An experiment was conducted to compare grazing management strategies that optimize stocker calf production and the agronomic performance of canola. This experiment evaluated four treatments including: Canola-early graze (CEG), canola-late graze (CLG), canola-no graze (CNG), and winter wheat (WW). Angus steers (343 d ± 3.3d) grazed CEG, CLG and WW treatments. Response variables included normalized difference vegetation index (NDVI), near infrared reflectance (NIR), leaf area index (LAI), red reflectance (RED), rising plate meter (RPM) estimated herbage mass, average daily gain (ADG) and forage quality, biomass yield, seed yield, oil percentage,. Animal performance was evaluated by assessing average daily gain; steers were weighed at the beginning and end of grazing which listed 48-d across all treatments. Grazing treatment did affect ($P < 0.05$) LAI, ADG, biomass yield, and seed yield but did not affect ($P = 0.15$) seed oil content. Seed yield was not different ($P = 0.03$) between CEG and CNG; however seed yield was different ($P = 0.03$) between CEG and CLG.

INDEX WORDS: Canola, Dual-purpose, Brassica, stocker cattle, no-till, interseeding
CANOLA AND CALVES: AN INTEGRATED CROP-LIVESTOCK FARMING SYSTEM FOR PRODUCING CANOLA AND STOCKER CATTLE IN THE SOUTHEAST

by

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DEDICATION

This work is dedicated to all of my family members, without each of them I would not be in the position I am today. To my wife, Allyson Ingram, I truly appreciate your support and love not only throughout this experience of graduate school, but life.
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CHAPTER 1
INTRODUCTION

Integrated crop-livestock systems have been used around the world for decades. These systems use the plants for forage prior to seed production (Kirkegaard et al., 2012). Wheat (*Triticum aestivum*) has been the crop of preference for an integrated crop-livestock system in the southern Great Plains region of the United States (Gadberry et al., 2010). Oklahoma producers reported that nearly one-half of the 2.5 million ha of wheat was planted in 2000 was used as a dual-purpose crop (Hossain et al., 2004). Canola (*Brassica napus*) is a valuable oilseed crop (Sovero, 1993) that has high nutritive value as forage and could potentially increase flexibility and profitability of an integrated crop-livestock system (Kirkegaard 2008a). The use of a dual-purpose, winter variety of canola in the southeast (SE) could perform well because of the region’s favorable environment. Significant seed yield losses can result from delayed maturity from grazing in the Southern Great Plains (Heer, 2006). Proper grazing management for a dual-purpose canola can potentially reduce or eliminate seed yield losses while adding weight gain to livestock.

A recent summary of 2008-2013 variety trials data indicated winter canola yields in the SE are very competitive with or superior to the yields in other regions (Stamm et al., 2013). Moreover, there is a substantial need for canola meal in the SE. Canola meal is a by-product of oil extraction and is classified as a protein supplement (Conrad et al., 1982). Finding a local, economical protein supplement would be ideal for the SE livestock producers (Patterson et al., 1999). Since the SE produces 75% of broiler chickens, 20% of swine, and 16% of cattle in the
U.S., canola has a tremendous opportunity to expand in the region (Franzluebbers et al., 2014). Yet, the SE currently represents less than 1% of total canola production in the U.S. (USDA, NASS 2014).

Brassicas, such as canola, produce large quantities of leaves and roots in late fall and early winter, which is a critical period in the nutritional management of SE cow herds (Reid et al., 1994). Dargatz et al. (2004) reported that most calves (63.9%) in the U.S. were born between February and April to take advantage of spring forages. Traditionally calves are sold shortly after weaning between August and October, but with market incentives resulting from seasonally short supplies of cattle and lower commodity prices, there is a substantial opportunity to retain and add value to these calves. Canola fits well into SE production systems that strive to maximize grazing, and provides a viable option for stockering young calves through the fall and early winter.

Little research has been conducted to develop grazing management strategies for canola as a dual-purpose crop. Kirkegaard et al. (2008) has reported effects of grazing canola sheep on (Ovis aries) in Australia. Stamm (2011) examined the effects of simulated grazing by sequential clippings on canola seed yield in Kansas and found a difference ($P < 0.05$) in seed yield for treatment. Research conducted in the SE will provide important region-specific information to producers interested in implementing integrated crop-livestock management systems.

Considering these opportunities, the goal of this experiment was to evaluate the grazing management guidelines of Kirkegaard et al. (2012) for canola and compare it to a more aggressive later grazing strategy and a standard grazing management of dual-purpose winter wheat. The experiment ran from October 2013 to June 2014. Forage production was evaluated through destructive and non-destructive sampling, at weekly and bi-weekly intervals, throughout
the experiment. Seed yield and oil percentage were evaluated through destructive sampling at harvest. Animal performance was evaluated by assessing weight gain by weighing the calves before and after being placed on treatment. These data will allow for the development of management recommendations and economic decision-aids that will improve production efficiency in operations that are utilizing canola as a dual-purpose crop. Positive findings can increase interest in producing the crop and expand its acreage in the SE.
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CHAPTER 2
THE REVIEW OF THE LITERATURE

Overview of Canola

Description and Production

The Brassicaceae family consists of approximately 375 genera and 3200 species of plants (Jessop et al., 1986). The Brassica genus contains approximately 100 species, including the species *Brassica napus* and *B. rapa*, commonly known as oilseed rape, rapeseed, or canola (Australian Government, Office of the Gene Technology Regulator, 2008). The main specie planted for oilseed production, *B. napus*, is believed to have been cultivated in Asia and the Mediterranean, beginning as early as 2000 BC in India (Colton et al., 1999). Historically, in western countries, *B. napus* was not considered an oil source for human and animal consumption because of its naturally high erucic acid and glucosinolate levels, which can be toxic. Intensive breeding programs initiated in the 1970’s around the world produced new varieties of *B. napus* that were significantly lower in these toxicants (Australian Government, Office of the Gene Technology Regulator, 2008). The varieties produced from the breeding programs in the 1970s increased the recognition and importance of *B. napus* as a source for food oil (OECD, 1997).

The term “canola” is a registered name for certain brassica varieties by the Western Canadian Oilseed Crushers Association and is derived from ‘Can*adian* oil, low acid’. Canola varieties must have an erucic acid content of less than two percent and less than 30 mg of glucosinolates per g of seed. These standards make canola a usable source of oil for human consumption and animal feed (Berglund et al., 2007). Oilseed brassicas are the second most
valuable source of edible oils in the world and account for 13% of the total oilseed production (Banuelos et al., 2013). In 1985, the U.S. Food and Drug Administration granted canola oil “Generally Recognized as Safe” (GRAS) status for use in human foods, and since this granted status it has gained a wider interest in the U.S. (Berglund et al., 2007).

A review of the National Winter Canola Variety Trial (NWCVT) for years 2008-2013 reported a national seed yield average of 374.84 kg/ha (Stamm et al., 2013). Canola production in the United States is concentrated in the Northern Plains region where a drier, shorter growing season makes corn and soybean production less attractive (USDA-ERS, 2012). The state leading in production of canola in the Northern Plains and U.S. is North Dakota, comprising 590,841 hectares of the 700,106 total hectares planted in the U.S. in 2012. (U.S. Canola Association, 2014). The acreage in all other regions has shown considerable fluctuation over the past ten years and each follows a similar trend. No single region in the U.S. has ever collectively produced more canola than North Dakota alone; however, stability of crop production outside the Northern Plains was forecasted for the near future because of increased planted acreage resulting from the growing demand for canola oil for both food and biodiesel (Brown et al., 2008). Specifically, the SE region of the U.S. is in a position for expansion because of its mild winters, moist spring seasons, and favorable market potential for canola meal. There is tremendous need for canola meal as a feedstock in the SE (Lourenco et al., 2014). Canola meal is an economical alternative to soybean meal and other sources of protein in the diets of dairy and beef cattle, swine, and poultry. Approximately 75% of all broilers, 26% of the egg-laying chicken flock, 20% of the hog population, and 16% of all cattle and calves in the U.S. are in the SE region (Franzluebbers et al., 2014). Much of the waste from these livestock industries is applied to beef cattle pastures and hayfields. As the result of applications of livestock manure, nutrient concentrations in the soils in
the pastures and hayfields of this region are quite high. For example, 50% and 58% of the
pasture and hayfield samples from the Southern Appalachian Ridges and Valley and Southern
Piedmont Major Land Resource Areas (MRLA), respectively, were found to have phosphorus
values rated as “High” or “Very High” (in an internal review of soil samples submitted to UGA’s
Soil, Plant, and Water Laboratory during 1997-2006). Soil sample analyses in this dataset also
showed that other macronutrients (K, Ca, Mg and S), all of which are important in oilseed
production, were frequently in ranges that are not limiting to crop yield. Buntin et al. (2010)
reported that canola uses a significant amount of phosphorus. The profitability of canola
production in the Southern Appalachian Ridges and Valleys and Southern Piedmont MRLAs
would be increased because of the potential elimination of phosphorus fertilization cost.

Canola has been grown commercially in Georgia, Alabama, South Carolina, and
northern Florida from the late 1980s, with a peak production at approximately 10,000 ha in the
mid 1990’s (Buntin et al., 2010). Canola has been very successful in the southern parts of
Georgia and also in South Carolina. Georgia produced 1973 ha of canola in 2012. This same
year, Alabama produced 867 ha and South Carolina produced 516 ha (USDA, NASS 2012).
European spring type varieties are well adapted to winter production in the SE region. Most of
these cultivars have adequate winter hardiness and typically start blooming later than Canadian
varieties. This makes these varieties more likely to escape the damage of spring frosts (Sovero,
1993). Despite the favorable environment for production, the SE currently only represents about
1% of U.S. production (USDA, NASS, 2012).
Species and Variety

The Brassica genus consists of approximately 100 species (Australian Government, Office of the Gene Technology Regulator, 2008). The relationship between the brassicas was established through taxonomic studies (U, 1935; Fig 1). It was proposed that the three species with higher chromosome numbers B. napus, B. juncea, and B. carinata are amphidiploids derived from the diploid species B. rapa, B. nigra and B. oleracea. The proposed cytogenetic relationship between the brassicas was later confirmed by chromosome pairing and artificial synthesis of amphidiploids, nuclear DNA content, DNA analysis and the use of genome specific chromosome markers (Australian Government, Office of the Gene Technology Regulator, 2008). The species used for canola (and rapeseed) production have the widest distribution of Brassica oilseeds in the world and include: Brassica napus, Brassica rapa, and the recently-developed Brassica juneca (Sovero, 1993). Brassica napus and B. junec are hybrids developed through natural hybridization between B. rapa x B. oleracea and B. rapa x B. nigra, respectively (Brown, 2008).

The most planted specie in the Northern plains is B. napus, which is planted in the spring. This cultivar requires no vernalization to flower and is harvested in late summer (Brown et al., 2008). A winter hardy variety of B. napus is grown in the SE and is planted in the fall because of the mild winters. It is harvested in late spring to early summer (Sovero, 1993).

The National Winter Canola Variety Trial (NWCVT) is a collaborative group of 42 cooperators in 21 states across the U.S. that conducts research to evaluate the performance of released and experimental varieties of canola. Participating states in the NWCVT are located in the Great Plains, Midwest, northern and southeastern regions of the U.S. One of the most
important focuses of this experiment was winter hardiness, which is vitally important when selecting a canola variety (Stamm et al., 2013). Cold hardiness is especially important for the Southeast because canola is typically planted to grow through the winter and may face moderately severe winter conditions (Brown, 2008). A summary of 2008-2013 NWCVT data has shown that winter canola seed yields in the SE region are very competitive with yield averages of the U.S., (352 kg/ha vs. 375 kg/ha). In fact, a summary of 2008-2013 NWCVT data from GA, shows seed yields of 439 kg/ha compared to a national average of 375 kg/ha (Stamm et al., 2013).

**Utilizing Dual-Purpose Crops**

The term “dual-purpose” describes the use of a crop for forage and seed production (Kirkegaard et al., 2012). Cereal crops (e.g., oats, triticale and wheat) have commonly been used as a dual-purpose crop in the U.S. (Sulc, 2013). Canola has also gained interest for its potential as a dual-purpose crop (Kirkegaard et al., 2008). Whether a cereal crop or canola, the dual-purpose crop can provide livestock feed, grain or seed, and multiple environmental benefits (Russelle et al., 2007).

Plant diseases that hinder crop performance can cause issues in cereal crop production when a single type of crop is planted in the same place for successive years. Septoria leaf blotch, tan spot, root rot, and *Fusarium* blight are commonly found in wheat stubble left in a field after harvesting grain (Lyon et al., 2014). Barkley et al., (2011) reported a decrease of seed yield of 145 kg/ha from tan spot disease and 135 kg/ha seed yield decrease from *Septoria nodrum*. A broadleaf, high quality forage and seed crop like canola could help alleviate disease issues by
establishing canola as a rotation crop in an area that was traditionally planted in cereal crops (Kirkegaard et al., 2008a).

There is also a need for more sustainability in agricultural production, and one major aspect of sustainability is having a diversity of cropping systems. Agricultural production has become highly specialized and, generally, lacks diversity in the crops that are produced. A committee on 21st century agricultural systems concluded that “…if U.S. agricultural production is to meet the challenge of maintaining long-term adequacy of food, fiber, feed, and bio-fuels under scarce or declining resources and under challenges posed by climate change and to minimize negative outcomes, agricultural production will have to substantially accelerate progress toward the four sustainability goals. Such acceleration needs to be undergirded by research and policy evolution that are designed to reduce tradeoffs and enhance synergies between the four goals and to manage risks and uncertainties associated with their pursuit” (NRC, 2010). The four goals set by the committee were: (1) satisfy human food, feed, and fiber needs, and contribute to biofuel needs, (2) enhance environmental quality and the resource base, (3) sustain the economic viability of agriculture, and (4) enhance the quality of life for farmers, farm workers, and the society as a whole (NRC, 2010). The increase of canola production in the SE can lead to a local supply of oilseed while diversifying the agriculture production in the region. The utilization of nutrients in existing pastures and hayfields would decrease production costs while reducing potential risk of nutrient runoff. Allison (1973) suggests a focus on nutrient recycling, returning animal manures to crop production land as efficiently as possible, stating that the world has already entered into an era where prevention of agricultural waste is necessary. Returning nutrients to the area in which they were utilized by crop completes the natural nutrient recycling process (White, 1979). An integrated crop-livestock system (ICLS) has been
considered a very efficient design for sustainable farming systems (Gliessman, 2006; Russelle et al., 2007; Hendrickson et al., 2008). Implementing this integrated crop-livestock system with the use of dual-purpose crops would complete the natural recycling process and make these farming operations more sustainable by the NRC’s definition.

Farming operations have become highly specialized in crop production from roughly five commodities per farm in 1900 to one commodity per farm in 2000 (Dimitri et al., 2005). Specialization in these operations has essentially separated the livestock and crop sectors, creating a large nutrient imbalance (Sulc et al., 2013).

**Performance of Dual-Purpose Crops**

Dual-purpose crops have been utilized in integrated crop-livestock systems for decades, providing grazing in the winter months when forages are low as well as a grain for harvest (McCormick, 2012). Cereal crops used for forage and grain are very common in the southern Great Plains of the U.S. (Dunphy et al., 1984; Carver et al., 1991). The main cereal crop that is planted and grazed in the winter months in the Great Plains is winter wheat (*Triticum aestivum*). Pinchak et al. (1996) estimated that grazing occurs on 30-80% of the eight million ha of winter wheat that is planted annually. Although the benefit of income generated from both the BW gain of the livestock and grain entices producers to plant dual-purpose crops, the production of cereal crops for dual-purpose requires very intensive management in order to maximize total income (Fieser, 2006). Because maximizing livestock gains and grain yields are often antagonistic, monitoring growth stage and correct selection of planting dates are critical to find an optimal balance between the two (Fieser, 2006).

**Forage production**
Dual-purpose cereal crops are usually planted earlier in the season to increase the grazing duration and total forage produced (Bonachela et al., 1995). In most growing seasons, dual-purpose wheat planted in mid-October or later does not provide adequate forage to support grazing (Hossain, 2003). In a series of experiments conducted over six growing seasons near Lahoma, OK, Epplin et al. (2000) found that removal of fall-winter forage in wheat does not decrease grain yield for a given planting date compared no removal of plant material. However, the results show that planting date is related to forage availability and seed yield. Forage production decreased for planting dates of September 1 to September 21 by 68% (2170 kg/ha to 690 kg/ha; Epplin et al., 2000). The termination date of grazing is another important consideration to maximize forage allowance and maintain grain yield (Fieser, 2006). A widely recognized practice is removing livestock prior to the development of the first hollow stem (FHS). To set the optimal planting date, a producer must take into account the production costs, economic outlook of grain prices, economic outlook of forage produced, and weight gained by livestock to make a sound financial plan on how to manage their dual purpose crop (Hossain, 2003).

**Grain Production**

Holliday (1956) summarized many studies and reported contrasting results for grain yield with some studies reporting a decrease in grain yield from grazing while other studies reported an increase in grain yield from grazing. Epplin et al. (2000) reported a 3-wk delay in planting from 1 to 21 September is associated with a 44% increase in grain yield (1750 kg/ha to 2250 kg /ha). Winter et al. (1987) reported no difference or an increase in grain yield of four semidwarf varieties used in a 3-yr study. The increased yield found by Winter (1987) was attributed to the lower incidence of lodging, which restricts the movement of nutrients and water in the plant
occurring in the grazed wheat compared to the ungrazed wheat (Winter et al., 1990). Edwards (2012) found that from 1991-1998, excluding 1994-1996 because of insufficient fall growth for grazing, a summary of grain yield showed grazed treatments averaged 319 kg/ha and non-grazed trails averaged 341 kg/ha with all trials being sown in early September. Grazing increased yield by 33 kg/ha in 1992, and although this is not typical, this is not the first research to show these findings. Edwards (2012) attributed the increase shown in 1993 to a decrease in water use and decrease in foliar disease, which has been shown to negatively impact grain yield in wheat. If grazing is terminated too late, wheat grain yield will be reduced (Taylor, 2010). Yield reductions were found to be 10% at 2 weeks past FHS, 20% at 3 weeks, and 30% at 4 weeks. Daily reductions in grain yield from grazing past FHS were reported by (Fieser, 2006) to be 22.5 kg/ha/day. Previous research by Redmon et al. (1996) reported a larger daily grain yield reduction (83 kg/ha/day) for grazing past FHS. Fieser (2006) attributed the difference to a heavier stocking density. Redmon et al. (1996) increased stocking density once winter wheat developed past FHS, but Fieser (2006) maintained the same stocking density throughout the experiment. Results from a 2-yr grazing trial by Francia et al. (2006) reported no difference ($P > 0.05$) in grain yield for one grazing trial that began and ended within Feekes GS 5 on oats compared to the ungrazed control (3538 kg/ha vs. 3447 kg/ha, respectively). However, Francia et al. (2006) noted a difference ($P < 0.05$) in grain yield for oat when grazed at Feekes GS 5 and Feekes GS 6 (3538 kg/ha vs. 2177 kg/ha, respectively). These data suggests termination of grazing is crucial to preserve seed yield. The stage at which cereal crops are grazed, the stocking density of the animals, and planting date have been shown as important factors influencing future grain yield (Epplin et. al., 2000; Hossain et al., 2003).
Animal Performance

The profit potential of cattle which grazed dual-purpose wheat is satisfactory because of the availability of high quality forage, which in turn can produce weight gains in excess of 1.0 kg per hd per d without additional supplemental feed (Horn et al., 2006). Average daily gain over a 4-yr trial reported by Horn (1986) for cattle grazing dual-purpose wheat was 1.05 kg per hd per d. Fieser (2006) reported ADG of steers grazing dual-purpose wheat from two individual studies for 2003 and 2005 of 1.60 kg per hd per d and 1.58 kg per hd per d, respectively. The difference in weight gain reported from the two studies is related to stocking density and days allowed to graze the wheat with steers since Horn (1986) reported 64 d of grazing wheat at 3.88 steers/ha, while Fieser (2006) reported grazing over 35 d for 2003 at 2.74 steers/ha and 52 d at 1.75 steers/ha in 2005. The higher stocking density and longer period of grazing explains much of the BW gain difference between the two trials (Fieser et al., 2006). Pinchak et al. (1996) observed 1.00 and 1.19 kg per hd per d for a 62 d grazing trial. Although gains of 1.00 kg or greater are consistent within these studies, animal performance on dual-purpose crops can also be affected by animal genotype, forage allowance and quality, and weather conditions (Fieser et al., 2006).

Canola as a Dual-Purpose Crop

Brassicas, such as canola, produce large quantities of leaves and roots in late fall and early winter, which is a critical period in the nutritional management of SE cow herds (Reid et al., 1994). Thus, canola has the potential to provide a source of forage, feed, and oil for animal and human consumption in a more integrated crop-livestock production system.
Canola Performance

Dual-purpose brassicas produce high yields of quality forage with an extensive root system during a critical time of the year when established perennial forages begin to decline in nutritional value and yield in late fall to early winter (Reid et al., 2014). Brassica crops are palatable, have a low dry matter (DM) content, and low concentrations of cellulose and detergent fibers (Pelletier et al., 1976; Faix et al., 1979). These qualities result in a forage that is highly digestible and can greatly increase animal performance. Winter canola cultivars are grazed by cattle in the Great Plains region of the U.S., but the harsh winters can cause significant yield losses as a result of delayed maturity caused by grazing (Heer, 2006). In the SE region of the U.S., less severe winter conditions and a longer spring growing season provide a greater opportunity to produce more biomass for a longer winter grazing period and a longer period of plant recovery to increase seed yield in the spring. Although this system has a greater opportunity for expansion, more strict grazing management must take place to preserve seed yield. Canola may be prone to greater damage by grazing than cereal grains because the meristem is above ground before elongation, which contrasts with the below ground growing point in the cereal grains (Kirkegaard et al., 2008). A standardized growth scale developed by BASF, Bayer, Ciba-Geigy, and Hoechst, named the BBCH decimal system, describes canola growth stages and can be used by producers as a tool for grazing management strategy (Allen et al., 1971). Kirkegaard et al (2012) suggested three general grazing strategies to preserve total biomass and seed yield: (1) safe stage, where effects on yield are independent of residual biomass; (2) sensitive stage, where yield recovery is dependent on residual biomass, (GS 3.1 or GS 3.2) with an anticipated accumulation of 900 chill hours and a post-grazing residual of at least 1000 kg of dry biomass/ha; and (3) unsafe stage, where there is insufficient time for
recovery irrespective of residual biomass (greater than GS 3.2). With favorable weather conditions and timely grazing management little or no effect of winter grazing on canola seed yield is possible (Kikegaard et al., 2008a; 2012).

Forage and Seed Production

Winter canola should be established early enough in the fall for development to the rosette stage for reliable winter survival (Moore et. al, 1997). Cooler temperatures are associated with later fall planting dates and lower soil temperatures decrease seed germination (Kondra et. al, 1983; Christensen et. al, 1984). Moore (1997) reported from a 2-yr study in Idaho, that planting in mid-August to early September in would produce the highest yield. Seed yield for treatments sown at 2.1 x 10^6 seeds/ha on dates in early August, mid-August, early September, and mid-September were 2488 kg/ha, 2532 kg/ha, 1988 kg/ha, and 1974 kg/ha, respectively. The decrease in yield with planting date were attributed to a decrease in germination in later fall planting dates. Buntin et al (2010) warns that planting too early in autumn for SE can increase the risk of winterkill. Selecting appropriate varieties and suggested planting dates will decrease the chances of winterkill.

Animal Performance

Only simulated grazing studies have been conducted in the U.S. to evaluate canola as a dual-purpose crop (Stamm, 2011). Animal performance data is limited to sheep and varieties of brassica that have been developed solely as forage, not as a dual-purpose crop. In Australia, Kirkegaard (2008) grazed canola with sheep (*Ovis aries*) but has not evaluated the effects of grazing cattle on canola. In this study, Kirkegaard (2008) noted liveweight gains of sheep grazing canola at 0.21 kg per hd per d. These results are similar to gains of 0.16-0.20 kg per hd per d reported by Dove et al. (2006) for lambs grazing a forage rape, but somewhat less than the
gains of 0.29/kg per hd per d reported by Kelman et. al (2007) grazing forage brassica (cv. Hunter).

**Conclusions**

Current literature has shown that canola has some potential as a dual-purpose crop and may provide forage during the winter while still maintaining oilseed yields. Planting date, grazing termination date, and stocking density showed a direct correlation with animal weight gains and seed yield in previous research. Therefore, canola grazing research should closely monitor stocking density, base the grazing termination date on sensitive growth/development stages, and ensure that the canola is planted on a date that will provide optimize the forage production potential. Few studies have been conducted to report cattle performance on brassicas and there are no reports where canola species were grazed by cattle. Research has shown that sheep (*Ovis aries*) can successfully graze canola, but hoof traffic and grazing intensity differences between the two livestock species necessitates proving that cattle can graze canola with equal success. The focus of the following research was to assess the potential for grazing management in cattle on canola with ADG and seed yield being the driving factor.
Figure 2.1 Genomic relationship of core cultivated Brassica species, referred to most often as the Triangle of U (U, 1935).
Literature Cited


CHAPTER 3

CANOLA AND CALVES: AN INTEGRATED CROP-LIVESTOCK FARMING SYSTEM
FOR PRODUCING CANOLA AND STOCKER CATTLE IN THE SOUTHEAST

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Abstract

Research was conducted to establish appropriate grazing management strategies that optimize stocker calf production and the seed yield of canola (*Brassica napus* L.) Sixteen 0.66-ha paddocks were blocked by previous tillage history and randomly assigned to one of four treatments, which included an ungrazed canola control (canola-no graze; CNG); canola lightly grazed with grazing terminated prior to growth stage (GS) 3.0 and a post-grazing residual of at least 1500 kg of dry biomass/ha (canola-early graze; CEG); canola heavily grazed with grazing terminated prior to GS 3.1 and a post-grazing residual of less than 1000 kg of dry biomass/ha (canola-late graze; CLG); and winter wheat grazed with grazing terminated prior to jointing (Feekes GS 6) and the post-grazing residual remains at a height greater than the height of the joint (WW). Angus steers (n=18; 248 ± 19 kg) were blocked by weight and randomly assigned to one of the 12 grazing paddocks. Growth stage, leaf area index (LAI), near infrared reflectance (NIR), red reflectance (RED), normalized difference vegetation index (NDVI), and herbage mass were assessed at two week intervals. Estimated herbage mass was calculated weekly in all paddocks using a rising plate meter (RPM). Nutritive value of treatment samples was determined by near infrared reflectance spectroscopy. Calves were weighed on d 0 and 49. All treatments were harvested to determine total biomass, seed yield and oil percentage. Paddock was considered the experimental unit and steer was the observational unit. Grazing treatment did affect RPM estimated herbage mass (*P* < 0.01), NIR (*P* < 0.01), NDVI (*P* < 0.01), GS (*P* < 0.01) and seed yield (*P* = 0.04). RPM estimated herbage mass was higher (*P* < 0.01) in the WW paddocks compared to all canola treatments. Crude protein was lowest (*P* <0.01) for WW treatment in comparison to all other treatments. ADG was similar across all treatments (*P* > 0.53). Seed yield was greatest (*P* < 0.05) for WW compared to all canola treatments. Within
canola treatments, seed yield was greater in the CEG than the CLG, with CNG intermediate and not different from either. These data show that implementation of appropriate grazing management strategies can optimize stocker calf production and not compromise seed yield and oil content of the canola.

**Key words:** dual-purpose, canola, stocker cattle, *Brassica*, grazing
Introduction

Beef cow-calf operations represent the largest agricultural land use in major land resources areas (MRLA) for southern Appalachian ridges and valleys and the southern piedmont. Pastures and hayfields in much of this region contain fescue, bermudagrass, or both (Ball et al., 2007). If canola production in the SE expands, it will likely be in pastures and hayfields converted to canola production. Forage production to fill the winter feed gap is a key objective of a dual-purpose crop (Kirkegaard, 2012). Research has shown that grazing winter annual grasses, legumes, or a combination of both can provide adequate weight gains for stocker cattle (greater than 0.8 kg per hd per d). Although these winter forages provide adequate weight gains, grazing does not commence on these pastures until January in most of the SE region.

Brassicas, such as canola (Brassica napus L.), produce substantial amounts of herbage when established perennial forages begin to decline in nutritional value and yield in late fall and early winter, which is a critical period in the nutritional management of SE cow herds (Reid et al., 1994). Brassica crops are also palatable, have a low dry matter (DM) content, and low concentrations of fiber (Pelletier et al., 1976, Faix et al., 1979), which result in a forage that is highly digestible and can greatly increase animal performance. Recent research has shown that there may be the potential to utilize canola as a dual-purpose crop in integrated crop-livestock production systems (Heer et al., 2006; Kirkegaard et al., 2008; Stamm and Martin, 2010; Kirkegaard et al., 2012). Winter canola cultivars are grazed by cattle in the Great Plains region of the U.S., but the harsh winters can cause significant yield losses as a result of delayed maturity caused by grazing (Heer, 2006). In the SE region of the U.S., less severe winter conditions and a longer spring growing season provide a significant opportunity to produce more biomass for a
longer winter grazing period and a longer period of plant recovery to increase seed yield in the spring.

In order to balance the value of the forage and oilseed yield, dual-purpose use of canola will rely on successful and timely establishment, an appropriate match of variety to environment, and careful grazing management (Kirkegaard et. al, 2008). Previous literature has reported that lambs grazing dual-purpose canola in Australia grew 210 g per d in the winter (Kirkegaard et al., 2008). Kirkegaard et al. (2012) reported insignificant yield losses when terminating grazing prior to the Harper and Berkenhamp (1975) predicted growth stage 3.1 and favorable spring growing conditions followed. In order to optimize both forage potential and seed yield, Kirkegaard et al. (2012) suggested consideration of three general stages: (1) safe stage, where effects on yield are independent of residual biomass; (2) sensitive stage, where yield recovery is dependent on residual biomass (GS 3.1 or GS 3.2) and a post-grazing residual of less than 1000 kg of dry biomass/ha; and (3) unsafe stage, where there is insufficient time for recovery irrespective of residual biomass (greater than GS 3.2). With favorable weather conditions and timely grazing management little or no effect of winter grazing on canola seed yield is possible (Kikegaard et al., 2008a; 2012). However, no literature is available evaluating canola as a dual-purpose crop for beef cattle production.

The goal of this research was to evaluate the potential of canola as a dual-purpose (forage and oilseed) crop in the SE. The objectives were to compare stocker cattle performance and oilseed yield of canola when grazing occurred and was terminated by the safe stage or the sensitive stage (as defined by Kirkegaard et al., 2012) relative to the oilseed yield of ungrazed canola and the cattle performance and grain yield of dual-purpose winter wheat.
**Materials and Methods**

All practices and procedures used in this study were examined and approved by the University of Georgia Animal Care and Use Committee. The experiment was conducted at the J. Phil Campbell, Sr. Research and Education Center in Watkinsville, GA.

**Treatment and Design**

Sixteen 0.66-ha paddocks were blocked by previous tillage history and randomly assigned to one of the four treatments including: canola not grazed by steers (canola no graze; CNG); canola lightly grazed by steers with grazing terminated prior to GS 3.0 and a post-grazing residual of at least 1500 kg of dry biomass/ha (canola-early graze; CEG); canola heavily grazed by steers with grazing terminated prior to GS 3.1 and a post-grazing residual less than 1000 kg of dry biomass/ha (canola-late graze; CLG); and winter wheat grazed by steers with grazing terminated prior to jointing (Feekes GS 6) and the post-grazing residual remains at a height greater than the height of the joint (WW). The canola management strategies were compared against dual-purpose wheat to serve as a benchmark for animal production and agronomic performance.

**Forage Management**

On 4 October 2013, a Great Plains no-till drill (1006NT, Great Plains Mfg., Inc., Salina, KS) with row spacings of 20 cm was used to plant canola seed (cv. ‘Inspiration’, a winter hybrid) at a seeding rate of 4.5 kg/ha. On that same day, a different Great Plains no-till drill (3P605NT) but essentially of the same design was used to plant winter wheat seed (cv. ‘AGS2038’, a dual-purpose winter variety) at a seeding rate of 82 seeds/m of row. Approximately 1 wk after emergence, all treatments received 56 kg N/ha applied via liquid N (32% urea ammonium nitrate). Seedling emergence was assessed at 14 d after planting by counting plants per 1 m of
row on 10 randomly selected locations in each paddock. Paddocks were sampled immediately prior to grazing initiation and throughout the grazing period to measure ground cover/leaf area index (LAI), red (RED), near infrared (NIR), normalized difference vegetation index (NDVI), herbage mass, and growth stage. Leaf area index was non-destructively assessed using a handheld LI-COR LAI 2200 Plant Canopy Analyzer (LI-COR Biosciences, Lincoln, NE) remote sensing device. During this same time, a handheld CropCircle (Holland Scientific, Lincoln, NE) was used to measure the amount of red reflectance (RED) and near infrared reflectance (NIR) reflected by the canopy and to calculate the normalized difference vegetation index (NDVI) using Eq. 3.1.

Eq. 3.1  \[ NDVI = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}} \]

Both devices were used at three randomly located 0.1-m² areas in each paddock to assess canopy characteristics throughout the grazing period. For each randomly located 0.1-m² area in each paddock, the CropCircle was held 1 m above the plant canopy. The device scanned only the 0.1 m² areas, making sure the area scanned was restricted to the boundaries of the sample area. Then, the LI-COR LAI 2200 Plant Canopy Analyzer assessed light interception from the same area. A 90°-view cap was used to block the operator and limiting the view of the sensor to the sample area for above and below readings with the sensor pointing toward the sky. The first reading with the Plant Canopy Analyzer measured the attenuation of diffuse sky radiation at five zenith angles simultaneously at 1 m above the canopy. The following four readings measured the attenuation of diffuse sky radiation at five zenith angles simultaneously directly below the canopy at the four corners of each 0.1-m² area. The leaf area index (LAI) for each area was calculated from the readings by dividing the five corresponding zenith angles for above and below readings.
Following the remotely sensed measures of the canopy, herbage mass within the 0.1-m² area was assessed using a Filip’s Manual Folding Plate Meter (Jenquip Agri-Business, New Zealand), otherwise known as a rising plate meter (RPM). The RPM measured the compressed sward height by recording the difference between the reading on the rising plate meter before and after setting the RPM on the 0.1-m² area. These measurements were subsequently used to create a calibration equation (Eq. 3.2; R²=0.67) that could be used to quantify available forage mass using subsequent RPM measurements throughout the paddock.

\[
\frac{\text{Forage Yield (kg DM)}}{\text{ha}} = (141.37 \times RPM) - 350.86
\]

Growth stage of the crop with each 0.1-m² area was then recorded prior to destructive sampling. Growth stage assessments were conducted by a single observer throughout the experimental period.

After all non-destructive samples were obtained, a destructive sample was hand-clipped to a stubble height of 3 cm in each randomly located 0.1-m² area for the purpose of quantifying herbage mass. Estimated herbage mass was also measured weekly in all paddocks utilizing a double sample technique. Rising plate meter measurements were measured at 40 observation sites along a randomly located transect in each paddock. The average RPM measurement was then used in Eq. 3.2 to determine herbage mass.

Herbage mass from each destructive sample was collected for determination of dry matter (DM) content and nutritive value. The forage samples were weighed initially on a scale, then dried in a forced-air oven at 60º C for 72-hr to calculate DM ((dry weight/wet weight) x 100)). Forage samples were then ground to pass a 1 mm sieve in a Model 4 Wiley Mill (Thomas Scientific, Sweensboro, NJ). Nutritive value of treatment samples was determined by near
infrared reflectance spectroscopy using a model 6500 (FOSS NIRSystem Inc. Laurel, Maryland) NIR analyzer at the University of Georgia’s Agricultural & Environmental Services Laboratory.

**Animal Management**

On 23 January, 16 steers (248 ± 19 kg) were weighed after fasting in a dry lot for a period of 12 hours, blocked by weight, and randomly assigned to and placed on one of the three grazing treatments (CEG, CLG, and WW). Prior to the experiment, the steers had been vaccinated at weaning with Express FP 10 and Alpha 7 (Boehringer Ingelheim Vetmedica, St. Joseph, MO), backgrounded on bermudagrass (*Cynodon dactylon*) and tall fescue (*Festuca arundinacea cv* Kentucky 31) pasture, and provided a pelleted feed containing 1:1 mix of soybean hulls and corn gluten was fed at a rate of 1.36 kg per hd per d with *ad libitum* annual ryegrass baleage.

During the grazing experiment, mineral supplement was provided to the steers weekly at a rate 0.9 kg per hd per wk and the calves had free access to water and shade. Due to the potentially high passage rate of canola and winter wheat during the grazing period, one bale (~380 kg DM) of low quality fescue/bermudagrass hay was provided in each grazing paddock for *ad libitum* intake as a roughage source. Each of these single bales remained in the paddock throughout the grazing period, however, based on visual observation, less than half of each bale was consumed during this time. At the termination of grazing, weights of the stocker calves were again obtained after fasting in a dry lot for a period of 12 hours.
**Crop Management**

Total biomass and seed production was assessed at the end of the experiment in three randomly located 0.5-m² areas in each paddock. The entire crop within each area was clipped to a 3 cm stubble height using a STIHL hedge trimmer (STIHL Inc., Virginia Beach, VA). All clipped biomass was placed on a tarp and weighed on a hanging scale immediately before the collected biomass was thrashed using Hege plot combine (Wintersteiger, Inc., Salt Lake City, UT). The plot combine was stationed under a shelter where seed could be separated from the chaff, with the seed collected in a bag and the chaff collected from the combine. The seed collected was used to calculate seed yield for each paddock. All biomass remaining after thrashing was collected from the combine and weighed in a tarp, utilizing a hanging scale. Separated seed samples were submitted to Resaca Sun Feeds, LLC (Resaca, GA) for analysis of oil content via nuclear magnetic resonance (NMR) as described in Hocking et al. (1997a).

**Statistical Analysis**

Data were analyzed using the MIXED procedure of SAS (SAS Institute Inc. Cary, NC) in a randomized complete block design with the four treatments of CEG, CLG, CNG and WW, three replications, and two observations per paddock. Individual paddocks were considered the experimental unit and individual steers were considered an observational unit within each paddock. Animals and replications were considered random effects, while treatment was considered as a fixed effect.
Results and Discussion

The 15-yr average cold duration hours and actual cold duration hours from September through June at the experiment site for the past 3 years were obtained from University of Georgia’s Automated Environmental Monitoring Network (2014) weather station on the UGA Plant Sciences’ farm in Watkinsville, GA and are presented in Figure 3.2. Actual cold duration hours for November, January, February, and March for the experimental period were higher than the 15-yr average and cold duration hours for every month of the experiment were more than the previous 2 yr for the same duration. The 15-yr average total rainfall and actual total rainfall at the experiment site for the past 3 yr are presented in Figure 3.3. September through November, and March for the experiment had lower precipitation than the 15-yr average, while all other months had higher precipitation than the 15-yr average. Even with six of the ten months in the experimental period having higher than normal precipitation, cold duration hours hampered forage growth thus delaying the start of grazing until 23 January 2014.

Forage Response

Average herbage mass (kg/ha) and RPM estimated herbage mass (kg/ha) for the experimental period are shown in Table 3.1. Despite managing the grazing to avoid too severely defoliating the CEG treatment, the average herbage mass was not different ($P = 0.30$) between treatments for the growing season. However, RPM estimated herbage mass was higher ($P < 0.01$) in the WW paddocks compared to all canola treatments. As assessed by the RPM, the CLG paddocks had less ($P < 0.01$) available forage (780 kg/ha vs. 1026 kg/ha and 922 kg/ha, respectively) than the CEG and CNG paddocks, which were not significantly different from each other ($P > 0.10$). With RPM estimated herbage mass being collected weekly at 40 observation sites and average herbage mass being collected at two week intervals at 3 observations sites,
RPM estimated herbage mass is likely a more accurate representation of the actual herbage mass made available in the treatments.

Herbage mass (kg/ha) for individual sample dates are provided in Figure 3.4. The amount of available forage was not different on 19 December \((P = 0.41)\), 9 January \((P = 0.22)\), and 22 January \((P = 0.39)\). After the initiation of grazing on 23 January, treatment differences appeared as expected. On 6 February, available forage tended \((P = 0.08)\) to differentiate, with the WW paddocks \((1278 \text{ kg/ha})\) having greater \((P < 0.05)\) biomass than all canola treatments, though the canola treatments did not differ from one another. Much of this difference is attributed to significant snow and ice accumulation on 28-29 January. On 20 February and 5 March, the CNG, CEG, and WW paddocks were not different, but the CLG treatment was the lower \((P < 0.05)\) than the other treatments on both dates \((453 \text{ kg/ha} \text{ and } 645 \text{ kg/ha}, \text{ respectively})\), which is more in line with the planned grazing pressure.

Seasonal crop characteristics are presented in Table 3.2. Growth stage was similar \((P = 0.06)\) for all canola treatments for the growing season as shown in Table 3.2. However, Figure 3.5 shows grazing treatment did affect growth stage \((P < 0.01)\) on 9 January sample date with CLG and CEG treatment having the highest values at GS 2.6, but remained similar across treatments for all other sample dates.

Leaf area index (LAI) was not affected \((P = 0.09)\) by treatment for the growing season (Table 3.2). However, there were differences on individual sampling dates (Figure 3.6). On 22 January, LAI was greater \((P = 0.05)\) for the WW than in the canola treatments, none of which were different from each other. On 22 February \((P < 0.01)\) and 5 March \((P < 0.01)\), the WW and CNG treatments had greater LAI than the CLG and CEG treatments. On the 20 February and 5 March sample dates, the LAI in the WW treatment was the highest \((1.64 \text{ and } 1.45, \text{ respectively})\)
while the CLG treatment was the lowest (0.44 and 0.42, respectively). Growth habit of the winter wheat and canola plants can provide partial explanation for these differences, but clearly the grazing management of the CLG treatment resulted in significantly less LAI on these sample dates.

Following the LAI trends, mean NDVI during the season was greatest \((P < 0.01)\) for WW, lowest for CLG, and CNG and CEG being intermediate and similar to each other (Table 3.2). Figure 3.7 shows that NDVI for the WW treatment for individual sample dates was higher \((P < 0.01)\) than all other treatments for the 22 January, 9 February, 20 February sample dates. On 22 January, WW was at Feekes 5.8. At GS 5, the plant’s nitrogen uptake is increasing (Thomason, 2009). Martin et al. (2007) found that NDVI increased with an increase in N application in maize (Zea mays). Average GS for canola at the 22 January sample date for all canola treatments was 2.5. Kandel (2011) described GS 2.0 for canola as having a rapid developing canopy with rapid and abundant leaf growth. Although both plants are growing at this point, the growth habits of the two plants are very different. Miller (1999) describes winter wheat at Feekes 5.0 as having dense tiller establishment while leaf sheaths become strongly erect. Kandel (2011) describes canola GS 2.0 as the rosette stage with older leaves at the base increasing in size and younger leaves developing in the center. The difference in growth habit for canola and winter wheat could partially explain the difference observed between the NDVI for the sample dates of 22 January, 9 February, and 20 February. Grazing was initiated on 23 January, which can also be an indication of the decreased NDVI from the 22 January sample date to the end of the grazing period.

The mean NIR for the season was different among treatments \((P < 0.01)\) with CNG being greatest and WW lowest. Figure 3.8 shows NIR reflectance was similar prior to the initiation of
grazing. However, the WW treatment exhibited the greatest \( (P = 0.01) \) NIR reflectance on 6 February, while the CNG treatment was greatest \( (P = 0.01) \) on 5 March. The NIR is directly correlated with the number of leaves within a canopy, and since the CNG treatment had no removal of plant material, it is reasonable that the CNG treatment would exhibit greater NIR reflectance than all the other treatments.

The mean RED reflectance showed no difference among treatments \( (P = 0.28) \) for the growing season (Table 3.2). However, RED reflectance within individual sample dates revealed differences among treatments with all canola treatments being higher than WW on 22 January, 20 February, and 5 March. The differences in growth habit for canola and winter could partially explain the higher values observed for RED, just as the difference between the NDVI values.

A summary of the total season forage quality for canola and winter wheat harvested during the experimental period is presented in Table 3.3. Dry matter was highest \( (P = 0.01) \) for WW treatment in comparison to all other treatments for the growing season. No treatment effect \( (P = 0.14) \) was observed for relative forage quality. Crude protein was lowest \( (P < 0.01) \) for the WW treatment in comparison to all of the canola treatments, which were not different from one another. However, CP levels in all of treatments would not be considered limiting for cattle gains of up to 1.1 kg per hd per d (NRC, 2000). Neutral detergent fiber (NDF) was greatest \( (P < 0.01) \) in the WW treatment. No differences \( (P = 0.78 \) and \( P = 0.13, \) respectively) were observed for acid detergent fibers and total digestible nutrients for the growing season. The WW treatment exhibited the lowest \( (P < 0.01) \) lignin content (0.72%) and the canola treatments did not differ from one another. Destructive samples were hand-clipped to a 3 cm stubble height for all treatments, but the plant structure of canola is different from winter wheat when grazed in this immature stage. Canola forms a rosette with larger stems and midribs that support the plant
leaves. In contrast, winter wheat forms several tillers and has relatively little fiber and vascular
tissue at this immature stage. This difference in growth habit can explain the differences(observed in lignin content.

Pelletier et al. (1976) reported forage quality of forage brassica crops at different sowing
dates and different N fertilization rates, leaf CP increased with later sowing dates from 12% (20
June), 13% (5 July) and 12% (20 July). Pelletier (1976) also reported an increase \( (P < 0.05) \) in
CP for an increase in N fertilization with 232 kg/ha having the highest CP at 17%. The crude
protein values from this experiment are much higher than the values reported by Pelletier (1976)
with the lowest treatment CP from the current experiment being CEG at 24%. These differences
are likely the result of less mature forage in the current study relative to that reported by Pelletier
et al. (1976). Furthermore, the growing conditions between the two experiments were much
different. The growing season for the current experiment was in the winter, while it was summer
in the work reported by Pelletier et al. (1976). Jones (2007) suggests that high temperatures
could increase the potential for N volatilization. With higher temperatures occurring in summer
months, an increase in volatilization could signal a decrease in uptake and conversion to CP from
Pelletier (1976). Similar to the current research, Stamm and Martin (2011) reported a range of
24.4 to 31.9% CP for canola receiving simulated grazing and grown during the winter.

**Animal Response**

Animal performance data is presented in Table 3.4. Initial BW, final BW, and ADG was
similar across all treatments \( (P > 0.53) \). No other study has reported ADG for cattle grazing
canola as a dual-purpose crop. The ADG reported for this study can only compare to forage
brassicas and dual-purpose canola being grazed by sheep. Kirkegaard (2008) observed 0.21 kg/d
for sheep grazing dual-purpose canola, while Reid (2008) reported similar gains. Expressed as a
percentage of BW, these gains are consistent with this current study. Kirkegaard et al (2008) reported 0.06% BW gain/d, while this study observed 0.05% BW gain/d. These gains would likely support a growth rate that would be required for a stocker production enterprise to be profitable.

**Crop Production**

Crop response of the canola treatments is presented in Table 3.5. Total biomass was not affected by treatment ($P = 0.17$). However, the management strategy for the canola affected ($P = 0.04$) seed yield with CLG and CNG resulting in lower seed yields than CEG (Table 3.5). These data conflict with other published data suggesting yield will be unaffected in crops grazed before bud elongation, GS 3.1 (Kirkegaard et al., 2012). This increase in yield may be attributed to reduced biomass during the growing season, which can reduce crop height thereby reducing lodging. Lodging can restrict the movement of nutrients and water in the plant, and increase the incidence of fungal disease (Kirkegaard et al., 2012). Similarly, McCormick et al (2012) reported final DM yield was reduced by grazing, but final seed yield was not affected. With cold duration hours being above normal for the growing season in the current experiment, it is hypothesized that removal of leaf area reduced cold injury and increased effective leaf area in CEG in comparison to CNG.

There was no effect ($P = 0.15$) of treatment on oil content in the canola seed. These findings are consistent with previous studies by Kirkegaard et al. (2008a), which noted no difference in seed oil content due to grazing. Oil content is commonly influenced by temperature during pod fill, declining 2.7% for every 1°C increase in average temperature during seed filling (Hocking et al., 1997b). If flowering delays occur as a result of grazing, it is possible to push flowering into the warmer portion of spring. However, the management strategies for grazing
canola are designed to avoid such delays, minimizing an impact on seed yield or oil content. Flowering for the current experiment was first noted in CNG on 12 March with full flowering being noted on 21 March for CNG, 2 April for CEG, and 9 April for CLG. The flowering delay from this experiment did not affect ($P = 0.15$) seed oil concentration. These findings are similar to those of Kirkegaard (2012) showing a flowering delay of 16 days having no affect ($P > 0.05$) on seed yield. Kirkegaard et al. (2008) also observed no difference ($P > 0.05$) in total biomass, which is consistent with this current study.

**Economic Returns**

The economic returns for crop and cattle production are summarized in Table 3.6. Gross returns after establishment costs are based on the costs estimated by Buntin (2010) and Smith (2013). Crop and calf value were based on market prices when the crop was harvested and the end of the grazing period. The value of gain in the calves was similar across all of the grazing treatments ($P > 0.22$). Crop value tended ($P = 0.08$) to be lower for CNG and CLG at $117.33/ha and $99.08/ha, respectively. Gross returns after establishment costs were similar across the grazing treatments, though each was greater ($P =0.08$) than CNG.

**Conclusions**

This research has shown that a producer can profit from utilizing canola as a dual-purpose crop. Weight gains for steers were similar to those of steers stockered on winter annual grasses. The management strategies used in the current experiment conserved seed yield and oil content relative to ungrazed canola production. This research demonstrates that utilizing canola as a dual-purpose crop with the management strategy of the CEG treatment is potentially profitable.
Literature Cited


Table 3.1. The mean herbage mass (kg DM/ha) during the grazing period for the canola-no graze (CNG), canola-early graze (CEG), canola-late graze (CLG), and winter wheat (WW) paddocks immediately prior to grazing. The herbage mass was assessed by bi-weekly hand clipping from three 0.1-m² areas/paddock and weekly measures of compressed sward height with a rising plate meter (RPM) in ca. 40 observation sites along a randomly located transect within each paddock and calculating the herbage mass using the calibration equation in Eq. 3.2.

<table>
<thead>
<tr>
<th>Herbage Mass Assessment Method</th>
<th>Treatment</th>
<th>CNG</th>
<th>CEG</th>
<th>CLG</th>
<th>WW</th>
<th>SE</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bi-Weekly Clipped Mass, (kg DM/ha)</td>
<td>866</td>
<td>963</td>
<td>790</td>
<td>1020</td>
<td>115.3</td>
<td>0.2981</td>
<td></td>
</tr>
<tr>
<td>Weekly RPM Estimation, (kg DM/ha)</td>
<td>922&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1026&lt;sup&gt;a&lt;/sup&gt;</td>
<td>780&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1164&lt;sup&gt;c&lt;/sup&gt;</td>
<td>68.4</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a-c</sup> Means within a row with different superscripts differ (P < 0.05).
Table 3.2. The mean crop canopy characteristics growth stage (GS), leaf area index (LAI), near difference vegetation index (NDVI), near infrared reflectance (NIR), and red reflectance (RED) during the grazing period for the canola-no graze (CNG), canola-early graze (CEG), canola-late graze (CLG), and winter wheat (WW) paddocks immediately prior to grazing. The data are presented as the mean of bi-weekly assessments from 23 January until 5 March.

<table>
<thead>
<tr>
<th>Item</th>
<th>CNG</th>
<th>CEG</th>
<th>CLG</th>
<th>WW</th>
<th>SE</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GS[^1]</td>
<td>2.6</td>
<td>2.7</td>
<td>2.7</td>
<td>5.8</td>
<td>0.05</td>
<td>0.0630</td>
</tr>
<tr>
<td>LAI</td>
<td>1.4</td>
<td>1.2</td>
<td>1.1</td>
<td>1.6</td>
<td>0.17</td>
<td>0.0901</td>
</tr>
<tr>
<td>NDVI</td>
<td>0.47[^b]</td>
<td>0.49[^{ab}]</td>
<td>0.46[^c]</td>
<td>0.54[^a]</td>
<td>0.01</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>NIR</td>
<td>2.6[^a]</td>
<td>2.1[^b]</td>
<td>2.2[^b]</td>
<td>1.9[^c]</td>
<td>.08</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>RED</td>
<td>3.2</td>
<td>3.2</td>
<td>3.4</td>
<td>3.4</td>
<td>0.10</td>
<td>0.2790</td>
</tr>
</tbody>
</table>

\[^a-c\] Means within a row with different superscripts differ (P < 0.05)

\[^1\] Growth Stage standard error and P value reflect comparison only for CNG, CEG, and CLG
Table 3.3. The mean forage quality characteristics during the grazing period for the canola-no graze (CNG), canola-early graze (CEG), canola-late graze (CLG), and winter wheat (WW) paddocks immediately prior to grazing. The data are presented as the mean of bi-weekly forage samples from 23 January until 5 March.

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment 1</th>
<th>CNG</th>
<th>CEG</th>
<th>CLG</th>
<th>WW</th>
<th>SE</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM², %</td>
<td>CNG</td>
<td>17.58</td>
<td>15.60</td>
<td>17.40</td>
<td>21.8</td>
<td>1.225</td>
<td>0.0101</td>
</tr>
<tr>
<td>RFQ³</td>
<td>CEG</td>
<td>196.59</td>
<td>199.77</td>
<td>191.77</td>
<td>202.54</td>
<td>3.608</td>
<td>0.1369</td>
</tr>
<tr>
<td>CP⁴, %</td>
<td>CLG</td>
<td>24.55</td>
<td>23.89</td>
<td>25.31</td>
<td>19.47</td>
<td>0.6453</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>NDF⁵, %</td>
<td>WW</td>
<td>30.14</td>
<td>30.71</td>
<td>30.24</td>
<td>39.62</td>
<td>0.6436</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>ADF⁶, %</td>
<td>WW</td>
<td>20.67</td>
<td>20.79</td>
<td>20.58</td>
<td>20.75</td>
<td>0.4877</td>
<td>0.7841</td>
</tr>
<tr>
<td>TDN⁷, %</td>
<td>WW</td>
<td>70.61</td>
<td>71.11</td>
<td>69.89</td>
<td>71.62</td>
<td>0.5590</td>
<td>0.1287</td>
</tr>
<tr>
<td>LIGNIN,%</td>
<td>WW</td>
<td>4.43</td>
<td>4.13</td>
<td>4.41</td>
<td>0.72</td>
<td>0.2326</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

a-b Means within a row with different superscripts differ (P < 0.05)

1 Treatments: CNG = Canola No Graze, CEG = Canola Early Graze, CLG = Canola Late Graze, WW = Winter Wheat

2 Dry Matter

3 Relative Forage Quality

4 Crude Protein

5 Neutral Detergent Fiber

6 Acid Detergent Fiber

7 Total Digestible Nutrients
Table 3.4. Body weight gains of stocker cattle grazing the canola-early graze (CEG), canola-late graze (CLG), and winter wheat (WW) treatments.

<table>
<thead>
<tr>
<th>Item</th>
<th>CEG</th>
<th>CLG</th>
<th>WW</th>
<th>SE</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial BW (kg)</td>
<td>249.7</td>
<td>247.1</td>
<td>244.6</td>
<td>5.83</td>
<td>0.8264</td>
</tr>
<tr>
<td>Final BW (kg)</td>
<td>299.6</td>
<td>309.6</td>
<td>306.8</td>
<td>0.07</td>
<td>0.5302</td>
</tr>
<tr>
<td>ADG (kg/d)</td>
<td>1.21</td>
<td>1.28</td>
<td>1.27</td>
<td>6.29</td>
<td>0.7750</td>
</tr>
</tbody>
</table>

\(\text{a-c}\) Means within a row with different superscripts differ (P < 0.05)
Table 3.5. The mean total aboveground biomass and seed yield produce by the canola-no graze (CNG), canola-early graze (CEG), canola-late graze (CLG), and winter wheat (WW) treatments, and oil content within the seed of the canola treatments.

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment</th>
<th>CNG</th>
<th>CEG</th>
<th>CLG</th>
<th>WW</th>
<th>SE</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Biomass, (kg/ha)</td>
<td></td>
<td>7589.9</td>
<td>8731.2</td>
<td>5920.7</td>
<td>9002.3</td>
<td>1050.7</td>
<td>0.1712</td>
</tr>
<tr>
<td>Seed Yield, (kg/ha)</td>
<td></td>
<td>1466.6&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>2008.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1238.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2798.2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>245.8</td>
<td>0.0043</td>
</tr>
<tr>
<td>Oil Content, %</td>
<td></td>
<td>40.6</td>
<td>42.4</td>
<td>41.4</td>
<td>-</td>
<td>0.005</td>
<td>0.1476</td>
</tr>
</tbody>
</table>

<sup>a-c</sup> Means within a row with different superscripts differ (P < 0.05).
**Table 3.6.** Value of the calf and crop production and total gross returns for the canola-no graze (CNG), canola-early graze (CEG), canola-late graze (CLG), and winter wheat (WW) treatments,

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment</th>
<th>CNG</th>
<th>CEG</th>
<th>CLG</th>
<th>WW</th>
<th>SE</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calf Value(^1) ($/ha)</td>
<td></td>
<td>-</td>
<td>666.37</td>
<td>836.25</td>
<td>832.20</td>
<td>68.54</td>
<td>0.2160</td>
</tr>
<tr>
<td>Crop Value(^2) ($/ha)</td>
<td></td>
<td>117.33</td>
<td>160.70</td>
<td>99.08</td>
<td>146.60</td>
<td>18.05</td>
<td>0.0874</td>
</tr>
<tr>
<td>Gross Return(^3) ($/ha)</td>
<td></td>
<td>36.39</td>
<td>746.13</td>
<td>854.39</td>
<td>877.63</td>
<td>176.75</td>
<td>0.0799</td>
</tr>
</tbody>
</table>

\(^{a-c}\) Means within a row with different superscripts differ \((P < 0.05)\).

1 Based on $0.08/kg ($9.25/bu) canola and $0.05/kg ($5.25/bu) wheat.

2 Based on $4.41/kg ($200/cwt) calf value.

3 Gross return over establishment cost.
**Figure 3.1.** The relationship between rising plate meter (RPM) values and actual herbage mass for samples taken every two weeks during the experiment. Data pairs represent the recorded RPM values and actual herbage mass clipped 0.1-m² sample areas.
Figure 3.2. Cold duration hours (hrs) ($\leq 0^\circ$C) for months within the experimental period, 2 yrs prior, and the 15 yr average were obtained from University of Georgia’s Automated Environmental Monitoring Network (2014) weather station on the Plant Sciences’ Farm in Watkinsville, GA.
Figure 3.3. Average precipitation (mm) for months within the experimental period, 2 yrs prior, and the 15 yr average obtained from University of Georgia’s Automated Environmental Monitoring Network (2014) weather station on the Plant Sciences’ Farm in Watkinsville, GA.
Figure 3.4. Herbage mass (kg/ha) of the canola-no graze (CNG), canola-early graze (CEG), canola-late graze (CLG) and winter wheat (WW) treatments throughout the growing season. Treatment means within a sample date followed by the same letter are not different ($P > 0.05$).
Figure 3.5. Harper and Berkenkamp (1975) Growth Stage development of the canola-no graze (CNG), canola-early graze (CEG), and canola-late graze (CLG) treatments and the Feekes growth stage for the winter wheat (WW) treatment throughout the growing season. Treatment means within a sample date followed by the same letter are not different ($P > 0.05$).
**Figure 3.6.** Effect of grazing management and environment on Leaf Area Index of the canola-no graze (CNG), canola-early graze (CEG), and canola-late graze (CLG) treatments throughout the growing season. Measurements were taken with a handheld a LI-COR LAI 2200 Plant Canopy Analyzer (LI-COR Biosciences, Lincoln, NE). Treatment means within a sample date followed by the same letter are not different ($P > 0.05$).
Figure 3.7. Normalized Difference Vegetation Index of the canola-no graze (CNG), canola-early graze (CEG), and canola-late graze (CLG) treatments throughout the growing season. Measurements were taken with a handheld CropCircle (Holland Scientific, Lincoln, NE) remote sensing device. Treatment means within a sample date followed by the same letter are not different ($P > 0.05$).
Figure 3.8. Near Infrared Reflectance measurements of the canola-no graze (CNG), canola-early graze (CEG), and canola-late graze (CLG) treatments throughout the growing season. Measurements were taken with a handheld CropCircle (Holland Scientific, Lincoln, NE) remote sensing device. Treatment means within a sample date followed by the same letter are not different ($P > 0.05$).
Figure 3.9. Red reflectance of the canola-no graze (CNG), canola-early graze (CEG), and canola-late graze (CLG) treatments throughout the growing season. Measurements were taken with a handheld CropCircle (Holland Scientific, Lincoln, NE) remote sensing device. Treatment means within a sample date followed by the same letter are not different ($P > 0.05$).
CHAPTER 4
CONCLUSIONS AND IMPLICATIONS

The research conducted has proven that proper grazing management will not limit seed yield, but possibly increase seed yield while providing adequate nutrition for weight gain in cattle. The term sustainable is a hot issue in agriculture today, and with the implementation of this integrated crop-livestock system, producers will be able to utilize forage and oilseed from a crop while recycling nutrients through cattle establishing a truly sustainable system. The use of these strategies has the potential to increase dual-purpose canola crop production in the SE, and the knowledge of integrated crop-livestock management systems.

Results from the experiment showed adequate forage could be produced to furnish adequate gains for stocker cattle. Weight gains for steers were not affected by grazing management strategy, with all treatments averaging 1.21 kg/d or greater. Management strategies were associated with seed yield but not oil content, showing that CEG is a better management strategy for seed yield and weight gain for cattle.

The expansion of canola production in the SE has another added incentive from this research. Favorable environments, crop rotation, increased demand for canola oil and increase cattle prices provide optimism for producers interested in implementing this crop-livestock system. This system has the opportunity to reduce nutrient overload for farms, diversify a farming operation and build a stronger sustainable farming system, and that is why further research is needed on the utilization of canola as a dual-purpose crop for stocker cattle.