CHARACTERIZING GOOSEGRASS AND CRABGRASS IN PASTURE-BASED DAIRY STSTEMS

by

JAMES MARK FREEMAN

(Under the Direction of Nick Hill)

ABSTRACT

The state of Georgia has seen a rapid increase in the number of cows raised in pasture-based dairy systems. Recently unforeseen summer annual weed problems have emerged. Goosegrass (*Eleusineindica*L. Gaertn.) and crabgrass (*Digitariasanguinalis*L.Scop.) compete directly with bermudagrass (*Cynodondactylon*L.Pers.). This competition may weaken forage stands thus; an experiment was conducted to determine if competition from winter annual forage grasses inhibited establishment of goosegrass and crabgrass. Summer annual weed suppression was greater following annual ryegrass (*Loliummultiflorum*L.) than oats (*Avenasativa*L.) or cereal rye (*Secalecereal*L.) under irrigation. Also the effect of goosegrass population density and defoliation strategy on bermudagrass biomass was examined and a decrease in bermudagrass biomass was seen where goosegrass was not harvested and as goosegrass population density increased. A third component of the research indicated that cell wall content of goosegrass was consistently less than that of bermudagrass and likely not a reason for grazing preferences for bermudagrass.

INDEX WORDS: Management intensive grazing dairies; goosegrass; crabgrass; population density; competition; NDF; ADF; Eleusine indica; Digitaria sanguinalis, Cnynodon dactylon; Lolium multiflorum

CHARACTERIZING GOOSEGRASS AND CRABGRASS IN MANAGEMENT INTENSIVE GRAZING DAIRIES

by

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BS, The University of Georgia, 2010

A Thesis Submitted to the Graduate Faculty of TheUniversity of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2013

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May2013

DEDICATION

This Thesis is dedicated to Sara Claire Freeman.

ACKNOWLEDGEMENTS

I would like to offer a big thank you to my major professor Dr. Nick Hill for believing in me and allowing me to do research on such an interesting and relevant topic in Georgia agriculture. As an undergraduate with no previous forage experience, I was very intrigued by Dr. Hill's forage course. His expertise and knowledge of forage systems and the pasture based dairy concepts were very instrumental in my interest in completing a Master's degree in Crop and Soil Science. I would also like to thank the other members of my graduate committee, Dr. William Vencill and Dr. Dennis Hancock, for their help and expertise on my research.

I would also like to give my appreciation to Kevin Roach who, without his help, much of the data collection and harvesting would not have been possible. Much of this project's data collection was done during the hot summer. Kevin and I had many a day spent on our hands and knees counting weeds and hand harvesting forage.

I also would like to thank Herb Yeomans, Josh Griffin, and Ryan Baerne from the Plant Science Farm for their help with the irrigation equipment setup and manual irrigation application during the Bermudagrass Competition experiment. Also thanks go to Kurk Lance and his student workers at the greenhouse complex for their help with irrigating and fertility management during my greenhouse experiment. Another thank you goes to the farm crew at the Central Georgia Research and Education Center for allowing me to conduct my research at this facility and for lending me the farm equipment needed to plant the experiment.

A final thank you goes to Crystal Gaillard, whose love and patience have helped me to complete my research and to write this thesis.

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INTRODUCTION AND LITERATURE REVIEW

Introduction

The State of Georgia and the rest of the southeastern Unites States are milk deficient states. By definition, the dairy production in these states is lower than what the fresh milk demand. This means that milk must be transported to meet the dairy needs of the region. Georgia's agricultural industry could be enhanced with an increase in dairy production.

The conventional confinement dairy system that is popular in the dairy industry was first introduced in regions that have the most dairy production. These confinement systems use animals that are very high milk producers and confine these animals inside where diets are fed that are comprised of feed grown in other areas. This is a system designed for areas where year-round grazing is not an option.

An alternative production strategy is pasture-based dairying. It is referred to this because the emphasis is on the forage management (Hancock and Andrae, 2009). In the pasture-based system, the animals graze and spend the majority of their lives on intensively managed pastures year-round. Pasture-based grazing employs rotational stocking, which differs from the continuous stocking where animals are allowed to graze on a single large pasture. Pasture-based grazing systems are intensively managed forage production systems that promote economically optimal productivity per unit of land. On a pasture-based farm, large pastures are divided into smaller paddocks with the use of electric fencing. Animals are then moved into paddocks and allowed to graze the forage to a specific height. When the paddock has been sufficiently grazed, the animals are moved to a new paddock where this process is repeated. Pasture-based dairy paddocks are managed for optimal forage quality. The highest forage qualities are typically seen when the grass is in a vegetative state of growth (Oliveira et al. 2011). To stay in this vegetative state animals must not be in a paddock long enough so that the paddock is overgrazed. An overgrazed paddock may also be more susceptible to weed establishment as pastures with that are grazed lower are more susceptible to weed establishment than pastures grazed higher (Schmidt and Renz, 2012). On the other hand, if the paddock is undergrazed the forage will grow out of the vegetative stage and forage will have a reduction in quality (Schmidt and Renz, 2012).

Weed management is different than in other pasture situations. One reason is because herbicides use restrictions pose a greater limitation. Grazing restrictions placed on many herbicides, particularly grassy weed control measures do not allow animals to be on the treated area for several weeks or months. Therefore, a paddock that has had herbicide application may be taken out of the pasture rotation.

Goosegrass (*Eleusine indica*L.Gaertn.) and crabgrass (*Digitaria sanguinalis*L. Scop.) are two emerging weeds that have been difficult to control in these grazing situations. These two weeds are summer annuals that compete well with bermudagrass and other summer forages. Weeds may decrease the quality and yield of the forage and weaken forage stands (King, 1963). Goosegrassis also reported to contain some level of prussic acid, which also could negatively affect animal performance (Cunningham et. al. 1992).

Therefore, cultural practices are needed to control these weeds in the pasture-based dairy system. One possible cultural control practice could be to change irrigation techniques to enhance forage growth rather than weed growth. Grazing the grass to the appropriate height also allows forage to out-compete weed seedlings for light and other requirements. Another cultural control practice is the planting of certain species and varieties of winter annual forage grasses.

Some ryegrasses are believed to have some allelopathic effects on weed seedling germination (A.E. Smith, 1990). Other than allelopathy, ryegrasses and other later maturing winter annuals may also out- compete summer annual weed seedlings for sunlight, water, and nutrients in the late spring (Pester, 1998).

The goal of this research is to determine the effect goosegrass populations on a mature bermudagrass pasture based on the yield of the bermudagrass. It will also evaluate different winter annual forages and irrigation techniques for their effectiveness at controlling summer annual weed seedling germination and proliferation. Goosegrass and crabgrass will also be compared against bermudagrass in a greenhouse experiment for differences in yield, NDF, ADF, IVDMD, and CP when harvested at three different heights (5, 10, and 15 cm) and frequencies (14, 21, and 42 days).

Literature Review

The number of cows located on pasture-based dairy farms is rapidly increasing in Georgia. This expansion is caused by a need for less expensive milk production, a desire to produce milk in different climates throughout the country and to improve the lifestyle of the dairy producer. There has been a dramatic decrease in the number of conventional dairy farms in parts of the country (Winsten et al, 2010). Management-intensive, pasture-based grazing dairy systems are an economical alternative to the total confinement dairy system in the Southeastern United States. Even though less milk is produced by each animal in a pasture-based system, there are fewer costs and a greater net return on investment (Dartt et al, 1999).

The pasture rotation system is sometimes referred to as management intensive grazing because the emphasis is on the forage management (Hancock and Andrae, 2009). In the pasture-based system the farmer must intensively manage the forage by rotating the animals to different paddocks. The cows are rotated from paddock to paddock when the forage is in a vegetative state so forage protein and digestibility levels are sufficient to meet energy demands by the animal. After the forage is grazed to the appropriate height, the cows are moved to a different paddock and the process is repeated. This rotation allows the forage in each paddock to have sufficient leaf area to stimulate regrowth and maintain forage in a linear rate of growth.

Georgia has seen a tremendous growth in the number of dairy cows on pasture-based systems. There has been an increase of about 14,000 cows to the State's herd since 2007. As the number of cows in pasture-based dairies has increased, there has been a concomitant decrease in the number of cows within confinement systems. The total number of head in the State of Georgia's dairy herd has decreased by 8,000 since 2007 (Hill and Hancock, 2009).

The Southeastern U.S. has 32% of the U.S. population but produces only 8% of the nation's milk supply (Anonymous, 2004; U.S. Census Bureau). Therefore, more milk production is needed in the Southeast to meet this demand. Pasture-based dairies have proven to be a profitable production method in this area of the United States because of several advantages that this region possesses for pasture based dairies. Climate and soils allow for a longer growing season and high yielding forages practically year round (Hill and Hancock, 2009). Unlike the confinement systems where waste is stored in lagoons and applied back to the land, cows in the pasture-based systems spend almost all of their time on the pasture and deposit >95% of their waste directly on the soil. The cows also evenly distribute the manure across the pasture (White el at, 2001). This reduces cost on manure handling and storage. In the confinement systems nitrates and phosphates can accumulate onsite and can become pollutants to streams and water sources by runoff and leaching (Campbell-Arvai, 2009). There are substantial costs saved on feed needed by the animals as well as improved cow health and longevity (Gerrish, 2004).

The rotational grazing system is superior to set stocking pasture systems. When livestock are stocked on a pasture continuously, the forage is not efficiently utilized. The animals will often only graze about 30-40% of the forage on the pasture, and the rest of the pasture is essentially wasted. Many times the grazing herd will only graze areas that are close to shade or water. These areas will be continuously overgrazed and the remaining areas will become mature grass that is tough and stemmy (Hancock and Andrae, 2009). A healthy forage stand is essential to the development and growth of the animals and production of milk and sustainability of the pastures is crucial to the survival of the farm.

The pasture-based grazing system requires inclusion of both warm season and cool season forage systems in Georgia. A perennial warm season grass such as 'Tifton-85'bermudagrass (*Cynodondactylon*L.Pers.) or 'Tifquick' bahiagrass (*Paspalum notatum* Flüggé.) are ideal forages for pasture-based systems to support grazing dairies in the summer months. Tifton-85 is a hybrid bermudagrass that is highly digestible and is the highest yielding variety in our environment and is also more palatable with larger leaves than the common bermudagrass. Tifquick bahiagrass is a rapidly germinating and fast growing variety of bahiagrass (Anderson et al, 2011). These warm season grasses green up in late spring and stay green until late fall.

For the winter months, annual forages such as annual ryegrass (*Lolium multiflorum*L.), cereal rye (*Secale cereal*L.), oats (*Aneva Sativa*L.) and wheat (*Triticum*L.) are overseeded into the bermudagrass or bahiagrass at the beginning of fall. These species have growth habits that provide forage in the fall, winter, and spring months (Figure 1). Tifton-85 has a higher metabolizable energy than bermudagrass cultivars (Burns and Fisher, 2007). The combination of the warm season grasses and the cool season annual grasses allows for forageproduction during a majority of the year.

Emerging weed problems

Goosegrass and crabgrass are two weeds that can be competitive with warm season grasses in pasture-based grazing systems. Competition from these weeds may weaken stands of perennial warm season grasses, rendering the system less productive. It is thought that goosegrass will lower the forage quality, but there is no research to validate this claim. Weeds can also reduce the overall amount of feed consumed by the animals (Monaco et al, 2002), which may reduce milk production

Goosegrass

Goosegrass is a weed that is native to the tropical regions of the world. In the Eastern United States,goosegrass is present in all but the Northern most parts of Maine and North-Central Plains. This grass is a bunch grass with no stolons or rhizomes (USDA, 1971). Goosegrass seeds germinate when soil temperatures reach 15.5°C (Johnson and Bhagirath, 2008).Germination is also high when day and night temperatures fluctuate. At constant temps of 20°, 25°, and 30°C, <10% of the seeds germinated; but once these seeds were exposed to fluctuating day/night temps of 30°-20° C and 35°-25° C resulted in 99% germination (Nishimoto and McCarty, 1997; Bhagirath and Joshnson, 2008). Goosegrass seeds have the highest rate of germination when they are placed on the soil surface. As goosegrass seed is buried deeper in the soil, the germination rates decline. Goosegrass planted at the soil surface had an 82% germination rate, seeds at 0.5 cm had a 63% germination rate, seeds at 6.0 cm had a 4.0% germination rate, and seeds at 8.0 cm had zero germination. Hypoxia and light conditions could be the main reason for the lack of germination at the deeper soil depths. Goosegrass seedling emergence decreases when crop residues remain on the soil surface and seedlings are sensitive to water stress (Bhagirath and Johnson, 2008). It is a tufted bunch grass that branches at the base, does not root at the node, and only reproduces by seed (USDA, 1971).

Goosegrass grows vigorously in compacted soils and can out-compete bermudagrass in these areas (McCullough et al., 2012). In pasture situations the areas where goosegrass infiltration tends to be the greatest are around gates, watering areas, shade, and other areas where animal traffic is heavy. Goosegrass also has a shallow fibrous root system that allows it to compete with bermudagrass when the pastures are watered frequently and lightly (Bryson and Defelice, 2009). Goosegrass has a more prostrate growth pattern than bermudagrass and this pattern makes it a troublesome weed in turf because it produces seed even with close defoliation. Therefore, the goosegrass growth habit could also pose the same problems in pasture situations.Grazing animals could harvest the taller bermudagrass leaving more residual leaf area belonging to the goosegrass. Goosegrass plants can produce up to 140,000 seed per plant (Chin, 1979) indicating that goosegrass populations can be very high when environmental conditions are optimal. These seeds are small, averaging approximately 0.4 mg (Bhagirath and Johnson, 2008).

Goosegrass is also susceptible to water stress early in its vegetative stage. Water stress can cause a decrease in plant growth potential as it matures and causes goosegrass to be less competitive with other plant species. (Sionet et al., 1987).

Crabgrass

Large crabgrass is also a summer annual weed. It is an aggressive growing weed that will restrict bermudagrass growth and can contribute to bermudagrass stand loss (Smith and Martin, 1992). Seed dormancy in large crabgrass is often broken by warm dry soil (Lanini, 1985). Large crabgrass seed will begin germination when soil temperatures meet or exceed 12.7 °C for four consecutive days and nights (Breedan and Brosnan, 2010). Germination is commonly enhanced by soil disturbance (Teutsch, et al, 2005). The plants that emerge first are the most competitive, but seedlings will germinate from spring to late summer. Crabgrass reproduces by seed and tillers.A single plant can produce 700 tillers and 188,000 seeds (Smith and Martin, 1992; Kim et al., 2002). Large crabgrass, like goosegrass, has a prostrate growth pattern. It can produce seed even when defoliated to heights as low as 0.6 cm. Thus, overgrazing could make crabgrass competitive with warm season perennial forages. Low mowing or grazing will help the large crabgrass compete with the bermudagrass because its prostrate growth allows more leaf area to escape mowing and grazing. The residual leaf area results in rapid regrowth and superior competitiveness. The prolific branching habit of the crabgrass allows it to spread rapidly and cover considerable ground (Lanini, 1985).

Seedling large crabgrass plants must have full sun to grow. Shade from a dense canopy will not allow seedlings to develop (Major and Schat, 2009). Grass that is cut or grazed higher shades the soil and reduces the competitiveness of the crabgrass. Like goosegrass, large crabgrass will out-compete bermudagrass when watered lightly and frequently (Clyde and Cudney, 2000).

Large crabgrass is actually a nutritious forage species and is relatively palatable in its vegetative state (Ball, Hoveland and Lacefield, 2002). Large crabgrass seed is nearly ubiquitous in Georgia soils. The seedbank permits the establishment of large crabgrass pasture systems and can occupy open soil surfaces. The sandy soils of the coastal plain are great soils for this species and it also responds well to nitrogen fertilization (Blount et al, 2003).

Independent studies suggest that,*in vitro* dry matter digestibility (IVDMD) and crude protein content (CP) of the Tifton-85, goosegrass, and crabgrass are similar but no studies have been conducted in which they are directly compared. Tifton-85 bermudagrass is reported to havean IVDMD of 61.3% and a CP of 12.6% while the crabgrass is reported to have an IVDMD of 67% at the vegetative stage, 54% at the flower/boot stage and 63% at the fruit/head stage (Ball, Hoveland and Lacefield, 2002). The percent of IVDMD for goosegrass in the vegetative stage is 67.7% with a CP of 12.1% (Nuwanyakpa et al, 1983). However, true comparisons of the forage quality parameters of goosegrass, crabgrass, and bermudagrass have not been conducted at different stages of development. Therefore, studies need to be conducted to compare these grasses side by side to get a more accurate comparison of forage quality.

Cultural Control

Cultural control of weeds is extremely important in order to manage weeds efficiently without the use of many herbicides. The use of herbicides may eliminate a pasture from the grazing rotation for an extended period of time because of restrictions placed on grazing following herbicide application. With the intensive management that goes into the pasture grazing rotations, this is unacceptable. There are a few possible cultural control practices that could be applied to help control goosegrass and crabgrass and permit legal re-entry into the pasture by the grazing animal.

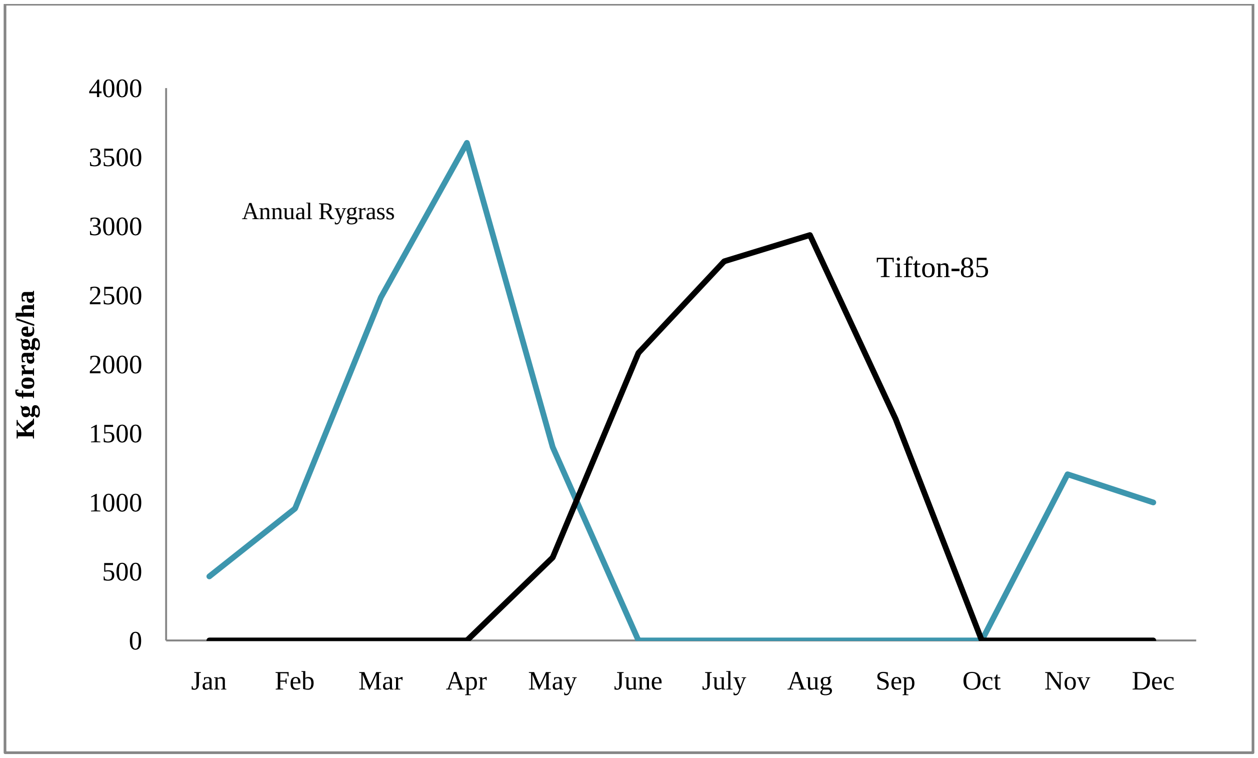
One option is to maintain a thick dense canopy of other forage grasses that will shade out goosegrass and crabgrass seedlings and minimize their competitiveness with warm season pasture grasses (Blount et al, 2003). Overgrazing reduces the canopy effect and may be detrimental to keeping a dense stand because it removes too much leaf tissue from the grass. Thus, the plants must regenerate new leaf tissue to compete with weeds. The bare ground and thin grass allows for more sunlight to reach the soil surface and accounts for a larger day-night temperature fluctuation in the upper layer of the soil. These could possibly contribute to higher germination rates of goosegrass and crabgrass (Arrieta and Busey, et al, 2009).

A second option may be to utilize correct irrigation techniques for goosegrass and crabgrass control. The goosegrass and crabgrass thrive and are more competitive than bermudagrass when they are watered lightly and frequently (Landschoot, 2009). Therefore, irrigating deeply and infrequently could help give other forage grasses like bermudagrass a competitive advantage. This deeper watering technique will allow a forage manager to utilize compensatory root growth and have an overall healthy root system. A healthy root system means a healthy plant that can better withstand stresses from drought and grazing.

During the cool season, allelopathy from plants like annual ryegrass can work to inhibit weed seed germination. Allelopathy is defined as the direct or indirect harmful effects of one plant on another through the production of chemical compounds that escape in to the environment (Rice, 1984). Allelopathy is also a thought to be very important in pasture and rangeland situations because allelopathy is more prominent when vegetation residues are left on the soil surface compared to when vegetation is incorporated into the soil (Guenzi, McCalla and Narstadt, 1967; A.E Smith, 1990). Annual ryegrass also forms a dense sod and may not allow the weed seedlings to compete for sunlight (Pester, 1998). The small seeds from goosegrass and crabgrass on the top of the soil surface may be more susceptible to ryegrass allelopathy than other seeds. Seeds that are larger in size and deeper in the soil surface were less affected by the allelopathy from the ryegrass. The small sized goosegrass seeds (Bhagirath and Johnson, 2008) may be more susceptible to allelopathy as the highest concentrations of the allelochemicals are close to the soil surface were the smaller seeded plants usually germinate (Pester, 1998).

Plant competition during the spring transition period may also play a role in the germination and establishment of goosegrass and crabgrass. Later maturing forage species may benefit by out competing emerging weed seedlings. Competition for sunlight is controlled by the species in the uppermost layers of the canopy (Vojtech, Turnbull, and Hector, 2007). Of all the plant requirements, sunlight may be the most important. Sunlight determines the energy available for all physiological processes and partially drives the acquisition of other resources (Keddy, 2001).

Figure 1 Distribution of cool & warm season forage growth in the coastal plain of South Georgia**.**



MANUSCRIPT

Introduction

The number of pasture-based dairy systems has increased dramatically in Georgia during the last decade (Hill and Hancock, 2009). These pasture-based systems utilize a program comprised of a perennial bermudagrass (*Cynodon dactylon*L.Pers.)forage base which is overseeded with winter annual grasses grown under irrigated conditions. Goosegrass (*Eleusine indica*L. Gaertn.)and crabgrass (*Digitaria sanguinalis*L. Scop.)are two summer annual weeds which appear to compete directly with bermudagrass throughout the summer growing season thereby weakening bermudagrass stands. Both weeds compete well with bermudagrass in turfgrass settings (Landschoot, 2009; Clyde and Cudney, 2000) and their prostrate growth habits allow for more residual leaf area after defoliation (Lanini, 1985).

Weed control measures are limited in pasture settings due a need for continual forage supply which is complicated by grazing restrictions following herbicide applications. Some winter annuals appear to possess traits that can inhibit the germination of summer annual weeds (Amini et al, 2009). These traits tend to be more inhibitory to small seeded, and may result in differences in weed populations in pastures planted to different winter annual species (Guenzi et al., 1967; Pester, 1998). The difference may be due to several factors including allelopathathic chemicals from the winter annuals (Smith, 1990; Smith and Martin, 1992) or competition for resources such as soil moisture, sunlight, and nutrients (Isselstein et al., 2002).

The objectives of this study were to: 1) determine the impact of overseeded winter annual forages on subsequent weed populations in bermudagrass, 2) examine the competitiveness of different population densities of goosegrass in established bermudagrass, and 3) determine growth patterns of goosegrass, crabgrass, and bermudagrass at varying defoliation frequencies and heights.

Materials and Methods

Objective 1. Determine the impact of overseeded winter annual forages on subsequent weed populations in bermudagrass.

An experiment was conducted at the Central Georgia Research and Education Center near Eatonton, Ga. to determine the impact of overseeded annual forages on subsequent weed populations in bermudagrass. The experiment was established on a Davidson clay loam soil (Fine, kaolinitic, thermic RhodicKandiudult). Four winter annual grass species were used as treatments consisting of 'Marshall' and 'Feast II' annual ryegrasses (*Lolium multiflorum*L.), 'Wrens abruzzi' cereal rye (*Secale cereal*L.), and 'Harrison' oats (*Avena sativa*L.). Seeding rates were 25 kg ha^{-1}, 120 kg ha^{-1}, and 100 kg ha^{-1} for the ryegrass, rye, and oat treatments, respectively. Winter annuals were established by suppressing 'Russell' bermudagrass (*Cynodon dactylon*L. Pers.)with 0.5 kg $aiha^{-1}$ of Roundup (glyphosate) herbicide (Monsanto, St. Louis, Mo) one week prior to planting. The winter annual forages were sod seeded into the suppressed bermudagrass using a Kincaid (Haven, KS) no-till plot planter.Plot areas were 1.5 x 6 m and planted on 7 Oct in 2010 and 2011. Plots were fertilized with 50 kg ha^{-1} N, P_2O_5, and K_2O after emergence and again following each harvest. Beginning in March, one half of the plot areas were irrigated every 2 days with 1.5 cm of water beginning at 0600 and ending at 0700 using an Orbit Irrigation Systems (Bountiful, UT) yard watering system.

Plots were harvested every 28 d beginning in February following establishment. Forage was cut to a 5 cm height using a Swift Machine and Welding (Swift Current, SK., Canada) forage harvester. Harvested forage weights were recorded and forage yield calculated. Weed establishment was estimated by counting seedlings within plots beginning in May of each year using a 30 cm x 30 cm quadrat randomly placed in seven locations within each plot. Weed seedling counts were repeated weekly for 28 d. Beginning in June of each year, a point frame quadrat system was used to determine basal cover of weeds and bermudagrass. The point frame quadrat was 1 m^2containing 100 points in a 10-cm grid. The quadrat was placed at three randomly chosen locations within each plot and the plant species under each grid point noted.

In the second year of the study a Li-Cor (Lincoln, NE) model LI-191 Line Quantum Sensor was used to measure light interception. Light measurements were taken from above the crop canopy to record incidental light followed by a second measurement at the soil surface within the crop canopy at three random locations within each plot. Light measurements were started 28 April, 2012 prior to forage harvest and every 7, 21, and 28 days post harvest until cool season grasses had expired. The percent light interception (LI) was calculated as:

Eq. 1. LI=(1-(mean of canopy light/mean of incidental light))*100.

Plots were arranged using a split block design, where irrigation treatments were used as the split. The forage species were randomly arranged within each irrigation split and the blocks were replicated four times.

Weed count and basal cover data were analyzed using the PROC MIXED subroutine of SAS (SAS 9.2, Cary, NC). Year was considered as a random effect in the statistical model, but sampling dates, forage species, irrigation, and replication were considered fixed effects. Treatment means were separated using a Fisher’s Protected LSD at the 0.05 level of probability. Data from the canopy light interception measurements were analyzed using the PROC ANOVA subroutine of SAS (SAS 9.2, Cary, NC). Sampling dates, forage species, irrigation, and replication were all considered fixed effects. Mean separation was performed using a Fisher's Protected LSD at the 0.05 level of probability.

Objective 2. Examine the competitiveness of different population densities of goosegrass in established bermudagrass.

An experiment was conducted at the UGA Plant Science Farm near Watkinsville, GA to investigate competitiveness of different population densities of goosegrass in established bermudagrass. The site was located on a Pacolet sandy clay loam soil (Fine, kaolinitic, thermic Typic Kanhapludult). Goosegrass seeds were germinated in a growth chamber set to alternating day/night temperatures of 30° and 20° C. Seedling plants were transplanted into cell-packs (International Greenhouse Company, Danville, IL; 50 mL per cell) containing Farfard germination mix 1 (Agawam, MA). Plants were transferred into a greenhouse and grown for 21 days. Fertilizer was applied weekly using a Dosatron (Clearwater, FL) DosaCart water powered dosing applicator model number HS15-16. Nutrients were applied at 400 mg kg^{-1} with a 20-20-20 fertilizer diluted to a 16:1 ration within the DosaCart.

A small auger was attached to a handheld drill and used to establish holes into which the seedling goosegrass plants were transplanted. Goosegrass plants were established in 0.38 m^2 plots at population densities of 0, 1, 3, or 5 plants per plot. Plots were fertilized with 50 $kgha^{-1}$ of N, P_2O_5, and K_2O using a 10-10-10 fertilizer immediately aftertransplanting and again after each harvest to maintain soil fertility. Sprinkler irrigation was applied, when pan evaporation exceeded rainfall beginning at 0600 and ended 0700 during these periods, with an emission rate of 1.5 $cmhr^{-1}$.

Plots were harvested by hand every two weeks beginning 1 June and ending 15 Sept of 2011 and 2012. Goosegrass and bermudagrass were harvested to a 5-cm stubble height using hand-held shears. Harvested forage was separated by species, placed into paper bags, and freeze dried in a Virtis Freezemobile 25 SL (Gardiner, NY).The dried forage was weighed and dry matter yield per m^2 calculated for each plant species.

The experiment was modified in 2012 by including treatments in which goosegrass was not defoliated. The treatments were assigned as a factorial of goosegrass population density and defoliation treatment. Freeze-dried goosegrass was ground to pass a 1-mm screen in a Tecator Cyclotec mill (Hoganus, Sweden). The goosegrass forage was analyzed for prussic acid using the picric acid method (Hogg and Ahlgren, 1942).

All plots were arranged in a randomized complete block with 5 replications. Treatments where goosegrass was defoliated were analyzed using the PROC MIXED subroutine of SAS (SAS 9.2; Cary, NC) where years were considered random effects, while population densities, defoliation events, and replications were considered fixed effects.

Data from 2012 were also analyzed independently from the 2011 data. These data were analyzed using the PROC ANOVA subroutine of SAS, where population densities, defoliation events, harvested vs. intact goosegrass, and replications were all considered fixed effects. Mean separation of all analyzes was performed using a Fisher's Protected LSD and the 0.05 level of probability. Data from 22 Aug, 2012 and 5 Sep, 2012 were analyzed using the PROC REG subroutine of SAS to compare population density and bermudagrass yields and well as compare goosegrass yields and bermudagrass yields on 5 Sep, 2012.

Objective 3.Determine growth patterns and forage quality parameters of goosegrass, crabgrass, and bermudagrass at varying defoliation frequencies and heights.

A greenhouse experiment was conducted in Athens, GA in 2011 and 2012 to determine the growth patterns and forage quality parameters of goosegrass, crabgrass, and bermudagrass harvested at varying defoliation intervals and heights. Goosegrass seed were collected from a wild population near Watkinsville, GA and cleaned using a SeedTech Systems model STS-WM3 (Wilton, CA) seed cleaner. Goosegrass seed and 'Red River' crabgrass were germinated in a growth chamber with alternating day/night temperatures of 30° and 20° C. The germinated seedlings were transplanted into cell-packs (International Greenhouse Company, Danville, IL; 50 mL per cell) containing Farfard (Agawam, MA) germination mix 1 and placed in the greenhouse for 21 days. Tifton-85 bermudagrass stolons were collected from a field site and cut to 12-cm lengths.

Fifteen-centimeter pots (height) were filled with a soil mix containing a 1:1:1 ratio of Farfard germination mix 1, sand, and Pacolet sandy clay loam soil (Fine, kaolinitic, thermic Typic Kanhapludult). Goosegrass and crabgrass plants, and bermudgrass stolons were transplanted into the pots containing the soil mix. Fertilizer was applied weekly using a Dosatron (Clearwater, FL) DosaCart water powered dosing applicator model number HS15-16. Nutrients were applied at 400 mg kg^{-1} with a 20-20-20 fertilizer diluted to a 16:1 ration within the DosaCart.

Experimental treatments consisted of a factorial of three harvest heights (5, 10, and 15 cm) and three defoliation frequencies (14, 21, and 42 days) for all plant species. After 42 days the harvest sequence was repeated so that two sequences of harvest treatments occurred in each of two years. All herbage was harvested using hand-held sheers. The harvested herbage was put into paper bags and dried in a Blue M Electric (Blue Island, Il.) Model Power-O-Matic dryer at 70° C for 120 hours and dried weights were recorded.Dried samples were ground through Wiley Mill (Arthur H. Thomas Philadelphia, PA) to pass through a 1-mm screen and analyzed for neutral and acid detergent fiber (Goering and Van Soest, 1970).

Pots were arranged using a split block design, where harvest frequency treatments were used at the split. Each of the pots were randomly arranged within each harvest frequency split and replicated four times. Data were analyzed using the PROC ANOVA subroutine of SAS (SAS 9.2, Cary, NC) where year, replication, sequence, species, harvest frequency, and height were all considered fixed effects. Experiments were ended after the second 42 day harvest had been completed. Harvests data were then compiled into sequence one and sequence two consisting of the first 42 days and second 42 days to balance the statistical model. Mean separation of all analyzes were performed using a Fisher's Protected LSD at the 0.05 level of probability.

Results and Discussion

Objective 1. Determine the impact of overseeded winter annual forages on subsequent weed populations in bermudagrass.

The analysis of variance indicated that the weed count data was consistent for all early season sampling dates during the month of May. However, there were significant year by irrigation treatment and forage by irrigation treatment interactions at the p=0.05 level. No other interactions occurred among the treatment variables.

Seedling weed populations were greater under irrigation in 2011 than in 2012 and there were more seedling weeds in irrigated plots than non-irrigated plots in 2011 (Table 1). However, there was no difference between irrigated and non-irrigated treatments in 2012. Rainfall in 2011 was 41 cm whereas in 2012 there was 17 cm of rainfall for the March through May period. Therefore it appears thatin the higher rainfall combined with irrigation in 2011 was sufficient to promote weed seed germination whereas irrigation was insufficient during the dry spring of 2012 to promote weed seed germination.

Summer annual weed seedling counts were not different among the forage species under non-irrigated conditions. However, the weed counts were greater when bermudagrass was overseeded with oats compared to annual ryegrasses under irrigated conditions (Table 2). The percent occupancy of weeds during the summer months mirrored that of the spring seedling weed counts (Table 3). The occupancy of bermudagrass was inversely proportional to the occupancy of weeds, and the percent occupancy of bermudagrass was consistently lower than weed occupancy under irrigated conditions. Bermudagrass occupancy and weed occupancy were similar under non-irrigated conditions in both years. These data suggest that summer annual seedling weed establishment in the spring impacts the occupancy of bermudagrass during the summer. Because irrigation promoted weed germination, these data suggests that prudent irrigation resource management can be a useful tool in weed management.

Overseeding with annual ryegrass resulted infewer summer annual weed seedlings under irrigated conditions (Table 2). There is speculation that annual ryegrass contains allelopathic chemicals that inhibit seed germination (Smith, 1990; Mattner, 2006). However, later seedhead development and maturation of annual ryegrass compared to other winter annual species may limit light penetration to the soil surface, and thus inhibit seed germination (Pester, 1998). Therefore, light penetration was measured among the winter annual forages at various stages of regrowth following defoliation during May of 2012. The data indicate that Feast II and Marshall annual ryegrass had greater light interception in late spring than did Wrens abruzzi cereal rye and tended to have greater light interception thanHarrison oats (Table 4), suggesting that annual ryegrass had a negative impact of the germination and establishment of summer annual weedseffect of light on seed germination.These data also suggest that summer weed populations can be managed through selection of the winter annual crops used to overseed the bermudagrass.

Objective 2. Examine the competitiveness of different population densities of goosegrass in established bermudagrass.

Treatments in which goosegrass was defoliated were consistent over years. Goosegrass did not tolerate the defoliation events and it succumbed to the competitiveness of the bermudagrass over the course of the year (Data not shown). Consequently, there was no effect of goosegrass population densities on bermudagrass growth when goosegrass was defoliated in consort with the bermudagrass.

It became evident in 2011 that the goosegrass was not thriving under defoliated conditions and bermudagrass was out-competing the goosegrass after the defoliation events. Therefore observations on livestock defoliation of goosegrass and bermudagrass were made at a commercial dairy located in Girard, Georgia. Observations were made as lactating cows returned to pastures immediately after milking, a period when the cows were most likely to be hungry and, consequently, less likely to selectively graze pastures (Forbes, 1995). Goosegrass was located in compacted areas of the paddocks near gates and water troughs. Grazing observations were made at three locations within the pastureover the course of approximately 4 hours. The cows consumed bermudagrass almost exclusively, and seemed to ubiquitously avoid goosegrass even though they were hungry. Therefore, the competition study between bermudagrass and goosegrass was modified in 2012 to add a non-defoliated treatment to determine whether defoliation impacted the goosegrass growth and competitiveness with bermudagrass.

In 2012 there was an interaction between harvest date and defoliation treatment for goosegrass and bermudagrass biomass. A decrease in bermudagrass biomass occurred among treatments where goosegrass populations were left intact compared to bermudagrass growth in treatments where the goosegrass was harvested. The decrease in bermudagrass biomass was observed only during the last two harvest dates, 22 Aug, 2012 and 5 Sep, 2012 (Table 5), indicating that the accumulated growth of the intact goosegrass plants throughout the year caused the decrease in bermudagrass yield late in the growing season. Thus, goosegrass may impair the bermudagrass stands if they are not defoliated.

There was no effect of goosegrass weed populations on bermudagrass growth during the early part of the summer. This was likely due to the small impact of seedling goosegrass plantson bermudagrass competitiveness. However,there was a negative impact on bermudagrass growth as the goosegrass matured. Goosegrass presence decreased bermudagrass yields in late August of 2012 when the goosegrass was not defoliated, but there was no effect of goosegrass on bermudagrass when goosegrass was defoliated (Figure 2).The impact of goosegrass on bermudagrass was also present at the final harvest date on 5 September, 2012 (Figure 3). On 5 September, 2012 the total goosegrass weights were summed for all harvests and plots containing intact goosegrass were harvested for biomass. Regression analysisindicated that goosegrass biomass had a negative effect on bermudagrass biomass (Figure 4).

It is not understood why livestock avoid grazing goosegrass. There are indications that the goosegrass may contain prussic acid (Bryson and Defelice, 2009) and that livestock may avoid grazing the weed as a result.Thus, goosegrass was freeze dried and analyzed for prussic acid. There was no prussic acid found in the goosegrass, thus it is not likely that grazing livestock avoided consuming goosegrass because of the presence of prussic acid.

Objective 3. Determine growth and forage quality parameters of goosegrass, crabgrass, and bermudagrass at varying defoliation frequencies and heights.

Analysis of variance indicated significant two, three, and four-way interactions among plant species, harvest frequency, year and sequence of defoliation. The only treatment variable that did not have any interactions with other treatment variables was harvest height. Some treatment interactions were magnitudinal in nature. Therefore, discussion of interactions are limited to only those two-way interactions which were not magnitudinal.

Harvested plant weight tended to increase with cutting height regardless of plant species (Table 6). However, the only significant differences among cutting height were between two extremes, 5 and 15 cm. Plants harvested at 5 cm had no residual leaf area, regardless of plant species. However, plants had noticeable leaf area when harvested at the 15 cm height. Therefore it was likely that the photosynthetic capacity of the plants receiving the 15 cm cutting height was greater than those receiving the 5 cm cutting height.

There was a significant interaction in harvested dry weight between species and sequence (Table 7). Goosegrass and crabgrass dry matter weights decreased from sequence one to sequence two, where as the dry matter weight of bermudagrass did not. These data suggest that repeated defoliation negatively impacted goosegrass and crabgrass. This negative effect on goosegrass growth is similar to what was seen in the field experiment of objective two.

Species also had a significant interaction with harvest frequency (Table 8). Among 14 day and 42 day treatments crabgrass had significantly higher dry matter weights than both bermudagrass and goosegrass, where as the 21 day treatment crabgrass and bermudagrass were not different. There were no differences for any species between 14 and 21 day frequencies, however all species had significantly higher dry matter weights when harvested atthe 42 day interval.

The analysis of variance indicated an interaction between species and harvest height on the percent NDF. The percent NDF increased with increased harvest height for both crabgrass and goosegrass, however harvest height had no effect on the NDF content of bermudagrass (Table 9). There were differences for NDF among species for all harvest heights. Bermudagrass contained the highest NDF content compared to the other species regardless of harvest height. The NDF content tended to be higher in goosegrass compared to crabgrass at the 5 cm and 15 cm harvest heights but they did not differ at the 10 cm harvest height (Table 9).

Similarly, an interaction between species and harvest height on percent ADF content occurred. The percent ADF increased as harvest heights increased for both crabgrass and goosegrass, however harvest height had no effect on the ADF content of bermudagrass (Table 9). There were differences for ADF among species for all harvest heights. Goosegrass and crabgrass did not differ from one another at any harvest height and were lower in ADF content than bermudagrass at the 5 and 10 cm harvest heights. At the 15 cm harvest height only goosegrass was lower in ADF content than bermudagrass. (Table 9).

An interaction between species and harvest frequency for ADF was present. The percent ADF increased with longer harvest frequencies for all species (Table 10). Bermudagrass contained the greatest amount of ADF at all harvest frequencies. Goosegrass and crabgrass did not differ at 21 or 42 day frequencies but goosegrass contained a greater ADF content compared to crabgrass at the 14 day frequency (Table 10).

Cell wall content is known to negatively affect forage intake by the animal (Ball et al., 2002; Valentine, 2001) and lower the nutritive value of forage (Morrison, 1956). Because the cell wall content of bermudagrass was greater than that of goosegrass, it is not likely that forage quality was the reason for livestock to select against goosegrass as observed in objective 2 of this study

SUMMARY

Summer annual weed populations were significantly lower following Marshall and Feast II annual ryegrasses compared to Harrison Oats and Wrens Abruzzi cereal rye under irrigated conditions. This was true for early season seedling populations and subsequent basal cover after summer annual seedling maturation. Light interception measurements in the month of May showed that the two ryegrass cultivars intercepted significantly more sunlight in the forage canopy than did the oats and cereal rye. Overall weed basal cover was significantly higher in irrigated plots compared to non-irrigated plots. Therefore, overseeding bermudagrass pastures with annual ryegrass and modifying spring irrigation practices could reduce weed populations during the ensuing summer.

When goosegrass was not defoliated it encroached on established bermudagrass, especially during late-summer months. Bermudagrass is selectively grazed by cows when in a mixed stand with goosegrass, an indication that goosegrass has reduced forage quality or toxic components. Despite reports that goosegrass contains prussic acid, the goosegrass in these studies did not contain prussic acid and the goosegrass had a lower fiber content than did bermudagrass. Therefore, avoidance of goosegrass must be associated with other anti-quality components of either taste, smell, or unknown toxin.

Table 1. The effect of irrigation on weed populations growing in bermudagrass over two years.

	Seedling Weed Counts (m^{-2})		
Year	Irrigated	Non-irrigated	LSD (0.05)
2011	338	104	44
2012	110	79	NS
LSD (0.05)	47	NS	

Table 2. The effect of winter annual forage species overseeded into bermudagrass on subsequent summer weed populations in early summer over two years.

Forage	Irrigation Treatment: Irrigated	Irrigation Treatment: Non-irrigated	LSD (0.05)
	Seedling Weed Counts (m^{-2})		
Wrens abruzzi	292.8	107.2	63.5
Harrison oats	262.8	99.9	83.9
Marshall ryegrass	181.9	93.8	48.4
Feast II ryegrass	157.1	65.3	44.1
LSD (0.05)	64.6	53.7	

Table 3. The effect of irrigation on bermudagrass and weed occupancy over two years.

	% Bermudagrass occupancy			% Weed occupancy		
Year	Irrigated	Non-irrigated	LSD (0.05)	Irrigated	Non-Irrigated	LSD (0.05)
2011	14.7	52.1	8.4	78.2	30.4	7.6
2012	36.2	45.1	8.7	62.5	54.8	NS
LSD (0.05)	7.2	NS		7.5	9.7	

Table 4. Percent of sunlight intercepted by the winter annual forage canopy during the month of May, 2012.

Forage	% Light Interception
Wrens abruzzi	28
Harrison oats	32
Marshall ryegrass	40
Feast II ryegrass	41
LSD (0.05)	9

Table 5. The effect of goosegrass defoliation strategy on bermudagrass growth over six harvest dates in 2012.

	Bermudagrass Biomass (g/m^{-2})		
Harvest Date	Goosegrass Harvested	Goosegrass Intact	LSD (0.05)
20 June, 2012	108.1	116.2	NS
5 July, 2012	87.7	107.9	NS
18 July, 2012	94.9	98.7	NS
7 Aug, 2012	111.4	101.7	NS
22 Aug, 2012	127.8	99.8	18.1
5 Sep, 2012	105.7	85.5	14.5

Table 6. The effect of harvest height on forage dry matter weight over two years.

Cutting Height (cm)	Plant Dry Weight (g)
5	6.23
10	7.02
15	7.34
LSD (0.05)	0.91

Table 7. The effect of sequence on the dry matter weight of forage species over two years.

	Sequence 1	Sequence 2	
	-----------g Dry Matter Plant $^{-1}$---------		LSD (0.05)
Bermudagrass	6.18	7.16	1.17
Crabgrass	8.92	6.98	1.39
Goosegrass	7.20	4.73	1.29
LSD (0.05)	1.74	0.57	

Table 8. The effect of defoliation frequency on subsequent dry matter weights for forage species over two years.

	14	21	42	LSD (0.05)
	---------------------g Dry Matter Plant $^{-1}$------------------------			
Bermudagrass	4.61	5.76	9.64	1.43
Crabgrass	5.37	6.36	12.13	1.70
Goosegrass	4.60	5.36	7.94	1.58
LSD (0.05)	0.56	0.83	2.57	

Table 9 The effect of harvest height on the cell wall contents of three forage species over two years.

	% NDF				% ADF			
Height (cm)	Goosegrass	Crabgrass	Bermudagrass	LSD (0.05)	Goosegrass	Crabgrass	Bermudagrass	LSD (0.05)
5	75.2	69.7	83.7	2.3	32.3	31.7	37.4	1.3
10	75.7	74.4	83.9	3.5	33.3	32.2	37.5	1.3
15	80.2	75.2	84.3	1.6	33.9	35.5	37.2	3.0
LSD (0.05)	3.0	2.7	NS		1.2	2.8	NS	

Table 10 The effect of harvest frequency on the cell wall contents of three forage species over two years.

	% NDF				% ADF			
Frequency (d)	Goosegrass	Crabgrass	Bermudagrass	LSD (0.05)	Goosegrass	Crabgrass	Bermudagrass	LSD (0.05)
14	76.1	70.4	83.9	NS	31.7	29.6	35.0	1.3
21	77.1	73.9	84.4	NS	32.0	33.7	36.8	2.9
42	77.9	75.1	83.5	NS	35.1	36.1	40.4	1.3
LSD (0.05)	NS	NS	NS		1.2	2.8	1.6	

Figure 2. The effect of weed population density on bermudagrass biomass on 22 August, 2012.

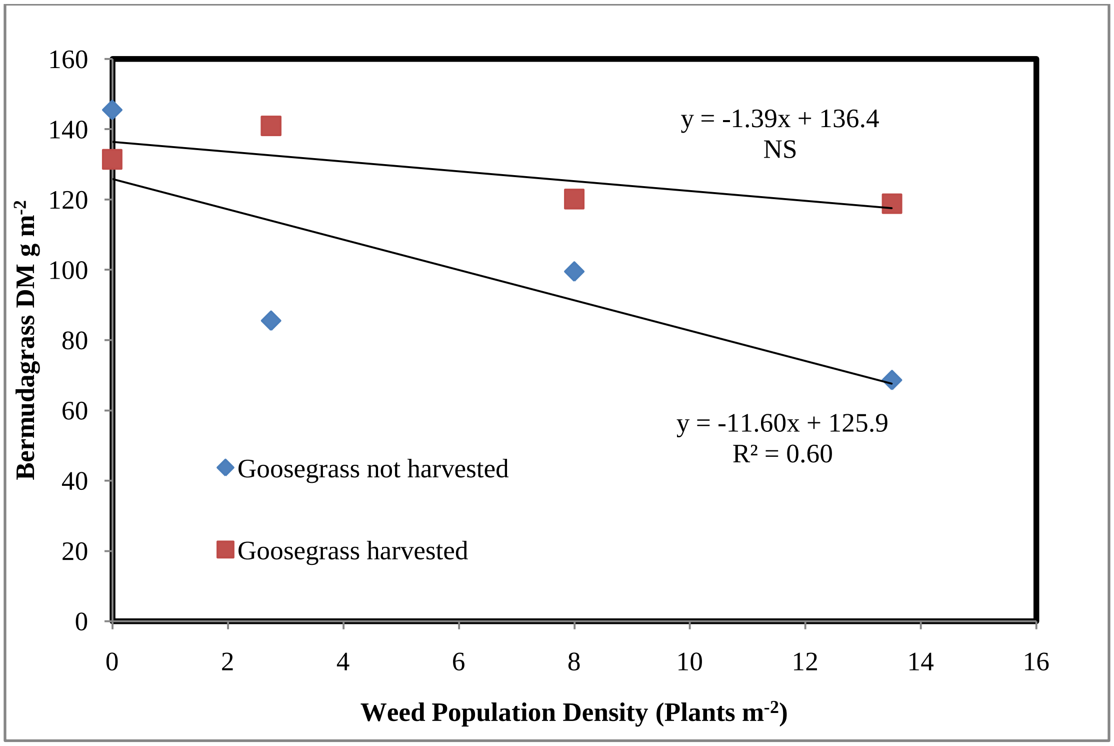


Figure 3 The effect of weed population density on bermudagrass biomass on 5 September, 2012.

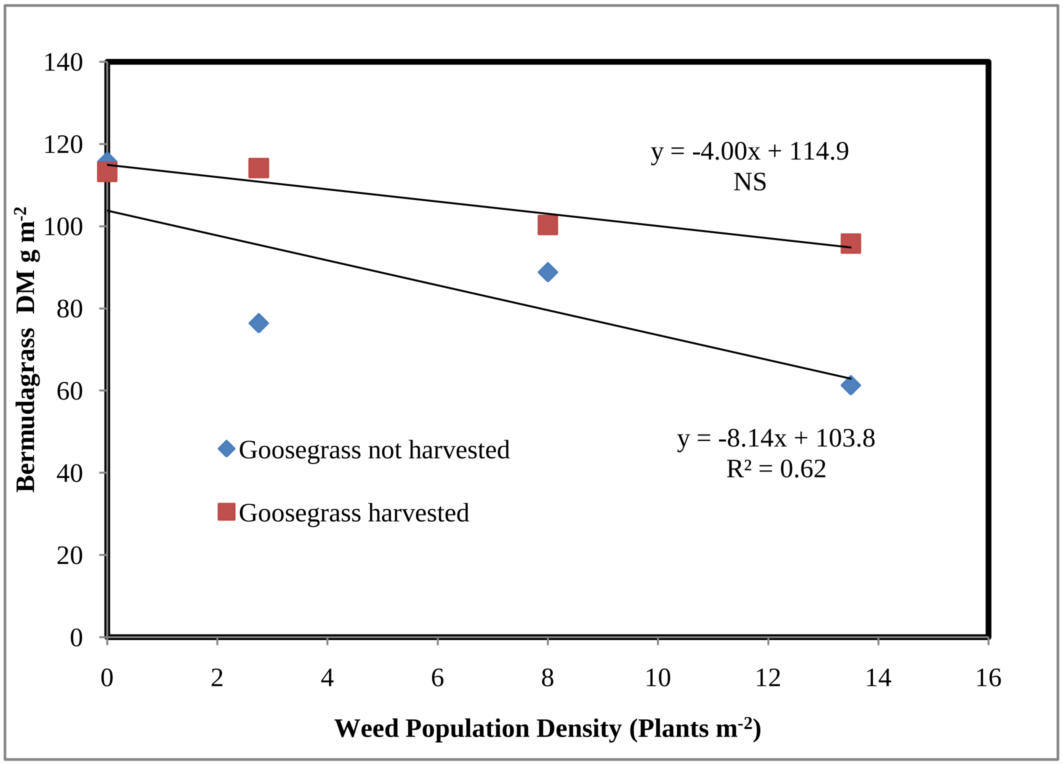
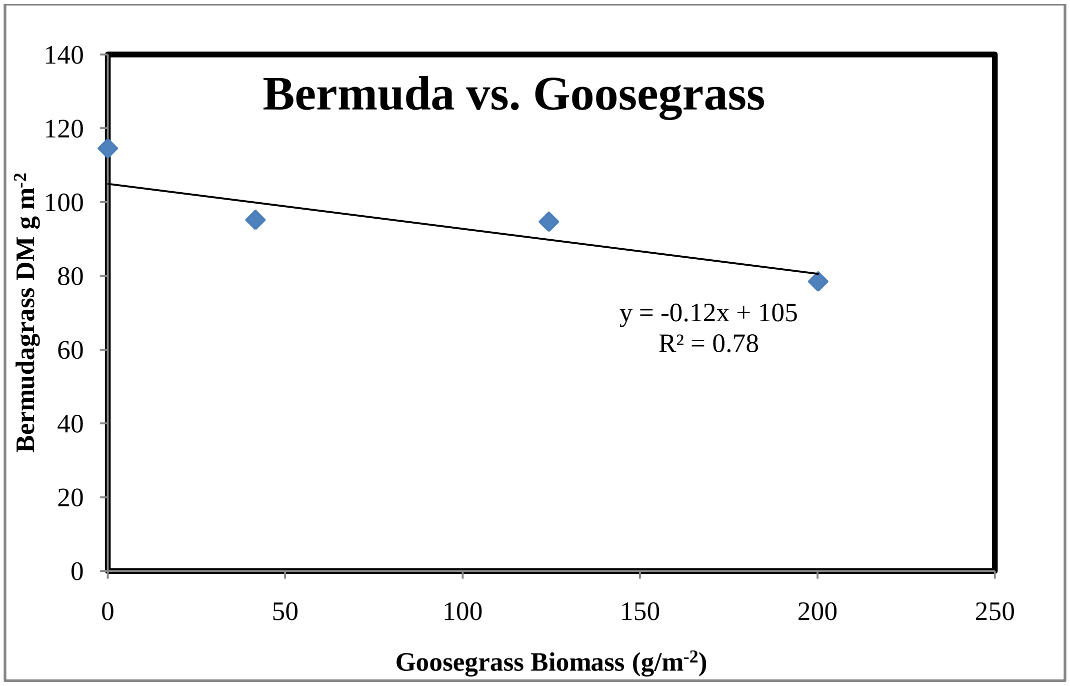


Figure 4.The effect of season-long accumulated goosegrass biomass on bermudagrass growth on 5 September, 2012.



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