Overseeding Eastern gamagrass with cool-season grasses or grass-legume mixtures

by

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Abstract

The first year and a half of a 2-yr study was conducted at Black Belt Research and Extension Center in Marion Junction, AL to evaluate the effects of overseeding early- vs. late-maturing cool-season forages on forage production, nutritive value, and persistence of Eastern gamagrass (*Tripsacum dactyloides*). The cool-season component compared four overseeding treatments: control, early-maturing 'Florida 401' rye (*Secale cereale*), mid-maturity 'Wrens Abruzzi' rye, and a mixture of 'Wrens Abruzzi' plus 'AU Red Ace' red clover (*Trifolium pratense*). During the warm season, plots were fertilized with either 67 kg nitrogen (N)/ha or 135 kg N/ha. Measurements of pre-graze forage mass, herbage harvested, and herbage accumulated were calculated from pre- and post-graze forage samples during both seasons. Hand-plucked samples were collected to determine nutritional value. Ground cover estimations and frequency ratings were taken during months in which Eastern gamagrass was breaking dormancy to determine effects of overseeding on persistence of Eastern gamagrass. The same measurements were taken as Eastern gamagrass began to go dormant at the end of the summer. Mob-stocking was used to simulate rotational grazing every 28 days. Data were analyzed using the MIXED procedure in SAS 9.4, and differences were declared significant when $P < 0.05$. Overseeding with 'Wrens Abruzzi' rye with or without red clover allowed for greater forage mass (P = 0.0355) and greater digestibility (P = 0.0012) compared with Florida 401 rye, but all treatments provided high-quality forage for grazing throughout the winter. Overall forage accumulation during the cool-season months was low (2,077 and 2,184 kg DM/ha in Yr 1 and Yr 2,

respectively) during both years of the evaluation. Warm-season results in Yr 1 indicate that harvest date had an effect on pre-graze forage mass (P = 0.0002) and forage accumulation (P = 0.0008), but N fertilization rate did not affect forage production of Eastern gamagrass (P = 0.1610). Forage mass peaked in June, then decreased through the late summer. Increasing N fertilization rate resulted in greater digestibility (P = 0.0264) and CP concentrations (P =0.0006) of Eastern gamagrass. Estimates of Eastern gamagrass ground cover and frequency of occurrence increased to 81% and 99%, respectively, over the summer growing season, which suggests that overseeding during the winter months did not impact persistence of Eastern gamagrass. A second year of the warm-season portion of this study is currently being conducted.

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"In their hearts humans plan their course, but the Lord establishes their steps" (Proverbs 16:9).

Table of Contents

List of Tables

List of Abbreviations

67N	67 kg N/ha
135N	135 kg N/ha
ADF	Acid-detergent fiber
C	Control
CP	Crude protein
DM	Dry matter
EG	Eastern gamagrass
F	'Florida 401' rye
IVD	*In vitro* digestibility
IVDMD	*In vitro* dry matter digestibility
IVTD	*In vitro* true digestibility
N	Nitrogen
NDF	Neutral-detergent fiber
NWSG	Native warm-season grasses
W	'Wrens Abruzzi' rye
W+C	'Wrens Abruzzi' rye plus 'AU Red Ace' red clover

I. REVIEW OF THE LITERATURE

Black Belt Region

Geographical Location and Formation

The Black Belt is a large, crescent-shaped area of land that extends from northeastern Mississippi southeastward across south-central Alabama. The Alabama Black Belt covers over 11,000 km^2 throughout a dozen counties. It is characterized by a distinctive soil type and vegetation. The region was once an ocean boundary, and the chalky material in the area was formed as calcareous mud at the bottom of the sea (Rankin, 1974).

Soil Challenges

The Black Belt and the Selma chalk, which is composed of rotten limestone, exist together in the soils within this region. Alkaline soils, those that have a pH greater than 7.0, were formed from the Selma chalk, and clay deposits on top of the Selma chalk gave rise to acid soils, those with a natural pH less than 7.0. The soils are intricately mixed throughout the Black Belt region, meaning pH extremes are dotted across the region (Rankin, 1974).

The Black Belt is largely composed of vertisols dominated by montmorillonite clay, which causes the soil to shrink and swell with changes in soil moisture (He et al., 2011; Rankin, 1974). This clay fraction is present in both the alkaline and acid soils. The Black Belt soils have slow water infiltration and permeability and high water-holding capacity. The shrink and swell characteristic of these soils results in large cracks during dry spells, which can make planting and establishment of crops difficult (Mitchell et al., 2006). Black Belt soils belong to the Udert suborder, meaning they have cracks that are open less than 90 cumulative days per year and less than 60 consecutive days during the summer (Grunwald, n.d.). The varied pH levels and clay content of the Black Belt soil can make cultivation somewhat difficult, and therefore, have a great influence on the types of forages found in the region, as well as pasture-based livestock production.

In pasture systems, treading by livestock can be a concern with clayey soils. Pugging, or heavy hoof pressure, on wet, clay soils can cause soil compaction and reduced plant growth. Damage is greater in wet, clay soils than in dry or sandy soils, as it reduces water infiltration, which results in less benefit from rainfall (Ball et al., 2015). Removing cattle from wet pastures can alleviate this damage, but may reduce the number of grazing days on pastures that are composed heavily of clay.

Forages Adapted to the Black Belt Region

Dallisgrass (*Paspalum dilatatum*) and tall fescue (*Festuca arundinacea*) are the predominant perennial forage grasses found in pastures in the Black Belt region (Anonymous, 2011). Eastern gamagrass (*Tripsacum dactyloides*) and johnsongrass (*Sorghum halepense*) are other warm-season perennials adapted to heavy soils (Johnson and Ball, 2013a). Kentucky bluegrass (*Poa pratensis*) can provide excellent pasture, if the land is fertilized with superphosphate prior to planting (Anonymous, 1934). Black medic (*Medicago lupulina*), caley pea (*Lathyrus hirsutus*), red clover (*Trifolium pratense*), and white clover (*Trifolium repens*) are legumes that can provide early spring grazing (Johnson and Ball, 2013b).

Tall Fescue

Growth and Adaptation

Tall fescue has active seasonal production from September through December and from March into June or July (Ball et al., 2015). Tall fescue is a desirable forage from an agronomic perspective due to its range of adaptation and tolerance to poor grazing management (Paterson et al., 1995). However, most of the tall fescue in the region is infected by the fungal endophyte *Neotyphodium coenophialum*, which can result in fescue toxicosis and have negative effects on animal performance. The endophyte produces ergovaline, an ergot alkaloid, that binds to serotonergic, adrenergic, and dopaminergic receptors in animals consuming infected fescue. The binding of these receptors and the actions of ergovaline as an agonist, partial agonist, or antagonist cause disruptions that result in decreases in serum prolactin, vasoconstriction, effects on gastrointestinal activity, and endocrine effects that cause decreases in reproductive performance in beef cattle (Klotz and Nicol, 2016).

Forage quality is ultimately defined in terms of animal performance, and takes into consideration intake, palatability, digestibility, and nutritive value (Ball et al., 2015). While endophyte infection influences animal performance, it does not seem to affect forage nutritive value. In a review by Pedersen et al. (1990), nutritive value and yield parameters were presented for endophyte-infected and endophyte-free 'Kentucky 31' tall fescue. Endophyte-infected tall fescue had 57% IVDMD, 64% NDF, 32% ADF, and 17% CP. Endophyte-free tall fescue managed similarly had 57% IVDMD, 65% NDF, 32% ADF, and 16% CP. Nutritive value parameters, regardless of endophyte status, were comparable to most cool-season perennial grasses adapted to the Eastern region of the US. Endophyte status does not appear to affect DM yield. Average DM yields of 'Kentucky 31' tall fescue in Tallassee, Alabama in 1978 to 1980 were 9,415 kg/ha/yr for endophyte-infected and 9,639 kg/ha/yr for endophyte-free (Pederson et al., 1990). However, under certain conditions such as drought, tall fescue DM yields may be enhanced by endophyte infection. Bush and Burrus (1988) reported similar results when evaluating tall fescue for forage yield and nutritive value. No differences were reported for dry matter yield or CP, ADF, or NDF values based on endophyte presence.

Cattle Performance

Fescue toxicosis is characterized by decreased weight gain, milk production, conception, and serum prolactin, and the inability to dissipate body heat (Paterson et al., 1995). In 1993, Hoveland estimated economic losses of $609 million annually due to reduced conception rates and decreased gains. In a study by Hoveland et al. (1983) comparing steer performance on fungus-infected tall fescue with relatively non-infected ‘Kentucky 31’ tall fescue pastures, crossbred steers were placed on paddocks that were either virtually free of *N. coenophialum* (less than 5% infestation) or heavily infested (nearly 94% infestation) with the endophyte. Beef gain per hectare averaged 28% greater over the 4-year period on the non-infected pastures (492 kg/ha) than on the fungus-infected pastures (384 kg/ha). The added gain reflects a 66% increase in average daily gain of steers on non-infected (0.83 kg/ha) versus fungus-infested pastures (0.50 kg/ha).

These data illustrate that tall fescue has the potential for excellent gain in beef animals, but the presence of a significant amount of plants infected by the endophyte could result in reduced weight gains. While other environmental factors may play a role in decreased steer performance, research strongly suggests that the endophyte is involved in the summer syndrome of fescue toxicosis. Significant losses in animal productivity and health are reason to look for alternative grazing systems in the Black Belt, especially during the summer months when fescue toxicosis is more prevalent.

Native Warm-Season Grasses

Adaptations and Characteristics

Native warm-season grasses (NWSG) are naturally adapted to the soils and climate in the mid-South. They are tall-growing bunch grasses with the potential for exceptional forage production. Peak growth of NWSG occurs in the summer, breaking dormancy in late March through early April and growing rapidly from mid-May through mid-summer, with growth slowing through late summer and into October (Keyser et al., 2011c). Because of this growth distribution, NWSG can complement production of existing cool-season forages, such as tall fescue, and provide an alternative grazing system during the time that fescue toxicosis can be most problematic.

Native warm-season grasses are widely adapted, perennial grasses that can persist in forage systems for 15 to 20 years under proper management (Keyser et al., 2011c). Perennial grasses can produce abundant biomass while saving input costs with seed and fertilizer. Perennial systems decrease establishment time and risks by only requiring one year of establishment for a long-term stand, rather than recurring yearly establishment for annual forage systems. Other advantages of NWSG include reduced fertility inputs, yields that can support growing cattle, and habitat for wildlife. Disadvantages of NWSG are time and intensity of establishment and management. A minimum of three growing-seasons are required for NWSG to fully establish, due to the deep, extensive root system that must develop (Keyser, 2011a) before use. Land that has just been cleared of timber or crop ground that has a history of non-grass crops or small grains make excellent establishment sites for NWSG. Hay and pasture ground planted in cool-season grasses produces more challenges, but can be established with proper planning and management. A clean, firm seedbed with a smooth surface to allow for shallow planting and advanced weed control are vital to establishment success. Planting can be conventional; however, no-till is the preferred method. Specialized equipment is required to plant NWSG; a drill equipped with a "native grass box" allows fluffy, long-awned seed to move through the drill more easily. Native warm-season grasses should be seeded when soil temperatures reach 15 to 18˚C, usually in mid-April to early May while there is early-season moisture. Most NWSG should be planted less than 0.6 cm deep, with the exception of Eastern gamagrass (1.9 to 3.2 cm) (Keyser at al., 2011a). Eastern gamagrass seed requires cold, moist stratification prior to planting to reduce seed unit dormancy (Alderson et al., 2007). After seeding, weed pressure should be controlled and sufficient time should be allowed for a successful stand to establish, typically more than two years. Stands with one or more seedling per square foot is ideal, one seedling per two square feet is acceptable, and stands below one seedling per four square feet should be reseeded. During the seedling year, plant populations are of greater importance than size, as plants will become robust in the next year (Keyser et al., 2011a).

Key species

There are several key species of NWSG that can be used for forage production. Eastern gamagrass and switchgrass (*Panicum virgatum*) produce high yields compared with other NWSG. Big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), and indiangrass (*Sorghastrum nutans*) provide highly palatable forage. Each species has varying establishment, management, and maturity attributes. These characteristics make NWSG a versatile option for forage production and grazing. (Keyser et al., 2011b, Keyser et al., 2011c).

Grazing recommendations

Proper grazing management strategies are essential with NWSG. The key is to manage grazing pressure in such a way that the forage does not get too short or too tall. Due to the tall growth of NWSG, they do not have many leaves or growing points near to the ground compared with other forages that are common in the mid-South. Therefore, NWSG are prone to overgrazing and should not be grazed closer than a 30-centimeter stubble height. If overgrazed, root reserves are reduced (Keyser et al., 2011b). Edwards et al. (1999) found that clipping Eastern gamagrass at 30-day intervals to a 10-cm height caused the stand to decline and allowed for weed competition. This study demonstrates the importance of proper grazing management to ensure a healthy, long-lasting stand.

During the beginning of the growing season, NWSG grow quickly, resulting in a great amount of forage mass compared with forage mass later in the season. Many times, the forage mass is too great when a pasture is understocked. Understocking results in mature, less palatable forage with a reduced nutritive quality. Grazing can be initiated when the average canopy height reaches 38 centimeters. It is important to monitor forage canopy height over time and adjust grazing pressure to maintain a proper grass height between 38 and 50 centimeters for NWSG (Keyser et al., 2011b).

Quality and Yield

Native warm-season grasses have the potential to provide excellent gains for stocker cattle. Grazing trials in Tennessee have shown average daily gains ranging from 0.48 to 0.96 kg per day in stocker cattle over the full season while grazing Eastern gamagrass, switchgrass, and a big bluestem and indiangrass mixture (Keyser et al., 2011b). Krueger and Curtis (1979) evaluated performance of yearling steers on big bluestem, indiangrass, sideoats grama, and switchgrass. Under continuous grazing in July through August, CP concentrations averaged 9%, average daily gain of steers ranged from 0.7 to 1.08 kg/day, and beef gains per hectare ranged from 112 to 147 kg/ha. The study concluded that big bluestem and switchgrass could be used successfully for beef production in the mid-summer months.

Edwards et al. (1999) reported CP concentrations from 7 to 13% for switchgrass, 8 to 12% for Eastern gamagrass, and 6 to 11% for bermudagrass clipped at 30-day intervals in a study evaluating clipping effect on yield and quality of the three species. Griffin and Jung (1983) evaluated nutritive quality of big bluestem and switchgrass. Samples were harvested at 10-day intervals at a 20-cm height. Nutritive quality parameters were averaged across grasses. Leaves provided 9.7% CP, 60.4% IVDMD, 60.0% NDF, and 4.7% lignin. Stems provided 4.3% CP, 50.0% IVDMD, 75.3% NDF, and 7.2% lignin. The study concluded that during the early vegetative stage, the high percentage (68%) of leaf tissue suggests potential use of big bluestem and switchgrass for ruminants with above maintenance energy requirements; however, as forage matures and stem tissue increases, nutritive value may only be enough to meet maintenance energy needs.

Faix et al. (1980) conducted a study in which Asiatic bluestems (*Bothriochloa* spp.) and Eastern gamagrass were evaluated for quality, yield, and survival in southern Illinois as an alternative forage to tall fescue during the summer. Forage was harvested with a self-propelled flail harvester at a 15-cm height in 1975 and 3 to 4 cm in 1976 and 1977. Harvest heights were lower than the recommended grazing heights for NWSG (Keyser et al., 2011b). Harvests were planned for when plants reached the late boot stage. There were 3 harvests in 1975 and 1977 and 4 harvests in 1976. Average yields for the Asiatic bluestems over the three-year period ranged from 11,650 kg/ha to 13,230 kg/ha and were not significantly different. Eastern gamagrass average yield was significantly greater at 17,670 kg/ha (three-year average). Average annual CP concentrations ranged from 10 to 11.2% and average annual IVD ranged from 47.9 to 54.9% for all grasses. The authors noted that imposing shorter cutting intervals may increase CP and IVD levels. The study found that all species showed satisfactory winter hardiness, and stand persistence was maintained under the harvest regime used.

Wildlife Habitat

Native grasses, due to their erect growth habits, can benefit many species of wildlife by providing cover and structure for habitat. Species that utilize native grasses for cover include the eastern cottontail, northern bobwhite, and many other avian species. This wildlife benefit is not seen in other common forage species, such as tall fescue or bermudagrass (Keyser et al., 2011c). It is hypothesized that declining populations of avian species associated with grasslands may be due to changes in species composition and management of hayfields and pastures. In a study by Giuliano and Daves (2002), avian abundance and richness were measured in warm and cool-season pastures. They compared pastures of switchgrass, big bluestem, and orchardgrass. Avian abundance, the number of birds present, and species richness, the number of avian species, were both 1.6 times greater in warm-season fields than in cool-season fields.

Adequate cover plays an important role in species success. During nesting season (April-May), there may be less cover in warm-season fields. However, because it is relatively undisturbed at that time and cover begins to increase throughout the nesting season, the warm-season grasses may provide more cover for avian species. Proper management of forages dictates that warm-season forages only be mowed or grazed to a 20 to 30 cm height, compared with less than 5 cm for cool-season grasses, providing adequate residual cover even after harvest (Giuliano and Daves, 2002). Adequate cover provided by warm-season grasses, specifically native warm-season grasses, creates habitat for wildlife and contributes to a healthy and diverse ecosystem.

Eastern Gamagrass

Characteristics and Adaptation

Eastern gamagrass is a long-lived, perennial bunchgrass native to the eastern Great Plains and eastern United States. It has long (30 to 76 centimeters) and wide leaves (1 to 3 centimeters) with rough edges and a well-defined midrib, and it can grow 1 to 2.5 meters tall (Alderson et al., 2007; Ball et al., 2015). It reproduces vegetatively from proaxes, which are thick, knotty, rhizome-like structures. Eastern gamagrass is a distant relative to corn (*Zea mays*), sharing the same subtribe, Tripsacinae. Like corn, it is monoecious with both male and female flowers. It is different from corn in that each spike of Eastern gamagrass contains both male and female flowers, with the male flowers on the top three-fourths of the spike and the female flowers in the bottom one-fourth (Alderson et al., 2007).

Eastern gamagrass is mainly used as a forage crop, and it is highly productive as intensively managed pasture, hay, and silage. It is a perennial alternative to summer annual forages, and it is more widely adaptable and productive earlier in the spring than other warm-season perennial grasses like bermudagrass. Eastern gamagrass reaches its peak yield during the summer months, when grasses like tall fescue are unproductive or dormant. Under dryland conditions, Eastern gamagrass flourishes in areas where average rainfall exceeds 89 centimeters, but it can produce respectable amounts of forage on good soils where average rainfall is 64 centimeters per year. Suggested minimum soil pH ranges from 5.1 to 5.4, and an estimate of maximum pH ranges from 6.0 to 7.5. It can tolerate a range of soils, from well-drained to somewhat poorly drained soils, but claypan soil layers may hinder root growth (Alderson et al., 2007).

Quality and Yield

The leaf-to-stem ratio of Eastern gamagrass is greater than in other warm-season grasses. The reproductive tillers are thick and contain a pith-like material in the center, which results in a digestibility comparable to that of the leaves. Generally, CP levels of Eastern gamagrass are greater than 12.5% at the boot and flowering stages. The boot stage is when the inflorescence is enclosed in the sheath of the uppermost leaf (Alderson et al., 2007). Data from several studies compiled by Alderson et al. (2007) showed that annual yields of Eastern gamagrass range from 5,380 to 16,364 kg/ha.

In a study by Ritchie et al. (2006), Eastern gamagrass was evaluated for biomass production over a 9-year period. Annual biomass production ranged from 1,345 to 7,846 kg/ha. While there were some differences among years, the study found that annual rainfall was not significantly correlated with Eastern gamagrass production. Rather, the authors indicated that timing of rainfall was more important that amount of rainfall. No trend toward reduced biomass production was noted over the 9-year period, even when fertilizer application was eliminated in the last 2 years of the study. This indicates that Eastern gamagrass could produce adequate forage biomass even under adverse environmental conditions.

Ten Eastern gamagrass ecotypes were evaluated for nutritive value in a study by Bidlack et al. (1999). The entries were from Oklahoma, Texas, and Kansas. Forage samples were evaluated for IVDMD and CP. Average IVDMD for leaves was 64.8% and 68.8%, and 60.4% and 58.9% for stems in 1992 and 1995, respectively. Crude protein for leaves was 19.0% and 8.2%, and 18.6% and 7.7% for stems in 1992 and 1995, respectively.

Harvest and Fertilizer Responses

Salon and Cherney (1999) evaluated nutritive value of Eastern gamagrass in the Northeast and determined effects of harvest date and interval. They found that with advancing initial spring harvest date, neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin increased, and *in vitro* true digestibility (IVTD) and digestible NDF (dNDF) decreased. Crude protein was not as greatly affected by harvest date. In the first year, IVTD ranged from 751 to 798 g/kg. Concentration of CP ranged from 159 to 164 g/kg. In the second year, IVTD and CP ranged from 794 to 843 and 130 to 135, respectively. They found significant differences for most variables measured between first cutting dates, indicating that timing of harvest is an important factor in nutritive value. Initial harvest date is dependent on acceptable forage yield and will have an effect of subsequent cuttings. However, this study showed that adequate nutritive value can be achieved with proper harvest management.

Brejda et al. (1996) evaluated Eastern gamagrass response to different harvest intervals and N rates. Plots were fertilized at 0, 56, 112, 168, 224 kg N/acre and harvested at 4-week or 6-week intervals. The authors found that CP concentration and forage yield increased in response to increasing N rate. Harvesting at a 4-week interval resulted in greater nutritive value and harvesting at a 6-week interval resulted in greater forage yield. The study concluded that harvest regimes should be based on the producer's objective. Grazing may be ideal at four-week intervals to provide higher protein forage, and hay production may be ideal at six-week intervals to capture greater yields with fewer harvests.

Animal performance

Burns et al. (1992) evaluated the diet characteristics of steers grazing flaccidgrass, bermudagrass, and Eastern gamagrass. The study reported average annual IVDMD values from 70.7 to 71.5% for all grasses. Crude protein differed between years, with a lower value of 18.7% in 1984 compared with 20.4% in 1985. However, CP was still adequate for growing steers. This study used a continuous grazing method, and steers gained an average of 0.82 kg/day over the season on Eastern gamagrass compared to 0.67 kg/day for flaccidgrass and 0.30 kg/day for bermudagrass. The authors found that leaves of Eastern gamagrass are much longer than those of other grasses, and this allows them to be extended for ease of animal prehension. Canopy characteristics and digesta kinetics found in this study show that Eastern gamagrass could provide a leaf-dominated feed source for cattle and result in good animal performance, making it a desirable forage for use during the summer months.

Overseeding Warm-Season Grasses

Background

Overseeding, interseeding, and sodseeding are terms used interchangeably to describe the practice of establishing annual forage crops into perennial, grass-dominant hay or pasture fields without destroying the existing sod (Ball et al., 2015). This can be done by broadcasting seed with or without disking or other tillage, or by planting into sod with a drill-type planter. Overseeding increases forage yield per acre and extends the length of time that a planted area of forages is productive. Warm-season perennial pasture may be productive for six to eight months per year, whereas an area overseeded with cool-season annuals may provide eight to ten months of forage production per year (Ball, 2007).

In the upper South, legumes, such as alfalfa and red clover, are planted into cool-season perennial stands of tall fescue or orchardgrass. In the lower South, cool-season annual grasses, such as small grains and annual ryegrass, are planted into warm-season perennial sods of bahiagrass or bermudagrass (Ball, 2007). Hoveland et al. (1961) evaluated the forage production of winter annuals sodseeded on dallisgrass-white clover pastures at the Black Belt Research & Extension Center. The study evaluated oats, rye, wheat, annual ryegrass, rescuegrass, caley peas, and vetch. Test crops were planted and fertilized in October. Additional nitrogen was applied in February and clippings were taken during the spring. Over the 3-year study, cool-season annual yields were below those obtained when planted on a prepared seedbed. However, sodseeded combinations were more productive than dalligrass-white clover alone. Generally, the authors observed no carryover effect of sodseeding on grass-clover yield during the summer and fall. The study concluded that sodseeding could extend the grazing season and present the opportunity to increase total forage yield.

Few studies have been conducted evaluating overseeding into native warm-season grass sods. A study by George et al. (1995) evaluated yield and botanical composition of legume-interseeded vs. nitrogen-fertilized switchgrass. The study showed that cool-season legumes, such as red clover, interseeded into switchgrass sods improved seasonal distribution of forage by increasing early summer forage supply (4.64 Mg/ha in June) compared with grass only (less than 0.5 Mg/ha), and when interseeded legumes declined within a stand, weed encroachment increased. The authors concluded that interseeding switchgrass with legumes could improve forage yields and reduce weed pressure by increasing soil nitrogen and enhance forage yield.

Ashworth et al. (2012) found that red clover, partridge pea, and crimson clover were the most persistent legumes for intercropping with NWSG. It is important to consider maturity dates and growth habits to result in proper legume density when interseeded into a native warm-season grass sod. Species grown together must be compatible and dense cool-season legume stands should be reduced by grazing or harvesting to prevent competition with NWSG early in the growing season.

Use of cool-season annuals

Ball et al. (2015) discussed specific challenges of overseeding cool-season annuals into warm-season sods. It is necessary to suppress warm-season grass or wait until it begins to enter dormancy so that it does not compete with seedlings. Grazing or clipping to a short stubble height increases likelihood of success. During the spring, growth of overseeded winter annuals may compete with warm-season perennials, so it is important to stock pastures heavily during this time to avoid growth suppression.

Cool-season annuals such as small grains, annual ryegrass, and legumes are frequently overseeded on warm-season perennial pastures to achieve a year-round growing season and reduce the need for stored forages. This method creates a system that has a greater nutritive value than warm-season grasses, provides spring weed control, and with legumes, adds N to the system (Evers, 2005). Hoveland et al. (1981a) interseeded legume species into tall fescue sod at four Alabama Agricultural Experiment Station locations, including Black Belt Research & Extension Center, over a five-year period. The study found that red clover was highly productive in this system. In some years, drought and insects played a role in failure of establishment, but in years with successful establishment, forage production and animal production increased. There has been little published work with interseeding into warm-season sods in the Black Belt region. Dillard et al. (2012) interseeded white clover (*Trifolium repens*) into Johnsongrass *(Sorghum halepense*) at the Black Belt Research & Extension Center in Alabama. The study reported no significant differences between DM yield of Johnsongrass alone compared with Johnsongrass interseeded with clover. However, white clover inclusion resulted in a greater CP concentration than for Johnsongrass alone.

Rye

Cereal rye (*Secale cereale*) is a cool-season, annual grain native to the Middle East (Ball et al., 2015). It grows upright to a height of 0.9 to 1.8 meters. It has flat leaf blades and is topped with awned flower spikes. Rye can grow in a variety of climate and soil conditions. It grows best in light loams or sandy loams, but can do well in clay soils. Rye can tolerate a pH from 4.5 to 8.2 (USDA, n.d.). There are many uses for rye including cover crop and green manure, grain, hay, and annual pasture. As annual pasture, it can be grown in a mixture and overseeded into an existing sod (Casey, 2012).

Rye is an excellent forage, especially when combined with red or crimson clover. It matures earlier than other small grains and has the highest CP concentrations. The main advantages of winter rye over other small grains are superior winter hardiness and attainment of optimum harvest maturity 7 to 10 days earlier. In an overseeding scenario, this earlier maturity can be of benefit, as it reduces competition with warm-season crops when they begin to break dormancy compared with later-type cool-season grasses. Because of its rapid growth and cold tolerance rye may provide more forage in late fall and early spring than other small grains (Oelke et al., 2000). Hoveland et al. (1978) evaluated beef cattle performance on bermudagrass pastures overseeded with winter annuals. The study compared overseeding treatments of ryegrass, rye plus arrowleaf and crimson clover, and arrowleaf and crimson clover with no overseeding. The authors found that overseeding with rye and clover increased the length of the grazing season by three months compared with no overseeding. Overseeding resulted in increased total cow and calf gains per hectare with 897, 785, 690, and 511 kg/ha for rye-clover, clover, ryegrass, and bermudagrass sod alone, respectively.

Red Clover

Red clover (*Trifolium pratense*) is an introduced biennial or short-lived perennial legume that originated in Asia Minor and southeastern Europe. There are two types: mammoth (single-cut) and medium (double-cut). Stem lengths are on average 46 cm for medium and 70 to 76 cm for mammoth type plants. Leaves consist of a slender stalk with three leaves, and flowers, rose-pink in color, are in compact clusters at the tips of the branches. It grows best on well-drained loamy soils with a pH of 6.0, but can tolerate less drained and moderately acid soils (St. John and Ogle, 2008).

Red clover is used as a winter annual in the southeastern United States. It is productive for a year in central and southern Alabama but may remain productive in a second year in the Black Belt region (Hoveland et al., 1981b). Red clover is low-yielding in February through March compared with other legumes, but has the potential to provide good-quality forage in the late spring and into the summer (Mosjidis, 2011). It is quick growing, easily established, and provides a source of nitrogen and high-yielding forage rich in protein. It can be planted with small grains and other forage grasses as a companion crop, and can be overseeded into warm-season sods (St. John and Ogle, 2008). Hoveland et al. (1981b) suggests that red clover can be planted in mixtures with small grains and ryegrass to extend the grazing season.

‘AU Red Ace’ is a double-cut red clover developed and released in 2008 by Auburn University and the Alabama Agricultural Experiment Station (Mosjidis, 2011). It can be grown with other winter annuals and produces consistently high yields. Two-year tests in Tallasee, AL and Fairhope, AL resulted in forage yields of 13,416 kg/ha and 9,829 kg/ha, respectively. The ‘AU Red Ace’ cultivar is well-adapted to Alabama due to selection of plants that had survived environmental stress and disease pressure at several locations across the state.

Summary

The Black Belt region of Alabama is characterized by heavy clay soils with varying pH extremes. The soil type creates challenges for forage system adaptation in the area. Tall fescue has typically dominated the Black Belt region; however, during the summer months, endophyte-infected tall fescue causes a decrease in animal productivity, specifically in grazing beef cattle.

Alternative forage systems could help alleviate the effects of endophyte-infected tall fescue on cattle. One of those alternative systems is native warm-season grasses. Several NWSG are native to the Mid-South, with characteristics such as drought tolerance, high summer yields, and reduced inputs. Eastern gamagrass is a native warm-season grass with adaptability to heavy soil types like those found in the Black Belt region. It has a wide growth distribution rate and produces yields that can support high stocking rates relative to other NWSG. It could be used in place of tall fescue in the summer as an alternate grazing option.

Overseeding Eastern gamagrass with cool-season annuals or cool-season annual-legume mixtures could extend the grazing season on a single unit of land and allow for higher-quality grazing throughout the winter months. Following the winter months, it is important to establish an economical fertilization rate to increase response from the Eastern gamagrass as it breaks dormancy. Creating a grazing system that provides nearly year-round grazeable forage with low inputs would benefit cattle producers in the Black Belt region.

II. OVERSEEDING EASTERN GAMAGRASS WITH COOL-SEASON GRASSES OR GRASS-LEGUME MIXTURES

INTRODUCTION

The Black Belt region of Alabama is characterized by heavy clay soils with varying pH extremes. The soil type creates challenges for forage species adaptation in the area. Tall fescue has typically dominated the Black Belt region; however, during the summer months, endophyte-infected tall fescue causes a decrease in animal productivity, specifically in grazing beef cattle. Alternative forage systems could help alleviate the negative effects of endophyte-infected tall fescue on cattle. One alternative may be the use of native warm-season grasses (NWSG). NWSG are adapted to the Mid-South region of the US, with characteristics such as drought tolerance, high summer yields, and performance under reduced fertility input. Eastern gamagrass (EG; *Tripsacum dactyloides*) is a native warm-season grass with adaptability to heavy soil types like those found in the Black Belt region. It has a wide seasonal growth distribution during the summer months and produces yields that can support high stocking rates relative to other NWSG. It could be used in place of tall fescue in the summer as an alternative grazing option.

Overseeding Eastern gamagrass with cool-season annuals or cool-season annual-legume mixtures could extend the grazing season and provide high-quality grazeable forage throughout the winter months. Following winter overseeding, it is important to determine the impacts of this practice on persistence of Eastern gamagrass and to identify an economical fertilization rate that may help the summer crop recover from this practice as it breaks dormancy. Evaluating this alternative forage production system may provide cattle producers with additional forage options within the Black Belt region of Alabama.

MATERIALS AND METHODS

Research Site

All procedures and experimental protocols were approved by the Institutional Animal Care and Use Committee (Protocol No. 2015-2782). The experiment was conducted during the 2015-2017 growing seasons at the Black Belt Research and Extension Center (BBREC) in Marion Junction, AL (32º28'50.29"N latitude, 87º15'26.61"W longitude). A 15-yr old stand of 'Highlander' Eastern gamagrass (*Tripscacum dactyloides*) was used. Prior to the study, the paddock was grazed no shorter than a 60-cm height. The stand was burned every year in early spring and field plots comprised of Houston clay (very-fine, smectitic, thermic Oxyaquic Hapluderts) (USDA, 1997) were demarcated on September 29, 2015.

Experimental Design

During the cool season, thirty-two plots (4-m × 4-m ea.) were arranged into four blocks, each of which comprised eight plots representing four experimental forage treatments in a randomized, complete block design (Appendix I). The experiment was designed with a 4 x 2 factorial arrangement of treatments, including three overseeding treatments plus a non-overseeded control in the winter months, followed by two levels of N fertilization in the summer growing season. Overseeding treatments included: control plots (no overseeding; C), 'Florida 401' rye (F), 'Wrens Abruzzi' rye (W), or a combination of 'Wrens Abruzzi' rye plus 'Red Ace' red clover (W+C). Seeding rates were 100 kg/ha of 'Florida 401' and 'Wrens Abruzzi' rye, and 67 kg/ha of 'Wrens Abruzzi' rye plus 11 kg/ha of 'Red Ace' red clover.

During the warm season, the same thirty-two plots (4-m × 4-m ea.) were arranged into four blocks, each of which comprised eight plots representing two experimental fertilization treatments in a randomized, complete block design. Nitrogen fertilization treatments included 67 kg N/ha (67N) and 135 kg N/ha (135N).

Forage Management

Fertilization

In Yr 1, a soil test was conducted by the Auburn University Soil Testing Laboratory on Nov 12, 2015. Test results concluded that soil pH was 6.7 (neutral), phosphorus levels were medium, and potassium, magnesium, and calcium levels were high or very high. Plots initially received 44 kg N/ha, 44 kg P/ha and 44 kg K/ha as N, P_2O_5 and K_2O, respectively, with 13-13-13 on Nov 17, 2015 based on soil test analysis and fertilization recommendations. Additional N was applied as 33-0-0 at 74 kg N/ha on Feb 2, 2016 and 37 kg N/ha on Feb 12, 2016, for a total of 155 kg N/ha in Yr 1. In Yr 2, 67 kg N/ha was applied as 33-0-0 on Jan 9 and 78 kg N/ha was applied on March 3, 2017 for a total of 145 kg N/ha in Yr 2.

Cool Season

Plots were overseeded according to treatment on October 14, 2015 and October 27, 2016. Grazing was initiated when rye reached a height of 20 cm. Control plots were not grazed during the cool-season portion of the study. In Yr 1, F plots were grazed on Jan 28, Mar 1, and Mar 29, 2016. Plots of W and W+C were grazed on Mar 8 and Apr 5, 2016. Plots of F were grazed beginning on Feb 24 and again Mar 22, 2017. Plots of W and W+C were grazed on Mar 22, 2017. Cattle were fasted overnight and placed on plots using a mob stocking technique (Mullenix et al., 2016) to simulate rotational stocking. In Yr 1, mature beef cattle were used and in Yr 2, heifers were used to graze plots to a target stubble height of 10 cm and then removed to mimic Extension recommended grazing strategies.

Warm Season

Plots were fertilized with 33-0-0 according to treatment on May 5, 2016. Grazing was initiated when Eastern gamagrass reached a height of 38 cm. In Yr 1, 135N plots were grazed on May 26, Jun 23, Jul 19, Aug 18, and Sep 15, 2016. The 67N plots were grazed on Jun 2, Jun 30, Jul 28, Aug 26, and Sep 22, 2016. Plots were mowed to a 25-cm stubble height following the Jul grazing events on Jul 28, 2016 to remove over-mature forage. Cattle were fasted overnight and placed on plots using a mob stocking technique (Mullenix et al., 2016) to simulate rotational stocking. Mature beef cattle were used to graze plots to a target stubble height of 25 cm and then removed to mimic Extension-recommended grazing strategies.

Forage responses

During the winter and summer months, forage production measurements were collected by taking two randomly selected pre-graze and post-graze samples from each plot at every grazing event. Pre- and post-graze samples were clipped from a 0.16-m^2 ring to a stubble height of 5 cm during the cool season and 20 cm during the warm season. Samples were placed in cloth bags and transported to Auburn University Ruminant Nutrition laboratory for drying. Samples were oven-dried at 50º C for 48 hr, and weighed to determine dry matter (DM) yield. Dried, air-equilibrated samples were ground in a Wiley Mill (Thomas Scientific, Swedesboro, NJ) to pass a 1-mm screen, and final concentration of DM was determined by oven-drying at 100º C according to procedures of AOAC (1995).

Forage mass (kg DM/ha) was estimated from the mass of the pre-graze samples for each grazing event. Herbage accumulation between grazing events was determined by the following equation: (pre-graze forage mass of event B − post graze forage mass of event A). Herbage harvested by cattle for a given grazing event was determined by the following equation: (pre-graze forage mass of event A – post-graze forage mass of event A).

Botanical composition estimates, ground cover, and frequency estimates were conducted during sampling events from Mar through May, and again at the end of the Eastern gamagrass growing season in September. This time period was selected to help determine how Eastern gamagrass forage production recovers following overseeding during the transition from spring to summer, and as Eastern gamagrass began to go dormant as a measure of change in persistence following the summer grazing season. Botanical composition estimations were taken from the two pre-graze samples for each grazing event. Before drying, samples were hand-separated into species components of Eastern gamagrass, rye, clover, and other (weeds). Ground cover estimations (% of ground covered by the desirable forage species) and frequency ratings (relative presence and distribution of desirable species within the grazed sward) were measured in two randomly selected areas per plot using a quadrat divided into ten 7.6-cm × 7.6-cm sections. Ground cover estimations measured percentage of Eastern gamagrass, rye, clover, and other (weeds or bare ground) in each section of the quadrat. Frequency ratings determined whether gamagrass was present in each section of the quadrat. Each section was given a '1' if gamagrass was present. These values were summed across the number of sections evaluated and a percentage of occurrence was calculated.

Laboratory analysis

Forage concentration of N was determined by the Kjeldahl procedure (AOAC, 1995), from which CP was calculated as N × 6.25. Forage *in vitro* true digestibility (IVTD) was determined according to the Van Soest (1991) modification of the Tilley and Terry procedure (1963) using the DaisyII incubator system (Ankom Technology™, Macedon, NY). Ruminal fluid was collected from a cannulated Holstein cow at the Auburn University College of Veterinary Medicine. The cow was fed 2.7 kg of 15% CP beef stocker pellets, 10.9 kg of dairy grain, 0.9 kg of cotton seed, and 0.2 kg of Megalac (Arm and Hammer Animal Nutrition, Princeton, NJ) twice daily and had access to free-choice bermudagrass hay. Fluid was stored in thermos containers to maintain a temperature supportive of the microbial population, and was transported to the Auburn University Ruminant Nutrition laboratory where it was immediately prepared for the batch-culture IVTD procedure.

Weather Data

Weather instruments operated by AWIS Weather Services, Inc. collected daily minimum and maximum ambient temperatures and daily total precipitation data throughout the experimental period. Weather instruments were located in Marion Junction, AL. Temperature data and total precipitation are reported in Tables 1 and 2.

Statistical analysis

Cool-season and warm-season forage mass and nutritive quality, and transitional period persistence, including ground cover, frequency, and botanical composition, data were analyzed using the MIXED procedure in SAS 9.4 (SAS Inst. Inc., Cary, NC) for a randomized, complete block design. Independent variables for forage mass, nutritive value, and persistence data included harvest date, forage treatment, and harvest date × forage treatment interaction. Vegetative regrowth harvests were treated as repeated measures of primary harvests, and block was considered as a random effect in the statistical model. Treatment means were separated using the PDIFF option of the LSMEANS procedure (SAS Inst. Inc., Cary, NC) when significant at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Temperature and precipitation

Monthly mean temperatures and 30-yr average monthly mean temperatures in Marion Junction, AL are presented in Table 1. Monthly total precipitation and 30-yr average monthly total precipitation are presented in Table 2. In Yr 1, mean temperatures were 12, 24, 70, 12, 20, 10, 4, 8, 6, 7, and 12% greater than the 30-yr average for October through September, respectively, except January which was 9% less. In Yr 2, mean temperatures were 17, 18, 24, 69, 47, and 16% greater than the 30-yr average for October through March., respectively. Warmer temperatures in Yr 2 led to cool-season forages reaching maturity more quickly and warm-season forage breaking dormancy earlier than in Yr 1. In Yr 1, total precipitation was 39, 80, 55, 40, and 41% greater than the 30-yr average in November, December, February, April, and August, respectively. Total precipitation was 21, 54, 32, 51, 31, 60, and 88% less than the 30-yr average in October, January, March, May, June, July, and September, respectively. In Yr 2, total precipitation was 67% greater than the 30-yr average in January. Precipitation was 78, 44, 22, 38, and 33% less than the 30-yr average in October, November, December, February, and March, respectively, reflecting drier than normal conditions that persisted through the winter months. In Yr 1, heavy rainfall in December and February made it difficult to allow cattle to graze plots without damage from trampling and pugging. Drought conditions throughout summer and fall of Yr 1 caused a delay in planting cool-season forages for Yr 2. Thus, cool-season forages emerged later and were grazed fewer times in Yr 2 than Yr 1.

Table 1. Monthly mean air temperatures (˚C) for Yr 1, Yr 2, and 30-yr averages for Marion Junction, AL.

Month	Year 1[1]			Year 2			30-yr Avg., ˚C
	Avg. High, ˚C†	Avg. Low, ˚C	Mean, ˚C	Avg. High, ˚C†	Avg. Low, ˚C	Mean, ˚C	
October	26.5	12.1	19.3	29.7	12.0	20.8	17.8
November	21.7	9.3	15.5	23.7	4.9	14.8	12.5
December	20.1	7.8	14.0	16.6	3.9	10.2	8.2
January	12.6	-0.2	6.2	17.7	5.4	11.5	6.8
February	17.4	2.6	10.0	20.6	5.7	13.1	8.9
March	22.6	9.0	15.8	22.6	8.0	15.3	13.2
April	25.6	11.4	18.4	--	--	--	16.8
May	28.8	15.6	22.2	--	--	--	21.4
June	34.6	20.4	27.4	--	--	--	25.4
July	35.7	22.2	29.0	--	--	--	27.3
August	34.9	22.5	28.7	--	--	--	26.9
September	34.2	19.4	26.8	--	--	--	24.0

†Data was collected from AWIS Weather Services, Inc.
[1]Year 1 = 2015/2016 and Year 2 = 2016/2017 growing seasons.

Table 2. Monthly total precipitation for Yr 1, Yr 2, and 30-yr averages and differences from 30-yr averages for Marion Junction, AL.

	Total Precipitation, mm†			Differences, mm	
Month	Yr 1[1]	Yr 2	30-yr Avg.	Yr 1	Yr 2
October	59.2	16.5	75.4	-16.2	-58.9
November	154.4	61.7	110.7	43.7	-49.0
December	230.1	95.8	127.8	102.3	-32.0
January	68.1	248.4	148.6	-80.5	99.8
February	184.4	73.9	119.1	65.3	-45.2
March	111.8	109.0	163.3	-51.5	-54.3
April	171.7	--	122.7	49.0	--
May	51.3	--	103.9	-52.6	--
June	77.5	--	112.5	-35.0	--
July	51.8	--	128.5	-76.7	--
August	119.6	--	85.1	34.5	--
September	12.2	--	100.3	-88.1	--

†Data was collected from AWIS Weather Services, Inc.
[1]Year 1 = 2015/2016 and Year 2 = 2016/2017 growing seasons.

Forage Mass, Herbage Harvested, and Herbage Accumulation

Because of differences in rainfall between years resulting in delayed planting in Yr 2, data from Yr 1 and Yr 2 were analyzed separately. In Yr 1, there were differences detected among forage variety treatments for pre-graze forage mass ($P = 0.0202$) for cool-season forages (Table 3). The W and W + C treatments produced greater forage mass than F during the season. Also, W and W + C produced greater herbage accumulation than F. There were no differences detected among treatments for herbage accumulation or herbage harvested ($P > 0.05$). However, differences were observed among pre-graze forage mass and herbage harvested among sampling dates ($P < 0.05$). April sampling dates had greater pre-graze forage mass ($P < 0.0001$) and herbage harvested ($P = 0.0168$) than March sampling dates across all forage treatments. This observation agrees with the expected growth distribution of small grains in the Southeast, where the expected production window is from November through April, with the greatest production in March and April (Ball et al., 2015). The results illustrate that these species mature and complete their life cycle during this time of the year. In Yr 2, there were differences detected ($P < 0.05$) among treatments for pre-graze forage mass ($P = 0.0018$), herbage accumulation ($P = 0.0226$), and herbage harvested ($P = 0.0140$) for cool season forages (Table 4). Pre-graze forage mass and herbage harvested were greater for W and W + C than F. This difference may be a result of the delayed planting date in Yr 2. 'Florida 401' is a variety of rye that matures earlier than 'Wrens Abruzzi.' Delayed planting caused later emergence, resulting in the window of production for 'Florida 401' being cut short. 'Florida 401' reached maturity very quickly once it emerged, whereas 'Wrens Abruzzi' rye grew during its optimal timeframe, even with delayed planting. The F, W, and W + C plots provided forage available to graze in the winter and early spring, whereas C plots did not. Although forage yields in this study were low, these results illustrate that overseeding with cool-season annuals extended the grazing season, which has been reported in other studies. George et al. (1995) reported that cool-season legumes interseeded into switchgrass increased early-summer forage supply compared with grass-only systems. Hoveland et al. (1961) reported low forage yields for several overseeded species (1,079 kg DM/ha for 'Abruzzi' rye); however, the study concluded that overseeding winter annuals extended the grazing season and could increase total yield. Production of overseeded forages is usually less than that of forages planted into a prepared seedbed, but overseeded forages can still provide important winter and early-spring grazing.

During the warm-season months, there were no differences ($P > 0.05$) among N-fertilization treatments for pre-graze forage mass, herbage harvested, or herbage accumulation of Eastern gamagrass (Table 5) in Yr 1. Brejda et al. (1996) reported increased forage yield with increasing N-fertilization rates. There were significant differences among sampling dates for forage production parameters for Eastern gamagrass. Pre-graze forage mass increased ($P = 0.0002$) from May to June, was greatest in June and July, and declined through August and September. Keyser et al. (2011c) indicated that NWSG grow rapidly from mid-May through mid-summer with growth slowing through the late summer and into October. Total herbage mass for May through September was 2,954 kg DM/ha. Herbage mass in the present study was low compared with results reported by Ritchie et al. (2006), where biomass production ranged from 1,345 to 7,846 kg/ha; however, the authors did not report harvest height. Edwards et al. (1999) reported biomass values from 4,155 to 14,709 kg/ha for Eastern gamagrass cut at a 10-cm height; the present study harvested at 20 cm. Differences in harvest height across studies influence forage production values, resulting in low production values for the present study. Herbage harvested followed a similar pattern, and was greatest ($P = 0.0353$) in May, June, and July, and decreased in August and September. Herbage accumulation was greatest ($P = 0.0002$) in May, June, and July, and declined through the end of the growing season. Overseeding did not affect production of EG, as it followed the expected growth distribution of NWSG in the Southeast. Yields were low compared with other studies, but no differences in forage production were observed among N rates. For pre-graze forage mass, there was less than a 100 kg DM/ha difference per grazing event between 67N and 135N. While this difference may provide forage for a few more head of cattle, input costs of doubling the N rate may not result in economic gain. The lower N rate would provide sufficient forage mass, while reducing costs.

Table 3. Forage treatment and harvest date effects of Yr 1 pre-grazing forage mass, herbage harvested, and herbage accumulation of cool-season forages.

Item	Pre-Graze Forage Mass	Herbage Harvested	Herbage Accumulation
	-------------------------------------kg DM/ha	--	
Forage Treatment			
'Florida 401' Rye	775[b]	297	1,062
'Wrens Abruzzi' Rye	1,289[a]	638	1,036
'Wrens' + 'AU Red Ace' Red Clover	1,253[a]	582	1,018
SEM	200	217	202
Date			
March	499[d]	264[d]	691[d]
April	1,712[c]	714[c]	1,386[c]
SEM	189	196	194
Seasonal Total	2,211	978	2,077

[a,b] Within a column, means differ (*P* < 0.05; n = 4).
[c,d] Within a column, means differ (*P* < 0.05; n = 12).

Table 4. Forage treatment and harvest date effects of Yr 2 pre-grazing forage mass, herbage harvested, and herbage accumulation of cool-season forages.

	Pre-Graze Forage Mass		Herbage Harvested		Herbage Accumulation	
Unit	------------------------------------		kg DM/ha		------------------------------------	
Date	February	March	February	March	February	March
Forage Treatment						
'Florida 401' Rye	477	321[b]	354	210[d]	477[e]	207[f,h]
'Wrens Abruzzi' Rye	--	757[a]	--	624[c]	--	757[g]
'Wrens' + 'AU Red Ace' Red Clover	--	743[a]	--	507[c]	--	743[g]
Seasonal Total	477	1,821	354	1,341	477	1,707

[a,b] Within a column, means differ (*P* < 0.05; SEM = 112; n = 4).
[c,d] Within a column, means differ (*P* < 0.05; SEM = 138; n = 4).
[e,f] Within a row, means differ (*P* < 0.05; SEM = 107; n = 4).
[g,h] Within a column, means differ (*P* < 0.05; SEM = 107; n = 4).

Table 5. Nitrogen fertilization rate and harvest date effects on Yr 1 pre-grazing forage mass, herbage harvested, and herbage accumulation of Eastern gamagrass.

Item	Pre-Graze Forage Mass	Herbage Harvested	Herbage Accumulation
	------------------------	kg DM/ha	------------------------
Nitrogen Fertilization Rate (kg N/ha)			
135	636	401	433
67	545	352	396
SEM	57	47	42
Date			
May	602^{bd}	409^{ac}	602^{a}
June	765^{a}	458^{a}	525^{ab}
July	721^{ab}	441^{a}	424^{b}
August	376^{c}	263^{b}	146^{c}
September	490^{cd}	313^{bc}	375^{b}
SEM	72	59	63
Seasonal Total	2,954	1,884	2,072

$^{a-e}$ Within a column, means differ ($P < 0.05$; n = 8).

Crude Protein and *in vitro* True Digestibility

In Yr 1, no differences (*P* = 0.1235) were detected among forage treatments for CP concentration in cool-season forages (Table 6). Concentration of CP was greater than 15% for each treatment, illustrating the high quality potential of cool-season forages. There were differences (*P* < 0.05) among forage treatments for *in vitro* true digestibility of cool-season forages. Both W and W + C had greater (*P* = 0.0012) digestibility than F. Whereas these differences were significant, the values for IVTD fell between 81.6 and 87.8%, indicating that all forages were highly digestible. Coffey et al. (2002) reported CP concentrations between 8.5 and 26.8%, and IVDMD values between 55.4 and 81.7% for rye and annual ryegrass mixtures sod-seeded into warm-season pastures; the authors reported gains between 97 and 112 kg over 119 days while grazing sod-seeded rye and annual ryegrass mixtures, indicating that sod-seeded cool-season annuals of similar nutritive quality would be sufficient for grazing animals. There were differences among harvest dates for both CP concentrations and IVTD. Concentrations of CP (*P* < 0.0001) and IVTD (*P* < 0.0001) were greater in March than April. In Yr 2, differences were detected among treatments for CP and IVTD (Table 7) of cool-season forages. Forage CP increased (*P* = 0.0033) and IVTD decreased (*P* = 0.0027) from February to March for F. As forage treatments began to enter reproductive stage of production, they became more mature and less digestible. However, the increase in CP might have been explained by the shorter interval between February and March grazing events compared with the amount of time that forage was allowed to grow before it was harvested for the first time in February, which resulted in more vegetative forage during the second harvest. In March, CP was greater (*P* = 0.0037) for W and W + C. Differences in maturity among rye varieties contribute to the greater CP. 'Wrens Abruzzi' rye is a mid-maturity rye which reaches maturity later than early 'Florida 401' rye. At the later grazing date in March, W was not as mature as F, resulting in a greater nutritive value. Clover also began to contribute to the greater CP in March. No differences in IVTD were detected (P = 0.1666) among treatments in March.

In Yr 1, N fertilization rate and harvest date had an effect on CP concentrations of Eastern gamagrass (Table 8). The greater N rate, 135 N, resulted in greater (P = 0.0006) CP concentrations than 67 N. Brejda et al. (1996) observed increased CP concentrations in Eastern gamagrass in response to increasing N fertilization rates. Forage CP concentrations were greatest (P < 0.0001) in May and declined to no lower than 12.1% throughout the growing season. Due to the relatively high grazing height requirements of NWSG, clipping at a 20-cm height resulted in samples composed of mostly leaf material, which is of the highest quality. There was an effect of N fertilization rate and harvest date on IVTD of Eastern gamagrass (Table 9). The 135 N treatment had a greater (P = 0.0264) digestibility than the 67 N. Eastern gamagrass IVTD was the greatest (P < 0.0001) in May and declined no lower than 62.5% throughout the summer. A decline in digestibility can result in a decrease in overall nutritive value, as digestibility is an integral component of forage quality. Regardless of other quality parameters, poor digestibility would be a limiting factor when determining nutritive value. The lowest CP and IVTD values were observed in July. Salon and Cherney (1999) reported CP concentrations between 13.0 and 16.4%, and IVTD values from 75.1 to 84.3%, which were greater than results in the present study; however, nutritive quality was still adequate for grazing animals. Mature forage may have led to greater selectivity by cattle during the July grazing events. Plots were mowed to a 25-cm stubble height to remove overly mature forage after July grazing events, which led to a greater nutritive value in August. Though differences in nutritive value were observed among N rates, the differences would not be biologically significant for grazing animals. The lower rate, 67N, provided sufficient nutritive value and yield and reduced N inputs compared with a typical warm-season forage system like bermudagrass, which could provide 16% CP and 58% IVDMD in the vegetative stage (Ball et al., 2015), but would require greater N input at 168 to 280 kg/ha (Hancock et al., 2017).

Table 6. Forage treatment and harvest date effects on Yr 1 cool-season forage concentrations of crude protein and *in vitro* true digestibility.

Item	Crude Protein	*In vitro* True Digestibility
	------------------------- %	-------------------------
Forage Treatment		
'Florida 401' Rye	16.3	81.6[b]
'Wrens Abruzzi' Rye	15.1	86.6[a]
'Wrens' + 'AU Red Ace' Red Clover	17.2	87.8[a]
SEM	0.6	0.7
Date		
January		
March	21.5[a]	91.5[a]
April	11.0[b]	79.1[b]
SEM	0.5	0.5

[a,b] Within a column, means differ ($P < 0.05$).

Table 7. Forage treatment and harvest date effects on concentrations of crude protein and *in vitro* true digestibility of Yr 2 cool-season forages.

	Crude Protein		*In vitro* True Digestibility	
Unit	-----------------------------	%	-----------------------------	
Date	February	March	February	March
Forage Treatment				
'Florida 401' Rye	12.5[b]	17.1[a,d]	90.2[e]	82.7[f]
'Wrens Abruzzi' Rye	--	20.4[c]	--	86.1
'Wrens' + 'AU Red Ace' Red Clover	--	21.6[c]	--	84.0

[a,b] Within a row, means differ ($P < 0.05$; SEM = 0.9; n = 4).
[c,d] Within a column, means differ ($P < 0.05$; SEM = 0.9; n = 4).
[e,f] Within a row, means differ ($P < 0.05$; SEM = 1.5; n = 4).

Table 8. Nitrogen fertilization and harvest date effects on concentrations of crude protein of Eastern gamagrass.

	Harvest Date					
	May	June	July	August	September	Mean
Unit	------------------------------		%	------------------------------		
Nitrogen Fertilization Rate (kg N/ha)						
135	19.3[f,j]	15.2[g,j]	13.4[h,j]	15.1[g,j]	12.8[i]	15.2[d]
67	15.3[f,k]	12.3[g,k]	10.8[h,k]	13.1[i,k]	12.4[g]	12.8[e]
Mean	17.3[a]	13.7[b]	12.1[c]	14.1[b]	12.6[c]	

[a-c] Within a row, means differ ($P < 0.05$; SEM = 0.2; n = 8).
[d,e] Within a column, means differ ($P < 0.05$; SEM = 0.1; n = 4).
[f-i] Within a row, means differ ($P < 0.05$, SEM = 0.2; n = 4).
[j,k] Within a column, means differ ($P < 0.05$; SEM = 0.2; n = 4).

Table 9. Nitrogen fertilization and harvest date effects on *in vitro* true digestibility of Eastern gamagrass.

	Harvest Date					
	May	June	July	August	September	Mean
Unit	------------------------------		%	------------------------------		
Nitrogen Fertilization Rate (kg N/ha)						
135	76.0[g,k]	66.6[hi,k]	65.5[h,k]	68.4[i]	65.1[h]	68.3[a]
67	73.6[g,l]	64.1[h,l]	59.6[i,l]	66.9[j]	65.6[hj]	66.0[b]
Mean	74.8[c]	65.3[d]	62.5[e]	67.7[f]	65.4[d]	

[a,b] Within a column, means differ ($P < 0.05$; SEM = 0.4; n = 4).
[c-f] Within a row, means differ ($P < 0.05$; SEM = 0.6; n = 8).
[g-j] Within a row, means differ ($P < 0.05$; SEM = 0.9; n = 4).
[k,l] Within a column, means differ ($P < 0.05$; SEM = 0.9; n = 4).

Botanical Composition, Frequency, and Ground Cover

During the transition months of March through June and at the end of the native-warm season grass growing season in September, forage botanical composition, ground cover, and frequency of occurrence estimates were collected. In Yr 1, forage treatment had an effect on cool-season forage botanical composition (Table 10) from March through June. Whereas grass and weed presence were not different among treatments, percentage of clover was greater (P = 0.0033) in W + C than in W or F. Overall, clover contribution was low (less than 10% of stand), especially during the window of the time that it was quantified by hand-separation of samples. Even though red clover has a growth distribution that extends into the early summer months (through June), when samples were clipped at a 20-cm height in the summer months, many clover plants were not tall enough to be included in the samples. This resulted in a low contribution value by clover. However, significant ground cover by red clover was observed in summer months.

Harvest date and forage treatment had a significant effect on frequency of Eastern gamagrass occurrence (Table 11). Frequency of Eastern gamagrass increased from March through June and was the greatest (P < 0.0001) in September. There were differences (P = 0.0292) among treatments such that W had the greatest frequency of gamagrass and W + C had the least, and C and F treatments were intermediate to these. Difference in forage treatment impacted frequency based on time of maturity of each forage. A more open canopy during transition months may explain intermediate values for C and F, and clover contribution resulted in a lower frequency of Eastern gamagrass for W + C. While there were differences among overseeding treatments, this practice did not seem to negatively impact Eastern gamagrass plant populations, as illustrated by the increasing frequency of Eastern gamagrass observed throughout the summer management season.

Differences were detected among forage varieties and among harvest dates for ground cover by rye during transition months (Table 12). In March and April, rye contributed 10% ground cover and declined ($P < 0.0001$) to zero in May, June, and September. Ground cover from rye did not differ among F, W, and W + C ($P > 0.05$). Percent ground cover of Eastern gamagrass was affected by harvest date (Table 13). Ground cover percentage of Eastern gamagrass was least ($P < 0.0001$) in March and April, increased in May and June, and was greatest in September, which follows the expected pattern of increased seasonal yield of Eastern gamagrass in late spring. Clover ground cover percentage was different among treatments and among harvest dates (Table 14). The C, F, and W treatments had zero percent ground cover by clover and were different from W + C ($P < 0.0001$). Contribution of red clover began to increase in the spring, with intermediate ground cover in March and April, and the greatest presence occurring in May and June. These data illustrate that red clover has more late spring/early summer growth distribution, and may provide high-quality forage in warm-season grass stands during this time of the year. Increased nutritive value and N contribution are advantages of adding red clover into this system; however, if clover presence is too great, over time it may have negative impacts on persistence of EG. Weeds were prevalent during the transition period as Eastern gamagrass broke dormancy and rye died off. Most of the weeds present were cool-season annuals. Clover contribution was not great during the early spring, but as annual weeds died off in late spring, clover was allowed more space to flourish. Differences were detected among forage varieties and among harvest dates for weed ground cover or bare ground (Table 15). The greatest ($P < 0.0001$) ground cover by weeds or bare ground present was observed in C plots, with F and W being intermediate, and the least present in W + C. Weed contribution in the C plots can be attributed to more open canopy that allowed for weed competition before Eastern gamagrass broke dormancy. Weeds and bare ground were most prevalent in March and April and declined ($P < 0.0001$) throughout the warm season, illustrating that the Eastern gamagrass canopy may have shaded warm-season weeds once it began to become productive in the late spring months.

Table 10. Forage treatment effects on Yr 1 cool-season forage botanical composition.

	Grass	Weeds	Clover
Unit	------------------------	%	------------------------
Forage Treatment			
‘Florida 401’ Rye	77	23	0[b]
‘Wrens Abruzzi’ Rye	77	23	0[b]
‘Wrens’ + ‘AU Red Ace’ Red Clover	77	17	6[a]
SEM	6.7	6.8	0.8

[a,b] Within a column, means differ ($P < 0.05$).

Table 11. Harvest date and forage treatment effects on frequency of Eastern gamagrass during Yr 1 transition months.

	Harvest Date			
	1†	2	3	Mean
Unit	----------------------------------	%	----------------------------------	
Forage Treatment				
Control	68	90	100	86[ab]
‘Florida 401’ Rye	69	91	100	87[ab]
‘Wrens Abruzzi’ Rye	76	96	100	91[a]
‘Wrens’ + ‘AU Red Ace’ Red Clover	64	80	98	81[b]
Mean	69[e]	89[d]	99[c]	

†Harvest date 1 = Mar 29 and Apr 5, 2017; 2 = May 5 and Jun 6, 2017; 3 = Sep 14 and Sep 21, 2017.

[a,b] Within a column, means differ ($P < 0.05$; SEM = 1.9; n = 4).

[c-e] Within a row, means differ ($P < 0.05$; SEM = 1.6; n = 16).

Harvest date × forage treatment ($P > 0.05$; SEM = 3.3, n = 4).

Table 12. Harvest date and forage treatment effects on percent ground cover by rye, Eastern gamagrass, clover, and weeds or bare ground during Yr 1 transition months.

	Species											
	Rye			Eastern gamagrass			Clover			Weeds/Bare Ground		
Date	1†	2	3	1	2	3	1	2	3	1	2	3
Unit	--%--											
Forage Treatment												
C	1^{e}	0	0	7^{h}	$30^{g,j}$	79^{f}	0^{p}	0^{p}	0	$91^{q,t}$	$70^{r,t}$	$21^{s,t}$
F	$12^{a,d}$	0^{b}	0^{b}	9^{h}	$33^{g,j}$	87^{f}	0^{p}	0^{p}	0	$79^{q,u}$	$67^{r,t}$	$13^{s,u}$
W	$12^{a,d}$	0^{b}	0^{b}	8^{h}	$51^{g,i}$	79^{f}	0^{p}	0^{p}	0	$79^{q,u}$	$49^{r,u}$	$21^{s,t}$
W+C	$15^{a,c}$	0^{b}	0^{b}	8^{h}	$33^{g,j}$	79^{f}	$11^{l,n}$	$48^{k,n}$	0^{m}	$65^{q,v}$	$20^{r,v}$	$21^{r,t}$
SEM		0.9‡			3.4			2.4			3.2	
Mean	10^{a}	0^{b}	0^{b}	8^{h}	37^{g}	81^{f}	3^{l}	12^{k}	0^{l}	79^{q}	51^{r}	19^{s}
SEM		0.5§			3.3			1.2			1.6	

†Harvest date 1 = Mar 29 and Apr 5, 2016; 2 = May 5 and Jun 6, 2016; 3 = Sep 14 and Sep 21, 2016.

‡SEM for harvest date × forage treatment interaction.

§SEM for harvest date main effect.

^{a,b} For rye, in a row, means differ ($P < 0.05$).

$^{c\text{-}e}$ For rye, in a column, means differ ($P < 0.05$).

$^{f\text{-}h}$ For Eastern gamagrass, in a row, means differ ($P < 0.05$).

^{i,j} For Eastern gamagrass, in a column, means differ ($P < 0.05$).

$^{k\text{-}m}$ For clover, in a row, means differ ($P < 0.05$).

^{n,p} For clover, in a column, means differ ($P < 0.05$).

$^{q\text{-}s}$ For weeds/bare ground, in a row, means differ ($P < 0.05$).

$^{t\text{-}v}$ For weeds/bare ground, in a column, means differ ($P < 0.05$).

Summary and Conclusions

Results of this study indicate that overseeding Eastern gamagrass with cool-season grasses or grass-legume mixtures could extend the grazing season and provide high-quality grazeable forage throughout the winter. Forage species and variety considerations and selection for use in overseeding systems should be made based on maturity and growth distribution. Specifically, small grains or small grain mixtures with legumes may be a fit for overseeding NWSG because of their seasonal growth distribution. Forage accumulation of cool-season annuals was low, which is characteristic of overseeded systems when compared with prepared seedbeds. Small grain forage varieties with an early maturity may provide forage DM for grazing earlier in the winter, but may result in a more rapid decline in forage nutritive value before Eastern gamagrass breaks dormancy. Although grazing may be earlier for 'Florida 401' rye, there were no differences in seasonal forage accumulation among cereal rye varieties or rye + red clover mixtures used in this evaluation. Overseeded grasses and clover could provide ground cover to alleviate weed pressure. During the transition from spring into and throughout the summer, changes in ground cover and composition indicate that overseeding did not have negative effects of persistence of Eastern gamagrass. Following the winter months, an economic fertilization rate for increased response from Eastern gamagrass must be established. This study shows that Eastern gamagrass will respond to reduced N fertility inputs to provide a grazing system with lower input costs. Overall, forage mass of the native warm-season grass component was lower compared with other studies; however, producers in the Black Belt region could utilize NWSG overseeded with cool-season annuals to create a longer grazing season, reduce winter feed needs, and reduce fertilizer inputs.

Future research should focus on different mixtures of grasses and legumes for overseeding native-warm season grasses in the Black Belt region, as well as overseeding other types of NWSG. Grazing and animal performance studies may be beneficial in demonstrating the intensive management practices required by native grass systems. Evaluating these alternative grazing systems is advantageous for producers who are looking for ways to alleviate the effects of grazing tall fescue during the summer months when fescue toxicosis is most prevalent. This study provides information about an alternative system that would fit well in the Black Belt region, alleviate problems associated with grazing fescue in the summer, and extend the grazing season.

LITERATURE CITED

Alderson, J.S., J.K. Allison, M.R. Brakie, S.B. Bruckerhoff, J.A. Dickerson, J.L. Douglas, R.G. Esquivel, J.M. Grabowski, J.F. Henson, M.J. Houck, Jr., J.U. Kaiser, M.S. Kirkland, R.L. Noricks, S.L. Pfaff, J.M. Row, P.R. Salon, J. Stevens, L.M. Tharel, M. van der Grinten, R. Wynia. Eastern gamagrass. 2007. USDA-NRCS Plant Fact Sheet.

Anonymous. Pastures for Alabama. 1934. Agricultural Experiment Station of the Alabama Polytechnic Institute.

Anonymous. Crop profile for hay and pasture in Alabama. 2001. National IPM Database. Alabama Cooperative Extension System.

AOAC. 1990. Official Methods of Analysis. 15th ed. Assoc. Offic. Anal. Chem., Arlington, VA.

Ashworth, A., P. D. Keyser, F. Allen, G. E. Bates, and C. A. Harper. 2012. Intercropping legumes with native warm-season grasses for livestock forage production in the Mid-South. SP731-G.

Ball, D. 2007. Overseeding summer sods with winter annuals. ANR-227. Alabama Cooperative Extension System.

Ball, D., C. S. Hoveland, and G. D. Lacefield. 2015. Southern Forages. 5th ed. Norcross, GA. International Plant Institute.

Bidack, J.E., J.E. Vaughan, and C.L. Dewald. 1999. Forage quality of 10 Eastern gamagrass [*Tripsacum dactyloides* (L.) L.] genotypes. J. Range. Manage. 52:661-665.

Brejda, J.J., J.R. Brown, T.E. Lorenz, J. Henry, J.L. Reid, and S.R. Lowry. 1996. Eastern gamagrass responses to different harvest intervals and nitrogen rates in northern Missouri. J. Prod. Agric. 9:130-135.

Burns, J.C., D.S. Fisher, K.R. Pond, and D.H. Timothy. 1992. Diet characteristics, digesta kinetics, and dry matter intakes of steers grazing eastern gamagrass. J. Anim. Sci. 70:1251-1261.

Bush, L.P. and P.B. Burrus, Jr. 1988. Tall fescue forage quality and agronomic performance as affected by the endophyte. J. Prod. Agric. 1:55-60.

Casey, P.A. 2012. Plant guide for cereal rye (*Secale cereale*). USDA-Natural Resources Conservation Service, Plant Materials Center, Elsberry, MO.

Campbell, J.J.N., and W.R. Seymour, Jr. 2011. A review of native vegetation types in the Black Belt of Mississippi and Alabama, with suggested relationships to the catenas of soil series. J. Miss. Acad. Sci. 56: 166-184.

Coffey, K.P., W.K. Coblentz, T.G. Montgomery, J.D. Shockey, K.J. Bryant, P.B. Francis, C.F. Rosenkranz, Jr., and S.A. Gunter. 2002. Growth performance of stocker calves backgrounded on sod-seeded winters annuals or hay and grain. J. Anim. Sci. 80:926-932.

Dillard, S.L., L.E Sturgeon, W.F Owsley, C. Wood, J.L. Holliman, and R.B. Muntifering. 2012. Productivity and nutritive quality of Johnsongrass (*Sorghum halepense*) as influenced by commercial fertilizer, broiler litter, and interseeded white clover (*Trifolium repens*). *Applied and Environmental Soil Science*.

Edwards, S., J. Douglas, and H. Bloodworth. 1999. Clipping Effect on Yield and Quality of Eastern Gamagrass, Switchgrass, and Bermudagrass. Proceedings of the 2nd Eastern Native Grass Symposium. Baltimore, MD. P. 121-126.

Evers, G.W. 2005. A guide to overseeding warm-season perennial grasses with cool-season annuals. Forage and Grazinglands, 3:1.

Faix, J.J., C.J. Kaiser, and F.C. Hinds. 1980. Quality, yield, and survival of Asiatic bluestems and an eastern gamagrass in southern Illinois. J. Range Mgmt. 33: 388-390.

Fribourg, H.A. and J.R. Overton. 1973. Forage production on bermudagrass sods overseeded with tall fescue and winter annual grasses. Agron. J. 65:295-298.

George, J.R., K.M. Blanchet, R.M. Gettle, D.R. Buxton, and K.J. Moore. 1995. Yield and botanical composition of legume-interseeded vs. nitrogen-fertilized switchgrass. Agron. J. 87:1147-1153.

Giuliano, W.M. and S.E. Daves. 2002. Avian response to warm-season grass use in pasture and hayfield management. Biological Conservation 106:1-9.

Griffin, J.L. and G.A. Jung. 1983. Leaf and stem forage quality of big bluestem and switchgrass. Agron. J. 75:723-726.

Grunwald, S. (n.d.) Vertisols. Soil and Water Science Department, University of Florida. Website. Accessed 2017.

Hancock, D.W., R.C. Lacy, R.L. Stewart, R.S. Tubbs, J. Kichler, T.W. Green, and R. Hicks. 2017. The management and use of bahiagrass. UGA Coop. Ext. Bull. 1362.

He, J., M. Dougherty, J. Shaw, J. Fulton, and F. Arrigia. 2011. Hydraulic management of a soil moisture controlled SDI wastewater dispersal system in an Alabama Black Belt soil. J. Env. Mgmt. 92: 2479-2485.

Hoveland, C.S., 1993. Importance and economic significance of the *Acremonium* endophytes to performance of animals and grass plant. Agric. Ecosystems Env., 44: 3-12.

Hoveland, C.S., M.W Alison, R. F. McCormick., W.B. Webster, V.H. Calvert, J.T. Eason, M.E. Ruf, W.A. Griffey, H.E. Burgess, L.A. Smith, and H.W. Grimes. 1981. Seeding legumes into tall fescue sod. Al. Exp. Station. Bull. 531.

Hoveland, C. S., W. B. Anthony, J. A. McGuire, and J. G. Starling. 1978. Beef Cow-Calf Performance on Coastal Bermudagrass Overseeded with Winter Annual Clovers and Grasses. Agron. J. 70:418-420.

Hoveland, C.S., R.L. Haaland, W.B. Webster, V.H. Calvert, II, R.A. Moore Jr., J.T. Eason, M.L. Ruf, L.L. Walker, H.C. Hoyle, L.A. Smith, and H.W. Grimes, Jr. 1981. Performance of red clover cultivars in Alabama. Departmental series No. 67. Dep. of Agronomy and Soils, Auburn University, Auburn, AL.

Hoveland, C. S., S. P. Schmidt, C. C. King, J. W. Odom, E. M. Clark, J. A. McGuire, L. A. Smith, H. W. Grimes, and J. L. Holliman. 1983. Steer performance and association of *Acremonium coenophialum* fungal endophyte on tall fescue pasture. Agron. J. 75:821-824.

Hoveland, C.S., L.A. Smith, and Grimes H.W. 1961. Forage production of winter annuals sod-seeded on dallisgrass-white clover. Ag. Exp. Sta. Lf 66.

Johnson, J. and D. Ball. 2013. Alabama planting guide for forage grasses. ANR-0149.

Johnson, J. and D. Ball. 2013. Alabama planting guide for forage legumes. ANR-0150.

Keyser, P. D., C. A. Harper, G. E. Bates, J. C. Waller, and E. D. Doxon. 2011. Establishing native warm-season grasses for livestock forage in the Mid-south. SP731-B.

Keyser, P. D., G. E. Bates, J. C. Waller, C. A. Harper, and E. D. Doxon. 2011. Grazing native warm-season grasses in the Mid-south. SP731-C.

Keyser, P. D., C. A. Harper, G. E. Bates, J. C. Waller, and E. D. Doxon. 2011. Native warm-season grasses for Mid-south forage production. SP731-A.

Klotz, J.L., and Nicol, A.M. 2016. Ergovaline, an endophytic alkaloid. 1. Animal physiology and metabolism. Anim. Prod. Sci. 56:1761-1774.

Krueger, C.R. and D.C. Curtis. 1979. Evaluation of big bluestem, indiangrass, sideoats grama, and switchgrass pastures with yearling steers. Agron. J. 71:480-482.

Mitchell, C.C., D. Rodekohr, and S. Harris. 2006. Soil descriptions and plant selections for the Montgomery/Prattville/Wetumpka area. ANR-966.

Mosjidis, J.A. 2011. 'AU Red Ace', a red clover for the lower south. J. Plant Reg. 5:11-13.

Mullenix, M. K., Sollenberger, L. E., Wallau, M. O., Blount, A. R., Vendramini, J., & Silveira, M. L. (2016). Herbage accumulation, nutritive value, and persistence responses of rhizoma peanut cultivars and germplasm to grazing management. *Crop Science*, *56*(2), 907-915.

Oelke, E. A., E. S. Oplinger, H. Bahri, B. R. Durgan, D. H. Putnam, J. D. Doll, and K. A. Kelling. 2000. Rye. Alternative Crops Manual. Online. http://www.hort.purdue.edu/newcrop/afcm/rye.html. Accessed Apr. 17, 2017.

Paterson, J., C. Forcherio, B. Larson, M. Samford, and M. Kerley. 1995. The effects of fescue toxicosis on beef cattle productivity. J. Anim. Sci. 73:889-898.

Pedersen, J.F., G.D. Lacefield, and D.M. Ball. 1990. A review of the agronomic characteristics of endophyte-free and endophyte-infected tall fescue. Agr. & Hort.- Faculty publications. Paper 958.

Rankin, H.T. 1974. Black Belt Prairie Montgomery County, Alabama, and Vicinity. Agric. Exp. Stn. Auburn Univ. Auburn, AL.

Ritchie, J.C., D.T. Krizek, D.C. Gitz III, and C.D. Foy. 2006. A nine-year study of biomass production by Eastern gamagrass. (30-35). In M.A. Sanderson et al (eds.). Proceedings of the Fifth Eastern Native Grass Symposium, Harrisburg, PA, October 10-13, 2006.

Salon, P.R. and D.J.R. Cherney. 1999. Eastern gamagrass forage quality as influenced by harvest management (298-304). Proceedings of the Second Eastern Native Grass Symposium, Baltimore, MD, November, 1999.

Smith, R.R., N.L. Taylor, and S.R. Bowley. 1985. Red clover. p. 457–470. In N.L. Taylor (ed.) Clover science and technology. Agron. Monogr. 25. ASA, CSSA, and SSSA, Madison, WI.

St. John, L. and D. Ogle. 2008. Plant guide for red clover (*Trifolium pratense*). USDA-Natural Resources Conservation Service, Plant Materials Center, Aberdeen, ID.

Tilley, J. M. A., and R. A. Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. J. Br. Grassl. Soc. 18:104–111.

United States Department of Agriculture. 1997. Houston Series. Online. https://soilseries.sc.egov.usda.gov/OSD_Docs/H/HOUSTON.html. Accessed Jun 27, 2017.

United States Department of Agriculture. NRCS: PLANTS Database. *Secale cereale*. Online. https://plants.usda.gov/java/charProfile?symbol=SECE. Accessed Apr. 17, 2017.

Van Soest, P. J., J.B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal production. J. Dairy Sci. 74: 3583-3597.

APPENDIX

I. Experimental layout and plot map of overseeding study at the Black Belt Research and Extension Center, Marion Junction, AL