Effects of Type and Level of Energy Supplementation on Stocker Cattle Performance from Annual Ryegrass

by

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Abstract

Previous research has indicated that supplementation of high-quality grazed forage with high-energy feedstuffs can improve animal performance and enable increased stocking rates in grazed ecosystems. However, the extent of performance improvement and direction of forage utilization response may be dependent upon supplementation level (% BW) and whether the supplement is a high-starch or highly-digestible-fiber feedstuff. For these reasons, a grazing experiment was conducted to determine the type and level of supplementation with select high-energy feedstuffs that yield optimum animal performance and forage utilization from annual ryegrass (*Lolium mulitflorum*). Twenty 0.81-ha pastures in Yr 1 and thirty 0.81-ha pastures in Yr 2 were each grazed by 4 crossbred steers (mean initial BW, 230 ± 16 and 242 ± 26 kg in Yr 1 and Yr 2, respectively) between February 6, and May 15, 2014 in Yr 1 and between December 18, 2014 and April 15, 2015 in Yr 2. Cracked corn, pelleted citrus pulp, or pelleted soybean hulls were fed at rates of 0.25, 0.50, and 0.75% BW daily (2 type × level replicates per treatment in Yr 1, and 3 replicates per treatment in Yr 2), including replicate pastures in which steers received no supplement. Steers were weighed every 28 d following a period of overnight shrink. Forage mass was measured every 28 d using the destructive harvest/disk meter double-sampling method. Grazing was discontinued after

98 d in Yr 1 and 119 d in Yr 2 when forage mass and quality could no longer support an ADG of 0.68 kg. Data were analyzed as completely randomized design by the PROC MIXED procedure of SAS 9.4 using pasture as the experimental unit. Main effects were supplement type, supplement level, and type × level interaction. Contrast statements were used in pre-planned comparisons of the control with individual supplement types and feeding levels. There were no type × level interactions for ADG, total gain (kg/ha), or supplement use efficiency (F:G ratio) in either yr. In Yr 1 across all supplement levels, ADG was greater ($P < 0.10$) for corn and soybean hull treatments than the unsupplemented control, and total gain/ha was greater ($P < 0.10$) for all supplement types than the unsupplemented control. Across all supplement types, ADG and total gain/ha were also greater ($P < 0.10$) for all supplement levels than the unsupplemented control. There were no differences ($P > 0.10$) in supplement F:G above the control in either yr. In Yr 2, across all supplement levels, ADG was again greater ($P < 0.10$) for corn and soybean hull treatments than the unsupplemented control, and total gain/ha was greater ($P < 0.10$) for all supplement types than the unsupplemented control. Across all supplement types, ADG was greater ($P < 0.10$) for all supplement levels than the unsupplemented control, and total gain was greater ($P < 0.10$) for the 0.25 and 0.50% BW treatments than the unsupplemented control.

In Yr 1 across all levels, supplementation with corn generally resulted in greater standing forage mass throughout the grazing season than citrus pulp, soybean hull, and the unsupplemented control. However, across all supplement types, forage mass at different levels of supplementation did not differ. In Yr 2, there were generally no differences in forage mass among the supplemented treatments across both type and level; however, supplemented treatments yielded greater forage mass than the unsupplemented control late in the grazing season. Additionally, forage mass change between Dec and Jan decreased more markedly for 0.25% BW than for any of the other levels.

In Yr 1, supplemented treatments displayed a decrease in forage allowance compared with the unsupplemented control on the April sampling date. Across all supplement types, there were generally no differences in standing forage mass; however, supplementation at the 0.50% BW resulted in decreased forage allowance on the April sampling date. In Yr 2, there were numerous type × level interactions observed for forage allowance; however, there did not appear to be any systematic pattern of response among the supplement types or levels. Overall, supplementation resulted in increased animal ADG and total gain/ha. However, pasture response in terms of forage mass and allowance varied greatly among supplement types and levels of feeding.

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I. Literature Review

Stocker Cattle Industry

Background

The term “stocker cattle” originated from people of montane origin who purchased cattle in the spring to stock lush, mountain pastures. Although the term has referred to many different styles and systems over the years, the purpose of stockering has not changed. Stocker cattle are newly weaned cattle that graze high-quality forages from weaning until they are approximately 350 kg, and stockering has become a common practice for adding weight to cattle before they are sent to feedlots for finishing (Ball et al., 2015). Stockering occurs throughout the year in various parts of the country. Depending on the relationship of input costs and calf prices, the stocker sector of the beef production industry has the potential to be profitable year round. Stocker cattle prices typically increase in winter, peaking in March and April. With the increase in grain prices in the past 15 years has come a 98% increase in the cost of body weight gain (Kuhl, 2000; Waggoner, 2015). The increase in cost of body weight gain combined with all-time low cattle numbers has made it increasingly important to increase weight gain in cattle prior to entering the feedlot, which has resulted in an increase in the value of BW gain in stocker cattle of 155% from 2000 to 2015 (USDA, 2015a).

The stocker sector provides the market with many services that benefit the entire beef industry. Cattle that have been stockered are not only more immunocompetent than newly weaned cattle, but are also accustomed to eating from feed bunks and drinking from various water sources. They also experience less stress than newly weaned cattle, as they have been grouped in load lots (Beck et al., 2013). Additionally, marketing cattle in groups, as is the case with the vast majority of stocker cattle, results in a 4% increase in sales prices (Troxel and Barham, 2012). These services rendered by the stocker sector serve to improve the beef industry as a whole; however, management of both input costs as well as the cattle themselves is vital in determining just how profitable purchasing and growing stocker cattle may be (Beck et al., 2013). Additional factors that can affect profitability of the stocker sector are grazing season length and stocking rate which, coupled with input costs, are largely dependent upon the region of the country in which the stocker operation is located.

Stockering in the southeastern United States

In the southeastern United States, stocker cattle production was realized as a relevant and economically viable addition to cow-calf production in the 1980s. Prior to that time, beef production in the Southeast was almost entirely limited to cow-calf production. Production was extremely inefficient and profit margins were low as producers used fertile pastureland solely to maintain cows and small, weaned calves, producing only about 70 kg/ha of body weight gain annually. Forages grow well on the vast expanses of land in the southern states that are not suitable for grain crop production. Utilizing these pastures throughout the year by planting cool-season forages and clovers has expanded the beef industry in the Southeast and increased economic returns for beef producers in the area. Additionally, adoption of beef cattle production systems and defined breeding and calving seasons has paved the way for a more structured and profitable industry (Hoveland, 1986). Stocker calves in the Southeast are typically purchased in the fall when most producers wean their calves and there is a large influx into the market, usually causing purchase prices to decrease. Because of its substantial rainfall and moderate winter temperatures, the Southeast is a prime location for adding weight to these weaned calves over the winter and early spring for relatively low input costs, making the purchase of stocker cattle a generally profitable enterprise for many farmers in the southeastern states (Ball et al., 2015).

Most stocker producers strive to maintain an average daily gain of 0.9 kg/d over the stocker period on forage alone in order to adequately spread both fixed and variable costs over production units and realize a profit (Beck et al., 2013). Medium-frame steers weighing approximately 225 kg require a diet containing 11.4% CP and 67.5% TDN in order to gain 0.9 kg/d (NRC, 1984). Several different methods may be employed in grazing or feeding stocker cattle. Perennial forages such as bermudagrass (*Cynodon dactylon*) and bahiagrass (*Paspalum notatum*) are the most common warm-season pasture forages for beef cow-calf production in the Southeast; however, they do not sustain profitable gains in stocker cattle due to elevated fiber concentrations and decreased digestible energy concentrations during mid- to late-summer (Beck et al., 2013). Stockpiled bermudagrass, however, may be included in a grazing system during the late fall and early winter months to maintain body weight or promote minimal weight gain until cool-season forages have accumulated adequate forage mass to be grazed (Scarbrough et al., 2001). Warm-season annuals such as pearl millet (*Pennisetum glaucum*) and sorghum-sudangrass (*Sorghum bicolor*) are highly productive, withstand intense stocking rates, and can produce adequate cattle performance; however, input costs and a relatively short grazing season do not lend themselves well to economic profitability (Ball et al., 2015). Ball and Prevatt (2009) evaluated 37 grazing experiments conducted throughout the state of Alabama to determine the best forage systems for grazing stocker cattle. Forage systems were ranked based on pasture costs per kilogram of BW gain, and systems utilizing annual ryegrass (*Lolium multiflorum*) and small grains were found to be the most cost-effective method of adding weight gain to stocker cattle.

Ball et al. (2015) reported that the most common forages utilized in stocker systems in the Southeast are tall fescue (*Lolium arundinaceum*), annual ryegrass, small grains, and clovers (*Trifolium* spp.). Animal performance and grazing season length vary with each forage or combination of forages due to the varying productivity and nutritive quality of the different forages. Tall fescue is a cool-season perennial originally developed in Europe, which generally supports the least ADG because most pastures are infected with the fungal endophyte, *Neotyphodium coenophialum* (Ball et al., 2015). Although pastures planted with novel endophyte-infected fescue produce greater ADG than traditional fungal endophyte infected fescue, gains are still less than gains from annual ryegrass or small-grain mixtures (Beck et al., 2008). Annual ryegrass alone or any combination of annual ryegrass planted with one or more of the commonly used small grains are the most popular forage mixtures for stocker production in the southeastern United States. Commonly planted small grains include wheat (*Triticum aestivum*), rye (*Secale cereale*), and oat (*Avena sativa*). While high in nutritive value, these forages are also expensive to establish year after year and must be intensely managed in order to provide an opportunity to generate profit. Clovers are excellent for extending the grazing season and are also valuable for their N-fixation capability, as this decreases the need for N fertilizer applications that can be costly (Ball et al., 2015).

Extending the Grazing Season

Grazing season length is a critical decisive factor in determining which forage system to utilize for grazing stocker cattle. Grazing is generally terminated when forage quality can no longer support the desired 0.9 kg ADG. In addition to forage quality, the number of grazing-days is also affected by the botanical composition of forages being grazed. Forage mixtures provide botanical diversity and, thus, opportunities to extend the grazing season. Botanical composition of the forage stand affects the number of grazing days because of differences in growth patterns between early- and late-maturing forages and legumes. Combining the use of early-maturing forage such as cereal rye or an early-maturing legume such as crimson clover with late-maturing forage such as annual ryegrass helps to greatly extend the grazing season (Ball et al., 2015). Supplementing grazed forage with grain concentrate, oilseed, or by-product/co-product feed sources can also extend the number of grazing days. It is important, however, to be mindful of the additional costs that come with additional sources of feed (Rankins and Prevatt, 2013).

Annual Ryegrass

Background

Several stocker grazing systems utilizing many different species and varieties of forage have been tested over time. Allen et al. (2000) conducted a study in the upper southern United States in which four year-round grazing systems were evaluated. These systems utilized various combinations of stockpiled tall fescue, bluegrass (*Poa praetensis*)-white clover (*Trifolium repens*) mixtures, caucasian bluestem (*Bothriochloa bladhii*), tall fescue-red clover (*Trifolium pratense*) mixtures, alfalfa (*Medicago sativa*)-orchardgrass (*Dactylis glomerata*) mixtures, rye, soybean (*Glycine max*)-millet silage, and tall fescue hay. Overall, the system using stockpiled tall fescue, caucasian bluestem and tall fescue-red clover mixtures, all perennial or biennial forages, yielded the greatest final weights, ADG and gain/hectare compared with the other feeding and grazing combinations.

Cool-season annuals, however, tend to provide greater amounts of forage mass, greater number of grazing days, and greater overall animal performance than do cool-season perennials (Islam et al., 2011). Annual ryegrass is the most common cool-season annual forage planted in the Southeast. Originally from Europe, annual ryegrass is a rapidly growing bunchgrass with dark, shiny, smooth-edged leaves, and is capable of growing nearly a meter tall (Blount and Prine, 2012). Similar in growth, perennial ryegrass (*Lolium perenne*), which is native to Europe, Asia and North Africa, is used more as a turfgrass and less for grazing pastureland than annual ryegrass in the Southeast (Ball and Lacefield, 2011). Less hardy than annual ryegrass, perennial ryegrass does not withstand close, continuous grazing and is less tolerant of heat and drought (Ball et al., 2015). Several varieties of annual ryegrass have been developed and are commercially available, including Big Daddy, Gulf, Jackson, Magnolia, Marshall, Rio, Rustmaster, Surrey, and TAMTBO cultivars. Each of these varieties excels in its own right and may be compared with regard to dry matter yield, rate of growth, early- vs. late-maturing, disease resistance, winter hardiness and other characteristics.

Establishment and Management

Annual ryegrass is easy to establish and has good seedling vigor. Best planted on a prepared seedbed, annual ryegrass should be planted by September 15 in the southern states and optimum production can be expected from November to May. Annual ryegrass is readily adaptable to many soil types. It is not shade tolerant, nor is it easily maintained during drought; however, it can be grown in heavy, wet soil and will even tolerate periods of flooding. Annual ryegrass is extremely responsive to fertilization and should receive a N-fertilizer application at planting and at least once more during winter and/or spring. Prepared seedbeds allow time for growth prior to the start of cold temperatures; however, over-seeding of warm-season grasses is also common. Planting techniques vary, and ryegrass may be drilled into a seedbed or broadcast and sequentially cultipacked or rolled into the soil to achieve optimum seed-soil contact. Seed should be planted between 0.63 and 1.27 cm deep. If overseeding, warm-season forages must be clipped to a height of no more than 5 cm. Pure stands of annual ryegrass require 28 to 34 kg of seed per hectare. If planted in combination with other forages, 17 to 23 kg/ha is sufficient (Blount and Prine, 2012).

Annual ryegrass is mostly utilized as pasture for grazing livestock; however, it can also be used for hay, silage, haylage, baleage or greenchop. It is often grown as a pure stand, particularly in the Coastal Plain region of the eastern US, but it also pairs well with small grains and annual clovers, which can help extend the grazing season (Lemus, 2009). Optimum dry matter production occurs in a temperature range between 7 and 24°C. Grazing should begin when forage height is between 18 and 20 cm, and should be maintained until a stubble height of no lower than 5 cm has been attained (Ball and Lacefield, 2011). Annual ryegrass is a hardy forage and will tolerate close, continuous grazing; however, it may be subject to damage from armyworms (*Pseudaletia* spp.) and crown rust (*Puccinia coronata*), particularly near the Gulf Coast (Ball et al., 2015). Natural reseeding of annual ryegrass may occur if grazing livestock are removed upon the appearance of seedheads, however due to the significantly reduced seed yields compared with those observed in the Pacific Northwest, seed production is not a common practice in the Southeast (Blount and Prine, 2012).

Varieties

Each year, approximately one million ha of annual ryegrass are grown in the southeastern United States for forage production (Evers, 1995). Today, more than 30 annual ryegrass varieties are commercially available, with common and 'Gulf' annual ryegrass representing approximately 80% of the planted acreage (Venuto et al., 2002). Gulf and Marshall annual ryegrass were the first two improved varieties developed for the southeastern region. Gulf provides increased yields, resistance to crown rust and is generally more successful in significantly milder climates, whereas Marshall was developed as a cold-tolerant cultivar for use in areas where the temperature will most certainly fall below freezing for a period (Weihing, 1963; Arnold et al., 1981). Gulf and Marshall cultivars have consistently been the most common varieties planted over time. With regard to overall performance, Redfearn et al. (2005) found Marshall and Gulf to be superior in Louisiana, however DM yield can be greatly affected by geographical location. Glass et al. (2015) reported superior DM yields from TAMTBO and Marshall varieties in central Alabama, however, Marshall was inferior to several other varieties at select locations in the southern portion of the state.

Rio, Marshall, Jackson and Surrey annual ryegrasses are all late-maturing varieties, and therefore allow producers to extend the grazing season and maintain higher forage quality well into late spring (Redfearn et al., 2002). Redfearn et al. (2005) compared early-, late- and total-season forage yields (kg DM/ha) of 28 commercially available annual ryegrass varieties with yields from Marshall and Gulf cultivars. Although several cultivars out-produced Gulf annual ryegrass with regard to late-season and total DM yield, Gulf still produced the greatest early-season DM yield. Marshall annual ryegrass did not produce consistent results across locations and years; however, it outperformed most cultivars with regard to late-season and total DM yield.

Hafley (1996) states that both Marshall and Surrey varieties withstand continuous grazing pressure and are capable of producing gains up to 1.5 kg/day. However, Bransby et al. (1997) state that Marshall is the annual ryegrass variety that is best suited to Alabama. Developed and released by Mississippi State University, Marshall annual ryegrass is particularly cold-tolerant, but is somewhat susceptible to crown rust. In a study conducted by Bransby et al. (1997), Marshall annual ryegrass was observed to better withstand grazing pressure and support more total kg of stocker gain than the Gulf variety. Although both varieties were observed to be rust susceptible and rust injury was more prevalent for the Marshall variety, the appearance of crown rust did not seem to have adverse effects on animal performance.

Both diploid and tetraploid varieties of annual ryegrass have been developed. Tetraploids typically have wider leaves, larger overall plants and greater resistance to crown rust (Nelson et al., 2006). Some tetraploid varieties are reputed to produce greater DM yields than diploid varieties; however, White and Lemus (2014) conducted an analysis of long-term, multi-location annual ryegrass growth and found that there were no differences between diploid and tetraploid varieties with regard to DM yield. Furthermore, White and Lemus suggest that management implementation affects DM yield more so than does variety selection. However, Blount et al. (2014) reported competitive DM yields from Earlyploid, a new tetraploid annual ryegrass variety. Earlyploid is both disease and cold tolerant and is the earliest producing tetraploid variety commercially available.

The metabolic pathways in which any plant carries out photosynthesis have a direct influence on the amount of forage mass that will be produced and available to an animal grazing that forage. Annual ryegrass is a C_3 plant, meaning that it fixes atmospheric CO_2 into 3-carbon intermediates rather than 4-carbon units, which is characteristic of a C_4 plant. C_3 plants are less efficient than C_4 plants in their CO_2 fixation because they can only utilize 25 to 50%, whereas C_4 plants can utilize nearly all available photosynthetically active radiation (PAR) for this purpose. C_3 plants, therefore, produce less standing forage mass in relation to available PAR. Not only is the method of performing photosynthesis important for grazing management, but forage quality must also be taken into account (Ball et al., 2015).

Ball et al. (2015) describe forage nutritive quality as a characteristic that must be determined by the animal rather than the human. Factors that affect quality include palatability, digestibility, and digestible energy and protein concentrations. The quality of forage is largely determined by its stage of maturity and tends to decline rapidly after the emergence of seed heads. Younger, less mature forages tend to have greater palatability, digestibility and protein concentrations. Immature forages also tend to contain more leafy plant parts than stems, contributing to their greater quality. Redfearn et al. (2002)

conducted a study on six different annual ryegrass varieties and found that 60% of seasonal annual ryegrass growth occurs in March to May, with 30% of growth occurring in April alone. Hafley (1996) reported a range of CP values for Marshall and Surrey varieties between 11.1 and 27%, and forage masses up to 2,720 kg/ha over the course of the 2-yr study. The capacity for high yields and high quality further suggest that annual ryegrass is the most suitable cool-season forage for grazing stocker cattle in the Southeast.

Supplementation

There are a number of reasons why a stocker operator would choose to implement supplementation of cattle grazing forages. Oftentimes, the desired level of animal production is not being achieved from grazed forage alone due to a shortfall in nutritive value, at which time energy and/or protein is then supplemented to boost animal performance and thus increase economic returns. Supplementing with energy is typically in the form of either starchy or highly digestible fibrous byproducts. Supplementation can also increase or decrease forage intake as a result of positive (synergistic) or negative (antagonistic) associative effects, respectively. Decreased forage intake might be favorable in years in which there is decreased forage DM yield. Substitution of forage intake by supplement can, however, become excessive and cause forage wastage. The challenge for nutritionists and cattle producers is to determine the best forage/supplement system that will improve cattle performance and forage utilization and do so in a cost-effective manner (Kunkle et al., 2000).

Protein Supplementation

Warm-season forages are generally lower in digestible energy and protein concentration than cool-season forages. Supplementing with a high-CP feedstuff generally increases intake of low-quality forage, whereas supplementing with energy generally decreases intake of high-quality forages (Guthrie and Wagner, 1988). Findings by Lofgreen and Garrett (1968) and others have resulted in adoption by the NRC (1984) of the predictive relationship NEm = 77 kcal × $BW_{kg}^{0.75}$. This relationship between maintenance net energy requirement and live weight was derived from experiments with pen-fed cattle and is not especially relevant to grazing cattle. Energy requirements for an animal that must travel over a large area while grazing will be greater than those of a penned animal (Ferrell, 1988). Factors that could possibly affect the range in energy requirement include the amount of time spent eating, maturity of forage, locomotion involved in grazing, and time and energy spent ruminating (Robbins, 1993). Because energy supplementation decreases forage intake, it stands to reason that it also decreases the amount of time spent grazing, and thereby lessens the energy requirement for a grazing animal (Krysl and Hess, 1993).

Studies with warm-season forages such as bermudagrass and prairie grass hay have utilized supplements that corrected for the lack of protein in these two forages. By supplementing these low-quality forages with additional ruminally degradable intake protein (RDP; also called degradable intake protein or DIP), the animals had a greater OM intake (Heldt et al., 1999). Bodine et al. (2001 and 2003) also reported a positive relationship between additional RDP and total OM intake and furthermore stated that supplementing low-quality, warm-season forages with high levels of energy did not depress forage intake when total dietary RDP requirements were met. Lardy et al. (2004) found that supplementation of prairie grass hay with a starchy supplement of barley (*Hordeum vulgare*) decreased forage intake linearly as barley intake was increased. However, supplementation with barley increased intake of total OM, with the most pronounced effect at 0.8 kg of barley/day, which was the lowest level of supplementation (around 0.4% body weight), suggesting that low levels of energy supplementation may stimulate increased total OM intake and thereby increase weight gain. It should also be noted that protein supplementation of primarily forage-based diets yields varying results for warm- and cool-season forages. Bohnert et al. (2011) found that protein supplementation increased warm-season forage DMI by 47% and digestibility by 21% while only increasing cool-season forage DMI and digestibility by 7% and 9%, respectively.

Energy Supplementation

Cool-season forages such as tall fescue, annual ryegrass and small grains are more energy-dense than warm-season forages, but may still benefit from supplementation. Although supplemental protein may increase forage digestibility and DM intake, a starchy or highly digestible fibrous energy feedstuff may help to achieve even greater gains in animal performance (Cappellozza et al., 2014). Hess et al. (1996) found that, in the case of medium-quality forages such as tall fescue, both a starchy supplement of cracked corn (*Zea mays*) and a highly digestible fibrous supplement of wheat bran decreased forage intake while simultaneously increasing ruminal production of VFA and molar proportion of propionate. Both supplements also increased weight gain and the rate at which cattle gained on the tall fescue pastures, so the decision for which supplement to use would depend on the relative cost of each. In contrast, Horn et al. (1995, 2005) compared the influence of high-starch and high-fiber energy supplements on the performance of stocker cattle grazing higher-quality wheat pasture, and found that cattle that were supplemented with either type of energy supplement had greater ADG than those that received no supplement. By utilizing an energy supplementation program, stocking density was increased by approximately one-third, and ADG was increased by 0.15 kg. Whereas both types of energy supplements yielded increased animal production compared with the non-supplemented animals, the fibrous energy supplement of soybean hulls and wheat middlings produced higher ADG than the corn-based starch energy supplement.

There are numerous types of forages that could conceivably benefit from energy supplementation and, likewise, there are numerous types of feedstuffs that might provide supplemental energy to a forage-based diet for growing calves including co-products, commercial supplements, and crops grown on farms and ranches. Farm-grown crops or feeds might include concentrates such as corn, barley and other cereal grains, whereas co-products might include soybean hulls, wheat middlings, corn gluten feed, distillers grains, beet pulp, and citrus pulp. These supplements can be sorted into two categories: starchy and fibrous, with the farm-grown crops and feeds constituting the starchy products, and the co-products comprising the fibrous products. The starchy products contain elevated concentrations of non-structural carbohydrates (NSC) such as starch and free sugars, whereas fibrous products contain greater concentrations of structural carbohydrates like cellulose, hemicellulose and lignin (Bowman and Sanson, 1996). Horn and McCollum (1987) reported that energy supplements generally reduce forage intake and digestibility, with greater reduction occurring with increasing supplement level. Conversely, Bowman et al. (2004) reported that supplementation with high-NSC feedstuffs increased forage intake for cattle consuming protein-deficient forage, whereas high-NSC feedstuffs decreased forage intake for cattle consuming protein-adequate forages.

Corn

Starchy (i.e., non-structural carbohydrate) supplements include corn, barley, and other cereal grains. Within this group, there are reports of differing effects of these supplements on forage intake and digestibility. Barley has been shown to have a more negative effect on forage fiber digestibility than corn (Herrera-Saldana and Huber, 1989). Additionally, there have been studies that showed no marked difference in organic matter intake among supplements, but found that cattle supplemented with corn or sorghum grain (*Sorghum bicolor*) had greater gains than those supplemented with wheat or barley (Galloway et al., 1993). Horn and McCollum (1987) suggested that high-NSC concentrates can be fed up to 0.5% of BW without severely depressing forage intake, whereas Bowman and Sanson (1996) stated that grain-based supplements should not be fed at a level greater than 0.25% of BW. Although the reported effects of non-structural carbohydrate supplements on NDF digestibility have been varied, for the most part they trend in the direction of decreasing overall digestibility of the forage (Bowman and Sanson, 1996). By and large, these non-structural carbohydrate supplements have been noted to decrease forage intake while alternately increasing the overall gain compared with a non-supplemented animal.

Corn has long been the industry standard for feeding livestock with the earliest reports dating back to the late 1800s (Ball, 1998). Roberts et al. (2009) reported increased ADG with increasing level of corn supplementation, indicating that corn is an excellent promoter of weight gain. However, forage intake decreased linearly as corn supplementation level increased. Corn prices rose to more than $3 per bushel in 2007 and continued to climb over the next 5 years, peaking at $7.63 per bushel in August 2012. Although corn prices have dropped steadily in recent years, with a current price of $3.58 per bushel or $166.72 per metric ton, price has been a major factor in motivating producers to seek alternative feed sources, particularly in the form of by-product feeds that are typically low in NSC (USDA, 2015b).

Soybean Hulls

Fibrous supplements, or by-products feeds, include soybean hulls, wheat middlings, dried distillers grains, beet (*Beta vulgaris*) pulp and citrus (*Citrus* spp.) pulp. These supplements are low in concentrations of non-structural carbohydrates such as starch and sugar and contain greater concentrations of highly digestible structural carbohydrates such as gums, mucilages, pectins and some oligosaccharides. Supplementation with these fibrous feeds has often been noted to cause an increase in total organic matter intake along with increased digestibility and utilization (Horn et al., 1995). Notably, the increase in overall NDF digestibility is likely due to the fact that the new digestibility value includes the digestibility of both the supplement and the forage and is most likely increased by the sheer fact that the digestibility of the fibrous supplement is greater than that of the forage (Bowman and Sanson, 1996). Like the non-structural carbohydrate supplements, supplementing with fibrous feeds increases animal gains. In some cases, as in the studies conducted by Horn et al. (1995, 2005), supplementation with a highly digestible fibrous mixture of soybean hulls and wheat middlings yielded greater animal gains than did supplementation with a starchy supplement of corn. Additionally, Loy et al. (2008) and Buttrey et al. (2012) both reported that supplements of dried distillers grains outperformed dry rolled corn with regard to ADG and G:F.

Soybean hulls, often referred to simply as soyhulls, are a byproduct of the soybean milling industry and are considered to be a highly digestible fibrous feedstuff (Hsu et al., 1987). Supplemented soybean hulls have yielded similar gains as corn and do not depress forage intake or digestibility except at high levels (approximately 0.7% BW), making them a valuable and cost-effective feed source (Martin and Hibberd, 1990). Furthermore, because soyhulls do not contain nearly as many non-structural carbohydrates (i.e., starch) as corn, soyhulls greatly reduce or even eliminate the possibility of acidosis in grazing cattle (Anderson et al., 1988). Orr et al. (2008) found that, compared with corn, soyhulls improved fiber digestion and promoted greater ruminal N utilization.

Garces-Yepez et al. (1997) also stated that soyhulls produced fewer negative associative effects than high-starch supplements when fed at elevated (0.8 to 1.0) percentages of BW; however, they found no differences between soyhulls and a corn-soybean meal mixture fed at lesser (0.4 to 0.5) percentages of BW. With BW gains and diet digestibility superior or equal to corn, the decision to utilize soybean hulls as an energy supplement is largely economic in nature. Soyhulls currently cost approximately $130 per metric ton, making them a more cost-effective energy supplement if locally available (USDA, 2015c).

Citrus Pulp

Over 80% of the United States citrus supply is grown in Florida, and almost 90% of that is processed into juice (Hodges et al., 2001). The by-products from processing include a mixture of peel, rag and seeds that is referred to as citrus pulp. The pulp is typically dried, pelleted, and marketed as a unique fibrous energy supplement to cattle producers (Arthington et al., 2002). The majority of citrus pulp is exported to Europe, but recent declines in export have brought citrus pulp to the forefront of fibrous energy feed discussion, particularly in the Southeast. Citrus pulp has long been utilized as a by-product feed source; however, it often spoiled before it could all be consumed (Walker, 1917). Dehydration of grapefruit by Scott (1926) marked the beginning of a new era for citrus pulp feeding. Although dehydration resulted in easier transportation and storage, citrus pulp remained a bulky feedstuff with a density of 211-372 kg/cubic meter. With the introduction of citrus pulp pellets, density was increased, dustiness was reduced, and handling was made easier (Ammerman et al., 1966).

Citrus pulp is composed of about 25% pectin, a different kind of structural carbohydrate than hemicelluloses, cellulose, or lignin. Pectins are highly digestible in the rumen, with an apparent digestibility of 98.7% compared with 79.4% for the cell wall components when digested in sheep (Ben-Ghedalia et al., 1989). Early feeding studies conducted by Chapman et al. (1953) reported in no significant difference in ADG or G:F between cattle supplemented with ground snapped corn and citrus pulp. However, Chapman et al. (1961) reported that steers fed citrus pulp had greater gains than did steers fed ground snapped corn, sugarcane molasses or a mixture of corn, citrus pulp and cottonseed meal. Other studies have resulted in increased gains with increasing percentage of citrus pulp in the diet up to a point between 44 and 66%, at which daily gain began to decline, suggesting that citrus pulp should not be included in the diet at greater than 50% of the total diet (Ammerman et al., 1963). Alkire (2003) found that citrus pulp increased ADG when used as a supplement for preconditioning cattle compared with unsupplemented cattle. Citrus pulp has also produced comparable gains to corn when included in feedlot rations (Peacock and Kirk, 1959) and even resulted in greater feed efficiency (Kirk et al., 1949). As with corn supplements, forage intake decreased with increasing citrus pulp in supplemental feed studies, but total organic matter intake and overall gain were both increased (Villarreal et al, 2006). With a current price per metric ton of $210, citrus pulp may not be the most cost-effective energy supplement; however, for producers in the southeastern United States, it should continue to be a viable alternative in the future (Gould, 2015).

Supplementation Levels

Oftentimes, animal performance responses to supplementation are either greater or less than expected. The deviation from expectation is often attributable to associative effects of supplements on OM intake and available concentrations of energy in the total diet (Moore et al., 1999). Feeding additional feedstuffs to a grazing animal involves maintaining a balance between potentially synergistic and antagonistic effects on forage intake and fiber digestibility. Supplementation often turns into substitution, which can lead to wasted forage and nutritional insufficiency. Substitution is quantified by a number called a substitution ratio, or the unit of change in forage intake per unit of increased supplement intake. This ratio can vary greatly depending on the quality of the forage and the species of animal grazing that forage (Horn and McCollum, 1987). The decrease in forage intake that often occurs when an energy supplementation program is implemented is a form of substitution. A certain amount of forage nutrients are being exchanged for supplemental nutrients (Caton and Dhuyvetter, 1997). In studies in which forage mass becomes limiting to the grazing animals, supplementation coupled with substitution are necessary and even favorable. This relationship of decreased intake due to increased supplementation is known as a negative associative effect, but can serve a desirable purpose to extend the forage supply (Horn and McCollum, 1987). In situations where forage is not limiting, however, it is the level of supplementation that determines whether there are negative or positive associative effects and, therefore, whether or not substitution occurs.

Kunkle et al. (1995) performed a study comparing supplements of corn, wheat middlings, and soybean hulls fed at 0.5% and 1.0% BW to growing steers fed high-quality bermudagrass. The results of this study concluded that gain, forage intake and digestibility were not different across supplements; however, when fed at 1.0% BW, cattle fed corn had lesser gain, forage intake and digestibility than those fed soybean hulls. Results of this study provide further evidence in favor of Demeyer's (1981) report that limited amounts of non-structural carbohydrates may stimulate fiber digestion, and that the level at which any feedstuff is supplemented is critical to determining whether or not substitution will occur. Altering the frequency with which supplements are fed may also affect forage intake, digestibility and N balance. Analysis of early studies found that decreasing the frequency of supplementation did not affect cattle performance (Kunkle et al., 2000). Melton and Riggs (1965) reported decreased intake but greater gains in less frequently supplemented cattle, due to what they suggested was an interruption of normal grazing behavior in cattle supplemented daily. Drewnoski and Poore (2012) reported that reducing frequency of steers fed a blend of soybean hulls and corn gluten feed, both fibrous energy supplements, to alternating days instead of daily decreased forage intake, but did not affect digestibility or N balance. However, it is important to note that these steers were fed supplement at extremely high levels of 1 and 2% of BW.

Results from Surber et al. (1996) further support the rationale that lower levels of supplementation are more favorable for enhancement of grazing forage rather than substituting supplement in place of the forage. In their study, the lowest level of non-structural carbohydrate supplement increased dietary intake of CP compared with supplements fed at elevated concentrations. Citrus pulp, although considered a fibrous or structural carbohydrate supplement, follows this same logic. Villarreal et al. (2006) reported that, in grazing trials in which citrus pulp was supplemented, elevated levels of supplementation resulted in the most pronounced decline in forage intake. Supplementation does not, however, always decrease forage intake and digestibility. In a meta-analysis of 66 studies, Moore et al. (1999) reported that supplementation increased forage intake when TDN:CP was > 7 (i.e., N-deficient forages) and decreased forage intake when TDN:CP was < 7 (i.e., N-adequate forages). Predicting BW gains of stocker cattle can be difficult. Factors to consider include health status, acclimation to feed and water sources, amount of forage and supplement consumed, interactions between forage and supplement, energy and protein concentration of the total diet, length of feeding period and previous plane of nutrition (Lalman et al. 2002). Estimates of cattle performance and economic returns from supplementation strategies require much consideration, and further research is constantly being conducted to identify and quantify interactions among various forages and supplements (Moore et al., 1999).

Implications to Current and Future Research

With the new trend of increased value of BW gain in stocker calves, the need for stockering cattle has and will continue to steadily increase (Beck et al., 2013). Given that implementation of supplementation programs result in increased ADG a vast majority of the time, it is important to seek out the most cost-effective and performance enhancing methods. Previous research has identified the various advantages and disadvantages associated with both starchy- and fibrous-energy supplements (Horn et al., 1995 and 2005; Bowman and Sanson, 1996; Loy et al., 2008). Analysis of previous research has also indicated a linear response in the increase of supplementation level and the decrease of forage intake (Moore et al., 1999; Kunkle et al., 2000). However, very little research has been conducted which utilizes a variety of supplement types and feeding levels concurrently. The research presented herein is novel to the extent that it considers main and interactive effects of supplement types and feeding levels on forage utilization and stocker production from annual ryegrass.

II. Effects of Type and Level of Energy Supplementation on Stocker Cattle Performance from Annual Ryegrass

Introduction

The stocker cattle industry has been expanding in the southeastern United States over the past 35 yr (Hoveland, 1986). The 155% increase in the value of BW gain since 2000 has made it more important than ever to find efficient, economical methods of adding weight to stocker cattle (USDA, 2015a). Considerable research has been conducted on protein and energy supplementation of grazed pasture, the most common reason for which is to correct nutrient deficiencies in low-quality warm-season forages (Kunkle et al., 2000). However, supplementation of high-quality cool-season annual grasses with starchy or fibrous energy feedstuffs may allow for increased gains and increased stocking rates in grazed ecosystems (Cappellozza et al., 2014). Moore et al. (1999) suggested that energy supplementation of high-quality forages often leads to substitution of forage intake, which can cause wasted forage and nutritional insufficiency. Horn and McCollum (1987) observed a decrease in forage intake with increasing supplement level, and Bowman et al. (2004) observed that supplements high in concentration of nonstructural carbohydrates decreased forage intake of high-quality forages. Additional studies have been conducted to determine differences in stocker performance response to starchy and fibrous energy supplements (Horn et al. 1995; Bodine and Purvis, 2003) as well as to different levels (% BW) of supplement fed (Kunkle et al., 1995; Roberts et al., 2009). However, no research has been reported in which diverse types of energy supplements fed across a wide range of supplementation rates were evaluated in a single experiment, including the response of grazed forage. The objective of this study was to determine the effect of type and level of energy supplementation on animal performance from continuously stocked ryegrass pastures.

Materials and Methods

Pasture establishment and fertilization

A 2-yr winter-grazing and supplementation experiment was conducted at the E.V. Smith Research Center in Milstead, AL (32.443° N lat, 85.897° W long). Thirty 0.81-ha paddocks composed of fine sandy loam were used for this experiment. All pastures had been previously planted with warm-season grasses including bahiagrass, dallisgrass and bermudagrass, and used for summer grazing.

Each year prior to planting, thirty 0.81-ha pastures were fertilized with 66.5 kg/ha each of N, P, and K. Pastures were planted with 32 kg/ha of 'Marshall' ryegrass seed (Wax Seed Company, Amory, MS). Seed was planted at a depth of 0.6 cm into a prepared seedbed. In Yr 1, pastures were fertilized on October 10 and 11, 2013, and seed was planted on October 15 and 17, 2013. An additional 27 kg N/ha was applied to each pasture on January 27, 2014. In Yr 2, pastures were fertilized on September 16 and 17, 2014, and seed was planted on September 18 and 19, 2014. An additional 27 kg N/ha was applied to each pasture on February 11, 2015. Picloram and 2,4-dichlorophenoxy were applied through the use of Grazeon® P&D (Dow AgroSciences, Indianapolis, IL) on February 11, 2015 at rates of 152 and 561 g a.i/ha, respectively, for the management of weeds in the pastures, particularly hairy buttercup (*Ranunculus* spp.).

Supplementation treatments

In Yr 1, supplementation treatments were randomly assigned to pastureswith the restriction that the same treatment could not be applied to adjacent pastures. Pastures were assigned in the same manner in Yr 2 with the added restriction that no pasture could receive the same treatment as in Yr 1. Supplementation treatments were arranged as a 3 x 3 factorial design consisting of 3 supplement types and 3 supplementation levels of feeding, and included a negative control (no supplementation). Supplement types included cracked corn, pelleted soybean hulls and pelleted citrus pulp. Levels of supplement feeding included 0.25%, 0.50% and 0.75% of animal BW. Because of suboptimal forage production due to lower than normal temperatures early in the growing season, only 20 pastures were utilized in Yr 1, resulting in only 2 replications per treatment. All 30 pastures were utilized in Yr 2, resulting in 3 replications per treatment. The experimental pasture layout is presented in Figure 1 for Yr 1 and 2.

Animal and pasture management

Each pasture was stocked with 4, non-implanted, crossbred steers of no more than 1/8 *Bos indicus* influence with an initial BW of 230 ± 16 and 242 ± 26 kg in Yr 1 and Yr 2, respectively. Steers were procured through contract with a stocker producer in Reform, AL and were delivered to E.V. Smith Research Center on January 20, 2014 (Yr 1) and December 16, 2014 (Yr 2), and were weighed on January 21, 2014 (Yr 1) and December 18, 2014 (Yr 2), respectively. In Yr 1, steers were turned out to a 2.03-ha ryegrass pasture for 16 d prior to

Figure 1. Layout of experimental plots in Yr 1 (top) and Yr 2 (bottom). CC = cracked corn, CP = citrus pulp, and SBH = soybean hull at 0.25, 0.50, or 0.75% of BW.

initiation of the trial, whereas steers in Yr 2 remained in drylot for 2 d with free-choice access to bermudagrass hay and water. Prior to the start of the study, animals were stratified by BW into 4 outcome groups of 20 steers each in Yr 1 and 30 steers each in Yr 2, randomly assigned from within groups to pastures, and ear-tagged for identification. Throughout the trial, animals had free-choice access to a commercial trace mineral block (Champion Choice, Wayzata, MN) and clean water. Cattle were fed supplement once daily at approximately 0800. Cattle were removed from feed but allowed access to water prior to weighing, and 24-hr shrunk weights were taken every 28 d throughout the study. Weights were then used to calculate amounts of supplement fed in successive 28-day periods. The management of cattle was conducted in accordance with a protocol (PRN 2013-2394) approved by the Institutional Animal Care and Use Committee of Auburn University.

In Yr 1, steers were weighed and grazing was initiated on February 6, 2014 when forage mass had achieved a mean value across all pastures of 668 kg DM/ha or a mean height of 8 cm. The resulting mean initial forage allowance (FA) was 0.52 kg forage DM/kg steer BW. In Yr 2, grazing was initiated on December 18, 2014 when forage mass had achieved a mean value across all pastures of 1,113 kg DM/ha or a mean height of 10 cm. The resulting mean initial FA was 0.93 kg forage DM/kg steer BW. In both yrs, steers were acclimated to supplementation over a period of 10 d following initiation of grazing. Grazing was terminated on May 15, 2014 and April 15, 2015 in Yr 1 and Yr 2, respectively, when forage mass and nutritive quality could no longer sustain an ADG of 0.68 kg.

Forage sampling and laboratory analysis

Prior to the initiation of grazing and every 28 d thereafter, with the exception of one 42-d period in yr 1 and one 35-d period in yr 2, forage disk height and mass was measured using the double-sampling method as described by Frame (1981). Twenty-five forage height measurements were taken in each test pasture. Prior to the study in each Yr, a separate set of 3 pastures designated as calibration pastures were each stocked with 3, 4, or 5 steers (stocking densities of 3.7, 4.9 and 6.2 steers/ha, respectively), resulting in a wide range of forage heights. Forty-eight destructive-harvest samples were collected from across the 3 calibration pastures such that multiple samples at each height were collected. Samples were clipped from within a 0.25-m^2 ring to a stubble height of approximately 5 cm, placed in labeled zip-loc bags, and placed in a cooler. Additionally, approximately 10 grab samples were collected from each pasture by clipping forage at an aboveground height of 5 cm, composited on a pasture basis, and placed in a cooler. All samples were subsequently transported to the Auburn University Ruminant Nutrition Laboratory. Samples were transferred to paper bags and dried for 72 hr at 60° C. The 48 destructive harvest samples were air-equilibrated and weighed. The recorded forage-mass values were plotted against their respective height values, and the resulting regression equation was used to calculate approximate forage mass for each test pasture based on previously measured forage heights. Additional forage samples were collected every 28 d and a new regression equation was produced following each sampling date. The regression equation enabled the calculation of estimated mean forage mass. The mean forage height from of each test pasture was multiplied by the slope of the regression line and added to the y-intercept value to yield the estimated mean forage mass in each test pasture. In addition to ADG and total kg BW gain/ha, response variables for this study included change in forage mass and forage allowance. Change in forage mass was reported as the net increase or decrease in kg forage DM/ha between successive sampling dates. Forage allowance was calculated as kg forage DM divided by kg total animal live weight per pasture.

Dried grab samples from each test pasture were ground in a Wiley mill (Thomas Scientific, Swedesboro, NJ) to pass a 1-mm screen. Concentrations of CP and DM were determined according to AOAC procedures (1995). Samples were analyzed for IVDMD based on the Van Soest (1991) modification of the Tilley and Terry procedure (1963) using the Daisy II® incubator system (Ankom Technology, Macedon, NY). Rumen fluid for batch-culture incubations was collected mid-afternoon from a rumen-fistulated Holstein cow that had free access to bermudagrass pasture and was limit-fed supplement containing cracked corn, distillers dried grains, corn gluten feed, soyhull pellets, soybean meal, and cottonseed hulls. Fluid was placed into an insulated container and transported immediately to the Auburn University Ruminant Nutrition Laboratory where it was filtered through cheesecloth and then combined with pre-heated (40^{o}C) buffer solution for incubation.

Statistical analysis

Data were analyzed by year as a completely randomized design using the PROC MIXED procedure of SAS 9.4 (SAS Inst. Inc., Cary, NC). Main effects were supplement type, supplement level, and type × level interaction. Contrast statements were used in pre-planned comparisons of the control with individual supplement types and feeding levels. The PDIFF option of LSMEANS was used to separate treatment means when protected by F-test at $\alpha = 0.10$.

Results and Discussion

Temperature and precipitation

Monthly mean and 30-yr average monthly temperatures at the research site from September to May of each yr are presented in Figure 2, and monthly and 30-yr average monthly precipitation totals from September to May of each yr are presented in Figure 3. In Yr 1, mean monthly temperatures were lower throughout the grazing season than than the 30-yr average. Extremely low precipitation in September and October resulted in later planting dates than usual for the region. Colder than average temperatures, particularly in January, likely depressed forage growth, resulting in limited forage production in some of the pastures and thus the decision to only utilize 20 of the 30 available pastures in Yr 1. Following a second application of N in February and increase in both temperature and precipitation, grazing was initiated on February 6, 2014 in Yr 1. Although precipitation was again lower than the 30-yr average in September in Yr 2, an extremely wet December coupled with average temperatures allowed for excellent forage production and a December 18, 2014 grazing initiation date. However, extremely low temperatures in January and February severely depressed forage production, and some pastures never fully recovered during March and April, resulting in a large decrease in forage mass and forage allowance for the remainder of the grazing season.

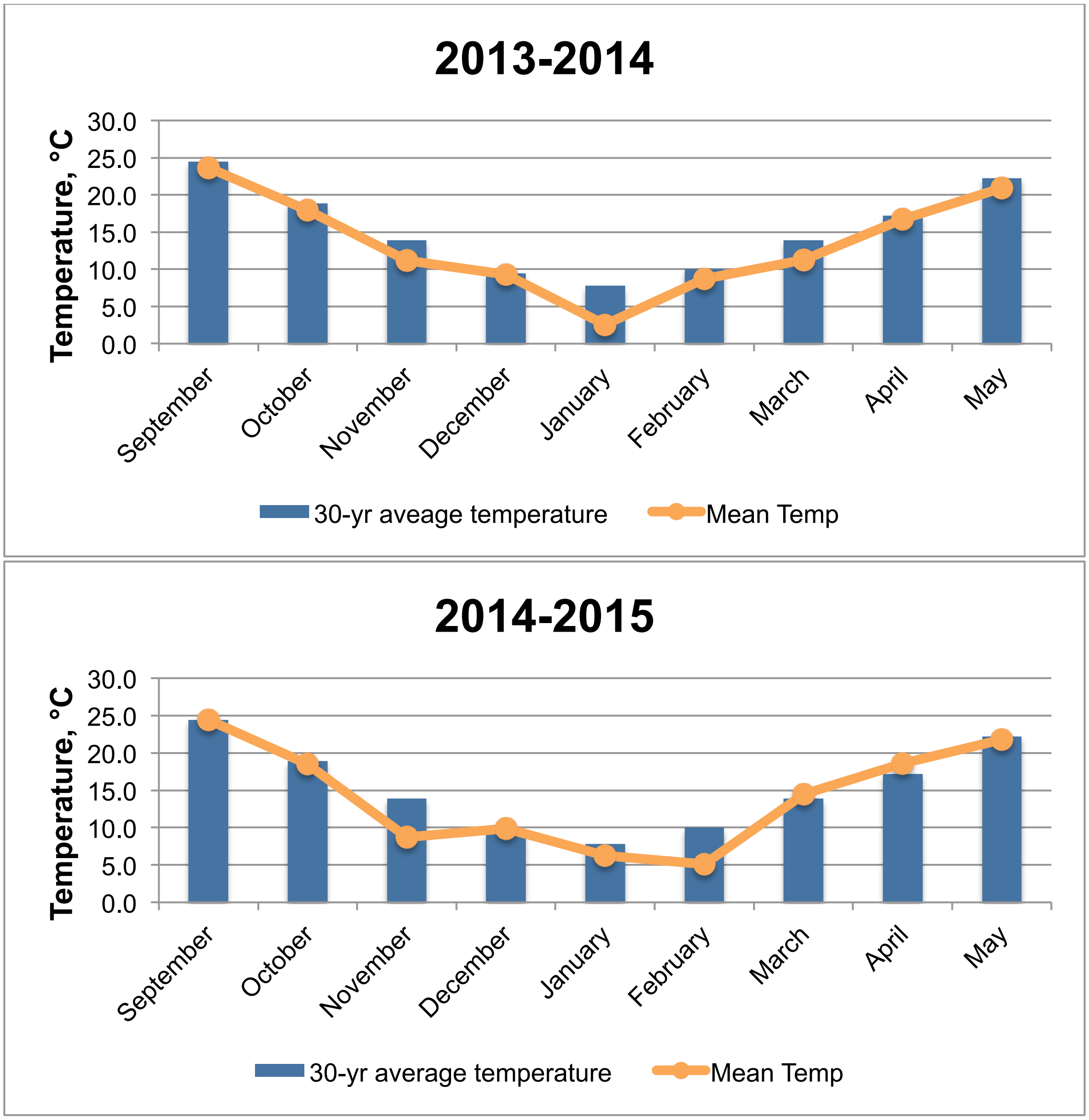


Figure 2. Monthly and 30-yr average temperatures from September to May by yr at E.V. Smith Research Center, Milstead, AL.

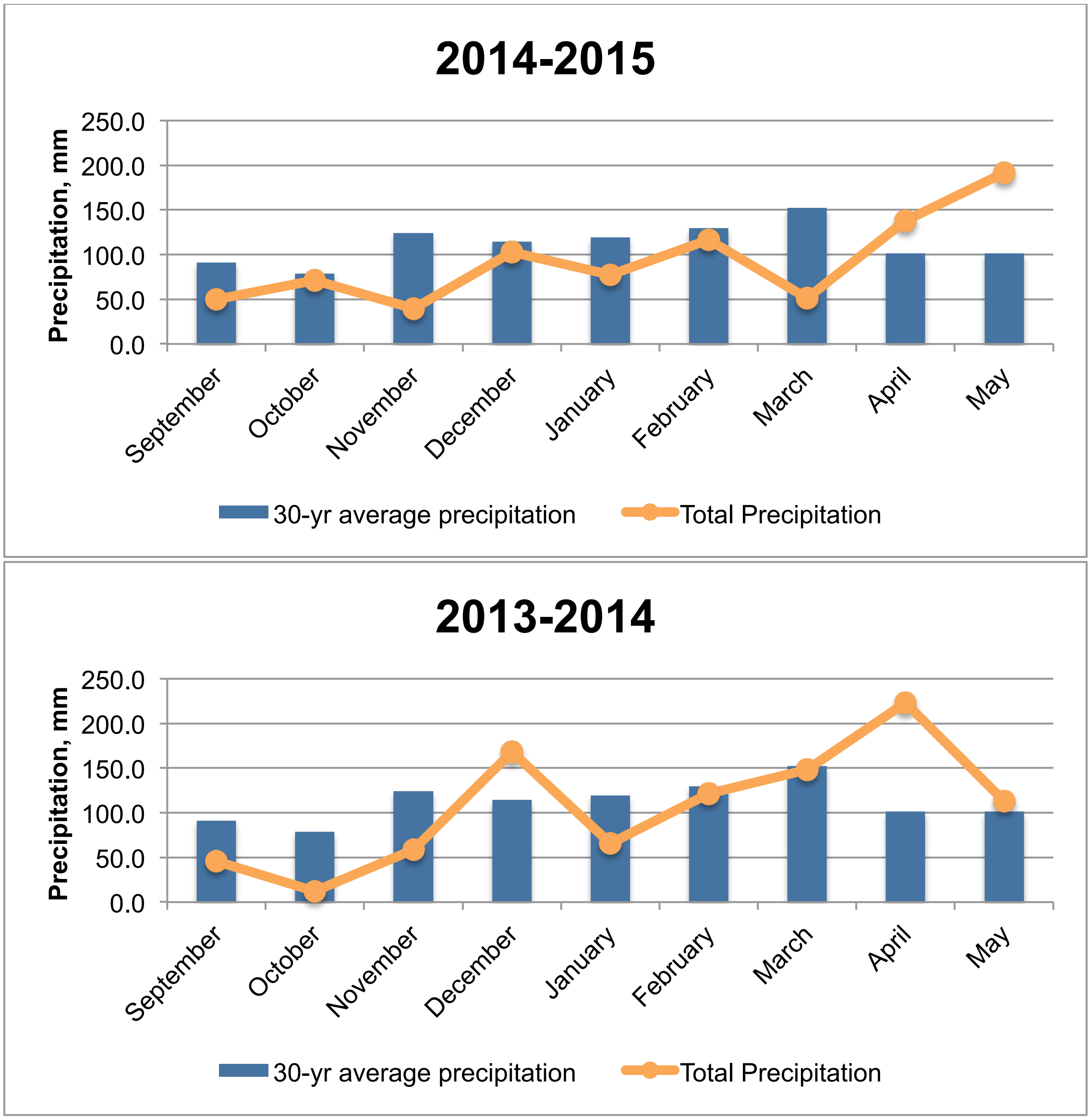


Figure 3. Monthly and 30-yr average monthly precipitation totals from September to May by yr at E.V. Smith Research Center, Milstead, AL.

Forage mass

Across all treatments, mean forage mass (FM) over the grazing season was 644 kg DM/ha in Yr 1 and 736 kg DM/ha in Yr 2. Forage mass data across all supplement types and levels at each sampling date are illustrated in Figure 4 for Yr 1 and Figure 5 for Yr 2. For both yrs, change in forage mass is reported in data tables 1 through 5 as the net increase or decrease in kg forage DM/ha between successive sampling dates (referred to as a sampling interval).

In Yr 1, there were 3 sampling intervals between late January and mid April. There were no type × level interactions ($P > 0.10$) for net forage mass change (FMC) in any of the sampling intervals in Yr 1. Between January 22 and March 5 across all levels of supplement fed, soybean hull and citrus pulp treatments had decreased ($P = 0.007$ and $P = 0.05$, respectively) FM compared with the corn treatments, which showed an increase in FM from the previous sampling date (Table 1). However, there were no differences ($P > 0.10$) in net FMC between the supplemented treatments and the unsupplemented control. There were no differences ($P > 0.10$) in net FMC between supplemented treatments and the unsupplemented control or among any of the supplement types between March 5 and April 2 or between April 2 and May 1 in Yr 1 (Table 1). Across all supplement types, there were no differences ($P > 0.10$) in net FMC between the supplemented treatments and the unsupplemented control or among the supplement levels in any of the sampling intervals in Yr 1 (Table 2).

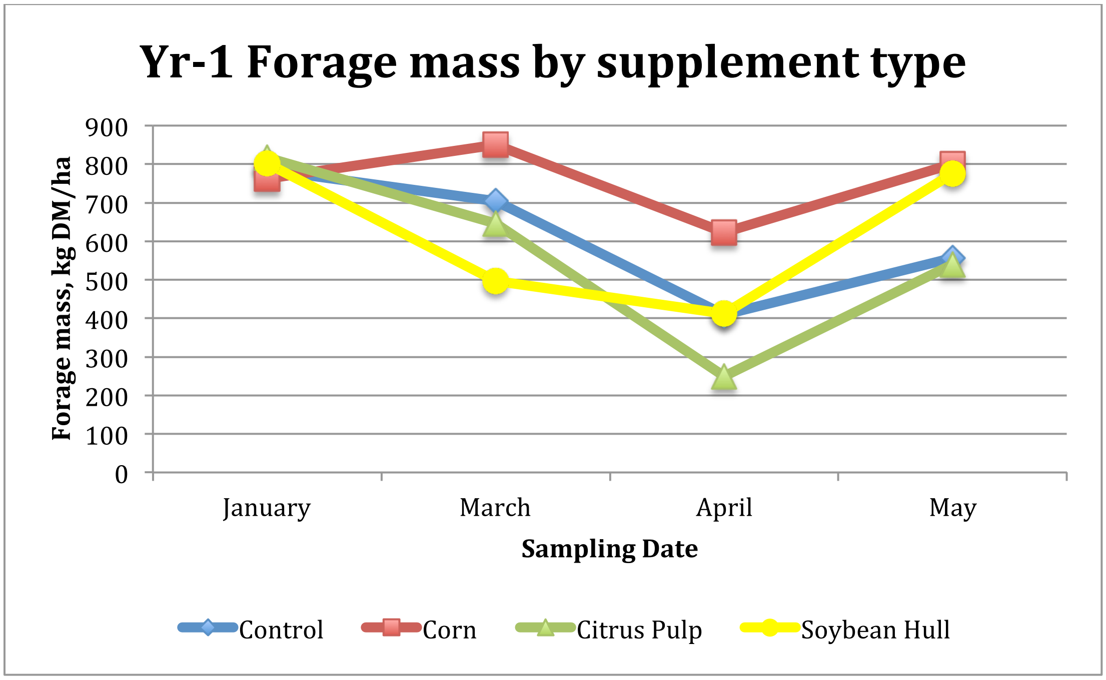
In Yr 2, there were 4 sampling intervals between mid December and mid April. Between December 15 and January 14, there was no difference ($P > 0.10$)

in net FMC between the supplemented treatments and the unsupplemented control; however, there was a type × level interaction ($P = 0.03$) (Table 3). At the supplementation level of 0.25% BW, net FMC was different between corn ($P = 0.02$) and citrus pulp ($P = 0.08$) treatments compared with the soybean hull treatment. At the level of 0.50% BW, net FMC was different ($P = 0.02$) between citrus pulp and corn treatments, with soybean hull treatments intermediate. At the level of 0.75% BW, there were no differences ($P > 0.10$) in net FMC among the supplement types. Among corn treatments, net FMC was different ($P = 0.09$) between the 0.50% BW and 0.75% BW treatments, with the 0.25% BW treatment intermediate. Among citrus pulp treatments, net FMC for the 0.25% BW and 0.75% BW treatments differed ($P = 0.10$ and $P = 0.04$, respectively) from the 0.50% BW treatment. Among soybean hull treatments, net FMC for the 0.50% BW and 0.75% BW treatments differed ($P = 0.02$ and $P = 0.06$, respectively) from the 0.25% BW treatment. Between January 14 and February 11 and between February 11 and March 18, there were no differences ($P > 0.10$) in FMC between supplemented treatments and the unsupplemented control or among supplement types or levels (Tables 4 & 5). Between March 18 and April 15, across all levels of supplement fed, net FMC for the control treatment differed from the corn ($P = 0.04$), citrus pulp ($P = 0.05$), and soybean hull ($P = 0.03$) treatments (Table 4). In the fourth sampling interval across all supplement types, net FMC for the control treatment was different from the 0.25% BW ($P = 0.10$), 0.5% BW ($P = 0.04$) and 0.75% BW ($P = 0.01$) treatments (Table 5).

Redfearn et al. (2002) observed that approximately 30% of total-season forage production from annual ryegrass occurs in April alone, in agreement with data from Yr 1 of the present study. The divergence from this trend in Yr 2 was most likely due to lower than usual temperatures recorded in January and February. Although temperatures were on par with 30-yr mean values in March and April, forage productivity was unable to fully recover. Hafley (1996) observed a mean FM of 2,061 kg/ha from Marshall ryegrass under continuous grazing conditions. Similarly, Mullenix et al. (2014) reported a mean FM of 1,493 kg DM/ha from continuously stocked ryegrass pasture. The greater FM values compared with the current study may be due to the lesser stocking rate utilized in these previous studies.

Horn et al. (1995) reported no difference in FM of wheat pasture grazed by stocker cattle fed high-fiber and high-starch supplements, in contrast to the present study. However, Bodine and Purvis (2003) observed a decrease in grazed forage intake for cattle receiving corn-based supplement compared with soybean meal or cottonseed hull supplements. Decreased forage intake may explain the increase in FM among corn treatments from January 22-March 3 in Yr 1 in the present study. The same may be said of the type × level interaction between December 15 and January 14 in Yr 2 in which a positive net FMC was exhibited by corn at the 0.25 and 0.75% BW levels, and by citrus pulp and soybean hull treatments at the 0.50% BW level. Decreased forage intake coupled with increasing temperature and maturation of the forage may also be responsible for the positive net FMC of the supplemented treatments between

March 18 and April 15 in Yr 2. Across multiple supplement types, increasing level of supplement fed may also affect forage intake and thus FM. Kunkle et al. (1995) reported no difference in intake of hay among corn, wheat middling, and soybean hull supplements fed at a level of 0.50% BW; however, when fed at 1.0% BW, corn-fed cattle had a decreased hay intake than soybean hull-fed cattle. Roberts et al. (2009) observed that ryegrass FM increased in the month of April with increasing level of supplementation, in agreement with the present study for Yr 2. However, in both studies some of the increased FM may have been due to the natural increased productivity of annual ryegrass during the month of April.



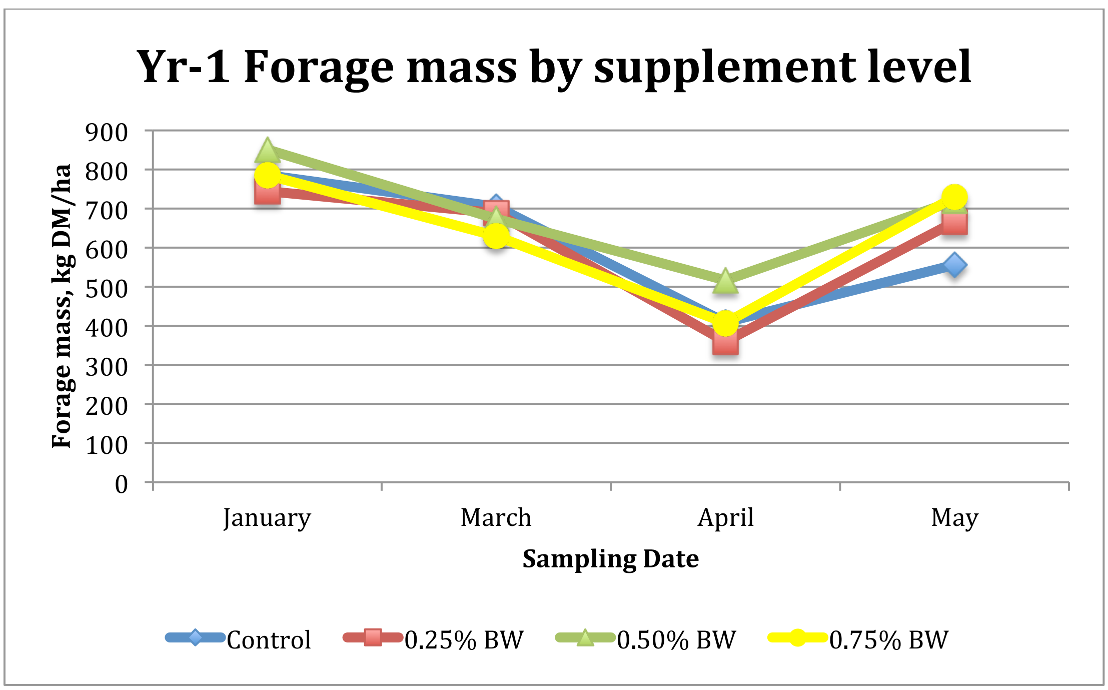
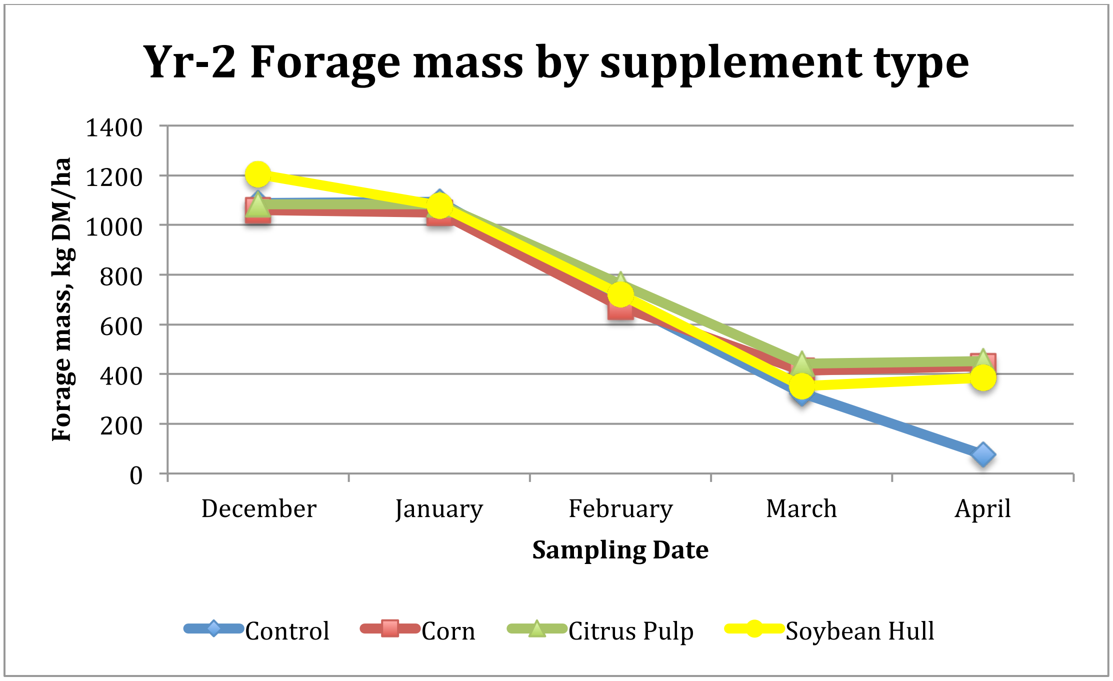


Figure 4. Forage mass by sampling date in ryegrass pastures grazed by steers receiving different types (top) and levels (bottom) of energy supplement (Yr 1).



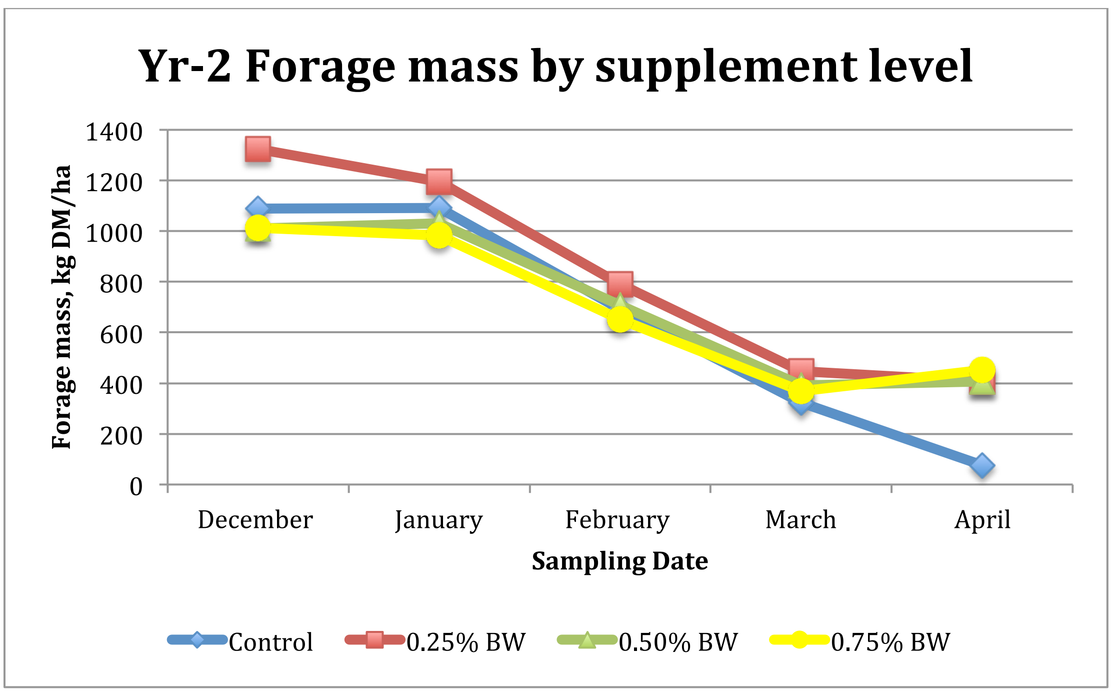


Figure 5. Forage mass by sampling date in ryegrass pastures grazed by steers receiving different types (top) and levels (bottom) of energy supplement (Yr 2).

Table 1. Net forage mass change (kg DM/ha) by sampling interval in ryegrass pastures grazed by steers receiving different types of energy supplement (Yr 1)

Sampling interval	Supplement type[1]				SEM
	Control	CC	CP	SBH	
Jan 22 to Mar 5	-81[ab]	88[a]	-170[b]	-305[b]	133
Mar 5 to Apr 2	-295	-227	-397	-85	239
Apr 2 to May 1	147	178	291	364	178

[1]Control = No supplement, CC = cracked corn, CP = citrus pulp, SBH = soybean hull.
[a,b] Within a row, means without a common superscript differ ($P < 0.10$).

Table 2. Net forage mass change (kg DM/ha) by sampling interval in ryegrass pastures grazed by steers receiving different levels of energy supplement (Yr 1)

Sampling interval	Supplement level[1]				SEM
	0	0.25	0.50	0.75	
Jan 22 to Mar 5	-81	-56	-176	-156	133
Mar 5 to Apr 2	-295	-329	-158	-222	239
Apr 2 to May 1	147	306	204	323	178

[1] 0 = No supplement, 0.25 = fed at 0.25% BW, 0.50 = fed at 0.50% BW, 0.75 = fed at 0.75% BW.

Table 3. Net forage mass change (kg DM/ha) in pastures grazed by steers receiving different types and levels of energy supplement (Yr 2, Dec 15 to Jan 14)

	Supplement type[1]		
Supplement level[2]	CC	CP	SBH
0.25	$60^{a,xy}$	$-71^{a,y}$	$-375^{b,y}$
0.50	$-190^{b,y}$	$213^{a,x}$	$33^{ab,x}$
0.75	100^{x}	-146^{y}	-42^{x}

[1] CC = cracked corn, CP = citrus pulp, SBH = soybean hull.
[2] 0.25 = fed at 0.25% BW, 0.50 = fed at 0.50% BW, 0.75 = fed at 0.75% BW.
[a,b] Within a row, means without a common superscript differ (*P* < 0.10, SEM = 116).
[x,y] Within a column, means without a common superscript differ (*P* < 0.10, SEM = 116).

Table 4. Net forage mass change (kg DM/ha) by sampling interval in ryegrass pastures grazed by steers receiving different types of energy supplement (Yr 2)

Sampling interval	Supplement type[1]				SEM
	Control	CC	CP	SBH	
Dec 15 to Jan 14	5	-10	-1	-129	167
Jan14 to Feb 11	-400	-380	-321	-358	94
Feb 11 to Mar 18	-369	-258	-320	-368	94
Mar 18 to Apr 15	-248[a]	18[b]	10[b]	35[b]	107

[1]Control = No supplement, CC = cracked corn, CP = citrus pulp, SBH = soybean hull.
[a,b] Within a row, means without a common superscript differ (P < 0.10).

Table 5. Net forage mass change (kg DM/ha) by sampling interval in ryegrass pastures grazed by steers receiving different levels of energy supplement (Yr 2)

Sampling interval	Supplement level[1]				SEM
	0	0.25	0.50	0.75	
Dec 15 to Jan 14	5	-129	19	-29	167
Jan 14 to Feb 11	-400	-405	-324	-330	94
Feb 11 to Mar 18	-369	-346	-316	-285	94
Mar 18 to Apr 15	-248[a]	-38[b]	17[b]	85[b]	107

[1] 0 = No supplement, 0.25 = fed at 0.25% BW, 0.50 = fed at 0.50% BW, 0.75 = fed at 0.75% BW.
[a,b] Within a row, means without a common superscript differ (P < 0.10).

Forage allowance

Forage allowance (FA) data across all supplement types and levels at each sampling date are illustrated in Figure 6 for Yr 1 and Figure 7 for Yr 2. Across all treatments, mean FA (kg forage DM/kg total steer BW) over the grazing season was 0.48 in Yr 1 and 0.54 in Yr 2.

In Yr 1, there were 4 sampling dates between late January and mid-April. On January 22 across all supplement types, there were no differences ($P > 0.10$) in FA among supplement levels (Table 7); however, across all levels of supplement fed, FA was greater for the citrus pulp treatment than the unsupplemented control ($P = 0.06$), corn ($P = 0.05$), and soybean hull ($P = 0.009$) treatments (Table 6). On March 3, there was no difference ($P > 0.10$) in FA between supplement treatments and the unsupplemented control across either type or level; however, there was a type × level interaction ($P = 0.002$) (Table 8). At the supplementation level of 0.25% BW, there were no differences ($P > 0.10$) in FA among supplement types. At the level of 0.50% BW, FA was greater for the soybean hull treatment than citrus pulp ($P = 0.002$) and corn ($P = 0.001$) treatments. However, at the 0.75% BW level, FA was greater for the citrus pulp than soybean hull ($P = 0.004$) and corn ($P = 0.01$) treatments. Among corn treatments, FA was greater for 0.25% BW than 0.50% BW ($P = 0.05$) and 0.75% BW ($P = 0.06$) levels. Among citrus pulp treatments, FA was greater ($P = 0.02$) for the 0.75% BW than 0.50% BW level, with the 0.25% BW level intermediate. Among soybean hull treatments, FA was greater for the 0.50% BW than 0.25% BW ($P = 0.01$) and 0.75% BW ($P < 0.001$) levels; and FA was greater ($P = 0.07$)

for the 0.25% BW than 0.75% BW level. On April 2 across all supplement levels, there were no differences (*P* > 0.10) among supplement types (Table 6); however, across all supplement types, FA was greater for the unsupplemented control (*P* = 0.09) and 0.25% BW (*P* = 0.06) treatments than the 0.50% BW treatment, with 0.75% BW being intermediate (Table 7). On May 1, across all levels of supplement fed, FA was greater for the unsupplemented control (*P* = 0.04) and citrus pulp (*P* = 0.04) treatments than soybean hulls, with corn intermediate (Table 6). Across all supplement types, FA was greater (*P* = 0.05) for the unsupplemented control than the 0.5% BW treatment (Table 7). There was also a type × level interaction (*P* = 0.04) for FA on May 1 (Table 9). At the supplementation level of 0.25% BW, FA was greater for citrus pulp than for corn (*P* = 0.01) and soybean hull (*P* = 0.004) treatments. At supplementation levels of 0.50% BW and 0.75% BW, there were no differences (*P* > 0.10) in FA among supplement types. Among corn treatments, FA was greater (*P* = 0.06) for the 0.75% BW than 0.50% BW level, with the 0.25% BW level intermediate. Among citrus pulp treatments, FA was greater for the 0.25% BW than 0.50% BW (*P* = 0.01) and 0.75% BW (*P* = 0.02) levels. For the soybean hull treatments, FA was not different (*P* > 0.10) among supplement levels.

In Yr 2 there were 5 sampling dates between mid-December and mid-April. On December 15 across all levels of supplement fed, FA was greater for the soybean hull treatment than the unsupplemented control (*P* = 0.04), corn (*P* = 0.01), and citrus pulp (*P* = 0.02) treatments (Table 10); and across all supplement types, there were no differences (*P* > 0.10) in FA among supplement levels (Table 11). On January 14 across all supplement levels, FA was greater (*P* = 0.01) for the soybean hull than citrus pulp treatment, with corn and the unsupplemented control treatments intermediate (Table 10). Across all supplement types, FA was greater (*P* = 0.03) for 0.50% BW than for 0.75% BW treatments (Table 11). On February 11 across all levels of supplement fed, FA was greater for the soybean hull treatment than the unsupplemented control (*P* = 0.03) and citrus pulp (*P* = 0.003) treatments; and FA was also greater (*P* = 0.08) for the corn than citrus pulp treatment (Table 10). Across all supplement types, there were no differences (*P* > 0.10) in FA among supplement levels (Table 11). On March 18, there were no differences (*P* > 0.10) in FA between the supplemented treatments and the unsupplemented control across either types or levels. Lastly, on April 15 across all levels of supplementation, there were no differences (*P* > 0.10) in FA among supplement types (Table 10); however, across all supplement types, FA was greater (*P* = 0.04) for the 0.25% BW than 0.50% BW treatments (Table 11).

Type × level interactions for FA were observed at every sampling date in Yr 2. On December 15 (Table 12) at the 0.25% BW level of supplementation, FA was greater for soybean hull treatments than corn (*P* = 0.02) and citrus pulp (*P* = 0.002) treatments. Similarly, at the 0.50% BW level of supplementation, FA was greater for the soybean hull than corn (*P* = 0.02) and citrus pulp (*P* = 0.02) treatments. However, at the level of 0.75% BW level of supplementation, FA was greater (*P* = 0.08) for the citrus pulp than soybean hull treatment, with the corn treatment intermediate. For the corn and citrus pulp treatments, there were no differences ($P > 0.10$) in FA among supplementation levels. However, among soybean hull treatments, FA was greater for the 0.25% BW ($P < 0.001$) and the 0.50% BW ($P < 0.001$) levels than the 0.75% BW level.

On January 14 (Table 13) at the 0.25% BW level of supplementation, FA was greater for the soybean hull than corn ($P = 0.02$) and citrus pulp ($P < 0.001$) treatments, and greater ($P = 0.04$) for the corn than citrus pulp treatment. At the 0.5% BW level of supplementation, FA was greater ($P = 0.05$) for the soybean hull than corn treatment, with citrus pulp intermediate. However, at the 0.75% BW level of supplementation, FA was greater ($P = 0.02$) for corn than for soybean hull treatments, with citrus pulp intermediate. Values for FA did not differ ($P < 0.10$) among corn treatments on January 14. Among citrus pulp treatments, FA was greater for the 0.50% BW ($P = 0.01$) and 0.75% BW ($P = 0.10$) levels than the 0.25% BW level. However, among soybean hull treatments, FA was greater for 0.25% BW ($P < 0.001$) and 0.50% BW ($P = 0.001$) treatments than the 0.75% BW treatments.

On February 11 (Table 14) at the 0.25% BW level of supplementation, FA was greater for soybean hull than for corn ($P = 0.001$) and citrus pulp ($P < 0.001$) treatments, and was likewise greater for soybean hull than for corn ($P = 0.01$) and citrus pulp ($P = 0.08$) treatments at the 0.5% BW level of supplementation. However, at the 0.75% BW level, FA was greater for the corn than citrus pulp ($P = 0.02$) and soybean hull ($P < 0.001$) treatments. Among all corn treatments, FA was greater for the 0.75% BW than 0.25% BW ($P = 0.006$) and 0.50% BW ($P = 0.008$) levles. Among all citrus pulp treatments, FA was greater for the 0.50%

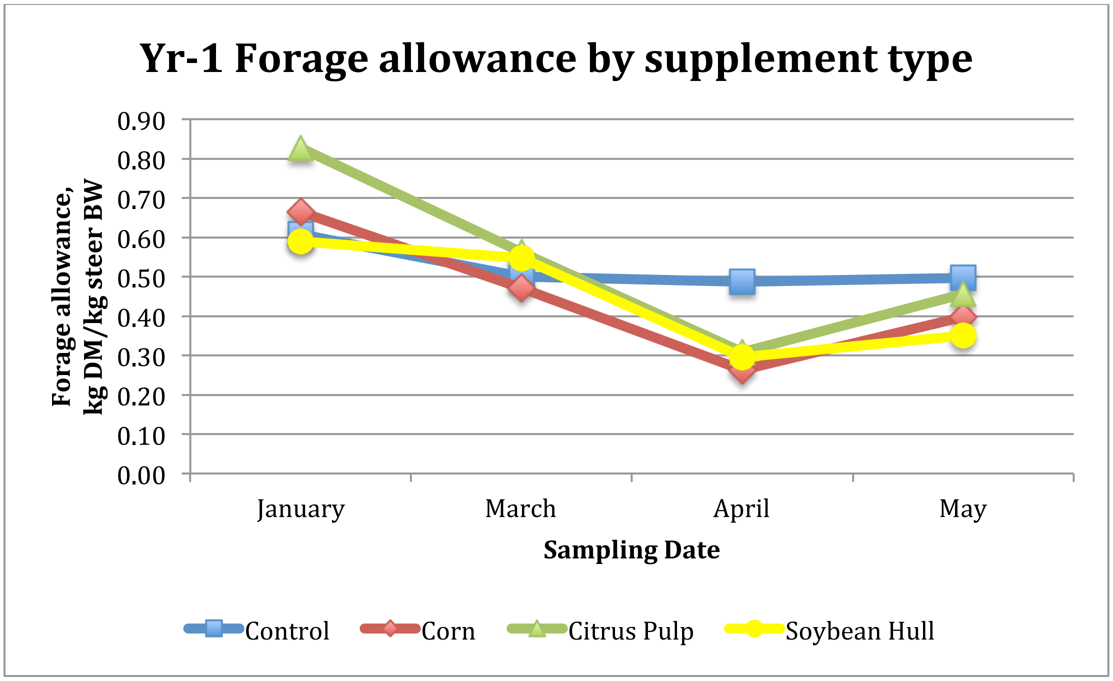
BW (0.03) and 0.75% BW (P = 0.05) levels than 0.25% BW level. However, among the soybean hull treatments, FA was greater for the 0.25% BW (P < 0.001) and 0.50% BW (P = 0.001) levels than the 0.75% BW level of supplementation.

On March 18 (Table 15) at the 0.25% BW level of supplementation, FA was greater for the soybean hull than corn (P = 0.04) and citrus pulp (P = 0.006) treatments. FA did not differ (P > 0.10) among 0.50% BW treatments and, at the 0.75% BW level of supplementation, FA was greater for the corn (P = 0.06) and citrus pulp (P = 0.02) than soybean hull treatment. Values for FA did not differ (P > 0.10) among levels of supplementation with corn, but was greater (P = 0.05) for the 0.75% BW than 0.25% BW levels of supplementation with citrus pulp, with the 0.50% BW level intermediate. Among all soybean hull treatments, FA was greater for 0.25% BW (P = 0.002) and 0.50% BW (P = 0.04) treatments than for 0.75% BW treatments.

On April 15 (Table 16) at the 0.25% BW level of supplementation, FA was greater for the soybean hull than corn (P = 0.06) and citrus pulp (P = .005) treatments, but did not differ (P > 0.10) among supplement types at either the 0.50% BW or 0.75% BW levels. Values for FA did not differ (P > 0.10) among levels of supplementation with corn, but were greater (P = 0.07) for the 0.75% BW than 0.25% BW level of supplementation with citrus pulp. Among levels of supplementation with soybean hull, FA was greater for the 0.25% BW than 0.50% BW (P = 0.01) and 0.75% BW (P = 0.02) treatments.

Scaglia et al. (2009) reported FA values between 0.60 and

1.14 from grazed ryegrass pastures stocked with 4.5 steers/ha and supplemented at different times of the day with corn gluten feed at 0.50% BW, which are slightly greater than FA values reported in the present study. The relationship between ADG and FA has been typically accepted to be linear up to a FA of approximately 3 kg DM/kg BW (McCartor and Rouquette, 1977). Beck et al. (2013) developed a nonlinear regression model which predicts that a FA of 1.8 is needed to maintain ADG of 0.9 kg. However, Mullenix et al. (2014) were able to produce ADG exceeding 1.2 kg/d from ryegrass and small-grain pastures with a FA of 1.36 kg DM/kg BW. Similarly, Marchant (2014) produced a mean ADG of 1.44 kg with a FA of 0.89 kg DM/kg BW. Additionally, Redmon et al. (1995) suggested that ADG from small-grain pasture does not suffer until FA has fallen below 0.21 kg DM/kg BW, further corroborating observed relationships between ADG and FA in the present study. Horn et al. (1995) reported FA values for wheat pasture that exceeded 2.8 for supplemented cattle and 4.0 for the unsupplemented control. There was no difference in FA across the grazing season in their study.



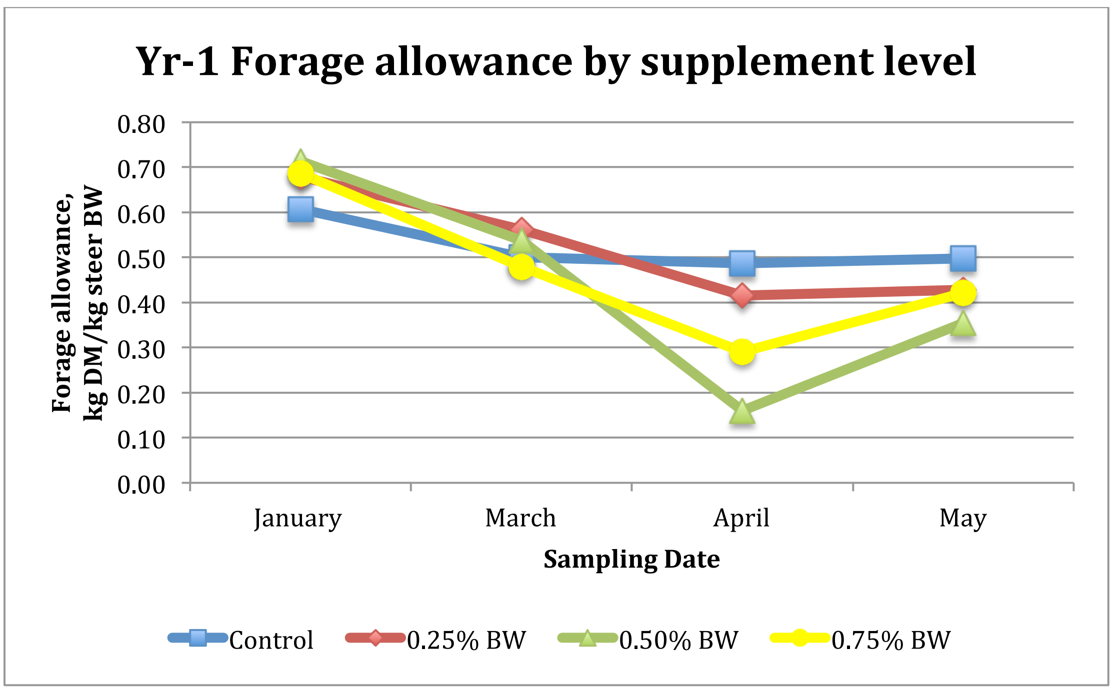
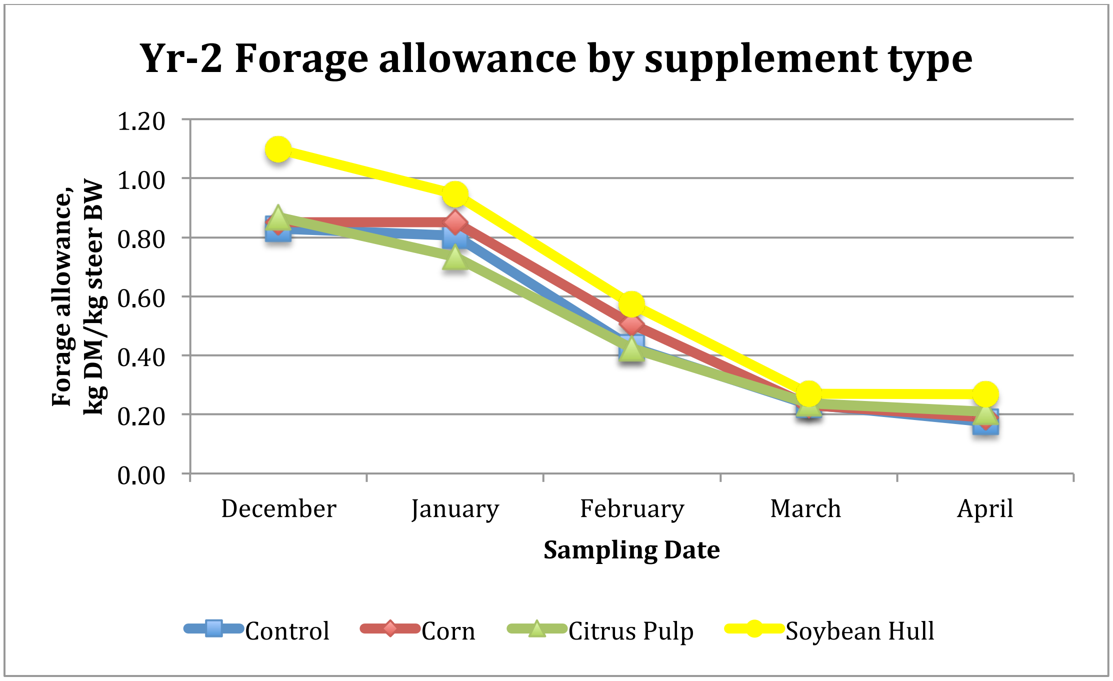


Figure 6. Forage allowance by sampling date in ryegrass pastures grazed by steers receiving different types (top) and levels (bottom) of energy supplement (Yr 1).



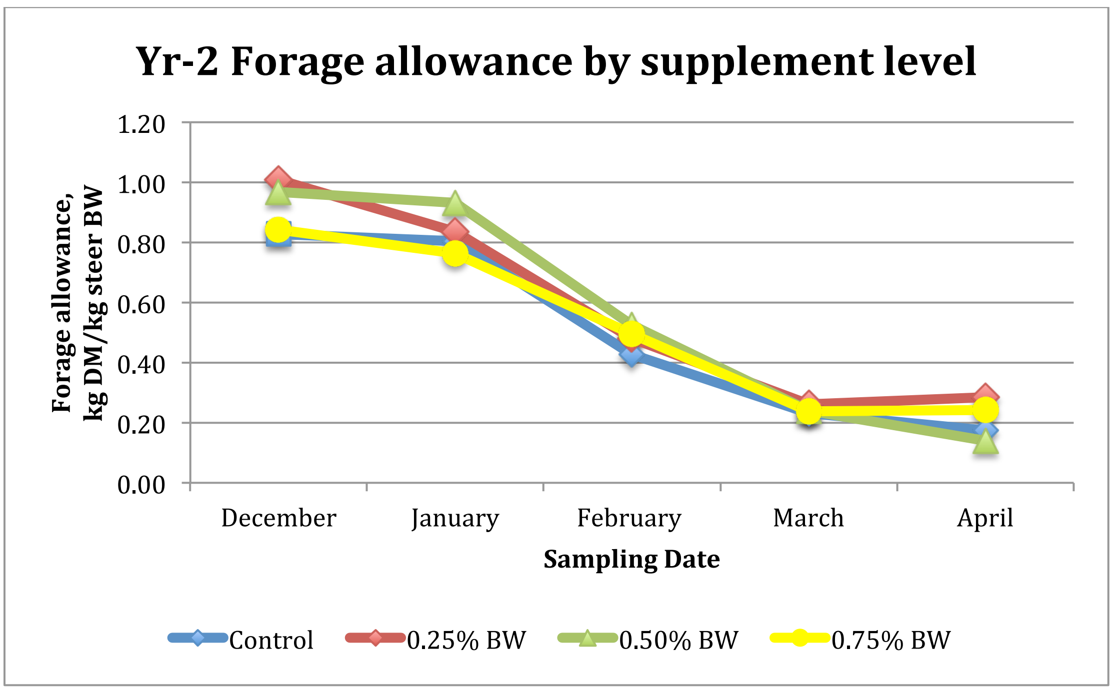


Figure 7. Forage allowance by sampling date in ryegrass pastures grazed by steers receiving different types (top) and levels (bottom) of energy supplement (Yr 2).

Table 6. Mean forage allowance (kg DM/kg BW) by sampling date in ryegrass pastures grazed by steers receiving different types of energy supplement (Yr 1)

	Supplement type[1]				
Sampling date	Control	CC	CP	SBH	SEM
January 22	0.61^{b}	0.67^{b}	0.83^{a}	0.59^{b}	0.09
March 3	0.50	0.47	0.56	0.55	0.08
April 2	0.49	0.26	0.31	0.30	0.15
May 1	0.50^{a}	0.40^{ab}	0.46^{a}	0.35^{b}	0.06

[1]Control = No supplement, CC = cracked corn, CP = citrus pulp, SBH = soybean hull.

[a,b] Within a row, means without a common superscript differ (*P* < 0.10).

Table 7. Mean forage allowance (kg DM/kg BW) by sampling date in ryegrass pastures grazed by steers receiving different levels of energy supplement (Yr 1)

	Supplement level[1]				
Sampling date	0	0.25	0.50	0.75	SEM
January 22	0.61	0.68	0.71	0.69	0.09
March 3	0.50	0.56	0.54	0.48	0.08
April 2	0.49^{a}	0.42^{a}	0.16^{b}	0.29^{ab}	0.15
May 1	0.50^{a}	0.43^{ab}	0.36^{b}	0.42^{ab}	0.06

[1] 0 = No supplement, 0.25 = fed at 0.25% BW, 0.50 = fed at 0.50% BW, 0.75 = fed at 0.75% BW.

[a,b] Within a row, means without a common superscript differ (*P* < 0.10).

Table 8. Mean forage allowance (kg DM/kg BW) in pastures grazed by steers receiving different types and levels of energy supplement (Yr 1, Mar 3)

	Supplement type[1]		
Supplement level[2]	CC	CP	SBH
0.25	0.59^{x}	0.58^{xy}	0.52^{y}
0.50	$0.41^{b,y}$	$0.44^{b,x}$	$0.78^{a,x}$
0.75	$0.42^{b,y}$	$0.67^{a,y}$	$0.35^{b,z}$

[1] CC = cracked corn, CP = citrus pulp, SBH = soybean hull.
[2] 0.25 = fed at 0.25% BW, 0.50 = fed at 0.50% BW, 0.75 = fed at 0.75% BW.
[a,b] Within a row, means without a common superscript differ (*P* < 0.10, SEM = 0.06).
[x-z] Within a column, means without a common superscript differ (*P* < 0.10, SEM = 0.06).

Table 9. Mean forage allowance (kg DM/kg BW) in pastures grazed by steers receiving different types and levels of energy supplement (Yr 1, May 1)

	Supplement type[1]		
Supplement level[2]	CC	CP	SBH
0.25	$0.37^{b,xy}$	$0.62^{a,x}$	0.31^{b}
0.50	0.33^{x}	0.36^{y}	0.38
0.75	0.50^{y}	0.40^{y}	0.36

[1] CC = cracked corn, CP = citrus pulp, SBH = soybean hull.
[2] 0.25 = fed at 0.25% BW, 0.50 = fed at 0.50% BW, 0.75 = fed at 0.75% BW.
[a,b] Within a row, means without a common superscript differ (*P* < 0.10, SEM = 0.06).
[x,y] Within a column, means without a common superscript differ (*P* < 0.10, SEM = 0.06).

Table 10. Mean forage allowance (kg DM/kg BW) by sampling date in ryegrass pastures grazed by steers receiving different types of energy supplement (Yr 2)

Sampling date	Supplement type[1]				SEM
	Control	CC	CP	SBH	
December 15	0.83[b]	0.85[b]	0.87[b]	1.10[a]	0.11
January 14	0.80[ab]	0.85[ab]	0.73[b]	0.95[a]	0.09
February 11	0.43[bc]	0.51[ab]	0.42[c]	0.58[a]	0.06
March 18	0.23	0.23	0.24	0.27	0.05
April 15	0.17	0.19	0.21	0.27	0.08

[1]Control = No supplement, CC = cracked corn, CP = citrus pulp, SBH = soybean hull.
[a-c] Within a row, means without a common superscript differ (*P* < 0.10).

Table 11. Mean forage allowance (kg DM/kg BW) by sampling date in ryegrass pastures grazed by steers receiving different levels of energy supplement (Yr 2)

Sampling date	Supplement level[1]				SEM
	0	0.25	0.50	0.75	
December 15	0.83	1.01	0.97	0.84	0.11
January 14	0.80[ab]	0.84[ab]	0.93[a]	0.76[b]	0.09
February 11	0.43	0.48	0.53	0.50	0.06
March 18	0.23	0.26	0.24	0.24	0.05
April 15	0.17[ab]	0.28[a]	0.14[b]	0.24[ab]	0.08

[1] 0 = No supplement, 0.25 = fed at 0.25% BW, 0.50 = fed at 0.50% BW, 0.75 = fed at 0.75% BW.
[a,b] Within a row, means without a common superscript differ (*P* < 0.10).

Table 12. Mean forage allowance (kg DM/kg BW) in pastures grazed by steers receiving different types and levels of energy supplement (Yr 2, Dec 15)

	Supplement type[1]		
Supplement level[2]	CC	CP	SBH
0.25	0.93^{b}	0.76^{b}	$1.33^{a,x}$
0.50	0.73^{b}	0.88^{b}	$1.29^{a,x}$
0.75	0.89^{ab}	0.96^{a}	$0.67^{b,y}$

[1] CC = cracked corn, CP = citrus pulp, SBH = soybean hull.
[2] 0.25 = fed at 0.25% BW, 0.50 = fed at 0.50% BW, 0.75 = fed at 0.75% BW.
[a,b] Within a row, means without a common superscript differ (*P* < 0.10, SEM = 0.11).
[x,y] Within a column, means without a common superscript differ (*P* < 0.10, SEM = 0.11).

Table 13. Mean forage allowance (kg DM/kg BW) in pastures grazed by steers receiving different types and levels of energy supplement (Yr 2, Jan 14)

	Supplement type[1]		
Supplement level[2]	CC	CP	SBH
0.25	0.82^{b}	$0.54^{c,x}$	$1.15^{a,x}$
0.50	0.82^{b}	$0.90^{ab,y}$	$1.08^{a,x}$
0.75	0.92^{a}	$0.76^{ab,y}$	$0.61^{b,y}$

[1] CC = cracked corn, CP = citrus pulp, SBH = soybean hull.
[2] 0.25 = fed at 0.25% BW, 0.50 = fed at 0.50% BW, 0.75 = fed at 0.75% BW.
[a-c] Within a row, means without a common superscript differ (*P* < 0.10, SEM = 0.09).
[x,y] Within a column, means without a common superscript differ (*P* < 0.10, SEM = 0.09).

Table 14. Mean forage allowance (kg DM/kg BW) in pastures grazed by steers receiving different types and levels of energy supplement (Yr 2, Feb 11)

	Supplement type[1]		
Supplement level[2]	CC	CP	SBH
0.25	$0.42^{b,y}$	$0.30^{b,y}$	$0.73^{a,x}$
0.50	$0.43^{b,y}$	$0.50^{b,x}$	$0.65^{a,x}$
0.75	$0.68^{a,x}$	$0.47^{b,x}$	$0.34^{b,y}$

[1] CC = cracked corn, CP = citrus pulp, SBH = soybean hull.
[2] 0.25 = fed at 0.25% BW, 0.50 = fed at 0.50% BW, 0.75 = fed at 0.75% BW.
[a,b] Within a row, means without a common superscript differ (*P* < 0.10, SEM = 0.06).
[x,y] Within a column, means without a common superscript differ (*P* < 0.10, SEM = 0.06).

Table 15. Mean forage allowance (kg DM/kg BW) in pastures grazed by steers receiving different types and levels of energy supplement (Yr 2, Mar 18)

	Supplement type[1]		
Supplement level[2]	CC	CP	SBH
0.25	0.23^{b}	$0.16^{b,y}$	$0.39^{a,x}$
0.50	0.19	0.24^{xy}	0.29^{x}
0.75	0.27^{a}	$0.31^{a,x}$	$0.13^{b,y}$

[1] CC = cracked corn, CP = citrus pulp, SBH = soybean hulls
[2] 0.25 = fed at 0.25% BW, 0.50 = fed at 0.50% BW, 0.75 = fed at 0.75% BW
[a,b] Within a row, means without a common superscript differ (*P* < 0.10, SEM = 0.05)
[x,y] Within a column, means without a common superscript differ (*P* < 0.10, SEM = 0.05)

Table 16. Mean forage allowance (kg DM/kg BW) in pastures grazed by steers receiving different types and levels of energy supplement (Yr 2, Apr 15)

Supplement level[2]	Supplement type[1]		
	CC	CP	SBH
0.25	0.25^{b}	$0.11^{b,y}$	$0.49^{a,x}$
0.50	0.10	0.17^{xy}	0.14^{y}
0.75	0.22	0.34^{x}	0.17^{y}

[1] CC = cracked corn, CP = citrus pulp, SBH = soybean hull.
[2] 0.25 = fed at 0.25% BW, 0.50 = fed at 0.50% BW, 0.75 = fed at 0.75% BW.
[a,b] Within a row, means without a common superscript differ (*P* < 0.10, SEM = 0.08).
[x,y] Within a column, means without a common superscript differ (*P* < 0.10, SEM = 0.08).

Steer ADG and total gain/ha

There were no type × level interactions ($P > 0.10$) in either yr for steer ADG or total gain/ha. Across both yrs, steer ADG was greater ($P < 0.10$) for supplemented treatments than the unsupplemented control. In Yr 1 across all levels of supplement fed, ADG was greater from corn ($P = 0.03$) and soybean hulls ($P = 0.07$) and tended to be greater from citrus pulp ($P = 0.11$) than the unsupplemented control (Table 17). Across all supplement types, steer ADG was greater for the 0.25 ($P = 0.08$), 0.50 ($P = 0.09$), and 0.75 ($P = 0.03$) % of BW treatments than the unsupplemented control (Table 18). In Yr 2 across all levels of supplement fed, steer ADG was greater from corn ($P = 0.01$) and soybean hulls ($P = 0.07$) and tended to be greater from citrus pulp ($P = 0.15$) than the unsupplemented control (Table 17). Across all supplement types, steer ADG was greater for 0.25 ($P = 0.06$), 0.50 ($P = 0.03$) and 0.75 ($P = 0.09$) % of BW treatments than the unsupplemented control (Table 18). Horn et al. (1995) also observed that cattle grazing wheat pasture and fed either 1.08 kg/d of high-starch supplement (corn-based) or 1.66 kg/d of high-fiber supplement (soybean hulls and wheat middlings) had greater ADG (1.14 kg) than unsupplemented cattle (0.99 kg); however, cattle fed the high-starch supplement had decreased ADG (1.11 kg) compared with cattle fed the high-fiber supplement (1.16 kg). The greater ADG of their high-fiber than high-starch supplement treatment was likely due to a substitution effect of the starchy supplement in which forage intake and ADG were decreased, in contrast to the present study. Roberts et al. (2009) observed a linear increase in ADG of steers grazing annual ryegrass with increasing level of corn supplementation, which may have been due to the wider range of corn supplementation levels (0.5 to 2.0% of BW) utilized in their study.

Across both yr, total steer BW gain/ha was greater ($P < 0.10$) for supplemented treatments than the unsupplemented control. In Yr 1 across all supplement levels, total gain/ha was greater from corn ($P = 0.03$), citrus pulp ($P = 0.10$), and soybean hulls ($P = 0.07$) than the unsupplemented control (Table 1). Across all supplement types, total gain/ha was greater for 0.25 ($P = 0.07$), 0.50 ($P = 0.09$), and 0.75 ($P = 0.03$) % of BW treatments than the unsupplemented control (Table 2). In Yr 2 across all supplement levels, total gain/ha was greater for corn ($P = 0.02$) and soybean hulls ($P = 0.10$) than the unsupplemented control, and total gain/ha was greater from corn ($P = 0.08$) than citrus pulp (Table 17). Across all supplement types, total gain/ha was greater for 0.25 ($P = 0.09$) and 0.50 ($P = 0.06$) % of BW treatments than the unsupplemented control (Table 18). Horn et al. (1995) reported greater total gain/ha for cattle fed a corn based supplement (154 kg/ha) and soybean hulls + wheat middlings supplement (161 kg/ha) than unsupplemented cattle (103 kg/ha), in agreement with the present study.

Table 17. Average daily gain and total gain/ha for steers from grazed ryegrass and different types of energy supplement (Yrs 1 and 2)

		Supplement type[1]				
Yr	Item	Control	CC	CP	SBH	SEM
1	ADG,kg	0.95^{b}	1.30^{a}	1.20^{ab}	1.23^{a}	0.12
	BW gain/ha, kg	460^{a}	630^{b}	579^{b}	597^{b}	58
2	ADG, kg	0.86^{a}	1.03^{b}	0.95^{ab}	0.98^{b}	0.06
	BW gain/ha, kg	506^{a}	608^{c}	554^{ab}	576^{bc}	35

[1] Control = No supplement, CC = cracked corn, CP = citrus pulp, SBH = soybean hull.

[a-c] Within a row, means without a common superscript differ (*P* < 0.10).

Table 18. Average daily gain and total gain/ha for steers from grazed ryegrass and different levels of energy supplement (Yrs 1 and 2)

		Supplement level[1]				
Yr	Item	0	0.25	0.50	0.75	SEM
1	ADG,kg	0.95^{a}	1.22^{b}	1.21^{b}	1.30^{b}	0.12
	BW gain/ha, kg	460^{a}	593^{b}	584^{b}	628^{b}	58
2	ADG, kg	0.86^{a}	0.99^{b}	1.01^{b}	0.97^{b}	0.06
	BW gain/ha, kg	506^{a}	579^{b}	588^{b}	572^{ab}	35

[1] 0 = No supplement, 0.25 = fed at 0.25% BW, 0.50 = fed at 0.50% BW, 0.75 = fed at 0.75% BW.

[a,b] Within a row, means without a common superscript differ (*P* < 0.10).

Supplement Use Efficiency

Efficiency of supplement utilization for gain relative to control steers was not different ($P > 0.10$) in either year among supplement types (Table 19) or among levels of supplement fed (Table 20). Bodine and Purvis (2003) observed greater supplement use efficiency for soybean meal (1.5 kg feed/kg gain) than for corn (7.2 kg feed/kg gain). In keeping with McCollum and Horn (1990), who suggested that supplemental conversions less than 3:1 indicate a supplementation effect wherein the response elicited is greater than that which could have been achieved from the supplement alone. Additionally, supplemental conversions of greater than 8:1 are indicative of a substitution effect wherein there is inefficient use of the supplement nutrients. Horn et al. (1995) subsequently reported greater supplemental conversions for soybean hull and wheat middling supplement (3.3 kg feed/kg gain) than for corn-based supplement (2.4 kg feed/kg gain). In Yr 2, supplement conversion efficiencies were negative for corn and citrus pulp treatments across all levels, and for the 0.50% BW level across all supplement types. These data may be misinterpreted to mean that cattle supplemented with corn and citrus pulp or at a level of 0.50% BW gained less over the grazing season than the unsupplemented control, which clearly was not the case. Negative values for supplement use efficiency are attributable to 3 pastures for which total gain was less than the unsupplemented control. If pasture replication is ignored, it is clear that supplemented cattle utilized supplement for increased gains above the unsupplemented control (Tables 21 and 22). Bodine et al. (2001) reported supplement conversions of 8.1

for high-grain (sorghum grain-based) and high-fiber (wheat middlings and soybean hull-based) feeds, in agreement with values for corn supplementation from Yr 2. However, the fibrous supplements in the current study produced superior conversions in Yr 2, indicating a greater degree of substitution that may have been due in part to the differences in forages grazed in each study. Bodine et al. (2001) investigated supplementation effects on utilization of bermudagrass whereas annual ryegrass was grazed in the present study.

Table 19. Supplement use efficiency (kg feed/kg gain) relative to the control for steers receiving different types of energy supplement (Yrs 1 and 2)

	Supplement type[1]			
Yr	CC	CP	SBH	SEM
1	47.1	6.1	5.1	25
2	-14.4	-17.4	12.1	20

[1] CC = cracked corn, CP = citrus pulp, SBH = soybean hull.

Table 20. Supplement use efficiency (kg feed/kg gain) relative to the control for steers receiving different levels of energy supplement (Yrs 1 and 2)

	Supplement level[1]			
Yr	0.25	0.50	0.75	SEM
1	3.0	48.5	6.7	25
2	6.5	-39.6	13.4	20

[1] 0.25 = fed at 0.25% BW, 0.50 = fed at 0.50% BW, 0.75 = fed at 0.75% BW.

Table 21. Supplement use efficiency (kg feed/kg gain) relative to the control for steers receiving different types of energy supplement without replications (Yrs 1 and 2).

	Supplement type[1]		
Yr	CC	CP	SBH
1	3.9	5.2	4.4
2	8.3	19.5	11.8

[1] CC = cracked corn, CP = citrus pulp, SBH = soybean hull.

Table 22. Supplement use efficiency (kg feed/kg gain) relative to the control for steers receiving different levels of energy supplement without replications (Yrs 1 and 2).

	Supplement level[1]		
Yr	0.25	0.50	0.75
1	2.7	5.3	5.5
2	7.3	9.7	22.7

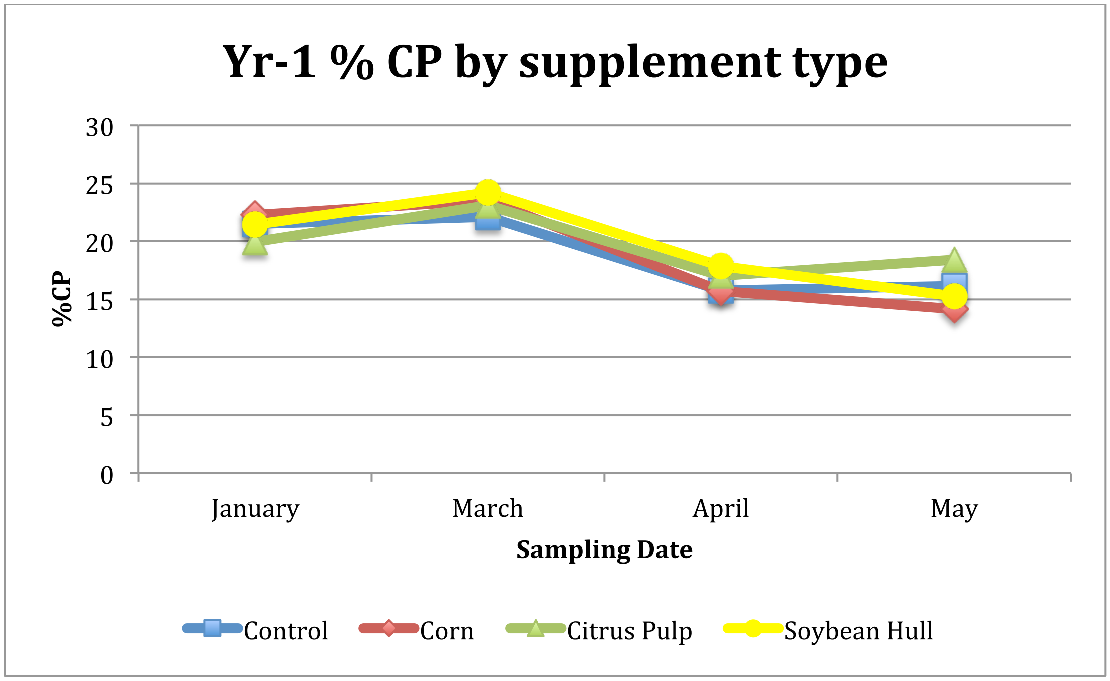
[1] 0.25 = fed at 0.25% BW, 0.50 = fed at 0.50% BW, 0.75 = fed at 0.75% BW.

Forage nutritive value

Forage concentrations of CP across supplement types and levels of supplement fed are illustrated in Figure 8 for Yr 1 and in Figure 9 for Yr 2. Mean concentration of CP across all treatments was 19% and 18% for Yr 1 and Yr 2, respectively. Ball et al. (2015) reported CP concentrations for annual ryegrass between 12 and 16% across the grazing season. Redfearn et al. (2002) reported values ranging as high as 29% CP in December to 10% CP in May. Similarly, Hafley (1996) reported CP concentrations between 10 and 27%. In the present study, values ranged from 23% during early production to 14% at the end of the grazing season in Yr 1 and from 21% to 14% in Yr 2. Throughout both grazing seasons, forage CP concentrations remained well above the requirement (11.4%) for growing-finishing beef steers to gain 0.90 kg/d (NRC, 1984).

Percentage forage IVDMD is illustrated across supplement types and levels of supplement fed in Figure 10 for Yr 1 and Figure 11 for Yr 2. Mean percentage IVDMD across all treatments was 93.1 and 93.4 for Yr 1 and Yr 2, respectively. Hafley (1996) reported IVDMD values ranging between 74 and 59. In a study conducted by Redfearn et al. (2002), percentage IVDMD was as high as 89 and as low as 62, and Myer et al. (2008) reported mean IVOMD of 80% for ryegrass. The lower digestibility values reported by Myer et al. (2008) are likely due to their utilization of a batch-culture procedure that include acid-pepsin treatment and resulted in microbial debris to yield estimates of apparent digestibility rather than true digestibility. Redfearn et al. (2002) and Hafley (1996) utilized neutral-detergent extraction of residues as in the present study, which produces true digestibility values (Van Soest, 1991). The lower values reported by Hafley (1996) may have resulted from factors such as varieties used and the stage of ryegrass maturity at harvest.

It is universally accepted that animal performance is improved by increasing forage nutritive value (Guerrero et al., 1984). Only when forage mass reaches sufficiently elevated values at which animals have the opportunity for preferential selection does quality become the driving force behind differences in animal performance. However, Sollenberger and Vanzant (2011) suggest that, across a wide range of forage mass, 60-90% of the variation in animal performance may be explained by variation in forage quantity, not quality. The meta-analysis of quantity vs. quality effects on ADG conducted by Sollenberger and Vanzant (2011) suggests that, in the case of intensively managed pastures such as in the present study, it is the amount of forage, not the quality of that forage, that accounts for most of the variation in animal performance. The highly satisfactory gains produced in the current study suggest that decreases in forage mass and allowance were not a deterrent to improved animal performance resulting from supplementation.



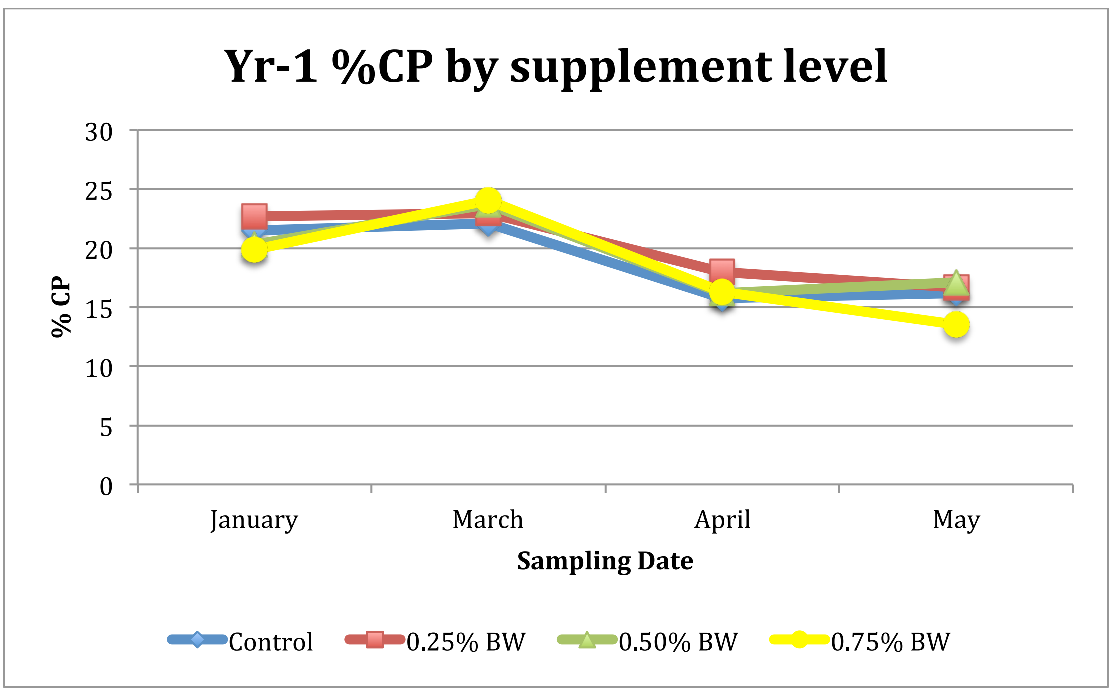
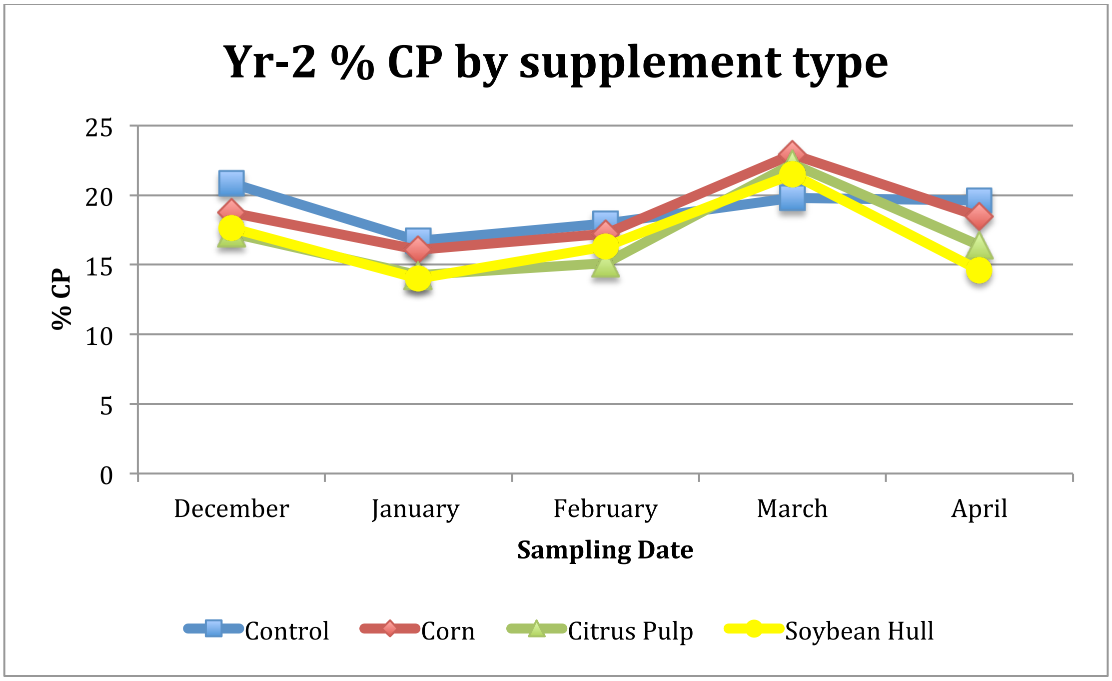


Figure 8. Forage percentage CP by sampling date for ryegrass pastures grazing by steers receiving different types (top) and levels (bottom) of energy supplement (Yr 1).



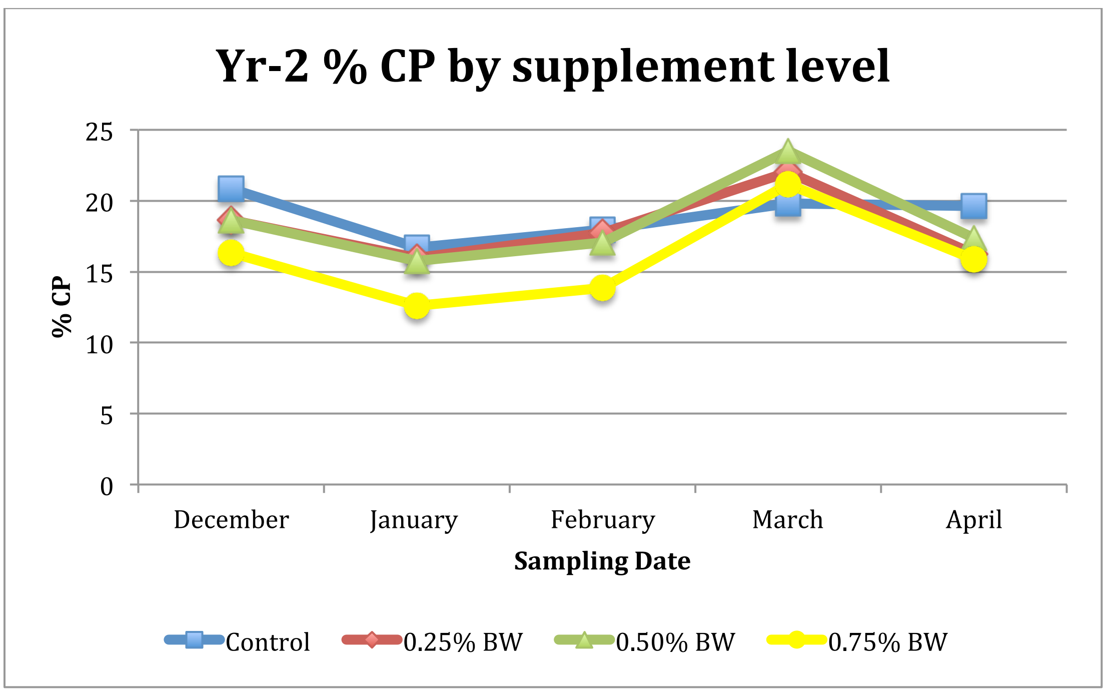
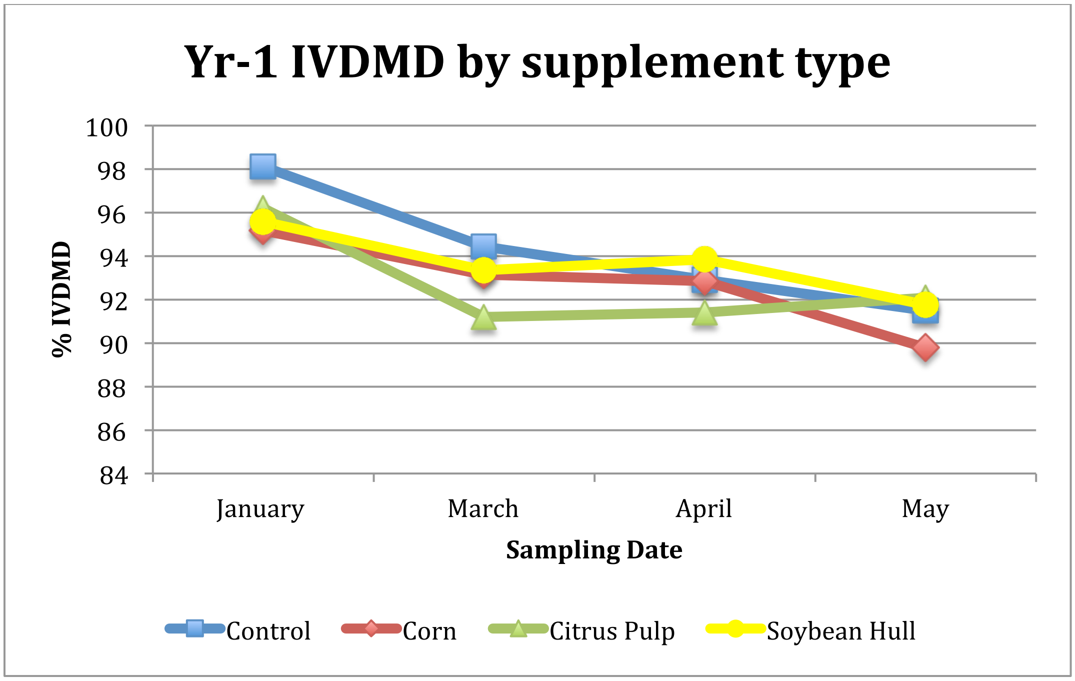


Figure 9. Forage percentage CP by sampling date for ryegrass pastures grazing by steers receiving different types (top) and levels (bottom) of energy supplement (Yr 2).



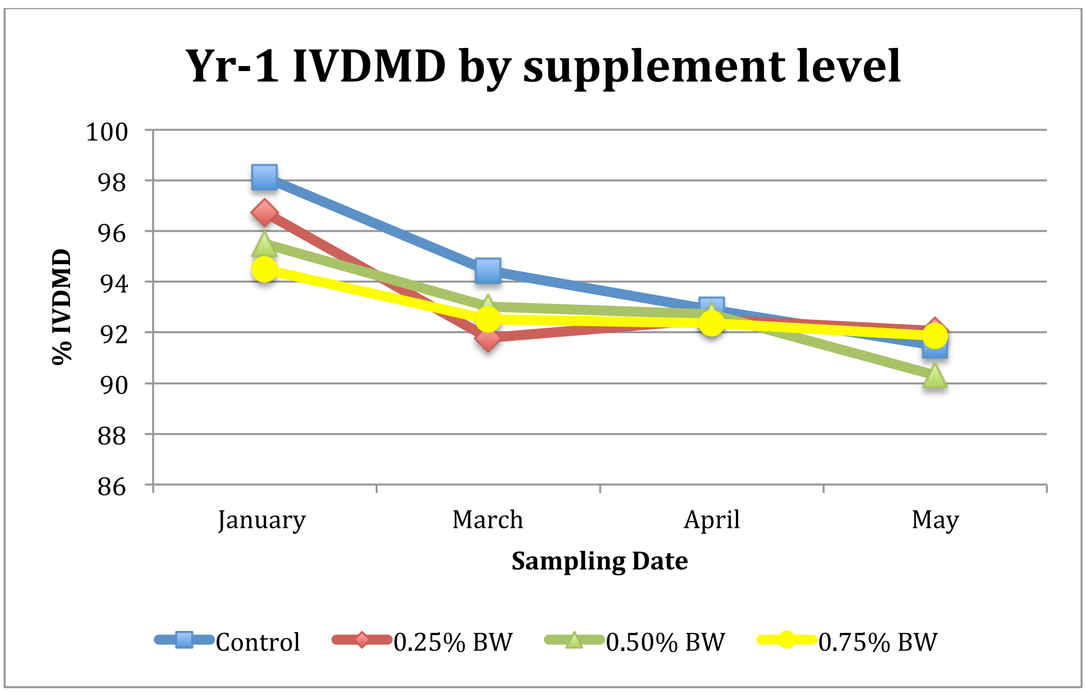
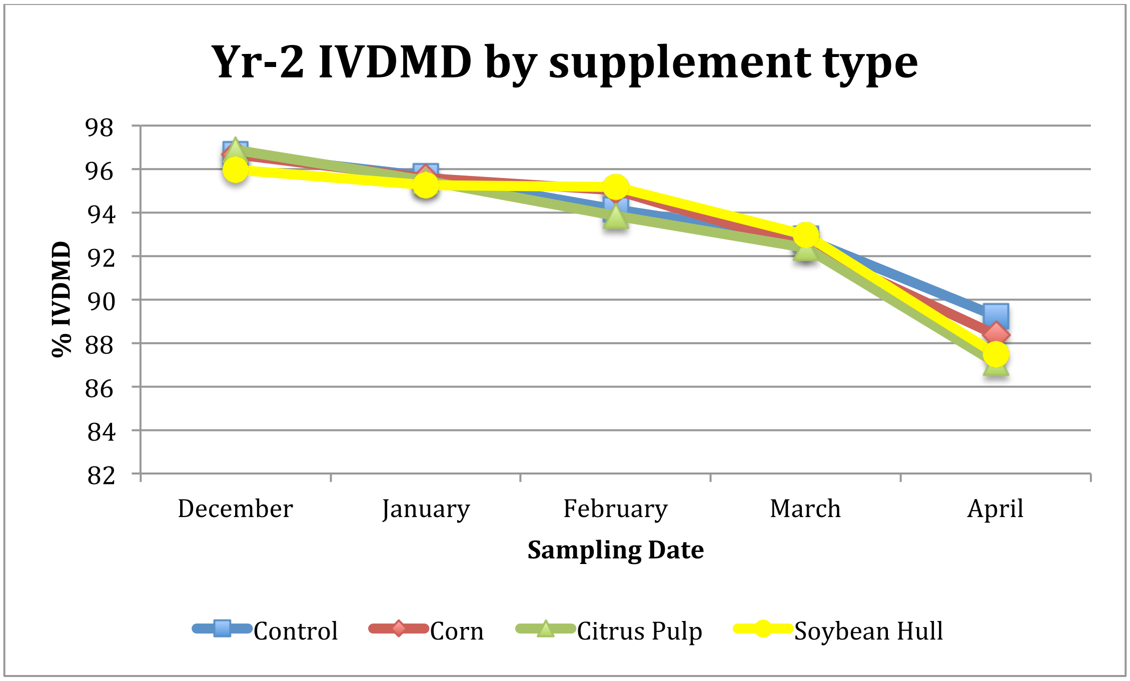


Figure 10. Forage percentage IVDMD by sampling date for ryegrass pastures grazing by steers receiving different types (top) and levels (bottom) of energy supplement (Yr 1).



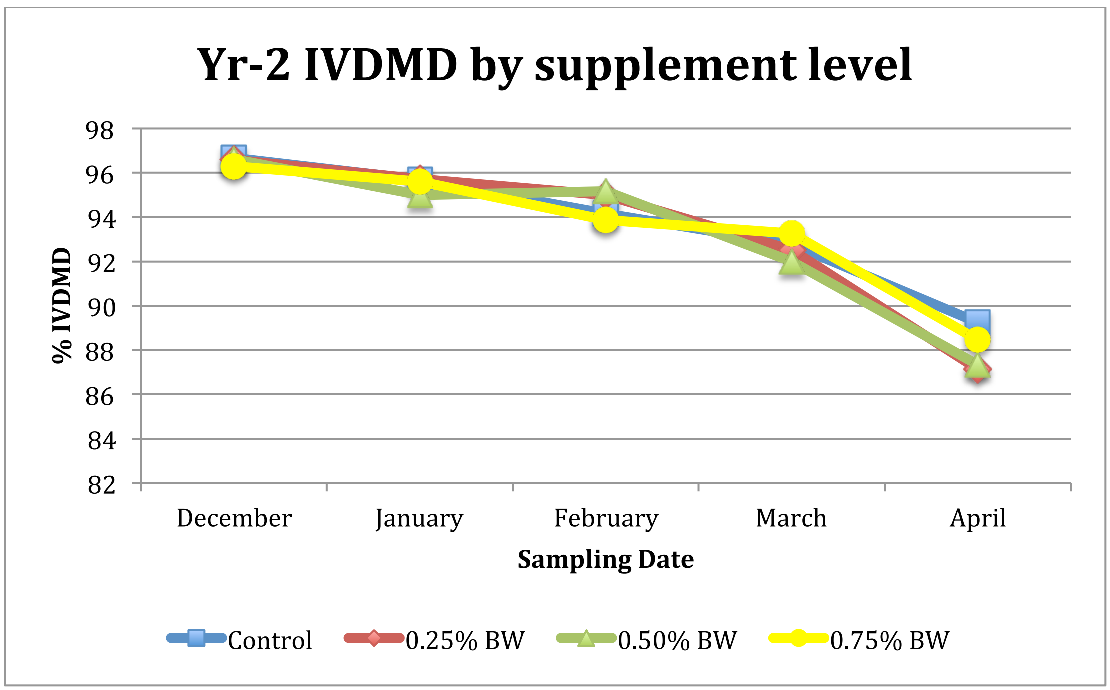


Figure 11. Forage percentage IVDMD by sampling date for ryegrass pastures grazing by steers receiving different types (top) and levels (bottom) of energy supplement (Yr 2).

Summary and Conclusions

Results of this 2-yr grazing experiment indicate that weather can greatly affect animal performance, forage productivity and, ultimately, the economic returns from stocker production from winter grazing of high-quality annual ryegrass. Although it may be concluded from results in Yr 1 that supplementation produces greater ADG and total gain/ha over grazed forage alone, results from Yr 2 revealed that supplemented cattle did not consistently achieve additional gain over unsupplemented controls as might have been expected. Observed forage mass and forage allowance response indicate that supplement type, supplement level and their interaction can produce widely differing effects over the course of a grazing season.

This study has produced novel results from its comprehensive investigation of effects of different types of energy supplements across a wide range of feeding rates under common grazing conditions at a single location. Both positive (supplementation) and negative (substitution) associative effects were observed during this study. In Yr 1, a supplementation effect was observed across all supplement types and across all supplement levels. However, in Yr 2 more of a substitution effect was observed for all supplement types and became more pronounced with increasing level of supplementation. The information and conclusions presented herein are especially relevant for stocker producers in the southeastern United States who may wish to increase their gains from stocker cattle grazing annual ryegrass through the use of an energy supplementation system. An economic analysis needs to be conducted to truly determine the most cost-effective method of adding gain to stocker cattle as well as the extent to which stocking rates may be increased by utilizing energy supplementation. Additional research is needed to determine what other locally available energy supplements may be used in an energy supplementation system.

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