DETERMINING THE EFFECTS OF PLANTING DATE AND LAND PREPARATION METHOD ON FORAGE YIELD AND QUALITY OF FORAGE BRASSICA.

by

TAYLER DENYSE DENMAN

(Under the Direction of Dennis W. Hancock)

ABSTRACT

Forage-type *Brassica* spp. can produce large amounts of forage that can be useful in a livestock grazing system, however, research that defines best management practices for establishment is limited. The objective of this study was to examine the effects of planting date and land preparation method on seedling emergence, forage yield and quality of two *Brassica* spp. Experiments compared four planting methods (conventional till, no-till after burning, no-till after mowing, and no-till with no residue removal) across four planting dates (1 September, 15 September, 1 October, and 15 October) in a randomized complete block design with four replications. Results have shown that planting early (S1 and S15) and into little residue (CT and NB) will produce the highest forage yields and provide a substantial amount of forage during times when little else is growing. Results have also shown that *Brassica* can provide high quality forage for livestock with high maintenance requirements.

INDEX WORDS: Forage *Brassica*, turnips, kale, canola, swedes, planting date, land preparation, forage yield, forage quality, CP, TDN, dNDF30, lignin

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INTRODUCTION

In any livestock enterprise, there is often a fine line between having an efficient and profitable operation, and not being able to break even. This is why it is crucial for any livestock operation to produce their product as efficiently and economically as possible to ensure a profit. One of the best ways to reduce input costs in a livestock operation is to extend the grazing season as long as possible and effectively reduce the number of days in which hay and concentrate supplementation is required (Stewart et al., 2013). In fact, supplementation of stored feeds can be up to two to three times more expensive to feed per day when compared to an efficient grazing system (Ball et al., 2008).

Forage Production in Georgia

Forage-based livestock producers in the Southeastern United States have a competitive advantage to producers in the northern United States because they have the ability to take advantage of the warm summers, mild winters, and high rainfall throughout the year for a grazing season that can last over 300 days (Hancock et al. 2011). This distinct advantage allows producers to take advantage of using both warm and cool season forages to increase the number of grazing days and reduce the number of days required to feed hay and other supplementations.

It is common practice in Georgia and other portions of the southeastern United States to utilize warm season perennial grasses, such as bermudagrass (*Cynodon dactylon*), due to their ability to produce significant forage yield in May through September (Figure 1.1). To extend the grazing season in the early part of the year (January through May), before the bermudagrass is productive, producers will interseed winter annual forages, such as cereal rye (*Secale cereale)* and annual ryegrass (*Lolium multiflorum),* into the dormant bermudagrass in early autumn (Hancock et al., 2011). Unfortunately, few forage species are available to fill the gap between the warm season and cool season forages in October through December that can be grown in Georgia and other parts of the southeastern United States.

Potential for Forage Brassica

Forage brassicas (turnips, kale, canola, swedes, etc.) are cool season annuals that are commonly used as forage crops in Australia, New Zealand, and many parts of Europe. Forage brassicas are often planted in the autumn, similar to other cool season annual forages. However, some of these species have the ability to rapidly establish and produce approximately 4000 kg ha^{-1} in late autumn or early winter in locations where winters are mild (Table 1.1; Figure 1.1; Lemus et al., 2014). Forage brassicas are also a high quality forage with observed crude protein of 200 to 250 g kg^{-1}, Neutral Detergent and Acid Detergent fiber around 19.8 and 16.8, respectively, and *in vitro* Digestible Dry Matter ranging from 650 to 800 g kg^{-1} (Table 1.2; Smart et al., 2004).

These unique characteristics can be beneficial especially at a time when nutrient requirements are particularly high, such as during a fall calving season or achieving high average daily gains in stocker cattle (Stewart et al., 2013). Growing such a crop that could provide substantial forage of high quality during the late autumn and early winter months could ultimately reduce the need for supplementation in the southeastern United States during these months thereby lowering input costs, extending the grazing season, and increasing profitability in forage-based livestock systems in this region.

Purpose of this Experiment

The usage of forage brassicas is common in other countries however, little research has been conducted on the ability of forage brassicas to be utilized in the southeastern United States, especially Georgia. There has been some research on potential forage yields in the southeastern United States (Lemus and White, 2014; Kalmbacher et al., 1982; Ingram, 2014), yet there is a notable information gap on the effects of basic agronomic management practices on the forage yield and quality of forage brassicas.

The objective of this study is to evaluate two agronomic management practices, planting dates and land preparation methods, on the forage yield and quality of a forage-type brassica. This information could then be used to further explore the potential for forage brassicas to be used in forage systems in Georgia.

Expected Results

It is hypothesized that the warmer weather of the earlier planting dates (1 September and 15 September) will allow for significantly higher forage yields than the later planting dates (1 October and 15 October) when temperatures are cooler. Additionally, it is hypothesized that no-till planting into land that has been closely mowed or physically burned will produce forage yields similar to conventionally-tilled land preparation techniques. This hypothesis is based on the ability of forage brassicas to establish rapidly and have a competitive advantage over weed pressure during a time when few weeds are actively growing. It is also hypothesized that planting into land with significant residue will decrease forage yields as a result of reduced light penetration to the soil surface and the seedlings of the forage brassicas.

Tables and Figures

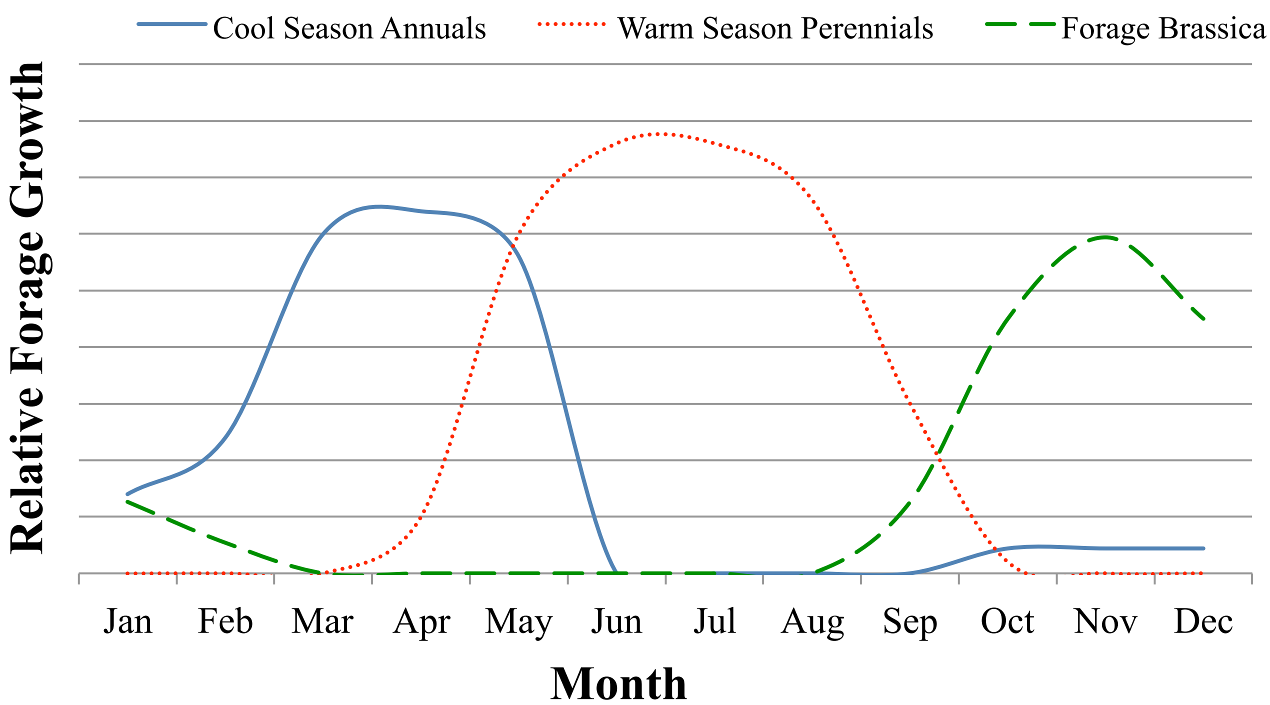

Figure 1.1. Estimated growth curves of cool season annual and warm season perennial forages grown in the southeastern United States. Adapted from Ball et al. (2008). Estimated forage brassica growth curve adapted from results of this study.

Table 1.1: Observed forage yield of forage brassicas grown near Starkville, MS (Lang et al., 2007).

Type[1]	21-Nov	24-Jan	26-Mar	Total
		kg DM ha^{-1}		
Rape				
Barnapoli	910	3248	4771	8931
Bonar	1036	2948	4732	8716
Dwarf Essex	1381	3498	5442	10322
T-Raptor	2016	4609	6962	13588
Turnips				
Appin	1761	2978	4403	9254
Brabas	1571	1957	2194	5722
Barkant	1391	2132	2728	6251
FL Broadleaf	1695	2808	3893	8396
Pasja	1592	4103	6457	12152
Purpletop	2662	2467	3799	8928
LSD[2]	628	499	596	971

1 Planted at 5.6 kg/ha^{-1} and fertilized with 67 kg N ha^{-1}, 22 kg P_20_5 ha^{-1}, and 45 kg K_20 ha^{-1} at planting and following each harvest

2 LSD = Least Significant Difference evaluated at $\alpha = 0.05$

Table 1.2: Forage nutritive value of brassica tops and bulbs in Brookings, SD (Smart et al., 2004)

		Harvest Date[1]		
Plant Part		**15-Oct**	**1-Nov**	**SE[2]**
Tops				
	NDF	19.8[3]	21.5	2.19
	ADF	16.8	18.3	2.02
	CP	15.3	14.5	0.79
Bulbs				
	NDF	24.7	12.7 a	3.18
	ADF	21.0	10.5 a	3.06
	CP	15.4	12.8 b	0.24

[1] Means sharing the same letter within a row are not significantly ($P < 0.05$) different.
[2] SE = Standard Error of the mean.
[3] Brassica was planted on 1 August.

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CHAPTER 2

LITERATURE REVIEW

Forage brassicas are cool season annual crops that can be planted in the summer and early autumn to help extend the grazing season into the late autumn and early winter months and provide a high quality forage to help reduce supplementation costs (Hall and Jung, 2008). There are four main species and one hybrid species of brassica that can be used as a source of forage. These species are kale (*Brassica oleracea*), rape, also known as canola (*Brassica napus*), swede (*Brassica napobrassica*), turnip (*Brassica rapa*) and turnip hybrids, all of which have their own unique characteristics.

Species

Kale (*Brassica oleracea*):

Kale is the most winter hardy of the brassicas in that they can survive temperatures as low as -12°C and can produce significant yields for up to 150 days. There are two varieties of kale that are used in forage systems: narrow stem and stemless varieties. Narrow stem varieties have larger stems and are generally only used for cattle production systems, since these stems can be difficult for small ruminants to consume. Stemless varieties establish faster and reach maximum production sooner than narrow stem varieties and are better suited for small ruminants (Lemus and White, 2014; Hall et al., 2008).

Rape (*Brassica napus*):

Rape is a multi-stemmed crop with various stem lengths and diameters. Rape is fast to establish and can be grazed as early as 60 days after planting (DAP). Rape does require careful management in that it must reach maturity prior to grazing to prevent potential health issues such as photosensitization in livestock (Hall et al., 2008).

Swede (*Brassica napus*):

Swedes are root crops that produce both above and below ground forage that livestock can consume. Swedes mature slower than turnips but have overall higher forage yield than turnips. Swedes tend to perform better in cooler environments compared to turnips and, therefore, are not usually recommended in the Southeastern United States (Hall et al., 2008).

Turnip (*Brassica rapa*) and turnip hybrids:

Like other species of brassica, turnips can establish rapidly and reach peak production within 90 DAP. Varieties differ in the proportion of foliage and bulb mass produced, with varieties that tend to produce larger bulbs generally exhibiting lower CP content than the leafier varieties. With light grazing pressure and careful management, turnip and turnip hybrids can provide significant forage mass in grazing systems (Lemus and White, 2014; Hall et al., 2008; and Smart et al., 2004).

Forage Yield by Planting Date of Brassica

Though forage brassica crops have the ability to produce substantive dry matter (DM) yields during transition periods between warm and cool season forage crops, research has shown that the total yield is dependent on temperature and soil moisture. Rao and Horn (1986) concluded that seedling emergence and establishment of forage brassica was slower in the spring due to cooler temperatures. Alternatively, greater moisture availability and warmer soil temperatures at early fall planting resulted in earlier seedling emergence and establishment. The fall planted brassica rate of growth declined with decreasing temperatures whereas spring planted brassica increased rate of growth with increasing temperatures. Similar results were observed by

Jung et al. (1983), and they concluded that seedlings exhibited delayed emergence, appeared yellow with poor leaf development, and grew slowly at mean soil temperatures of 12°C. Mean soil temperatures of 21°C produced healthy, dark green seedlings with vigorous growth.

A study conducted in South Florida observed mean total yields of 4040 kg ha^{-1} for October-sown brassica with a consistent decrease in overall yield in the subsequent November and January planting dates (2820 kg ha^{-1} and 1550 kg ha^{-1} respectively) and a decrease in growing season (150 days, 130 days, and 110 days respectively), indicating a decline in overall forage yield and growing season as mean temperatures decrease (Kalmbacher et al., 1982). Additionally, planting date, air temperatures, and plant maturity also have a direct impact on the DM partitioning between foliage and roots. A study conducted by Jung et al. (1993) observed in the 'Purpletop' turnip cultivar twice as much dry matter partitioned to the tops when compared to the roots in the June/July plantings; however, it partitioned up to four times the DM to the tops when compared the roots in the later August planting date. This indicated that delaying the planting date and exposing brassica to even warmer air temperatures allow the brassica to partition more dry matter to the tops than the roots. In addition, the partitioning of dry matter from tops to the roots tends to increase as harvest date is delayed. Results have shown top/root quotients to be approximately one third to one half the ratio of top/root DM compared to that at 60 DAP, indicating that as the plant matures, dry matter begins to partition more to the roots than the tops of the plant.

Late summer planting dates that time establishment during warmer temperatures result in faster stand development than later planting dates (Kalmbacher et al., 1982). Similar results were observed by Guillard et al. (1988) with forage yields ranging from 2845 to 4055 kg ha^{-1} when exposed to autumn weather conditions and overall significantly higher yields, ranging from 3091 to 4618 kg ha^{-1} when grown during the summer months. These results indicate that temperature, moisture, and light intensity may all have an effect on the rate of growth and total dry matter production of forage brassica. In addition, Kalmbacher et al. (1982) found forage brassica exceeded yield expectations in years when ambient temperatures were above 32°C and rainfall accumulation averaged 120 cm annually. Thus, warm temperatures in late summer may not have the negative impact on forage yields as previously anticipated and may actually favor greater forage production. These results are consistent with various other studies where warmer growing conditions allow for faster seedling emergence and overall forage yield than cooler growing conditions (Kalmbacher et al., 1982; Guillard et al., 1988; Jung et al., 1983; Jung et al. 1986; and Rao and Horn, 1986).

Forage Yield Potential Among the Varieties and Species of Brassica

Substantial variation in early season growth rate and total forage yield has been observed among the different varieties and species of brassica. Horn and Rao (1986) observed forage yields peaking at 85 to 95 DAP for turnips and turnip hybrids. ‘Cyclon’ and ‘Purpletop’ turnips produced peak forage accumulation at 85 DAP with yields of 5680 and 5130 kg ha^{-1}, respectively. However, the hybrid variety ‘Tyfon’ produced higher forage yields (6450 kg ha^{-1}) than either Cyclon or Purpletop, though it reached maximum yield at 95 DAP. The higher yield of the hybrid was likely the result of greater partitioning of photosynthate to foliage production, as root mass was decreased compared to Purpletop and Cyclon turnips. In the same study, kale appeared to mature slower than the turnip and turnip hybrid varieties, and it had slower herbage DM accumulation than rape. However, Horn and Rao (1986) observed kale to be more winter hardy, as it had the ability to grow longer into the fall than rape, presumably allowing for greater overall herbage yield. Harper and Compton (1980) observed similar results, confirming that, despite having a slower accumulation rate, kale has a longer growing season and produces more forage yield than rape. Similarly, Kalmbacher et al. (1982) reported that kale required 150 to 180 days to reach maximum forage yield relative to the 100 to 120 days required by rape or turnips. These authors also reported that kale produced maximum DM yields (6220 kg ha $^{-1}$) when planted in October and allowed to stockpile.

Kalmbacher et al. (1982) also found that when kale was subjected to multiple cuttings, which occurred when the plant reached a height of 38cm,, forage yield was significantly decreased (2250 kg ha^{-1}). Alternatively, rape produced the highest yields (4630 kg ha^{-1}) when subjected to multiple cuttings, suggesting that rape has the ability to recover quicker from a harvest when compared to kale. In contrast, turnips produced greater foliage mass in a multiple cut system than in a stockpiled system (2900 and 1200 kg ha^{-1} respectively), though the multiple cuttings resulted in lower root yields than when stockpiled (2060 and 3580 kg ha^{-1} respectively). When comparing a stockpiled versus multiple cutting management system, total turnip biomass (foliage and root mass) was not significant from one another.

Overall, growth rate trends suggest that turnip, turnip hybrids, and rape produce forage more rapidly than kale. However, the winterhardiness of kale gives it an advantage if used for production systems where a longer growing season than the other brassicas and only one harvest is acceptable. Turnip and turnip hybrids produce substantial forage mass when grazed or cut multiple times during the growing season, but root mass is negatively affected, causing a decrease in edible root yield. Rape can produce a significant amount of foliage yield that in multiple cut systems higher than turnip and turnip hybrids; however, when combining root and shoot yield of turnips, they can produce higher overall forage yields than rape (Rao and Horn, 1986; Harper and Compton, 1980; and Kalmbacher et al., 1982).

Bulb Yields of Brassica

A positive attribute of swedes, turnips, and turnip hybrids is the production of nutrient dense bulbous taproots that livestock are able to consume. Research has shown that bulb turnips are typically 55% leaf and 45% bulb biomass, while the bulb yields of swedes may be over 75% of the total biomass production (Westwood et al., 2012). In addition to the aforementioned negative effect of defoliation on root yields, an inverse relationship between brassica herbage yields and bulb yields has also been observed. Guillard et al. (1988) observed foliage yields were the highest in turnip hybrids and lowest in swedes, whereas root yields were highest in the swedes (2027 kg ha^{-1}) and lowest for the turnip hybrid (1327 kg ha^{-1}). Kalmbacher et al. (1982) observed similar results with turnip forage yields highest of the two root crops (2310 kg ha^{1}) compared to swedes (2140 kg ha^{-1}) however, swedes produced higher root yields (1600 kg ha^{-1}) than turnips (930 kg ha^{-1}).

This inverse relationship between root and forage yields in brassica is not absolute, as both can decline under poor growing conditions. For example, drought conditions tend to induce a state of dormancy that can drastically reduce overall root yields (Jung et al., 1993). Similar results were also observed by Dragland (1982) in which swede bulb yields were significantly lower when exposed to drought conditions.

Kalmbacher et al. (1982) concluded that root yield was significantly lower in a multiple cut system than in a single cut system and bulb yields were more significantly reduced in turnips than in swedes. It was also reported that the turnip and swede root diameter declined proportionally as planting date was delayed (7.8, 6.9, and 4.9 cm, respectively). Jung et al. (1983) also found that root diameter in the crop was reduced with increasing seeding rate and narrower row spacings. It is also worth noting that the aforementioned temperature effect on herbage mass can also play an important role in root yield. As mentioned above, Jung et al. (1993) also concluded that delay of planting date and temperature caused a change in the proportion of DM partitioned to the roots between the June/July planting dates which were only 54 % the partitioning of the DM to the tops compared to the August planting date.

Forage Quality of Brassica

Forage brassicas have the potential to produce highly digestible forage. *In Vitro* Dry Matter Digestibility (IVDMD) values reportedly ranged from 770 to 991 g kg^{-1}. However, the average DM content in forage brassicas are quite low (75 to 230 g kg^{-1}) across all brassica species, though the DM content is observed to be approximately 60% lower in the roots than in the leaves (Kalmbacher et al., 1982; Westwood et al., 2012; Bokhari et al., 1981; Rugoho et al., 2014).

Weidenhoeft et al. (1994) observed CP levels as high as 198 g kg^{-1}, which is comparable to legumes and, in general, much higher than other grasses such as bermudagrass. Rugoho et al. (2014) found whole plant kale and Italian ryegrass (*Lolium multiflorum* Lam.) had comparable CP concentrations (175 and 175 g kg^{-1}, respectively). Whole plant CP concentrations of leafy turnips (226 g kg^{-1}) appear to be the highest among forage brassicas, followed by bulb turnips, swedes, and rape (142, 137, and 108 g kg^{-1}, respectively; Westwood et al., 2012). Similar results were observed by Jung et al. (1986) where mean CP concentrations were highest in turnips and lowest in rape (225 g kg^{-1} and 155 g kg^{-1}, respectively).

The season in which the crop is grown and planting date has been observed to affect CP concentrations of brassica crops (Kalmbacher et al., 1982; Rao and Horn, 1986). For example, Rao and Horn (1986) observed CP concentrations decreased more rapidly in spring-grown brassica than in fall grown crops. Overall CP concentrations were also observed to be lower in brassica planted earlier compared to a later planting (Kalmbacher et al., 1982).

Additionally, Jung et al. (1993) observed an inverse relationship between overall yield and CP concentration. For example, CP concentration was lowest (242 g kg^{-1}) at the point when yields were highest and CP concentration was highest (281 g kg^{-1}) when yields were lowest. This relationship between yield and CP concentration is consistent with the aforementioned results observed by Kalmbacher et al.(1982) where CP concentrations were lowest in earlier planting dates and yields were highest and the results of Rao and Horn (1986) where there was an overall trend for nutritional quality to be higher in the lower yielding fall sown brassica than in the higher yielding spring sown brassica.

Negative effects of cutting interval have also been observed on CP concentrations. Westwood et al. (2012) observed higher CP concentrations (226 g kg^{-1}) in the initial cutting of leafy forage brassica than the later cutting (153 g kg^{-1}). The observed CP values across all species and cultivars were observed to be well above nutritional requirements for a lactating beef cow and also meet requirements for steers to gain 1 kg day^{-1} (Rao and Horn, 1986; NRC 2016)

Several studies report low neutral detergent fiber (NDF; range of 140 to 420 g kg^{-1}) and acid detergent fiber (ADF; range of 110 to 360 g kg^{-1}) values for all forage brassicas, even relative to values typically observed in legumes and some grasses (Westwood et al., 2012; Guillard et al., 1988; Bokhari et al., 1981). Higher NDF and ADF values have been reported in rape and kale than in turnips and swedes, with these differences being attributed to their higher stem to leaf ratio (Guillard et al., 1988; Westwood et al., 2012). Across all the forage brassica species, such low NDF concentrations indicate it is a low fiber and rapidly digestible forage which could risk inducing ruminal acidosis and would be considered too low to be utilized as a sole diet for ruminants (Westwood et al., 2012) since minimum NDF values for optimal rumen function is 270 – 300 g kg^{-1} (NRC 2016). Westwood et al. (2012) found that, at 13.8 MJ of metabolizable energy (ME) kg^{-1}, swedes had higher energy concentrations than leafy turnip, bulb turnip, rape, or kale (13.2, 11.7, 12.9, and 11.2 MJ ME kg^{-1}, respectively).

In vitro dry matter disappearance (IVDMD) of brassica was observed in a few studies ranging from 700 to 910 g kg^{-1} (Rao and Horn, 1986; Jung et al., 1986). Rao and Horn (1986) observed a linear increase in IVDMD of leafy stem crops (kale and rape) as DAP increased (from 730 to 780 g kg^{-1}) and a quadratic trend in root crops (turnips and swedes). Maximum values of IVDMD were observed 80 to 95 DAP followed by a drastic decline in IVDMD values. Higher IVDMD values were observed by Jung et al. (1986) across all cultivars at 90 and 120 DAP but values tended to be lower in kale (~821 to 836 g kg^{-1}). Overall, the CP and IVDMD of forage brassicas exceed the nutritional requirements for most ruminant livestock (Rao and Horn, 1986; NRC, 2016), but NDF and ADF values may be too low if brassica is the sole component in the diet (Westwood et al., 2012; NRC, 2016).

Root and Bulb Quality of Brassica

The nutrient-dense bulbs of some species of swedes and turnips are often large enough that livestock can extricate and consume them. Like the foliage, the DM content of these bulbs is low (ranging 150 to 230 g kg^{-1}) and would not provide sufficient DM for proper ruminal function and optimal livestock production (Bokhari et al., 1981; NRC, 2016). Though the nutritive value of the bulbs differs from the foliage, the bulbs contain high concentrations of highly digestible nutrients and should be considered when livestock graze on these forages.

Bohkari et al. (1981) observed mean CP concentrations had a tendency to be 35 to 92 g kg^{-1} lower in the roots than in the shoot portion of the plant, while Rao and Horn (1986) found the difference to typically be 60 g kg^{-1}. However, Jung et al. (1986) observed no significant differences in the CP concentrations of turnip and swede bulbs (136 and 130 g kg^{-1}, respectively). Growing season was also observed to have an effect on decline in CP concentrations. It was noted that CP concentrations decreased more rapidly in the spring than in fall grown crops and that the mean rate of CP concentration decreased by 1.0 g kg^{-1} day^{-1} in the roots of the crops (Horn et al., 1986).

Mean NDF values in the roots (179 to 206 g kg^{-1}) were observed to be similar to those of the foliage (184 to 251 g kg^{-1}; (Bokhari et al., 1981). However, Westwood and Mulcock (2012) found the mean NDF in the bulbs of fall grown crops to be only 72% of that found in summer grown crops. In contrast, they found that ADF values were similar across planting dates, with a mean value of 141 g kg^{-1}. They also reported that digestible energy (DE) values of roots ranged from 13.5 to 14.9 MJ kg^{-1}. Horn et al. (1986) observed the IVDMD of the bulbs ranged from 800 to 860 g kg^{-1} and increased with sampling dates, presumably as the result of increased starch and non-structural carbohydrate concentrations.

Mineral and Chemical Composition of Brassica

To ensure that livestock are consuming sufficient minerals in the diet, it is important to understand the mineral composition of any feed or forage. Unfortunately, there is very limited research on the mineral composition of brassica.

Calcium levels of brassica often average around 40 g kg^{-1} (Ruiter et al. 2009) which should easily meet the nutrient requirements for Ca for most ruminant species and classes (e.g., NRC, 2016). Ruiter et al. (2009) also reported P concentrations in brassica of 2 to 4 g kg^{-1}, which may be insufficient to meet the requirements of dry, pregnant beef cows (24 g P day^{-1}; NRC, 2016), much less other ruminant classes and species. Thus, supplemental P may need to be provided. Brassicas are also reportedly high in K and low in Mg, which can result in hypomagnesaemia and issues in late gestation. Because of the low magnesium, it is highly recommended to supplement with a high Mg mineral. It is also recommended to supplement with Cu when brassica is the majority of the diet fed to cattle, since brassica has been observed to be very low in copper and cattle may become Cu deficient if fed brassica over an extended period of time (Ruiter et al., 2009).

Brassica also has notoriously high concentrations of sulfur (5.6 g kg $^{-1}$ to 8.5 g kg $^{-}$1) when compared to other forages, and the maximum tolerable total sulfur concentration in a ruminant diet is 4.0 g kg $^{-1}$ (Sargison, 2003; Sun et al., 2012; NRC, 2016). The high sulfur concentrations are likely as a result of high concentrations of S–methyl–cysteine sulphoxide amino acid (SMCO) and glucosinolates present in brassica. These compounds are anti-quality factors and can be dangerous in high concentrations. The SMCO molecule is broken down by ruminal microbes to produce dimethyl disulfide, which can cause haemolytic anemeia (Sargison, 2003). High concentrations of glucosinolates in the diet are also often degraded by ruminal mircobes, and they may release chemical compounds that inhibit goitrogens and reduce the uptake of iodine by the thyroid gland. This induces an iodine deficiency and, as a result, goiters and other health issues may occur (Barry, 2013).

Research has shown that there are ways to reduce the amount of SMCO in brassica fed to livestock. Several studies have observed that SMCO concentrations tend to be higher in kale and swedes than in turnips and rape (Table 2.1). Kunelius (1987) observed similar results in that SMCO concentrations were generally lower in turnip than in rape and kale. Glucosinolate concentrations have also been observed to be higher in swedes and lower in kale; however, no data were available on turnips or rape (Forss and Barry, 1983).

Ruiter et al. (2009) suggested reducing the amount of S fertilizer could decrease the amount of SMCO concentration in the forage. Along with supplementation with other forages that are low in these compounds, the amount of SMCO and glucosinolate compounds the animal is consuming can be diluted and thereby diluting the amount of potentially toxic compounds being formed. It was also observed that SMCO concentrations increased as planting date was delayed (Table 2.1). These observed results were similar to that of Bradshaw and Borzucki (1983), which suggests that SMCO concentrations may increase especially when brassica are subjected to frost conditions. Perhaps brassica species and planting date may have an effect on the concentration of SMCO and glucosinolate and may play a role in reducing these risks.

Animal Performance on Brassica

Clearly, brassicas produce a forage that is highly digestible and contains high concentrations of energy and CP; however, research has shown that when brassica was fed as a sole diet the anticipated growth is often less than expected. This may simply be due to the fact that brassicas are very low in fiber, which is required to help stimulate rumination, stabilize gut function, optimize passage rate, and, thereby, maximize the absorption rate of nutrients. A lack of fiber in the diet can decrease the efficiency of the utilization of the forage. Along with this, the high concentration of SMCO and glucosinolate compounds have been shown to be a likely cause in reduction of voluntary feed intake (VFI) and, therefore, have been implicated as the cause of animal performance that is less than expected (Ruiter et al., 2009 and Barry, 2013).

Barry (2013) reviewed multiple grazing experiments and found that mean weight gains of young sheep fed solely a diet of turnips or forage rape was higher (173 and 225 g d^{-1}, respectively) than a kale diet (150 g d^{-1}). This was attributed to the higher SMCO concentration in kale relative to the turnips and rape (Table 2.1), further indicating that SMCO and glucosinolate concentrations can have an effect on animal performance.

Results from a grazing trial conducted by Brunsvig et al. (2017) indicate that grazing behavior may also have an effect. They observed that the brassica to grass ratio consumed by cattle was lowest two days after the start of the trial, but brassica consumption had increased at 24 days after initiating grazing before decreasing to low levels again at 46 days after initiating grazing. These observations line up with the initial lag period in growth of lambs for 4 to 6 weeks when lambs transitioned from grass-based pastures to forage brassica that was reported by Nichol and Barry (1980). This lag phase was then followed by an increase in growth. Similarly, Barry et al. (1981) observed a similar phase of slow growth in young cattle grazing forage brassica (0.23 to 0.27 kg d^{-1}) but after 6 weeks live weight gains (LWG) increased to 0.49 kg d^{-1}.

In the Brunsvig et al. (2017) study, there were notable changes in ruminal function over the 46 days. Particulate fill differences were observed in the rumen between day 2 and day 24 of grazing. As the proportion of brassica in the diet increased from day 2 to 24, the particulate fill in the gut was only 52 % of the fill that was observed in day 2 when the proportion of brassica was significantly lower in the diet. A relationship between the B:G ratio and NDF values of ruminal diet samples was also observed. The NDF value was at its highest at 2 days after grazing (482 g kg^{-1}), then decreased as the amount of brassica in the diet increased (355 g kg^{-1}) and decreased again as B:G ratio decreased (428 g kg^{-1}). A similar yet not as drastic trend was observed with ADF values (336, 328, and 341 g kg^{-1}, respectively). This clearly indicates that the amount of brassica in the diet can have a direct impact on the animal (Brunsvig et al., 2017). Introducing brassica to livestock slowly by allowing access for a few hours a day and gradually increasing their time and allowance of brassicas over the course of 10 days can help mitigate health consequences that occur with abrupt changes in diet. It is also important to supplement with forages high in fiber to help slow the passage rate and increase ruminal absorption of nutrients and overall efficiency of forage brassica being utilized by the animal, thereby diluting the SMCO and glucosinolate concentrations in the diet (Ruiter et al., 2009).

Many studies have observed increased production of animals when using brassica as supplemental forage. For example, a study conducted by Vipond et al. (1982) observed responses in protein supplementation via soybean meal in lactating ewes increased swede intake by 0.14 causing a theoretical increase in milk yield that resulted in a secondary growth response in the ewes' lambs of an addition 54 g d^{-1}. In addition, Moorby et al. (2003) conducted a study comparing two systems, one with a kale and barley bi crop diet and one with a grass only diet. It was observed that cows fed the kale and barley bi crop produced significantly higher milk yields than the grass only mixture (24.0 and 22.6 kg d^{-1} respectively) however, cattle consuming the kale barley bi crop had significantly lower milk fat than that of cattle consuming grass only (1020 and 1076 g d^{-1} respectively). This indicates that the nutritive quality of the kale in the kale barley bi crop provided enough nutrition for higher milk yields however, results indicated that milk fat may have been decreased.

Notably, a grazing trial conducted in Watkinsville, GA indicated that canola can produce weight gains of 1.21 kg d^{-1} in stocker cattle and that with proper grazing management, canola can be utilized as a dual-purpose crop to be harvested for oilseed (Ingram 2014).

Overall, brassica can be a valuable forage to increase production in livestock due to the quality of the forage. Because most ruminants are more accustomed to consuming grasses rather than forbs, it is best to provide brassica as a supplemental forage to increase animal performance.

Tables and Figures

Table 2.1: Reported concentrations of S–methyl–cysteine sulphoxide amino acid (SMCO) and glucosinolates in forage brassicas. Adapted from Barry (2013).

Compound	Plant part	Swedes	Turnips	Kale	Rape
SMCO (g kg^{-1} DM)					
Whittle et. al., 1976	Leaf	10.9	4.3	7.5	3.9
	Bulb	7.9	4.2	-[†]	-
Stewart and Judson, 2004	Leaf	5.9	2.9	7.4	4.2
	Bulb	5.0	4.5	-	-
Kunelius et. al., 1987					
23 May Planting	Leaf	-	4.6	4.2	3.2
24 Aug Planting	Leaf	-	5.2	8.2	6.8
Glucosinolates (µml/g/DM)					
Forss and Barry, 1983	Leaf	23.7	-	9.1	-
	Bulb	11.6	-	-	-

[†] - = not reported.

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CHAPTER 3

SEEDLING EMERGENCE, FORAGE YIELD, AND QUALITY OF FORAGE BRASSICAS[1]

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Abstract

Several *Brassica* spp. can produce leafy forage material of sufficient quantity and quality to be useful in a livestock grazing system. Forage brassica are gaining popularity in the southeastern USA, yet research that defines best management practices for establishment is limited. The objective of this study was to conduct experiments with canola and a forage-type hybrid turnip that examine the effects of planting date and land preparation method on seedling emergence, forage yield, and quality. Experiments compared conventional till (CT), no-till after burning (NB), no-till after mowing (NM), and no-till with no residue removal (NR) planting methods across 1 September (S1), 15 September (S15), 1 October (O1), and 15 October (O15) planting dates in a randomized complete block design with four replications. No treatment effects were observed on seedling emergence in experiment 1, but the treatments with greater residue (NM and NR) exhibited reduced seedling emergence in experiment 2. The earlier planting dates of both experiments, CT or NB plots generally had higher forage yields than either the NM or NR plots, which did not differ. In contrast, poor production from both brassica types was observed when planted at the later dates, and the effect of planting method treatment did affect forage yield. CP, TDN and lignin concentrations were all sufficient for livestock with high nutrient demands. Overall, planting as early as possible (S1 and S15) into as little residue as possible (CT and NB) produced the highest forage yields.

Introduction

Varieties of several *Brassica* spp., including turnips, kale, canola, and swedes, have been used successfully as a supplemental forage crop. In the southeastern United States, forage brassicas have the potential to produce up to ca. 4,000 kg ha^{-1} amounts of forage biomass during the transition period between warm season and cool season species, thereby extending the grazing season (Lemus et al., 2014). Of the *Brassica* species, the use of canola (*Brassica napus* L.) and forage-type turnips (*Brassica rapa* L., and hybrids with it) appears to offer the most promise as economical forage crops in the southeastern USA, because the former can be used as a dual-purpose crop that provides limited grazing and an oilseed crop and the latter's ability to produce grazeable quantities within 60 to 75 days after planting (DAP).

Canola crops are most often grown around the world for oil for human consumption and the byproducts are used as protein supplementation in dairy and beef industries (Begna et al., 2017). One additional and often overlooked aspect of canola is the ability to produce significantly high forage yields that are high quality (Kalmbacher et al., 1982; Harper and Compton, 1980; Rao and Horn 1986; Westwood et al., 2012). Research has been done in Australia and the United States Southern Great Plains on evaluating the ability of canola to be used as a dual purpose crop (forage and seed for eventual oil and canola meal production) with results indicating that canola forage and seed yields were most often comparable to other dual purpose crops (Kirkegard et al., 2012; and Begna et al., 2017). Though some preliminary research conducted in the southeastern United States indicates that there could be a place for canola as a dual purpose crop (Ingram, 2014), there is no research on the effect of common agronomic management practices such as planting date and land preparation method on the forage yield of canola, especially when subject to the Georgia climate.

Forage type brassicas such as turnips and turnip hybrids also have the potential to be a profitable forage source in niche situations. Forage brassicas have the ability to rapidly establish and produce around 4000 kg ha^{-1} of high quality forage in late fall and early winter (Lemus et al., 2014). Forage production at this time of year can be useful and can effectively reduce the number of days in which conserved forage feeding is required (Stewart et al., 2013). Brassicas are commonly used in other countries with great success, and research in the United States has indicated potential for forage type turnip and turnip hybrids to be used in a livestock enterprise. However, there is insufficient information on how basic agronomic management practices affect the yield and quality of forage brassicas in the Southeastern USA.

The objective of this study was to develop best management practices for rapidly establishing brassica for grazing by evaluate the effects of land preparation practices and planting date on the herbage yield and quality of canola and forage turnips.

Methods and Materials

To examine the effects of land preparation practices and planting date on the herbage yield and quality of these two species, two experiments comparing the same treatments were conducted on canola (cv. 'Inspiration') and a hybrid, forage-type turnip (cv. 'T-Raptor', a hybrid of forage turnip [*B. rapa* subsp. Rapa and *B. rapa* L.), respectively.

Experiment 1

Experiment 1 was conducted in one year (the 2014 – 2015 growing season) at two separate sites using canola. One site was located at the University of Georgia's Northwest Georgia Research and Education Center near Calhoun, GA (34° 20' N; -85° 07' W; Calhoun) on an Etowah loam soil (fine-loamy, siliceous, semiactive, thermic Typic Paleudults) with two to six percent slope. The site had previously been a stand of tall fescue [*Lolium arundinaceum* (Schreb.) S.J. Darbyshire] for more than 5 years. The second site of this experiment was located at the J. Phil Campbell, Sr. Research and Education Center in Watkinsville, GA (33° 52' N; -83° 25' W; Watkinsville) on a moderately eroded Cecil sandy loam soil (fine, kaolinitic, thermic Typic Kanhapludults) with two to six percent slopes.

Based on soil test results and recommendations from the University of Georgia's Soil, Plant, and Water Laboratory, the Calhoun site was limed with dolomitic limestone at a rate of 1120 kg ha^{-1} three months prior to establishment and fertilized with 22 kg ha^{-1} of P_2O_5 at planting. Soil tests from the Watkinsville site indicated no soil pH adjustment was required, and it was fertilized with 168 kg ha^{-1} K_2O and 112 kg ha^{-1} P_2O_5 at planting based on the soil results and recommendations.

Experimental Design

This experiment was conducted as a randomized complete block design with four replications at each experiment site for one year. Treatments consisted of a factorial arrangement comparing land preparation practices of conventional tillage (CT), no-till after burning (NB), no-till after mowing (NM), and no-till with no residue removal (NR) planting methods across 1 September (S1), 15 September (S15), 1 October (O1), and 15 October (O15) planting dates for a total of 16 treatment combinations per replication at each location. Individual experimental units were 1.6 x 9.1-m plots, which had a 0.6-m buffer between plots and a 4.6-m alley between replications.

Two months prior to planting, all plot treatments within that planting date (CT, NB, NM and NR) were cut with a Gravely (Gravely© Brillion, Wisconsin) forage plot harvester to a residue height of 5 cm. One week prior to planting, glyphosate (Roundup Ultra®) was applied at a rate of 1248 g a.i. ha^{-1} to the NB, NM and NR treatments. A few days prior to planting, the CT plots were tilled to a depth of 15 cm with a roto-tiller and cultipacked to prepare the seedbed, the NB plots were physically burned, and the NM plots were mowed using the forage plot harvester to a residue stubble height of 5 cm. The NR plots had no residue removal except for that which occurred two months prior to planting.

Plots were planted at a rate of 4.48 kg ha^{-1} and adjusted for 98% germination rate for a total of 11.5 g $plot^{-1}$ on 19.1-cm row spacing and planted at a depth of 0.6 cm using a Great Plains no-till drill (3P605NT; Great Plains Manufacturing Inc; Salina, Kansas) fitted with a Kincaid cone planter attachment (Kincaid; Haven, Kansas). A mixture of clomazone (Command 3ME®) at a rate of 91.9 g a.i. ha^{-1} and metolachlor (Dual Magnum®) at a rate of 234 g a.i. ha^{-1} was applied as a pre-emergent herbicide to the plots one week after planting. In accordance with

University of Georgia's Soil, Plant, and Water Laboratory recommendations, all plots were fertilized at a rate of 56 kg N ha^{-1} 14 DAP and again on 15 March.

The insecticide zeta-cypermethrin (Mustang Maxx®) was applied at a rate of 27.8 g a.i. ha^{-1} to the Watkinsville location on 24 September and both the Calhoun and Watkinsville location received a fungicide application of prothioconazole (Proline 480 SC®) at a rate of 1596 g ha^{-1} on 12 March and 11 March, respectively, to prophylactically control disease.

Data Collection

Seedling emergence was evaluated on each of the plots 14 DAP. Data were collected by randomly placing a 1.8-m long stick with 20 evenly-spaced pegs along a planted row and counting the percentage of pegs that intersected with a canola plant. If a seedling was between pegs it was not counted. A total of three seedling count observations were obtained per plot.

At 45 and 90 DAP, the growth stage of the canola was assessed using the Harper and Berkenkamp (1974) method, and one end of the plots for each replication was randomly designated for biomass yield assessments. These assessments consisted of two sampling methods upon random points within the half of the plots designated for biomass harvest. The remaining half of the plot remained unharvested until seed was harvested. First, a rising plate meter (RPM) measurement was taken from the point and then the foliage within a 0.9-m^2 quadrat was clipped to the soil surface. Each quadrat area that was sampled was then flagged to prevent overlapping of sampling areas. No sampling points were within 0.5 m of a previously sampled point. Samples were placed in a forced-air drying oven at 60°C for several days until the final weight did not change. The dry weight was then used to calculate forage yield in kg DM ha^{-1}. The nutritive value of the forage produced by the canola in Experiment 1 was not determined.

Experiment 2

Experiment 2 was located at the J. Phil Campbell, Sr. Research and Education Center in Watkinsville, GA (33° 52' N; -83° 25' W; Watkinsville) on a moderately eroded Cecil sandy loam soil (fine, kaolinitic, thermic Typic Kanhapludults) with two to six percent slopes. Based on soil test results and recommendations from the University of Georgia's Soil, Plant, and Water Laboratory, no lime or fertilizer was applied prior to the start of the experiment.

Experimental Design

This experiment was conducted on the forage-type hybrid turnip as a randomized complete block design with four replications for a duration of two years. Treatments consisted of the same factorial arrangement of land preparation practices and planting dates as described for Experiment 1. Individual experimental units were 1.8 x 6.0-m plots, which had a 0.6-m buffer between plots and a 6.0-m alley between replications. In 2017-18, plots were shifted to a site adjacent to the 2016-17 plot area to prevent any confounding residual effects. In both years, the site had been planted to pearl millet [*Pennisetum glaucum* (L.) R. Br.] the preceding April and had a substantial amount of volunteer crabgrass [*Digitaria ciliaris* (Retz). Koel.].

Treatments

Approximately one month prior to 1 September (S1), the plot area was cut and removed for baled silage leaving a residue height of 5 cm. Just prior to S1, the height of the regrowth following the removal of forage for baleage was noted as 30 cm and this height of residue was reproduced for each planting date by clipping the pearl millet and crabgrass using a forage plot harvester and the clipped mass was removed from the plots. The NR plots had no further residue removal beyond this clipping to a 30-cm height. Approximately one week prior to planting in 2016-17, the NB plots were sprayed with glyphosate (Helosate Plus Advanced) at a rate of 1123 g a.i. ha^{-1}. In contrast, all plots were sprayed with glyphosate at the aforementioned rate and formulation approximately week prior to planting in 2017-18. A few days prior to planting in both years, the CT plots were tilled to a depth of 15 cm with a roto-tiller and cultipacked to prepare the seedbed, the NB plots were physically burned, and the NM plots were mowed using the forage plot harvester to a residue stubble height of 5 cm.

Each of the plots were planted at a rate of 4.48 kg pure live seed ha^{-1} (90% PLS adjusted rate of 4.98 kg ha^{-1}) on 19.1-cm row spacing and planted at a depth of 0.6 cm using a Great Plains no-till drill (3P605NT; Great Plains Manufacturing Inc; Salina, Kansas) fitted with a Kincaid cone planter attachment (Kincaid; Haven, Kansas) in 2016-17. In 2017-18, the plots were planted with a Hege Model 80 research plot cone planter (Hege Equipment, Colwich, KS).

In 2016-17, all plots were fertilized one month after planting with 56 kg N ha^{-1}; however, were fertilized one week after planting in 2017-18 plots at the same rate of N. In both years, all plots were fertilized with an additional 56 kg N ha^{-1} following a complete harvest of biomass from the plots 100 DAP.

In 2016-17, the plot area was irrigated using nearby pond water with a solid-set irrigation gun to supply a minimum of 17 mm $week^{-1}$ in which naturally occurring rainfall did not exceed this amount. No irrigation occurred in 2017-18, as a result of adequate or excessive soil moisture around the planting dates.

Data Collection

Seedling emergence was evaluated at 14 DAP as described for Experiment 1. At 30, 45, 60, and 90 DAP, the growth stage of the turnips was assessed using the Harper and Berkenkamp (1974) method, and biomass yield assessments were conducted using the RPM and clipping method described for Experiment 1. After drying, samples taken at 60 and 90 DAP were ground to pass a 2-mm sieve through a Wiley® Mill (Thomas Scientific, Swedesboro, NJ) and then through a 1-mm screen, in a Cyclotec 1093 Sample Mill (Foss, Hillerod, Denmark). Subsamples were then submitted to the University of Georgia's Feed and Environmental Water Lab for determination of crude protein (CP), lignin, total digestible nutrients (TDN), and digestible Neutral Detergent Fiber at 30 hours (dNDF30) by near infrared reflectance spectroscopy using a model FOSS 6500 (FOSS NIRS system Inc., Laurel, Maryland) spectrophotometer. Subsamples were also analyzed for nitrate (NO_3-N) concentration using the nitration of salicylic acid method described by Cataldo et al., 1975. The absorbance of the chromophore produced from the nitration of salicylic acid is directly proportional to the amount of NO_3-N present in the samples, thus by measuring the absorbance with a Shimadzu UV-2450 spectrophotometer the concentration of NO_3-N present in the samples was determined.

At 100 DAP, plots were visually assessed for weed encroachment and an additional harvest was obtained. This was done by cutting a known area from the unsampled half of the plot with the aforementioned plot harvester to a residue height of 5 cm and weighing the cut material. A subsample of the contents was then obtained, a wet weight obtained, and then the subsamples were dried in a forced-air drying oven at 60°C for several days. A dry weight was then obtained and used for DM correction to calculate total DM yield of the harvested area. After the remaining area of the plots was harvested to a height of 5 cm, the biomass was removed and the plots were fertilized with an additional 56 kg N ha^{-1}. On 14 March of both years, all plots were harvested a final time using the same harvesting method that was used at 100 days after planting.

Statistical Analysis

Data were analyzed using a generalized linear mixed models procedure in JMP Pro Statistical Discovery™ from SAS version 13 (SAS Institute, Inc., 2016) with fixed effects of location (Exp. 1) or year (Exp. 2), planting date, and land preparation method and replication as a random effect. Effects were evaluated as full factorial interactions on all of the treatments. Mean separation was performed with an F-protected Least Squares Difference (LSD). Treatment effects and interactions were considered significant at $\alpha = 0.05$, unless otherwise noted.

For experiment 1, the statistical analysis was conducted on seedling count, dry matter yield at 45 and 90 DAP for all planting dates. For experiment 2, the statistical analysis was conducted on seedling count and dry matter yield at 30, 45, 60 and 90 DAP for all planting dates. Only the CT treatment in the S1 and O1 planting dates provided sufficient quantities of sample for all plots in those treatments across both years to enable a comparison of forage nutritive value. For that land preparation treatment and those planting dates, data analysis was conducted on crude protein (CP), total digestible nutrients (TDN), digestible neutral detergent fiber (dNDF), and lignin.

Results

Weather

Experiment 1

Mean maximum and minimum temperatures at both locations (Calhoun and Watkinsville) were at their peak at Week 1 of the study (1 September; Figure 3.1). Both the maximum temperature and minimum temperature decreased an average of 1°C per week at the Watkinsville location and decreased an average of 1.1°C per week at the Calhoun location for the duration of the 22 weeks. The Watkinsville location reached weekly average minimum temperatures below 0°C a total of three weeks whereas the Calhoun location reached weekly average minimum temperatures below 0°C a total of four weeks. Both locations had a total of 6 weeks in which no rainfall occurred however, the mean weekly sum of rainfall across the 22 weeks was 17 mm at the Watkinsville location and 24 mm at the Calhoun location.

Experiment 2

The mean maximum weekly temperature of Experiment 2 peaked in week 2 and 3 in 2016-17 and 2017-18, respectively (Figure 3.2). The mean minimum weekly temperature of Experiment 2 also peaked in week 2 in 2016-17, but did not peak until week 6 in 2017-18. In 2016-17, the mean maximum and minimum temperatures decreased by 0.9°C and 0.8°C per week, respectively, on average across the duration of the study, though it exhibited more drastic swings in temperature between weeks especially at the end of the study. In contrast, the 2017-18 had a more steady decline in temperatures. In 2017-18, mean maximum temperatures decreased on average 1.2°C per week and mean minimum temperatures decreased an average of 1.1°C per week across the duration of the study. In 2016-17, only one week had an average low temperature below 0°C, whereas the 2017-18 season had a total of 5 weeks in which the average low temperature was below 0°C, including three consecutive weeks in a row (Weeks 18 through 20).

The 2016-17 season was notably drought stricken, with 10 of the 22 weeks (including 7 consecutive weeks) receiving no rainfall (Figure 3.2). Irrigation was applied to the plots in 2016-17 to allow for consistent soil moisture during the study. An average of 19 mm of rainfall occurred across the 2017-18 year, which resulted in more consistent natural rainfall during the study. The remnants of Hurricanes Irma and Nate provided 83 mm and 75 mm of rainfall on week 2 and 6 in the 2017-18 season, respectively. No rainfall occurred in the 3 intervening weeks, but soil moisture remained high during that time. There were 3 other weeks in which no rainfall occurred, though soil moisture was never considered limiting and irrigation was not applied in the 2017-18 season.

Seedling Emergence

Experiment 1

Though seedling counts 14 DAP differed ($P < 0.002$) among the combinations of planting date, land preparation, and location, there was no discernable trend and the differences did not appear to be of biological importance (Appendix 3.1).

Experiment 2

Seedling counts 14 DAP were affected by land preparation treatment ($P < 0.001$) and a planting date effect that differed ($P < 0.001$) between the two seasons. Because of this, data are presented by seasons with respect to planting date (Fig. 3.3) and also by treatment across both of the seasons and the planting dates (Fig. 3.4).

In 2016-17, there was an observable increasing trend in seedling count as planting date was delayed (Fig 3.3). The S1 planting had the lowest seedling counts (2.8 seedlings m^{-1} of row) and the O15 had the highest (5.3 seedlings m^{-1} of row), while the S15 and O1 planting dates (4.0 and 3.9 seedlings m^{-1} of row, respectively) were intermediate and not different from the highest or lowest. In contrast, the S1 planting had the highest seedling count (4.4 seedlings m^{-1} of row) and S15 was the lowest (1.0 seedlings m^{-1} of row) in 2017-18, while the O1 and O15 planting dates (3.0 and 1.8 seedlings m^{-1} of row, respectively) had seedling counts that were intermediate and not different from the highest or lowest. With the exception of the S15 planting date, the 2017-18 trends for higher seedling counts with earlier planting dates are in agreement with the findings of Kalmbacher et al. (1982), Jung et al. (1983), and Rao and Horn (1986), wherein warmer temperatures allowed for faster establishment than cooler temperatures. The S15 outlier in 2017-18 is likely the result of heavy rainfall from the remnants of hurricane Irma followed by several weeks of drought (Fig. 3.2). The seeds likely germinated but the seedlings either were not able to emerge from the soil or did not survive the extended periods drought that followed.

A clearer trend was observed for the land preparation methods, as the treatments with the least residue consistently had the highest seedling counts (Fig. 3.4). The CT treatment had the highest seedling counts (5.1 seedlings m^{-1} of row) and was consistently greater than the NM and NR treatments, which were not different from each other (2.3 and 2.0 seedlings m^{-1} of row, respectively). The seedling counts of the NB treatment were intermediate (3.5 seedlings m^{-1} of row) and not different from the CT, NM, or NR treatments. This indicates that there was an inverse relationship between the amount of residue in which the brassica was planted into and seedling count 14 DAP. This is likely due to the very small seed size and inhibition of light reaching the soil surface as the amount of remaining residue increases.

Forage Yield

Experiment 1

Location, planting date, and land preparation method interacted ($P < 0.001$) to affect the forage yield of canola at 45 and 90 DAP. Yields were substantially higher in Calhoun than in Watkinsville, thereby muting the treatment differences at the latter. Therefore, the data are presented for each planting date and land preparation method at each location at 45 and 90 DAP (Table 3.1).

Significant treatment differences were only observed within the O15 planting date in Calhoun and the S1 planting date in Watkinsville for the 45 DAP yield assessments and the S1 and O15 planting dates in Calhoun and the S15 and O15 planting dates in Watkinsville for the 90 DAP yield assessments. When significant differences occurred, the CT or NB treatments always provided the highest forage yield, and the NR treatment provided the lowest forage yield with the exception of the O15 planting date at the Calhoun location. Otherwise, a discernable trend for the effect of planting method was not detected. This indicates that there may be several interacting factors that affect forage yield rather than just planting date and land preparation method and land preparation may have some impact but not a large impact on forage yield.

The S1 and S15 planting dates at the Calhoun location (2183 and 2152 kg DM ha^{-1} at 45 DAP, respectively and 5545 and 3451 kg DM ha^{-1} at 90 DAP, respectively) performed better than the O1 and O15 planting dates (491 and 18 kg DM ha^{-1} at 45 DAP, respectively and 1491 and 13 kg DM ha^{-1} at 90 DAP, respectively). This is consistent with the results of Kalmbacher et al. (1982) which showed that earlier planting dates and warmer weather have a positive impact on forage yield (Fig 3.1 and Table 3.1). However, planting dates at the Watkinsville location did not follow this trend. One possible reason for the lower forage yields for the S1 and S15 planting dates at the Watkinsville location is that location had a longer period of time in which no rainfall occurred during that time when compared to the Calhoun location. Clearly, a lack of soil moisture can have a larger impact on forage yield than temperatures.

The ability of the canola in experiment 1 to be used as a dual-purpose crop was evaluated across treatments by obtaining seed yield for oilseed production. No statistical significances were evaluated at the Watkinsville location and there were no discernable trends in seed yield at the Calhoun location (Appendix 3.2).

Experiment 2

An interaction of year and planting date was observed at 30 DAP ($P < 0.001$) and three-way interactions of year, planting date, and land preparation method were observed at 45 ($P = 0.040$), 60 ($P = 0.003$) and 90 DAP ($P < 0.001$). Therefore, data are presented for each year, planting date, and land preparation method (Table 3.2).

Similar to the results in experiment 1, CT treatment provided ($P < 0.05$) or tended ($P < 0.10$) to provide the highest forage yield at 30, 45, 60, and 90 DAP for all planting dates in both years whenever significant differences were observed. The CT and NB treatments had yields that were not different from each other, except for the O15 planting date in 2017-18 where CT was higher than the NB treatment at 30, 45, and 60 DAP. Moreover, the NR treatments provided ($P < 0.05$) or tended ($P < 0.10$) to provide the lowest forage yield at 30, 45, 60, and 90 DAP for each planting date and year whenever significant differences occurred, and the NR treatments were not superior to the NM treatments.

The S1 and S15 planting dates in the 2016-17 season (e.g., 4669 and 4937 kg DM ha^{-1} at 90 DAP, respectively) performed better than the O1 and O15 planting dates (1431 and 1610 kg DM ha^{-1} at 90 DAP, respectively). Similar results may have occurred in the 2017-18 season, had it not been for heavy rainfall from the remnants of a hurricane immediately following the S15 planting date. These results are consistent with those of Kalmbacher et al. (1982) where October sown brassica produced higher forage yields (4040 kg DM ha^{-1}) when exposed to warmer growing conditions than the November and January planting dates (2820 and 1550 kg DM ha^{-1} respectively) and the autumn-grown brassica yields (2839 to 4046 kg DM ha^{-1}) reported by Guillard et al. (1988).

Forage Quality of Forage Turnip (Exp. 2)

In Experiment 1, assessments of canola forage quality were not conducted because of insufficient funding. In Experiment 2, only the CT treatment in the S1 and O1 planting dates provided sufficient quantities of sample for a complete set of plots and treatments across both years to enable a comparison of forage nutritive value.

Crude Protein

Crude Protein (CP) concentrations differed by year (P = 0.017) and planting date (P = 0.048), but those factors did not interact at 60 DAP. The CP concentration of forage at 90 DAP was affected by a year by planting date interaction was observed.

Mean CP concentrations were higher in 2016-17 than in 2017-18 at 60 DAP (254 and 225 g kg^{-1}, respectively) when pooled across both planting dates. When pooled across years, mean CP concentrations were observed to be higher in forage from the S1 than the O1 planting dates at 60DAP (228 and 253 g kg^{-1}, respectively). At 90 DAP, there was no difference between CP concentrations of the S1 and O1 planting dates in 2016-17 (173 and 207 g kg^{-1}, respectively), while the S1 planting date had lower CP concentrations than the O1 planting date (151 and 227 g kg^{-1}, respectively) in 2017-18. These results are similar to that observed by Kalmbacher et al.

(1982) in which they also observed an increase in CP concentrations as planting date was delayed.

Weidenhoeft et al. (1994) observed CP concentrations slightly lower (198 g kg^{-1}) than those observed in the current study, though they also observed a similar trend in that the earlier planting dates tended to have lower CP concentrations than the later planting dates. Both Jung et al. (1993) and Kalmbacher et al. (1982) observed an inverse relationship between forage yield and CP concentrations. This inverse relationship was also observed in our experiment in that the later planting date (O1) had higher CP concentrations yet lower forage yields than the S1 planting date that had higher forage yield but lower CP concentrations. Crude protein concentrations also decreased between 60 and 90 DAP, which is presumably the result of increasing plant maturity.

The CP levels reported here are comparable to those observed by Westwood et al. (2012) for forage type turnips (226 g kg^{-1}). Observed CP concentrations in the current study and those reported by Westwood et al. (2012) are comparable to bud stage alfalfa (220 to 260 g kg^{-1} CP). These concentrations are more than sufficient to support a lactating beef cow (110 to 130 g kg^{-1} CP concentrations; NRC 2016), though the proportion of this protein that is rumen-degradable, rumen-undegradable, and indigestible will require further research.

Total Digestible Nutrients

There were no differences in TDN concentrations across year or planting date at 60 DAP, though the S1 planting date had lower ($P < 0.004$) TDN values than the O1 planting date (740 and 786 g kg^{-1} respectively) at 90DAP. The TDN values observed in the current study are higher than bud stage alfalfa (640 to 670 g TDN kg^{-1}) or an early flower red clover (640 to 670 g TDN kg^{-1}) and high enough to easily meet requirements for a growing beef steer and a lactating beef cow (680 and 600 g kg^{-1}, respectively; NRC 2016).

Digestible Neutral Detergent Fiber (30 hours)

The effect of planting date on differed by year at both 60 and 90 DAP ($P < 0.008$ and $P < 0.004$ respectively). In 2016-17, there was no difference between planting dates in dNDF30 values (114 and 122 g dNDF30 kg^{-1}, respectively) at 60 DAP. In contrast, the dNDF30 values year were higher in the S1 planting date than the O1 planting date (152 and 123 g kg^{-1} respectively) at 60 DAP in 2017-18. At 90 DAP, the S1 planting date had higher dNDF30 values than the O1 planting date in both years (156 vs. 136 g kg^{-1} for S1 and O1, respectively in 2016-17 and 187 vs 125 g kg^{-1} for S1 and O1, respectively in 2017-18).

Lignin

No statistical significance in Lignin concentrations was observed across year or planting date at 60 DAP, though there was a planting date effect ($P = 0.003$) at 90 DAP where the S1 planting date had higher lignin concentration than the O1 planting date (710 and 540 g kg^{-1} respectively) however, the overall low lignin concentrations across both planting dates at 90 DAP would not be of biological significance because the lignin concentration would not be high enough to be detrimental to the forage quality and overall rumen function.

Conclusion

Overall, it appears that planting date and land preparation methods do have an impact on forage yield and quality of forage brassica. Results obtained from experiments 1 and 2 indicate that earlier planting dates (S1 and S15) result in higher overall forage yields when compared to later planting dates (O1 and O15). These results are comparable to various other studies conducted by Kalmbacher et al. (1982) and Guilliard et al. (1988).

It also appears that delayed planting has some impact on forage quality as well. When comparing S1 to O1 planting dates, CP concentration and TDN values increased whereas dNDF30 and lignin values tended to decrease. Overall, CP and TDN values of brassica are more than sufficient to sustain livestock with high maintenance requirements such as lactating beef cattle (Ball et al., 2007; NRC 2016). The effect of planting date on seedling emergence is still unclear. In 2016-17, it appeared that seedling emergence increased as planting date was delayed however, contradicting information was obtained in the 2017-18 year however, previous research indicates that warmer temperatures increase seedling emergence and vigor (Rao and Horn 1986; and Jung et al., 1983). Of the results obtained it does not appear that seedling emergence is a direct reflection of forage yield.

Land preparation method also has a significant effect on forage yield and seedling emergence. In both experiments 1 and 2, in instances where significant differences were observed, either the CT or NB plots were almost always significantly highest in forage yield whereas NM and NR plots were almost always lowest in overall forage yield. This indicates that planting into as little residue as possible (CT and NB) will provide the highest forage yields. Land preparation method also had a significant effect on seedling emergence in Experiment 2 with results indicating that as the amount of residue in which the brassica was planted into increases, the seedling emergence decreases.

In conclusion, Planting brassica as early as possible (S1 and S15) into as little residue as possible (CT and NB) will produce the highest forage yields. Forage quality is slightly less in earlier planted brassica however, the quality is still high enough to sustain animals with high maintenance requirements.

Tables and Figures

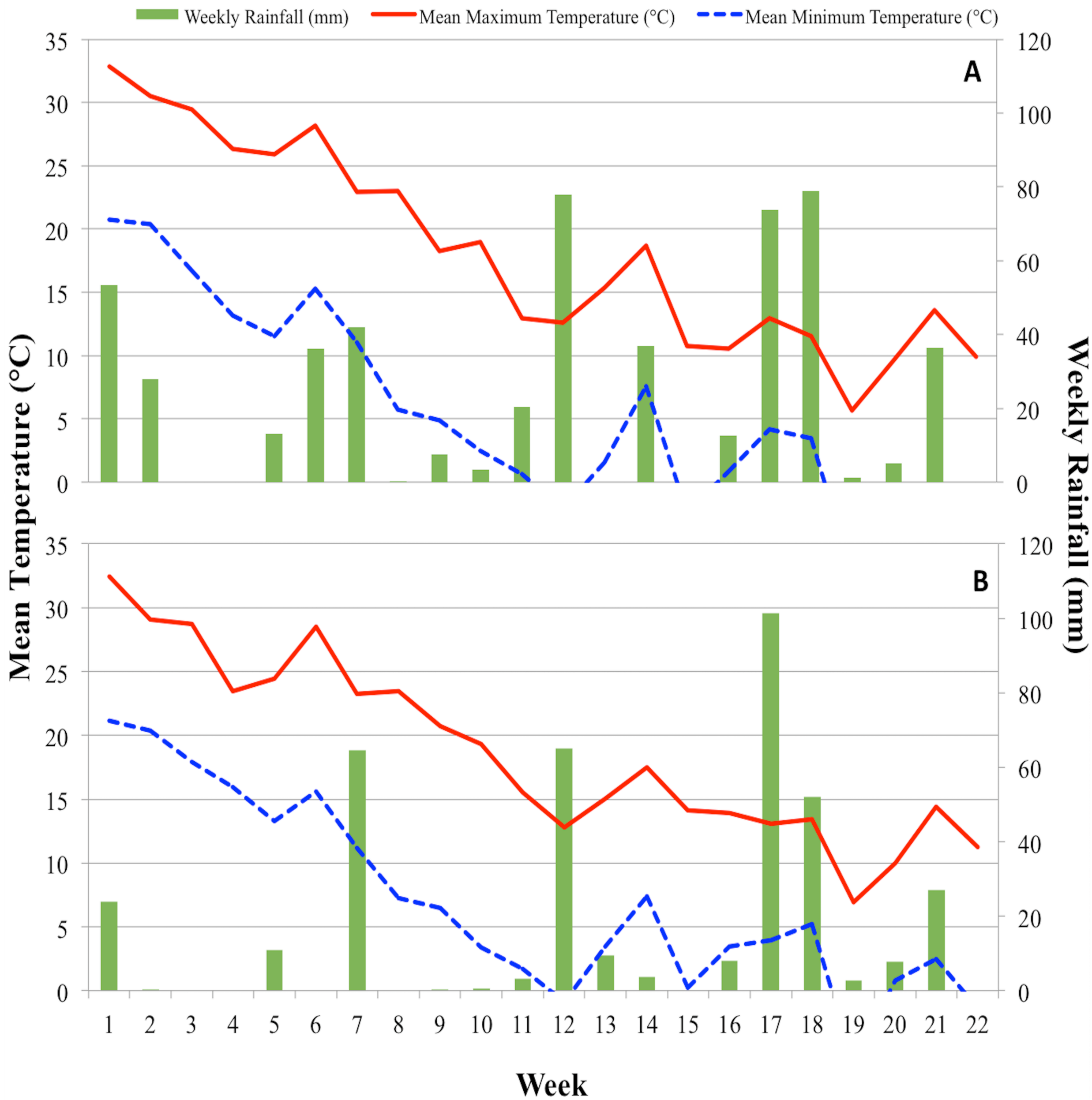

Figure 3.1: Mean maximum (solid red line) and minimum (dashed blue line) temperature at the Calhoun (A) and Watkinsville (B) location during Experiment 1. Week 1 corresponds to the week of the 1 September 2014 planting date and week 22 corresponds to 31 January 2015.

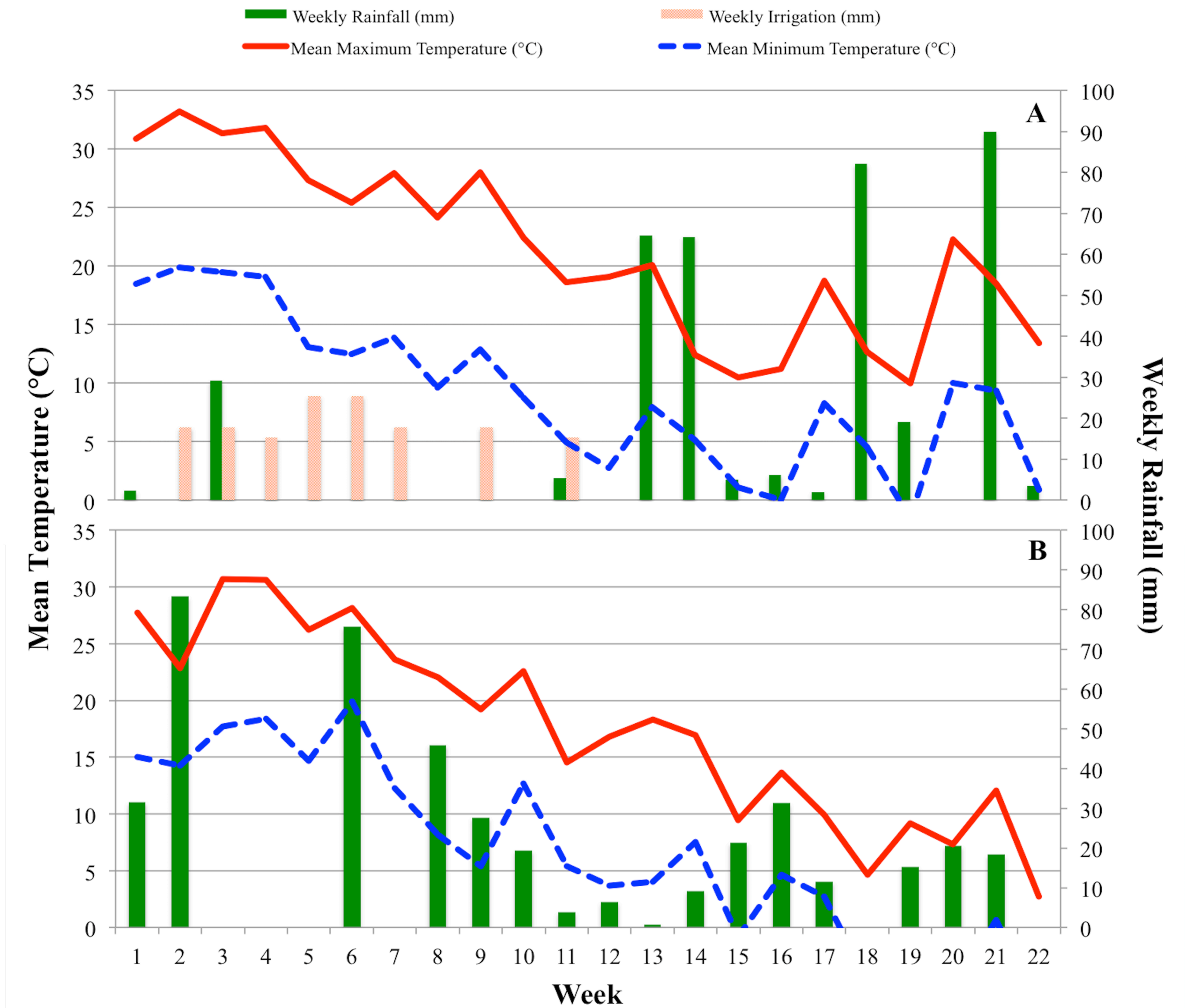

Figure 3.2: Mean maximum (solid red line) and minimum (dashed blue line) temperature for the 2016-17 (A) and 2017-18 (B) growing seasons of Experiment 2. Week 1 corresponds to the week of the 1 September planting date and week 22 corresponds to the end January in each year.

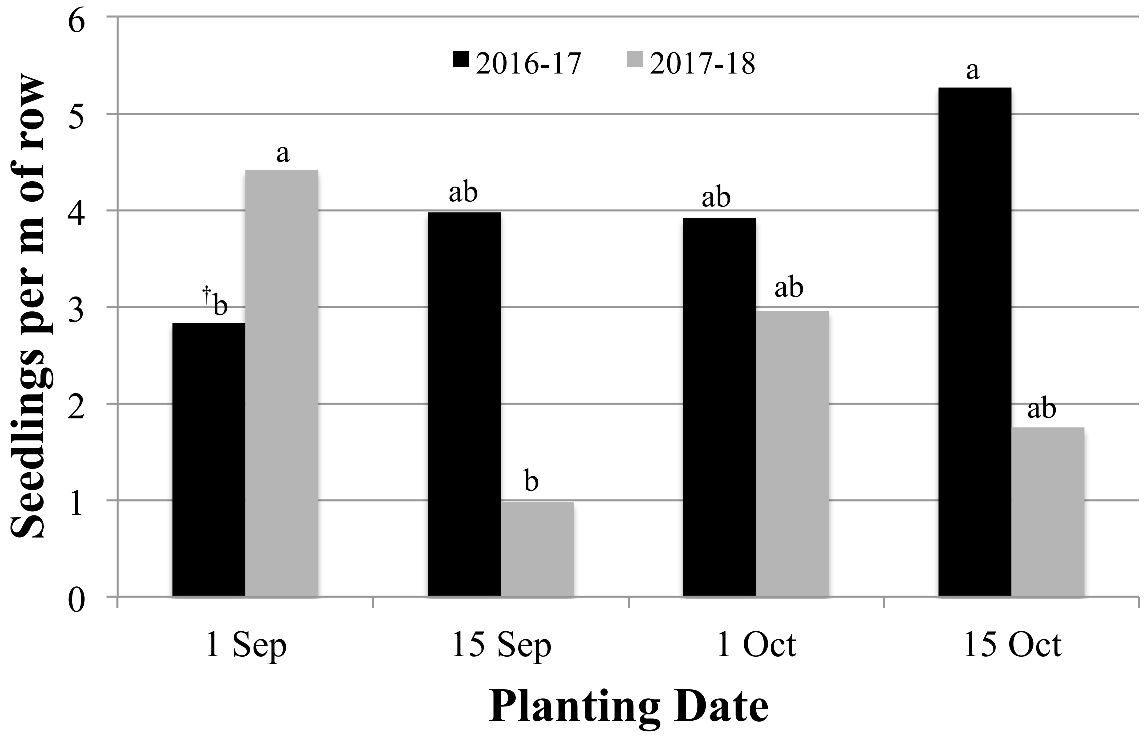

Figure 3.3: Seedling counts 14 days after planting for the 1 September (S1), 15 September (S15), 1 October (O1), and 15 October (O15) planting dates in the 2016-17 (black columns) and 2017-18 (gray columns) growing seasons of Experiment 2.

† Means within the same year sharing the same letters are not different (P < 0.05).

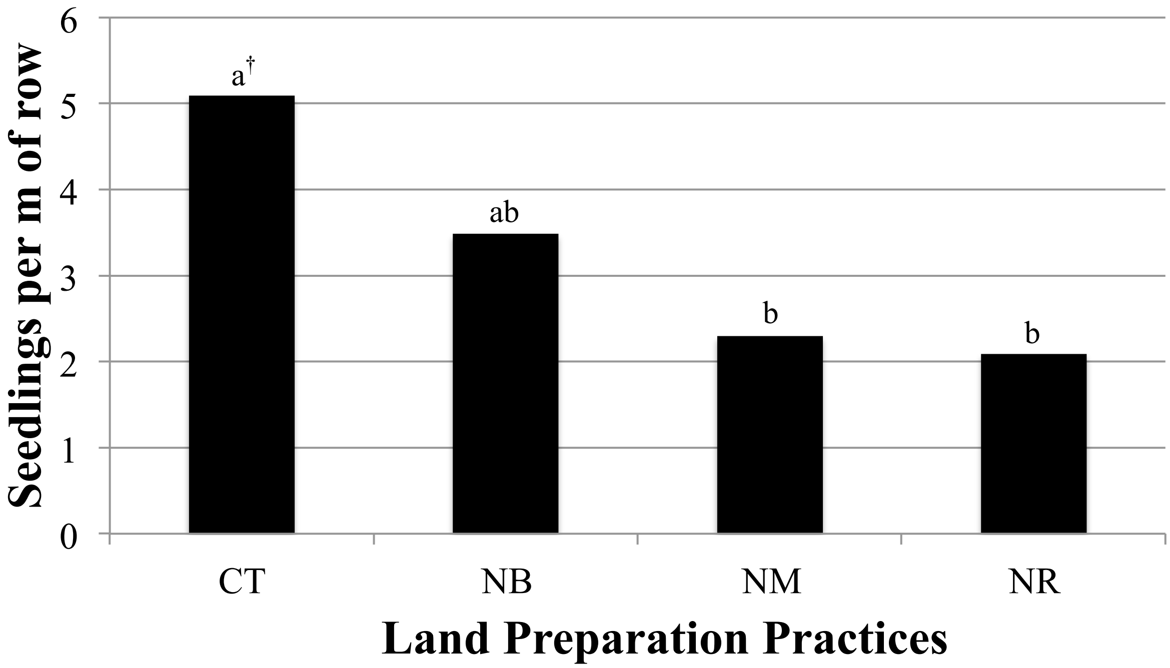

Figure 3.4: Seedling counts 14 days after planting for the land preparation practices of conventional tillage (CT), no-till after burning (NB), no-till after mowing (NM), and no-till with no residue removal (NR) averaged across the growing seasons of Experiment 2.

† Means sharing the same letters are not different ($P < 0.05$).

Table 3.1: The effect of conventional till (CT), no – till burn (NB), no – till mow (NM), and no till with residue (NR) land preparation methods at four planting dates: 1 September, 15 September, 1 October, and 15 October at the Calhoun, GA and Watkinsville, GA locations in Experiment 1.

			Forage Yield	
Location	Planting Date	Treatment	45 DAP	90 DAP
			kg DM ha⁻¹	
Calhoun	1 Sep	CT	2183a	5545a
		NB	1232b	2893b
		NM	-	-
		NR	1473ab	3634ab
		$LSD_{0.05}$	753	2599
	15 Sep	CT	2152	3451
		NB	1361	2531
		NM	1625	3215
		NR	1313	3107
		$LSD_{0.05}$	998	1552
	1 Oct	CT	491	1491
		NB	755	1777
		NM	393	857
		NR	335	638
		$LSD_{0.05}$	509	1181
	15 Oct	CT	18b	13b

		NB	54a	228a
		NM	49a	36b
		NR	13b	9b
		LSD 0.05	25	132
Watkinsville	1 Sept	CT	31ab	232
		NB	45a	170
		NM	22b	138
		NR	13b	165
		LSD 0.05	25	227
	15 Sept	CT	49	755a
		NB	49	188b
		NM	36	71b
		NR	36	45b
		LSD 0.05	19	428
	1 Oct	CT	89	799
		NB	40	210
		NM	49	183
		NR	45	263
		LSD 0.05	59	699
	15 Oct	CT	54	397ab
		NB	54	496a
		NM	67	214abc
		NR	63	40c

LSD $_{0.05}$	39	310

† Means within a planting date and land preparation method combination sharing the same letters are not different ($P < 0.05$).

‡ Mistake at planting resulted in this treatment combination not being established.

Table 3.2: The effect of conventional till (CT), no – till burn (NB), no – till mow (NM), and no till with residue (NR) land preparation methods at four planting dates: 1 September, 15 September, 1 October, and 15 October in the 2016 – 2017 and 2017 – 2018 growing season in Experiment 2.

			Forage Yield			
Year	Planting Date	Treatment	30 DAP	45 DAP	60 DAP	90 DAP
			kg DM ha^{-1}			
2016 - 17	1 Sept	CT	116a†	1360a	2173a	4669a
		NB	80ab	903ab	1163ab	2147ab
		NM	36b	80bc	116b	116b
		NR	18b	18c	27b	27b
		$LSD_{0.05}$	62	873	1371	2851
	15 Sept	CT	483a	1091a	1771ab	2254ab
		NB	358ab	1154a	2889a	4937a
		NM	63bc	89b	161bc	868b
		NR	27c	36b	18c	18b
	$LSD_{0.05}$		298	746	1667	3297
	1 Oct	CT	98	599a	1324a	1431a
		NB	98	510ab	1351a	1324a
		NM	89	179bc	662ab	1261a
		NR	72	63c	116b	161b
	$LSD_{0.05}$		27	379	952	1075

	15 Oct	CT	134	519a	859a	1610a
		NB	89	358ab	555ab	1324ab
		NM	80	107bc	116b	80b
		NR	89	54c	72b	9b
	LSD 0.05		48	292	542	1379
2017 - 18	1 Sept	CT	533	1297a	3381a	4481a
		NB	883	742ab	1968ab	2379a
		NM	31	546b	751b	3068a
		NR	54	805ab	1816ab	2862a
	LSD $_{0.05}$		861	698	1714	2807
	15 Sept	CT	73	438	689	778
		NB	1	1	0	0
		NM	37	153	64	946
		NR	2	57	1	437
	LSD $_{0.05}$		90	530	823	1222
	1 Oct	CT	35ab	229ab	700a	1714a
		NB	68a	298a	433ab	814ab
		NM	11ab	23b	119b	254b
		NR	4b	25ab	177b	288b
	LSD $_{0.05}$		61	212	463	1125
	15 Oct	CT	34a	196a	378a	270a
		NB	8b	31b	126b	150ab
		NM	5b	26b	103b	128ab

NR	0b	14b	25b	0b
LSD $_{0.05}$	22	111	246	244

† Means within a planting date and land preparation method combination sharing the same letters are not different ($P < 0.05$).

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Appendix

Appendix 3.1: Seedling count 14 days after planting for canola for each combination of location, land preparation method, and planting dates compared in Experiment 1.

Location	Land Preparation Treatment		Planting Date 1 Sep	15 Sep	1 Oct	15 Oct
Calhoun			*Seedlings per m row*			
	CT		10.0 a[†]	7.6	7.3 ab	6 ab
	NB		6.6 b	8.3	9.9 a	7.3 a
	NM		-[‡]	7.3	6.3 b	6.5 ab
	NR		6.4 b	5.8	7.7 ab	4.9 b
		$LSD_{0.05}$	2.73	2.81	3.42	2.23
Watkinsville						
	CT		9.3	6.0 ab	7.1 a	7.0
	NB		10.9	6.2 a	3.8 b	7.4
	NM		11.6	4.4 ab	5.7 ab	6.7
	NR		11.4	3.3 b	7.9 a	8.4
		$LSD_{0.05}$	3.80	2.72	2.87	2.11

[†] Means within a planting date and land preparation method combination sharing the same letters are not different ($P < 0.05$).

[‡] Mistake at planting resulted in this treatment combination not being established.

Appendix 3.2: The effects of planting date and conventional tillage (CT), no-till after mowing (NM), no-till after burning (NB), and no-till into sod residue (NR) establishment on seed yield (kg ha^{-1}) in Calhoun and Watkinsville, GA for Experiment 1.

Location	Land Preparation Treatment	Planting Date 1-Sep	15-Sep	1-Oct	15-Oct
Calhoun		---------------------- kg ha-1 ----------------------			
	CT	1758ab†	1934a	858c	1401b
	NB	1479a	1926b	1453a	1569ab
	NM	-‡	2024a	1144b	574c
	NR	976a	1833b	1268a	52c
	LSD0.05	461.8	461.8	461.8	461.8
Watkinsville					
	CT	306	416	286	549
	NB	140	189	250	484
	NM	94	151	118	538
	NR	95	147	94	193
	LSD0.05	461.8	461.8	461.8	461.8

† Data with different lettered superscripts within a column are significantly different at the $P < 0.05$ level.

‡ Mistake at planting resulted in this treatment combination not being established.

CHAPTER 4

SUMMARY AND CONCLUSION

Reducing input costs is imperative in any livestock operation, especially since there is often a fine line between having an efficient and profitable operation and not being able to break even. One way that livestock producers can reduce their input costs is to reduce the number of days in which hay and concentrate supplementation is needed. Georgia and the rest of the southeastern United States have a distinct advantage in that the warm summers and mild winters allow for a nearly year-round grazing. Even with the usage of warm season and cool season forages, there is still a gap in the year (October – December) when the transition between forages causes a deficit of quality forage available for grazing. The unique characteristics of forage brassica have the ability to help fill that forage gap and extend the grazing season even longer.

Forage brassica have been used successfully in New Zealand and have shown some promise in the United States however, there is a clear lack of information on how the effects of planting date along with land preparation methods affect forage yield and quality of forage brassica, especially in Georgia. It is predicted that the ability of forage brassica to grow rapidly during the transition period between warm season and cool season forages will give it a competitive advantage to residue it is planted into and still produce significant forage yields.

This study was conducted as two separate experiments: Both experiments evaluated the effect of planting date (S1, S15, O1 and O15) and land preparation method (CT, NB, NM and NR) on the seedling emergence and forage yield of forage *Brassica* and experiment 2 evaluated the forage quality as well.

Of the results obtained, it appears that both planting date and land preparation method have an impact on forage yield and quality of brassica. Both experiments 1 and 2 indicated that the earlier planting dates (S1 and S15) result in higher overall forage yields than the later planting dates (O1 and O15). These results are comparable to various other studies in which the effect of planting date on forage yield was evaluated. As for land preparation method, it appears that the amount of residue in which brassica was planted into does in fact have an effect on forage yield. In both experiments 1 and 2, in instances where significant differences were observed, either the CT or NB treatments had significantly higher forage yields (with the exception of very few instances) than the NM or NR treatments. This disproves the initial hypothesis and is likely due to the amount of soil contact and light intensity that was able to reach the very small brassica seeds in the thicker residue.

Results from experiment 2 indicate that there is a slight impact on forage quality as planting date is delayed. Both the CP and TDN values increased as planting date was delayed whereas dNDF30 and lignin values tended to decrease as planting date was delayed. Overall, CP and TDN values of brassica are more than sufficient to sustain livestock with high maintenance requirements such as a lactating beef cow or growing stocker calf.

In conclusion, planting brassica as early as possible (S1 and S15) into as little residue as possible will produce the highest forage yields at 60 and 90 DAP which is right around November and December when there is a forage deficit due to the transition period of warm season and cool season forages. Significant forage yields during this time will help extend the grazing season and provide a high quality additional forage source and ultimately reduce the need for expensive supplementation measures such as hay and concentrates.

Additional research on the ability of forage brassica to be planted in mixed stands with other cool season forages would provide great benefit to evaluate length of grazing season and animal performance with the addition of brassica.