AN ECONOMIC ANALYSIS OF ANNUAL RYEGRASS MANAGEMENT PRACTICES IN SOYBEAN PRODUCTION

A Thesis

by

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ABSTRACT

AN ECONOMIC ANALYSIS OF ANNUAL RYEGRASS MANAGEMENT PRACTICES IN SOYBEAN PRODUCTION

Henry Flowers, MS
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This study evaluates the effect ryegrass cover crop has on no-till soybean yield, grain density, and plant height. Additionally, it intends to calculate the profitability of harvesting ryegrass for forage. Annual ryegrass can be considered a dual-purpose crop, it is a cool-season annual bunchgrass which due to his high palatability and digestibility is considered high valued for forage (Hannaway et al., 1999). Grazing cover crops is economically viable when returns offset establishment costs without reducing crop yields (Schomberg et al., 2014). This research studied plots with emerged volunteer annual ryegrass. Plots were 1.5 m (5 ft) in width and 6.1 m (20 ft) in length with at least 4 replications in a randomized complete design. Eight treatments, all followed by soybean, were stablished on December 23, 2020: volunteer ryegrass as a cover crop, ryegrass clipped on late spring, ryegrass clipped on early spring, broad-leaf herbicide application (Atrazine) on early spring followed by late spring clipping, three different herbicides applications that vary in timing (December, February, and March application), and herbicide plus a residual on winter. All forage and cover crop plots were terminated with Glyphosate or Paraquat at least 2 weeks prior to planting soybeans. Plots were harvested using a plot combine.

ANOVA and Tukey Tests were conducted with an alpha of 0.05 to determine if statistical differences existed among soybean yield, height, and density. A sensitivity analysis was conducted to determine the profitability of using ryegrass as forage a using 2020 Texas Agriculture Custom Rates (Klose, 2020) on Excel 2016 version. Results showed that there is no difference between the cover cropping treatment and ryegrass forage production compared to herbicide treatments for any of the variables evaluated. Results also indicated that ryegrass can produce up to 2,446 pounds of dry matter that can be commercialized as hay and generate a profit between $115 and $122 per acre. Lastly, results indicated that if land is leased for grazing it could generated a profit of $25.40 per acre, this considering that ryegrass will regrow evenly in the field for two cycles producing 449 pounds of dry matter per cycle.

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INTRODUCTION

According to the United States Department of Agriculture (USDA) Farm Service Agency (FSA) (USDA, 2021a), 70% of the farmland in the United States (US) is used for corn and soybean production (Figure 1). Farmers in the US practice crop rotation with corn and soybeans, with wheat being the third most common crop included in the rotation. USDA in 2013 also reported that even though 82-94% of the crops are grown under rotations (Wallander, 2013), using conservation crops is not common, only 3-7% of farms include cover crops in their rotation

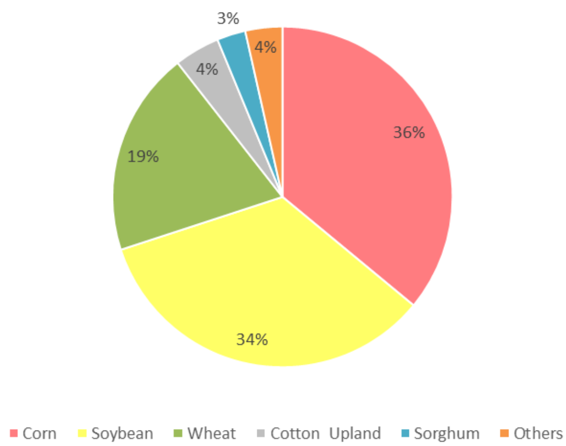

Figure 1. Planted acres in the US, 2011.
Source: USDA-FSA (2021a)

Cover Crops

Cover crops are crops used to cover the soil before the cash-crop season starts. Among the benefits attributed to cover crops are reduced fertilizers, herbicides and other pesticides, enhanced soil health, erosion prevention, soil moisture conservation, protection of water quality, and safeguard personal health (Clark, 2012). Cover crops can either help to enrich the soil with nitrogen or scavenge for excess of it (Clark, 2012). Covering the soil with a cover crop reduces the appearance of weeds and potential pests associated with those weeds. Yield improvement in the cash crops due to cover crops is possible since the roots of the cover crops can facilitate infiltration, relieve compaction, and improve soil structure. On the other hand, all the vegetative portion of the cover crop contributes to the organic matter of the soil, encouraging microbial life and enhancing the nutrient cycle (Clark, 2012). It is also important to mention that cover crops allow for water retention therefore reducing evaporation and increasing infiltration (Clark, 2012). Other benefits of cover crops include holding the soil in place and reducing the impact of rain and wind over empty soil. Lastly, the reduction of pesticides, herbicides, and fertilizers has two benefits. First it reduces health risks associated with the use of these type of products, and second it protects groundwater from runoff pollution (Clark, 2012).

First, the selection of the cover crop to use depends on what you want to accomplish with the cover crop (reduce soil erosion, increase soil nutrients, increase soil moisture, etc.). Second, the area and timing that will be used need to be determined; and last, cover crop options need to be listed and the most appropriate need to be selected (Clark, 2012). For example, if your main objective is to increase nitrogen in the soil, using a legume is vital because legumes grab the nitrogen gas in the atmosphere and translocate it in to the soil (Lindemann, 2015). On the other hand, if your objective is to reduce nitrogen in the soil, you can use cereal grains or grasses to scavenge excessive nutrients in the soil. The following example illustrates the second step of selection, identify area and timing. Annual ryegrass (*Lolium multiflorum*) is an excellent option to use as a cover crop when the location of the area needed to cover has cold winters. Lastly, having a list of potential cover crops increases the chances of choosing one that better aligns to the farmers' needs. Having options is important because it allows us to compare and contrast benefits.

Dual-Purpose Crops

Dual-purpose crops are those that can be used for more than one purpose. Annual ryegrass is a cool-season annual bunchgrass native from Southern Europe (Hannaway et al., 1999) which due to its high palatability and digestibility is considered high valued for forage. Ryegrass can be considered a dual-purpose grass given that it can be used as a cover crop and as forage. In states like Mississippi, 550,000 acres are planted annually and used for pasture and hay systems (Lemus, 2017). Even though cover cropping is not popular in the US, Trostel (2018) reported producers across Texas are becoming more familiar with the concepts, asking about it and trying it in some way.

Ryegrass is widely grown in the US every year, with the greatest concentration in the Deep South from East Texas to North Carolina, but some varieties do not tolerate winter enough to be grown in the Midwest (Ball and Lacefield, 2011). It is a leafy grass that often exceeds 70% digestible dry matter and 20% crude protein (Ball and Lacefield, 2011). In Texas, ryegrass is also a detrimental weed in cultivated Texas fields, showing up every year. Ryegrass resistance has been reported in a broad spectrum of herbicides (Singh et al., 2020), which leads to the need of developing new methods for controlling or managing it.

Cattle Production and Rye Grass as a Forage

USDA reported in May of 2021 that cattle production is the most important agriculture industry in the US and that it is forecasted to represent 17% of the total cash receipts for agricultural commodities in 2021 (USDA, 2021b). In cow-calf operations, beef cows graze on forages from grasslands to maintain themselves and raise a calf with very little, or no grain input; cows are maintained on pastures year-round, as is the calf until it is weaned (USDA, 2021b). Annual ryegrass grazing studies in Southern states have shown excellent animal performances, average daily gains of 1.8 to 2.2 pounds, gain per steer of 250 to 350 pounds, and gain per acre of 300 to 450 pounds are common, with many studies showing higher values (Lacefield et al., 2003).

USDA reported in 2021 that 29% of the nation's total acreage is used as pasture lands and private owned ranges (USDA, 2021a). It also reported that this area has decreased 3% compared to 1949. USDA also denominated other type of land named cropland pasture that in contrast to grassland pasture and ranges, is considered to be in crop rotation or could be used for crops without improvements. There is a total of 13 million acres used as cropland pastures in the US (Bigelow and Borchers, 2017), 3% of the total cropland. Furthermore, the US hay production has decreased from 153,603 million tons in 2000 to 126,812 million tons in 2020 (Shahbandeh, 2021).

Soybean and Rygrass Cropping System

In 2018, ryegrass was reported to be one of the most common cover crops on soybean systems, Figure 2 (Bowman and Wallander, 2021). The US is the number one producer of soybeans in the world and the second leader exporter (Bowman and Wallander, 2021). According to USDA the US produced 4.4 billion bushels of soybean in 2021 with a density of 51.4 bushels per acre (Barret, 2022).

Bean and Miller (1998) reported that soybean season in Texas starts from middle of May to early July. Considering that soybean takes 80-120 days until harvest, soybean seasons will end from Sepetember to early November depending on the date it was seeded. Farmers that only grow soybean will have at least half of the year with their land not being productive, but they will still need to make chemical controls to keep weeds out of it.

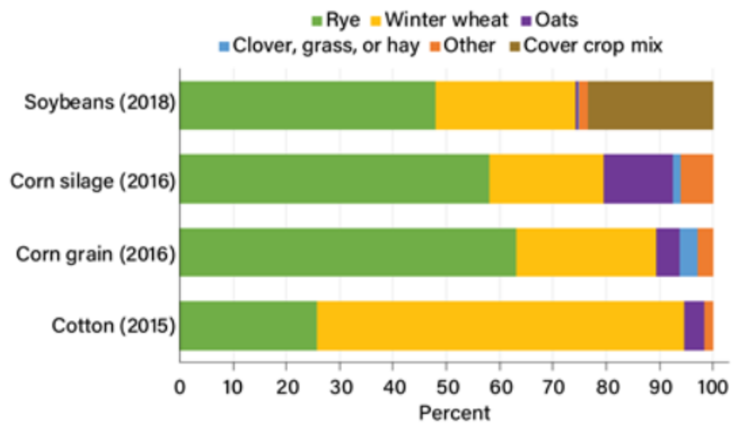

Figure 2. Survey report of cover crops used in the US in cotton, corn grain, corn silage and soybean from 2015 to 2018.

Note: For all years, rye includes both cereal rye and annual ryegrass. Cover crop mix was not a reporting option in 2015 and 2016.

Source: Bowman and Wallander (2021).

Some farmers do several herbicide applications along the non-productive period, others just make two applications, and others just make one large application before the soybean seasons starts. On the other hand, farmers that use cover crops will suppress weeds and reduce erosion. Addiotionally, if they decide to use a dual purpose crop like ryegrass, farmers could generate income by selling it as forage. USDA (2021c) reported the ryegrass hay price per ton to be between $185 and $200 depending on the quaility. Other ways of making money from forage is by leasing the land for grazing. Texas lease rates averaged in 2020 was $95 per acre for irrgated cropland, $30 for non-irrigated cropland, and $7 for pastureland (Dowell, 2020). When leasing the land for catte feeding purposes, it is important to consider that high intensity of grazing may impact soil compaction, and subsequently crop yields adversely (Planisich et al., 2021).

Statement of the Problem

Historically, farmers in the US are not familiar with using cover crops in their crop rotation systems and even less familiar with harvesting a cool-season grass in winter and spring. However, USDA (Wallander et al., 2021) reported that cover crop use has increased 50% from 2012 to 2017. Farmers are spending thousands of dollars in managing weeds that are also a temporary home of future pests instead of taking advantage of the benefits of cover crops. According to FarmProgress network (2005), 65% of the pesticide expenditures used by US farmers are herbicides for weed control.

Annual ryegrass is voluntarily growing in Texas, suppressing weeds and scavenging nitrogen in the soil while protecting it from compaction and erosion. Ryegrass accompanied with good management could result in an extra income for farmers until the cash crop season starts in late spring. Cool-season annual grasses like ryegrass are extremely high in nutritive quality, forage production, from early fall through the spring (Beck, Gadberry, and Jennings, 2013). Since herbicide prices are constantly increasing and ryegrass voluntarily grows along fields, its use as a forage or cover crop could be an alternative for Texas farmers to increase their annual profits.

Purpose of the Study

This study analyzes alternatives for more efficient use of soybean cropping land during fall and spring. In particular, the effect of the uses of volunteer annual ryegrass as a cover crop before no-till soybean is evaluated. Additionally, this study intends to evaluate the viability of using ryegrass as a forage. USDA has financed research investigating the importance of cover crops; Clark (2015) defines the benefits of different cover crops over cropping land. Planish et al.

(2021) studied the effects of cattle grazing on production of annual ryegrass (*Lolium multiflorum*) in an integrated ryegrass–soybean rotation system.

Hypotheses

Soybean farmers will be able to increase profits by using volunteer annual ryegrass as a cover crop and forage in winter in a no-till soybean rotation system. The study aspires to identify if having soybean and ryegrass on a system is more profitable than soybean without a cover crop; and if there is no impact on the soybean yield, grain density, and height when stablished in a system with ryegrass.

Research Questions

This research intends to answer the following questions:

1. How much impact does volunteer annual ryegrass cover crop have over the yield, height, and grains density of no-till soybean?
2. Do residual herbicide applications in fall affect the yield, height, and grain density of no-till soybean?
3. Does the timing of an herbicide application affects the yield, height, and grain density of no-till soybean?
4. What is the forage yield of volunteer annual ryegrass, in the cool-season, from late fall to late spring?
5. How much profit can be made from haying and grazing volunteer annual ryegrass forage when established before soybean?

Significance of the Study

Many studies have assessed the efficiency of annual ryegrass as a cover crop and their effect on a cash crop. This study not only evaluates soybean yield, grain density, and plant height on a cover crop no-till system, but also intends to assess the yield and profitability of annual ryegrass forage. Results of this study will provide farmers with an alternative and more profitable way of taking care of their land during winter and spring.

Definitions of Terms

The following are important concepts to consider in this research project:

Cover crop. According to Clark (2015), a cover crop is a plant that is used primarily to slow erosion, improve soil health, enhance water availability, smother weeds, help control pests and diseases, increase biodiversity and bring a host of other benefits to your farm.

Crop rotation. Crop rotation is a cropping practice in which crops grown in a field are changed (rotated) for others, usually season by season, in order of reducing pest population and better weed controls (USDA, 2022a).

Forage. Forages are grasses and legumes fed to animals in the form of pastures, hay and silage (USDA, 2022b).

Grazing. According to Oregon State University (2022a), grazing is allowing livestock to directly consume the growing forage; grasses, legumes, and forbs, in a pasture or rangeland. It is harvesting by animal instead of by machines. In this study a grazing simulation was done instead of real grazing, meaning that grass was harvested using a machine to simulate animal consumption.

Haying. Haying is the harvesting of hay. According to Encyclopedia Britannica (1998), hay is grass that has been cut and dried to be used as food for animals.

No-till. No-till is a farming system in which the soil is left undisturbed by tillage and the residue is left on the soil surface (Gellatly and Dennis, 2011). In this study, all treatments were conducted under a no-till rotation system.

Limitations and Delimitations

The following are the limitations of this study:

1. Cattle, tractors and heavy equipment were not used in the study so variables like palatability, trampling, and soil compaction were not considered.
2. Custom rates will vary from time to time, prices and costs used in this experiment might not be the same (due to inflation) for next years but will provide an estimate.

Assumptions

This research makes the following assumptions:

1. All the ryegrass harvested for forage will be sold, that is there is no losses.
2. Volunteer annual ryegrass grew evenly on all the plots evaluated.
3. Hay prices are 2020 prices.
4. Annual ryegrass in the grazing simulation has two cycles before soybean establishment and regrew evenly along the plots.
5. This study only considers volunteer annual ryegrass (*Lolium multiflorum*).

Chapter 2

REVIEW OF THE LITERATURE

Ryegrass Origin and Description

Annual ryegrass is originated from southern Europe; according to reports, from the thirteenth century, it was grown in Northern Italy and that is why it is also called Italian ryegrass (Evers et al, 1997). It is not known when American farmers started using it as a forage but annual ryegrass arrived in the US in the early colonial days (Holt and Bashaw, 1976). Annual ryegrass is a cross-pollinating specie and due to large genetic variability, this grass is highly adaptable to a wide range of environments (Evers, 1995). Its seed possess the ability to stay dormant during unsuitable conditions and germinate when conditions have changed (Nelson, 1995). Seeds could be dormant for several years in the soil if conditions remain adverse for them to germinate (Rampton and Ching, 1970). According to the Department of Primary Industries and Regional Development, Agriculture and Food division, Australia (2020), annual ryegrass produces an extremely high number of seeds per plant; under ideal conditions, it could produce 45,000 seeds per square meter. Its leaves are dark and shiny with smooth edges and rolled in the bud; its root can go as far as six feet deep on no-till fields, braking compacted layers, improving soil structure and increasing organic content (Perszewski, 2004). Ryegrass is considered a bunch grass due to its roots growing in a bunch, its roots have minimal lateral spreading (Oregon State University, 2022b).

Annual Ryegrass Cover Crop and Forage

Cover crops have demonstrated to be beneficial when incorporated in a rotation system, for soil or water conservation. According to Ditscha and Alley (1991) ryegrass' winter hardiness makes it ideal to be a winter cover crop. In 2019, it was reported that cover cropping has no effect on soybean height and that it increased soybean yield, but that this could vary depending on the tillage system and cover crop type (Acharya et al., 2019). Rye has also shown to be good for mulching in no-till soybean (Eckert, 1988). However, research has also found that decomposing cereal rye residues have allelopathic effect on other plant species, retarding their growth and development (Rice, 1995). Another negative effect is that ryegrass residuals have demonstrated to reduce the number of seeds that reaches the soil in corn and soybean rotations (Eckert, 1988). Ryegrass decomposition has also shown an immobilization of inorganic nitrogen reflecting on a decrease of corn grain yield (Blevins et al., 1990).

Grazing cover crops could encourage cover crop adoption if returns offset establishment costs without reducing crop yields (Schomberg et al., 2014). Grazing winter cereal rye cover crop in a cotton no-till system study in Southern Piedmont, US, demonstrated an increase in profit for cotton producers but a negative effect on soil compaction (Schomberg et al., 2014). Farmers received $110 more per hectare, based on 2012 prices, between grazed and non-grazed land (Schomberg et al., 2014). In a corn-ryegrass-soybean rotation, an increase Nitrous oxide (N2O) emissions was observed, nevertheless, the rotation soybean-ryegrass-corn had no impacts on N2O emissions (Smith et al., 2011). A long-term study of winter ryegrass cover crop, as part of a corn-soybean crop rotation, in the Midwestern US reported that ryegrass improves soil-water dynamics without sacrificing cash crop growth; no statistical difference was found in the cash crops' yield when comparing cover and no cover crop treatments (Basche et al., 2016). On corn systems ryegrass has demonstrated to be ideal as cover crop by not affecting corn yield and conserving inorganic Nitrogen over an 8-year field experiment (Snapp and Surapur, 2018).

Annual ryegrass is considered one of the best cool season grasses, demonstrating great amounts of protein, digestibility, vitamins, minerals and palatability in its leafy stage (Lacefield et al., 2003). From initial growth until seed head emerge vegetative annual ryegrass pastures can have 20% of crude protein and 70% of total digestibility (McCormick et al., 2013). Even if harvested at a late stage of maturity for hay it can provide up to 10% of crude protein and 55% of total digestible nutrients (McCormick et al., 2013). Beef cattle have exhibited daily gains of 1.8-2.2 pounds while dairy with adequate milking potential and that their principal feed source is annual ryegrass have demonstrated a milk production of 35-40 pounds of milk daily (Lacefield et al., 2003). Planisich at al. (2021) reported that grazed annual ryegrass is a viable cover crop option for integrated crop-livestock systems, with 12-18 centimeter being the ideal sward heights offering the opportunity to optimize forage production and animal performance, while keeping adequate residual soil cover. When grazing cover crops it is very important to consider the stocking rates. Lower stocking rates and grazing intensities will increase voluntary intake of cover crops and animal weight gains (Cangiano et al., 2002; Carvalho et al., 2010). On the other hand, higher grazing intensities and stocking rates may have negative repercussions on daily gains, future cash-crop yield, and soil compaction (Planisich et al., 2021).

Another option for taking advantage of ryegrass cover crop is stockpiling. Kallenbach et al. (2003) reported that ryegrass stockpiling never exceeded 252 g/kg of acid detergent fiber and neutral detergent fiber never exceeded 455 g/kg, suggesting that stockpiled ryegrass could be used as high-quality winter forage for grazing livestock. Climate conditions will highly influence on the way ryegrass forage is exploited. In the dairy industry no difference was found in milk production between ryegrass hay and bailage, but in condition that are poorly favorable (humid) for producing high quality hay, bailage will be the best option (McCormick et al., 2013).

Burndown and No-Tillage Systems

Before the establishment of a cash crop, the usage of burndown herbicides is critical to terminate the cover crop and early season weeds (Price and Kelton, 2013). Residual herbicides are also recommended in order to extend weed control into the season (Price and Kelton, 2013). Annual ryegrass has demonstrated resistance to broad spectrum herbicides like Glyphosate (Singh, 2020), so it is important to have a rotation of products and apply them at the indicated rate. This includes using products with different active ingredients and at the dose established on the label. According to Cornelius and Bradley (2017) the control of grass cover crop species is best with Glyphosate alone or combined with 2,4-D, Dicamba, or Saflufenacil, but herbicides like Paraquat and Glufosinate did not provide adequate annual ryegrass control. Lins et al. (2009) stated that the highest control on annual ryegrass was observed when using a high dose of Glyphosate and applied at the early flower stage but that any Glyphosate rate provided complete control or biomass reduction of the annual ryegrass cover crop.

Tillage is an important factor you have to consider when establishing crops. In 2004, 62.4 million acres in the US were using no tillage for crop production. Around 10.2 million acres were used for soybean and one third of those acres were no-tillage systems. This has been increasing at 5% since 2002 (Iowa State University, 2021). Under long term rotation systems Pedersen and Lauer (2003) observed a 6% greater yield in soybean planted in a no-tillage system compared to a conventional tillage system. On the other hand, in a two year fertility study at Illinois, it was observed that soybean planted in a no-tillage system presented a lower yield than soybean planted under various tillage systems evaluated (Vasilas et al., 1988).

Annual ryegrass since its arrival to the US during the colonial days has increased its genetic variability and adapted to conditions in the country. US farmers have incorporated it as a cover crop and forage, but it has also been an important weed that has developed herbicide resistance. Studies are contradictory since some report that ryegrass cover cropping do not affect soybean yield but other have demonstrated the opposite. Additionally, ryegrass has demonstrated to be a good winter forage for both dairy and beef cattle.

Chapter 3

METHOD OF PROCEDURE

For this study an experimental research design was conducted. The experiment took place at Texas A&M-University Commerce farm located in Greenville, Texas. Plots were established on December 23, 2020 in fields with emerged volunteer annual ryegrass. There was no need of seeding annual ryegrass because volunteer ryegrass grew evenly along the field.

Eight treatments, all followed by soybeans, were established (Table 1). The first treatment consisted of leaving volunteer ryegrass to grow in the plot through the fall and spring season; that is cover cropping. The second treatment consisted in leaving ryegrass in fall but harvesting it for hay in late spring, May. Third treatment is similar to the previous one but including an application of a broadleaf herbicide, atrazine, during winter. The fourth treatment consisted in an early ryegrass forage cut to simulate grazing in early spring, January. The fifth, sixth, and seventh treatment consisted of single herbicide applications to terminate ryegrass. Plots under this treatments were applied with either Paraquat or Glyphosate. The difference between these treatments was the timing of the application, December, February and March respectively. The last treatment included an herbicide application of Paraquat or Glyphosate on winter plus a residual herbicide and a surfactant. Residual herbicides active ingredients used were: S-metolachlor, metribuzin, flumioxazin, pyroxasulfone, and carfentrazone. The surfactant rate used was 0.025% of the total volume of application. For a visual appreciation of when the treatments where conducted refer to Appendix C. Individual plots were 1.5 m (5 ft) in width and 6.1 m (20 ft) in length. The experiment consisted of a randomized complete block design with at least 4 replications per treatment.

All forage and cover crop plots (treatments 1 through 4) were terminated with Glyphosate or Paraquat at least 2 weeks prior to planting soybean. It is important to mention that this study does not aim to verify the efficiency of the herbicide treatments. The purpose of the herbicide treatments is to compare the impact of ryegrass cover cropping, forage, and grazing impact in the future soybean production with herbicide applications which is what farmers normally do to their land off-season.

Table 1. Eight Treatments Evaluated in the Study

Treatment Number	Treatment Name
1	Volunteer Annual ryegrass cover crop (cover cropping).
2	Annual ryegrass forage harvested as hay (hay production).
3	Broadleaf herbicide, atrazine, application during winter followed by Ryegrass forage harvested as hay (hay production + atrazine).
4	Annual ryegrass forage harvested one early spring (grazing simulation).
5	Glyphosate or Paraquat application in December.
6	Glyphosate or Paraquat application in February.
7	Glyphosate or Paraquat application in March.
8	Glyphosate or Paraquat plus a residual herbicide and a surfactant in December.

Complete plots with ryegrass forage production, treatments two through four, were clipped and weight to calculate forage production potential. Clipping was done using a Black and Decker electric battery powered hedge trimmer at a 3-inch height. Forage was stored in paper bags and then weighted on a regular platform scale.

In order of determine the amount of hay that could be produced with ryegrass, dry matter needed to be calculated. Forage dry matter was calculated by first taking a 600 gram sample of each of the forage bags collected in treatments two and three. Followed by extracting the humidity in them by using a forced air oven at 160 °F for 48 hours. Then samples were weighted again and weeds were manually separated from them and weighted. The weed weight was subtracted from the dry forage weight in order to obtain the quantity of clean dry forage. The percentage of dry clean forage was calculated by dividing the quantity of clean dry forage by the initial 600 grams. Percentage of dry clean forage was multiplied by the total weigh of the forage harvested on the plot to obtain total dry matter production per plot.

Herbicide treatments were applied using a broadcast sprayer with a five feet hand boom and CO_2 propellant at 35 PSI. The total volume of applications was 15 gallons per acre. Paraquat, Glyphosate, and Atrazine rates of applications were 32 fluid ounces per acre (2.35 liters per hectare). Residual herbicide rates used were the maximum recommended in the label according to the soil type, heavy clay.

Soybeans were seeded on June 23, 2021 with a Glyphosate and Dicamba tolerant variety (Asgrow AG49X). All plots received a post emergent application of Glyphosate, S-metolachlor, and Dicamba to control weeds until harvest. Soybean seed was harvested on October 26, 2021 with a plot combine and stored in paper bags. Seeds were then cleaned and weighed using a regular platform scale to obtain soybean yield. Soybean height was determined by measuring five plants of each plots using a wooden ruler. The measurements were obtained before harvesting. Grain density was determined using test weight method and with pound per bushel as the unit. Test weight method consist in pouring soybean seed to a pint cup using a funnel, followed by scalping off the excess the grain by doing three zigzag equal movements with a hardwood striker. Finally, the seed was calculated to obtain the weight of grain necessary to fill a pint evenly, test weight.

An analysis of variance was made with a p-value of 0.05 in order to identify if differences existed between treatment on soybean yield, height, and grain density. This was accomplished using proc GLM of the Statistical Analysis System software (SAS) version 9.4. Additionally, Tukey tests were conducted to identify which means were statistically different from each other.

To assess the viability of harvesting ryegrass as hay and for grazing, three sensitivity analyses were conducted. Sensitivity analyses were elaborated in Microsoft Excel 2016 using the 2020 Texas Agricultural Custom Rates in conjunction with commercial prices of herbicides (Farmers Business Network, 2022) (Table 2). Two sensitivity analyses were done for the hay treatment, one considering ryegrass was terminated with Glyphosate and the other considering it was terminated with Paraquat (Gramoxone); both of them after cutting ryegrass for hay. The third sensitivity analysis was done for the grazing treatment. For the grazing evaluation dry matter of treatment 4 was used to measure the potential profit of grazing lightweight calves (500 pounds). Additionally, consumption was determined to be 3.0% of animal weight (Schwab, 2010) and daily gain was determined as 2.5 pounds daily (Filley and Mueller, 2013). Two cycles of grazing were considered in the analysis due to annual ryegrass 4 weeks regrow cycle (Oregon State University, 2022c). Meaning that dry matter calculated in treatment 4 will be produced at least twice before soybean establishment in early May. Cost and variables used for the grazing sensitivity analyses are reported in Table 3.

Total costs were calculated on a per acre basis as well as the forage yields were extrapolated in order to make the analysis. Ryegrass seed (Speir and Hancock, 2017) and establishment costs were considered in the sensitivity analysis at a rate of 25 pounds per acre.

Data

This section summarizes information about the variables used in the study. The four main variables used in this study were annual ryegrass forage, soybean yield, soybean height and soybean grain density (test weight). Annual ryegrass forage production data was collected twice in the study, first for the grazing simulation (January) and second for the hay production treatments (April). Forage was harvested, stored, dried, cleaned, and weighted to obtain dry matter production. Soybean height data was collected the same day soybean was harvested (October) using a wooden ruler to measure 5 plants per plot. Soybean yield was obtain after harvesting and storing soybean grains in independent paper bags. Soybean was then cleaned and weighted to estimate the bushel per acre (unit of yield used for soybean) production. Lastly, soybean density was obtained using the test weight method used in commercial elevators. All data was collected on the Texas A&M-University Commerce farm located in Greenville, Texas, under no-till heavy clay soils without any irrigation nor fertilization.

Table 2. Costs and Earnings Considered for the Sensitivity Analyses of Hay Production

Description	U.S Dollars	U.S Dollars	Quantity
Costs			
Grass Seeding Rate	$ 21.54		Per Acre
Herbicides Flat Rate Ground Application	$ 10.11		Per Acre
Paraquat/Glyphosate (Second Column)	$ 7.53	$ 13.38	32 fl oz per acre
Crop Production Consulting Services	$ 8.00		Per Acre
Ryegrass Seed	$ 17.50		Per 25 lb
Round Bales Over 1500 lbs Full Wrap	$ 47.42		Per 1500 lbs
Hauling hay (Field to Storage)	$ 10.94		Per 1500 lbs
Total Cost	**$ 123.04**	**$ 128.89**	**Per Acre**
Earnings			
Hay Pricing (Good quality, 23% protein)	$ 200.00	$ 200.00	Per Ton
Tons Produced			1.22 Tons
Total Earnings	$ 244.60	$ 244.60	Per Acre
Total Profit	**$ 121.56**	**$ 115.71**	**Per Acre**

Note: Custom rates from Texas Agriculture Custom Rates (Klose, 2020). Commercial Herbicide prices from FBN (2022).

Table 3. Costs, Earnings, and Other Variables Considered for the Sensitivity Analysis of Grazing Simulation

Description	U.S Dollars	Quantity
Costs		
Grass Seeding Rate	$ 21.54	Per Acre
Herbicides Flat Rate Ground Application	$ 10.11	Per Acre
Crop Production Consulting Services	$ 8.00	Per Acre
Ryegrass Seed	$ 17.50	Per 25 Pounds
Paraquat	$ 7.25	Per Acre
Total Cost	**$ 64.40**	**Per Acre**
Earnings		
Cattle Grazing Lease Contract	$ 0.60	Per Pound Gain
Quantity of Dry Matter Produced		449 Pounds
Cycles of Ryegrass		2 Cycles
Calf Consumption Daily		15 Pounds (3% of weight)
Days of Occupancy		60 days (500 Pounds Calf)
Pounds of Gain		2.5 Pounds Per Day
Weight Gain		160 Pounds
Total Earnings	**$ 89.80**	**Per Acre**
Total Profit	**$ 25.40**	**Per Acre**

Note: Custom rates from Texas Agriculture Custom Rates (Klose, 2020). Commercial Herbicide prices from FBN (2022).

Chapter 4

PRESENTATION OF FINDINGS (or DATA)

Soybean yield average in the US is 51.4 bushels per acre but Texas is estimated to be a little lower with a production of 38 bushels per acre (Barrett, 2022). Soybean yields found on this study do not exceed 22.1 bushels per acre; elevated temperatures in conjunction to lack of precipitation in North Texas are the reason of lower soybean in comparison to the state's average.

A p-value of 0.0088 was obtain from the ANOVA (refer to Appendix A) tests indicating that at least one of the treatments evaluated produced a different soybean yield average. Table 4 reports soybean yield (bushels/acre) per treatment for crop season 2020-2021. Statistical difference was found between treatment 4 (22.14 bushel/acre) and treatment 5 (13.66 bushel/acre), and between treatment 4 and 8 (15.25 bushel/acre) (Table 4). Treatment 4 was the grazing simulation, treatment 5 was the Glyphosate or Paraquat application in December, and treatment 8 was the Glyphosate or Paraquat plus a residual herbicide and a surfactant in winter.

Results indicated that one early herbicide application (not followed by a second one before soybean establishment) will negatively impact soybean yield. Using just one early application of herbicide allowed resistant ryegrass and other existent weeds (that were not killed by the application) to grow and spread along the plot. This consequently, reduced the amount of soybean seed that reached the soil and increased the resource competition, between weeds and soybean, until weeds were eliminated on the soybean post planting herbicide application. Theisen and Bastiaans (2015) demonstrated that annual weeds can prevent soybean seed to be exposed to the soil and germinate when using standard seeders, situation that can be avoided with modified seeders, In the grazing simulation (treatment 4) the combination between an early forage cut and a late herbicide application allowed for a better amount of soybean seed germination and resulted in better weed management resulting in a higher soybean yield

Table 4. Least-Squares Mean Comparisons for Soybean Yield

Treatment	**LSMEAN (Bushels/Acre)**		
4	22.139687	A	
7	20.033137	A	B
2	19.390647	A	B
3	18.601057	A	B
6	17.347254	A	B
1	16.934537	A	B
8	15.248164		B
5	13.666588		B

Note: Treatments with different letters are statistically different.

Additionally, the usage of residual herbicides has demonstrated to negatively affect soybean yield in comparison to the grazing treatment. Results in this study differ from Whalen et al. (2019) who reported that pre-plant residual herbicide applications on soybean productions can produce higher yield compared to cover cropping. Nevertheless, soil residual herbicides can remain active in the soil for a period of weeks to months after application (Zimmer and Johnson, 2020). Farmers need to make sure to consider application rates and the time of residuality, which is stated in the herbicide label, in order to avoid potential damage in their cash crop.

A p-value of 0.0436 was obtained for the ANOVA test (refer to Appendix A) for soybean height, suggesting that soybean height for at least one treatment is statistically different from the other treatments. Differences were found only between treatments 4 and 8 (Table 5), height for treatment 4 was 22.375 inches and for treatment 8 was 19.825 inches. Stowe 2022 indicated that soybean height could vary from 3 to 5 feet which suggests that the height measurements in this experiment were under the national average for all treatment evaluated.

Table 5. Least-Squares Mean Comparisons for Soybean Height

Treatment	LSMEAN Height (Inches)		
4	22.375	A	
3	22.188	A	B
2	21.406	A	B
1	20.979	A	B
6	20.906	A	B
7	20.875	A	B
5	19.938	A	B
8	19.825		B

Note: Treatments with different letters are statistically different.

The lack of growth and low yields in all plots in this study can be attributed to irrigation and fertilization. Irrigation and fertilization were not used in this study. Irrigation is one of the important factors that influence soybean growth (Mahmoud et al., 2013). Additionally, irrigation and fertilization have demonstrated to be very important to the normal growth of continuously cropped soybean (Cao et al., 2020).

The last dependent variable measured was soybean density, test weight. No statistically difference, at an alpha of 0.05 (refer to Appendix A), was found in any of the treatments for the soybean test weight. Treatments reported a mean test weight of 51.48 lb/bu. Soybean standard test weight is 60 lb/bu and some elevators can reject loads with test weights below 49 lb/bu (Heatherly, 2015). Soybean in this research can be categorized as grade 4 and can have a discount that ranges between $0.005 and $0.02 per bushel when sold (Heatherly, 2015).

Average ryegrass dry matter production in the hay production treatments was 2,446 pound per acre. Considering 2021 hay prices and costs stated in Table 2. Ryegrass hay production demonstrated to have the potential to generate a profit of $121.84 per acre when using Paraquat to kill ryegrass crop residues before stablishing soybean, and $115.71 when using Glyphosate. Sensibility analysis for ryegrass demonstrated that if hay prices drops to $100 per acre, ryegrass production will not be profitable. Similarly, if production of dry matter decrease to 1200 lb/acre, ryegrass hay production will be unprofitable. The italic values on parenthesis in Table 6 (Paraquat Analysis) and Table 7 (Glyphosate Analysis) represent all unprofitable situations for farmers, considering hay prices and dry matter production as changing variables but keeping costs fixed. The bold value is the baseline scenario, which consists of 2,446 pounds of annual ryegrass dry matter produced at a price of $200 per hay bale. The baseline scenario is obtained from using the values from Table 2.

Table 6. Sensitivity Analysis for Seeded Annual Ryegrass Hay Production Terminated with Paraquat Contact Herbicide (Conservative Scenario)

	Dry Mater Produced (Pounds)						
Hay Price ($)	**1200**	**1600**	**1800**	**2000**	**2200**	**2446**	**2600**
$ 100	*$ (62.76)*	*$ (42.76)*	*$ (32.76)*	*$ (22.76)*	*$ (12.76)*	*$ (0.46)*	$ 7.24
$ 125	*$ (47.76)*	*$ (22.76)*	*$ (10.26)*	$ 2.24	$ 14.74	$ 30.11	$ 39.74
$ 150	*$ (32.76)*	*$ (2.76)*	$ 12.24	$ 27.24	$ 42.24	$ 60.69	$ 72.24
$ 175	*$ (17.76)*	$ 17.24	$ 34.74	$ 52.24	$ 69.74	$ 91.26	$ 104.74
$ 200	*$ (2.76)*	$ 37.24	$ 57.24	$ 77.24	$ 97.24	**$ 121.84**	$ 137.24
$ 225	$ 12.24	$ 57.24	$ 79.74	$ 102.24	$ 124.74	$ 152.41	$ 169.74
$ 250	$ 27.24	$ 77.24	$ 102.24	$ 127.24	$ 152.24	$ 182.99	$ 202.24
$ 275	$ 42.24	$ 97.24	$ 124.74	$ 152.24	$ 179.74	$ 213.56	$ 234.74
$ 300	$ 57.24	$ 117.24	$ 147.24	$ 177.24	$ 207.24	$ 244.14	$ 267.24
$ 325	$ 72.24	$ 137.24	$ 169.74	$ 202.24	$ 234.74	$ 274.71	$ 299.74
$ 350	$ 87.24	$ 157.24	$ 192.24	$ 227.24	$ 262.24	$ 305.29	$ 332.24

Note: The conservative scenario includes seeding rate and seed price in profit ($/acre) calculations reported inside the table.

Table 7. Sensitivity Analysis for Seeded Annual Ryegrass Hay Production Terminated with Glyphosate Systemic Herbicide (Conservative Scenario)

	Dry Mater Produced (Pounds)						
Hay Price ($)	**1200**	**1600**	**1800**	**2000**	**2200**	**2446**	**2600**
$ 100	*$ (68.89)*	*$ (48.89)*	*$ (38.89)*	*$ (28.89)*	*$ (18.89)*	*$ (6.59)*	$ 1.11
$ 125	*$ (53.89)*	*$ (28.89)*	*$ (16.39)*	*$ (3.89)*	$ 8.61	$ 23.98	$ 33.61
$ 150	*$ (38.89)*	*$ (8.89)*	$ 6.11	$ 21.11	$ 36.11	$ 54.56	$ 66.11
$ 175	*$ (23.89)*	$ 11.11	$ 28.61	$ 46.11	$ 63.61	$ 85.13	$ 98.61
$ 200	*$ (8.89)*	$ 31.11	$ 51.11	$ 71.11	$ 91.11	**$ 115.71**	$ 131.11
$ 225	$ 6.11	$ 51.11	$ 73.61	$ 96.11	$ 118.61	$ 146.28	$ 163.61
$ 250	$ 21.11	$ 71.11	$ 96.11	$ 121.11	$ 146.11	$ 176.86	$ 196.11
$ 275	$ 36.11	$ 91.11	$ 118.61	$ 146.11	$ 173.61	$ 207.43	$ 228.61
$ 300	$ 51.11	$ 111.11	$ 141.11	$ 171.11	$ 201.11	$ 238.01	$ 261.11
$ 325	$ 66.11	$ 131.11	$ 163.61	$ 196.11	$ 228.61	$ 268.58	$ 293.61
$ 350	$ 81.11	$ 151.11	$ 186.11	$ 221.11	$ 256.11	$ 299.16	$ 326.11

Note: The conservative scenario includes seeding rate and seed price in profit ($/acre) calculations reported inside the table.

In treatment 4 (grazing simulation) annual ryegrass produced 449 pounds of dry matter. Total cost was calculated to be $64.40 and generate a revenue of $82.32 per acre. A total profit of $17.92 per acre could be generated from the land if leasing it to calf owners who want to take advantage of the annual ryegrass at a rate of $0.60 per pound gain (Hofstrand, 2015) for a period of 60 days. The sensitivity analysis shows that at the actual dry matter production of 449 pounds of dry matter per cycle from treatment 4, and considering two cycles of cutting the leasing rate in dollar per pound gain cannot be less than $0.45 per pound gain. Sensitivity analysis also reveals that at the actual leasing rate, dry matter production cannot be lower 350 lbs. Table 8 shows many possible scenarios for different dry matter production and leasing rates. Italic values on parenthesis are all the scenarios that will not be profitable for the farmers and the bold value is the baseline scenario. The baseline scenario is obtained from using the values from Table 3.

Table 8. Sensitivity Analysis for Seeded Annual Ryegrass Grazing Simulation Terminated with Paraquat Contact Herbicide (Conservative Scenario)

	Dry Mater Produced (Pounds)						
Grazing rate ($ per pound)	**250**	**300**	**350**	**400**	**449**	**500**	**550**
$ 0.40	*$ (31.07)*	*$ (24.40)*	*$ (17.73)*	*$ (11.07)*	*$ (4.53)*	$ 2.27	$ 8.93
$ 0.45	*$ (26.90)*	*$ (19.40)*	*$ (11.90)*	*$ (4.40)*	$ 2.95	$ 10.60	$ 18.10
$ 0.50	*$ (22.73)*	*$ (14.40)*	*$ (6.07)*	$ 2.27	$ 10.43	$ 18.93	$ 27.27
$ 0.55	*$ (18.57)*	*$ (9.40)*	*$ (0.23)*	$ 8.93	$ 17.92	$ 27.27	$ 36.43
$ 0.60	*$ (14.40)*	*$ (4.40)*	$ 5.60	$ 15.60	**$ 25.40**	$ 35.60	$ 45.60
$ 0.65	*$ (10.23)*	$ 0.60	$ 11.43	$ 22.27	$ 32.88	$ 43.93	$ 54.77
$ 0.70	*$ (6.07)*	$ 5.60	$ 17.27	$ 28.93	$ 40.37	$ 52.27	$ 63.93
$ 0.75	*$ (1.90)*	$ 10.60	$ 23.10	$ 35.60	$ 47.85	$ 60.60	$ 73.10
$ 0.80	$ 2.27	$ 15.60	$ 28.93	$ 42.27	$ 55.33	$ 68.93	$ 82.27
$ 0.85	$ 6.43	$ 20.60	$ 34.77	$ 48.93	$ 62.82	$ 77.27	$ 91.43
$ 0.90	$ 10.60	$ 25.60	$ 40.60	$ 55.60	$ 70.30	$ 85.60	$ 100.60

Note: The conservative scenario includes seeding rate and seed price in profit ($/acre) calculations reported inside the table.

The sensitivity analysis in this study reports a conservative scenario where costs of seed and seeding rate were considered in the profit calculation, as shown in tables 2 and 3. The conservative scenario is beneficial to farmers who do not have annual ryegrass voluntarily growing in their fields. Appendix B reports a more optimistic scenario, which is useful to farmers who have volunteer annual ryegrass growing in their land. In other words, the optimistic sensitive analysis (Appendix B) excludes costs of seed and seeding rate, which make establishment costs to reduce and profit to increase.

Additionally, a weed visual inspection in fall indicated that ryegrass cover cropping treatment was able to control for 90-100% of the broadleaf weeds in the land. Treatment 5 controlled 85% of the total weed in its plot considering broadleaves and annual ryegrass, treatment 6 controlled 90%, and treatment 7 controlled 90%. Lastly, the residual herbicide application (treatment 8) was able to control 80%-90% of the total weed in the plots.

Chapter 5

SUMMARY OF THE STUDY AND THE FINDINGS, CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS FOR FUTURE RESEARCH

This study demonstrates that cover cropping annual ryegrass (treatment 1) in no-till soybean land offseason will have no negative effect on soybean yield, height, and density. There was no difference at the 0.05 alpha significance level for the cover crop treatment with any other treatment when conducting multiple mean comparisons. This implies that farmers could start implementing ryegrass cover cropping in their land without fearing of detrimental soybean performance. With herbicide prices booming, cover cropping is an alternative to increase farmer's profits, by reducing their expenditure in other weed management practices.

Residual herbicide applications on ryegrass reported to have a lower yield and height compared to the grazing simulation (ryegrass early cut), but no difference with cover cropping. This result differs from Whalen et al. (2019) who reported that residual herbicide applications on soybean productions could produce higher yield compared to cover cropping.
The same happened with an early application of herbicide, December; (Treatment 5) lower soybean yields compared to grazing treatment. Poor and late seed germination was observed on this treatment's plots.

Annual ryegrass produced 2,446 pounds of dry matter per acre from late fall to late spring that can generate a profit from $115 to $121. This depends on the method used to terminate annual ryegrass before stablishing soybean (Glyphosate or Paraquat) and if commercialized as hay at $200 per bale. Since hay production treatment (treatments 2) had no statistical difference in soybean production with any herbicide or cover cropping treatment when conducting multiple mean comparisons, using annual ryegrass as a dual purpose crop (forage and cover crop) is the most profitable treatment evaluated for farmers in North Texas(refer to Table 6 and 7 versus Table 8).

Lastly, ryegrass grazing simulation treatment indicated that 449 pounds of dry matter were produced per acre on an early ryegrass cut. Assuming that ryegrass will have at least 2 cycles before soybean establishment and that it has an even regrow, 898 pounds of dry matter of ryegrass can be produced in total (over the 2 cycles). A leasing contract of $0.60 per pound gain can generate a profit of $25.40 per acre if leased to graze 500 pounds calves for a period of 60 days. Bigger animals will have a higher conversion ratio resulting in a lower profit. Further studies should incorporate the use of calves to calculate the animals' real consumptions and consider variables like ryegrass palatability, grass trampling, and soil compaction.

It should be noted that treatments four through eight allow farmers to have a rotation such as wheat-soybean-wheat because all these treatments include a herbicide application or a ryegrass cut that terminates ryegrass and does not allow it to reach its seeding stage. Eliminating volunteer annual ryegrass during its vegetative or elongation stage reduces the incidence of this plant in the subsequent crop season. In treatments one through three, a rotation corn-soybean-corn will be more suitable because annual ryegrass will not be controlled and it will reach its seeding stage. If ryegrass reaches, its seeding stage stablishing wheat will not be possible because the herbicide controls needed to manage ryegrass weed will also affect wheats development. Wheat and ryegrass plants belong the same family, Poaceae.

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APPENDICES

APPENDIX A

SAS OUTPUTS (SOYBEAN YIELD, HEIGHT, AND DENSITY)

SAS OUTPUTS (SOYBEAN YIELD, HEIGHT, AND DENSITY)

Table 9. ANOVA Test for Soybean Yield (Bushel/Acre) Using the GLM Procedure

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	547.432801	78.204686	2.91	0.0088
Error	86	2310.76726	26.869387		
Corrected Total	93	2858.20007			

R-Square	Coeff Var	Root MSE	BU_AC Mean
0.191531	30.4979	5.183569	16.99646

Table 10. Least-Squares Means for Soybean Yield (Bushels/Acre) Using Adjustment Tukey-Kramer

Least Squares Means for effect Treatment								
Pr > |t| for H0: LSMean(i)=LSMean(j)								
i/j	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1		0.9671	0.9993	0.3622	0.8633	1.0000	0.8928	0.9758
2	0.9671		1.0000	0.9631	0.3571	0.9933	1.0000	0.4524
3	0.9993	1.0000		0.9519	0.7754	0.9999	0.9998	0.9205
4	0.3622	0.9631	0.9519		0.0319	0.5890	0.9920	0.0208
5	0.8633	0.3571	0.7754	0.0319		0.8455	0.2285	0.9935
6	1.0000	0.9933	0.9999	0.589	0.8455		0.9675	0.9666
7	0.8928	1.0000	0.9998	0.992	0.2285	0.9675		0.2679
8	0.9758	0.4524	0.9205	0.0208	0.9935	0.9666	0.2679	

Note: Values in the table report the p-values of comparison between two treatments. P-values under 0.05 indicates that treatments are different.

Table 11. ANOVA Test for Soybean Height (Inches) Using the GLM Procedure

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	71.1026042	10.157515	2.33	0.0312
Error	88	383.082292	4.3532079		
Corrected Total	95	454.184896			

R-Square	Coeff Var	Root MSE	Height Mean
0.15655	10.1288	2.086434	20.59896

Table 12. Least-Squares Means for Soybean Height (Inches) Using Adjustment Tukey-Kramer

Least Squares Means for effect trmt

Pr > |t| for H0: LSMean(i)=LSMean(j)

i/j	1	2	3	4	5	6	7	8
1		0.9998	0.9728	0.8232	0.9565	1.0000	1.0000	0.6995
2	0.9998		0.9986	0.9824	0.8513	0.9997	0.9996	0.5165
3	0.9728	0.9986		1.0000	0.6476	0.9729	0.9690	0.3864
4	0.8232	0.9824	1.0000		0.2862	0.8513	0.8371	0.0436
5	0.9565	0.8513	0.6476	0.2862		0.9824	0.9855	1.0000
6	1.0000	0.9997	0.9729	0.8513	0.9824		1.0000	0.8817
7	1.0000	0.9996	0.9690	0.8371	0.9855	1.0000		0.8968
8	0.6995	0.5165	0.3864	0.0436	1.0000	0.8817	0.8968	

Note: Values in the table report the p-values of comparison between two treatments. P-values under 0.05 indicates that treatments are different.

Table 13. ANOVA Test for Soybean Density (Pounds per Bushel) Using the GLM Procedure

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	7	13.49011160	1.9271588	0.52	0.8178
Error	87	322.8689872	3.7111378		
Corrected Total	94	336.3590988			

R-Square	**Coeff Var**	**Root MSE**	**Test Weight Mean**
0.040106	3.741864	1.926431	51.4832

Table 14. Least-Squares Means for Soybean Density (Pounds per Bushel) Using Adjustment Tukey-Kramer

Least Squares Means for effect trmt

Pr > |t| for H0: LSMean(i)=LSMean(j)

i/j	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1		1.0000	0.9997	0.9998	0.9999	1.0000	0.9979	0.9945
2	1.0000		0.9980	1.0000	0.9987	0.9995	0.9999	0.9816
3	0.9997	0.9980		0.9923	1.0000	1.0000	0.9793	1.0000
4	0.9998	1.0000	0.9923		0.9927	0.9962	1.0000	0.9337
5	0.9999	0.9987	1.0000	0.9927		1.0000	0.9760	1.0000
6	1.0000	0.9995	1.0000	0.9962	1.0000		0.9853	1.0000
7	0.9979	0.9999	0.9793	1.0000	0.9760	0.9853		0.8453
8	0.9945	0.9816	1.0000	0.9337	1.0000	1.0000	0.8453	

Note: Values in the table report the p-values of comparison between two treatments. P-values under 0.05 indicates that treatments are different.

APPENDIX B

OPTIMISTIC SENSITIVITY ANALYSIS FOR THE HAY PRODUCTION TREATMENTS AND GRAZING SIMULATION

OPTIMISTIC SENSITIVITY ANALYSIS FOR THE HAY PRODUCTION TREATMENTS AND GRAZING SIMULATION

Table 15. Sensitivity Analysis for Volunteer Annual Ryegrass Hay Production Terminated with Paraquat Contact Herbicide (Optimistic Scenario)

	Dry Mater Produced (Pounds)					
Hay Price ($)	**1200**	**1600**	**1800**	**2000**	**2200**	**2446**
$ 50	*$ (53.72)*	*$ (43.72)*	*$ (38.72)*	*$ (33.72)*	*$ (28.72)*	*$ (22.57)*
$ 100	*$ (23.72)*	*$ (3.72)*	$ 6.28	$ 16.28	$ 26.28	$ 38.58
$ 125	*$ (8.72)*	$ 16.28	$ 28.78	$ 41.28	$ 53.78	$ 69.15
$ 150	$ 6.28	$ 36.28	$ 51.28	$ 66.28	$ 81.28	$ 99.73
$ 200	$ 36.28	$ 76.28	$ 96.28	$ 116.28	$ 136.28	**$ 160.88**
$ 225	$ 51.28	$ 96.28	$ 118.78	$ 141.28	$ 163.78	$ 191.45
$ 250	$ 66.28	$ 116.28	$ 141.28	$ 166.28	$ 191.28	$ 222.03
$ 275	$ 81.28	$ 136.28	$ 163.78	$ 191.28	$ 218.78	$ 252.60
$ 300	$ 96.28	$ 156.28	$ 186.28	$ 216.28	$ 246.28	$ 283.18
$ 325	$ 111.28	$ 176.28	$ 208.78	$ 241.28	$ 273.78	$ 313.75
$ 350	$ 126.28	$ 196.28	$ 231.28	$ 266.28	$ 301.28	$ 344.33

Note: The optimistic scenario excludes seeding rate and seed price in the profit ($/acre) calculations reported inside the table.

Table 16. Sensitivity Analysis for Volunteer Annual Ryegrass Hay Production Terminated with Glyphosate Systemic Herbicide (Optimistic Scenario)

	Dry Mater Produced (Pounds)					
Hay Price ($)	**1200**	**1600**	**1800**	**2000**	**2200**	**2446**
$ 50	*$ (59.85)*	*$ (49.85)*	*$ (44.85)*	*$ (39.85)*	*$ (34.85)*	*$ (28.70)*
$ 100	*$ (29.85)*	*$ (9.85)*	$ 0.15	$ 10.15	$ 20.15	$ 32.45
$ 125	*$ (14.85)*	$ 10.15	$ 22.65	$ 35.15	$ 47.65	$ 63.02
$ 150	$ 0.15	$ 30.15	$ 45.15	$ 60.15	$ 75.15	$ 93.60
$ 200	$ 30.15	$ 70.15	$ 90.15	$ 110.15	$ 130.15	**$ 154.75**
$ 225	$ 45.15	$ 90.15	$ 112.65	$ 135.15	$ 157.65	$ 185.32
$ 250	$ 60.15	$ 110.15	$ 135.15	$ 160.15	$ 185.15	$ 215.90
$ 275	$ 75.15	$ 130.15	$ 157.65	$ 185.15	$ 212.65	$ 246.47
$ 300	$ 90.15	$ 150.15	$ 180.15	$ 210.15	$ 240.15	$ 277.05
$ 325	$ 105.15	$ 170.15	$ 202.65	$ 235.15	$ 267.65	$ 307.62
$ 350	$ 120.15	$ 190.15	$ 225.15	$ 260.15	$ 295.15	$ 338.20

Note: The optimistic scenario excludes seeding rate and seed price in the profit ($/acre) calculations reported inside the table.

Table 17. Sensitivity Analysis for Volunteer Annual Ryegrass Grazing Simulation Terminated with Paraquat Contact Herbicide (Optimistic Scenario)

	Dry Mater Produced (Pounds)					
Grazing rate ($ per pound)	**250**	**300**	**350**	**400**	**449**	**500**
$ 0.40	$ 7.97	$ 14.64	$ 21.31	$ 27.97	$ 34.51	$ 41.31
$ 0.45	$ 12.14	$ 19.64	$ 27.14	$ 34.64	$ 41.99	$ 49.64
$ 0.50	$ 16.31	$ 24.64	$ 32.97	$ 41.31	$ 49.47	$ 57.97
$ 0.55	$ 20.47	$ 29.64	$ 38.81	$ 47.97	$ 56.96	$ 66.31
$ 0.60	$ 24.64	$ 34.64	$ 44.64	$ 54.64	**$ 64.44**	$ 74.64
$ 0.65	$ 28.81	$ 39.64	$ 50.47	$ 61.31	$ 71.92	$ 82.97
$ 0.70	$ 32.97	$ 44.64	$ 56.31	$ 67.97	$ 79.41	$ 91.31
$ 0.75	$ 37.14	$ 49.64	$ 62.14	$ 74.64	$ 86.89	$ 99.64
$ 0.80	$ 41.31	$ 54.64	$ 67.97	$ 81.31	$ 94.37	$ 107.97
$ 0.85	$ 45.47	$ 59.64	$ 73.81	$ 87.97	$ 101.86	$ 116.31

Note: The optimistic scenario excludes seeding rate and seed price in the profit ($/acre) calculations reported inside the table.

APPENDIX C

TIMELINE OF TREATMENTS

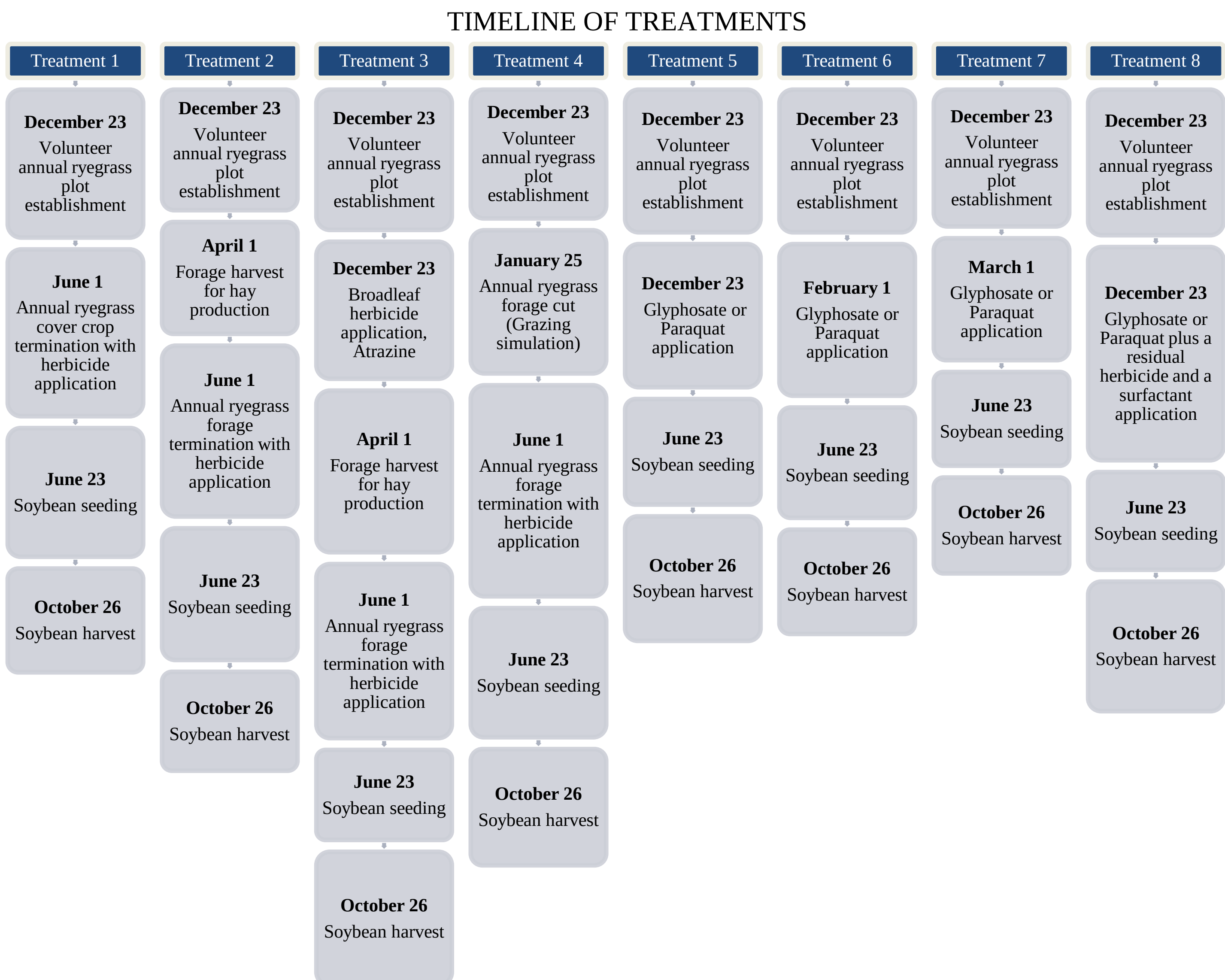

Figure 3. Timeline of the treatments evaluated.

VITA

I got my bachelor's degree in Agricultural Sciences and Production at the best agriculture school in Latin America, Escuela Agricola Panamericana Zamorano. This school is located in Honduras, the greatest coffee producer country of Central America. Since I graduated from Zamorano in 2019, I have been involved in both research and agriculture production.

During the 2020 pandemic lockdown, I did an internship at Auburn University for 6 months working on research focused on food science, feed elaboration, and poultry. The rest of 2020 I worked in my home country, Guatemala, at a melon company named Sol Group. I was a supervisor in the department of weed and pest management.

In 2021, I was granted with a graduate assistantship at Texas A&M-University Commerce to work on a project funded by USDA NIFA, to promote financial benchmarking to Texan farmers. While I lived in Commerce, I volunteered with Texas A&M Agrilife in research related to cotton, corn, and soybean. I participated in many poster presentations around Texas and won some awards. Additionally, I joined many organizations on campus that allowed me to serve the local community and my community back home. In summer 2022 I graduated of two master degrees, Master of Science in Agriculture and Master in Business Administration. I accepted an offer from Texas Tech University in Lubbock, Texas to pursue my Philosophy Doctorate in Agricultural and Applied Economics.

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