GRAZING MANAGEMENT OF WARM-SEASON GRASSES IN SOUTH FLORIDA

By

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To my parents and sister for all the support

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Limpograss [*Hemarthria altissima* (Poir) Stapf and C.E. Hubb] is a widely used forage for cow-calf production in South Florida because it produces greater herbage mass and contains greater total digestible nutrients concentration than other warm-season grasses at late maturity during the autumn and winter. However, crude protein concentrations may reach levels below the animal requirements and supplementation may be necessary to maintain animal production. Research was conducted at Ona, FL to investigate the effects of urea or cottonseed meal as sources of rumen-degradable protein supplementation on performance of cow-calf pairs receiving stockpiled limpograss forage. There were no differences in animal performance, pasture characteristics, forage and total dry matter intake, and rumen metabolites between treatments. In addition, a grazing study was conducted to evaluate the effects of creep-feeding calves with increasing levels of soybean meal on performance of cow-calf pairs grazing limpograss pastures. Treatments were 0 or 200 g d^{-1} and 0, 200, or 400 g d^{-1} of soybean meal in 2011 and 2012, respectively. There were no differences in forage characteristics and animal performance in 2011; however, there was a linear increase in average daily gain as levels of soybean meal increased in 2012. Results of these

experiments indicate that urea can be the main source of rumen-degradable protein for cow-calf pairs grazing stockpiled limpograss pastures. In addition, creep-feeding calves with soybean meal may be an effective management practice to increase calf body weight and weaning weights.

There is an increasing interest in ‘Jiggs’ bermudagrass [*Cynodon dactylon* (L.) Pers.] for grazing systems in Florida; however, there is limited information about grazing management of Jiggs. Research was conducted to test the effect of stocking rates [SR; 4, 9, and 13 animal units (450 kg liveweight) ha^{-1}] on animal performance and herbage characteristics of Jiggs pastures. There was a linear decrease in herbage mass, forage height, and herbage allowance with increasing stocking rate. Animal performance and ground cover decreased with increasing stocking rate. Jiggs is a useful warm-season perennial grass to be grazed in South Florida; however, grazing at shorter stubble heights must be avoided due to negative effects on animal performance and forage persistence.

CHAPTER 1
INTRODUCTION

The majority of cow-calf operations in the United States are located in the Southeast and Southern Plain regions. These regions are more suitable for forage production, require less supplemental feed, and have lower production costs compared to other regions in the United States (McBride and Matthews, 2011). Florida is the 10th state in number of beef cows and 16th in total cattle number in the United States, with approximately one million animals (USDA, 2012). Florida is one of the most important calf producer regions in the United States with 890,000 calves born in 2011 (USDA, 2012). Cow-calf operations in Florida rely heavily on warm-season grass pastures with limited supplemental feed used during the winter period.

Florida grasslands cover ~ 4.5 million ha and the predominant forages are C4 (warm-season) grasses (Vendramini et al., 2008a). The climate in southern Florida varies during the year; with average temperatures ranging from 16°C during the winter to 28°C in the summer, and few events below 0°C occur during the winter. This temperature variation during the year has significant effects on herbage yield and nutritive value of warm-season grasses. Limited forage production and nutritive value during the winter months may limit livestock production in Florida (Vendramini et al., 2006). Therefore, an efficient grazing management program, which includes conserved forage and supplementation, is crucial to improve the profitability of cow-calf operations in Florida.

Stockpiling forage for the winter months has some advantages compared to hay or haylage, including less equipment, labor, fuel, and consequently at lower cost. Poore et al. (2000) concluded that stockpiled tall fescue grass (*Festuca arundinacea* Schreb.)

with moderate N fertilization levels (50 and 100 kg ha^{-1}) was more economical than hay to provide forage for cows during the winter. According to Lalman et al. (2000), stockpiled bermudagrass can be used to reduce cost of animal production and is more economical than making or purchasing hay. However, nutritional strategies are needed during fall and winter to maintain animal production on stockpiled pastures (Stateler et al., 1995). Supplemental strategies can decrease weight loss in cows and optimize stocker gains during the winter (Rush and Totusek, 1976).

Limpograss [*Hemarthria altissima* (Poir.) Stapf & C.E. Hubb.] is a warm-season forage species widely planted in seasonally flooded areas of South Florida. Limpograss is tolerant to poorly drained soils and has significant winter growth when compared to other warm-season grass species. Additionally, limpograss tends to have greater digestibility than other warm-season grasses at greater maturity and has been used successfully as stockpiled forage for beef cattle production in South Florida. However, limpograss has low crude protein (CP) concentrations at late maturity, which may limit animal performance (Sollenberger et al., 1988, Rusland et al., 1988, da Lima et al., 1999, Newman et al., 2002). Nitrogen fertilization, protein supplementation, and overseeding with legumes are some strategies used to overcome the limited CP concentrations of limpograss.

Supplemental feed, such as hay, haylage, and concentrated feed may represent approximately 60% of the total production cost of cow-calf operations (Quanbeck and Johson, 2009). Supplementation strategies, such as different rates and ingredients, need to be investigated to improve efficiency and decrease cost of supplemental feed.

Supplementing grazing animals with rumen-degradable protein is a strategy that can be used to improve performance of cattle grazing warm-season grass.

Creep-feeding is another approach for offering supplemental nutrients to nursing calves and increasing weaning weights (Stricker et al., 1979; Tarr et al., 1994; Faulkner et al., 1994). In addition, creep-feeding concentrate to nursing calves may increase total tract organic matter digestibility (Soto-Navarro, 2004) and decrease forage intake (Cremin et al., 1991; Falkner et al., 1994). Furthermore, creep-feeding has potential to increase body weight of heifer calves and decrease age of puberty, increasing pregnancy rates at earlier ages. However, feed conversion (supplemented feed/gain) of creep-fed calves is often low; approximately 8 kg of concentrate feed per kg of added gain, and may not be economically feasible (Sticker et al., 1979; Reed et al., 2006). An alternative management practice is to limit creep feed protein supplements to nursing calves (Lusby et al., 1985). Lusby et al. (1985) reported an improvement in calf performance (0.13 kg d^{-1} of added gain) and feed efficiency (2.5 kg of concentrate feed per kg of extra gain) when calves were supplemented with 0.37 kg d^{-1} of cottonseed (*Gossypium* spp.) meal for 63 d. Thus, limit creep-feeding rumen-degradable protein to nursing calves grazing limpograss may be an efficient management practice to increase weaning weights and profitability of cow-calf operations in South Florida.

Screening and testing new forage germplasm under grazing is another management practice to improve the efficiency of cow-calf operations in South Florida (Mislevy et al., 2008). According to Staples (2003), bermudagrass [*Cynodon dactylon* (L.) Pers.] is the most planted warm-season perennial forage in the southeastern USA because of high yields, resistance to dry periods and acid soils, long-term persistence when well-managed, and tolerance to frequent defoliation. In addition, bermudagrass can also be used to produce silage and hay. In 1943, the release of ‘Coastal’ bermudagrass, the first bermudagrass hybrid, was a landmark in bermudagrass breeding and forage production in the southeastern USA. Other bermudagrass hybrids were subsequently released, such as ‘Tifton 85’ (*Cynodon* spp.) (Burton et al., 1993). Although Coastal and Tifton 85 are the most planted cultivars of bermudagrass in the southern USA, they are not productive and persistent on poorly drained soils, which are commonly found in South Florida. The bermudagrass cultivar ‘Jiggs’ is a bermudagrass hybrid released in Texas with perceived greater tolerance to poorly drained soils. Vendramini et al. (2010) observed that Jiggs harvested at 6-wk regrowth interval had greater herbage accumulation than Tifton 85 in poorly drained soils in South Florida. There is increasing interest in Jiggs for grazing systems in South Florida; however, there is limited information in the literature on grazing management of Jiggs pastures available.

The general objective of the studies listed in this dissertation is to increase the efficiency of forage and livestock production in Florida. The specific objectives are to evaluate the effects of rumen-degradable protein supplementation on cow-calf pairs grazing limpograss pastures and to determine the effects of stocking rates on forage characteristics and animal performance of beef heifers grazing Jiggs bermudagrass pastures.

In order to address those objectives three grazing studies were conducted. The first study evaluated the effects of different sources of rumen-degradable protein supplementation on performance of cows and calves grazing stockpiled limpograss pastures during the winter. The second experiment evaluated the effect of creep-feeding increasing levels of soybean meal supplements to nursing calves grazing limpograss pastures during the summer. Lastly, the third study evaluated the effects of stocking rate on forage characteristics and animal performance of beef heifers grazing Jiggs bermudagrass pastures.

CHAPTER 2
LITERATURE REVIEW

Warm-season Grasses

In 1972, Parson stated that warm-season perennial grasses from Africa were introduced in the United States and had potential to improve livestock production in the southern part of North America, northern part of South America, and Central America. Currently, Florida has ~ 4.5 million ha of grasslands and several species of warm-season grasses, including bermudagrass [*Cynodon dactylon* (L.) Pers.], elephantgrass (*Pennisetum purpureum* Schumach), limpograss [*Hemarthria altissima* (Poir.) Stapf et C. E. Hubb.], stargrass (*Cynodon nlemfuensis* Vanderyst var. *nlemfuensis*), and brachiariagrass (*Brachiaria* sp.), which are originally from Africa. These grasses are being used in grazing systems and as conserved forage for livestock production. Warm-season grasses have superior production in tropical and subtropical regions of the world, however, are generally low in nutritive value and may not meet animal requirements (Moore, 1992).

Brown and Simmons (1979) reported that warm-season grasses produce more forage than cool-season grasses in tropical and subtropical climates, as a result of better water use and light conversion efficiency. However, warm-season grasses tend to have lesser nutritive value [crude protein (CP) and digestibility] than cool-season grasses, due in part to the parenchyma bundle sheath cells and a higher proportion of cell-wall material (Akin and Burdick, 1975). Although cell walls are potentially digestible, chemical barriers and anatomical structures decrease microbial attachment, degradation rate, and fermentation (Akin and Burdick, 1975). The leaves of warm-season grasses have lower degradability in the rumen compared to leaves of cool-season grasses (Van Soest, 1982) due to greater proportions of vascular tissues, bundle sheath, and sclerenchyma (Coleman et al., 2004).

Warm-season grasses differ from cool-season grasses in carbon fixation pathway. In C3 plants, the first stable product of CO_2 fixation is 3-phosphoglyceric acid (3-PGA). This reaction occurs at the carboxylation site in the mesophyll cells where CO_2 and H_2O are added to ribulose-1,5-bisphosphate by the enzyme ribulose bisphosphate carboxylase-oxygenase (Rubisco). In C4 plants, the first product of CO_2 fixation is the four-carbon compound oxaloacetate (OAA) that is converted to malic or aspartic acid. The C4 pathway begins in the mesophyll cells when CO_2 diffuses across the mesophyll cell membrane into the cytoplasm where it is converted to HCO_3^-. In the mesophyll, HCO_3^- is incorporated by the enzyme phosphoenolpyruvate carboxylase (PEP) into OAA. Oxaloacetate is then converted into malate or aspartate in the cytoplasm and transported to the bundle sheath cells. In the bundle sheath cells, malate or aspartate is decarboxylated and CO_2 is released.

Phosphoenolpyruvate carboxylase has a high affinity for CO_2, which can efficiently fix CO_2 into the 4-C compound. The decarboxylation of this 4-C compound in the bundle sheath increases the CO_2 concentration around Rubisco, not allowing O_2 to compete for binding sites. Photorespiration does not occur in C4 plants due to the high efficiency of the PEP enzyme and the CO_2 shuttle mechanism of the 4-C compound that moves CO_2 from the mesophyll to the bundle sheath.

The increase in herbage yield of warm-season grasses is observed during the summer, while during the winter, the production decreases significantly as a consequence of dry and cold weather (Brown and Simmons, 1979). Warm-season grasses have their optimum growth when temperature is between 20-35°C, while the range of growth temperatures is 15-45°C (Bassam, 1998). Growth is minimal below 15°C (Volenec and Nelson, 2003) and temperatures above the optimum can increase lignin and cell wall concentrations, and decrease soluble carbohydrates (Van Soest, 1994). According to MacAdam and Nelson (2003), temperatures below 0°C have an effect on rate of maintenance respiration of the plants and cause damage to membranes, especially for C4 plants with low adaptation to those conditions.

Limpograss General Description

Limpograss is a perennial warm-season grass from the Poaceae family originated from the Limpopo River region in South Africa. It is a stoloniferous grass, with decumbent branching stems, simple long leaf, spikelike raceme inflorescence, small membranous ligule, no rhizomes, and can grow up to 150 cm tall (Bodgan, 1977). The propagation of limpograss occurs primarily vegetatively from stolons (Wilms et al., 1970; Newman, 2001; Vendramini, 2008). The usage of limpograss has been increasing in the last decades and it is cultivated on approximately 150,000 ha in the state of Florida (IFAS, 2007). Limpograss is well-adapted to seasonally flooded soils, has superior herbage accumulation during the winter, and is resistant to most pests and diseases (Wilms et al., 1970, Quesenberry et al., 1984).

Four cultivars of limpograss were introduced in Florida in 1964 by Dr. Oakes, with three species being introduced vegetatively (Wilms et al., 1970). In a study comparing diploid, tetraploid and hexaploid limpograss cultivars, Wilms et al. (1970) reported that diploid plants had more leaves, were more erect and had shorter internodes than polyploids. In addition, the authors indicated the possibility to cross those plants to obtain more productivity hybrids. Dr. Quesenberry started a limpograss selection program and released three cultivars, ‘Redalta’ and ‘Greenalta’ (diploids) and ‘Bigalta’ in 1978 (Quesenberry et al., 1978). Bigalta has greater nutritive value and is more accepted by cattle; however it lacks persistence under grazing (Pitman et al. 1994; Quesenberry et al., 2004).

Kretschmer and Snyder (1979) evaluated the production and quality of three limpograss cultivars (Redalta, Greenalta, and Bigalta), ‘Pangola’ and ‘Transvala’ digitgrass (*Digitaria decumbens Stent.*) and Coastcross-1bermudagrass [*Cynodon dactylon* (L.) Pers.] from September to June 1969 to 1971. All grasses had the same fertilization level (84, 37, and 70 kg of N, P, K ha^{-1}, respectively) and three cutting intervals were tested (2, 3, and 4 weeks). The forage was harvested at 10-cm stubble height. Pangola had the least herbage accumulation compared to the other grasses. Herbage accumulation of Bigalta, Redalta and Greenalta were 15.2, 13.7, and 14.8 Mg ha^{-1}, respectively. Bigalta had the greatest IVDOM (633 g kg^{-1}) compared to Greenalta (599 g kg^{-1}) and Redalta (556 g kg^{-1}) which had similar values to Transvala (627 g kg^{-1}) and Pangola (622 g kg^{-1}). Coastcross 1 had the least in vitro digestible organic matter (IVDOM) concentrations (588 g kg^{-1}). There were no differences in herbage accumulation between Bigalta, Coastcross, and Transvala at the same cutting intervals; however, Bigalta produced less forage at the 2-wk regrowth interval treatments. The authors also concluded that Bigalta can be fertilized early in the autumn and would produce 4.0 to 5.0 Mg ha^{-1} as hay or as deferred forage. Subsequently, Quesenberry et al. (1983, 1984) released a tetraploid cultivar named ‘Floralta’ that was more persistent than Bigalta under grazing. According to Christiansen et al. (1988), Floralta stem is highly digestible because it has higher percentage of parenchyma cells and starch and less percentage of vascular bundles and structural carbohydrates. Currently, Floralta is the most planted limpograss cultivar in Florida, due to its persistence under grazing, high yield, long grazing season, reasonable digestibility, and cold tolerance (Sollenberger et al., 1989; Newman, 2001; Vendramini and Arthington, 2010).

Limpograss Forage Management

Sollenberger et al. (1988) evaluated animal performance, nutritive value and carrying capacity of continuously stocked bahiagrass (*Paspalum notatum* Flügge) and limpograss pastures. Pastures were stocked with variable stocking rate to maintain stubble height of 15 and 30 cm for bahiagrass and limpograss, respectively. Limpograss showed greater IVDOM when compared to bahiagrass, 539 vs. 484 g kg^{-1}; however CP was greater for bahiagrass than for limpograss, 93 vs. 58 g kg^{-1}. There was no difference in average daily gain (ADG) between the grasses, 0.35 kg d^{-1}. In spite of greater digestibility of limpograss, CP was deficient and led to poor animal performance. Similar conclusions were reached by Sollenberger et al. (1989) comparing Floralta limpograss and ‘Pensacola’ bahiagrass in a 3-yr study evaluating animal and forage performance. Pastures were rotationally stocked to 20- to 25- and 6- to 8-cm stubble height for limpograss and bahiagrass, respectively. On average, Pensacola had greater CP concentration, 116 vs. 83 g kg^{-1}. In vitro digestible of organic matter was greater for limpograss, 613 vs. 581g kg^{-1}; however, here was no difference in ADG between species (0.41 and 0.38 kg d^{-1} for limpograss and bahiagrass, respectively). Limpograss supported greater stocking rate than bahiagrass, 2150 vs. 1680 kg of live weight ha^{-1} d^{-1}, and produced greater live weight gain, 460 vs. 318 kg ha^{-1}.

Pitman et al. (1994) compared Bigalta and Floralta and concluded that Bigalta had greater in vitro digestible organic matter (IVDOM) (520 vs. 480 g kg^{-1}) and CP (61 vs. 51 g kg^{-1}) when pastures were stocked with low stocking rate (4 yearling steers ha^{-1}), and resulted in greater ADG (0.5 vs. 0.3 kg d^{-1}). In addition, green leaves had almost four times the CP values than stems, 7 to 8 vs. 2 g kg^{-1} in both cultivars. Although limpograss can maintain greater levels of IVDOM concentrations than other warm-season grasses at late maturity, the CP levels are usually less than 70 g kg^{-1} (Quesenberry and Ocumpaugh, 1980), which may limit animal performance. Several studies reported low CP values and animal performances with acceptable levels of IVDOM, 550 g kg^{-1} (Sollenberger et al., 1987, Sollenberger et al., 1988, Rusland et al., 1988, Sollenberger et al., 1989, Holderbaum et al. 1991, Pitman et al., 1994, Lima et al., 1999, Newman et al., 2002).

In order to address the potential protein deficiency in animals grazing limpograss pastures, Sollenberger et al. (1987) tested overseeding aeschynomene (*Aeschynomene americana* L.) on limpograss pastures to increase forage CP concentration. Overseeding with aeschynomene was effective in increasing CP concentration of the consumed forage from 40 to 70 g kg^{-1}. Rusland et al. (1988) measured animal performance on limpograss pastures overseeded with aeschynomene (LA) and fertilized with nitrogen (LN) during three years. Animals grazing LA had on average 80% greater ADG than animals grazing LN. Aeschynomene hand-plucked samples had 250 g kg^{-1} of CP, and 720 g kg^{-1} of IVDOM, whereas limpograss hand plucked samples from LN pastures had greater CP compared to limpograss samples from LA. Total diet consumed by animals had greater nutritive value for animals grazing LA leading to an increase in animal performance. In addition carrying capacity was greater for LN pastures than for LA (2200 vs. 1700 kg live weight ha^{-1} per day). The authors also concluded that N fertilization can be used to increase nutritive value in limpograss pastures.

Holderbaum et al. (1992) evaluated rotationally stocked limpograss pastures with 35 d of resting and 7 d of grazing period. Pre-grazed forage was harvested from 5 cm above the soil level and was divided similarly in two parts, upper and lower. The authors reported a greater leaf/stem ratio for the upper layer compared to the lower layer, values from three to six times greater but varying through the summer. Herbage mass was greater in the lower layer compared to the upper layer with approximately 50% difference between layers.

Newman et al. (2003) evaluated the effect of different canopy heights on bulk density and plant-part proportion of continuously stocked limpograss pastures. Canopy heights were 20, 40, and 60 cm and plants were separated into three strata, top 5 cm, upper 25% by height, and the remaining 50% of the canopy height. The authors reported a decrease in the bulk density, from 137 to 63 kg ha^{-1} cm^{-1} as stubble height increased from 20 to 60 cm. The upper layer had the greatest percentage of leaves (mean = 19%) followed by the remaining 50% layer (mean = 11%). Nutritive value varied among layers. Crude protein concentration of leaf (from 129 to 123 g kg^{-1}) and stem (from 50 to 40 g kg^{-1}) was greater for upper than lower layers, respectively. There was a linear decrease in leaf IVDOM from approximately 650 to 600 g kg^{-1} as stubble height increased from 20 to 60 cm and the lower layer had inferior IVDOM compared to upper and 5-cm layer, approximately 630 and 600 g kg^{-1}, respectively. The variation in CP was more prominent than in IVDOM for leaf and stem, and the 40-cm stubble height was recommended by the authors due to the greater opportunity for leaf selection and greater nutritive value.

According to Moore et al. (1999), ruminants consuming forage with IVDOM:CP ratio greater than 7 may respond positively to protein supplementation. Limpograss plant parts vary widely in their nutritive value. Limpograss leaves usually have IVDOM:CP ratio below 7; however, the stems tend to have greater IVDOM:CP ratio (Pittman et al., 1994). Crude protein supplementation is typically required to overcome the CP deficiency of beef cattle grazing warm-season grasses. Holderbaum et al. (1991) supplemented steers with two levels of corn (*Zea mays* L.)-urea supplement with low (21%) and high (50%) CP concentrations and compared animal performance to non-supplemented (NS) steers grazing limpograss pastures overseeded with aeschynomene (LA). A rotational stocking management of 7 d grazing and 35 d resting period was used. Pastures were grazed to a 20-cm stubble height using a variable stocking rate. Blood urea nitrogen (BUN) was used to monitor the N status of the animals. The steers grazing overseeded pastures or receiving high and low CP supplements had similar BUN, 11.0, 11.4, and 8.2 mg dL^{-1}, respectively. Those values were greater than the NS treatment (6.0 mg dL^{-1}). Steers receiving the supplement treatments or grazing overseeded pastures had greater ADG (0.60 kg^{-1}) than non-supplemented animals (0.30 kg d^{-1}). In addition, the authors reported the relationship between digestible organic matter (DOM) and CP was 8.7 for limpograss pastures alone, suggesting the benefits of protein supplementation when the relationship is greater than 7 to 8 (Moore et al., 1999).

Lima et al. (1999) evaluated the effects of N fertilization levels (50 and 150 kg ha^{-1}) and supplementation with 0.27 kg d^{-1} of rumen-degradable protein (RDP) and two levels of rumen-undegradable protein (RUP), 0.05 and 0.140 kg d^{-1}. Heifers supplemented with a greater amount of RUP had superior gain compared to the RDP treatment (0.52 vs. 0.40 kg d^{-1}) and both supplemented treatments had greater gains than unsupplemented (0.21 kg d^{-1}). Supplementation had no effect on ADG when 150 kg ha^{-1} of N was applied and increasing N levels from 50 to 150 kg ha^{-1} increased ADG on unsupplemented animals from 0.06 to 0.36 kg d^{-1}. Hand plucked samples from pastures fertilized with 150 kg N ha^{-1} showed greater CP concentration than 50 kg N ha^{-1}, 56 vs. 73 g kg^{-1}. Limpograss pastures fertilized with greater N had DOM:CP of ~7.4, a level at which protein supplementation is unlikely to be effective (Moore et al., 1999). Conversely, lower levels of N fertilization resulted in DOM:CP of 9.1 and protein supplementation increased animal performance. Newman et al. (2002) reported an increase in animal performance of supplemented animals with corn plus urea over nonsupplemented animals when animals grazed limpograss to 20 and 60 cm stubble height, primarily due to decreased RDP of the forage.

Limpograss is an important forage for South Florida due to tolerance to poorly drained soils, acceptable digestibility after extended regrowth interval, and greater production than other warm-season grasses during the winter. Despite of reasonable HM accumulation, CP protein may be limiting and protein supplementation may increase animal performance.

Stockpiling

Conserved or stockpiled forage are alternatives to supply forage for ruminants during the periods of forage shortage, usually late autumn and winter (Ruelke and

Quesenberry, 1983). According to Mays and Washko, (1960), stockpiling is a practice that allows forage to grow for a certain period of time for future utilization. Stockpiled forage can be used to maintain pregnancy and body condition score (BCS) in beef cows during the winter at low cost (Hitz and Russel, 1998).

A distinct characteristic of limpograss is the slower decline in digestibility with advancing maturity during the growing season when compared with other warm-season grass species (Schank et al., 1973). In addition, limpograss is a feasible option as winter forage because it can produce approximately 35% of its annual herbage accumulation during the winter in Florida (Brown and Kalmbacher, 1998). In a 2-yr study in North-Central Florida, Quesenberry and Ocumpaugh (1980) compared stockpiled Bigalta, Redalta and Greenalta. Pastures were staged at three different dates in the first year, early and late July and late August, and harvested from September to March. There was no difference in dry matter yield between the two July staging dates, which were higher than staging in late August. Redalta had the greatest herbage accumulation in both years (11.5 and 6.8 Mg ha^{-1} for Year 1 and 2, respectively). In addition, there was no difference in nutritive value (CP and digestibility) between staging dates. Bigalta had the lowest decline in digestibility (from 700 to 450 g kg^{-1}) from August to March, compared with a 50% decline for Greenalta and Redalta.

Ruelke and Quesenberry (1983) evaluated yield and nutritive value of stockpiled Floralta limpograss. Pastures were staged and fertilized with 75 kg N ha^{-1} in August and harvested through February at 2-wk intervals. Herbage mass reached ~8 Mg ha^{-1} in late September and was similar from late September to December (~10 Mg ha^{-1}). Crude protein was at a maximum in the middle of September (110 g kg^{-1}) and decreased to below 50 g kg^{-1} in December. After the first frost, the CP concentrations of limpograss decreased to 40 g kg^{-1}.

Davis et al. (1987) imposed eight levels of fertilization (0 to 400 kg N ha^{-1}) on Bigalta limpograss staged in early October; monthly samples were taken from December to April and analyzed for nutritive value. There was no effect on neutral detergent fiber (NDF) and acid detergent fiber (ADF) between fertilization rates; however, CP and IVDMD increased when N fertilization was greater than 68 kg ha^{-1}. In addition, there was an increase in yield from 0.55 to 4.35 Mg ha^{-1} with N fertilization levels from 0 to 135 kg N ha^{-1}. Kretschmer et al. (1996) evaluated different autumn application dates (early and late autumn) and N levels (0, 50 and 150 kg ha^{-1}) on stockpiled Bigalta and reported no difference in dry matter yield, IVDOM, and TDN between all combinations of dates and N fertilization levels. However CP was greater when late fertilization was used.

Kalmbacher et al. (1998) evaluated the effects of fertilization levels on stockpiled limpograss. Pastures were fertilized with fixed 50 N ha^{-1} level and different doses of phosphorus and potassium. Fertilization occurred at different times of the year from June to November but not in July, and forage was sampled from September to December generating stockpiling periods ranging from 30 to 105 d. There was no difference in limpograss yield among P and K fertilization treatments, but the fertilized treatments had greater yield (13.0 Mg ha^{-1}) than the unfertilized control (9.9 Mg ha^{-1}). In addition CP and IVDOM concentrations increased with N fertilization levels. Vendramini and Arthington (2010) reported that heifers grazing stockpiled limpograss had increasing ADG (0.14, 0.44, and 0.64 kg d^{-1}) when receiving increasing levels of cottonseed (*Gossypium* spp.) meal (CSM) (0, 1.1, and 2.2 kg $head^{-1}$ d^{-1}), respectively.

Producers rely on different management strategies to overcome the decreased production of warm-season grasses during the winter. Stockpiling forage may be an economically attractive management practice to supply forage to beef cattle during the winter in South Florida. However, supplementation may be necessary to meet the animal requirements due to the usually limited nutritive value of stockpiled warm-season grasses.

Supplementation on Forage-Based Systems

Most of the cow-calf production in Florida occurs in grazing system using warm-season grasses; therefore, seasonal herbage accumulation and decreased nutritive value may limit animal production during some months of the year (Moore et al., 1991). Well-managed warm-season grasses may meet the nutritional requirements of the cow herd during spring, summer, and early fall, however a supplementation program is required to support the nutritional status of the herd during the periods of shortage of forage (Vendramini and Arthington, 2010). Moore et al. (1991) summarized the nutritive value of forages commonly used in Florida and reported that the majority of the samples have CP concentrations between 50 to 70 g kg^{-1} and total digestible nutrients (TDN) from 480 to 510 g kg^{-1}. According to the NRC (1984), these values do not meet the requirement of a lactating beef cow (110 g CP kg^{-1} and 620 g TDN kg^{-1}).

When energy and protein requirements increase due to lactation, pregnancy, and growth, part of the forage component of the diet may need to be replaced by concentrates (Fontaneli, 1999). Concentrates generally are more digestible than forages and have greater fermentation rates. According to Stockdale et al. (1987), several factors may affect the response to supplementation, including forage quantity and quality, and the amount and composition of the concentrate fed. A database developed by Moore et al. (1991) from a large number of publications involving CP supplementation of temperate and tropical grasses and crop residues revealed that cattle consuming forages with TDN:CP ratio of 7.0 likely have positive responses to CP supplementation. Protein and energy are the nutrients required in greater quantities by ruminants; therefore, protein and energy supplementation programs are the most explored during the periods of decreased forage supply in beef cattle production systems.

Protein and Energy Supplementation

Energy and protein are the nutrients required in greater amounts by grazing cattle, therefore, those are the main components supplemented to grazing livestock. There are usually interactions between supplement and forage, also known as associative effects, which may decrease or increase forage digestibility and intake (Moore et al., 1999). Such interactions occur by changes in passage and digestion rate of the forage by the supplement (Ellis, 1978) which alters forage dry matter intake (DMI) (McCollum and Galyean, 1985).

Protein Supplementation

Protein is a compound that yields N in an amino form and contains one or more chains of aminoacids, in addition to C, H, O, and N plus S. In feedstuffs for livestock, CP is generally expressed as the N concentration multiplied by 6.25. In ruminant nutrition, CP can be fractionated into three different components, RDP which is converted into microbial protein, RUP that is degraded in the gastrointestinal tract, and lastly undegradable protein which is excreted in feces (NRC, 2001). Rumen-degradable protein is divided in non-protein nitrogen and true protein which are the sources of nitrogen for rumen microbial population (Owens and Zinn, 1998).

Rumen-Degradable Protein

Rumen-degradable protein is the protein fraction that is degraded in the rumen by the microbial population and produces microbial protein and amino acids. The proportion of the protein ingested by ruminants that can be degraded in the rumen ranges from 20 to 100% (Owens and Zinn, 1998). Rumen-degradable protein is used to improve microbial protein production in the rumen. Microbial protein is a high quality protein that is highly digestible in the small intestine. The usual amino acid profile expressed as a percent of total CP in the ruminal microbial protein are: histidine (2.2%), isoleucine (7.3%), leucine (9.4%), phenylalanine (6.8%), threonine (6.4%), tryptophan (6.8%), valine (7.2%), methionine (2.6%) and lysine (11.3%), the last two aminoacids are known as the first limiting amino acids in the ruminant diet (Van Soest, 1994). According to NRC (2001) feedstuffs have lower values of essential amino acids than microbial protein, and amino acids from microbial protein have greater use efficiency due to balance, consistence of the aminoacid profile, and extensive degradation (Owens and Zinn, 1988).

Animals grazing low nutritive value forage are usually deficient in RDP, which is the first limiting factor for forage digestibility in the rumen (Köster et al., 1996) due to limited microbial activity. Rumen-degradable protein increases forage intake and digestibility, improving microbial synthesis, and improving performance of animals grazing low quality forage (Guthrie and Wagner, 1988; McCollum and Horn, 1990; Mathis et al., 1999).There is a positive relationship between RDP and rumen ammonia (McCollum and Galyean, 1985; Mathis et al., 2000) to levels above the minimum required 5 mg dL^{-1} (Satter and Slyter, 1974). Köster et al., (1996) reported that supplementation of 4 g of RDP kg^{-1} $BW^{.75}$ increased the total tract digestibility of NDF, digestibility of organic matter, which leaded to an increase in forage intake on cows consuming tallgrass-prairie forage.

Guthrie and Wagner (1988) worked with steers and heifers receiving low nutritive value prairie hay (52 g kg DM^{-1} CP), which consisted mainly of little bluestem (*Schizycharium scoparius* (Michx.) Nash]), big bluestem (*Andropogon gerardii* Vitman), indiangrass [*Sorgbastrum nutans* (L.) Nash] and switchgrass (*Panicum virgatum* L.), and supplemented with different levels of CP, low level (0.36 kg d^{-1} of 320 g kg^{-1} CP), high level (0.67 kg d^{-1} of 340 g kg^{-1} CP), grain based supplement (1.41 kg d^{-1} of 130 g kg^{-1} CP), or control (no supplement). The low CP level and grain supplements provided the same amount of CP, which was half of the high level of CP. There were greater dry matter intake, digestibility, and faster passage rates for animals supplemented with high CP supplement level than the other treatments. Animals receiving low CP supplementation levels and grain-based supplement had similar dry matter intake, which was greater than the dry matter intake of animals that did not receive concentrate supplementation.

Mathis et al. (1999) evaluated the performance of beef cows grazing low quality tall prairie (53 g kg^{-1} CP, 490 g kg^{-1} RDP) forage and consuming increasing soybean [*Glycine max* (L.) Merr] meal levels from 0.08 to 0.48 % body weight (BW) daily. Soybean meal supplementation with 0.30% BW d^{-1} improved performance of cows grazing low-quality pastures. Wickersham et al. (2008) reported a linear increase in total organic matter and NDF digestibility increasing organic matter intake on crossbred steers receiving tallgrass-prairie hay (big bluestem, little bluestem and indiangrass) as RDP intake increased from 0 to 177 mg N kg^{-1} BW . In general, RDP increases dry matter intake as a consequence of the increase in passage rate and forage digestion (McCollum and Galyean, 1985). In addition, Wickersham et al. (2008) stated that RDP supplementation increases N recycling in the rumen providing from 25 to 33% of N utilized by ruminal microbes and retained in the rumen, which improved forage utilization by providing N for microbial protein synthesis.

Non-Protein Nitrogen

The term non-protein nitrogen (NPN) is used in ruminant nutrition to describe feedstuffs that are not protein but can be converted into microbial protein by ruminal microbes through incorporation of the ammonia released by the enzymatic breakdown of NPN (Hammond, 1992). Usually animal performance increases when NPN is fed to low nutritive value forage based diet moreover animals can live and reproduce when NPN is the only source of nitrogen in the diet (Owens and Zinn, 1998). The most common source of NPN is urea. Urea has 450 g N kg^{-1} and it is 100% soluble with a digestion rate of 400%/hr (NRC, 2000). Urea has been utilized in ruminant diets for more than 100 years (Kertz, 2010). Urea is often used to decrease the cost of protein supplementation and can substitute up to 33% of the degradable protein intake in high protein supplement without affecting cow-calf performance (Köster et al., 2002); however, it is not recommended to exceed 1% of the total dry matter intake in the concentrate, or 20% of the total dietary CP (Kertz, 2010).

Urea is rapidly dissolved and hydrolyzed to ammonia in the rumen and utilized by microorganisms to convert ammonia into microbial protein. Excess ammonium in the rumen can increase rumen pH, increase ammonia absorption by the rumen epithelial, and may reach toxic levels in the blood (Essig et al., 1988). Urea is a feasible CP supplement that can be added to liquid molasses to supplement grazing animals (Tillman et al., 1951; Brown et al., 1987). Holderbaum et al. (1991) reported an increase in ADG of steers grazing limpograss pastures fed corn-urea supplement compared to non-supplemented steers, 0.53 vs. 0.29 kg d^{-1}. Brown and Adjei (2001) tested the inclusion of urea and/or hydrolyzed poultry feather meal in molasses supplement of yearling steers grazing limpograss pastures. Supplements were isonitrogenous and with the same amount of RDP and RUP. The authors reported improved performance of supplemented steers in one out of three years of the experiment, but there was no difference between supplement types.

In several experiments, Köster et al. (2002) tested different levels of urea in the supplement on forage intake, digestion, and animal performance of cows consuming tallgrass-prairie or forage sorghum (*Sorghum bicolor* L.). Levels of urea were 0, 20, 40, and 60% of RDP and 0, 15, 30, and 45 % of the supplemental RDP. There was no difference in total OM and forage intake and OM and NDF digestibility of tallgrass-prairie hay (CP = 24.2 g kg^{-1}). However, there was a linear increase in rumen ammonia as urea concentration increased. There was no effect of urea concentrations on performance of cows and calves or on body condition score of the cows grazing dormant tallgrass-prairie pastures. Cows fed forage sorghum hay in the feedlot for two months and moved to tallgrass-prairie pastures had no difference in cumulative body weight change and body condition score and there was no difference in calf performance; however, there were linear decreases in body weight change as urea concentration increased. Cows grazing dormant tallgrass-prairie decreased body weight and body condition score during calving and breeding season in all treatments but not during weaning season. In addition, calf performance was not affected on any of the experiments.

Currier et al. (2004) tested the effect of NPN source on performance of cows consuming low nutritive value hard fescue (*Festuca trachyphylla* Hack. Krajina) straw (CP = 43 g d^{-1}) on drylot. The NPN sources were urea and biuret to provide 90% of RDP requirement. Cows receiving protein supplementation had greater body weight change than the control treatment during the pre-calving season (33 vs. 10 kg). Additionally, cows lost less weight during post-calving season (-14 vs. -40 kg). Kim et al. (2007) compared two sources of protein, soybean meal and urea, mixed with a dried citrus pulp-based supplement on performance and dry matter intake on steers consuming bahiagrass hay (CP = 72 g kg^{-1}). The authors reported an increase in hay consumption for the urea treatment compared to the control, while the greatest hay intake was for steers consuming soybean meal. In addition ADG was greater for steers consuming soybean meal than for urea which was greater than control. Due to the usual limited CP concentration of warm-season grasses, RDP is an important nutritional entity to provide N to the microbial population and potentially increase forage digestibility and intake. When RDP requirements are met, RUP supplementation may improve animal performance.

Rumen-Undegradable Protein

Rumen-undegradable protein is defined as the fraction of the protein that is not digested in the rumen by microorganisms but escapes rumen digestion and is digested in the gastrointestinal tract (GIT), starting in the abomasum and finishing in the large intestine. The digestion is enzymatic until reaches large intestine (Owens and Zinn, 1988). According to Van Soest (1994), the sum of microbial protein plus the RUP that escapes rumen digestion is the amount of protein that is digested in the GIT. The author also stated that protein not digested in the rumen has better utilization efficiency if essential amino acids are present. The amount of protein that escapes ruminal digestion is affected by feed processing, dry matter intake, rate of passage, and digestion rate (Van Soest, 1994).

Vendramini et al. (2008) observed that 700 g CP kg^{-1} of total CP of 'Tifton 85' (*Cynodon* spp.) disappeared in the rumen. However, growing animals may not meet the metabolizable protein requirements from warm-season grasses only and RUP supplementation may be needed (Klopfenstein et al., 1996). Supplementing animals with RUP has the objective of increasing amino acid flow to gastrointestinal tract, especially the small intestine (Legleiter et al., 2005).

Anderson et al. (1988) fed yearling steers a diet based of smooth bromegrass (*Bromus inermis* Leyss) (CP = 124 g kg^{-1}) with three levels of RUP supplement, 0.11, 0.23, and 0.34 kg d^{-1} of a blood meal and corn gluten meal supplement. The authors observed linear and quadratic effects of supplement levels on animal performance (from 0.91 to 1.01 kg d^{-1}) as supplementation levels increased (from 0.11 to 0.34 kg d^{-1}). Lima et al. (1999) supplemented beef heifers grazing limpograss pastures with RDP and RUP plus RDP in combination with two pasture N fertilization levels (50 vs. 150 kg N ha^{-1}). The authors reported an increase in animal performance from 0.06 to 0.41 to 0.56 kg d^{-1} for control, RDP alone, and RDP plus RUP, respectively, when pastures were fertilized with 50 kg N ha^{-1}. However the response was less when pastures were fertilized with 150 kg N ha^{-1}, 0.36, 0.39 and 0.47 for control, RDP, and RDP plus RUP, respectively. The forage CP increased from 56 to 73 g kg^{-1} as fertilization increased from 50 to 150 kg N ha^{-1}. Low levels of forage CP plus RDP and RUP supplement increased animal performance; however when forage CP was higher, as with a greater rate of N fertilizer, there was no response to supplementation, suggesting that animal protein requirement was met by RUP supplementation or by increasing N fertilization.

Wickersham et al. (2008) reported a decrease in forage digestibility but an increase in forage dry matter intake and N when steers were infused in the abomasum with increasing levels of casein (0, 62, 124, and 186 mg N kg BW^{-1}). The authors also found an increase in N recycling as infusion levels increased providing N for microbial forage digestion.

Vendramini et al. (2012) tested the effect of increasing levels of RUP supplementation on performance of calves grazing stargrass pastures. The authors reported no difference in performance (ADG = 0.56 kg d^{-1}) of early weaned steers grazing stargrass (CP = 171 g kg^{-1}, RDP = 550 g kg^{-1} and RUP = 450 g kg^{-1} of total CP) pastures and supplemented with three levels of RUP (0.350, 0.475, and 0.600 kg d^{-1}) in Florida. In addition, there was no effect of supplementation on forage and total dry matter intake; however, apparent forage dry matter digestibility was negatively affected by RUP supplementation. The authors stated that supplementation with RUP did not affect performance because CP of the forage was above animal requirements. Bandyk et al. (2001) stated that animal performance responses to RUP are expected after the RDP requirements are met.

Energy Supplementation

During the seasonal periods of decreased forage production or nutritive value, forage only may not meet the energy requirement for maintenance, gestation, and milk production of grazing beef cows (NRC, 2001). Consequently supplemental feed is required to meet cow requirements and maintain animal production. Differently from protein supplementation, energy supplements tend to reduce forage intake when supplemental feed was offered at greater rates than 0.7% of BW (Moore et al., 1999). The decrease in forage intake has been correlated with decreased ruminal pH, which reduces activity of the cellulolytic enzymes (Martin et al., 2001) and fiber digestion (Mould et al., 1983). Moreover microbial protein is also affected by lowering the ruminal pH (NRC, 2001).

In an energy supplementation review, Caton and Dhuyvetter (1997) reported that the decrease in forage intake is correlated with substitution of forage by energy supplement, however, when energy supplement is offered at low levels, forage dry matter intake and digestibility may be improved. According to Poppi and McLennan (1995), energy supplements for grazing animals are fiber, sugar, and starch. The most common energy supplement in South of Florida is sugarcane (*Saccharum officinarum* L.) molasses due to low cost, availability of the product, and convenience of less frequent feeding. One of the most used supplementation energy source used by beef cattle producers in Florida is molasses.

Molasses. Sugarcane molasses is any feed containing more than 43% sugar and a minimum of 79.5° Brix (Curtin, 1983). Molasses had been used in animal supplementation for more than 50 yr and the most used molasses product in Florida is the blackstrap molasses (Pate and Kunkle, 1989). Molasses is a source of readily available carbohydrate for ruminants. Molasses may improve diet digestibility; however, it may decrease forage and fiber digestibility. The amount of molasses and protein in the final diet drives the magnitude of the decrease (Pate, 1983). Molasses has low levels of protein, thus adding protein sources to molasses is necessary to have a better energy:protein balance in the supplement. According to Pate and Kunkle (1989), Florida molasses has higher levels of protein compared to molasses from other regions.

In a review of molasses utilization in beef cattle nutrition, Pate (1983) summarized several studies comparing molasses with other sources of supplementation to beef cattle. The authors stated that molasses supplementation had similar outcomes to corn grain supplementation as an energy source, when plant protein sources were added to the mixture. However, when urea was used as source of CP supplementation added to molasses, animal performance was negatively affected when compared to corn grain. In a 4-yr study, Pate et al. (1990) compared the inclusion of CP supplements (urea and cottonseed meal) fed to cow-calf pairs grazing dormant bahiagrass pastures receiving stargrass hay and molasses supplements during the winter in Florida. There were no differences in cow ADG and body condition score, although an increase in pregnancy rate was found for cows that received molasses-cottonseed meal-urea supplement. In addition, no differences were found in performance of the calves. Mature cows (3-yr-old) were heavier when supplemented with molasses-cottonseed meal-urea supplement than molasses.

Kalmbacher et al. (1995) reported an increase in apparent OM digestibility of bluestem (*Schizachyrium scoparium* var. stoloniferum) fed to mature cows supplemented with molasses with or without urea or soybean meal. The molasses-urea-soybean meal treatment decreased apparent NDF, ADF, and hemicellulose digestibility. Moreover, molasses supplement plus urea was as efficient as soybean meal in maintaining cow body condition score and calf weaning weight. Vendramini and Arthington (2010) studied the effect of soybean hulls added to molasses supplement on first calf heifers grazing bahiagrass. Heifers received three levels of soybean hulls (0, 1.6, and 3.2 kg DM heifer^{-1}d^{-1}) plus 1.6 kg of liquid molasses and 0.8 kg of cottonseed meal. The authors reported a linear increase in ADG, body condition score change, and calf ADG with increasing soybean hull supplementation levels. In addition, in a second experiment with heifers in a drylot, dry matter intake of stargrass hay decreased quadratically as the level of soybean hull supplementation increased.

In addition to the composition of the supplement, frequency of supplementation may be an important factor on efficiency and profitability of supplementation programs for grazing animals (Kunkle et al., 1999). Wettemann and Lusby (1994) tested two different supplementation frequencies (3 and 6 d wk^{-1}) on performance of cows grazing dormant bermudagrass and receiving a 400 g kg^{-1} CP supplement. Authors reported no difference in weight loss, body condition score, and pregnancy rate by cows consuming supplement 3 or 6 d wk^{-1}. Huston et al. (1999) stated that no difference in body weight change and body condition score on cows grazing warm-season grasses supplemented daily, 3x, or 1x wk^{-1} with a protein supplement (410 g kg^{-1} CP) . In addition, there was no difference in forage intake between supplementation frequencies. In a review of supplementation studies, Kunkle et al. (2002) reported that cattle receiving protein supplement fed infrequently had similar performance when compared to animals receiving daily supplementation.

Bohnert et al. (2002) reported no difference in cow body weight change, pre-calving (14 d of calving) - and post-calving (within 24 h of calving) body condition score change, and calf birth date between animals fed RDP and RUP supplement daily, 2x, or 6x wk^{-1}. Farmer et al. (2004) tested the effect of frequency of feeding and levels of protein supplementation on cow performance grazing tallgrass and reported similar performance for cows. The authors reported an improvement in OM and NDF digestibility for animals fed daily compared to 3x wk^{-1}; however, no difference in forage, supplement and digestible OM intake were detected. Additionally no differences in cow and calf ADG and cow body condition score were detected. Schauer et al. (2005) fed grazing cows either daily or 1x wk^{-1} with cottonseed meal (430 g kg^{-1} CP) and reported no difference in ADG and no effect on grazing behavior between supplementation frequencies. Cows in both supplement treatments had greater performance than non-supplemented animals.

Drewnoski et al. (2012) supplemented steers daily, 2x, or 3x $wk^{-1}$with a blend of corn gluten and soybean hulls and tall fescue (*Festuca arundinacea* Shreb.) hay. The authors reported a decrease in hay and total dry matter intake as frequency of supplementation decreased. There was a positive effect of supplementation on ADG compared to the control; nonetheless, no difference in animals performance was reported between supplementation frequencies. Further, feed efficiency improved as frequency of supplementation decreased.

Molasses is a supplement with self-limiting intake and allow the convenience of infrequent feeding events, which is a favorable characteristic in supplementation of beef cattle grazing systems.

Cooke et al. (2007) compared molasses-based supplement fed 3x wk^{-1} with citrus pulp-based supplement fed 3x wk^{-1} or daily to beef steers. The authors reported greater performance of steers fed with citrus pulp supplement. No differences in animal performance between supplementation frequencies were observed. Cooke et al. (2008) studied the effect of two supplementation frequencies (daily or 3x wk^{-1}) of an energy supplement based on fibrous byproducts [wheat (*Triticum* spp.) middlings and soybean hulls] and molasses on performance of heifers grazing bahiagrass pastures. The authors reported greater ADG for heifers fed daily compared to infrequent supplementation (0.41 vs. 0.33 kg d^{-1}) and heifers fed daily reached puberty earlier and had greater pregnancy rate.

It is imperative to design a supplementation programs to achieve desirable performance and increase the efficiency of cow-calf production systems. Molasses has been a feasible supplement to beef cows in Florida due to the convenience of infrequent feeding and availability of molasses base supplements in South Florida. In addition to provide supplements to the cows, supplementing the calves may be an option to improve weaning weights and increase the profitability of cow-calf operations.

Creep Feeding

Creep feeding is a supplementation strategy used to provide additional nutrients to nursing calves. Creep feeding can be used to overcome limited herbage allowance, improve calf uniformity, supply extra nutrients for calves, provide adaptation to concentrate diets before weaning, and increasing weaning weight (Bray, 1934; Powell, 1936; Stricker et al. 1979; Martin et al., 1981; Lusby and Wettemann, 1986; Faulkner et al. 1994, Moriel and Arthington, 2013).

Ad libitum creep feeding has been correlated with increased calf performance; however, the concentrate:gain ratio is usually inefficient, with 5-15 kg feed required per additional kg of body weight gain (Stricker et al., 1979). Such low feed efficiency can be related to decreased forage intake, likely due to decreased ruminal and total tract NDF digestibility when calves are fed with grain in excess of 25% of their diet (Mould et al., 1983; Cremin et al., 1990). In addition, several authors have reported that calves can substitute forage and/or milk for the concentrate (Wyatt, 1977, Cremin et al., 1991, Tarr et al., 1994, Faulkner et al., 1994). Milk is a high quality feed that can potentially meet the amino acid requirement of calves, thus a decrease in milk intake would decrease intake of amino acids (Loy et al., 2002). Energy supplements, commonly used in creep-feeding diets, may lead to more starch digestion, increasing volatile fatty acid (VFA) production, and lowering ruminal pH (Tarr et al., 1994).

Bray (1934) compared non-supplemented calves with two creep feeding supplementation periods, 70 and 133 d before weaning. Creep feeding supplement was corn, rice bran (*Oryza sativa* L.), and cottonseed meal mix. Average daily consumption of feed was 1.5 kg of both creep-feeding treatments. Authors concluded that creep-feeding calves for 133 d resulted in a gain of 40%, and for 70 d a gain of 28.4% more body weight than non-supplemented calves. Moreover, there was a net increase in value for creep-fed calves. Creep-fed calves had 0.2 kg d^{-1} greater ADG than non-creep fed calves (Bray, 1934).

Powell (1935) tested three levels of creep-feeding supplement containing 150, 172, and 190 g kg^{-1} of CP for 187 d and compared these treatments to non-supplemented calves. The average supplement intake was 0.8, 1.0, and 1.4 kg d^{-1} per calf, respectively, for the protein levels. The author reported an improvement in ADG for 20% of creep-fed calves; however, no differences due to level of protein were found. Powell (1935) compared the ADG of non-supplemented calves with calves supplemented with 126, 126, and 131 g kg^{-1} of CP supplement consuming 1.4, 0.88, and 1.22 kg d^{-1} during 165 d. Creep-fed calves gained on average 15% more weight and were more uniform than non-supplemented calves.

Sticker et al. (1979) reported a 32 kg weaning weight increase in creep-fed calves supplemented with 1.9 kg d^{-1} of an energy supplement compared to control calves; however, the feed efficiency was ~ 10 kg of supplement per extra kg of weight gain. In this study, creep-feeding was not an economically viable practice due to low feed:gain efficiency. Martin et al. (1981) reported in a creep-feeding literature review that creep-fed calves with *ad libitum* energy supplement had superior performance (additional 15 kg BW) than calves that were non-supplemented. Prichard et al. (1989) compared two creep-feeding periods (154 vs. 64 d) using a high-energy supplement to a non-supplemented group and reported greater ADG for creep-fed groups compared to control. The feed:gain efficiency was 5.3 kg of supplement per extra kg of gain, and no difference between creep-fed periods was reported. Similarly, Tarr et al. (1994) compared three creep-feeding supplementation periods (28, 56, and 84 d prior to weaning) on calves grazing endophyte-infected tall fescue. There was a linear increase in calf ADG as creep-feeding period increased, however, 56 d prior weaning showed the best feed efficiency. No effects of creep-feeding periods were observed on cow performance. There is sufficient evidence in the literature that creep-feeding calves using a grain-based energy supplement increases calf ADG, however, the economical feasibility is doubtful due to the decreased feed:gain efficiency.

Warm-season forages may have decreased CP and RDP concentrations (Minson, 1990), thus providing a limited amount of RDP may improve calf performance with greater feed:gain efficiency than unlimited creep-fed energy supplements. It is expected that protein supplementation would increase the dry matter intake and digestibility of warm-season forages with limiting CP concentration and increase the forage utilization by calves receiving protein supplementation (Wheeler et al., 2002).

Lusby et al. (1985) proposed a limit-fed protein supplementation (0.37 kg CSM d^{-1}) to nursing calves for 63 d in Year 1 and 76 d in Year 2. Creep-fed calves had 0.13 kg greater ADG than control calves with a feed efficiency of 2.5 kg of supplement per extra kg of gain. There was no effect on cow performance. In addition, authors stated that in order to have the greater feed:gain efficiency, there was an increase in forage intake and/or improvement in forage digestibility. Lusby and Wettemann (1986) supplemented calves (77 kg initial BW) with 0.45 kg soybean meal d^{-1} in creep feeding and compared to non-supplemented calves for five months. There was greater ADG in the creep-fed than control calves from December to March likely due to decline in milk production of the cows and increased forage intake of the calves. There was no difference in cow performance between treatments.

Cremin et al. (1990) compared limited intake of low and high protein supplements, or unlimited low protein supplement with a control group grazing cool-season forages. There was no difference in forage, organic matter (OM), NDF, ADF, and milk intake between limited protein supplement treatments. Calves receiving the unlimited low protein treatment consumed less forage and the total OM intake (forage plus supplement) was greater than the other treatments. Ruminal pH decreased as creep feeding levels increased, resulting in a decreased ruminal fiber digestibility. However, no differences were reported in NDF total tract digestibility between control and limited creep-fed treatments. The authors attributed the similar NDF digestibility to a longer ruminal retention, which allowed the forage to be digested at a lower rate.

Faulkner et al. (1994) compared calves that did not receive creep feeding supplementation (control) with creep-fed calves supplemented with two different sources of energy, corn or soyhulls, with unlimited or limited intake of endophyte-infected tall fescue. There was a quadratic increase in calf ADG from control (0.66 kg d^{-1}), limited (0.92 kg d^{-1}), and unlimited forage intake treatments (1.04 kg d^{-1}) and no difference between sources of supplement. However, calves consumed less soybean hulls than corn (1.53 vs. 1.77 kg d^{-1}) on unlimited forage intake treatments. Feed efficiency (feed:gain) was similar between treatments. In addition, there was a negative correlation between supplement consumption and forage intake, and corn decreased forage digestibility at greater magnitude than soybean hulls. The authors concluded that soybean hulls can substitute for corn as a creep supplement without affecting performance and fiber digestion.

Moriel and Arthington (2013) reported inconsistent benefits of limited-fed protein creep-feeding to calves 112 d prior to weaning. Calves were supplemented 3 x wk^{-1} at 0.23 kg $d^{-1}$of a loose meal protein supplement (CP = 210 g kg^{-1}, TDN = 750 g kg^{-1}).There was an increase in ADG from 0.88 to 0.95 kg for control and creep-fed calves, respectively. In a second experiment, calves were fed a cubed supplement (CP = 190 g kg^{-1} and TDN 711 g kg^{-1}) and there was no difference in calf performance between treatments. Although creep feeding is a management practice known for several years, it is not widely adopted to the low gain:feed efficiency. However, limited creep feeding is an approach with potential to be incorporated into cow-calf enterprises seeking to increase calf performance with greater gain:feed efficiency.

Bermudagrass

Hill et al. (2001) reported that bermudagrass is one of the most important grasses in southern USA. Bermudagrass covers around 15 million ha in the USA (Taliaferro et al., 2004). According to Hanna and Sollenberger (2007), bermudagrass is present in tropical and subtropical regions in all continents. Bermudagrass was introduced in the USA around the late 1600s, although breeding programs were not started until 1937 by Dr. Glenn Burton, United Stated Department of Agriculture – Agriculture Research Service (USDA-ARS), Tifton, GA. ‘Coastal’ bermudagrass was released in 1943, and was planted by several producers in the southeastern USA. Hill et al. (2001) reported that bermudagrass supports the beef and dairy industry grazing programs from spring until autumn, and some dairy farmers use it as primary forage in the total mixed diets to feed dry cows and replacement heifers. Redfearn and Nelson (2003) stated that bermudagrass is used as a perennial forage and can be used for grazing, hay, or haylage in the southern USA.

Bermudagrass is a warm-season perennial grass, propagated by rhizomes and stolons. It forms a dense mat above the soil, tolerates a range of soils and soil conditions, but it does require high soil nutrient levels to produce and persist (Vendramini, 2005; Liu, 2009). It has a deep root system that allows growth during dry periods, and its rhizomes provide protected bud sites for winter survival and spring regrowth (Pitman, 1991).

In 1993, the hybrid Tifton 85 bermudagrass was released and according to Burton et al. (1993), Tifton 85 produced greater herbage accumulation, is taller, has broader leaves, and is more digestible than Coastal and 'Tifton 68'. Tifton 85 herbage yield was 26% greater and herbage was 11% more digestible than Coastal bermudagrass (Hill et al., 1993). Mislevy and Martin (1998) compared Tifton 85 with 'Florakirk' bermudagrass and 'Florico' and 'Florona' stargrass (*Cynodon nlemfuensis* Vanderyst var. *nlemfuensis*). They reported a greater total DM yield during summer for Tifton 85 compared to the other grasses. Mandebvu et al. (1999) reported that Tifton 85 had greater dry matter (DM) yield (7.1%) and greater in vitro dry matter digestibility (IVDMD, 7.1%) than Coastal bermudagrass. Coastal had lower NDF and ADF levels than Tifton 85; however, Coastal had lesser IVDOM concentrations than Tifton 85 due to greater lignin and ether-linked ferulic acid concentration.

Although Tifton 85 is tolerant to drought and no stand losses occurred during dry periods (Hill et al., 2001), it is not tolerant of poorly drained soils (Newman et al., 2011). Seasonal flood events are commonly found in poorly drained soils in South Florida, where loss in Tifton 85 stand has been reported. Consequently, producers have cultivated Jiggs bermudagrass with the perception of greater tolerance to poorly drained soils.

Jiggs is a bermudagrass variety that was released by J.C. Riggs in Texas (Ocumpaugh and Stichler, 2000). The parental material and date of release are unknown. According to Vendramini (2008), Jiggs tolerates poorly drained soils and has thinner stems than other bermudagrasses, which is a desirable characteristic for hay production. In addition, Jiggs establishes faster than other bermudagrass cultivars (Bade, 2000). Mislevy et al. (2008) compared Jiggs and Tifton 85 in a grazing study using the mob stocking technique and reported greater DM yield for Jiggs than Tifton 85

(13.9 and 11.9 Mg ha^{-1}, respectively). The same authors did not find a difference in CP concentration but Tifton 85 had greater IVDOM concentration than Jiggs (638 vs. 561 g kg^{-1}). Similar results were reported by Vendramini et al. (2010) working with different warm-season grasses (elephantgrass, bahiagrass, stargrass, brachiariagrass, limpograss, and four cultivars of bermudagrass, Jiggs, 'Coastcross-2', Tifton-85, and Florakirk). Jiggs had lesser herbage accumulation (4.6 Mg ha^{-1}) than elephantgrass (13.0 Mg ha^{-1}) but greater than the others grasses. However, no differences were found in the CP concentrations among the forage species and cultivars, (~ 100 g kg^{-1}).

The clipping studies published in the literature has shown that Jiggs has favorable herbage accumulation and nutritive value when compared to other warm-season grasses in South Florida; therefore, Jiggs may have potential to be used in grazing systems.

Grazing Management and Animal Responses

Hill et al. (1993) compared the performance of steers grazing Tifton 78 and Tifton 85 for 3 yr. The authors reported no difference in ADG (0.66 kg d^{-1}); however, gain per area was greater for Tifton 85 than Tifton 78 (1160 vs. 790 kg ha^{-1}) and this was explained by greater number of steer grazing d ha^{-1} for Tifton 85 than Tifton 78 (1820 vs. 1320 d). In a 3-yr grazing study comparing DM production and animal performance on Tifton 85 and Florakirk bermudagrass, Pedreira et al. (1998) reported similar ADG (0.6 kg d^{-1}) between Tifton 85 and Florakirk; however, Tifton 85 supported greater stocking rates (6.0 vs. 4.0 heifers ha^{-1}) and gain per area (648 vs. 371 kg ha^{-1}). Corriher et al. (2007) reported greater ADG (0.94 vs. 0.79 kg d^{-1}) and weaning weights (253 vs. 240 kg) for calves grazing Tifton 85 than Coastal. Cows grazing Tifton 85 had greater milk protein than cows grazing Coastal. Burns and Fisher (2008) reported no difference in forage mass between ‘Tifton 44’ and Coastal pastures grazed at similar canopy heights of 6, 10, and 13 cm (2.36, 4.08; and 5.25 Mg ha^{-1}), although steers grazing Tifton 44 had greater ADG than steers grazing Coastal (0.58 vs. 0.51 kg d^{-1}). Increasing canopy height resulted in a linear increase in herbage mass (from 2.3 to 5.2 Mg ha^{-1}) and ADG in both cultivars (from 0.40 to 0.59 kg). Burns and Fisher (2010) reported ADG of 0.57 kg d^{-1} with stocking rate of 10 steers ha^{-1} on continuously stocked Coastal bermudagrass pastures.

Liu et al. (2011) compared different post-grazing stubble heights (8, 16, and 24 cm) and grazing cycles (14, 21, and 28 d) on Tifton 85 in a 3-yr study in Central Florida. The authors concluded that the greatest herbage accumulation rate occurred with an 8-cm stubble height and 28-d grazing cycle or with a taller stubble height of 24 cm and shorter grazing cycle of 14 d. In addition, the greatest nutritive value was achieved when Tifton 85 was grazed at 8-cm stubble height.

Radunz (2005) observed that thoroughbred pregnant mares (*Equus caballis*) preferred grazing Jiggs than Tifton 68 and Tifton 85 due to the larger amount of leaves. The mares spent more time grazing Jiggs (26%) followed by Tifton 85 (18%) and Tifton 68 (13%). In addition, no difference was found in DM production between those three grasses (3.8 Mg DM ha^{-1}). Nutritive value was superior for Jiggs and Tifton 68 than Tifton 85 (180, 193, and 149 g kg^{-1} CP and 624, 595, and 667 g kg^{-1} NDF, for Jiggs, Tifton 68, and Tifton 85, respectively).

Baker (2005) observed that Jiggs plots harvested at 7.6-cm stubble height had an average herbage accumulation of 7.9 Mg DM ha^{-1} yr^{-1} and CP concentration of 132 g kg^{-1} from 1996 to 2006 in Ardmore, OK. Dore (2006) compared three bermudagrasses (common, ‘Russel’ and Jiggs) and reported that Jiggs had greater herbage mass (1.2, 6.7, 8.6, 10.6, and 8.9 Mg DM ha^{-1}) with different days of growth (14, 28, 42, 56, and 70 d) respectively, although CP (208, 114, 80, 58, and 58 g kg^{-1}) and NDF (581, 638, 689, 679, and 706 g kg^{-1}) were similar among cultivars. Common bermudagrass had the least ADF (247, 284, 302, 29.6, and 294 g kg^{-1}), while Jiggs and Russel had similar ADF values (274, 344, 359, 350, and 365 g kg^{-1}).

Stocking Rate

Stocking rate is defined as the relationship between weight or number of animals per unit of area in a certain period of time (Allen et al., 2011). Among of all the variables in the grazing management, stocking rate is the most important because it is related to herbage mass, animal performance and profitability of grazing systems (Hull et al., 1965, Hernández Garay et al., 2004, Gunter et al., 2005). Pastures stocked at low stocking rate tend to increase animal selection for superior nutritive value material, due to a greater herbage mass and allowance, which has potential to increase animal performance. Conversely, greater stocking rate tends to increase animal production per area (Mott, 1960; Adjei et al., 1980; Rouquette et al., 1983; Brasby et al., 1988, Gunter et al., 2005; Inyang et al., 2010). Moreover, there is an upper limit in stocking rate when maximum gain per area can be achieved (Riewe, 1961) and each forage type and grazing system would have its own relationship between stocking rate and animal performance (Brasby et al., 1988).

Animal Performance and Forage Responses

Hull et al. (1965) compared three stocking rates (4.5, 9.0, and 13.5 steers ha^{-1}) on performance of steers grazing orchardgrass (*Dactylis glomerata* L.) and Ladino clover (*Trifolium repens* L.) previously fed with two levels of energy intake. The authors reported a decrease in animal performance as stocking rate increased for all steers. Average daily gain for steers previously receiving low energy supplementation was 0.76, 0.57, and 0.38 kg d^{-1} for 4.5, 9.0, and 13.5 steers ha^{-1}, respectively. Steers previously receiving medium energy supplementation gained 0.52, 0.38, 0.19 kg d^{-1} for 4.5, 9.0, and 13.5 steers ha^{-1}, respectively. In addition, there was linear decrease in dry matter intake as stocking rate increased from 8.2 to 5.7 kg DM d^{-1}. Herbage accumulation rate was greater for low and medium than for heavy stocking rate (80 vs. 68 DM ha^{-1} d^{-1}).

Adjei et al. (1980) tested three stocking rates on three stargrass cultivars UF-4' (*Cynodon nlemfuensis* Vanderyst var. *nlemfuensis*), 'UF-5' and 'McCaleb' (*Cynodon aethiopicus* Clayton and Harlan). The stocking rates were 7.5, 10, and 15 steers (240 kg LW ha^{-1}).There were different magnitude of responses to stocking rates by different cultivars; however, there was a linear decrease in ADG with increasing stocking rate for all cultivars (from 0.47 to 0.21 kg d^{-1}).

Rouquette et al. (1983) tested the effect of three stocking rates (2.0, 3.4, and 6.7 AU ha^{-1}, low, medium, and heavy, respectively) on performance of weanling calves grazing bermudagrass, 'Gulf" ryegrass (*Lolium multifolium* Lam), and "Yuchi' arrowleaf clover (*Trifolium vesiculosum* Savi). There was greater ADG for low and medium (average 1.11 kg d^{-1}) compared to heavy stocking rate (0.77 kg d^{-1}), and heavier calves were reported for low stocking rate (333 kg) at weaning compared to medium and heavy stocking rate (average 283 kg). In contrast, a linear increase in gain per area was reported (308, 478, 687 kg ha^{-1} for low, medium and heavy stocking rate, respectively). Guerrero et al. (1984) concluded that ADG was inversely related to stocking rate for five different bermudagrass forages, and although the amplitude of the difference varied among forage types, the linear decline was similar for all. In addition, there was a decline in herbage mass for all forage types as stocking rate increased. Conversely, digestibility increased as stocking rate increased.

Aiken et al. (1991) tested the effect of three stocking rates (2.0, 3.5, 5 steers ha^{-1} for Year 1 and 3.0, 5.3, 7.5 steers ha^{-1} for Year 2) on forage and animal responses. Steers (256 kg) grazed bahiagrass pastures overseeded with carpon desmodium [*Desmodium heterocaropon* (L.) DC.], aeschynomene, or phasey bean [*Macroptilium lathyroides* (L.) Urb.]. Results showed a linear decrease in herbage allowance and ADG as stocking rate increased and a positive relationship between stocking rate and gain per unit area in the first year of the study.

Hernández Garay et al. (2004) studied the effects of three stocking rate (2.5, 5.0, and 7.5 bulls ha^{-1}) on stargrass pastures and cattle performance. Authors reported a linear and quadratic effect on herbage accumulation on the first year and no differences in the second year as stocking rate increased. In addition there was a linear effect on herbage mass in both years of the study as stocking rate increased. Nutritive value increased linearly as stocking rate increased moreover there was a linear and quadratic effect on herbage allowance on both years. Average daily gain decreased quadratically as stocking rate increased in Year 1 (0.70, 0.53, and 0.26 kg d^{-1}) and Year 2 (0.65, 0.55, and 0.35 kg d^{-1}).

Gunter et al. (2005) tested the effects of N fertilization and stocking rate on performance of steer calves (231 kg) grazing dallisgrass (*Paspalum dilatatum* Poir.) and bermudagrass mixed pastures. There was a linear decrease in ADG (0.63, 0.61, 0.51

and 0.34 kg d^{-1} for stocking rates of 3.7, 6.2, 8.6, and 11.1 steer ha^{-1}, respectively) when pastures were fertilized with 112 kg N ha^{-1}; however, ADG was not affected when the pastures were fertilized with 224 or 336 kg N ha^{-1}. Inyang et al. (2010) tested the effect of three stocking rates on herbage characteristics and animal response of beef heifers grazing bahiagrass or 'Mulato II' (*Brachiaria* sp.). Authors reported a linear decrease in herbage mass (5.9 to 3.2 Mg ha^{-1}) and a quadratic increase in herbage accumulation rate (106 to 118 kg ha^{-1} d^{-1}) as stocking rate increased from 4 to 12 heifers ha^{-1}. A quadratic effect was also reported on herbage allowance (2.8, 1.2 and 0.6 kg DM kg^{-1} LW) and live weight gain (190, 353, and 218 kg ha^{-1}) for 4, 8, and 12 heifers ha^{-1}. On the other hand, there was a linear decrease in ADG from 0.28 to 0.01 kg d^{-1}. Stocking rate had a greater effect on animal performance than forage species.

There is limited information available in the literature about using Jiggs in grazing systems. Due to the importance of stocking rates on forage and animal production, there is a necessity to evaluate the effects of a range of socking rates on Jiggs forage characteristics and animal performance.

CHAPTER 3
THE EFFECTS OF DIFFERENT SOURCES OF RUMEN-DEGRADABLE PROTEIN (RDP) SUPPLEMENTATION ON PERFORMANCE OF COWS AND CALVES GRAZING STOCKPILED LIMPOGRASS PASTURES IN FLORIDA DURING THE WINTER

Overview of the Research Problem

Limpograss [*Hemarthria altissima* (Poir.) Stapf et C. E. Hubb.] can produce approximately 35% of annual herbage accumulation during the winter in Florida (Brown and Kalmbacher, 1998) and generally contains greater total digestible nutrients (TDN) concentration than other tropical grasses at advanced maturity (Sollenberger et al., 1988). Moore et al. (1981) utilized sheep (*Ovis aries*) in a feeding trial to estimate the digestibility and intake of bahiagrass (*Paspalum notatum* Flügge), bermudagrass [*Cynodon dactylon* (L.) Pers.], stargrass (*Cynodon nlenfuensis* Vanderyst), and limpograss at 4, 6, and 8 wk of regrowth interval. The digestibility of limpograss was the greatest at all regrowth intervals, resulting in greater forage intake. For these reasons, limpograss is a suitable warm-season grass species to be stockpiled in the autumn for subsequent grazing during the winter in South Florida.

Although limpograss usually has greater digestibility than most other tropical grasses at mature regrowth intervals, crude protein (CP) concentration decreases significantly (Sollenberger et al., 1988), reaching levels below the minimum requirement for maintenance of a non-lactating mature cow of ~80 g kg^{-1} (NRC, 1996). Therefore, CP supplementation is often required to maintain adequate nutritional status of the cow herd.

In Florida, as well as in much of the Gulf Coast region, the use of molasses-based supplements for beef cows is common (Pate and Kunkle, 1989). due to decreased cost and convenience associated with infrequent feeding because of self-limiting intake characteristics. Arthington et al. (2004) compared heifers receiving the same amounts of CP and TDN as dry feed or molasses and observed that heifers receiving dry feed consumed the supplement in less than 1 h, while the molasses was consumed in ~ 48 h. The authors concluded that heifers receiving liquid supplement had greater pregnancy rates than heifers receiving dry feed, primarily due to slower intake of the liquid supplement. The consumption of a relatively large amount of supplement in a short period of time may result in alteration of the metabolic body rate and may negatively impact pregnancy rates (Arthington et al., 2004).

Urea is commonly used as a non-protein N source in molasses supplements, primarily due to the reduced cost when compared to true protein supplements, such as cottonseed (*Gossypium* spp.) meal. Holroyd et al. (1979a, 1979b) observed that adding urea to molasses to lactating cows grazing native pastures improved pregnancy rate but not milk production or calf weaning weight. However, in a subsequent study, Holroyd et al. (1983) observed that lactating cows grazing native pasture and fed molasses-urea supplement had pregnancy rates and calf weaning weights similar to cows not supplemented with urea. Pate et al. (1990) compared performance of cows receiving stargrass hay and supplemented with molasses plus urea or molasses plus cottonseed meal plus urea and observed that body condition score (BCS) and pregnancy rates were similar between treatments.

According to Klopfenstein (1996), grazing cattle need approximately 130 g RDP kg^{-1} of digestible organic matter consumed, but microbial protein alone is likely sufficient to meet the needs of cattle at or near maintenance. Young growing cattle and lactating cows need RDP in addition to the microbial protein to meet the metabolizable protein needs (Klopfenstein, 1996).

Therefore, it is necessary to identify whether the different increased performance of cow-calf pairs receiving molasses plus cottonseed meal versus molasses plus urea supplementation, observed in the previous studies mentioned above, occurred due to the supply of amino acids to rumen microbes or to the additional RDP provided by the cottonseed meal. In addition, the effects of supplementing different sources of RDP to cow-calf pairs grazing stockpiled limpograss are not known. The objective of this study was to evaluate the performance of cow and calves grazing stockpiled limpograss pastures in South Florida supplemented with different sources of RDP.

Material and Methods

Grazing Study

The study was conducted at the UF/IFAS Range Cattle Research and Education Center (RCREC), Ona, FL (27^o 26' N and 82^o 55' W) from January to March 2011 and 2012. The soil at the research site is classified as Pomona fine sand (siliceous, hyperthermic, Ultic Alaquod). Before the initiation of the study, mean soil pH (in water) was 5.1, and Mehlich-I (0.05 M HCl + 0.0125 M H2SO4) extractable P, K, Mg, and Ca concentrations in the Ap1 horizon (0- to 15-cm depth) were 35, 75, 155, and 1450 mg kg^{-1}, respectively.

Eight ‘Floralta’ limpograss pastures (experimental units, 1 ha per experimental unit) were established in 2010. Pastures were clipped at a 10-cm stubble height in early October 2011 and fertilized with 56 kg N ha^{-1}. The forage was stockpiled for approximately 90 d from October to January in 2011/2012 and 2012/2013.

Twenty four crossbred cows and calves (Angus-sired on crossbred cows) with initial body weight of 418 ± 59 kg and 100 ± 19 kg in 2011 and 413 ± 46 kg and 78 ± 12 kg in 2012 were randomly allocated to the eight pastures (three cow-calf pairs per pasture). Pastures were stocked continuously using a fixed stocking rate.

Treatments were two sources of RDP supplement, urea or cottonseed meal, replicated four times in a randomized complete block design. The composition of the supplement is described in Table 3-1. The treatments were isonitrogenous, with similar concentrations of RDP and rumen-undegradable protein (RUP), and isocaloric. The supplement was fed 3x wk^{-1}, therefore the amount of supplement fed in each of the three events was the daily amount multiplied by seven and divided by three. In a review of supplement studies, Kunkle et al. (2000) reported that cattle receiving protein supplement fed infrequently had similar performance when compared with animals receiving daily supplementation. Cows and calves had ad libitum access to complete salt-based trace mineral mix (14% Ca, 9% P, 24% NaCl, 0.20% K, 0.30% Mg, 0.20% S, 0.005% Co, 0.15% Cu, 0.02% I, 0.05% Mn, 0.004% Se, 0.3% Zn, 0.08% F, and 82 IU/g of vitamin A).

Pasture Sampling

Pastures were sampled just prior to initiation of grazing and every 14 d during the grazing period. Herbage mass (HM), and nutritive value [CP and in vitro digestible organic matter (IVDOM)] were measured. A direct measure was taken to determine HM which involved hand clipping all herbage from soil level to the top of the canopy using an electric clipper inside a 0.25-m^2 ring. A total of six measurements were taken in each experimental unit. Clipped forage was dried for 72 h and weighed. Herbage allowance (HA) was calculated for each pasture as the average HM (mean across two sampling dates within each 28-d period) divided by the average total cow-calf live weight during that period (Sollenberger et al., 2005).

Table 3-1: Ingredient composition and nutrient profile of treatments fed to animals during Experiments 1, 2, and 3.

Item Ingredient, kg DM d^{-1}	CSM[1]	Urea
Cotton-seed meal	1.20	
Urea		0.13
Feather Meal		0.28
Corn Meal		0.81
Molasses	1.80	1.80
Nutrient Intake, DM basis		
CP, kg d^{-1}	0.75	0.76
RDP[2], kg d^{-1}	0.48	0.49
RUP[3], kg d^{-1}	0.28	0.28
TDN[4], kg d^{-1}	2.57	2.66

[1]Cotton-seed meal
[2]Rumen-degradable protein
[3]Rumen-undegradable protein
[4]Total digestible nutrients

Herbage CP and IVDOM concentration were measured at the initiation of grazing and every 14 d thereafter. Hand-plucked samples were taken from each pasture. Herbage was composited across sites, dried at 60°C for 48 h in a forced-air oven to constant weight, and ground in a Wiley mill (Model 4, Thomas-Wiley Laboratory Mill, Thomas Scientific, Swedesboro, NJ) to pass a 1-mm stainless steel screen. Analyses were performed at the University of Florida Forage Evaluation Support Laboratory using the micro-Kjeldahl technique for N (Gallaher et al., 1975), and CP was determined by multiplying N concentration by 6.25. The two-stage technique was used for IVDOM as described by Tilley and Terry (1963) and modified by Moore and Mott (1974).

Animal Response Variables

Cattle were weighed at initiation of the experiment and every 28 d thereafter. Cow body weight and calf body weight were recorded every 28 d. Cow body condition score was visually estimated at the beginning and end of the study. Weights were taken at 0800 h following a 16-h feed and water fast. Average daily gain (ADG) was calculated each 28-d period through the experiment.

Milk production was measured by the weigh-suckle-weigh technique at the beginning and end of the study. Calves were separated from their dams for 12 h, allowed to suckle for 30 minutes, and separated again for 8 h and the procedure repeated. Milk yield was calculated as the difference between pre- and post-suckling calf BW. Milk yield was adjusted to 24 h by dividing the observed difference in pre- and post-suckling calf BW by 20 hours and multiplying by 24 hours.

The blood urea nitrogen (BUN) of cows was determined using a kit (Kit B-7551-120, Pointe Scientific, Inc., Detroit, MI) and read on a plate reader at 620 nm. Blood was collected from the jugular vein at each weighing. Samples were placed into 9-mL, Na-heparinized syringes (Luer Monovette, LH, Sarstedt, Inc., Newton, NC) and placed on ice. Blood was centrifuged (2000 × g relative centrifuge force for 30 min) and plasma was separated and frozen at –20°C on the same day.

Statistical Analysis

Response variables were ADG, BCS, calf ADG, BUN, gain per hectare (GHA), HM, HA, CP, and IVDOM. The data were analyzed using PROC MIXED of SAS (SAS Institute Inc., 2006) with treatment (main plot), year (subplot), and month as fixed effects. Month was a repeated measure. Replicates and their interactions were considered random effects. Treatments were considered different when $P < 0.10$. The means reported were least squares means and were compared using PDIFF (SAS Institute Inc., 2006).

Drylot Study

This study was conducted at the UF/IFAS Range Cattle Research and Education Center (RCREC), Ona, FL (27^{o} 26' N and 82^{o} 55' W) in April 2011 and 2012.Treatments were the same as described for the grazing study and distributed in a completely randomized design with four replicates. The composition of the supplement is presented in Table 3-1. The supplement treatment was offered three times a week, with the daily amount been multiplied by seven and divided by three.

Sixteen cow-calf pairs (two pairs per pen) were allocated to one of eight drylot pens to evaluate the effect of the supplement treatment on voluntary forage dry matter intake. The cow-calf pairs were selected from the grazing study and maintained in the same treatment. Cows and calves received ground limpograss hay (63 g kg^{-1} CP and 520 g kg^{-1} TDN) with 10% refusals. The hay was processed through a hay chopper (Balebuster 2100, Haybuster Jamestown, ND) to an approximately 5-cm particle size and was fed four times a day. Cows and calves were fed hay separately and only the cows had access to the supplement. Cows and calves had ad libitum access to water and a complete salt-based trace mineral mix as described previously for the grazing study.

The experimental period included a 10-d adaptation period and a 7-d collection period. Daily dry matter intake was determined for each pen. All feed refusals were collected every morning at 0800, weighed, and subsampled for determination of DM.

Statistical Analysis

Response variables were total dry matter intake and forage dry matter intake. The data were analyzed using PROC MIXED of SAS (SAS Institute Inc., 2006) with treatment (main plot) and year (subplot). Day was analyzed as a repeated measure. Replicates and their interactions were considered random effects. Treatments were considered different when $P < 0.10$. The means reported were least squares means and were compared using PDIFF (SAS Institute Inc., 2006).

Metabolic Study

This experiment was also conducted at the UF/IFAS Range Cattle Research and Education Center from April to May 2011 and 2012. The treatments were the same as those described in the grazing study and were tested in a 2 x 2 Latin square design.

Two rumen-fistulated steers (500 kg of initial BW) were allocated in one of two metabolic cages and were fed the supplement treatments three times per week (Monday, Wednesday and Friday) with the daily amount being multiplied by seven and divided by three. Steers received ground limpograss hay (63 g kg^{-1} CP and 520 g kg^{-1} TDN) with 10% refusals during the experimental period. The hay was processed through a hay chopper (Balebuster 2100, Haybuster Jamestown, ND) to an approximately 5-cm particle size and was fed four times a day.

The experimental period consisted of a 10 d adaptation period followed by 2 d of blood and rumen fluid collection. Blood and rumen fluid were collected in a two hour interval for the first 24 h and every four hours on the next 24 h after the supplement was offered. The steers stayed in a drylot for 10 d between experimental periods with ad libitum access to water, hay, and a mineral supplement.

Blood was collected from the jugular vein into sodium heparin-containing blood collection tubes (Vacuntainer, 10 mL, Becton Dickinson, Franklin Lakes, NJ), placed on ice and then centrifuged (2000 × g relative centrifuge force for 15 min), plasma was separated and frozen at –20°C on the same day. The BUN was determined using a kit (Kit B-7551-120, Pointe Scientific, Inc., Detroit, MI) and read on a plate reader at 620 nm.

Rumen fluid was collected (50 ml) and filtered through four layers of cheesecloth into a 200 ml plastic container and pH was measured [Orion pH meter (Model 330) Perphect LOgR Orion Research, Boston, MA]. Rumen fluid was then transferred into a plastic container and 0.5 ml of a 20% sulfuric acid solution was added. The container was placed in ice and frozen at -20°C until further analysis. Before volatile fatty acids (VFA) and ammonia analysis rumen fluid was transferred to a plastic container and centrifuged (Beckman Coultier, Avanti JE – rotor JA-20) for 15 min at 14000 rpm and 10°C and 3 ml of the solution was transferred to a container. Rumen fluid was analyzed for VFA’s (Broderick and Kang, 1980) and quantified using a Beckman DU Spectrophotometer (Beckman Coulter, Palo Alto, CA) set at 620 nm and VFA using Agilent 7820A Gas Chromatograph (Agilent Technologies, Palo Alto, CA, 2.5 m x 0.32 mm x 0.45 mm glass column). Rumen ammonia was performed according to Broderick and Kang (1980) and quantifying using a spectrophotometer (Beckman Coulter AD340 microplate reader, Beckman Coulter, Fullerton, CA) at 630 nm.

Statistical Analysis

The response variables were pH, BUN, VFA concentrations, and ruminal ammonia. The data was analyzed using PROC MIXED of SAS (SAS Institute Inc., 2006) with treatment (main plot) and year (subplot). Day was analyzed as a repeated measure. Replicates and their interactions were considered random effects. Treatments were considered different when $P < 0.10$. The means reported were least squares means and were compared using PDIFF (SAS Institute Inc., 2006).

Results and Discussion

Grazing Study

There was no treatment effect on HM (mean = 3.3 Mg ha^{-1}, P = 0.78, SE = 0.4) (Table 3-2); however, there was a year effect (P = 0.02) with greater HM in 2012 than in 2011 (Table 3-3). There was less rainfall during the stockpiling phase (October to December) in 2010 than in 2011(Table 3-4), resulting in lesser HM during the 2011 experimental period. In addition there were five below 0°C events in 2010 and none in 2011 (Table 3-5) contributing to the greater HM in 2012 (Table 3-3). The freezing events can affect growth by causing inhibiting photosynthesis (Quesenberry and Ocumpaugh, 1980) and limiting the potential of limpograss to accumulate HM in the winter months. Ruelke and Quesenberry (1983) reported greater HM in December (10 Mg ha^{-1}) when forage was harvested at 2-wk intervals from August to February for limpograss pastures fertilized with 75 kg N ha^{-1} in August. Herbage mass of stockpiled pastures was variable and highly dependent on weather conditions from the time of staging to the time of use (Sollenberger et al., 2012). Rainfall, below 0°C temperatures, and N fertilization are the main factors affecting HM of stockpiled limpograss.

Table 3-2: Month effects on herbage mass, in vitro digestible organic matter concentrations and herbage allowance of stockpiled limpograss pastures grazed by cow-calf pairs supplemented with molasses and urea or cotton seed meal.

Response Variable	Month			*P* value	SE
	January	February	March		
Herbage Mass (Mg ha^{-1})	4.1 a†	3.1 b	2.6 b	0.08	0.4
In vitro digestible organic matter (g kg^{-1})	466 a	421 b	396 c	< 0.01	22
Herbage allowance (kg DM kg^{-1} LW)	2.5 a	1.8 b	1.4 b	0.02	0.2

†Means within rows are different if followed by different letters ($P \leq 0.10$).

Table 3-3: Year effect on crude protein and in vitro digestible organic matter concentrations of stockpiled limpograss pastures

Response variables	Year		*P* value	SE
	2011	2012		
Herbage mass (Mg ha^{-1})	2.9 b†	3.6 a	0.02	0.3
Crude protein (g kg^{-1})	149 a	96 b	<0.01	4
In vitro digestible organic matter (g kg^{-1})	467 a	388 b	<0.01	21

†Means within rows are different if followed by different letters ($P \leq 0.10$).

Table 3-4: Average monthly precipitation from 1942 to 2012 and during the experimental period from 2010 to 2012 at the Range Cattle Research and Education Center, Ona, FL.

Month	Rainfall (mm)				
	2010	2011	2012	3-yr average	69-yr average
January	50	63	12	42	47
February	61	9	10	27	45
March	150	148	7	101	81
October	0.0	100	129	76	69
November	68	4	14	29	39
December	21	3	30	18	47

Table 3-5: Average monthly temperature from 1942 to 2012 and during the experimental period from 2010 to 2012 at the Range Cattle Research and Education Center, Ona, FL.

Month	Temperature (°C)				
	2010	2011	2012	3-yr average	69-yr average
January	12.5	14.9	15.3	14.2	12.0
February	12.6	17.8	19.0	16.5	13.3
March	15.4	19.1	20.8	18.4	15.5
October	22.7	21.9	23.3	22.6	20.6
November	19.2	19.7	17.3	18.7	16.4
December	10.9	18.1	17.8	15.6	13.4

There was a decrease in HM from January to March (Table 3-3). The decrease likely occurred due to the limited herbage accumulation and forage consumption by the animals. Vendramini and Arthington (2010) reported a decrease in HM of stockpiled limpograss pastures grazed from February to April (2.7 to 1.5 Mg ha^{-1}). During the grazing period (January to March), there was greater rainfall in 2011 than in 2012, especially in January and March (Table 3-4). Rainfall events tend to affect negatively the HM of stockpiled pastures because it lays the forage down in contact with the soil and decreases access to the animals. There were three freeze events during the grazing period in 2012 and only one in 2011(Table 3-5).

There was no effect of treatment on CP (mean = 122 g kg^{-1}, P = 0.61, SE = 4) and IVDOM (mean = 428 g kg^{-1}, P = 0.69, SE = 22) concentration of stockpiled limpograss pastures. Arthington and Brown (2005) reported CP concentration lower than 50 g kg^{-1} on stockpiled limpograss for 10 wk; however, values were from whole plant. The average CP of the hand-plucked samples reported in this study was similar to values reported by Vendramini and Arthington (2010), 120 g kg^{-1}. Crude protein concentrations were greater in 2011 than 2012 (Table 3-3). Mislevy and Martin (2007) reported no difference in CP concentration of limpograss pastures 1, 2, and 4 wk after freezing averaging 8.8 g kg^{-1}. The decreased CP observed in 2012 may be the result of a greater number of freezing events during the grazing period or alternatively to dilution associated with greater HM in 2012 than 2011. In addition, there was no month effect ($P = 0.44$, SE = 4) on CP concentration.

Vendramini and Arthington (2010) reported a decrease in CP concentration from February to March and no further decrease in April for the first year of the study; however, there was no change in CP from February to March and an increase was reported in April. It was expected that CP concentration would decrease throughout the experimental period due to the decrease in proportion of leaves in the sward during grazing, the negative effects of freezing events, and increasing maturity of the plants. Instead, the appearance of new tissue with greater CP concentration during the experimental period may have compensated for the decrease in CP. Vendramini and Arthington (2010) stated that even though CP concentration was adequate, RDP may not meet animal requirement since a greater proportion of the CP of forages with long regrowth period is associated with the acid detergent fiber fraction which is not degradable in the rumen (Vendramini et al., 2008b).

There was a month and year effect on IVDOM (Table 3-2 and 3-3). The IVDOM concentration was greater in 2011 compared to 2012. The decrease in IVDOM in 2012 was likely the result of greater number of freezing events in 2012. Mislevy and Martin (2007) reported a decrease in IVDOM of limpograss pastures after 1, 2, and 4 wk after freeze, from 627 to 539 g kg^{-1}. Vendramini and Arthington (2010) reported no month effect on IVDOM of stockpiled limpograss pastures averaging 500 g kg^{-1}, but authors reported a year effect on IVDOM concentration. Similar results were reported by Arthington and Brown (2005) for the year effect on IVDOM concentration with values of 523 and 445 g kg^{-1} in 1999 and 2000, respectively. Rainfall and temperature differed between years and impacted HM and forage nutritive value. Greater rainfall and temperatures during the stockpiling liked increased HM, which decreased IVDOM concentrations. The IVDOM concentration decreased over time from January to March. The decrease in IVDOM concentrations is contrasting with the maintenance of the CP concentrations from January to March. Leaf aging, senescence, death and deterioration on stockpiled forages may reduce forage nutritive value (Burns and Chamblee, 2000). There may be a greater proportion of mature tissues with decreased IVDOM concentrations than young tissues, but still with greater CP concentrations.

There was no effect of sources of RDP supplementation on HA (mean = 2.2 kg DM kg^{-1} LW, P = 0.98, SE = 0.3); however, there was a decrease in HA from January to March (Table 3-3). These results were expected because the treatments had similar stocking rates and HM, and there was a decrease in HM from January to March. Although the relationship of animal performance and HA in stockpiled pastures is not well documented in the literature, it is expected that HA greater than 1 kg DM kg^{-1} LW is sufficient for ad libitum forage consumption when forage is the only source of feed to cattle (Sollenberger and Moore, 1997). Therefore, it is expected that forage quantity was sufficient during the experiment, and variations in animal performance could be related to the RDP supplementation treatment or forage nutritive value. Herbage allowance was greater in 2012 than 2011 because of the greater HM in 2012 (Table 3-6).

Table 3-6: Year effect on animal response variables of stockpiled limpograss pastures.

	Year			
Response Variable	2011	2012	*P* value	SE
Body condition score	4.9 a[†]	4.4 b	<0.01	0.1
Milk yield (kg d^{-1})	6.5 b	7.6 a	0.40	0.8
Herbage allowance (kg DM kg^{-1} LW)	1.8 b	2.1 a	0.09	0.2

[†]Means are different if followed by different letters ($P \leq 0.10$).

There was a treatment x month x year interaction ($P < 0.01$, SE = 0.04) on cow ADG (Table 3-7). The interaction on cow ADG occurred because there was no difference in January and February 2011 among treatments, however, cows receiving cottonseed meal had greater ADG than urea in March 2011. In 2012, there was no difference between treatments in January and March; however, cows receiving urea had greater ADG in February. Greater cow ADG in January 2011 and 2012 may be due to filling effects caused by greater HM and potentially greater forage intake in January 2011 and 2012. The variation in cow ADG throughout the experimental period may be intrinsic to the variation in mature animals with greater ruminal capacity when compared to young animals, since the variation in rumen content is the main source of error on animal weight (Bath et al., 1966).

Pate et al. (1990) reported a variation on cow weight change from 15 to 30% during the experimental period. Kalmbacher et al. (1995) observed no differences on cow weight change (mean = 21 kg) and calf final weight (mean = 194 kg) on cows supplemented with urea or cottonseed meal-urea (1.6 kg d^{-1}) on a molasses based supplement (CP = 300 g kg^{-1}) grazing creeping bluestem [*Schizachyrium scoparium*

(Michx.) ash var. stoloniferum (Nash) J. Wipff] (CP = 47 g kg^{-1}) in South Florida. These authors also found a significant variation in cow body weight throughout the experimental period. Although it is reported that natural protein supplements are often more effective than urea (Clanton, 1978, Pate and Kunkle, 1989), the differences in cottonseed meal or urea as a source of RDP in this study were not conclusive.

Table 3-7: Year x treatment x month interaction on average daily gain (kg d^{-1}) of cows grazing stockpiled limpograss pastures supplemented with molasses-based supplement plus urea or cotton seed meal (CSM).

	Month			
Year/Treatment	January	February	March	SE
2011		-----------kg d^{-1}-----------		
CSM	1.60 a†	-0.52 c	0.09 b	0.2
UREA	1.61 a	-0.62 b	-0.48 b	0.2
P‡ value	0.97	0.69	<0.01	
2012				
CSM	0.63 a	-0.31 c	0.23 b	0.2
UREA	0.36 a	0.15 a	0.14 a	0.2
P value	0.28	<0.01	0.69	
SE		0.2		

†Means followed by the same letter lowercase letter within rows are not different ($P > 0.10$).
‡ *P* value for treatments effect within year and month.

Similarly, Pate et al. (1990) reported no differences of cow performance when supplemented with molasses, molasses-urea, and molasses-cottonseed meal-urea and receiving stargrass hay. In general, the ADG of cows was greater in 2011 than 2012, probably reflecting the greater forage nutritive value in 2011. There was no effect of the treatments on body condition score; however, body condition score of the cows was greater in 2011 than 2012 (Table 3-5), likely because of the greater forage nutritive value in 2011. The diets were formulated for the cows to maintain a body condition score of 5; however, the lesser than expected IVDOM of the forage likely decreased body condition score.

There was a treatment x month x year interaction on cow BUN (Table 3-8). Although there was no difference between treatments, BUN concentrations increased from January to March in 2011. In 2012, BUN concentrations increased from January to February and were similar in February and March. Urea is more soluble than true sources of protein in the rumen, and if the N is not captured by the rumen microbes promptly, it may be absorbed by the rumen epithelial and increase levels of BUN concentrations. However, the levels of RDP provided by different sources in this study likely resulted in similar amounts of N being absorbed in the rumen epithelial. Cross et al. (1974) observed no difference in BUN concentration (mean = 12 mg dL^{-1}) for steers fed urea or cottonseed meal supplement. Brown and Adjei (2001) reported similar BUN concentrations for heifers grazing limpograss and supplemented with urea, feather meal, or urea plus feather meal (mean = 13 mg dL^{-1}). Blood urea nitrogen concentrations were greater in 2012 than 2011 (Table 3-8). Changes in BUN concentration may be related to energy intake at similar levels of protein intake (Hammond, 1997). Greater energy intake may lead to increases in ruminal microbes and better utilization of the ruminal N. Therefore, the decreased limpograss IVDOM in 2012 may have led to decreased N use by the ruminal microbes and greater N amounts being absorbed by the rumen epithelial.

According to Hammond et al. (1997), cattle BUN concentrations from 9 to 12 mg dL^{-1} represent a transition range below which responses to protein supplementation are generally positive. In the current study, cows had BUN concentrations above the optimal range (9 and 12 mg dL^{-1}) for all but the first month of the first year, indicating that RDP was consumed in excess or the ruminal protein:energy ratio was inadequate to optimize ruminal fermentation and a greater amount of N was absorbed by the rumen epithelium. Absorption and excretion of excess ammonia wastes energy that otherwise could be used to improve animal performance (Van Vuuren et al., 1993).

Table 3-8: Year x treatment x month interaction on blood urea nitrogen (mg dL^{-1}) of cows grazing stockpiled limpograss pastures supplemented with molasses-based supplement plus urea or cotton seed meal (CSM).

	Month			
Year/Treatment	January	February	March	SE
	-------------mg dL^{-1}-------------			
2011				
CSM	6.4 c[†]	14.4 b	19.1 a	1.5
Urea	8.4 c	14.1 b	17.1 a	1.5
P[‡] value	0.25	0.83	0.24	
2012				
CSM	17.6 b	20.2 a	21.1 a	1.5
Urea	16.3 b	18.5 ab	20.5 a	1.5
P value	0.44	0.31	0.71	
SE		1.5		

[†]Means followed by the same letter lowercase letter within rows are not different ($P >$ 0.10).
[‡]*P* value for treatment effect within year and month.

There was no effect (mean = 7.3 kg d^{-1}, $P = 0.42$, SE = 0.3) on milk production of cows supplemented with different sources of RDP (Table 3-6). Similar values for milk production (6.6 kg milk d^{-1}) of crossbred cows consuming low-nutritive value forage were reported by Brown and Brown (2002). Alderton et al. (2000) reported no differences in milk production of 60, 90, and 120 d postpartum, approximately 9, 8, and 7 kg milk d^{-1}, respectively, for cows receiving RUP, RDP, or a combination of RUP and RDP.

There was a treatment x month x year interaction on calf ADG (Table 3-9). There was a no difference in calf ADG between treatments in 2011; however, calves from cows receiving urea had greater ADG than from the cottonseed meal treatment in February 2012. Conversely, calves from cows receiving cottonseed meal had greater ADG than urea treatments in March 2012. Pate et al. (1990) observed that calves from 3-yr-old cows receiving molasses plus cottonseed meal plus urea had greater weaning weight than calves from cows receiving molasses but ADG was not different from the cows receiving molasses plus urea. Considering that the calves did not have access to the supplement, similar performance of the calves was expected because there was no difference in milk production between treatments.

Drylot Study

There were no differences in hay dry matter intake (HDMI) (mean = 2.1% of BW, $P = 0.16$) and total dry matter intake (TDMI) (mean = 2.5% of BW, $P = 0.11$) between the two sources of RDP. Similar to those results, Köster et al. (1997) substituted true protein (casein) for urea in levels from 0 to 100% on a supplement with 400 g kg^{-1} of CP and reported no difference in tallgrass-prairie forage (CP = 24 g kg^{-1}) dry matter intake between treatments. Köster et al. (2002) reported no differences in forage and total intake for steers consuming dormant tallgrass-prairie hay (CP = 24.2 g kg^{-1}) when soybean meal was substituted for urea at 0, 20, or 40% of RDP. The authors stated that differences between true-protein versus urea-based protein on forage dry matter intake are not expected.

Table 3-9: Year x treatment x month interaction on average daily gain (kg d^{-1}) of calves grazing stockpiled limpograss pastures supplemented with molasses-based supplement plus urea or cotton seed meal (CSM).

Year/Treatment	January	February	March	SE
		Month		
		-----------kg d^{-1}-----------		
2011				
CSM	1.37 a[†]	0.53 c	0.91 b	0.1
UREA	1.28 a	0.57 b	0.86 b	0.1
P[‡] value	0.37	0.65	0.7	
2012				
CSM	0.70 a	0.22 b	0.72 a	0.1
UREA	0.71 a	0.47 b	0.52 b	0.1
P value	0.94	0.02	0.07	
SE		0.1		

[†]Within rows, means followed by the same letter lowercase letter are not different ($P > 0.10$).
[‡] *P* value for treatments effect within year and month.

Koeing and Beauchemin (2013) fed supplement to beef heifers with barley silage based diets (CP = 120 g kg^{-1}) and did not find differences in dry matter intake between different supplements, urea, urea+canola meal, urea+corn gluten meal, and urea+corn gluten meal+ xylose-treated soybean meal. In addition, McGuire et al. (2013) reported no difference in hard fescue [*Festuca trachyphylla* (Hack.) Krajina] straw and total dry matter intake of steers supplemented with urea or soybean meal daily or every other day with a CP intake of 0.10% of BW d^{-1}. Authors showed no effect of infrequent supplementation on DMI and nutrient digestibility. Kalmbacher et al. (1995) fed steers with bluestem (*Schizachyrium scoparium* var. stoloniferum) hay (CP = 47 g kg^{-1}) and supplemented with molasses plus urea or soybean meal and reported no effect on organic matter intake between protein supplementation and control (no supplement). Different sources of RDP supplement are not likely to affect forage dry matter intake on cows consuming forage with decreased nutritive value.

Metabolic Study

There was no effect of the supplements in rumen fluid pH between treatments (mean = 6.5, P = 0.39) (Table 3-10). Similarly, there were no differences in total ruminal VFA (mean = 120 mM, P = 0.35) and branched chain VFA (mean = 1.3 mM, P = 0.24) between treatments (Table 3-10). In a review of several studies using molasses in beef nutrition, Pate (1983) concluded that molasses did not affect rumen pH and VFA concentration when fed at 15% of the diet. In this study, molasses was 9.3% of the total dry matter intake and the pH and VFA concentrations corroborated the findings by Pate (1983). Koeing and Beauchemin (2013) reported no differences in total (mean = 132 mM) and branched ruminal VFA concentrations and pH (mean = 6.24) when feeding animals different protein supplements including urea, urea plus canola meal, urea plus corn gluten meal, and urea plus canola meal plus xylose-treated soybean meal and consuming barley silage and concentrate (CP = 120 g kg^{-1}). Köster et al. (1997) substituted urea for true protein (casein) from 0 to 100% on a basal diet of dormant tallgrass-prairie forage (CP = 24 g kg^{-1}) and reported no difference on total VFA production (mean 82.4 mM) and pH (mean = 6.5). Köster et al. (2002) fed dormant tallgrass hay to steers and showed no differences in total and branched VFA production when steers were supplemented with increasing levels of urea from 0 to 40% of the RDP, in substitution of soybean meal.

There were no differences in propionic (mean = 25 mol 100 mol^{-1}, P = 0.80), acetic (mean = 69.2 mol 100 mol^{-1}, P = 0.92), butyric acids (mean = 4.5 mol 100 mol^{-1}, P = 0.92), nor in branched chain VFA (mean 1.3 mol 100 mol^{-1}, P = 0.24) proportions between sources of RDP (Table 3-10).

Table 3-10: Treatment effects on rumen and blood parameters of fistulated steers fed with limpograss hay and supplemented with molasses-based supplement and urea or cottonseed meal (CSM).

	Treatment			
Response variables	CSM	Urea	*P* value	SE
Ruminal ammonia, mg dL^{-1}	14.5	14.5	0.99	2.6
Ruminal pH	6.5	6.6	0.39	0.1
BUN, mg dL^{-1}	7.9	7.8	0.91	0.8
Total VFA, m*M*	116.2	123.7	0.35	5.5
Individual VFA, mol/100 ml				
Acetic acid	69.1	69.3	0.92	2.9
Propionic acid	25.2	24.7	0.80	2.2
Butyric acid	4.5	4.5	0.97	0.5
Branched chain acids	1.2	1.5	0.24	0.3

Köster et al. (2002) supplemented steers with three levels of urea (0, 20, or 40 %) and decreasing levels of soybean meal and reported no differences in propionate, acetate and butyrate concentrations among levels of protein supplementation. Wickersham et al. (2008) evaluated steers fed low nutritive value hay and supplemented daily or every third day and reported no differences in propionate, acetate and butyrate with levels of supplementation. Conversely, Köster et al. (1996) reported an increase in acetate and a decrease in butyrate proportions but no difference in propionate for steers fed dormant tallgrass-prairie hay. The authors stated that the difference in butyrate proportion was affected by the increase in acetate proportion. Similar concentrations of acetate were expected because there was similar forage dry matter intake between treatments in the metabolic and drylot study.

Further there were no differences in rumen fluid ammonia (mean = 14.5 mg dL^{-1}, P = 0.99) and BUN (mean = 7.9 mg dL^{-1}, P = 0.91) (Table 3-10). Animals were receiving molasses as a base supplement, which limits intake (Kunkle et al., 1995, Arthington et al., 2002). Urea has greater solubility than cottonseed meal in the rumen (400 vs. 175 % h^{-1}) (NRC, 2000); however, the animals consumed the concentrate in 24 h, decreasing the rate of intake of the protein supplement. In dry feed supplements, as urea increased in the diet from 0 up to 40% in substitution for soybean meal, there was an increase in rumen ammonia levels from 3.2 to 31.8 mg dL^{-1} (Köster et al., 2002). The slow rate of supplement consumption and soluble carbohydrates present in the molasses may have led to similar levels of BUN between treatments.

There was a time effect on ruminal ammonia ($P < 0.01$), pH ($P < 0.01$) and BUN ($P = 0.05$) (Figures 3-1 and 3-2). The pH values ranged from 6.2 to 6.7 (Figure 3-1) and according to Köster et al. (1997), the pH was adequate to maintain the activity of cellulolytic bacteria in the rumen. Ruminal ammonia reached the greatest concentration 2 h after feeding and decreased from 2 to 16 h. The concentration of ammonia was below 5 mg dL^{-1} at 40 h after feeding, which can affect ruminal microbial growth (Satter and Slyter, 1974). Farmer et al. (2001) reported an increase in ruminal ammonia 2 h after feeding for steers receiving dormant tallgrass-prairie hay and supplemented three or five times a week with protein supplement. The increase of rumen ammonia was likely due to supplement intake and a consequence of the infrequent protein supplementation (Wickersham et al., 2008). According to Hammond (1983) ruminal ammonia is highly correlated with BUN. Similar to ruminal ammonia, BUN concentration increased from 0 to 12 h after feeding and decreased from 12 to 48 hours. Hammond (1997) reported a maximum performance of mature cows when BUN concentrations were between 7 and 8 mg dL^{-1} and the levels observed in this study were in the referred range.

Important Findings and Implications

There were no differences in herbage responses and performance of cow-calf pairs grazing stockpiled limpograss pastures and receiving molasses with cottonseed meal or urea as a source of RDP. Cows supplemented with different sources of RDP had similar hay DMI and total DMI in a dry lot. In addition, ruminal parameters and BUN concentrations were also similar among steers receiving different sources of rumen-degradable protein. The self-limiting intake of molasses decreased the intake rate of urea and optimized the N use efficiency in the rumen. Urea can be as effective as cottonseed meal as a source of RDP to mature lactating beef cows grazing stockpiled limpograss pastures and the decision to use urea or cottonseed meal should be based on the cost of those protein supplements.

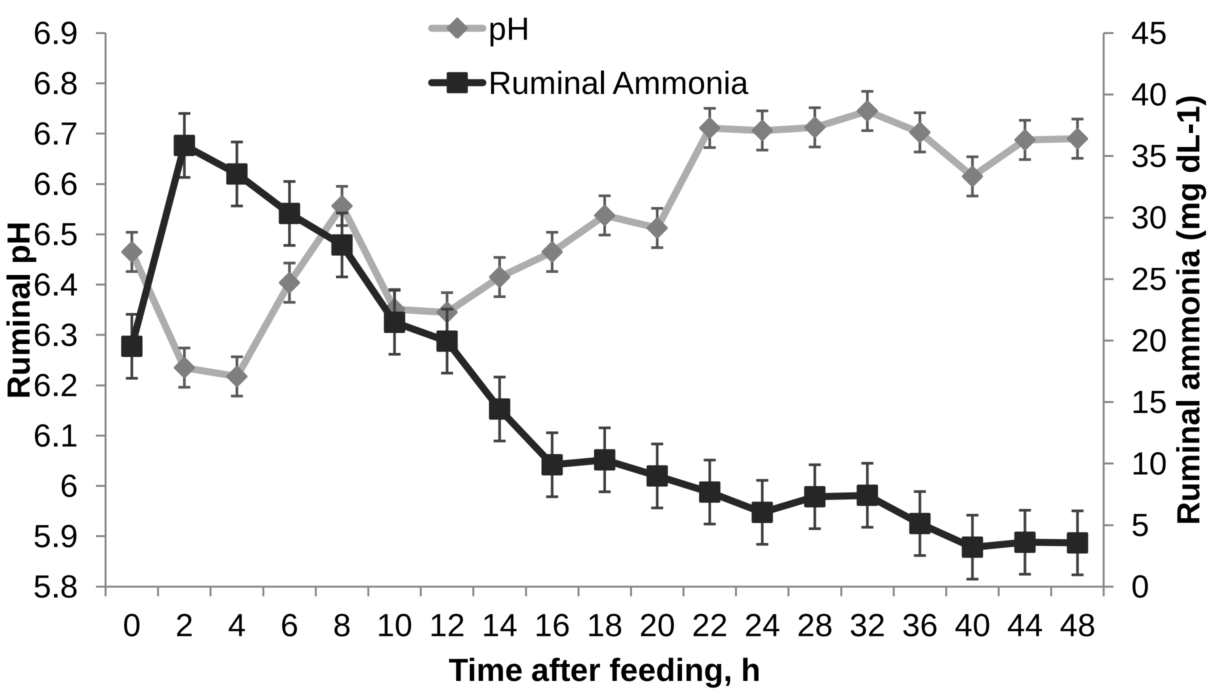

Figure 3-1: Time effect on ruminal pH (*P* < 0.01) and ammonia (*P* < 0.01) on fistulated steers supplemented with two sources of rumen-degradable protein, mean between treatments.

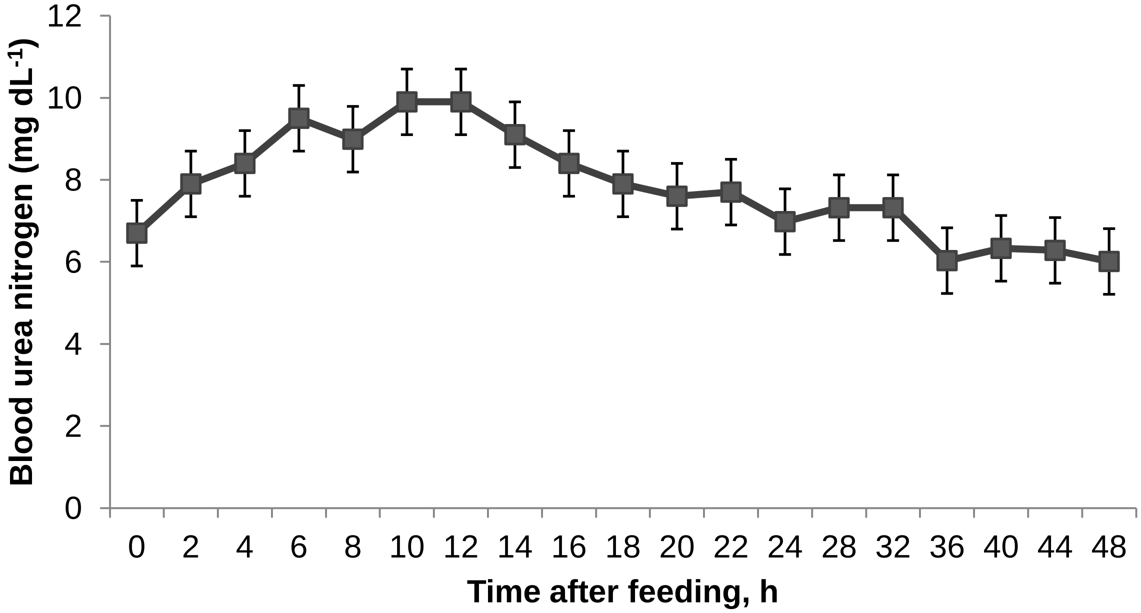

Figure 3-2: Time effect on blood urea nitrogen on fistulated steers supplemented with two sources of rumen-degradable protein, mean between treatments (*P* = 0.06).

CHAPTER 4
EFFECTS OF LIMIT CREEP-FEEDING SUPPLEMENT ON PERFORMANCE OF COWS AND CALVES GRAZING LIMPOGRASS PASTURES IN SOUTH FLORIDA

Overview of the Research Problem

Limpograss [*Hemarthria altissima* (Poir.) Stapf et C. E. Hubb.] is a perennial warm-season grass adapted to poorly drained soil, with reduced crude protein (CP) concentrations (Pitman et al., 1994). Thus, supplementation of animals grazing limpograss may be a feasible management practice to optimize animal production (Sollenberger et al., 1988 and Newman et al., 2002).

In Florida, creep-feeding heifer calves with high protein diets may increase weaning weights, which could decrease the age of puberty and time of first conception (Petterson et al., 1992, Yelich et al., 1995). Another benefit reported by creep-feeding calves is an increase in cow performance (Prichard et al., 1989). However, the benefit of creep-feeding on cow performance is not consistently reported in the literature (Lusby and Wettmann, 1986; Tarr et al., 1994; Vendramini et al., 2012).

Ad libitum access to concentrate decreases feed efficiency (5 to 15 kg feed per kg of additional body weight gain) limiting the economic feasibility of creep-feeding beef calves. (Stricker et al., 1979; Cremin et al., 1989; Faulker et al., 1993). Nevertheless, creep-feeding the most limiting nutrients for calf growth in smaller quantities may be an efficient management practice to improve calf performance and decrease feed cost.

Limited creep-feeding protein is generally used to provide N sources to rumen microbes to improve fiber digestibility, forage intake, and improve calf performance (Lusby and Wettemann, 1986, Cremin et al., 1991). Lusby et al. (1985) proposed a limited creep-fed protein supplement of 0.37 kg cottonseed (*Gossypium* spp.) meal d^{-1} to cow-calf pairs grazing for 63 d and reported an increase of 0.13 kg d^{-1} in ADG of supplemented compared to control calves with feed efficiency of 2.5 kg of supplement per extra kg of gain. However, no difference in cow performance and body condition score was found.

Moriel and Arthington (2013) reported inconsistent benefits of limit-fed protein creep-fed to calves for 112 d prior to weaning. In Experiment 1, calves were supplemented 3x wk^{-1} with 0.23 kg d^{-1} of a cubed protein supplement (CP = 210 g kg^{-1}). There was an increase in ADG from 0.88 to 0.95 kg d^{-1} for control and creep-fed calves, respectively. In Experiment 2, calves were supplemented with a meal protein supplement (CP = 190 g kg^{-1}) and there was no difference in calf performance between treatments. Soybean [*Glycine max* (L.) Merr.] meal improves rumen degradability, enhance digestibility of low nutritive value forage, forage intake, and consequently improve animal performance and has concentrations of high quality aminoacids (). Soybean meal supplementation may (Mathis et al., 1999, and NRC, 2000).

Although there is evidence in the literature of the benefits of limit creep-feeding nursing calves grazing warm-season grasses, the results are not consistent. In addition, the effects of creep-feeding nursing calves grazing limpograss pastures are not known. The objective of this study was to test the effect of limited creep-feeding protein supplements to calves grazing limpograss pastures.

Material and Methods

The research projects were conducted at the UF/IFAS Range Cattle Research and Education Center (RCREC), Ona, FL (27^{o} 26' N and 82^{o} 55' W) from June to September 2011 (Experiment 1) and from June to August 2012 (Experiment 2). The soil at the research site is classified as Pomona fine sand (siliceous, hyperthermic, Ultic Alaquod). Before initiation of the study, mean soil pH (in water) was 5.1, and Mehlich-I

(0.05 M HCl + 0.0125 M H2SO4) extractable P, K, Mg, and Ca concentrations in the Ap1 horizon (0- to 15-cm depth) were 35, 75, 155, and 1450 mg kg^{-1}, respectively. Pastures were fertilized with 90 kg N ha^{-1} in April 2011 and 2012. The source of N fertilizer was ammonium nitrate.

Limpograss pastures (1.0 ha per pasture, experimental units) were established in 2010 and grazed in 2011 and 2012. Twenty-four cow and heifer calves (Angus-sired on crossbred cows) were randomly distributed in eight limpograss pastures with 3 cow-calf pairs per pastures. Calves were approximately 6 mo of age at the initiation of the study.

In Experiment 1, treatments were: 1) calves receiving 200 g d^{-1} of soybean meal (480 g CP kg^{-1}) by creep feeding, or 2) calves not receiving supplement (Control). Treatments were distributed in a randomized complete block design with four replicates. In Experiment 2, treatments were: 1) calves receiving 200 g d^{-1} of soybean meal by creep feeding (200), 2) calves receiving 400 g d^{-1} of soybean meal by creep feeding (400), or 3) calves not receiving supplement (Control). The treatments were distributed in a randomized incomplete block design with three replicates for control and 200 treatments, and two replicates for the 400 treatment.

Herbage Measurements

In Experiments 1 and 2, pastures were stocked continuously using a fixed stocking rate. Pastures were sampled just prior to initiation of grazing and every 14 d thereafter. Herbage mass and nutritive value [CP and in vitro digestible organic matter (IVDOM)] were measured. Herbage mass was determined by the double sampling technique. The indirect measure was the settling height of a 0.25-m^2 aluminum disk, whereas direct measure involved hand clipping all herbage at soil level to the top of the canopy using an electric clipper. One or two double samples were taken from each of the eight experimental units for a total of 20 in a 28-d interval. Sites were chosen to represent the range of herbage mass present on the pastures. At each site, the disk settling height was measured and the forage was clipped at ground level. Clipped forage was dried for 72 h and weighed. In order to ensure that all sections of the pasture were represented by the disk plate, 20 sites were chosen by walking a fixed number of steps between each drop of the disk on the choose point for the disk measurement in a 14 d interval.

The average disk height of the 20 sites was entered into the equation to predict actual HM. A cage technique was used to measure herbage accumulation since pastures were stocked continuously, by placing three 1-m^2 cages in the pasture at the initial sampling date. Placement sites were chosen where the disk settling height was the same (± 1 cm) as that of the pasture average. Disk settling height was recorded at a specific site and the cage placed. After 28 d, the cage was removed and the new disk settling height recorded.

Herbage allowance (HA) was calculated for each pasture as the average HM (mean across two sampling dates within each 28-d period) divided by the average total cow-calf live weight during that period (Sollenberger et al., 2005). Hand-plucked sampling technique was used to estimate herbage CP and IVDOM concentration at the initiation of grazing and at every 14 d thereafter. Herbage samples were composited across sites, dried at 60°C for 48 h in a forced-air oven to constant weight and were ground in a Wiley mill (Model 4, Thomas-Wiley Laboratory Mill, Thomas Scientific, Swedesboro, NJ) to pass a 1-mm stainless steel screen. Analyses were performed at the University of Florida Forage Evaluation Support Laboratory using the micro-Kjeldahl technique for N (Gallaher et al., 1975) and the two-stage technique for IVDOM (Moore and Mott, 1974).

Animal Responses

The cow-calf pairs were weighed at initiation of the experiment and every 28 d thereafter. Initial and final weights were taken at 0800 h with shrink period of 16 h and the animals were unshrunk for the intermediate weights. The difference in BW was used to calculate ADG. The body condition score of the cows was evaluated on the same schedule. The gain per ha was determined based on the ADG of the calves multiplied by the number of calves within the pasture during that experimental period and adjusted to a hectare basis.

Economics

The descriptive cost of added gain and efficiency of added gain were calculated. Cost of added gain was calculated by dividing the cost of feed by the added gain (BW gain of creep-fed calves – ADG of control calves) and efficiency of added gain calculated by dividing the amount of feed consumed for the entire experimental period by the added gain. The cost, income, and return on Experiment 2 were calculated. The income was calculated based on the gain per area multiplied by the calf price and the return was calculated by the added gain per area subtracted by the cost of feed.

Statistical Analyses

Response variables were cow ADG and BCS, calf ADG, gain per ha (GHA), HM, HA, CP, IVDOM, income, and return. The data were analyzed using PROC GLIMMIX of SAS (SAS Institute Inc., 2006) with creep-feeding supplementation levels and month as fixed effects. Replicate and their interactions were considered random effects. Months were analyzed as repeated measures. Years were analyzed separately because of different creep-feeding supplementation levels used in 2011 and 2012. In Experiment 2, single degree of freedom orthogonal polynomial contrasts were used to test the treatment effects. Treatments were considered different when $P < 0.10$. The means reported are least squares means and were compared using PDIFF (SAS Institute Inc., 2006).

Results and Discussion

Herbage Responses

There was no difference in HM among treatments in Experiment 1 and 2 (Tables 4-1 and 4-3). In Experiment 1, HM was greater in June and decreased from June to September (Table 4-2). Pastures were fertilized in April and the extended regrowth period from April to June resulted in increased HM at the start of the experimental period. In Experiment 2, HM decreased from June to July and subsequently increased in August (Table 4-4), probably due to favorable rainfall in August 2012 (Figure 4-1). Corroborating this finding, Vendramini et al. (2011) did not report differences in bahiagrass (*Paspalum notatum* Flügge) HM of pastures with cow-calf pairs receiving creep-feeding or control. It was expected that the soybean meal supplementation would increase forage digestibility and forage intake by calves (Vendramini et al., 2013); however, the magnitude of the increased intake was not sufficient to cause differences in HM.

Crude protein and IVDOM were not affected by the creep-feeding treatments in Experiments 1 and 2 (Tables 4-1 and 4-3). Reed et al. (2006) reported no difference in forage nutritive value (mean CP = 124 and IVDOM = 503 g kg^{-1}) of pastures grazed by creep-fed and no creep-fed nursing calves. There was a month effect on CP and IVDOM concentrations in Experiments 1 and 2. In Experiment 1, CP increased from

June to July and subsequently decreased from July to August and September. In Experiment 2, CP and IVDOM decreased from June to August. The decreased CP and IVDOM in June were likely because of the greater regrowth period from fertilization to starting the experimental period. The increased CP and IVDOM in Experiment 1 were likely related to the lesser HM and greater appearance of new tissues with greater nutritive value.

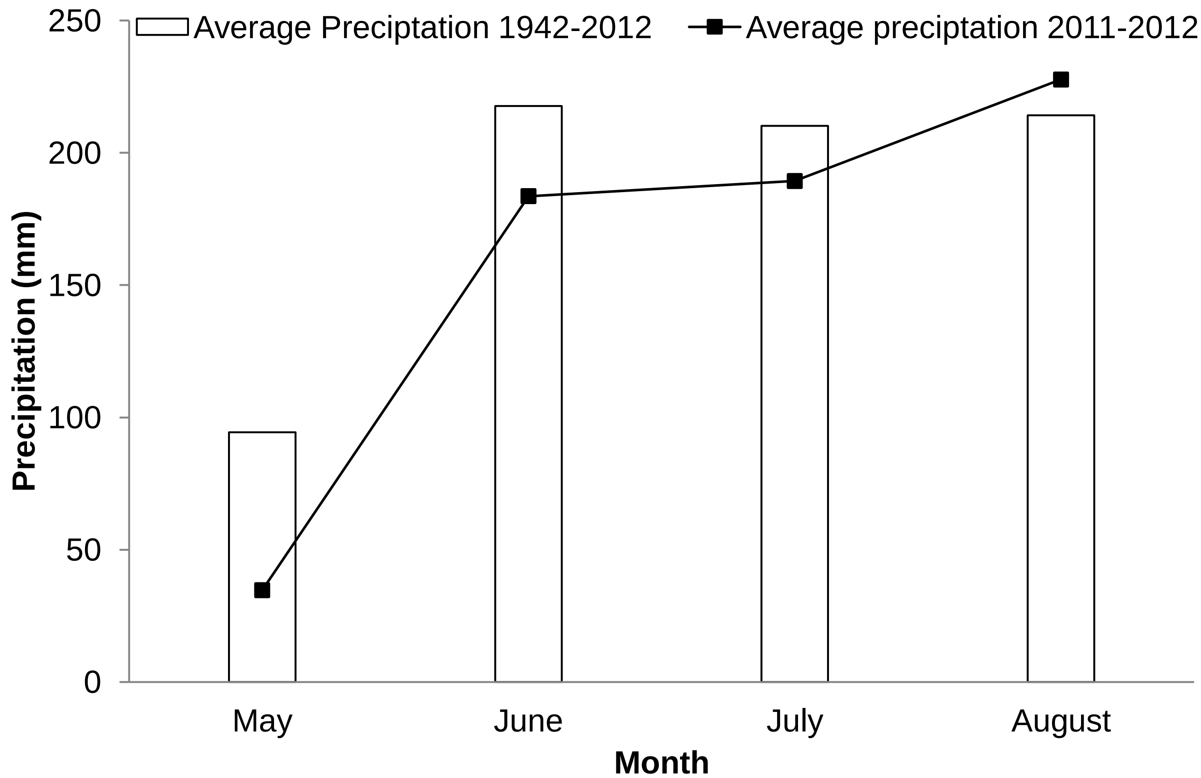

Figure 4-1: Average monthly precipitation from 1942 to 2012 and during the experimental period 2011 to 2012 at the Range Cattle Research and Education Center, Ona, FL.

Table 4-1: Herbage and animal responses of cow-calf pairs grazing limpograss pastures supplemented on creep-feeding with 200 g d^{-1} of soybean meal (200) or control (no supplement) in 2011 (Experiment 1).

Response variables	Treatment Control	200	*P* value	SE
Herbage responses				
Herbage mass (Mg ha^{-1})	4.4	4.7	0.54	0.8
Crude protein (g kg^{-1})	143	153	0.14	9
In vitro digestible organic matter (g kg^{-1})	624	626	0.92	14
Animal responses				
Herbage allowance (kg DM kg^{-1} LW)	2.2	2.4	0.68	0.3
Average daily gain (kg d^{-1})				
Calf	0.50	0.60	0.24	0.10
Cow	0.20	0.30	0.51	0.10
Cow body condition score	4.7	5.0	0.47	0.24
Gain per hectare (kg ha^{-1})	168	203	0.18	23

Table 4-2: Month effects on herbage and animal responses of cow-calf pairs grazing limpograss pastures and supplemented on creep-feeding with 200 g d^{-1} of soybean meal (200) or control (no supplement) in 2011 (Experiment 1).

Response variables	Month June	July	August	September	$P^{‡}$ value	SE
Herbage responses						
Herbage mass (Mg ha^{-1})	6.2 a†	5.0 b	4.3 c	2.8 d	<.0001	0.8
Crude protein (g kg^{-1})	105 c	177 a	131 b	140 b	<.0001	10
In vitro digestible organic matter (g kg^{-1})	582 b	652 a	606 b	660 a	<.0001	15
Animal responses						
Herbage allowance (kg DM kg^{-1} LW)	3.2 a	2.5 b	2.1 c	1.4 d	<.0001	0.3
Calf average daily gain (kg d^{-1})	1.1 a	0.7 b	0.3 c	0.2 d	0.02	0.1
Cow average daily gain (kg d^{-1})	1.0 a	-0.2 c	-0.1 c	0.3 b	0.34	0.1

†Means followed by the same letter within rows are not different ($P > 0.10$).
‡ *P* value for month effect.

Table 4-3: Herbage and animal responses of cow-calf pairs grazing limpograss pastures and supplemented by creep-feeding with 400 g d^{-1} of soybean meal (400), 200 g d^{-1} of soybean meal (200), or control (no supplement) in 2012 (Experiment 2).

Response variable	Treatment			Contrast		
	Control	200	400	Linear	Quadratic	SE
Herbage responses						
Herbage mass (Mg ha^{-1})	6.4	7.1	6.7	0.28	0.95	0.7
Crude protein (g kg^{-1})	126	108	119	0.17	0.63	8
In vitro digestible organic matter (g kg^{-1})	544	521	497	0.31	0.99	35
Animal responses						
Herbage allowance (kg DM kg^{-1} LW)	3.3	3.6	3.7	0.43	0.59	0.4
Average daily gain (kg d^{-1})						
Calf	0.33	0.44	0.62	0.03	0.76	0.10
Cow	0.10	0.40	0.20	0.44	0.39	0.12
Gain per hectare (kg ha^{-1})	82	112	152	0.03	0.69	17

Conversely, there was greater HM throughout the experimental period in Experiment 2, which likely resulted in greater proportion of stems and decreased nutritive value. It was observed by Inyang et al. (2010) that warm-season grass pastures with lesser HM tended to have greater nutritive value. Newman et al. (2002) observed that limpograss canopies grazed at 60-cm stubble height had greater HM and decreased nutritive value compared canopies grazed at 40 cm.

Animal Responses

Herbage allowance did not differ among treatments for Experiments 1 and 2 (Table 4-2). Similar HA was expected because of similar stocking rates and HM among treatments. There was a decrease in HA from June to September (Table 4-2) in Experiment 1. In Experiment 2, HA decreased from June to July and was similar in July and August (Table 4-4). The variation in HM was the main factor affecting HA, considering that there was little variation in body weight and stocking rates among treatments throughout the experimental period. Fike et al. (2003) indicated that HA levels below 1.0 kg DM kg^{-1} LW may result in decreased forage intake and animal performance. Inyang et al. (2010) observed that heifers grazing Mulato (*Brachiaria* spp.) and bahiagrass had decreased ADG at HA below 1.4 kg DM kg^{-1} LW. The HA levels observed in this study were above 1.4 kg DM kg^{-1} LW, indicating that forage quantity likely did not limit animal performance.

In Experiment 1, there was no difference in ADG of calves receiving supplementation on creep-feeding and control (Table 4-1). As a consequence, there was no difference in GHA between treatments. In Experiment 2, there was a linear increase in ADG of calves from control to supplementation with 400 g soybean meal d^{-1}.

Table 4-4: Month effects on herbage and animal responses of cow-calf pairs grazing limpograss pastures and supplemented by creep-feeding with 400 g d^{-1} of soybean meal (400), 200 g d^{-1} of soybean meal (200), or control (no supplement) in 2012 (Experiment 2).

Response variables	Month			$P^{‡}$ value	SE
	June	July	August		
Herbage responses					
Herbage mass (Mg ha^{-1})	8.2 a†	5.7 c	6.3 b	<.0001	0.6
Crude protein (g kg^{-1})	133 a	117 a	96 b	0.003	6
In vitro digestible organic matter (g kg^{-1})	627 a	485 b	450 c	<.0001	25
Animal responses					
Herbage allowance (kg DM kg^{-1} LW)	4.5 a	2.9 b	3.2 b	<.0001	0.4
Cow average daily gain (kg d^{-1})	0.7 a	-0.2 c	0.2 b	0.001	0.12

† Means followed by the same letter within rows are not different ($P > 0.10$).
‡ *P* values for month effect.

The increased levels of soybean meal likely resulted in greater rumen-degradable protein levels in the rumen and increased forage digestibility and intake (Vendramini et al., 2013). Lusby et al. (1985) reported an increase in ADG by 0.145 kg d^{-1} of calves grazing native pastures and 0.13 kg d^{-1} of calves grazing bermudagrass receiving on average 0.31 kg d^{-1} of cotton seed meal over the non-supplemented calves and no difference on cow ADG.

Calves supplemented with 0.45 kg d^{-1} of soybean meal grazing native pastures gained more weight than non-supplemented calves during the winter when forage nutritive value was low and when cows had limited milk production (Lusby and Wettemann, 1986). It is expected that calves receiving limited creep feed with a maximum of 0.6 kg d^{-1} of a 350 g kg^{-1} CP supplement decrease ruminal fiber and total tract NDF digestibility (Cremin et al., 1990). However, positive results to limited creep-fed CP supplement are not consistently achieved. Moriel and Arthington (2013a) reported two experiments testing creep-feeding molasses plus urea supplements (0.18

kg d^{-1}) to nursing calves and observed positive responses in only one experiment. Therefore, it is expected that the response to limit creep-feeding CP supplements to nursing calves may be significantly affected by factors other than the supplement, such as forage quantity and quality, environmental factors, and cow milk production.

There was a decline in ADG of calves from June to September (experiment 1) and June to August (experiment 2). The usual decrease in ADG in suckling calves generally occurs because of high rainfall and temperatures during the summer, which resulted in water standing on the pastures and likely depression in forage intake (Butris and Philips, 1987; Aiken et al., 1991). A linear increase in GHA was observed from control to 400 g soybean meal d^{-1} as a result of greater ADG.

There was no difference in ADG and body condition score of the cows from the creep-feeding or control treatments in Experiments 1 and no difference on ADG of cows in Experiment 2 (Table 4-1 and 4-3). Although there are few reports in the literature showing that creep-feeding may increase performance of the cows (Sticker et al., 1979; Prichard et al., 1989), it is usually observed that suckling calves will not replace milk by concentrate feed, expecting the cow to have the same nutrient requirements in creep-fed and control treatments. Tarr et al. (1994) found no difference in cow weight change between creep and no-creep treatments (mean = -19.0 kg) when calves were fed for 28, 56, or 84 d. Vendramini et al. (2012) observed that there was no difference in ADG of cows between calves receiving 10 g kg^{-1} of concentrate supplementation in creep-feeding and control.

There was a month effect on ADG of the cows in Experiment 1 and 2 (Table 4-2 and 4-4). The cows decreased ADG from June to July and subsequently increased from

July to August. The greater ADG in June may be result of filling effects caused by the transition of the cows from bahiagrass pastures to the experimental units with superior HM. The decrease in ADG in July may be a negative result of the greater rainfall and water standing on the pasture.

Economics Analysis

Calves supplemented with 200 and 400 g of soybean meal d^{-1} had an efficiency of added gain of 0.60 and 0.75, respectively (Table 4-5). Lower efficiency on calves consuming limited amount of protein supplemented feed have been reported in the literature from 0.14 to 0.21 (Faulkner et al., 1994 and Tarr et al., 1994). Moriel and Arthington (2013a) reported an overall gain efficiency of 0.38 for calves supplemented with molasses and urea. Greater values were reported by Lusby et al. (1985) when calves consumed limited amount of cottonseed meal grazing bahiagrass pastures 0.44 and native grasses, 0.36. The efficiency of added gain found in Experiment 2 is likely greater than the values found in the literature because the control calves in this study had decreased ADG, increasing the added gain and the efficiency of added gain. The cost of added gain was \$0.80 and \$0.64 kg LW^{-1}, for the 200 and 400 treatments, respectively (Table 4-5). There was a linear increase in income and return as supplement levels increased (Table 4-6). The linear increase in return was the result of the significant increase in added gain and limited feed amounts, which resulted in decreased feed cost.

Table 4-5: Average daily gain, added gain, added BW, amount of feed, cost of feed, cost of added gain, and efficiency of added gain responses of suckling calves grazing limpograss pastures and supplemented on creep-feeding 400 g d^{-1} of soybean meal, 200 g d^{-1} of soybean meal, or control in 2012 (Experiment 2).

	Treatment[1]		
Response variables	0	200	400
Average daily gain (kg d^{-1})	0.32	0.44	0.62
Added average daily gain (kg)		0.12	0.30
Added body weight (84 d)		10.1	25.2
Amount of feed (kg/animal)		16.8	33.6
Cost of feed ($, period)[2]		8.1	16.1
Cost of added gain ($/kg)[3]		0.80	0.64
Efficiency of added gain (kg SBM/kg BW)[4]		0.60	0.75

[1] 0, 200, or 400 g/d of soybean meal, price ($/kg) = 0.48
[2] Amount of feed*cost/kg
[3] Cost of feed/added body weight
[4] Amount of feed/added body weight

Table 4-6: Economic analysis of cow-calf pairs grazing limpograss pastures and supplemented on creep-feeding with 400 g d^{-1} of soybean meal, 200 g d^{-1} of soybean meal, or control in 2012 (Experiment 2).

		Treatment[1]				
Response variables	0	200	400	Contrast	*P* value	SE
Feed cost[1]	0	24.2	48.4			
Gross income[2]	278.0	418.0	522.0	L	0.03	43
Gross return[3]	278.0	393.8	473.6	L	0.06	55

[1] 0, 200, or 400 g/d of soybean meal, price ($/kg) = 0.48
[2] Gain per area (kg ha^{-1})*calf price ($/kg) = 3.3
[3] Income – feed cost

Important Findings and Implications

Limit creep-feeding of 200 g soybean meal d^{-1} to cow-calf pairs grazing limpograss pastures had no effect on ADG of the calves; however, increasing levels of limited creep-feeding soybean meal from 0 to 400 g d^{-1} linearly increased the ADG of the calves in Experiment 2. There was no effect of creep-feeding treatments on forage characteristics and performance of the cows in both experiments. Forage quantity and nutritive value varied throughout the experiment periods, which may have affected the performance of cows and calves. However, the excessive rainfall and water standing on the pastures during the summer in South Florida may be the main reason for the decrease in calf performance from June to August. It seems that greater levels of soybean meal supplementation may alleviate the decrease in ADG of the calves in the summer months, resulting in heavier calves at weaning. The economic analyses demonstrated that the 400 g soybean meal d^{-1} was the most efficient gain with the greatest economic return. Due to the inconsistency in ADG of calves receiving creep-feeding, further studies on the duration and levels of creep feeding are necessary to verify the precision of creep-feeding 400 g soybean meal d^{-1} as a minimum levels to efficiently increase weaning weights in cow-calf operations in Florida.

CHAPTER 5
EFFECT OF STOCKING RATE ON HERBAGE RESPONSES AND ANIMAL PERFORMANCE OF BEEF HEIFERS GRAZING ‘JIGGS’ BERMUDAGRASS PASTURES

Overview of the Research Problem

Bermudagrass [*Cynodon dactylon* (L.) Pers.] is an important warm-season grass species for livestock production in the southeast USA (Hill et al., 2001) and can be used for grazing, hay, or silage (Taliaferro et al., 2004). In 1943, ‘Coastal’ bermudagrass was the first hybrid bermudagrass released, and others followed (Taliaferro et al., 2004). Most of the bermudagrass cultivars released were suitable for livestock production, but the majority of them are not adapted to poorly drained soils. Production and persistence may be decreased under those conditions. Furness and Breen (1982) reported a decrease of 74% in the area covered by bermudagrass after flooding periods of 161 d in South Africa. During flooding, plant respiration slows due to decreasing oxygen in the root zone, followed by depletion in carbohydrates, and increase of toxic compounds, which can consequently affect growth and cause death of plants (Colmer and Voesenek, 2009).

Jiggs is a bermudagrass that was distributed by a private company in Texas (Ocumpaugh and Stichler, 2000); however, there is no report of the release published in the literature. According to Vendramini (2008), Jiggs tolerates poorly drained soils and may be a productive bermudagrass cultivar for the poorly drained flatwoods soils in South Florida unlike other bermudagrass cultivars. Vendramini et al. (2010) compared four bermudagrasses, Jiggs, ‘Coastcross-2’, ‘Tifton-85’ (*Cynodon* spp.), and ‘Florakirk’, and reported that Jiggs had the greatest herbage accumulation among the bermudagrass cultivars during the summer in Florida. Mislevy et al. (2008) evaluated herbage accumulation and nutritive value of Jiggs and Tifton 85 using the mob stocking technique and reported greater herbage accumulation for Jiggs than Tifton 85 (13.9 vs. 11.9 Mg ha^{-1}). The same authors did not find differences in crude protein (CP) among cultivars but Tifton 85 had greater in vitro digestible organic matter (IVDOM) concentrations than Jiggs (638 vs. 561 g kg^{-1}). Despite the preliminary information presented by Mislevy et al. (2008), further information on the effects of grazing management on Jiggs is not known.

Stocking rate is one of the most important management factors in grazing systems and has a direct effect on herbage mass (HM) and animal performance (Burns et al., 1999). Hernández Garay et al. (2004) evaluated the effects of stocking rates from 2.5 to 7.5 head ha^{-1} on stargrass (*Cynodon nlemfuensis* Vanderyst) herbage mass (HM), nutritive value, and animal performance. They observed that there was a linear decrease in HM and average daily gain (ADG) with increasing stocking rates. Conversely, there were linear increases in CP and neutral detergent fiber (NDF) concentrations. Inyang et al. (2010) reported a linear decrease in HM and a quadratic increase in herbage accumulation rate (HAR) on bahiagrass (*Paspalum notatum* Flügge) and Mulato II (*Brachiaria* spp.) pastures as stocking rate increased from 4 to 12 heifers ha^{-1}. The authors also reported a linear decrease in ADG and a quadratic effect on animal liveweight gain per area as stocking rate increased. In addition to the effects on herbage quantity, nutritive value, and animal performance, stocking rate and grazing intensity can affect persistence of warm-season grass pastures. Inyang et al. (2010) observed that ground cover of Mulato II plots declined from 87 to 74% as the harvest stubble height decreased from 12.5 to 2.5 cm.

Despite preliminary information presented by Mislevy et al. (2008), further information is needed on the effects of grazing on Jiggs bermudagrass. In addition, there are no known studies evaluating performance of beef cattle grazing Jiggs pastures. The objective of this study was to evaluate animal performance and forage characteristics of Jiggs bermudagrass pastures grazed at different stocking rates.

Material and Methods

The study was conducted at the UF/IFAS University of Florida Range Cattle Research and Education Center (RCREC), Ona, FL (27^{o} 26' N and 82^{o} 55' W) from May to August 2011 and 2012. The soil at the research site was a Pomona fine sand (siliceous, hyperthermic, Ultic Alaquod) that is poorly drained with slow permeability. Prior to initiation of the grazing trial, mean soil pH (in water) was 6.4. Mehlich-I (0.05-M HCl + 0.0125-M H2SO4) extractable P, K, Mg, and Ca concentrations in the Ap1 horizon (0- to 15-cm depth) were 48, 83, 361, and 2202 mg kg^{-1}. Pastures were fertilized in March 2011 and 2012 with 40, 18, and 33 kg of N, P, and K ha^{-1}, respectively, followed by two applications of 40 kg N ha^{-1} in mid-June and early August. The N fertilizer used was ammonium nitrate.

Pastures (0.25-ha experimental units) were established in August 2010 and grazing was initiated in May 2011 and 2012. The experimental period was from May to August of 2011 and 2012.Heifers were Angus-sired (crossbred cows sired by Angus bulls) early weaned beef heifers (*Bos* spp.) with initial body weight (BW) of 172 ± 23 kg and 168 ± 21 kg in 2011 and 2012, respectively. The final BW was 216 ± 26 and 218± 30 kg in 2011 and 2012, respectively. Calves were weaned at approximately 90 d of age and grazed annual ryegrass (*Lolium multiflorum* Lam.) while receiving 10 g kg^{-1} BW in concentrate supplement (140 g kg^{-1} CP and 780 g kg^{-1} TDN) supplement from January to May 2011 and 2012.

Treatments were the factorial arrangement of three stocking rates [2 (low), 5 (medium), and 8 (high) heifers ha^{-1}] in a randomized incomplete block design with three replicates for low and medium and two replicates for the high stocking rate treatment. The average stocking rates proposed in this study were the equivalent of 3.7, 8.8, and 13.1 animal units (450 kg LW) ha^{-1}. Pastures were grazed using a fixed and continuous stocking rate. Although the initial and final BW of the calves were similar among treatments and years, the final stocking rate for low, medium and high stocked pastures were 3.6, 8.9, and 14.2 AU ha^{-1}, respectively.

Herbage Measurements

Pastures were sampled just prior to initiation of grazing and every 14 d during the grazing period. Herbage mass, herbage accumulation rate (HAR), herbage height, canopy light interception, and herbage CP and IVDOM were measured. The double sampling technique was used to determine HM. The indirect measure was the settling height of a 0.25-m^2 aluminum disk, and the direct measure involved hand clipping all herbage to 2.5 cm above soil level using an electric clipper. Every 28 d, two or three double samples were taken from each of the eight experimental units for a total of 20 double samples per date. Sites for double sampling were chosen to represent the range of herbage mass present on the pastures. At each site, the disk settling height was measured and the forage under the disk was clipped at ground level. Clipped forage was dried for 72 h and weighed. Indirect measures (disk heights) were taken every 14 d at 20 sites per pasture. Sites were selected by walking a fixed number of steps between each drop of the disk to ensure that all sections of the pasture were represented. The average disk height of the 20 indirect measures was entered into the regression equation developed from double sampling to predict HM. The average r^2 values for the equations were 0.70 and 0.88 for 2011 and 2012, respectively.

Because these pastures were stocked continuously, a cage technique was used to measure HAR. Three 1-m^2 cages were placed in the pasture at the initial sampling date. Placement sites were chosen where the disk settling height was the same (± 1 cm) as the pasture average. Disk settling height was recorded at a specific site and the cage placed. After 28 d, the cage was removed and the new disk settling height recorded. Herbage accumulation rate was calculated as the change in HM during the 28 d that the cage was present. At the end of each 28-d period, cages were moved to new locations on the pasture with a current average disk settling height. Herbage allowance was calculated for each pasture as the average HM (mean across two sampling dates within each 28-d period) divided by the average total heifer live weight during that period (Sollenberger et al., 2005).

Herbage CP and IVDOM concentration were measured at the initiation of grazing and every 14 d thereafter for a composite of twenty hand-plucked samples taken from each pasture. Samples were taken to the average stubble height of each pasture to attempted simulate what animals were consuming during each period of the collection. Hand-plucked samples were dried at 60°C for 48 h in a forced-air oven to constant weight, and ground in a Wiley mill (Model 4, Thomas-Wiley Laboratory Mill, Thomas Scientific, Swedesboro, NJ) to pass a 1-mm stainless steel screen. Analyses were performed at the University of Florida Forage Evaluation Support Laboratory using the micro-Kjeldahl technique for N (Gallaher et al., 1975) and the two-stage technique for IVDOM (Moore and Mott, 1974).

Three forage samples per experimental unit were harvested from a 0.25-m^2 area at 2.5-cm stubble height and manually separated in leaf and stem every 14 d. The proportion of leaf, stem, and senescent material in the canopy and CP and IVDOM of leaf and stem was reported. Canopy light interception (LI) was measured using AccuPAR LP-80 ceptometer (Decagon Devices, Pullman, WA). Eight readings were taken in each experimental unit at 1000 h every 14 d. The beam fraction sensor was placed at the center of each half of the paddock and four readings were taken with a 90° distance from each other with the probe placed at ground level. The probe was placed in the same direction for all measurements. The measurements provided by the Accupar system were light transmitted, spread and incident, beam fraction, zenith angle. Canopy LI was calculated by dividing transmitted by incident light times 100 and subtracted from 100. Mean undisturbed sward height was measured at eight sites per experimental unit every 14 d.

Animal Measurements

Body weight of the heifers was recorded at initiation of the experiment and every 28 d thereafter. Weights were taken at 0800 h following a 16-h shrink period. Average daily gain was calculated each 28-d period through the entire grazing season. Gain per hectare (GHA) was calculated for each pasture over the entire grazing season. Animals received a concentrate supplement (140 g kg^{-1} CP and 780 g kg^{-1} TDN) at 10 g kg^{-1} body weight daily. Previous research showed that 10 g kg^{-1} of body weight of concentrate energy supplementation (146 g CP kg^{-1} and 780 g TDN kg^{-1}) is necessary for early weaned beef calves grazing warm-season annual pastures to have satisfactory performance (Vendramini et al., 2007).

Statistical Analyses

The response variables (ADG, GHA, HM, HAR, forage height, LI, HA, CP, and IVDOM) were analyzed by fitting mixed-effects models using the PROC MIXED procedure of SAS (SAS Institute Inc., 1996). Block, year, and its interactions were considered random effects. Months were analyzed as repeated measures. Treatments were considered different when $P < 0.10$. Interactions not discussed were not significant ($P > 0.10$). Single degree of freedom orthogonal contrasts were used to compare stocking rate effects. The means reported are least squares means and were separated by Fisher's protected least significant difference (LSD) at $P < 0.10$. Pearson correlation coefficients among LI, HA, and sward height were generated using PROC CORR of SAS (SAS Institute Inc., 2006).

Results and Discussion

Herbage Responses

Herbage mass decreased linearly from 3.8 to 2.4 Mg ha^{-1} as stocking rate increased from low to high (Table 5-1). The effects of stocking rate on HM has been reported in the literature and a decrease in HM with greater stocking rates is a consequence of increased forage intake from a greater number of animals. Likewise, Inyang et al. (2010) reported a decrease in HM from 5.9 to 3.2 Mg ha^{-1} as stocking rate increased from 4 to 12 heifers ha^{-1}. There was a decrease in HM from May to June and a subsequent increase in July. There was no difference in HM between July and August (Table 5-2). The greater HM in May was consequence of the HM accumulation from the spring to the time of the initiation of the study. Herbage mass decreased in June due to grazing and subsequently increased in July likely because of the N fertilization in late June and favorable rainfall and temperature (Figure 5-1).

Table 5-1: Effects of stocking rate on herbage responses of Jiggs bermudagrass pastures.

Response variable	Treatment			Contrast		
	Low	Medium	High	Linear	Quadratic	SE
Herbage mass (Mg ha^{-1})	3.8	3.2	2.4	<0.01	0.53	0.4
Light intercepted (%)	94	85	71	<0.01	0.68	1
Height (cm)	17	12	9	<0.01	0.62	1
Herbage accumulation rate (kg ha^{-1} d^{-1})	63	73	78	0.09	0.72	5
Crude protein (g kg^{-1})						
Hand-plucked sample	158	158	158	0.97	0.98	6
Leaf	192	201	222	0.02	0.37	5
Stem	102	97	103	0.98	0.42	6
In vitro digestible organic matter (g kg^{-1})						
Hand-plucked sample	486	482	516	0.23	0.35	18
Leaf	518	530	569	<0.01	0.20	18
Stem	520	507	510	0.97	0.21	12

Table 5-2: Month effects on forage responses of Jiggs bermudagrass pastures. Data are means across three stocking rates.

	Month				
Response variable	May	June	July	August	SE
Herbage mass (Mg ha^{-1})	3.6 a†	2.4 c	3.1 b	3.3 b	0.3
Herbage accumulation rate (kg ha^{-1} d^{-1})	30 c	43 c	98 b	114 a	9
Light interception (%)	93 a	82 b	80 b	78 b	2
Height (cm)	14 a	11 c	13 b	13 b	1
Crude protein (g kg^{-1})	158	165	161	150	8
In vitro digestible organic matter (g kg^{-1})	468 b	462 b	519 a	530 a	21

†Within rows, means followed by the same lowercase letter are not different ($P > 0.10$).

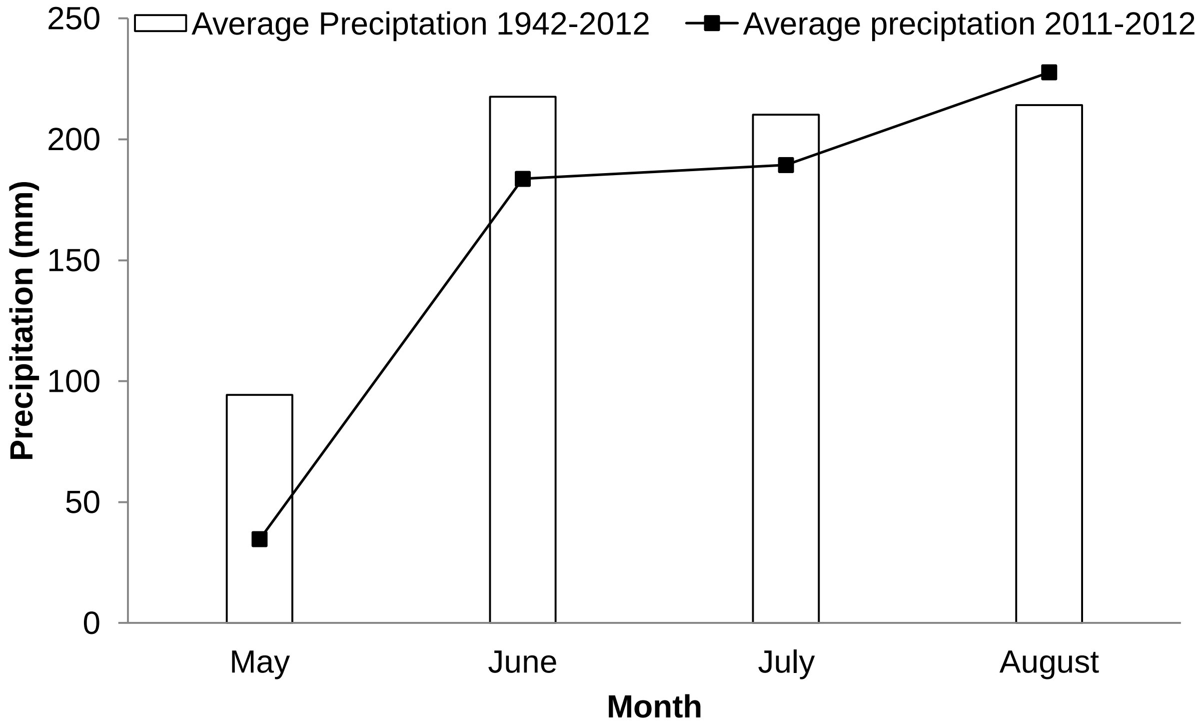

Figure 5-1: Average monthly precipitation from 1942 to 2012 and during the experimental period 2011 to 2012 at the Range Cattle Research and Education Center, Ona, FL.

There was a linear increase in HAR as stocking rate increased (Table 5-1). Pastures grazed at low stocking rate had decreased HAR because the excess HM, which resulted in self-shading, accumulation of non-photosynthetic residue, especially on the young basal tillers (Adjei et al., 1980), and reduced photosynthesis (Parsons et al., 1988; Hernandez Garay et al., 2000). Similar results were reported by L'Huillier (1987), which demonstrated that there was an increase in HAR from 51.3 to 68.2 kg ha^{-1} d^{-1} as stocking rate of dry jersey cows grazing perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.) pastures increased from 2.77 to 4.28 cows ha^{-1} during the summer. Additionally there was a month effect (Table 5-2) in HAR. The HAR was similar in May and June and increased in July and August (Table 5-2). The increase in HAR in July and August occurred because of the N fertilization and greater rainfall in those months (Figure 5-1).

There was no difference among treatments in proportion of leaf, stem, and senescent material, with averages of 14, 45, and 41%, respectively; however, there was monthly variation in plant morphology. The leaf:stem ratio increased from May to June before decreasing in July and August (Table 5-3). The reason for increasing proportion of stems is likely due to greater HAR resulted from greater temperature and rainfall. According to Mislevy et al. (2001) and Ezenwa et al. (2006), higher temperatures may result in rapid growth and greater contribution of lignified tissues with reduced digestibility. In addition, animals likely selected leaves with greater nutritive value (Table 5-2) and decreased the proportion of leaves.

Table 5-3: Month effect on leaf, stem, and dead material proportion of Jiggs bermudagrass pastures. Data are moans across three stocking rates

	Month				
Response variable	May	June	July	August	SE
	--------------%------------				
Leaf	8 c[†]	16a	16 a	13 b	2
Stem	41 b	35 c	53 a	51 a	2
Dead	51 a	48 a	31 c	36 b	2

[†]Within rows, means followed by the same lowercase letter are not different ($P > 0.10$).

There was a linear decrease in canopy LI and forage height as stocking rate increased from low to high (Table 5-1). Light interception decreased from May to June and remained constant until August (Table 5-2). The low stocking rate treatment had 93% LI, which is similar to the 95% LI indicated by da Silva and Nascimento Junior (2007) as optimum levels for herbage accumulation and nutritive value of warm-season grasses. The medium and high stocking rates had LI below 95% but with greater HAR than for low stocking rate. This may indicate that 95% LI does not always maximize HAR across a range of species. Forage height decreased from May to June, increased in July, and remained constant in August, corroborating the HM and HAR data (Table 5-2). Forage height was greater in May, likely because of the extended growing period before the initiation of the experiment, and decreased in June as result of grazing and decreased HAR. Correlations between LI and forage height were significant (Table 5-4), however, only 31% of the relationship between the variables was explained by the model (r = 0.31). da Silva and Nascimento Junior (2007) stated that forage height and light interception are well correlated, therefore it is practical to have a constant grazing height to manage warm-season grasses for optimum herbage accumulation and nutritive value. The low correlation coefficient between height and LI in this experiment calls into question this conclusion. Management practices and climatic conditions may affect plant structure, especially density and leaf angle (Fagundes et al., 1999) and may be responsible for variation in the relationship between LI and forage height.

Table 5-4: Correlations among herbage mass, light interception, and forage height of Jiggs bermudagrass pastures grazed at different stocking rates.

Response Variable	Herbage mass	Light interception	Forage height
Herbage mass	-	$r = 0.11$	$r = 0.71$
		$P = 0.37$	$P < 0.01$
Light interception	$r = 0.11$		$r = 0.56$
	$P = 0.37$	-	$P < 0.01$
Forage height	$r = 0.71$	$r = 0.56$	
	$P < 0.01$	$P < 0.01$	-

Nutritive Value and Botanical Composition

There was no difference in hand-plucked herbage CP and IVDOM concentrations among treatments (Table 5-2). It was observed in previous studies with warm-season grasses that increasing stocking rate increased forage nutritive value (Inyang et al., 2010; Hernandez Gray et al., 2004) mainly due to the more frequent appearance of new tissue with greater nutritive value. Crude protein concentrations were also similar across months; however, there was an increase in IVDOM from May to August. The long regrowth period from the start of the growing season to the start of the experimental period (May) decreased IVDOM. Vendramini et al. (2007) reported an increase in IVDOM from May to June (from 573 to 681 g kg^{-1}) but a decrease in July and August, 603 and 640 g kg^{-1}, respectively on Tifton 85 pastures; however, there was no month effect on CP concentration.

There was a linear decrease in Jiggs ground cover with increasing stocking rate after the 2-yr experiment. Conversely, there was a linear increase in common bermudagrass and a quadratic increase in broadleaf weeds (Table 5-5). Greater stocking rate treatments resulted in shorter forage height and lesser canopy LI, which likely resulted in insufficient leaf area to optimize photosynthesis and restore plant reserves. Common bermudagrass tolerates shorter stubble heights and likely occupied the open spaces in the pastures. Mislevy et al. (1998) reported an increase in common bermudagrass (36%) when 'Florico' stargrass (*Cynodon nlemfuensis* Vanderyst var. nlemfuensis) was grazed at a 2-wk interval for 3 yr. Interrante et al. (2009) found that frequent and intense defoliation reduced 'Tifton 9' and 'UF-Riata' bahiagrass ground cover to < 40%, indicating that even more persistent warm-season grass species may decrease ground cover under severe defoliation.

Table 5-5: Botanical composition of Jiggs bermudagrass pastures.

	Treatment			Polynomial Contrast		
Response Variable	Low	Medium	High	Linear	Quadratic	SE
	---------- % ----------					
Jiggs	95	78	39	<0.01	0.16	8
Common Bermuda	4	17	36	0.02	0.67	9
Weed	2	5	25	<0.01	0.01	2

Animal Responses

There was a linear decrease from 2.3 to 0.4 kg DM kg^{-1} LW in HA from low to high stocking rates (Table 5-6). The decrease in HM and greater stocking rates were the main factors influencing the decrease in HA. Inyang et al. (2010) reported a decrease in HA from 2.8 to 0.6 kg DM kg^{-1} LW as stocking rates increased from 4 to 12 heifers ha^{-1} grazing bahiagrass and Mulato pastures. There was a month effect on HA, which was similar to the variation in HM. The greatest HA was observed in May with subsequent decline in June and similar HA from June to August (Table 5-7).

Table 5-6: Animal responses of heifers grazing Jiggs bermudagrass pastures.

	Treatment			Polynomial Contrast		
Response variable	Low	Medium	High	Linear	Quadratic	SE
Herbage allowance (kg DM kg^{-1} LW)	2.3	0.8	0.4	<0.01	0.04	0.1
Average daily gain (kg d^{-1})	0.7	0.4	0.3	<0.01	0.13	0.04
Gain per hectare (kg ha^{-1})	692	975	1064	0.01	0.20	72

Average daily gain decreased linearly from 0.7 to 0.3 kg d^{-1} as stocking rate increased from low to high (Table 5-6). The decrease in ADG was likely caused by the decrease in HA with increasing stocking rates. Inyang et al. (2010) observed that HA of less than 1.4 kg DM kg^{-1} LW decreased ADG of heifers grazing bahiagrass and Mulato pastures. In this study, calves were supplemented with 10 g kg^{-1} of body weight, which likely decreased forage intake and the required levels of HA. Vendramini et al. (2013) observed that 10 g kg^{-1} of body weight of concentrate supplementation is approximately 33% of the total dry matter intake of early weaned calves receiving stargrass. However, Vendramini and Arthington (2008) reported that there was a decrease in ADG of early weaned calves grazing stargrass pastures when HA decreased from 1.0 to 0.7 kg DM kg^{-1} LW. In addition, the decrease in HA with greater stocking rates likely decreased the opportunity for calves to select plant parts with greater nutritive value. This resulted in intake of forage with lesser nutritive value and resulted in reduced ADG.

There was a month effect on ADG (Table 5-7). Animal performance declined from May to June, increasing again in July and declining in August. The greater ADG in May occurred due to greater gut fill resulting from the transition of the calves from annual ryegrass pastures to bermudagrass in May, which was also observed in previous studies (Vendramini and Arthington, 2008). The decline in ADG in June and subsequent increase in July may be related to the variation in HA in those months (Table 5-7). In August, greater temperature and rainfall resulted in water standing on the pastures and decreased performance of the calves. Such conditions decrease grazing time, forage intake and animal performance (Butris and Philips, 1987; Aiken et al., 1991).

Table 5-7: Month effects on animal responses of Jiggs bermudagrass pastures. Data are means across three stocking rates.

Response variable	Month				
	May	June	July	August	SE
Herbage allowance (kg DM kg LW^{-1})	1.6 a†	0.9 c	1.1 b	1.1 b	0.2
Average daily gain (kg d^{-1})	0.9 a	0.4 c	0.6 b	0.0 d	0.1

†Within rows, means followed by the same lowercase letter are not different (P>0.10).

There was a linear increase from 692 to 1064 kg ha^{-1} in GHA as stocking rate increased from low to high (Table 5-6). Despite greater ADG with low stocking rates, the increased number of animals in the high stocking rate resulted in greater GHA. Derner et al. (2008), working with mixed-grass prairie and yearlings steers (247 ± 24 kg), reported a linear increase in GHA from ~10 to 60 kg ha^{-1} as stocking rate increased from 0.20 to 0.44 steers ha^{-1}. According to Mott and Moore (1985), there should be a linear decrease in ADG and quadratic relationship of GHA with increasing stocking rates. In this study, the inclusion of concentrate in the diet of the calves may have influenced the shape of the response of GHA to increasing stocking rates.

Important Findings and Implications

Stocking rate had significant effects on forage and animal responses on Jiggs bermudagrass pastures. Increasing stocking rates decreased HM, forage height, canopy LI, and HA, which decreased ADG of calves. However, GHA increased linearly with increasing stocking rate. The greatest detrimental effect of increasing stocking rates was the reduction in forage height and LI, which resulted in significant reduction in Jiggs ground cover after 2 yr of grazing. Considering that persistence is one of the most important attributes of warm-season perennial grasses, Jiggs pastures must be managed as the low SR treatment in this experiment and should not be grazed below 17-cm stubble to maintain the ground cover of the desirable forage species.

CHAPTER 6
SUMMARY AND CONCLUSIONS

Summary

Warm-season grasses are the main source of forage for cow-calf operations in Florida. Although warm-season grasses have rapid forage accumulation during the growing season (spring, summer, and early autumn) in tropical and subtropical regions, herbage accumulation and nutritive value are reduced during the winter. Therefore, supplementation may be necessary to maintain the productivity of the cattle herd during the months with shortage of forage quantity and limited quality.

Stockpiling forage is a strategy that allows forage to accumulate during the growing season to be grazed at a later date, usually during the winter when growth ceases of most warm-season grasses. Limpograss [*Hemarthria altissima* (Poir.) Stapf & C.E. Hubb.] is commonly used for stockpiled forage mainly because it has greater herbage accumulation and digestibility than other warm-season grasses in the winter; however, crude protein (CP) concentration is usually limiting. Therefore, a protein supplementation program is necessary to overcome the reduced CP concentrations of stockpiled limpograss.

The most common protein supplements are soybean [*Glycine max* (L.) Merr.] meal, cottonseed (*Gossypium* spp.) meal, and urea mixed with molasses-based supplement. Studies have been conducted to evaluate different sources of protein for animals grazing warm-season grasses; however, there are few studies that have tested the effects of different sources of rumen-degradable protein (RDP) on performance of cow-calf pairs grazing stockpiled limpograss.

Creep feeding is another supplementation strategy that can be used to provide supplement to calves on pasture. Creep feeding is a management practice used to provide extra nutrients to suckling calves in a sectioned-off part of the pasture, which prevents the mother from gaining access to the feed. Creep feeding has been used extensively in cow-calf production systems; however, low feed efficiency generally results in reduced economic feasibility and limited interest by producers. Creep feeding programs that target nutrients in limited supply for calves has been somewhat effective in improving performance when forages are of poor nutritive value. Supplementing limited sources of RDP to calves in creep feeding may be an effective management practice to increase productivity of cow-calf systems. The effects of creep feeding limited amounts of RDP to cow-calf pairs grazing limpograss pastures during the summer in Florida are not known.

Bermudagrasses [*Cynodon dactylon* (L.) Pers.] are the most planted warm-season grass in the southeastern USA. They are characterized by high yields, good nutritive value, and persistence under grazing. The most planted bermudagrasses in the southern USA are ‘Coastal” and ‘Tifton 85’ (*Cynodon* spp.); however, they are not persistent and productive on the poorly drained soils commonly found in South Florida. Jiggs bermudagrass has generated interest from producers in South Florida because it tolerates poorly drained soils. Clipping studies have been conducted in South Florida and showed superior herbage accumulation and comparable nutritive value of Jiggs when compared with other warm-season grasses. However, there is limited information on grazing management of Jiggs bermudagrass pastures.

In order to generate information about supplementation strategies on limpograss pastures and grazing management of Jiggs pastures, three studies were conducted. The first study (Chapter 3) evaluated the effect of feeding different sources of RDP supplement, cottonseed meal vs. urea, on performance of cow-calf pairs grazing stockpiled limpograss pastures during the winter. The second study (Chapter 4) evaluated the effects of creep feeding limited protein supplement on performance of cow-calf pairs grazing limpograss pastures during summer. The third study (Chapter 5) assessed the effect of stocking rate on herbage responses and performance of beef heifers grazing Jiggs pastures during summer. The studies were conducted at the UF/IFAS Range Cattle and Education Center, Ona, FL, in 2011 and 2012. The general objective of these studies was to improve the efficiency of forage utilization and performance of beef cattle production in South Florida.

Stockpiled Limpograss Studies

Grazing study

This experiment was conducted from January to March 2011 and 2012. Treatments were two sources of RDP supplement, urea or cottonseed meal, in addition to a molasses-based supplement. Treatments were isonitrogenous (750 g CP d^{-1}), with the same amount of RDP (480 g d^{-1}) and rumen-undegradable protein (RUP; 270 g d^{-1}), and isocaloric (2.57 kg total digestible nutrients d^{-1}). Each treatment was replicated four times in a completely randomized design. The supplement was offered three times a week, Monday, Wednesday, and Friday. Pastures (experimental units) were stocked continuously using a fixed stocking rate with three cow-calf pairs per pasture. Cows averaged 418 ± 59 and 413 ± 46 kg of body weight (BW) and calves 100 ± 19 in 2011 and 78 ± 12 kg of BW in 2011 and 2012, respectively. Pastures (1-ha experimental units) were clipped at 10-cm stubble height in October of 2010 and 2011, fertilized with 90 kg N ha^{-1}, and stockpiled for ~ 90 d.

Herbage mass (HM), allowance (HA), and nutritive value were similar on stockpiled limpograss pastures grazed by cow-calf pairs supplemented with two sources of RDP. There was a year and month effect on all herbage responses. Different rainfall patterns and number and timing of freezing events during the stockpiling and grazing period resulted in greater HM in 2012 compared to 2011. There were no differences between treatments in cow-calf performance, however there were year and month effects on cow and calf average daily gain (ADG). Animal performance decreased over time and followed the same pattern of decrease as HM and HA. Blood urea nitrogen (BUN) increased over time as consequence of the protein supplementation.

Drylot study

A drylot study was conducted to evaluate the dry matter intake (DMI) of cows receiving the same treatments described in the grazing phase. Cow-calf pairs (two pairs per pen, four replicates per treatment) received ground limpograss hay (63 g kg^{-1} CP and 520 g kg^{-1} TDN) with 10% refusals. Only the cows had access to the supplement and hay, and calves were fed separately. There were 10 d of adaptation period and 7 d of DMI collection in 2011 and 2012. Dry matter intake was determined daily. There were no differences in forage and total DMI between treatments, supporting the data from the grazing study where no differences were found on cow and calf performance.

Metabolic study

Two rumen-fistulated steers were allocated in one of two metabolic cages and received the same treatments described in the grazing study in a 2 x 2 Latin square design in 2011 and 2012. There were 10 d of adaptation, followed by 2 d of blood and rumen fluid collection in a 2-h interval for the first 24 h and every 4 h for the next 24 h after the supplement was offered.

There were no differences in BUN, ruminal pH and ammonia, total volatile fatty acids concentration, propionic, acetic, and butyric acid concentrations, and branched chain fatty acids between treatments. There was a time effect on ruminal ammonia and pH, and BUN. Blood urea nitrogen and ruminal ammonia increased after supplementation and decreased thereafter, while ruminal pH decreased after supplement was offered and increased subsequently. Urea was as effective as cottonseed meal as a source of RDP for cows grazing stockpiled limpograss when fed with molasses supplements.

Creep-feeding Study

Two experiments were conducted to test the effect of limit creep-feeding protein supplements to calves grazing limpograss pastures during summer 2011 (June to September, Experiment 1) and 2012 (June to August, Experiment 2). In Experiment 1, treatments were calves receiving 0 or 200 g d^{-1} of SBM (480 g CP kg^{-1}) in a randomized complete block design with four replicates. In Experiment 2, the treatments were 0, 200, and 400 g d^{-1} of SBM in a randomized incomplete block design with three replicates for Control and 200 treatments, and two replicates for the 400 treatment. There were eight limpograss pastures (1-ha experimental units) with three cow-calf pairs per pasture. Calves were approximately 6 mo of age at the initiation of the study. Pastures were fertilized with 90 kg N ha^{-1} in April 2011 and 2012.

No treatment differences were found for HM, HA, and nutritive value in either experiment. There was no difference in cow-calf performance in Experiment 1, but in Experiment 2, there was a linear increase in calf ADG and GHA as supplement increased from 0 to 400 g d^{-1}. There were no differences in cow performance. During both experiments, cow-calf performance decreased over time, as a consequence of the decline in HM and HA, as well as adverse environmental conditions including water standing on the pastures and high temperature and humidity. In Experiment 2, there was a linear increase in income and return as supplementation increased from 0 to 400 g of SBM d^{-1}.

Jiggs Bermudagrass Grazing Study

The study was conducted during the summer 2011 and 2012. Treatments were a factorial arrangement of three stocking rates (SR) [2 (low), 5 (medium), and 8 (high) heifers ha^{-1}) in a randomized incomplete block design with three replicates for low and medium and two replicates for the high stocking rate treatment. The equivalent stocking rates of 3.7, 8.8, and 13.1 animal units (450 kg LW) ha^{-1} were targeted in this study. Eight 0.25-ha Jiggs pastures were used as experimental units. Fertilization management was 40, 18, and 33 kg of N, P, and K ha^{-1}, respectively, applied in March 2011 and 2012 followed by two applications of 40 kg N ha^{-1} in the middle of June and early August each year. Animals were Angus-sired heifers (crossbred cows sired by Angus bulls) with initial BW of 172 ± 23 kg and 168 ± 21 kg in 2011 and 2012, respectively, and final BW of 216 ± 26 and 218± 30 kg in 2011 and 2012, respectively. Pastures were grazed using a continuous and fixed stocking rate during the experimental period. Heifers received 10 g kg^{-1} BW in concentrate supplement (140 g kg^{-1} CP and 780 g kg^{-1} TDN) daily.

There was a linear decrease in HM, canopy light interception, and forage height as stocking rate increased from low to high. Herbage mass and forage height decreased in the first month and increased thereafter, while light interception decreased in the first month and was constant until the end of the trial. On the other hand, herbage accumulation rate (HAR) increased with increasing stocking rate. There was a month effect on HAR, where it was similar in May and June and increased in July and August, likely due to N fertilization and favorable rainfall.

No differences were found in forage nutritive value and leaf, stem, and senescent material proportion in the sward. Jiggs ground cover decreased over the 2 yr of grazing as stocking rate increased. Herbage allowance also decreased as stocking rate increased, both because of the decrease in HM and an increase in animal live weight per area. Average daily gain decreased as stocking rate increased. Herbage allowance and climatic conditions were likely the main factors affecting ADG throughout the experimental period. Additionally, there was a linear increase in GHA as stocking rate increased. Heifers in the high stocking rate treatment had decreased ADG; however, a greater number of animals resulted in a greater gain per area.

Conclusions

Urea was as affective as cottonseed meal as the main source of RDP when supplemented with molasses to cows-calf pairs grazing stockpiled limpograss pastures. Urea has greater solubility in the rumen than cottonseed meal, which may lead to inefficient use of N in the rumen. However, the slower intake of urea fed with molasses likely decreased levels of urea being consumed over time, promoting greater synchrony of N and energy in the rumen. It also likely decreased the amount of N being absorbed by the rumen epithelium, and increased microbial protein formation. It is important to state that the supplements were adjusted for similar RUP and energy concentrations with additional sources of feed (feather and corn meal), and this practice may be difficult to implement because most producers do not have the capability of storing and mixing commodities in addition to molasses on the farm. Therefore, this study provides important information for future studies to investigate including whether the additional levels of energy and RDP provided by the cottonseed would impact the performance of cow-calf pairs grazing stockpiled limpograss pastures at the levels of supplement used in this study.

Creep feeding 400 g kg^{-1} of soybean meal to suckling calves grazing limpograss pastures was effective in increasing performance of the calves with superior gain:feed ratio. This implies that this management practice could be readily adopted by producers with potential positive impacts in cow-calf production. The efficient extra gain provided by creep feeding would be beneficial to increase weaning weights, which would increase the market value of the calf. In addition, the greater weaning weight may also decrease age of puberty and reduce the time to first conception. Although raising and breeding heifers at 14-15 mo may be costly, the current market price for a bred heifer may be twice the price offered for a weaned heifer. This study also generates useful information for further research to test the effect of creep feeding other RDP sources to calves grazing limpograss pastures.

Finally, Jiggs bermudagrass showed similar production and nutritive value characteristics to other bermudagrasses; however, grazing Jiggs to stubble heights shorter than 15 to 20 cm is detrimental to the stand favoring the appearance of undesirable plant species in the pasture. Jiggs should be used in rotational stocking, primarily because of the option to move animals to a different pasture and the opportunity to exercise greater control over stubble heights. On the other hand, producers with flexibility to adjust stocking rate using continuous stocking may also be able to maintain a desirable stubble height and promote production and persistence of Jiggs. The levels of decrease in stand presented at the high stocking rate treatment indicated that Jiggs would need to be re-established after a few years of grazing. Considering that establishment is one of the most costly factors in warm-season perennial grass grazing systems, the utilization of Jiggs should be avoided in extensive grazing systems with limited inputs and management practices.

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BIOGRAPHICAL SKETCH

André De-Stefani Aguiar was born in São Paulo-SP, Brazil. He is the oldest son of Heliodoro Aguiar, and Renata Aguiar; and brother of Priscila Aguiar. He graduated with a Bachelor of Science degree in Animal Science from the “Faculdades Associadas de Uberaba” (FAZU) in Brazil in 2007. After his undergraduate studies he moved to Texas in the Spring of 2007 to attend an internship program and in the Fall of 2007 he started his M.S. program in Animal Science at Texas A&M University with emphasis in Ruminant Nutrition. He received his M.S. degree in May of 2010. In the Spring of 2010 he moved to Florida to work on his Ph.D. under the guidance of Dr. Vendramini in the area of forage management and supplementation strategies with beef cattle. After graduation André hopes to pursue a career in the beef cattle industry. He received his Ph.D. from University of Florida in the fall of 2013.