Evaluating cover crops to determine the best management practice for the suppression of tall waterhemp and Italian ryegrass

By

Samuel R. Reeves

Approved by:

Daniel B. Reynolds (Major Professor)
Jason A. Bond (Committee Member)
J. Connor Ferguson (Committee Member)
William E. Maples (Committee Member)
Michael S. Cox (Graduate Coordinator)
Scott T. Willard (Dean, College of Agriculture and Life Sciences)

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Name: Samuel R. Reeves

Date of Degree: May 13, 2022

Institution: Mississippi State University

Major Field: Weed Science

Committee Chair: Daniel B. Reynolds

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To combat herbicide resistance among weeds, non-herbicide methods of control, such as cover crops, are becoming widely adapted. Experiments were conducted to determine how to effectively establish and manage cover crops in order to suppress tall waterhemp and Italian ryegrass and to assess their overall impact on soybean growth and yield. Various cover crop establishment methods were evaluated, and it was determined that interseeding at the R7 growth stage of soybean was the least effective method for proper cover crop establishment. Biomass data demonstrated that interseeding created the least amount of cover crop biomass, with no differences found among the other establishment methods that included drilling and sowing broadcast. At soybean planting timing, treatments with tillage had greater control of tall waterhemp than those without tillage. Wheat was shown to have the greatest weed suppressive capabilities, largely due to its ability to create high levels of residual biomass. Daikon radish produced the least biomass residue and had the poorest tall waterhemp control. The termination experiment of Elbon rye determined that treatments with rolling could impact soybean emergence and plant height largely due to dense biomass that lay flat onto the soil surface.

DEDICATION

This work is dedicated to my grandmother Betty Hart Swindle. Her love and never-quit attitude inspired me to always go after what I want in life. She taught me that quitting is never an option, and that success comes by hard work. She left school in the 8th grade to help aid the family and because of that she always wanted me to always further my education. I would not be the man I am today without her support. I hope that I too one day can be a positive influence for someone that achieves great success.

Betty Hart Swindle

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CHAPTER I

INTRODUCTION

Glyphosate tolerant soybean were introduced to row crop production in 1996 and provided a new mode of action for broad spectrum in season weed control (Padgett et al.1995). This, however, lead to the overuse of glyphosate spray application and lead to certain weeds developing glyphosate resistance (Kruger et al. 2009). Today, around thirty-eight weed species are resistant to glyphosate with around seventeen being found in agronomic row crop production (Heap and Duke 2018). Weeds that are of specific economic concern internationally, are of the genera *Amaranthus*, *Lolium*, *Conyza* and *Echinochloa* (Heap 2014). Specifically, tall waterhemp (*Amaranthus tuberculatus*) and Italian ryegrass (*Lolium perenne ssp. multiflorum*) are of great concern in Mississippi row crop production, due to their resistance to multiple herbicide modes of action. Tall and common waterhemp can grow upward of 3 meters (Trucco and Tranel 2011), produce up to 1 million seeds per plant (Nordby et al. 2007), and can reduce soybean (*Glycine max*) yield reduction by 56% when emerged at the same time as soybean (Steckel and Sprague 2004). In 2008, glyphosate resistant tall waterhemp was discovered in Washington County, Mississippi and was determined to be five-fold more glyphosate resistant than glyphosate susceptible tall waterhemp (Nandula et al. 2013). Norsworthy et al. 2014, found that Amaranthus species should have a “zero-tolerance” threshold to alleviate further colonization that have a direct farm economic impact. Another problematic weed in Mississippi row crop production, Italian ryegrass, is a short annual or biannual bunch grass that can grow 90 cm in height and can typically out compete surrounding species (Davies1928; Bond et al. 2014). The optimum growth timing for Italian ryegrass is during winter and early spring and can heavily compete with other species for sunlight, water and nutrients. It was found that two populations of Italian ryegrass were resistant to glyphosate at 0.84 and 1.68 kg ae ha^{-1}. Glyphosate resistant Italian ryegrass complicates preplant burndown applications in early season reduced-tillage row crop production systems (Nandula et al. 2007). Glyphosate has typically been used as a pre-plant burndown, over the top application, and sometimes as a harvest aid in Mississippi (Bond et al. 2014). Field and greenhouse experiments were conducted to determine glyphosate resistance levels of Italian ryegrass at different phenological stages. Their data concluded a linear relationship with phenological advances and glyphosate resistance (Christoffoleti et al. 2005), meaning as the plant continues to grow the more resistant to glyphosate it becomes.

Due to both Italian ryegrass and tall waterhemp becoming more widely resistant to glyphosate in Mississippi, a successful non herbicide treatment could provide growers with adequate control without developing greater herbicide resistance. A practice that hasn't been widely used since the wide adaptation of no-till practices, is deep-tillage. Deep tillage has shown to be an effective means to reduce *Amaranthus* species emergence by burying the seed to unfavorable depths to inhibit germination (DeVore et al. 2013). In a study conducted by (Farmer et al. 2017) it was found that a treatment of deep tillage compared to conventional, minimum, and no tillage systems resulted in 62, 67, and 73% reduction in *Amaranthus* emergence, respectively. Varying soil types has been shown to influence seed depth within the soil caused by tillage and can create different emergent outcomes (Swanton et al. 2000). In an Italian ryegrass study, tillage was shown to affect the seed bank, by creating uniform distribution within the soil and reduced Italian ryegrass populations, when compared to no-till systems (Guareschi et al.

2020). Cover crop use in agronomic row crop production is primarily used to reduce soil erosion, as well as to reduce the use of both fertilizer and herbicide applications (Creamer et al. 1996). One objective in using winter annual cover crops is to create an unfavorable environment for weed seed germination and establishment (Teasdale 1996). Winter annual cover crops can suppress weeds to where an early season herbicide is unwarranted and reduces the chance of weedy herbicide resistance (Norsworthy et al. 2012.) Cover crops can be broadcasted or drilled on or into the soil surface, normally post-harvest of the cash crop. Establishment methods such as interseeding the cover crop between the cash crop pre-harvest, can be an effective way to establish cover crop growth immediately after post-harvest, however, the practice has not been well established in the midsouthern region of the United States. Interseeding cereal rye into soybeans at the R7 growth stage resulted in the greatest ground coverage by the cover crop, as well as, providing 56% control of tall waterhemp (Calhoun 2019). Cover crops can be used in conjunction with a herbicide program allowing for optimum grower profitability. A study by (Loux et al. 2017) showed that cereal rye had the highest potential to reduce Amaranthus species populations with the combination of a comprehensive herbicide program. The combination of cover crop, and pre-emergent herbicides have been shown to greatly reduce grower profits potential. (Edwards 2015). (Devore et al. 2013) documented that when averaged over tillage, cereal rye cover crop reduced palmer amaranth emergence by 67% compared to a no cover crop treatment. Cover crop biomass is more influential on weed suppression, than an individual cover crop(s) capabilities to reduce weeds, due to nutrient and light competition (MacLaren et al. 2019). This aligns with an experiment conducted by (Teasdale et al. 1991) showing a correlation between cover crop biomass and weed reduction. Cover crop biomass residue can alter weed seed germination by light interception, affecting soil temperature and moisture, as well as allelopathic release from the cover crops (Creamer et al. 1996). However, cover crop residue alone cannot provide adequate weed control in cash crops (Teasdale et al. 1996; Reddy 2001).

To ensure cover crops do not directly affect cash crop capabilities, proper termination methods should be used. Cover crops can be self-terminated (senescence), mechanically terminated, chemically terminated, or a combination of both mechanical and chemical termination. Mechanical termination such as, rolling the cover crop, has shown to be an effective method to achieve desired termination percentage. Termination from rolling usually results from breaking, cutting, crushing, or crimping the cover crops stems. Rolling, creates a mulch on the soil surface that may last for a substantial period providing longer weed suppression capabilities (Creamer and Dabney 2002). It was found that crimper-rolling cereal crops at anthesis, resulted in the greatest covercrop control (Ashford and Reeves 2003). This corelates with other research that shows cereal rye is best controlled by rolling at the anthesis growth stage (Mirsky et al. 2009). Termination timing in cover crops is also important to reduce potential cover crop vs cash crop competition that could result in yield declination. Cereal rye biomass has been documented to increase by cause of later termination timing and earlier planting which directly influences weed biomass (Nord et al. 2012).

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CHAPTER II

UTILIZING VARIOUS COVER CROP MANAGEMENT PRACTICES FOR THE CONTROL OF TALL WATERHEMP AND ITALIAN RYEGRASS

ABSTRACT

Populations of tall waterhemp (*Amaranthus tuberculatus*) and Italian ryegrass (*Lolium perenne ssp. multiflorum*) are resistant to multiple herbicides, resulting in weed management challenges in soybean (*Glycine max*). Multiple field experiments were conducted at three locations across Mississippi to assess various cover crop(s), rates, mixtures, and establishment methods for the control of tall waterhemp and Italian ryegrass. The experiments consisted of a six by four factorial arrangement of treatments in an RCB design with factors being cover crops, and establishment methods. Cover crops evaluated included Elbon rye (134 kg ha^{-1}) , wheat (134 kg ha^{-1}), daikon radish (11 kg ha^{-1}) , Elbon rye (101 kg ha^{-1}) plus daikon radish (7 kg ha^{-1}), wheat (101 kg ha^{-1}) plus daikon radish (7 kg ha^{-1}) and a combination of Elbon rye (56 kg ha^{-1}), wheat (56 kg ha^{-1}) daikon radish (5.6 kg ha^{-1}). Establishment methods included: interseeding of the cover crop at the R7 soybean growth stage; broadcast of cover crop followed by (FB) tillage; tillage FB broadcast cover crops; and drilled. Weed control populations were recorded 0 to 28 days after planting (DAP) soybean. Cover crop biomass samples were collected, pre-termination of the cover crop. Daikon radishes offered the least weed control, regardless of establishment method. Wheat and wheat mixtures were the most consistent at suppressing tall waterhemp. Wheat also produced the most biomass which may be linked to its tall waterhemp suppression

capabilities. Interseeding at the R7 growth stage was least effective in establishing a cover crop for weed control purposes. Treatments with tillage provided greater control of tall waterhemp than those without tillage**.** Interseeding a cover crop was shown to be the most inconsistent method to establish a cover crop, and resulted in poor biomass production and yield. While it was the cheapest establishment method used, cost per percent control analysis determined it to be impractical due to expense from lack of weed control.

INTRODUCTION

The overuse of glyphosate has led to certain weed species evolving resistance (Kruger et al. 2009). Tall waterhemp (*Amaranthus tuberculatus*) and Italian ryegrass (*Lolium perenne ssp. multiflorum*) are problematic in Mississippi row crop production due to their competitiveness and resistance to many herbicides. Tall waterhemp, a summer annual, is highly competitive and can reduce soybean yields by as much as 56% (Steckel and Sprague 2004). Amaranthus spp. have the capabilities to produce up to 1 million seeds per plant (Nordby et al. 2007) that can lead to rapid colonization into a new area. The first documentation of glyphosate-resistant tall waterhemp in Mississippi was in 2008 and those populations were determined to be five times more resistant than glyphosate-susceptible tall waterhemp (Nandula et al. 2013). Italian ryegrass, a winter annual, is a bunch grass that can grow up to 90 cm and typically outcompetes surrounding species (Davies 1928; Bond et al. 2014). The optimum growing season for Italian ryegrass is during the winter months and competes with spring planted crops for sunlight, water and nutrients. In two locations in Mississippi, it was found that Italian ryegrass survived applications of glyphosate at rates of 0.84 and 1.68 kg ae ha^{-1} (Nandula et al. 2007). Herbicide methods of treatment have been previously researched to mitigate further herbicide resistance. Deep tillage has been shown to be effective in reducing *Palmer amaranth* by as much as 81 percent, in a two year period, by burying seed to unfavorable depths that inhibit germination (DeVore et al. 2013). Deep tillage when compared to conventional, minimum, and no tillage systems reduced *Amaranthus* species emergence by 62, 67, and 73 % (Farmer et al.2017). Italian ryegrass emergence can also be inhibited by deep tillage. One goal for using winter annual cover crops is to create an unfavorable environment for summer annual weeds to inhibit germination and establishment (Teasdale 1996). Winter annual cover crops can suppress weeds enough to eliminate the need for early-season herbicides (Norsworthy et al. 2012). In a cover crop economic study, it was reported that cover crops in a PRE herbicide program reduced profit margins when compared to cover crops in a post-emergent herbicide program (Edwards 2015). It was found that cereal rye and winter wheat cover crop programs included in a residual herbicide program had profit losses ranging from \$186.73 to \$290.11 and \$75.96 to 250.25 ha^{-1}. Cover crops can be broadcast onto the soil surface or drilled, post-harvest of the cash crop. Interseeding of the cover crop into the cash crop has been used by some growers in the northern regions of the United States but is not widely adopted into the southern region. In an study observing interseeding cover crops between various growth stages of soybean, it was determined that the R7 growth stage resulted in the greatest cover crop emergence and *Amaranthus* control (Calhoun 2019).

The objective of this research was to utilize tillage, cover crop establishment, and weed suppression capabilities in order to determine the best management practice for cover crop weed control. This research will help Mississippi row crop producers have success controlling tall waterhemp and Italian ryegrass with a cover crop while also enhancing profits.

MATERIALS AND METHODS

Treatments were arranged as a six by four factorial in a randomized complete block design with four replications. Factor A consisted of the six cover crops and the rate used ha^{-1}. Elbon rye (134 kg ha^{-1}) , VNS wheat (134 kg ha^{-1}), daikon radish (11 kg ha^{-1}) , Elbon rye (101 kg ha^{-1}) plus daikon radish (7 kg ha^{-1}),wheat (101 kg ha^{-1}) plus daikon radish (7 kg ha^{-1}) and a combination of Elbon rye (56 kg ha^{-1}), wheat (56 kg ha^{-1}) daikon radish (5.6 kg ha^{-1}). When calculating mixture seeding rates for cover crops it was important to ensure that the mixture was consistent among species, this was done by following NRCS cover crop mixture seeding recommendations. Factor B consisted of four establishment methods interseeding of the cover crop at the R7 soybean growth stage, broadcast of cover crop followed by (FB) tillage, tillage FB broadcast cover crops, and drilled. Interseeding of the cover crop was the only treatment that occurred preharvest, other treatments occurred after harvest of the previous year's soybean crop.

The cover crop experiment was implemented in the fall of 2019 and 2020 with data collection occurring the following spring at the time of soybean planting. Experiments were located at the Mississippi Agricultural & Forestry R.R. Foil Plant Science Research Center near Starkville, MS, (33°28'27" N 88°46'21" W), the Mississippi Agricultural & Forestry Black Belt Experiment Station near Brooksville, MS, (33°15'22" N 88°33'02" W) and at the Delta Research and Extension Center near Stoneville, MS (33°26'28.35" N 90°54'17.60" W). The soil series for Starkville was Marietta fine sandy loam (Fine-loamy, siliceous, active, thermic Fluvaquentic Eutrudepts) with a pH of 7.3, Brooksville soil series was Okolona silty clay (Fine, smectitic, thermic Oxyaquic Hapluderts) with a pH of 6.5 and Stoneville soil series was commerce silt clay loam (Fine-silty, mixed, superactive, nonacid, thermic Fluvaquentic Endoaquepts) with a pH of 6.9. Starkville and Brooksville experimental sites had a continuous soybean system with 101.6

cm row spacings. The Stoneville plot location was left fallow for year 2019. Minimal herbicides were previously used at these locations in order to increase tall waterhemp and Italian ryegrass production for future weed experiments. All locations were conducted on non-irrigated soil. It should be noted that while cover crops were incorporated at the Delta Research and Extension Center, in 2020, the cover crops did not survive winter frost leaving only two cover crop site years for 2021.

The treatments of interseeded, broadcast FB tillage, and tillage FB broadcast were all broadcast by a chest type broadcast seed spreader to ensure appropriate distribution among plots. The drilled treatments were incorporated with a seed drill (Great Plains 1520, Great Plains Mfg., Inc., 1525 East North St., Salina, KS 6740). The drill was calibrated to ensure the correct seeding rate was applied. In 2020, a fertilizer regimen was added to create more biomass, due to the previous year having a lack of consistent biomass. Urea fertilizer (46-0-0) at 37 kg nitrogen ha^{-1} was applied in the fall at the Starkville and Brooksville locations. Cover crops were terminated two weeks prior to planting with glyphosate at 1.26 kg ha^{1}. Soybean were planted at 321,100 seeds ha^{1}. In 2020, and 2021 Asgrow soybean AG46X6 (Asgrow seed, Bayer, 800 N Lindbergh Blvd, Creve Coeur, MO 63141) soybean were planted among all locations. Plot dimensions at Starkville and Brooksville plots were 12.19 m x 6 m with 76.2 cm row spacings. Plots at Stoneville were 9.14 m x 4.06 m with 101.6 cm row spacings. Visible weed control ratings, were collected 0, 14, 21, and 28 days after planting (DAP), or until weeds were no longer controlled. Visible control ratings were in a scale from 0-100, 100 having complete control and 0 representing no control of weeds. When various plots consistently had a visual rating of 0 prior to 28 DAP, visual control data collection was concluded. The Starkville and Brooksville locations focused on the presence of tall waterhemp (*Amaranthus tuberculatus*) while the

Stoneville location focused on Italian ryegrass (*Lolium perenne*). Since Italian ryegrass is a winter annual weed control data had to be collected differently. Plot density percentage ratings of Italian ryegrass were collected 0, 14, 21, and 28 days after planting (DAP). Cover crop biomass samples were collected in the spring of 2021 before termination with a m^2 quadra for each experimental unit. Cover crop biomass samples were not collected for sites in 2020. The cover crop biomass weight was then recorded and placed in a dryer for 3 days with a constant temperature between 68-71° and reweighed to collect dry biomass. Weed densities were determined with a m^2 quadra for each experimental unit 28 DAP or when visual weed control ratings were consistently rated as 0 control throughout the plots. Weight was recorded for the weed biomass and then placed in a dryer for 3 days with a constant temperature between 68-71° C and reweighed to collect dry weed biomass.

Aerial images were collected throughout the growing season in 2021 at the Starkville and Brooksville locations using an unmanned aerial vehicle (UAV) with a rededge Mx (Micasense, 1300 N Northlake Way #100 Seattle, WA 98103) to sense vegetative indices. Soil adjusted vegetative index (SAVI) is calculated by the equation $SAVI = NIR - \frac{RED}{(NIR+RED+L)} * (1 + L)$.

Aerial images were downloaded into an orthomosaic and the SAVI was calculated using Pix4Dmapper 4.5.4 (Pix4D, Route de Renens 24 1008 Prilly, Switzerland). An RGB-colored map of the SAVI was exported to ArcGIS Pro (Esri, 380 New York Street Redlands, CA 92373-8100) to extract an average SAVI value for each plot using the workflow developed by (Wilber 2021). Data collected from the orthomosaic was analyzed separately by location. When spring data collection was concluded, plots were treated with 1.26 glyphosate (Roundup Powermax, Bayer, 800 N Lindbergh Blvd, Creve Coeur, MO 63141) plus dicamba at 0.558 kg ae ha^{-1}

(Extendimax, Bayer, 800 N Lindbergh Blvd, Creve Coeur, MO 63141) to control weeds.

Soybean seedling density was recorded 14 days after emergence by counting the number of plants in two random meter sections in rows two, three, six and seven, and converting plants m^2. Plant heights were taken 14 days after emergence and at maturity. Soybean yields were collected at Starkville and Brooksville.

A partial budget was also constructed among the different treatments to determine cost differentials among the various establishment methods and cover crops. Purchase price was used to calculate total cover crop cost ha^{-1} and establishment method expenses were determined from the 2020 budget report by The Department of Agricultural Economics at Mississippi State University (MSU,2020). University To determine establishment method cost per percent control; the prices for each method ha^{-1}, determined from The Mississippi State Agricultural Department 2020 budget report were divided by establishment method control percentage of tall waterhemp and Italian ryegrass. The cost per percent control of establishment methods and cover crops were then added together to give a total cost per percent control a hectare

All data were analyzed in SAS 9.4 using ANOVA mixed effect model (SAS Institute Inc., 100 SAS Campus Drive Cary, NC 27513-2414).

RESULTS AND DISCUSSION

TALL WATERHEMP CONTROL

Our results demonstrated that interseeding cover crops at the R7 growth stage in soybean was the least effective method in establishing a cover crop to reduce tall waterhemp (Table 2.1) At soybean planting, treatments with tillage had greater control of tall waterhemp which agrees with research that showed deep tillage had greater effect upon *Amaranthus* control when compared to conventional tillage and no-till systems (Farmer et al. 2017). Daikon radish was the least effective in controlling tall waterhemp (Table 2.2). Wheat and wheat mixtures were most consistent at suppressing tall waterhemp. Wheat also produced the most biomass which may be linked to its tall waterhemp suppression capabilities. Daikon radish produced the least biomass and had the lowest tall waterhemp control. Previous research has shown biomass to be the greatest influencer for cover crop weed suppression (MacLaren, et al. 2019). When compared to wheat, Elbon rye biomass was lower, but when in mixture with wheat biomass increased by 1,702 kg ha^{-1}. This infers that most of the biomass from the mixture of wheat and rye would be from the wheat. Interseeding was determined to create the least cover crop biomass with no differences between other establishment methods. Cover crop and establishment method did not show detrimental influence regarding soybean seedling density and height, however, yield differences were detected. Treatments with tillage led to the greatest yield with drilling having the least soybean yield. The various cover crops used also showed differences in yield data with the Elbon rye plus radish mixture having the greatest yield, while wheat and radish mixture had the least amount of yield.

An interaction of cover crop and establishment method was detected for tall waterhemp biomass (Table 2.3). Plots treated with wheat, and Elbon rye plus wheat plus daikon radish broadcasted FB tillage, were shown to have the least tall waterhemp biomass across year and location. Radish that were drilled were shown to allow the greatest tall waterhemp biomass. These data can be compared to the weed control results, with the greatest visual control corresponding to least tall waterhemp biomass per m^2 and the lowest percent control treatments having the greatest amount of tall waterhemp biomass per m^2. Drilling cover crops resulted in the greatest stand count of tall waterhemp,with treatments with tillage having the lowest tall waterhemp plot count.

Processed data from 2021 UAV images 28 DAP determined that Daikon radish plots had the greatest SAVI value, (Table 2.4) with wheat and wheat mixtures having the least SAVI values. The processed data determined that there were no differences among establishment methods at the Starkville location, but differences did occur at the Brooksville location. Interseeding was shown to have the greatest SAVI value at the Brooksville location (Table 2.5). The UAV aerial imaging data correlates to the weed control data by cover crop and establishment methods for 2021 and we can infer that the higher index values represent an influx of tall waterhemp. UAV images for Starkville (Figure 2.1) and Brooksville (Figure 2.2) were made with plots being designated by treatment numbers (Table 2.6). SAVI index legend is also listed to designate the specific coloring description within the images (Figures 2.3,2.4).

ITALIAN RYEGRASS CONTROL

The plot density percentage analysis of Italian ryegrass determined that interseeding was the least effective method in controlling Italian ryegrass with drilled wheat and wheat mixtures having the greatest effect up to 28 DAP (Table 2.7). An interaction occurred across all data collection timings between cover crops and establishment methods with interseeding, regardless of what cover crop was used, having the least effect on Italian ryegrass suppression. Weed biomass samples determined that interseeding had the greatest grams/m^2 of Italian ryegrass with no differences being found amongst the other three treatments. Interseeding cover crops was determined to allow the greatest stand count of Italian ryegrass per m^2 (Table 2.8).

PARTIAL BUDGET

Using the purchase price for the cover crops and rates (Table 2.9) and establishment method expense (Table 2.10) a total cost ha^{-1} was created for both locations (Tables 2.11)

(Tables 2.12). Since fertilizer was applied after the first year of study, fertilizer cost was averaged between the two years for the tall waterhemp locations. The Italian ryegrass location only had one site year with no fertilize and therefore was not added to the budget. Interseeding was the cheapest establishment method used. No substantial differences in treatment expenses were present between drilling, and methods with tillage and broadcasting. Elbon rye was the most expensive cover crop used and radish was the cheapest. While radish was the cheapest cover crop option, overall weed control was poor. Wheat was \$60.77 less ha^{-1} than Elbon rye but was \$23.21 more ha^{-1} than radish.

A cost per percent control was calculated to determine the best overall treatment for weed control and monetary gain. This was calculated in two parts since two factors were used. The cost ha^{-1} of the six cover crop rates and mixtures were divided by their impact on weed control of either tall waterhemp or Italian ryegrass to give a cost percent control analysis. Drilling wheat was shown to be the favorable option regarding cost per percent control of tall waterhemp (Table 2.13) and Italian ryegrass (Table 2.14). Interseeding alone was the cheapest establishment method used but resulted in the lowest control of tall waterhemp and Italian ryegrass. The poor control of tall waterhemp and Italian ryegrass is why a steep inflation of expense between interseeding cost and cost per percent control, exists.

CONCLUSIONS

Cover crops incorporated with certain establishment methods can be an effective practice to suppress tall waterhemp and Italian ryegrass but cannot solely provide enough weed control for Mississippi row crop production. This correlates to other research that states cover crop usage alone cannot control weeds and must be collaborated with other control measures (Teasdale et al. 1996; Reddy 2001). Our research showed the detrimental effect tillage had upon tall waterhemp populations, which was also found in other studies by Farmer et al.2017. Interseeding at the R7 growth stage was the least effective method for establishing a cover crop. With early soybean planting dates becoming more common in Mississippi, the R7 growth stage can develop in a period of warm temperatures resulting in non-optimum timing for cover crop interseeding. While interseeding was shown to be the cheapest establishment method used, the risk of cover crop failure is too great to put into practice. Daikon radish was the least effective cover crop to suppress tall waterhemp emergence. The Daikon radish variety did not have the hardiness to survive winter frost, leaving bare ground to minimal biomass residue to inhibit spring tall waterhemp emergence. Wheat produced the greatest biomass and was the most consistent in controlling tall waterhemp and Italian ryegrass. This agrees with research by Teasdale et al. 1991 that stated there is a direct correlation between cover crop biomass and weed suppression. The low expense cost of wheat also makes it an ideal cover crop for weed suppression and to generate a greater overall return on investment. Future research should include various cereal cover crop rates and mixtures to determine an economically sustainable herbicide resistance management plan. Recommendations for Mississippi growers looking to add a non-herbicide method of control for weeds is to drill wheat at 134 kg ha^{-1} with a non-production fertilizing plan to limit expense and to aid in creating a dense biomass that can inhibit tall waterhemp germination and compete heavily with Italian ryegrass.

Table 2.1 Establishment Method Pulled Over Cover Crop and its Effect Upon Tall Waterhemp Control, Stand Count, Cover Crop Biomass and Soybean Yield

Tall Waterhemp Control				Tall Waterhemp Stand Count	Cover Crop Biomass	Soybean Yield
	DAP[a] (%)Visual Control			--(Species per m^2)--	-------(kg ha^{-1})-------	
Est. method	At Planting	14 DAP	21 DAP	28 DAP	CBT[b]	CAH[c]
Interseeded	83 C	59 B	38 B	24 AB	3105 B	2623 AB
Broadcast FB tillage	90 AB	70 A	48 A*	16 B	4445 A	2757 A*
Tillage FB broadcast	92 A*	71 A*	48 A	16 B	5158 A*	2690 A
Drilled	87 B	68 A	48 A	32 A*	5040 A	2555 B

*Asterisk indicates differences among treatments, within columns, according to LSMEANS (α=0.05).

[a]Abbreviations: DAP; days after planting: CBT; collected before termination: CAH; collected at harvest

Table 2.2 Cover Crop Rates and Mixtures Pooled Over Est. Method and its Effect Upon Tall Waterhemp Control, Tall Waterhemp biomass, and Soybean Yield

	DAP[a] (%)Visual Control			FCCB[b]	DCCB[c]	Soybean Yield
Cover Crop	At Planting	14 DAP	21 DAP	--------(kg ha^{-1})---------		
Elbon rye	88 A	62 C	42 B	3238.7 B	1125.1 CD	2680 ABC
Wheat	90 A*	76 A*	58 A*	5755 A*	2108.3 A*	2644 ABC
Radish	82 B	55 D	29 C	1986.2 B	628.7 D	2730 AB
Elbon rye + radish	88 A	66 BC	42 B	4764 A	1534.6 BC	2782 A*
Wheat + radish	90 A	72 A	53 A	5967.7 A*	2188 A	2531 C
Elbon rye + wheat + radish	90 A	71 AB	50 AB	4940 A	1878.7 AB	2575 BC

*Asterisk indicates differences among treatments, within columns, according to LSMEANS (α=0.05).

[a]Abbreviations: DAP; days after planting: FCCB; fresh cover crop biomass: DCBB; dried cover crop biomass

Table 2.3 The Interaction of Cover Crop Type and Establishment Method on Tall Waterhemp Biomass Pooled Across Year and Location

Cover Crop	Tall waterhemp biomass		
	Est. method	FTWB[b] (grams per m^2)	DTWB[C] (grams per m^2)
Elbon rye	Interseeded	58.8 BC	12 B-E
	Broadcast FB tillage	40.8 BC	7.2 CDE
	Tillage FB broadcast	114.8 B	20 B
	Drilled	86.4 BC	15.6 B-E
Wheat	Interseeded	53.2 BC	9.6 B-E
	Broadcast FB tillage	34.4 C	6 DE
	Tillage FB broadcast	20.8 BC	3.2 D
	Drilled	52.8 BC	8.4 B-E
Radish	Interseeded	86.4 BC	17.2 BCD
	Broadcast FB tillage	81.2 BC	18.4 BCD
	Tillage FB broadcast	61.6 BC	7.6 B-E
	Drilled	239.2 A	36.4 A
Elbon rye +radish	Interseeded	110 BC	19.6 BC
	Broadcast FB tillage	110.4 BC	18.4 BCD
	Tillage FB broadcast	49.2 BC	7.6 B-E
	Drilled	42 BC	8 B-E
Wheat +radish	Interseeded	52 BC	10.4 B-E
	Broadcast FB tillage	48 BC	6 DE
	Tillage FB broadcast	51.2 BC	10 B-E
	Drilled	51.6 BC	9.6 B-E
Elbon rye + wheat + radish	Interseeded	54 BC	10.8 B-E
	Broadcast FB tillage	26.8 C	3.8 D
	Tillage FB broadcast	44.8 BC	7.6 B-E
	Drilled	52.4 BC	10 B-E

[a] Tall waterhemp field biomass means within the column followed by similar letters are not significantly different based on LSMEANS at (α=0.05).
[b] Abbreviations: FTWB; fresh tall waterhemp biomass: DTWB; dried tall waterhemp biomass

Table 2.4 2021 SAVI Values of Six Cover Crops at Starkville and Brooksville Pooled Over Est. Method

	Starkville	Brooksville
Cover crop	SAVI values	
Elbon rye	0.1822 B	0.4185 AB
Wheat	0.1401 D	0.3805 C
Radish	0.2465 A*	0.4442 A*
Elbon rye + radish	0.1716 BC	0.4060 BC
Wheat + radish	0.1701 BC	0.3885 C
Elbon rye + wheat + radish	0.1550 CD	0.4043 BC

*Asterisk indicates differences among treatments, within columns, according to LSMEANS (α=0.05).

The closer the index value is to 1, the more vegetation is present

Table 2.5 Brooksville Soil Adjusted Vegetative Index Values (SAVI) of Four Establishment Methods Pooled over Cover Crop

Establishment method	SAVI values
Interseeded	0.4240 A*
Broadcast FB tillage	0.4092 AB
Tillage FB broadcast	0.3982 B
Drilled	0.3966 B

*Asterisk indicates differences among treatments, within columns, according to LSMEANS (α=0.05).
The closer the index value is to 1, the more vegetation is present.

Table 2.6 Cover Crop Treatments, Rate, and Establishment Method for All Sights and Years

Treatment Number	Cover Crop	Rate kg ha^{-1}	Establishment Method
1	Elbon rye	134	Interseeding
2	Elbon rye	134	Broadcast FB Tillage
3	Elbon rye	134	Tillage FB Broadcast
4	Elbon rye	134	Drilled
5	Wheat	134	Interseeding
6	Wheat	134	Broadcast FB Tillage
7	Wheat	134	Tillage FB Broadcast
8	Wheat	134	Drilled
9	Daikon radish	11	Interseeding
10	Daikon radish	11	Broadcast FB Tillage
11	Daikon radish	11	Tillage FB Broadcast
12	Daikon radish	11	Drilled
13	Elbon rye + Daikon radish	100 + 7	Interseeding
14	Elbon rye + Daikon radish	100 + 7	Broadcast FB Tillage
15	Elbon rye + Daikon radish	100 + 7	Tillage FB Broadcast
16	Elbon rye + Daikon radish	100 + 7	Drilled
17	Wheat + Daikon radish	100 + 7	Interseeding
18	Wheat + Daikon radish	100 + 7	Broadcast FB Tillage
19	Wheat + Daikon radish	100 + 7	Tillage FB Broadcast
20	Wheat + Daikon radish	100 + 7	Drilled
21	Elbon rye + Wheat + Daikon radish	50 + 50 + 5.6	Interseeding

Table 2.6 (Continued)

Treatment Number	Cover Crop	Rate kg ha^{-1}	Establishment Method
22	Elbon rye + Wheat + Daikon radish	50 + 50 + 5.6	Broadcast FB Tillage
23	Elbon rye + Wheat + Daikon radish	50 + 50 + 5.6	Tillage FB Broadcast
24	Elbon rye + Wheat + Daikon radish	50 + 50 + 5.6	Drilled
25	Untreated	N/A	N/A

Table 2.7 Interaction of Cover Crop Type and Establishment Method on The Control of Italian Ryegrass

		Italian ryegrass plot density %			
Cover Crop	Est. Method	At Planting	14 DAP[b]	21 DAP	28 DAP
Elbon rye	Interseeded	95 A	94 A*	90 A*	86 A*
	Broadcast FB tillage	59 EFG	48 E-H	31 FGH	13 C
	Tillage FB broadcast	54 EFG	49 E-H	31 FGH	16 C
	Drilled	60 DEF	46 E-I	29 E-H	15 C
Wheat	Interseeded	89 A-D	90 ABC	75 AB	61 B
	Broadcast FB tillage	29 HI	26 HIJ	18 FGH	10 C
	Tillage FB broadcast	23 I	19 J	19 FGH	6 C
	Drilled	26 HI	25 HIJ	13 H	5 C
Daikon radish	Interseeded	98 A	95 AB	85 AB	76 AB
	Broadcast FB tillage	74 B-E	71 A-E	36 E-H	16 C
	Tillage FB broadcast	76 A-E	70 B-E	49 CDE	25 C
	Drilled	63 EFG	53 D-G	29 E-H	20 C
Elbon rye + Daikon radish	Interseeded	70 DEF	75 A-D	64 BCD	59 B
	Broadcast FB tillage	71 CDE	64 CDE	36 E-H	20 C
	Tillage FB broadcast	69 DEF	69 B-E	48 CDE	19 C
	Drilled	66 DEF	63 DEF	41 DEF	21 C
Wheat + Daikon radish	Interseeded	96 AB	96 A	91 A	71 AB
	Broadcast FB tillage	55 EFG	29 G-J	14 GH	5 C
	Tillage FB broadcast	48 FG	43 F-J	38 EFG	20 C
	Drilled	30 HI	28 G-J	15 GH	4 C
Elbon rye + wheat + Daikon radish	Interseeded	94 ABC	92.5 ABC	68 AB	60 B
	Broadcast FB tillage	25 HI	25 HIJ	20 FGH	5 C
	Tillage FB broadcast	44 HIJ	44 E-H	34 E-H	7 C
	Drilled	30 HI	21 IJ	15 GH	6 C

[a]Italian ryegrass plot density means within the column followed by similar letters are not significantly different based on LSMeans at (α=0.05)
[b]Abbreviations: DAP; days after planting

Table 2.8 Field biomass and Stand Count of Italian Ryegrass Influenced by Four Est. Methods

Est. method	Italian ryegrass Biomass ----------(grams m^2)----------	Italian ryegrass Stand Count -------(Species per m^2)-------
	28 DAP[a]	
Interseeded	52 A*	120A*
Broadcast FB tillage	16 B	40 B
Tillage FB broadcast	16 B	32 B
Drilled	12 B	32 B

*Asterisk indicates differences among treatments, within columns, according to LSMEANS (α=0.05).

[a]Abbreviations: DAP; days after planting

Table 2.9 Cover Crop cost per ha^{-1} based upon local seed purchase price and seeding rate

Cover Crop	Seeding rate kg ha^{-1}	-------($ ha^{-1})-------
Elbon rye	134	$133.38
Wheat	134	$72.61
Daikon radish	11	$49.40
Elbon rye + Daikon radish	101 + 7	$129.68
Wheat + Daikon radish	101 + 7	$84.10
Elbon rye + Wheat +Daikon radish	56 + 56 + 5.6	$110.53

Table 2.10 MSU Budget for Applied Establishment Treatment ($) ha^{-1}

Establishment Method	($) ha^{-1}
Rotary Spreader	$10.47
Tillage	$29.86
Grain drill	$40.68
Fertilizer	$17.45

Table 2.11 Establishment methods and cover crop $/ha^{-1}for Tall Waterhemp Locations

Cover Crop	Est. method	Treatment cost
		----($/ha^{-1})----
Elbon rye	Interseeded	161.30
	Broadcast FB tillage	191.17
	Tillage FB broadcast	191.17
	Drilled	191.76
Wheat	Interseeded	100.54
	Broadcast FB tillage	130.40
	Tillage FB broadcast	130.40
	Drilled	131.00
Daikon radish	Interseeded	77.32
	Broadcast FB tillage	107.19
	Tillage FB broadcast	107.19
	Drilled	107.78
Elbon rye + Daikon radish	Interseeded	157.60
	Broadcast FB tillage	187.46
	Tillage FB broadcast	187.46
	Drilled	188.05
Wheat + Daikon radish	Interseeded	112.03
	Broadcast FB tillage	141.89
	Tillage FB broadcast	141.89
	Drilled	142.48
Elbon rye + wheat + Daikon radish	Interseeded	138.46
	Broadcast FB tillage	168.32
	Tillage FB broadcast	168.32
	Drilled	168.91

Table 2.12 Establishment methods and cover crop \$/ha^{-1} for Italian Ryegrass Location

Cover Crop	Est. method	Treatment cost
		----(\$/ha^{-1})----
Elbon rye	Interseeded	143.85
	Broadcast FB tillage	173.72
	Tillage FB broadcast	173.72
	Drilled	174.31
Wheat	Interseeded	83.09
	Broadcast FB tillage	112.95
	Tillage FB broadcast	112.95
	Drilled	113.55
Daikon radish	Interseeded	59.87
	Broadcast FB tillage	89.74
	Tillage FB broadcast	89.74
	Drilled	90.33
Elbon rye + Daikon radish	Interseeded	140.15
	Broadcast FB tillage	170.01
	Tillage FB broadcast	170.01
	Drilled	170.60
Wheat + Daikon radish	Interseeded	94.58
	Broadcast FB tillage	124.44
	Tillage FB broadcast	124.44
	Drilled	125.03
Elbon rye + wheat + Daikon radish	Interseeded	121.01
	Broadcast FB tillage	150.87
	Tillage FB broadcast	150.87
	Drilled	151.46

Table 2.13 Cover Crop Type and Establishment Method Cost Per Control % of Tall Waterhemp ha^{-1}, Pooled Over Location and Year

		Tall waterhemp cost per control %		
Cover Crop	Est. Method	At Planting	14 DAP[a]	21 DAP
Elbon Rye	Interseeded	$ 2.31	$3.27	$4.84
	Broadcast FB tillage	$ 2.62	$3.66	$5.39
	Tillage FB Broadcast	$2.61	$3.65	$5.39
	Drilled	$2.30	$3.20	$4.69
Wheat	Interseeded	$1.58	$1.90	$2.53
	Broadcast FB tillage	$1.90	$2.29	$3.09
	Tillage FB Broadcast	$1.89	$2.28	$3.09
	Drilled	$1.59	$1.92	$2.59
Daikon Radish	Interseeded	$1.44	$2.14	$3.99
	Broadcast FB tillage	$1.76	$2.52	$4.54
	Tillage FB Broadcast	$1.75	$2.52	$4.54
	Drilled	$1.41	$2.01	$3.52
Elbon rye + Daikon radish	Interseeded	$2.26	$3.03	$4.75
	Broadcast FB tillage	$2.58	$3.42	$5.30
	Tillage FB Broadcast	$2.57	$3.41	$5.30
	Drilled	$2.26	$2.99	$4.60
Wheat + Daikon radish	Interseeded	$1.71	$2.16	$2.96
	Broadcast FB tillage	$2.02	$2.55	$3.52
	Tillage FB Broadcast	$2.01	$2.54	$3.52
	Drilled	$1.72	$2.16	$2.97
Elbon rye + wheat + Daikon radish	Interseeded	$2.00	$2.56	$3.65
	Broadcast FB tillage	$2.32	$2.70	$4.21
	Tillage FB Broadcast	$2.31	$2.69	$4.21
	Drilled	$2.01	$2.31	$3.62

[a]Abbreviations: DAP; days after planting

Table 2.14 Cover Crop Type and Establishment Method Cost Per Control % of Italian ryegrass for 2020 ha^{-1}

		Italian Ryegrass cost per control %			
Cover Crop	Est. Method	At Planting	14 DAP[a]	21 DAP	28 DAP
Elbon Rye	Interseeded	$28.77	$23.98	$14.39	$10.28
	Broadcast FB tillage	$4.24	$3.34	$2.52	$2.00
	Tillage FB Broadcast	$3.78	$3.41	$2.52	$2.07
	Drilled	$4.36	$3.23	$2.46	$2.05
Wheat	Interseeded	$7.55	$8.31	$3.32	$2.13
	Broadcast FB tillage	$1.59	$1.53	$1.38	$1.26
	Tillage FB Broadcast	$1.47	$1.39	$1.39	$1.20
	Drilled	$1.53	$1.51	$1.31	$1.20
Daikon Radish	Interseeded	$29.94	$11.97	$3.99	$2.49
	Broadcast FB tillage	$3.45	$3.09	$1.40	$1.07
	Tillage FB Broadcast	$3.74	$2.99	$1.76	$1.20
	Drilled	$2.44	$1.92	$1.27	$1.13
Elbon rye + Daikon radish	Interseeded	$4.67	$5.61	$3.89	$3.42
	Broadcast FB tillage	$5.86	$4.72	$2.66	$2.13
	Tillage FB Broadcast	$5.48	$5.48	$3.27	$2.10
	Drilled	$5.02	$4.61	$2.89	$2.16
Wheat + Daikon radish	Interseeded	$23.65	$23.65	$10.51	$3.26
	Broadcast FB tillage	$2.77	$1.75	$1.45	$1.31
	Tillage FB Broadcast	$2.39	$2.18	$2.01	$1.56
	Drilled	$1.79	$1.74	$1.47	$1.30
Elbon rye + wheat + Daikon radish	Interseeded	$20.17	$17.29	$3.78	$3.03
	Broadcast FB tillage	$2.01	$2.01	$1.89	$1.59
	Tillage FB Broadcast	$2.69	$2.69	$2.29	$1.62
	Drilled	$2.16	$1.92	$1.78	$1.61

[a]Abbreviations: DAP; days after planting

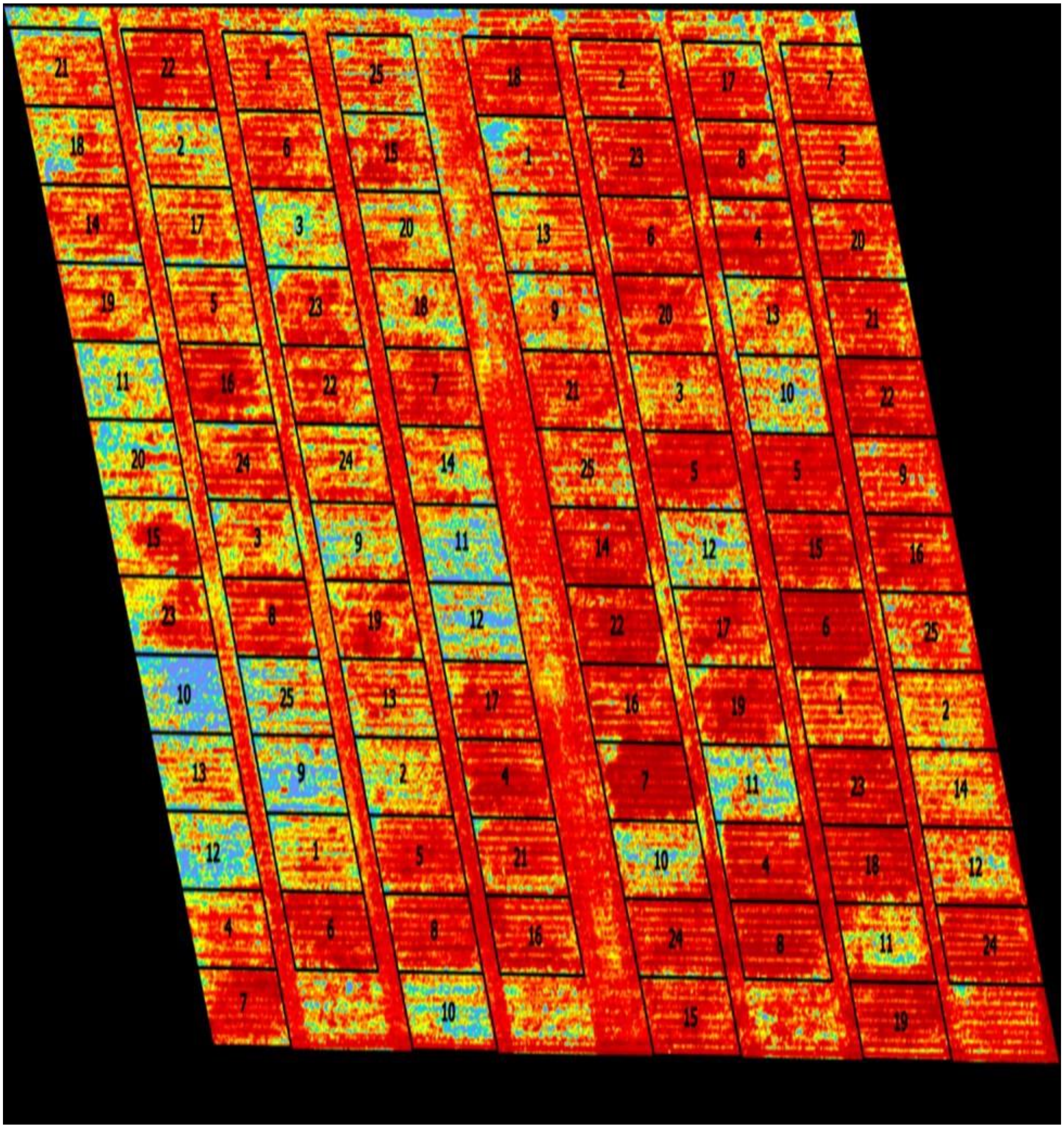

Figure 2.1 Starkville 2021 UAV Aerial Plot Image of Starkville 28 DAP

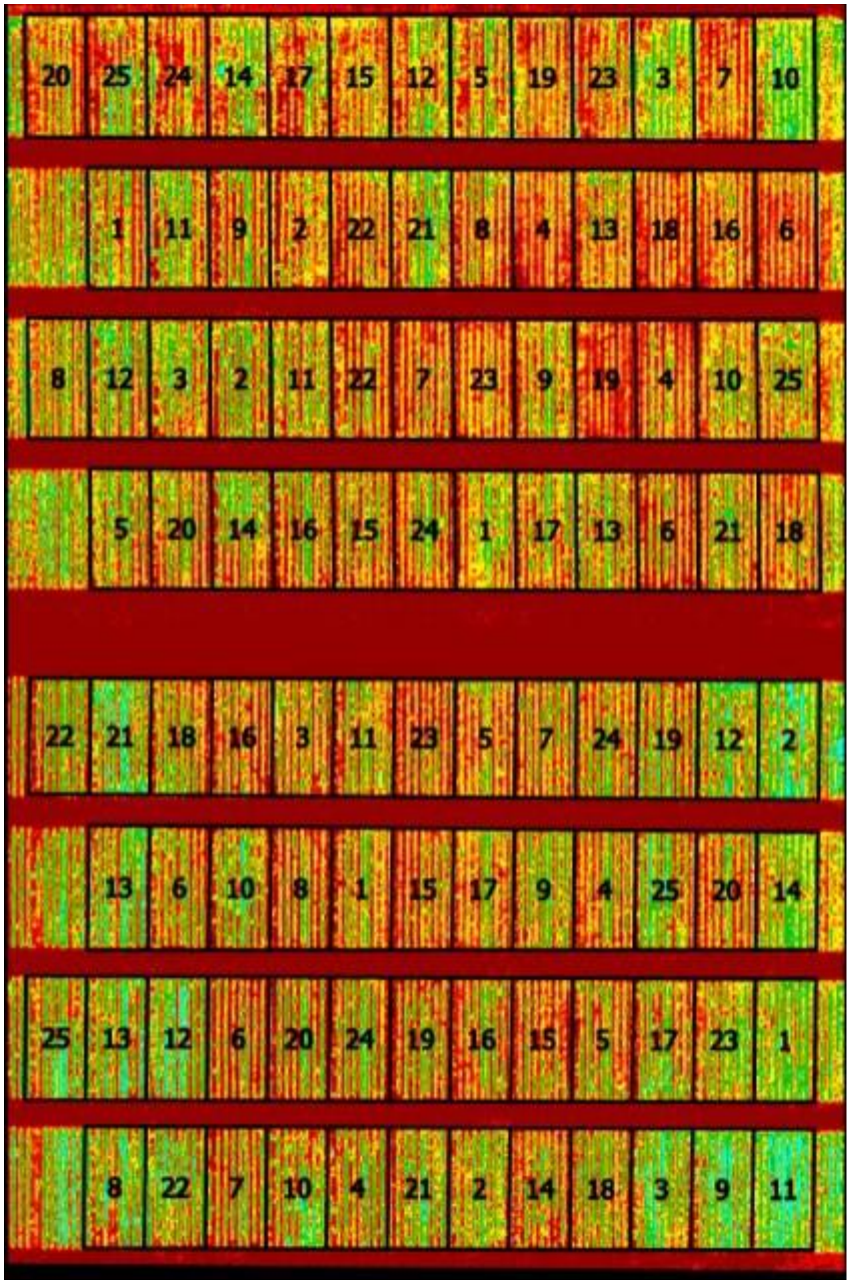

Figure 2.2 2021 UAV Aerial Plot Image of Brooksville 28 DAP

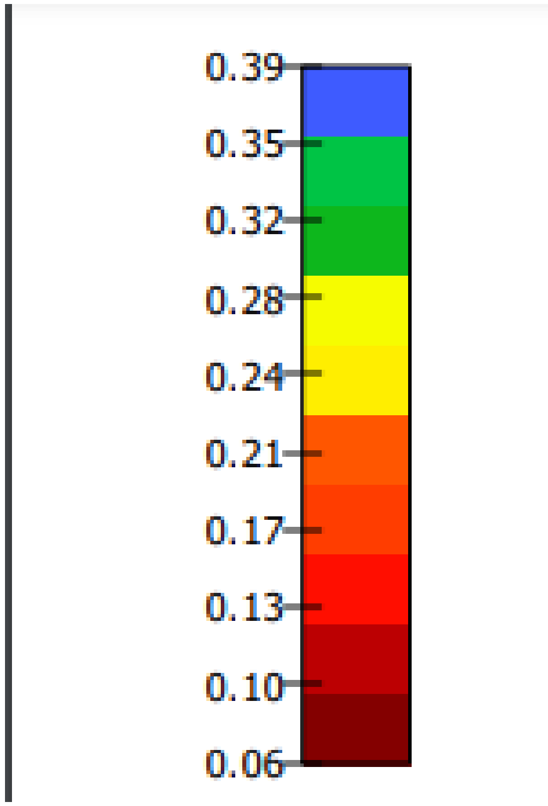

Figure 2.3 Starkville SAVI Values to Depict Differences for (Figure 2.1)

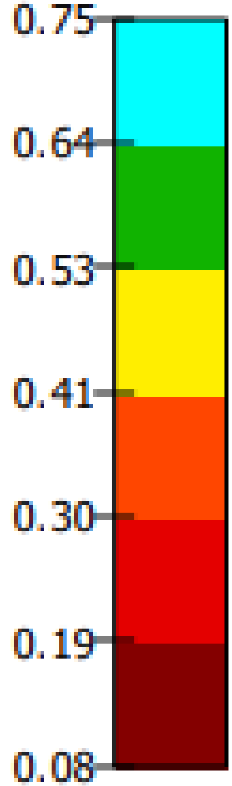

Figure 2.4 SAVI Values to Depict Differences for (Figure 2.2)

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CHAPTER III

TERMINATION EFFECTIVENESS OF A CEREAL RYE COVER CROP AND ITS IMPACT ON SOYBEAN ESTABLISHMENT

ABSTRACT

Termination timing and method can have an impact on weed suppression and soybean establishment. Elbon rye (*Secale cereal*) has physiological properties that can suppress weeds. The objective was to determine the best termination timing and method for control of tall waterhemp (*Amaranthus tuberculatus*) and Italian ryegrass (*Lolium multiflorum*) to supplement Elbon rye weed suppressive capabilities. Elbon rye was drilled at a rate of 134 kg ha^{-1} at three locations across Mississippi. The experiment was arranged as RCB design among 7 treatments. Weed control ratings were taken 0 to 28 days after planting (DAP). Soybean stand counts were also collected and were harvested at the end of the growing season. All data were analyzed using SAS 9.4 at alpha = 0.05. Terminations treatments were shown to have minimal or no effect on weed control, however treatments that included termination by rolling had variation between years with soybean development and yield.

INTRODUCTION

Cover crop usage is becoming a common practice to reduce the need for herbicide and fertilizer applications. Cover crop biomass residue has been shown to alter weed seed germination by light interception, disruption in soil temperature and moisture, as well as, allelopathic release (Creamer et al. 1996). However, cover crop residue alone cannot provide adequate weed control in cash crops (Teasdale,1996; Reddy,2001). To further enhance cover crop weed suppression capabilities, mechanical and chemical applications can be used in conjunction with cover crops. Cover crops can be self-terminated (senescence), mechanically terminated, chemically terminated, or a combination of both mechanical and chemical termination. Mechanical termination such as, rolling the cover crop, has shown to be an effective method to achieve desired termination percentage. Termination from rolling usually results from breaking, cutting, crushing, or crimping the cover crops. Rolling, creates a mulch on the soil surface that will last for a substantial period during the cash crop growing season that can provide longer weed suppression capabilities (Creamer and Dabney 2002). (Ashford and Reeves 2003) found that crimper-rolling cereal crops at anthesis, resulted in the highest kill percentage of the cover crop. This corelates with other research that shows that cereal rye is best controlled by rolling at the anthesis growth stage (Mirsky et al. 2009). Cover crop termination timing is also important to reduce potential cover crop vs cash crop competition that could result in yield declination. Cereal rye biomass has been documented to increase by cause of later termination timing and earlier planting which directly influences weed biomass (Nord et al. 2012). High biomass production of the cover crop has been shown to reduce weedy emergence, however, concerns of cash crop emergence through biomass residue has been questioned. One study determined that no difference was found when soybean was planted into bare-top soil when compared to planting into cover crop residue (Moore et al. 1994). The objective of this study is to determine the best termination method of a cereal rye cover crop to suppress weeds, that also provides adequate soybean development.

MATERIALS AND METHODS

Rye termination treatments were arranged in a randomized complete block design with four replications. Seven total treatments were used with varying termination timings and methods. Chemical termination consisted of 1.26 kg ae ha^{-1} of glyphosate (Roundup Powermax, Bayer, 800 N Lindbergh Blvd, Creve Coeur, MO 63141) and mechanical termination consisted of rolling the cover crop using a pull behind water filled roller to create a flat mulch layer of rye onto the soil surface. The only treatment without mechanical or chemical termination was interplanting the soybean into the Elbon rye and allowing it to naturally reach senescence. Termination treatments included pre-plant termination, post-plant termination and a combination of pre and post-planting termination methods (Table 3.1).

Elbon rye was drilled at a rate of 134 kg ha^{-1} in the fall months of 2019 and 2020 with a great plains seed drill (Great Plains 1520, Great Plains Mfg., Inc., 1525 East North St., Salina, KS 6740) with terminations to be conducted the following spring. Treatment protocols for preplant terminations were implemented two weeks prior to planting. The trial locations were at the Mississippi Agricultural & Forestry R.R. Foil Plant Science Research Center near Starkville, Starkville, MS, (33°28’27” N 88°46’21” W) MS, the Mississippi Agricultural and Forestry Black Belt Experiment Station near Brooksville, MS (33°15’22” N 88°33’02” W), and at the Delta Research and Extension Center near Stoneville, MS (33°26’28.35” N 90°54’17.60” W). The soil series for Starkville was Marietta fine sandy loam (Fine-loamy, siliceous, active, thermic Fluvaquentic Eutrudepts) with a pH of 7.3, Brooksville soil series was Okolona silty clay (Fine, smectitic, thermic Oxyaquic Hapluderts) with a pH of 6.5 and Stoneville soil series was commerce silt clay loam (Fine-silty, mixed, superactive, nonacid, thermic Fluvaquentic Endoaquepts) with a pH of 6.9. All locations were conducted on non-irrigated soil. It should be documented that while Elbon rye was drilled at the Delta Research and Extension Center, in 2020, the rye did not survive winter frost leaving only two termination site years for 2021. In 2020, a fertilizer regiment was added in the fall in order to help create a better stand of Elbon rye. Urea fertilizer (46-0-0) at 37 kg of nitrogen ha^{-1} was applied at the Starkville and Brooksville locations. Soybeans were planted at a population rate of 321,100 seeds ha ^{1}. In 2020, and 2021 Asgrow soybean AG46X6 (Asgrow seed, Bayer, 800 N Lindbergh Blvd, Creve Coeur, MO 63141) were planted at all locations. The Starkville and Brooksville plots dimensions were 12.19 m x 6 m with 76.2 cm row spacings. The Stoneville plot dimensions were 9.14 m x 4.06 m with 101.6 cm row spacings. Visual weed control ratings were collected 0, 14, 21, and 28 days after planting (DAP), or until weeds were no longer controlled. Visible control ratings were in a scale from 0-100, 100 having complete control and 0 representing no control of weeds. When various plots consistently had a visual rating of 0 prior to 28 DAP, visual control data collection was concluded. The Starkville and Brooksville experiment locations focused on the presence of tall waterhemp (*Amaranthus tuberculatus*) while the Stoneville location focused on Italian ryegrass (*Lolium perenne ssp. multiflorum*) presence. Weed Densities were collected with a ¼ m^{2} quadrant square for each plot 28 DAP or when weed control was lost. Weight was recorded for the weed material and then placed in a dryer for 3 days and reweighed to collect dry matter weight. When spring data collection was concluded, plots were then sprayed with 1.26 kg ae ha^{-1} of glyphosate + 0.558 kg ae ha^{-1} of dicamba to control weeds. Soybean stand counts were taken 14 days after emergence by counting the number of plants in two random sections in rows two, three, six and seven to calculate plants per square meter. Plant heights were taken 14 days after emergence and at maturity. Soybeans yields were collected at the Starkville and Brooksville locations.

All data were analyzed in SAS 9.4 using the ANOVA mixed effects model (SAS Institute Inc., Cary, NC). Treatment means were separated using Fischer's protected LSD at α=0.05.

RESULTS AND DISCUSSION

Termination timings and method did not have a significant effect on tall waterhemp control other than at the 2020 Brooksville location at planting (Table 3.1). Spraying and rolling of the Elbon rye cover crop showed the greatest control of tall waterhemp with 96% control. Pre plant termination treatments were shown to have greater control of tall waterhemp than post planting termination treatments. Termination timings and methods was shown to have no difference with respect to Italian ryegrass control from planting to 28 DAP. Heights 14 DAP and soybean stand counts were shown to not have a treatment by year interaction and allowed data to be pooled across years and locations. It was determined that termination treatments that did not include rolling, had the greatest soybean height at 14 DAP and soybean stand count in plants per square meter Plant height at maturity and yield for 2020 locations were shown to not have any differences. In the fall of 2020, when the second year of Elbon rye was drilled, a fertilizer regime of urea (46-0-0) was added at a rate of 37 kg ha^{-1} in order to create a denser stand of Elbon rye for the spring. Spring 2021 data showed that termination methods have no differences with controlling tall waterhemp at any data collection timing. Treatment differences did exist for 2021 soybean plant height at maturity and soybean yield. Termination treatments that did not include rolling, were shown to have the greatest plant soybean plant height at maturity and this was also correlated to yield. Termination treatments that did not include rolling was shown to have the greatest yield for 2021. Allowing rye to reach senescence, and spraying glyphosate pre-planting was shown to contribute to the greatest soybean yield among treatments.

CONCLUSION

Terminations treatments of Elbon rye was shown to not have any real significance with respect to tall waterhemp control. Soybean establishment differed among termination treatments across years. Rolling was shown to inhibit plant height, and overall yield for 2021 locations. The addition of fertilizer across the 2021 locations created a dense stand of rye in the spring, that when rolled, also created a dense flat mulch on top of the soil surface that could have created difficulties for soybean emergence. Determining a termination method to apply to Elbon rye should be selected by soybean planting date. If the planting date is later into the season, when rye is reaching senescence, our data shows that a mechanical or chemical termination treatment is unwarranted. Rolling of the cover crop has shown to be beneficial in other studies in controlling weeds, moisture retention for cash crops, and light interference with other species but our collective data determined that rolling caused soybean establishment and yield to falter when compared to other treatments. When rolling Elbon rye it is important to consider the interference that could occur with soybean emergence and the rolled cover crop mulch.

Table 3.1 Termination Treatment effect on Tall Waterhemp Control at Brooksville; 2021 Soybean Height at Maturity, Soybean Heights 14 DAE, Soybean stand count, and yield pooled across year and location

Termination Treatments					Brooksville Tall Waterhemp control	Soybean Height		Soybean Stand Count	Soybean Yield
					At Planting	14 DAE	At Maturity		
					(%)Visual Control	(Plant height in cm)		-(Plants m^2)-	--(kg ha^{-1})--
---;	---;	Planted;	---;	---	85 AB	12.9 A*	70 A	14 BC	2421 A
---;	---;	Planted;	Rolled;	---	66 C	11.7 BC	61 B	13 C	1749 C
---;	---;	Planted;	---;	Sprayed	74 BC	12 BC	67 A	15 AB	2354 A
---;	---;	Planted;	Rolled;	Sprayed	79 BC	11.4 C	59 B	13 C	1816 BC
---;	Sprayed;	Planted;	---;	---;	87 AB	12.5 AB	72 A*	16 A*	2421 A*
---;	Sprayed;	Planted;	Rolled;	---;	81 B	11.2 C	61 B	13 C	1816 BC
Rolled;	Sprayed;	Planted;	---;	---;	96 A*	11.7 BC	62 B	14 BC	2152 BC

*Asterisk indicates differences among treatments, within columns, according to Fisher's LSD (α=0.05)
[a]Abbreviations: DAP; days after planting: DAE; days after emergence
Termination method sequence are arranged either pre-planting or post planting. (---) indicates that a termination method did not occur for that treatment. I.E. (---;---;Planted; Rolled;---) indicates rolling post planting was the only method of termination used.
Sprayed; applied 1.26 kg ae ha^{1} of glyphosate. Rolled; terminated with pull behind water filled roller.

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