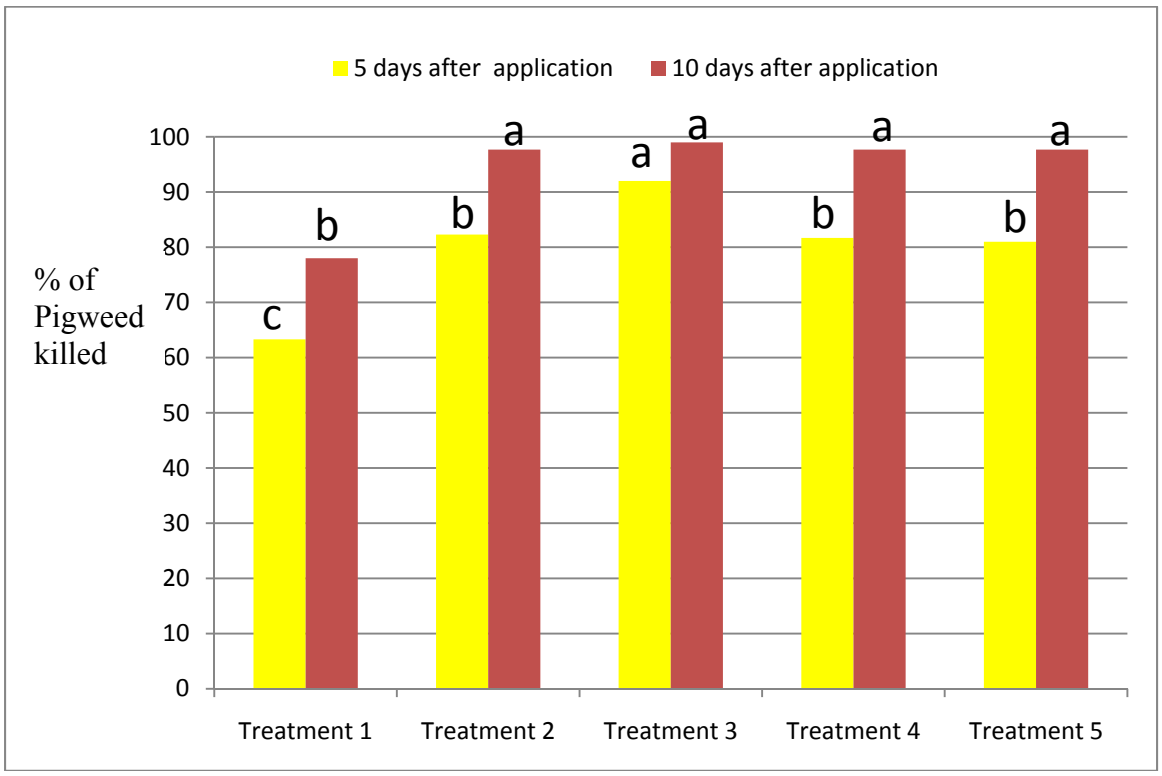

Figure 3: Pigweed killed from herbicide treatments

*Within each rating time, treatments with the same letter are not significantly different according to Tukey's test ($P < 0.05$)

Chapter V - Conclusion

Soybean production is very important to Gibson County and Tennessee as a whole. The control of the invasive weed palmer amaranth (pigweed) is becoming more important as this weed develops resistance to glyphosate and other herbicides. It is very important to control palmer amaranth populations in our agricultural fields due to the high seed rates these plants produce. Producers need to know which herbicide will best control their glyphosate resistant pigweeds with minimum damage to the soybean plant. Timing of glufosinate application is very important as pigweeds are rapidly growing plants that have to be dealt with promptly. Liberty Link® Soybean became commercially available for the 2009 growing season, but there were many questions about what would happen if different rates of glufosinate and mixtures with other herbicides were applied to the crop.

In this study, there were significant differences ($P < 0.0001$) among herbicides treatments for pigweed control. By 10 days after application, all treatments but the lowest rate (22 ounces per acre) of Ignite 280®, provided adequate (>97%) control of pigweed. There were also significant differences ($P < 0.0001$) for soybean injury. By 10 days after application, the Ignite 280® treatments were at 0% injury but the Ignite 280® + Cadet® 0.6 ounces per acre still had a damage rating of 20%.

The results of this study indicate that the best product and rate to use in the control of glyphosate resistant pigweed is Ignite 280® at 29 ounces per acre. This produced no significant damage to the soybean crop while controlling the rapidly growing palmer amaranth. The 44 ounce rate of Ignite also controlled pigweed with little or no damage to soybeans but the label on Ignite 280® states that only 44 ounces per acre

can be used per growing season. This would limit the producer to applying this product only once and having to rely on another product to control later emerging pigweed. A follow up trial should be done to look at two applications of 22 ounces each compared to single applications of 29 and 44 ounces per acre. Producers must keep up with new technologies in integrated weed management if they are to control glyphosate-resistant pigweed as well as other herbicide-resistant weeds.

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APPENDIX

Table A.1: Summary of ANOVA results for soybean injury 5 days after herbicide application.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Treatment	4	2971.1	742.8	152.6	< 0.0001
Block	2	32.4	16.2	3.3	0.0887
Error	8	38.9	4.9		
Corrected Total	14	3042.4			

Table A.2: Summary of ANOVA results for soybean injury 10 days after herbicide application.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Treatment	4	938.4	234.6	391.0	< 0.0001
Block	2	1.2	0.6	1.0	0.4096
Error	8	4.8	0.6		
Corrected Total	14	944.4			

Table A.3: Summary of ANOVA results for pigweed control 5 days after herbicide application.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Treatment	4	1292.9	323.2	46.6	< 0.0001
Block	2	22.5	11.3	1.6	0.2557
Error	8	55.5	6.9		
Corrected Total	14	1370.9			

Table A.4: Summary of ANOVA results for pigweed control 10 days after herbicide application.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Treatment	4	964.0	241.0	241.0	< 0.0001
Block	2	5.2	2.6	2.6	0.1561
Error	8	8.8	1.1		
Corrected Total	14	978.0			