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Analysis of the Effects of Four Forage Mixtures Designed for Tennessee and Kentucky Organic Dairy Systems

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DEDICATION

I dedicate my work to my family and friends.

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ABSTRACT

Quantity and quality of pastures are significantly impacted by irregular weather patterns in the Southeastern US. Predominate forage types observed in Kentucky and Tennessee are cool season (CS) species which grow best in atmospheric temperatures ranging from 8-24°C. However, in this area, temperatures can reach above 32°C during the summer months. With average temperatures higher than required for CS species, growth and quality decline during the summer. Therefore, an increase in summer forage performance would benefit pasture-based organic dairies to help sustain milk production. Warm season (WS) forages flourish in atmospheric temperatures from 25 to 35°C, which reflect summer temperatures observed in the Southeast. This led to our first hypothesis that incorporation of WS forages would increase forage yield and quality in summer. To test this, four forage mixtures were designed with one mixture containing only CS species, while the remaining three contained CS and WS species: Mixtures contained a combination CS legumes and grasses, WS legumes and grasses, and/or brassicas. Compared with the CS mixture, mixtures containing WS species did not increase yields of DM in summer. Yields of legume were significantly greater in the CS mixture, with this mixture also maintaining the highest quality. First-year results indicated that the inclusion of WS forages might not increase pasture quality and yield and CS forages may be best for pasture-based organic dairy farms in Tennessee and Kentucky.

The second hypothesis of this work was that the forage mixtures used to test the first hypothesis would affect predictions of milk production. Using observed forage yield and quality from the previous hypothesis, a whole-farm model (FARMAX, New Zealand) predicted milk production of pasture-based dairy farm systems. Inputted forage content of crude protein and energy was the highest for the CS mixture throughout the simulated grazing season and these

levels affected predictions of milk and milk component yields. Therefore, the CS mixture predicted the highest average milk and milk component yields. With results from conditions experienced in this study, incorporation of WS forages with CS forages did not help promote increased forage yield and quality, or average milk production during the summer season.

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INTRODUCTION

High pasture quality and quantity are essential in maximizing the amount of nutrients cattle can receive while grazing pasture. Nutrient intake is paramount for grazing based systems to ensure cattle production. For ruminant livestock producers who aim to take advantage of pasture as a primary feed resource, it is essential to produce high quality pastures, which remain consistent qualitatively and quantitatively throughout the entire grazing season. Organic dairy producers must graze their cattle for at least 120 days per year and 30% of their dry matter intake must come from consuming fresh pasture (USDA-AMS, 2015). A multitude of factors are considered when analyzing both the quality and quantity of pasture, including but not limited to the amount of fiber, protein levels, and total dry matter yields.

In organic agriculture, pasture quality and production can be impacted by a variety of factors, but forages are particularly impacted by the irregular weather patterns of Kentucky and Tennessee, especially during hot summer months. From late June to August, during increased ambient temperatures, the drop in forage production is referred to as the “summer slump”. During this time pastures are exposed to periods of drought and high temperatures that can have a significant impact on many perennial and annual cool season forages. This is augmented by the changes in soil temperature and moisture levels which affect plant nutrient uptake, therefore limiting plant growth (Collins et al., 1990 and Lobet et al., 2014). This is further amplified for organic producers who are limited in pasture management techniques they may use to maintain forage productivity. For example, organic producers must only utilize organic fertilizers and may not use herbicides or pesticides (USDA, AMS- 2015).

Warm season plants are well adapted to increased ambient temperatures and are more drought resistant than many cool season plants that dominate Kentucky and Tennessee (Salisbury and Ross, 1985). Therefore, to work against the forage slump, different species such as warm season C4 plants may be sowed into pastures to increase forage mass yield and quality during hot summer months and the grazing season of organic pasture-based dairy producers.

Literature Review

Quality and quantity are key factors in maximizing the amount of nutrients obtained from pasture (Muller, 1990). Nutritional quality and quantity can differ by area and location, environment, species of forage, and management (Rojas-Downing et al., 2017). Location and geographical area of pasture can greatly affect the quality and quantity of pasture performance. Factors such as length of growing season, temperature, and precipitation have great effects on nutritive quality of pastures. Length of growing season affects the forage availability for ruminants grazing, while soil moisture is key in nutrient absorption. Therefore decreased soil moisture can inhibit both growth and quality (Rojas-Downing et al., 2017; Lobet et al., 2014). Kentucky and Tennessee are prone to periods of draught throughout the year, especially in the summer season, which causes a significant decrease in soil moisture. For example in July 2015 in Hopkinsville, Kentucky where four of the five organic farms enrolled on this study are located, total precipitation in July was 0mm with maximum temperatures reaching 34°C (U.S. Climate Data; 2015-2018), proving draught a problem for producers in this area with grazing pastures.

Organic certified dairy cattle must graze at least 120 days out of the year and consume at least 30% of their dry matter intake on pasture (USDA – AMS, 2015). In order to meet this requirement, producers must graze through all three grazing seasons (spring, summer, and fall) where the quality and yield of pasture can be variable due to changes in weather and other environmental factors. In addition to changing weather, producers are limited in ways they can increase pasture yield and quality. Organic producers may not utilize herbicides, pesticides, and are limited in the types of fertilizers they may use. These restrictions challenge producers in ways to maintain quality soil and crops, especially maintenance of nitrogen (N) in the soil. There are different approaches used by organic producers to increase N, however, one effective way that can be utilized to increase N in the soil is by the addition of the legumes into pastures. Legumes help to maintain N levels in the soil by reducing N^2 to NH_3 through their symbiotic relationship with *Rhisobium* bacteria (Phillips, 1980) With limited resources and the significant effects of environmental variation, changes in pasture quality can have significant effects on dairy cow performance, health, and ergo producer profits. Therefore, it is useful to identify forage mixtures with consistent quality and sufficient yields throughout the entire grazing season.

Cool Season Forage in Kentucky and Tennessee

Cool season forages are known for naturally higher amounts of crude protein and lower amounts of indigestible fiber leading to their common use amongst producers. However, many common cool season forages, such as Tall Fescue, have an optimum growth rate between 10-20°C (Butler et al., 2017). In Kentucky and Tennessee, average monthly high temperatures during the grazing season (March-November) range from 16-31°C with variable weather patterns and inconsistent rainfall, especially during the summer season. Increased temperatures and dry patterns are observed during this time with temperatures reaching above 34°C (weatherunderground.com, 2018). Cool season species predominate in many pasture systems are known as Carbon 3 (C3) plants based upon the carbon molecules (two 3-carbon molecules) that are produced when CO_2 reacts with ribulose 1, 5-biphosphate (RuBP) in the first step of the Calvin Cycle.

Plants identified as C3 only utilize the C3 pathway, which is known as the Calvin Cycle or the dark reaction of photosynthesis. Photosynthesis in C3 plants uses the Calvin cycle to fix carbon dioxide and water into glucose and oxygen. This process takes place inside the chloroplast in the mesophyll cell in C3 plants (Wang et al., 2012) and is extremely efficient in creating energy for the plant in the correct conditions. Conditions for optimal growth of C3 plants include: atmospheric temperatures ranging from 18-24°C and soil temperatures greater than 4°C (Butler et al., 2017).

Increased temperatures affect C3 plants by increasing the need for photorespiration, an inefficient side reaction that wastes carbon and energy. Photorespiration is the process in which RuBP oxygenase-carboxylase (Rubisco) binds to oxygen instead of carbon dioxide during the carbon fixation step at the beginning of the Calvin cycle. This binding creates phosphoglycolate (3-PGA), which cannot enter the Calvin cycle at this step, thus removing two carbons from the cycle. In order to retake the lost carbons and proceed with the Calvin cycle, plants will then use the photorespiration pathway to recover approximately three-fourths of the lost carbon, which can then enter the Calvin cycle in the chloroplast at the appropriate stage. The net effect of photorespiration is a 3 fixed-carbon loss, while under normal Calvin cycle conditions, the plant gains 6-fixed carbons. Increased photorespiration is observed in warmer areas due to the lack of time the stomata can stay open to take up carbon dioxide into the plant. When the stomata are open, carbon dioxide and oxygen enter while water diffuses out. When water is not plentiful and temperature is high, the plant will conserve water by keeping the stomata closed and preventing water evaporation. When the stomata are closed, an increase of oxygen and decrease in carbon dioxide concentrations are observed, allowing more oxygen to bind rather than carbon dioxide to RuBP, carbon loss ensues, and plant growth is stunted (Kaiser and Bassham, 1979; Salisbury and Ross, 1985).

Incorporation of Warm Season Species

Warm season plants do not use photorespiration. They have higher optimum growth temperatures (25-35°C) and are more tolerant of dry soil conditions. This is due to the advanced anatomy of warm season species, in particularly the advancement of the chloroplast. Warm season plants, in addition to using the Calvin cycle, also utilize the Carbon 4 (C4) cycle, or the Hatch-Slack pathway. C4 plants have developed two types of photosynthetic cells, mesophyll and bundle sheath cells. These cells are arranged in a wreath like manner (Kranz wreath) with the bundle sheath cells surrounding the mesophyll cells. The cells are attached using plasmodesmata and cytoplasmic bridges. This arrangement keeps the light and dark reactions separate, allowing the release of oxygen, which takes place in the light reaction, to be separate from carbon fixation in the dark reaction, preventing oxygen from binding to Rubisco and photorespiration from occurring (Wang et al., 2012; Salisbury and Ross, 1985).

With C4 plants having adapted to limit photorespiration, it allows them to be more productive in warmer temperatures and when soil moisture is low. Conditions for optimal growth of C4 plants includes: atmospheric temperatures ranging from 25-35°C and soil temperatures greater than 16°C (Salisbury and Ross, 1985). With temperatures in Tennessee and Kentucky reaching 35°C or higher (U.S. Climate Data, 2015-2018) the addition of warm season forages into pastures may be beneficial to potentially increase both pasture yield and quality.

In general, C4 plants are not considered as high a quality grazing forage as C3 plants due to naturally lower levels of crude protein and higher levels of fiber, which is linked to their higher growth rates. However, when calculating the amount of nutrients per acre on a yield basis, nutrients such as crude protein, have the potential to be supplied in higher amounts with warm season forages during the summer months due to the high yields of the C4 plants and the low yields of the C3 plants. For example in a study conducted by Ruh et al. (2018), the warm season species of brown mid-rib (BMR) sorghum sudangrass and teff grass were incorporated into grazing systems and compared to forage quality and production of cool season pasture mixtures in the upper Mid-West. The cool season mixtures included a mixture of cool season perennial grasses and legumes such as orchard grass and alfalfa, and warm season mixture included cool season perennials with the incorporation of the warm season annuals BMR sorghum sudangrass and teff grass. Results from this study indicated forage quality was similar between the cool and warm season pasture systems. However, the cool season mixture had both higher levels of production and crude protein than the warm season mixture (Ruh et al., 2018).

Though incorporation of warm season species did not have a significant effect in the upper Mid-West, incorporation of warm season species has been observed to have positive effects in other areas, especially in climates warmer than Minnesota. In Minnesota, average summer temperatures reach only 26.8°C (U.S. Climate Data, 2015-2018). In a study conducted in Camden, Australia by Clark et al. (2018) looking at the use of warm and cool season grasses, the summer average maximum temperatures ranged from 22.2-32.9°C. In this study a type of turf grass, kikuyugrass (*Pennisetum clandestinum*) was used in the summer season and compared to the use of annual ryegrass (*Lolium multiflorum* L.) in the spring season which had average maximum temperatures ranging from 21.5-36°C. When calculating the yields of crude protein (CP) and organic matter (OM) as well as in vitro dry matter digestibility (IVDMD); kikuyugrass had a greater yield of CP compared to annual ryegrass. However, the annual ryegrass did yield less OM and IVDMD.

Effects of Pasture on Animal Production

Though research in other areas have shown a variety of results with the incorporation of warm season forage species, little research has been conducted in Kentucky and Tennessee, US on the incorporation of warm season species into pasture systems. In addition to this, little research has been conducted to analyze the effects of pasture quality and production of dairies in this area, in particularly organic dairy milk production. For ruminants out on pasture, nutrient requirements can be variable depending on environment and terrain, for instance variable activity requirements. Energy required for maintenance for dairy cows in confinement has a 10% allowance for activity (NRC, 2001). Cows out on pasture, however, have a much higher activity rate due to greater distance needed to travel from feed source (pasture) to the parlor, changing elevation on pasture, and more time spent eating (grazing). This is calculated by taking into account distance, topography, and cow body weight (BW) to calculate additional energy needed. On average, according to the dairy NRC (2001), the net energy for lactation (NE_L) required for excessive walking was an additional 0.00045 Mcal/kg per kilometer walked on a flat surface, with additional energy needed for hilly topography.

Therefore, it is key for producers to provide high quality pastures for cows to consume enough nutrients to meet the increased demands grazing cows have in comparison to confinement cows with equivalent production. In addition to having high quality and high yielding pastures, it is key for cows to not only consume enough energy and nutrients, but also to minimize energy spent while grazing. The time cows spend grazing is dependent on its relative availability and the amount of forage consumed (NRC, 2001). The less forage there is available, the more time and energy cows spend moving and grazing to consume the same amount of forage.

Forage Effects on Dairy Production

With additional energy being needed for grazing cows, one of the first limiting nutrients for cows on pasture is energy. For lactating dairy cows, the net energy needed for milk production is defined as the energy contained within the milk the cow produced (NE_L; NRC, 2001). This is calculated by determining the energy of combustion produced from the milk components. To calculate the NE_L of the forage a cow is grazing the following equation is utilized: Where NE_{Lp} represents NE_L at production levels of intake, and ME_p represents metabolizable energy at production levels of intake:

$$NE_{Lp}\ (\text{Mcal/kg}) = [0.703 \times ME_p\ (\text{Mcal/kg})] - 0.19$$

In non-pasture based systems, energy requirements are met predominantly by supplying concentrated carbohydrate rich feedstuffs such as corn silage, sorghum silage, barley, and other high energy feeds. However, organic dairy producers are limited in the amount of concentrates and stored feeds they may supply their cows. No more than 70% of cow total DMI may come from stored feeds (USDA-AMS, 2015). Therefore, it is key to provide pastures with ample energy levels. The amount of energy available in forage depends on the concentrations of two main carbohydrate components: non-structural carbohydrates (NSC) and structural carbohydrates. Nonstructural carbohydrates consist of sugars, starches, organic acids, and other carbohydrates (NRC, 2001). These fractions are highly digestible and energy dense. In forages, the major components of the NSC fraction are fructans and sucrose.

The three major components of structural fiber include: hemicellulose, cellulose, and lignin. The concentration of these components within a forage are expressed most commonly in two measurements: neutral detergent fiber (NDF) and acid detergent fiber (ADF). Neutral detergent fiber measures the amount of all three components: hemicellulose, cellulose, and lignin. This measurement is the best representation of the available fiber to the cow. Neutral detergent fiber is utilized to predict cow dry matter intake (DMI). The higher the amount of fiber in the diet, the less feed the cow can consume. The chemical composition, or the digestibility of the fiber, is also related to the amount of energy a cow can consume. Fiber digestibility, or the amount of energy supplied by the fiber, is directly related to the chemical composition of the feed, or the amount of hemicellulose, cellulose, and lignin. A negative correlation exists between the amount of fiber and energy available in the forage (NRC, 2001). This correlation relates to the rate at which cellulose is utilized by ruminal microorganisms, which is limited by association with lignin (Van Soest, 1973).

Hemicellulose is the most digestible of the fiber components, followed by cellulose. These fractions can eventually be broken down by the rumen microbiota and used by the cow in the form of energy. Lignin, however, is not digestible and therefore not available to the cow. Acid detergent fiber measures only cellulose and lignin, or the less digestible fiber fractions. Therefore, ADF is generally utilized as a measurement of energy available in the forage due to lignin being a determining factor in fiber digestion (NRC, 2001).

Fiber, energy, and yield are all important qualities that affect the nutrient intake of dairy cows on pasture. For organic dairy producers utilizing an intensive grazing system, these changes in pasture quality can have significant effects on milk yield. Maintaining similar quality and quantity throughout the grazing season may help producers to identify what mixture of species best supports maintenance of cow health and goal milk production.

Estimating Effects of Forage on Milk Production

Whole farm modeling has been used to estimate performance of dairy, beef, and other farm operations (Crosson et al., 2011). Certain whole farm modeling systems have been designed specifically designed for grazing dairy operations. Farmax Dairy Pro is a whole-farm decision support model that utilizes weekly estimates of different farm aspects including: pasture growth and quality, herd production, health, and other factors to determine production and economic outcomes to use in decision making on farm. It was developed using Delphi®. Farmax Dairy Pro is a combination of pasture model originally called Stockpol (Marshall et al., 1991; Webby et al., 1995) with the animal components of MOOSIM (Bryant et al., 2008). The model also includes mechanistic and empirical representations of animals that come together to create different models: two short-term and one long-term model to make different types of managerial decisions (Bryant et al, 2010; Smith & Foran 1988). To predict pasture growth, historical data of monthly growth rates are utilized and described in Marshall et al. (1991). The program utilizes past information from different feeds and pastures such as regrowth rates, decay, pasture cover, and pasture thresholds in predicting pasture growth rates throughout each month and season. (Bryant et al., 2010).

Farmax, therefore, can be utilized to estimate the performance of grazing dairy herds consuming a variety of different feedstuffs and different quality pastures. It can potentially help producers identify mixtures of forages that will help to maintain similar quality and quantity pastures throughout the grazing season. This may help producers to balance their feeding and grazing regimes, identify what mixture of species best supports milk production, and how to balance feed inputs to maintain goal milk production with the inclusion of the effects or pasture performance.

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CHAPTER I
PASTURE PRODUCTION AND QUALITY OF FOUR DIFFERENT ORGANIC FORAGE MIXTURES DESIGNED FOR TENNESSEE AND KENTUCKY, US DAIRY PRODUCTION

Abstract

In summer months, elevated ambient temperatures and decreased rainfall have negative effects on cool season grasses and legumes. This leads to a drop in forage quality and quantity known as the summer slump period. In order to increase sward yield and quality, warm season and cool season grasses and legumes have been incorporated in organic pasture-based dairy farms in northern regions of North America. However, studies have not been conducted in organic pasture-based dairy farms in the Southeast where a number of dairy operations are located. Therefore, this study was conducted to evaluate the mass yield and quality of four forage mixtures on organic dairy farms. Our hypothesis was that incorporation of warm season grasses and legumes would increase forage yield and quality in summer. To test this hypothesis, warm and cool season forages were incorporated into four forage mixtures. The mixtures contained the following species in each: Cool Season mixture (CS; cool season species of orchard grass, tall fescue, red clover, and alfalfa), Warm Red Clover mixture (WRC, warm season species of crab grass and annual lespedeza mixed with the cool season species of annual ryegrass and red clover, Warm Crimson Clover mixture (WCC, warm season species of sorghum-X sudan-grass hybrid (sudex) and cowpea mixed with the cool season species of annual ryegrass and crimson clover, and Warm Turnip and Rape mixture (WTR, warm season species of sudex and cowpea mixed with the cool season species of oats, annual ryegrass, turnip, and rape). Mixtures were planted in 0.1 to 0.2 ha plots at five locations on organic dairy farms in Kentucky and Tennessee. Forage mass yield (dry matter, DM) was determined from March-November and forage samples were collected and analyzed using near infrared spectroscopy (NIRS; Foss-DS2500) to determine crude protein (CP) and fiber contents. Near infrared spectroscopy and DM yield records were analyzed in SAS 9.4 using the GLIMMIX procedure. Data were averaged and analyzed by season including spring (March – May) and summer (June – August). Results indicated that atmospheric temperature highs from from June-August were up to 6°C lower (2017 average ± SD = 27.2 ± 2.67) than that registered (historical average ± SD = 31.5 ± 1.2°C) for Kentucky and Tennessee. June-August, had 35 mm/month (2017 average ± SD = 133 ± 31mm/month) more precipitation than the area historical average 98 ± 11 mm/month for Kentucky and Tennessee. Compared with the CS mixture, mixtures including warm season species did not increase yields of DM in spring and summer. When analyzing the effect of location on yields of DM, significant differences were observed based upon plot location ($P = 0.01$), while trends were observed on percent of legumes based upon location ($P \leq 0.08$). Proportion of legumes were significantly greater in the CS mixture, compared with mixtures including warm season species. However, mixtures including warm season species had a significantly higher proportion of grasses than the CS mixture ($P < 0.05$). The CS mixture maintained the highest quality in spring and summer when compared to the warm season mixtures. Under the conditions of this study, results indicated that the incorporation of warm season grasses and legumes did not increase forage yield and quality during summer in Kentucky and Tennessee.

Introduction

Organic dairy cows must graze at least 120 days out of the year and over 30% of their dry matter intake (DMI) must come from grazing pasture (USDA-AMS, 2015). In the southeast US, particularly in Tennessee and Kentucky, forage quality and quantity can have significant impacts on dairy cow productivity. For dairy cows grazing pasture, major macronutrients consumed are carbohydrates and protein (NRC, 2001). The predominant forages utilized in the southeast to supply these macronutrients are cool season grasses and legumes (Scaglia et al., 2008).

Cool season forages flourish in the cool and rain filled spring and fall seasons in the southeast US. In Hopkinsville, Kentucky yearly atmospheric temperature highs average 21°C and rainfall average 109 mm/month (U.S. Climate Data, 2015-2018). Kentucky and Tennessee lie within the transition belt between the subtropical and temperate regions. In this region both cool and warmer temperatures are observed. For example, summer temperatures in this area reach above 35°C and rainfall decreases on average 27 ± 19 mm/month in comparison to spring (spring average ± SD =125 ± 17 mm/month). Extreme weather conditions during summer can have detrimental effects on cool season species growth and quality (U.S. Climate Data, 2015-2018). The decrease in forage yield and quality is known as the "summer slump".

During the summer slump, cool season pastures are characterized by lowered protein content and increased fiber (Fales, 1986; Ford et al., 1979). For example, in a study by Ford et al. (1979) trends of increased hemicellulose content in temperate grasses were observed as temperature increased from 21-32°C during the day. Cool season forage fiber content increased greater than 10% in some temperate species. This decrease in both quality and production can have significant negative impacts on dairy cow production. For example, when fiber increases above 44%, intake of dairy cows will decrease, potentially decreasing production of those cows (NRC, 2001). In contrast, tropical (warm season grasses) do not increase in hemicellulose content, with 2.5% reported as the largest increase in warm season grasses. Warm season species are well adapted to increased temperatures, resist drought, and flourish in the summer months with optimum growth ambient temperatures ranging from 30-35°C (Collins et al., 2017).

Therefore, if both warm and cool season forages were combined, warm season could combat the summer slump by maintaining forage yield and quality during the hot summer month between the peak growth seasons of cool season forges. Sanderson et al. (2005) reported pastures containing a high diversity of different functional forage groups were more productive during the summer dry season and also decreased weed presence. However, this study was conducted in Pennsylvania, which is located in the temperate zone and will potentially yield different results.

Therefore in the Southeast, production and quality could be maintained by combining the use of both warm and cool season forage species (grasses and legumes) on pasture-based organic dairy farms throughout the spring and summer months. Therefore, the objective of this study was to determine the effect of four different forage mixtures (i.e. cool season and warm season annual and perennial species) containing multiple functional groups (i.e. grasses, legumes) designed for organic dairy farms in the Kentucky and Tennessee. We hypothesize that the incorporation of warm season grasses and legumes would increase forage yield and quality in summer.

Materials and Methods

Experimental Design and Treatment

To study the effect of mixing functional forage groups, four mixtures were created containing cool and warm season grasses, legumes, and brassicas. Species mixtures were selected based upon performance in the transition climate and nutritive quality. The three warm season mixtures created included both warm season grass and legume species and differed in other included species, most notably which cool season species or legume/brassica that was included. One mixture contained only cool season species (CS; orchard grass, tall fescue, red clover, and alfalfa) and three mixtures contained cool and warm season species. The first included the warm season species of crab grass and annual lespedeza mixed with the cool season species of annual ryegrass and red clover (WRC), the second included the warm season species of sorghum-X sudan-grass hybrid (sudex) and cowpea mixed with the cool season species of annual ryegrass and crimson clover (WCC), and the third contained the warm season species sudex and cowpea mixed with cool season species oats and annual ryegrass, and cold tolerant forage brassicas turnip and rape (WTR).

Planting and Sampling

Cool season species and brassicas were planted between August 16 and September 10, 2016. Cool season annuals were planted using a no-till drill to a depth of approximately 7 mm at variable seeding rates, while perennials were broadcasted and rolled (seeding rates shown in Table 1.2). Warm season grasses and legumes were planted between May 20 - June 10, 2017 using a no-till drill with the exception of Sudex and Cowpea species, which were drilled into pastures during the same time frame. Mixtures contained 4-6 of species shown in Table 1.2. Each forage mixture was planted in 0.1 to 0.2 ha plots on USDA-certified organic dairy farms (n=5) located in the southwest region of Kentucky (altitude: 161 M above sea level) and the southeast region of Tennessee (altitude: 303 M above sea level). Farms were grouped based upon distance from each other into 3 different locations. The Kentucky locations contained silt loam soil with an average rainfall of 1,299 mm/year (U.S. Climate Data, 2015-2018; WebSoilSurvey, NRCS, USDA). The Tennessee location also contained silt loam soil with a mean annual rainfall of 1,224 mm/year throughout the grazing season (U.S. Climate Data, 2015-2018; WebSoilSurvey, NRCS, USDA). An average of 167 and 523 kg/ha of phosphorus and potassium respectively were applied to plots. Mean monthly temperature, soil moisture, and rainfall across all farms are shown in Table 1.1. Soil moisture, atmospheric temperature, and rainfall data from June to November were collected using Onset U30-NRC HOBO loggers (HOBO ware, Bourne, MA) on each farm. However, data from March-May were collected from the Hopkinsville, Kentucky Woolridge Road Station and the Madisonville, Tennessee Hiwa S See Station (weatherunderground.com, 2018) due to inability to set up loggers until this time.

Forage mixtures were sampled throughout the grazing season before being grazed by organic dairy herds (March-November 2017). Herds grazed these plots based upon forage availability and grazing management was dependent upon individual farmer. Grab samples of each mixture were collected from March 21, 2017 to November 11, 2017 within 5.9 ± 5.6 days prior to herds grazing the plots. Forage samples were collected using a 0.3 m × 0.3 m square and cut 2.5 cm from the ground, with the exception of the sudex plants which were cut to 15cm above the ground, then stored at 4°C before processing.

Forage Processing and NIRS Analysis

Botanical composition and DM content were determined and used to estimate total DM yield and species yields. After samples were collected, the samples were pooled, weighed, and recorded before being split into two equal parts. The first part of the samples were weighed and then immediately placed in a 55°C forced air oven for 72 + h then weighed again to determine percent DM. Dried samples were ground through a 1-mm screen (Wiley mill, Arthur H. Thomas, Philadelphia, PA) and analyzed by near-infrared spectroscopy (NIRS) using a Foss-DS2500 to determine *in vitro* digestibility- 48 hr (IVD48), crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), lignin, crude fat, digestibility of NDF at 48 h (dNDF48), and ash content. Forage nutritive values were determined by using near-infrared spectroscopy (NIRS) technology provided by a Unity Scientific SpectraStar 2500XL-R (Milford, MA) using the 2017 Mixed Hay calibration for provided by the NIRS forage and feed testing consortium (Hillsboro, WI). From these values relative feed quality (RFQ), relative feed value (RFV), and net energy of lactation (NE_L) were calculated using the following equations:

$$RFQ = (DMI \times TDN) / 1.23$$

$$RFV = (DMI \times DDM) / 1.29$$

$$NE_L = (0.703 \times ME) - 0.19$$

Where DDM = digestible dry matter, the percent *in vitro* digestibility at 48h (NIRS output), DMI = estimated dry matter intake (Roseler et al., 1997); TDN = total digestible nutrients (calculated by inputting the NIRS outputs for percent: NDF, crude fat, CP, and ash into the equation from Rohweder et al. 1978), and ME = metabolizable energy (Mcal/kg) calculated using the ME from the Agrifood Laboratories (Guelph, ON, Canada). The second part of the samples were separated based on species. Any species not planted in the plot were considered weeds. Species separation samples were then placed into a 55°C forced air oven for 72 + h.

After samples were dried, the dry weights for both the DM samples and species samples were added together to determine total dry weight to calculate DM per Ha when sample was collected. Dry weights of the species separations were added together based upon forage type (legume, grass, and weeds) to compare botanical composition across mixtures. Brassicas were not compared across mixtures due to the functional forage group only being planted in mixture WTR, however, brassica yields were included in total DM yields.

Statistical Analysis

This study was set up as a complete randomized block design. In this study, 228 forage samples were collected and analyzed during the course of 34 weeks with 154 samples from Kentucky and 74 from Tennessee. Sample results were analyzed in SAS 9.4 using a MIXED ANOVA procedure. The locations used in this analysis were based upon farm area and position, with one farm being its own pair (location) by planting replicates of the mixtures on the same farm. Therefore, there were two replicates of each forage mixture within each of the three locations. Forage quality samples were analyzed using grazing seasons (spring, summer, and fall) as the unit of time to analyze the effects of treatment on forage quality and yield. The model analyzed the effects of treatments by spring (March-May), summer (June-August), and fall (September-November). The model included:

$$Y_{ijkn} = \mu + M_i + S_j + L_k + (M_i \times S)_{ij} + R(L \times M)_{ikn} + e_{ijkn}$$

Where Y_{ijkn} = the dependent variable; μ = the overall mean; M_i = the fixed effect of the ith mix; S_j = the fixed effect of the jth season; $(M \times S)_{ij}$ = the fixed effect of the ith mixture and the jth season; L_k = the random effect of the kth location; $R(L \times M)_{ikn}$ = the random effect of the kth location and the ith mixture nested within the nth replication; and e_{ijkn}= the random error.

For mixtures, composition of species and total pasture yield results were analyzed in SAS 9.4 using a MIXED ANOVA procedure. Species composition results in each mixture were combined into groups based on forage type: grass, legume, or weed. Due to lack of rainfall, producers began to transition cows from pasture to stored feeds in September 2017 which limited grazing and the collection of forage samples. Thus, the fall season was not included in the analysis for yield or composition. As a result of uncontrollable variables such as distance between farms (up to 335 km), grazing management styles (heavier or lighter use of grazing), and fertilization rates (amounts of chicken scratch or other compost used); significant differences were observed between farm locations in total pasture yields and forage group yields. Therefore, the analysis was conducted with location as a fixed effect instead of as a random effect to analyze the effect of location. The model with location set as a fixed effect included:

$$Y_{ijk} = \mu + M_i + S_j + (S \times M)_{ij} + L_k + (L \times S \times M)_{ijk} + e_{ijk}$$

Where Y_{ijklm} = the dependent variable; μ = the overall mean; M_i = the fixed effect of the ith mix; S_j= the fixed effect of the jth season; L_k = the fixed effect of the kth location; $(S \times M)_{ij}$ = the random effect of the j^{th} season and the i^{th} mixture; $(L \times S \times M)_{ijk}$ = the fixed effect of the j^{th} season, the i^{th} mixture, and the k^{th} location ; and e_{ijk}= the random error.

Significant results were declared at a P-Value ≤ 0.05 and trends were declared at a P-Value ≤ 0.10.

Results

Weather

Air temperatures ranged from 9.0-26.4 °C throughout the grazing season. The spring, summer, and fall temperatures ± SD were 15.8 ± 5.3 °C, 25.2 ± 1.1 °C, and 16.9 ± 7.3°C respectively across all farms involved in this study. Average ± SD of rainfall was 123.7 ± 13.4 mm/month in the spring, 208.3 ± 92.6 mm/month in the summer, and 82.3 ± 30.3 mm/month in the fall (Table 1.1).

Forage Yield

Forage yields were compared between spring and summer only. Fall results were not included due to changes in grazing management in response to draught like conditions in fall, which limited the number of plot samples taken. When comparing spring and summer yields, results were not different between mixtures with an average of 10,008 ± 2361 kg DM/ Ha between mixtures (P > 0.10; Table 1.3). However, season and location both had effects on forage yield (P ≤ 0.01) where spring had a significantly higher yield than summer (12,470 kg DM/Ha vs. 7547 kg DM/Ha; Table 1.3). No interactions were observed between mixture and season, location and mixture, or season by location by mixture (P > 0.10).

Botanical Composition

A difference was observed between proportions of grasses and legumes amongst mixtures (P ≤ 0.05). Mixture CS contained the highest percentage of legumes with 38.3 ± 9.5%

while mixture WTR contained the lowest amount of legumes with 0% in spring (Table 1.3). Significant differences were observed in percent composition of grass ($P \leq 0.05$). Mixture WCC contained the highest percentage of grass in spring (68 ± 2.7%) and second highest percentage in summer (81.8 ± 6.1%). Mixture CS contained the lowest with an average of 36.8% (Table 1.3). However, no differences were observed between mixtures in weed percent ($P > 0.10$). Due to uncontrollable variables such as distance and management styles such as height of forage at grazing, significant differences were observed between farm locations. When analyzing the effect of location on yields of total dry matter and legumes, significant effects were observed on dry matter yields ($P = 0.01$), while trends were observed on percent of legumes ($P \leq 0.08$).

Forage Quality

When analyzing forage quality in relation to season (spring, summer, and fall), differences in percent CP were observed between the different mixtures as well as season ($P < 0.01$; Figure 1.1). Crude protein ranged from 14.8 to 26.5% across mixtures and on average protein concentrations were highest within the fall season and lowest within the summer season. Mixtures WRC and CS had greater CP concentrations averaging 20.2% and 20.4 % CP respectively in each mixture across the spring, summer, and fall seasons. Mixtures CS and WTR remained steady across seasons in CP percent with an average of 18.3% and 16.6% CP, respectively, across all three seasons ($P=0.003$; Figure 1.1).

Concentrations of ADF between mixtures did not differ ($P = 0.25$), however, ADF concentrations differed among seasons ($P < 0.01$; Figure 1.1). When examining the concentrations of ADF relative to season, mixtures did not differ between season with the exception of mixture CS. Mixture CS had lower ADF during the summer grazing season with over 4% less ADF than the other summer mixtures ($P < 0.05$). However, in spring and fall when

ADF values were lower, no differences were observed between mixtures and season when ADF values were lower. Concentrations of ADF were highest in the summer with an average of 35.41 ± 1.23 % ADF and lowest in fall with an average of 27.0 ± 1.23 % ADF, which is almost a 10% difference between the two seasons.

Concentrations of NDF followed a similar trend to ADF. No differences were observed between mixtures ($P = 0.37$), but there was a difference between seasons ($P < 0.01$; Figure 1.1). Mixture CS did not have lower NDF values than the other mixtures and within mixture remained at similar NDF concentrations the entire length of the grazing season with an average of 45.0% NDF. Mixtures WRC and WTR had lower NDF ($P < 0.01$) during the fall season, with 36.6 and 37.8% NDF respectively. In contrast, Mixture WCC varied across all seasons, with the highest concentration in summer with 58.5 ± 1.8. % NDF and lowest in fall with 34.8 ± 3.03 % NDF (Figure 1.1).

Results for net energy of lactation (NE_L) were similar across mixtures with no differences observed ($P > 0.05$). However, when analyzing the interaction between mixture and season, significant differences were observed in both summer and fall with no significant differences in spring. In the summer, mixture CS had a significantly higher energy content than that of all the warm season mixtures averaging an NE_L value of 1.1, which was 10% greater than the warm season mixtures. Once shifted into fall, however, the warm season mixture WTR was higher in energy than the CS mixture with 1.3 and 1.2 Mcal/kg DM respectively ($P < 0.01$). Mixtures WRC and WCC were similar to both WTR and CS in fall.

When analyzing both the RFV and RFQ, values did not differ across mixture; however, season had a significant effect on feed values ($P < 0.01$).Both RFV and RFQ were highest in fall with an average of 18.3 and 14.4 RFV and RFQ respectively. When analyzing the interaction between mixture and season, a significant effect was observed for both RFV and RFQ. For mixture CS, there were no significant differences between all three seasons, with an average RFV value of 17.8 and a RFQ value of 13.3 (Figure 1.1). For mixtures WRC, WCC and WTR; RFV values were significantly lower in summer compared to fall with fall RFV values for WRC, WCC, and WTR mixtures averaging 18.4% RFV collectively. However, mixture WCC had a significantly lower RFQ (P = 0.05) in summer compared to both spring and fall (Figure 1.1).

Discussion

Warm season forage mixtures produced equivalent DM yields to cool season mixtures in the summer months, suggesting that inclusion of warm season species did not help increase summer yields. This may be due to lower than average summer temperatures and greater than average summer rainfall observed in the area during the first year of this study. Summer weather conditions were milder than previous years and may have led mixture CS to maintain the highest quality throughout the grazing season (March-November). Therefore, results from 2017 suggest that inclusion of warm season forages did not increase summer yield or quality of mixtures and did not help to increase mass yield during this year.

Forage Yield

In our study, total DM yields did not differ between the CS mixture and the warm season mixtures in spring or summer, however, all mixtures significantly decreased in mass yield in summer compared to spring. The perennial cool season mixture, CS, did not differ in yields from those mixtures containing warm season species; therefore suggesting seasonal effects were not extreme enough to have a significant impact on forage growth of cool season species. Average temperature highs in 2017 in Hopkinsville, Kentucky from June-August ranged from 24.1-29°C. However, temperatures from the past 30 years indicated average high temperatures ranged from

30.1-32.2 °C. This is more than 6°C higher than observed temperatures in 2017. In addition, rainfall was greater in 2017 than it had been in previous years. In 2017 average rainfall from June – August was 133 mm/month, while in 1981-2010; an average of 98 mm monthly rainfall was observed (U.S. Climate Data, 2015-2018). Increased rainfall and lower temperatures may have led to an increased yield in temperate grasses and decreased yield in warm season forages due to optimal temperatures for growth. Cool season forages flourish at 8-24°C while warm season forages optimal growth temperatures range between 25-35°C (Butler et al., 2017; Salisbury and Ross, 1985). With average high temperatures remaining within or close to optimal growth temperatures for cool season species and increased rainfall, this may have led to the cool season forage's ability to maintain yields throughout the summer season and benefit them more than the warm season forages. In addition, the effect location on yields of total dry matter was significant. This may be due to the differences in grazing management observed on each farm, for example grazing rate and grazing height which effect yield of forage on pasture at time of grazing.

Botanical Composition and Forage Quality

The significantly lower percent of legumes in mixture WTR was due to both a lack cool season legumes being planted within the mixture (brassicas replaced cool season legumes in WTR mix), but also the cool summer conditions were not ideal for WTR's warm season legume's optimum growth rate. Mixture WTR's only legumes species was a warm season legume, cow pea, which grew during the summer season. All other mixtures contained at least two different legume species. The CS mixture contained two cool season legume species, red clover and alfalfa. The CS mixture supported the highest percent of legumes of all the mixtures throughout the year and had a significantly higher legume content when compared to the WTR mixture ($P \leq 0.05$). However, no significant interactions were observed between mixtures and seasons in legume yields. The CS mixture maintained legume percentages. This may be due to the cool season species red clover can be very productive in warmer temperatures due to its draught tolerance (Peterson et al., 1991), therefore, leading to the consistent legume content observed from spring to summer in mixture CS as well as the overall cooler temperatures observed during this time.

Increased legume concentrations could have led to the high CP concentration in mixture CS (Table 1.3) as well as quality of the main legume species in the mixture, alfalfa. Alfalfa is known to have CP concentrations averaging 20.6% CP (Hall et al. 2000 and Cassida et al. 2000), which is 2% higher than other mixtures' cool season legume species including: red clover, which has an 18.6 average % CP content, and red clover that averages 17.9% CP (Cassida et al., 2000; Broderick et al., 2001). When analyzing CP content in spring, all mixtures were similar in CP concentration no matter the legume species or lack of in spring. This may be due to the addition of turnips and rape to WTR, which average 12% CP (Griffin et al., 1984). As mixtures transitioned into summer and fall, no significant differences were observed in CP content between mixtures within season. However, mixtures WRC and WCC contained higher CP concentrations in fall than in both spring and summer. In conclusion increased legumes concentrations as well as quality of individual legumes species may have led to the increased concentrations of CP within the CS mixture.

Mixtures produced similar energy levels (NE_L) in spring; however, the CS mixture had significantly higher values in summer compared to the warm season mixtures. As seasons moved into fall, the brassica mixture, WTR, increased and became significantly higher in energy than the CS mixture and similar to the other warm season mixtures in energy. This may be due to the high energy content in brassicas that began to reestablish during this time. Limited composition collections from fall indicated that brassicas reestablished during this time. Turnips and rape average 1.4 MJ/kg (Griffin et al., 1984), which is significantly higher than the other values observed on this study. In conclusion, cool season species provided more energy on average than that of the warm season mixtures during the course of the grazing season.

Although brassica composition was not evaluated during this study, the percentage of grasses in each mixture was. The warm season mixtures had significantly higher percentages of grasses than that of the CS mixture. Mixture CS was the only mixture in which the legumes planted were both cool season species, which flourished due to mild temperatures during the grazing season. The extremely high percentage of legumes in spring may have led to decreased grass yields in both spring and summer in the CS mixture. When analyzing the grass content in the warm season mixtures, mixtures included either the warm species sudex or crab grass. Sudex is known for its high DM yields during the summer months, however, yield of grass in WCC and WTR, which contain sudex, were not significantly different from WRC which contains crabgrass (a warm season grass; Jahanzad et al., 2013). This may have been due to the very strong stands of crabgrass observed during this time.

Within grasses, fiber concentrations are higher when compared to many legume species. Concentrations of fiber, ADF and NDF, followed similar trends from spring – fall in mixtures. For both NDF and ADF, no significant differences were observed between mixtures within season; however, differences within mixtures were observed across seasons. In general, fiber was lowest in fall followed closely by spring. Highest concentrations of fiber were observed in summer, which could be due to a multitude of factors from species to environmental. Warm season species, which are present in the summer season, naturally have higher concentrations of fiber (Ford et al., 1979). For example, Sudex, a warm season grass, which was planted in mixtures WTR and WCC, averages 57% NDF and 26% ADF when harvested in summer months (Jahanzad et al., 2012). Orchard grass, a cool season species planted in the CS mixture averages 14.4% NDF in optimal growth temperatures which is 40% lower than Sudex (Collins and Casler, 1990). However, fiber concentrations in the CS mixture did not increase in summer and were lower than typically observed summer averages for Orchard grass species, and in this study fiber concentrations remained consistent from spring – fall. This suggests that the weather and environment did not have a significant effect on quality of the cool season species planted in this mixture.

The ADF and NDF contents were lower in fall than spring. Maturity has a significant effect on fiber levels and the availability of structural carbohydrates because lignification of forages increases with maturity (Elgersma and Søegaard, 2018). Fiber (ADF) is important in intake of cows on pasture, and is negatively correlated to energy content (NRC, 2001). The higher the indigestible fiber yields, the lower the potential energy of the forage. Therefore, lower yields of both ADF and NDF in forage should help to increase DMI and potential energy intake. It is possible that grazing forages at an earlier stage due to fall regrowth of cool season forages may have helped to decrease fiber levels.

Total weed percentage (or unsown species yields) remained similar from spring to summer in 2017, with percentage of weeds decreasing in both the CS and WTR mixture from spring in to summer. There was no significant effect of mixture on weed percentage; however, numerically the CS mixture produced the highest average percentage of weeds with 22.9%. This may be due to the decreased numerical yield in pasture, or the decreased amount of species diversity. When pasture cover is low, and open ground is available this allows for weeds to permeate the area. Therefore by incorporating forages with different growth patterns into the warm season mixtures, this may have helped to keep weed yields down in mixtures with higher diversity, for example the WCC mixture. This mixture contained a high diversity of plants with warm and cool season legumes and grasses and had numerically lower weeds. Similar results have been observed in other studies. For example in a study by Sanderson et al. (2005) it was found that increasing diversity of pasture helped to decrease weed yield throughout the grazing season. Therefore diversity within mixtures may have led to numerically less weeds within mixture.

Conclusion

Pastures across all mixtures yielded greater DM in spring than summer. The effect of location on yields of total dry matter and legumes was significant, however when averaged across locations warm season forage mixtures produced equivalent yields of pasture to cool season mixtures in the summer months, suggesting inclusion of warm season species did not help increase summer yields. This may be due to decreased summer temperatures and increased rainfall observed in the area where 80% of the farms were located (U.S. Climate Data, 2015-2018). These weather conditions were milder than previous years and may have led to the maintenance of quality and yield in the CS mixture. Mixture CS maintained the highest quality throughout the grazing season (March-November) with its consistent high CP and energy values. Therefore, results from 2017 suggest that inclusion of warm season forages did not increase summer yield or quality of pastures and did not help to maintain pasture production from March – November. Ergo, inclusion of warm season forages into pastures in the 2017 grazing season in Kentucky and Tennessee did not help producers to maintain consistent producing pastures.

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Appendix

Table 1.1 Average monthly atmospheric temperature, rainfall, and soil moisture among all five experimental farms during the 2017-grazing season using both HOBO loggers (HOBO ware, Bourne, MA) and information from the Hopkinsville, KY Woolridge Road Station and the Madisonville, TN Hiwa S See Station (weatherunderground.com, 2018).

Month	Air Temperature, □	Rainfall, mm	Soil Moisture (0-13 cm), $m^3 m^{-3}$
March	9.8	114.8	-
April	17.8	117.2	-
May	19.8	139.2	-
June	24.2	215.21	0.29
July	26.4	112.4	0.26
August	25.0	297.3	0.24
September	23.4	94.6	0.26
October	18.2	104.5	0.26
November	9.0	47.7	0.34

Table 1.2 Species and seeding rates (kg seed Ha -1) used in planting forage mixtures

Species	[1]Mixture Seeding Rates (kg seed Ha $^{-1}$)			
	CS	WRC	WCC	WTR
Cool Season Grasses				
Tall Fescue (*Schedonorus arundinaceus;* cv. BarOptima Plus E34)	9.0	-	-	-
Orchard Grass (*Dactylis glomerata;* cv. Persist)	5.6	-	-	-
Annual Rye-Grass (*Dactylis glomerata;* cv. Persist)	-	22.4	22.4	13.5
Oats (*Avena sativa;* cv. Proleaf 234)	-	-	-	35.9
Cool Season Legumes				
Red Clover (*Trifolium pratense;* cv. Freedom!)	5.6	9.0	-	-
Crimson Clover (*T. incarnatum;* cv. Dixie)	-	-	17.9	-
Alfalfa (*Medicago sativa;* cv. Anerustabd 403T)	11.2	-	-	-
Warm Season Grasses				
Sorghum-X Sudan-Grass Hybrid(*Sorghum bicolor x S. bicolor* var. *sudanense;* cv. Sweet Six BMR)	-	-	33.6	33.6
Crab Grass(*Digitaria ciliaris*; cv. Red river)	-	4	-	-
Warm Season Legumes				
Cowpea (*Vigna unguiculata;* cv. Iron & Clay)	-	-	28.0	28.0
Annual Lespedeza (*Kummerowia spp.;* cv. Kobe)	-	16.8	-	-
Brassicas				
Turnip (*Brassica campestris* var. *rapa;* BarKant)	-	-	-	3.4
Rape (*Brassica napus*; cv. Barsica).	-	-	-	4.5

[1]CS (Alfalfa, Red Clover, Orchard Grass, and Tall Fescue), WRC (Annual Ryegrass, Red Clover, Crab Grass, and Annual Lespedeza), WCC (Annual Ryegrass, Crimson Clover, Sorghum-X Sudan-grass Hybrid, and Cowpea), and WTR (Turnip, Rape, Oats, Annual Ryegrass, Sorghum-X Sudan-grass Hybrid, and Cowpea

Table 1.3 Forage mixture spring, summer, and total yields (DM kg/ha) and spring (March-June) and summer (July-August) composition (%)

	Forage Mixtures[1,2]				
	Spring				
	CS	**WRC**	**WCC**	**WTR**	**SEM**
Percent, %[3]					
Legume	38.3[a]	12.2[b]	16.1[bc]	0.0[c]	2.7
Grasses	33.3[a]	66.6[a]	68.0[b]	56.5[a]	6.1
Weeds	28.4	21.2	16.0	25.4	5.9
Brassica	0.0	0.0	0.0	20.2	1.8
Total Pasture Yield*, kg DM/ha	8496	14635	13525	13225	2361
	Summer				
	CS	**WRC**	**WCC**	**WTR**	**SEM**
Percent, %					
Legume	35.2[a]	22.0[b]	1.8[bc]	2.1[c]	4.8
Grasses	45.8[a]	55.1[a]	81.8[b]	83.8[a]	8.0
Weeds	17.4	21.8	16.4	14.1	7.7
Total Pasture Yield*, kg DM/ha	7506	6619	7354	8710	2163

[1]CS (Alfalfa, Red Clover, Orchard Grass, and Tall Fescue), WRC (Annual Ryegrass, Red Clover, Crab Grass, and Annual Lespedeza), WCC (Annual Ryegrass, Crimson Clover, Sorghum-X Sudan-grass Hybrid, and Cowpea), and WTR (Turnip, Rape, Oats, Annual Ryegrass, Sorghum-X Sudan-grass Hybrid, and Cowpea)
[2]Missing percentage due to absence of inclusion of dead matter percent in table
[2]Brassica percent was not included in statistical analysis due to brassicas only being present in spring in mixture WTR.
[abc] Mixtures were significantly different in percent yield of legume and grasses ($P \leq 0.05$)

a)

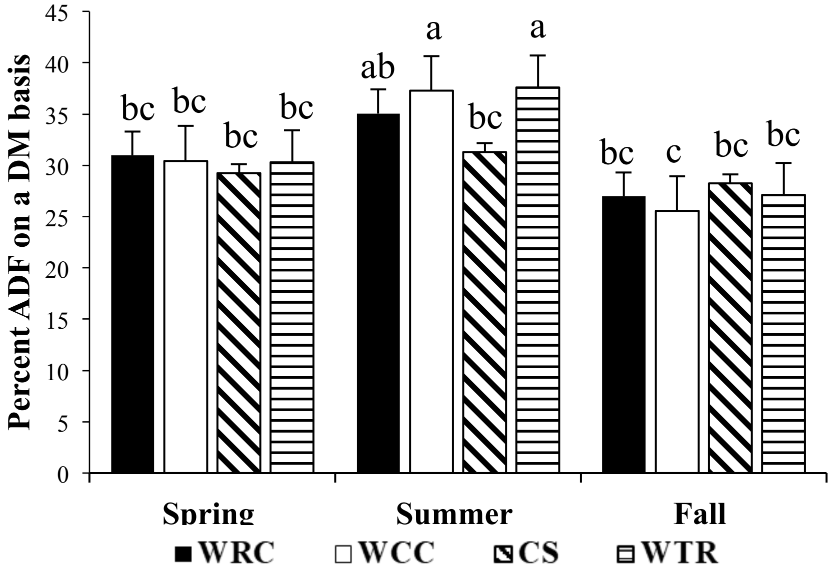
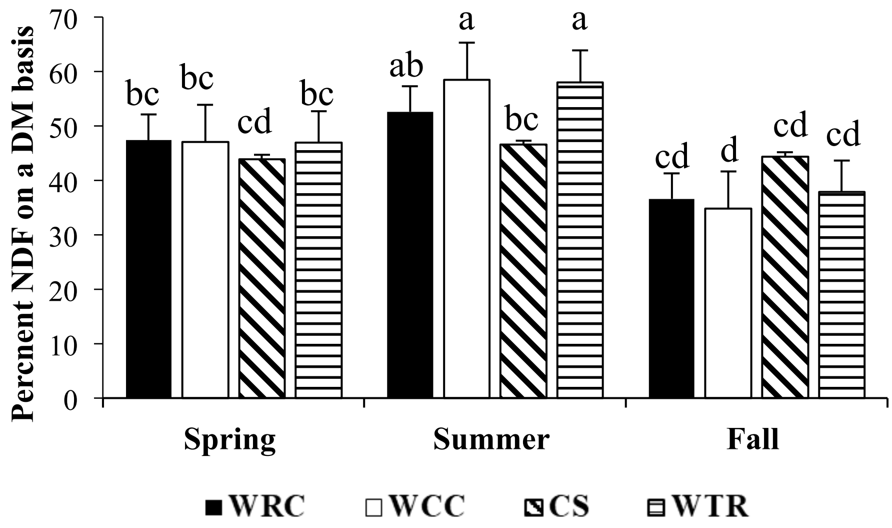


Figure 1.1 (a – g). Forage mixture[1] quality across the three grazing seasons: Spring (March-June), Summer (July-August), and Fall (September-November) measuring a) Acid Detergent Fiber (ADF), b) Neutral Detergent Fiber (NDF), c) Crude Protein (CP), d). ADF to NDF Ratio, e) Net Energy of Lactation (NE_L), f) Relative Feed Value (RFV), and g) Relative Feed Quality (RFQ)

[1]Mixtures: CS (Alfalfa, Red Clover, Orchard Grass, and Tall Fescue), WRC (Annual Ryegrass, Red Clover, Crab Grass, and Annual Lespedeza), WCC (Annual Ryegrass, Crimson Clover, Sorghum-X Sudan-grass Hybrid, and Cowpea), and WTR (Turnip, Rape, Oats, Annual Ryegrass, Sorghum-X Sudan-grass Hybrid, and Cowpea)

[abcd]Mixtures significantly across season ($P \leq 0.05$)

b)



c)

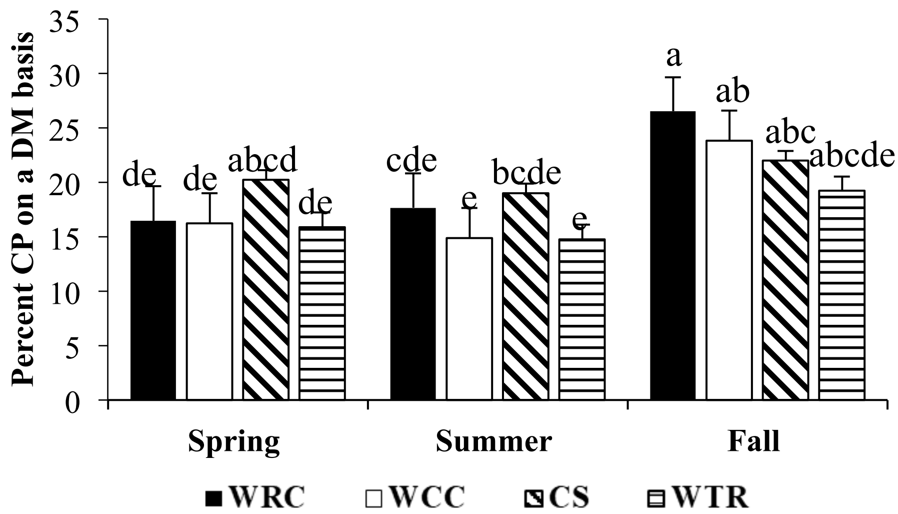
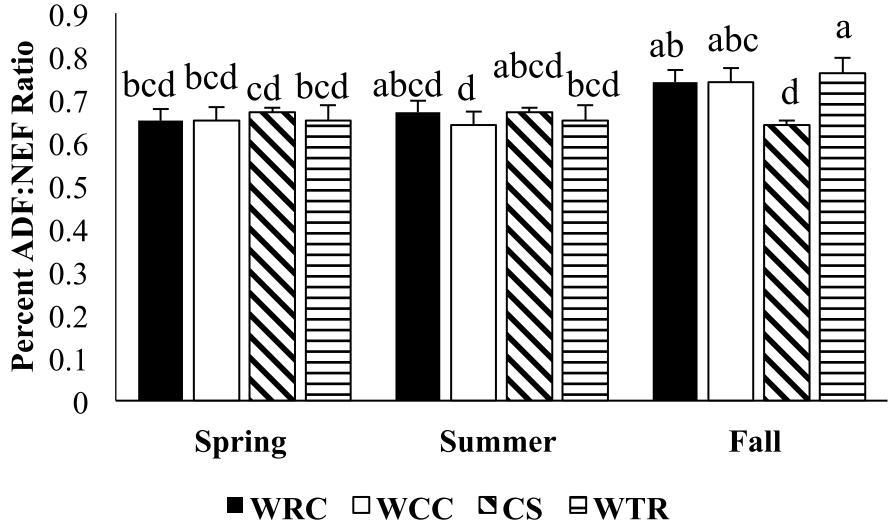


Figure 1.1 Continued

d)



e)

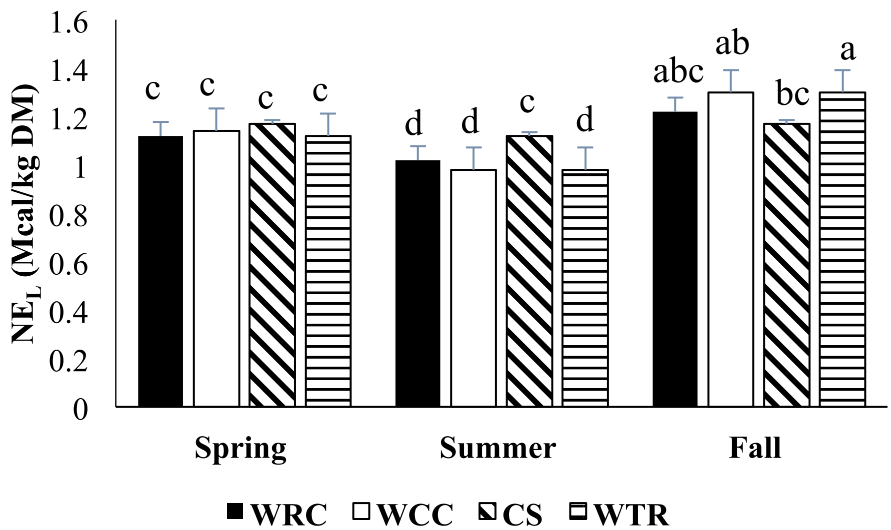
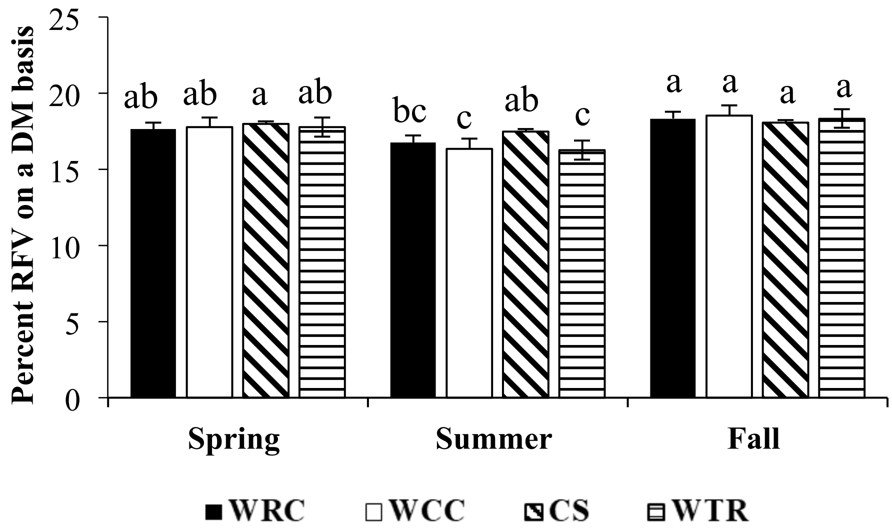


Figure 1.1 Continued

f)



g)

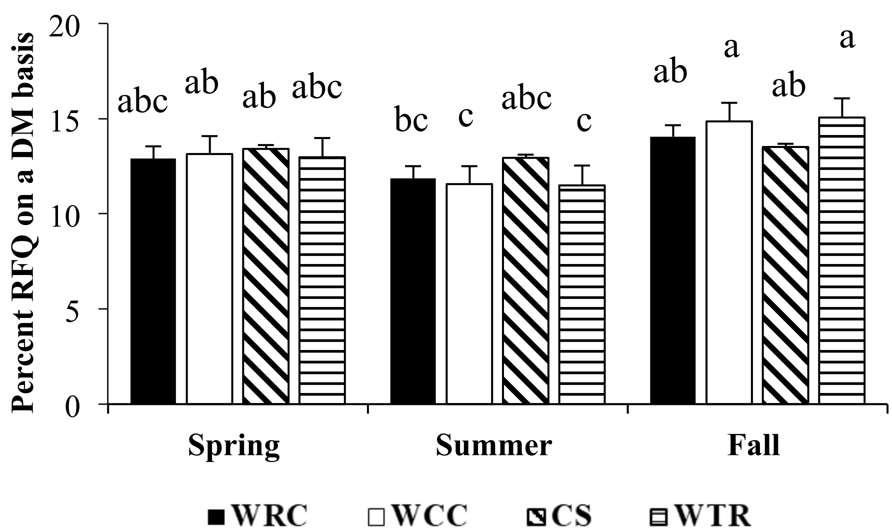


Figure 1.1 Continued

CHAPTER II
PREDICTING THE EFFECTS OF FOUR DIFFERENT FORAGE MIXTURES ON ORGANIC MILK PRODUCTION IN KENTUCKY AND TENNESSEE, US

Abstract

There is an interest for some US southeast organic dairy producers to increase forage utilization in order to decrease feed costs. Therefore, it is essential to identify productive and nutritious forage mixtures for organic pasture-based dairy farms that will maintain forage production and quality as well as help organic farmers meet dairy production goals. In a previous study conducted in Kentucky and Tennessee, the performance of four different forage mixtures containing either cool season forages or a mixture of warm and cool season forages were tested during the spring and summer months in 2017 using ¼ to ½ ha plots. However, the impact of these forage mixtures on cow productivity was not assessed due to the small plot size. Therefore, the objective of this study was to predict the effect of the four tested forage mixtures on dairy cow productivity. We hypothesized that incorporation of warm season forages would increase forage quality and quality and therefore help to maintain predicted organic dairy milk production through the grazing season. To test this hypothesis, actual mass yield and quality of the four mixtures used in the previous study were imported into a whole-farm modeling system (FARMAX, New Zealand). Settings in FARMAX Dairy Pro were developed using Jersey or Holstein Friesian cows with either a low or high corn silage supplementation level. Predictions of milk production were then obtained using the following settings: Holstein Friesian High-Input (HF-HI), Holstein Friesian Low-Input (HF-LI), Jersey High-Input (J-HI), and Jersey Low-Input (J-LI). Each scenario included 50 cows with calving in the fall season. Forage data of mass yield and quality from mixtures Cool Season (CS), Warm Red Clover (WRC), Warm Crimson Clover (WCC), and Warm Turnip and Rape (WTR) from study one were entered into the model, and a one-year analysis was conducted. Compared with warm season forage mixtures, Mixture CS predicted the greatest milk yields in HF-LI, J-HI, and J-LI, particularly during the summer. The

CS mixture also had the highest average milk yield across all system. Therefore, with information inputted from only 2017 forage results in FARMAX, incorporation of warm season forages did not help to increase predicted milk production throughout the grazing season in farm systems.

Introduction

Pasture production and quality are essential components of grazing operations, especially for certified organic dairy grazing operations where cows must consume more than 30% of their total dry matter intake (DMI) from pasture each year (USDA-AMS, 2015). Changing temperatures, as well as other elements including rain fall, pasture management, and soil quality can have significantly effects on pasture development and therefore cow DMI (Butler et al., 2017; Lobet et al., 2014). The grazing season in Tennessee and Kentucky, as well as other areas in the southeast US states runs from March into November. Typical forages utilized in this area are cool season forages, such as tall fescue. These cool season forages have optimal growth rates at atmospheric temperatures ranging from 18-24°C and soil temperatures greater than 4°C (Butler et al., 2017). However, during the grazing season weather can fluctuate significantly. Average temperatures in Hopkinsville, KY (where the majority of farms in this study were located) over the past 30 years from March-November ranged from 8.7-26.0°C during the grazing season with average highs reaching well above 35°C. This increase in temperature can lead to a sharp decrease in forage production of cool season forages, or the “summer slump”.

Decrease in the productivity of these forages can have effects on dairy cow production due to not only decreased forage yields, but also decreased nutrient availability in those forages. In order to combat this slump, previous researchers in other areas of the US have incorporated warm season forages in with cool season ones to fill this slump (Ruh et al., 2018). Warm season forages flourish in warmer temperatures with higher optimum growth rates at atmospheric temperatures ranging from 25-35°C and soil temperatures greater than 16°C. These warm season forages are more productive during the hot summer season, and utilization of warm season forages with cool season forages may potentially increase both quality and yield of forage mixtures during the summer season therefore filling the summer slump (Salisbury and Ross, 1985).

In Chapter 1, the effect of four different forage mixtures containing both warm and cool season forages on organic pasture production was analyzed. The mixtures included: the cool season mixture (CS) which contained only cool season species: orchard grass, tall fescue, red clover, and alfalfa. The warm season mixtures included the: Warm Red Clover mixture (WRC) which contained the warm season species of crab grass and annual lespedeza with the cool season species of annual ryegrass and red clover, the Warm Crimson Clover mixture (WCC) contained the warm season species of sorghum-X sudan-grass hybrid (sudex) and cowpea with the cool season species of annual ryegrass and crimson clover, and lastly the Warm Turnip and Rape mixture (WTR) which contained warm season species: sudex and cowpea, cool season grasses: oats and annual ryegrass, and cold tolerant forage brassicas: turnip and rape. This study found that in atypical mild summer conditions, when incorporating warm season forages in with cool season ones, pasture quantity of mixtures containing warm season species remained the same as the cool season mixtures in summer, however, numerically all warm season mixtures produced more kg DM/ha than the cool season mixture. During the trial the pasture containing all cool season species had the highest forage quality (highest concentrations or crude protein and lowest fiber levels) across the whole year. However, in this study the impact of pasture mixtures on milk production per season was not able to be analyzed due to the small size of the forage mixtures planted on farm and the size of the herds grazing them (0.1-0.2 ha plots, 40 + milking cows). Therefore, in order to answer this question, a whole farm modeling system was utilized to predict the effects of the different forage mixtures on dairy cow production.

FARMAX (New Zealand) is a whole farm system mathematical model designed for dairy producers who utilize pasture to make managerial decisions based upon certain farm factors. FARMAX Dairy Pro was developed using Delphi®. FARMAX Dairy Pro is a combination of pasture model originally called Stockpol (Marshall et al., 1991; Webby et al., 1995) with the animal components of MOOSIM (Bryant et al., 2008). The program utilizes past information from different feeds and pastures such as regrowth rates, decay, pasture cover, and pasture thresholds in predicting pasture growth rates throughout each month and season (Bryant et al., 2010).

This system also analyzes the effects of forage production on a monthly to bi-weekly basis, allowing detailed analysis on the effect of forage mixtures on each of the different farm systems created (Bryant et al., 2010). Therefore in order to estimate the impact of four different forage mixtures from Chapter 1, Farmax was utilized to predict farm system milk responses to each forage mixture. The goal of this study was to predict the effects of four different forage mixtures on milk production in pasture-based dairy systems in Tennessee and Kentucky, US. It was hypothesized that as forage quality and production increase, organic dairy farm systems will increase in production.

Materials and Methods

Farm Collections and Forage Inputs

Forage mixture production results in Chapter 1 from March-November, 2017 were entered into Farmax Dairy (New Zealand) to replicate forage quality and growth of the four mixtures tested (Table 2.2). The effects of changing quality and quantity of forages on milk production were then predicted using Farmax (New Zealand). Forage samples were collected 5.9 ± 5.6 days prior to grazing from all four different forage mixtures (Table 2.1) to determine forage yield, composition, and quality. Quality measurements including: acid detergent fiber (ADF), neutral detergent fiber (NDF), and digestibility of each plot were analyzed using near infrared spectroscopy (NIRS). Forage nutritive values were determined by using near-infrared spectroscopy (NIRS) technology provided by a Unity Scientific SpectraStar 2500XL-R (Milford, MA) using the 2017 Mixed Hay calibration for provided by the NIRS Consortium (Hillsboro, WI). Metabolizable energy (ME) was calculated using the equation adapted from the equation for forage TDN from SGS Agrifood Laboratories (Guelph, ON) and the equation for ME for lactating cows from NRC, 2001:

$$\text{ME (MJ/kg)} = (1.01 \times (0.04409 \times \text{TDN}) - 0.45) \times 4.184$$

Nutritive values from these mixtures were plugged into the whole farm model (Farmax Dairy Base, New Zealand; Table 2.2). Simulations in model included nutrient quality measures of spring mixtures from March – May, summer mixtures from June – August, and a fall mixtures from September – November. Fall yields were estimated by averaging the yields from spring and fall for each mix. Estimations for each season's yields were then used to calculate the growth rate of each mixture:

$$\text{Growth rate (kg DM/cow/d)} = \text{Seasonal yield (kg DM/ha)} / \text{number of months} / 30 \text{ days}$$

The growth rate calculations for each forage mixture were then plugged in for each forage mixtures in each season accordingly to accurately simulate forage performance in the model.

Farm System Assumptions

Four farms systems were created and included Jersey (J), Holstein Friesian (HF), high-input, and low-input systems (Holstein Friesian High-Input [HF-HI], Holstein Friesian Low-Input [HF-LI], Jersey High-Input [J-HI], and Jersey Low-Input [J-LI]; Table 2.3). All farms have 50 lactating cows throughout the year grazing at a rate of 2 cows/ha (25 ha of grazing pasture), an initial mating date of September 15, a 60 day dry period, and a calving rage of ~10 weeks from June 21 - August 31. Breeding worth (BW; a New Zealand based calculation which ranks cows on their expected ability to breed profitable and efficient replacements) for HF herds was BW= 241, while the breeding worth for J systems was BW = 243. These numbers were derived from the top 5% of herds from Dairy NZ (www.dairynz.co.nz). Average BCS for all herds was 5 on the New Zealand scale, which when converted to the US scale is approximately a BCS of 3. In order to convert to the United States BCS score (BCS_{US}; 1-5) from the New Zealand score (BCS_{NZ}; 1-9) used in Farmax, the equation from Roche et al. (2004) was utilized:

$$BCS_{NZ} = (BCS_{US} \times 2) + 0.5$$

Body weight inputted for HF (498kg) and J (369kg) represented the average of each breed on pasture-based systems (Prendiville et al., 2009). Farms were set up in the Northland area of New Zealand, where temperatures were closet to those found in the Southeast area. Simulations of high-input systems consumed forage mixtures throughout the grazing season, annual ryegrass hay, corn grain, and corn silage. Simulations of low-input systems consumed forage mixtures throughout the grazing season and corn grain with offered amounts varying by breed and system (Table 2.4). These values were then plugged into the performance tab for dairy cows in Farmax and milking performance was predicted.

Whole Farm Analysis (FARMAX) Description

Farmax Dairy Pro was developed using Delphi®. Farmax Dairy Pro is a combination of pasture model originally called Stockpol (Marshall et al., 1991; Webby et al., 1995) with the animal components of MOOSIM (Bryant et al., 2008). To predict pasture growth, historical data of monthly growth rates are utilized and described in Marshall et al. (1991). The program utilizes past information from different feeds and pastures such as regrowth rates, decay, pasture cover, and pasture thresholds in predicting pasture growth rates throughout each month and season (Bryant et al., 2010).

Model Simulations

Simulations were conducted using Northland, NZ with hilly terrain. The Farmax model system accounts for weather patterns in the South Pacific region. To account for this, when inputting information into the model, months were flipped for season to reflect months and seasons of the northern hemisphere. Results in this study were reported as the months mimicked in the US. Systems were fed test mixtures from March-November; with cows consuming forage mixtures from March- November (Table 2.4). Systems were feed hay, corn grain, and corn silage if a HI system in the winter months (December – February). Monthly estimations for herd milk yield; milk protein, and milk fat (kg/cow/d) were analyzed throughout the entire year. Results are conferred in terms of average monthly production from December 2016 - November 2017.

Results

Predicted Milk Yields

Simulations predicted that milk yields across all systems and forage mixtures would peak in March and decline until August. As expected, the high input systems estimated higher milk production than their low input counterparts. However, after peak production, the model predicted similar milk yields for both high-input and low-input systems within breed until August (simulated mid to late stage lactation). After August when farm systems transitioned into fall grazing, in farm systems that consumed the CS mixture, milk yields plateaued across all systems creating a parabola shaped lactation curve instead of a wave. However, in predictions for farm systems consuming warm season mixtures in fall, all but the J-HI increased milk yields and observed a wave shaped lactation curve. In spring, however, the Jersey and Holstein Friesian low input systems reacted differently to the introduction of forage mixtures in March (Figure 2.1). Predictions of the HF-LI system indicated that estimated milk yield increased an average of 8.8 kg/cow/d across mixtures when introduced to forage mixtures in March. Although the J-LI system predicted increases from February to March as well, the average increase across mixtures was 4.5 kg/d, which is approximately half the increase estimated for the HF-LI system (Figure 2.1).

When average daily milk yields were calculated, the HF-HI system averaged the highest milk yields with 23.6 kg/cow/d across all forage mixtures. The average milk yields across all mixtures were estimated to be the highest in the CS mixture, which averaged 19.8 kg/cow/d milk yields across all systems. All warm season mixture predictions averaged from 18.7-18.9 kg/cow/d milk yields with the lowest average (18.6 kg/cow/d) in the WTR mixture (Table 2.5).

Milk Components

Both milk fat and milk protein followed similar trends across systems. Milk fat yield estimations peaked in spring (March – May) with the exception of the HF-HI system while grazing the turnip mixture. When introduced to the WTR mixture in March, yield estimations decreased slightly (Figure 2.2). Across all mixtures and systems, average milk fat was estimated to increase in spring, decrease through summer, and then increase slightly in fall with the exception of a select few farm systems on different forage mixtures (Figure 2.2). The J-HI system did not predict increases in fall in all warm season mixtures. While J-HI consumed the CS mixture, yield predictions increased more drastically in fall. In warm season mixtures, milk fat yield predictions increased less than 0.1 kg/cow/d in fat yield compared to the 0.23 kg/cow/d increase in milk fat yield estimated while consuming the CS mixture from September – November (Figure 2.2).

Average daily milk fat yields were highest in the in the J-HI system when consuming the CS mixture with an average of 1.13 kg/cow/d of milk fat. The CS mixture averaged the highest quality, leading to not only the J-HI producing the highest amount of milk fat out of all systems, but the mixtures producing the highest average on a whole across all systems with an average milk fat/cow/d of 0.99 kg. The warm season mixtures of WCC and WTR averaged 0.90kg/d milk fat yields across all systems. However, the WRC mixture averaged slightly higher estimations with an average of 0.91kg/cow/d milk yield.

Milk protein yields followed the same trends: increasing protein yield during the spring, decreasing as the systems moved into summer, and then increasing yields of protein or plateaued yields in fall depending on system and forage mixture (Figure 2.3). Milk protein yields were greatest in the HF-HI system with the highest yields observed while grazing the WRC mixture with 1.19 kg/d milk protein (Figure 2.3). Similar to the milk fat yields, the HF-LI was significantly affected by the introduction to forage mixtures, with spikes in milk protein yields increasing up to an additional 0.19 kg/d. All other systems also increased during this time, however, not to the same extent (Figure 2.3).

Average milk protein yields were highest in the CS mixture, or the highest quality mixture, which averaged 0.80 kg/d predicted milk protein yields across all systems. All warm season mixtures ranged from 0.72-0.74 kg/d milk protein yields, with the WRC mixture yielding 0.74kg/cow/d milk protein yield. The other mixtures, WCC and WTR, which had lower average energy levels in summer, averaged 0.73 and 0.72 kg/cow/d milk protein respectively.

Discussion

When analyzing the milk curves predicted by FARMAX, many of the predictions did not follow a typical lactation curve that is experienced by a cow in confinement, or a curve that increases until ~ 90 days and then slowly declines until dry off (Garcia and Holmes, 2001). This was expected for the HI systems in this study who are not as dependent on forage quality, however, this was not the case. This is due to the fact that cows who are pasture based can exhibit different lactation curves depending on a multitude of factors, including not only forage quality but also calving season. In a study conducted by Garcia and Holmes (2001), spring and fall calving lactation curves were analyzed. Spring- calved cows exhibited lactation curves similar to those of cows fed a TMR in a confinement system, or the curve that peaks at ~90 days and then drops off. However, fall-calved cows exhibited a different shaped lactation curve. Fall calved cows exhibited lower yields at peak lactation, but higher yields in mid and late lactation. This caused a curve more similar to a wave rather than a parabola. In this study, calving was inputted to be in fall to mimic organic operations utilized in the study from Chapter 1. Lactation curves for the low-input farm systems estimated similar lactation curves to those calculated in the study by Garcia and Holmes with a wave shaped lactation curve (2001). However, this did not hold true for all systems.

Milk yield predictions across all systems and forage mixtures increased from winter (December – February) into spring (March-May) and then declined into summer (June-August). However, depending on inputted forage mixture performance, cow breed, and concentrate input level, fall trends in milk yield varied. When performance was predicted for systems consuming the CS mixture, all farm systems did not predict an increase in fall milk production as expected. This was not expected due to the calving inputs, however, the lack of increase in milk yield in fall across all farms could be due to the consistency of the high energy and low fiber levels the CS mixture exhibited in 2017 from spring – fall. When analyzing the quality of the CS mixture, it maintained similar energy, fiber, and protein from spring-fall. Therefore, without the increased nutrient content in fall, milk production may have been predicted to continue to decrease rather than increase again during this time.

The sustained high quality of the CS mixture also lead to the highest average yields of milk/cow/d. Although some mixtures may have had higher milk yields varying from system to system, when all of the systems were averaged within each mixture, the CS had the highest average milk yield/cow/d with 1kg/cow/d more than the next highest forage mixture (the WRC mixture). All warm season forages averaged to be very similar in ilk yields, although predictions for each system within mixtures varied depending on whether the systems were HI or LI.

However, significant changes in quality were observed in the warm season mixtures, which all increased in quality in the fall season compared to summer season. Warm season forage mixtures decreased in fiber and increased in energy from summer to fall, and many increased in CP as well (Table 2.2). These changes did have an effect on milk production estimates. Decreased fiber levels lead to increased predicted intake, which was observed across farms from summer into fall. For example in the WTR mixture, estimated intakes averaged 15.2 kg DMI in summer and 16.0 kg DMI in fall across farm systems while grazing the warm season forage mixtures. In addition to increased DMI, fiber is also inversely correlated to energy (NRC, 2001). Therefore, not only were the cows predicted to consume more forage, but also consume a more energy dense forage mixture. For example, the average energy for warm season forage mixtures in summer was 9.38 MJ/ kg DM. However, once forages transitioned into fall, energy increased to 10.8 MJ/ kg DM on average across mixtures. This increase in forage quality (energy) in fall in the warm season mixtures may have led to the increased predictions across farm systems in milk yield in the fall season (September – November).

Increases in milk yield held true for all but the J-HI farm system, whose estimations consistently plateaued in milk yield in fall across all mixtures. This was first believed to be due to the effects of increased supplementation, however, when analyzing the estimates for milk yield in the HF-HI system, milk yield increased in fall when cows were grazing the warm season forage mixtures. Therefore, this lack of increase may be due to differences in HF and J feed energy conversion and efficiency. Jersey cattle are more efficient at converting energy into milk than HF cattle, and therefore are predicted to not be as effected by changes in forage quality. Ergo, milk production in J systems may not increase as much in fall when forage quality increases (Prendiville et al., 2009).

Forage mixture quality also appeared to have greater predicted effects on HF than J cows when looking at the lactation curves in spring. In the spring season, when low input cows are first transitioned from hay to forage mixtures, a significantly higher increase in milk production was observed in HF cows than J cows, with +8.9 and +4 kg/cow/d milk yield increase on average respectively. Like-wise in both the HF-HI and HF-LI systems, milk yield increased in the fall season when forage quality increased while the J-HI did not, suggesting again that HF are more effected by forage quality in this model system for milk yields (Bryant et al., 2010).

Estimates for yields of both milk protein and milk fat followed similar trends. Yields of components increased into the spring and declined into summer. However, unlike milk yields,

yields of both protein and fat for many of the farm systems in fall increased instead of plateauing off or continuing to decline. For milk fat, the J LI farm system predicted increased fat yields the end of lactation on the CS and WRC mixtures; however, the J-HI system did not increase in milk fat yields in fall while grazing these forage mixtures. This again, may be due to the consistency of the CS mixture. Across all warm season mixtures, the HF-HI system predicted the highest yields of milk fat in spring, however, once entering summer and fall, both high-input groups produced similar fat yields. In the CS mixture, however, the HF-HI estimated the largest yields of milk fat in the winter, but during the summer and fall, the J-HI group produced more milk fat. This may be due to genetics and the Jersey cow's increased heat tolerance as well as the average higher amount of energy allowing them to produce more fat (Bryant et al., 2010)

Milk protein yield predictions were greatest in the HF-HI system. Holstein Friesians are genetically predispositioned to produce more milk protein than jerseys due to higher milk yields. Although Jersey cows produce higher protein percent protein and fat, in yield of protein, Holstein Friesians have greater yields (Prendiville et al., 2009). Therefore, both the HF-HI and HF-LI systems predicted highest yields of milk protein in the spring grazing season on warm season mixtures when forage quality and yields were high. However, once the season switched to summer, all farm systems dropped in milk protein production with HF-LI yielding lower milk protein than the J-HI system. This may be due to the higher efficiency of Jerseys on pasture (Prendiville et al., 2009). When analyzing the predicted effects of mixture on milk protein yields, again the CS mixture which had the highest quality averaged the highest yield of milk protein (Table 2.5). The CS mixture estimated 0.6kg/cow/d more on average compared to the next highest mixture (the WRC mixture, which was also very similar to the other warm season mixtures with the WRC mixture being only 0.1-0.2kg./cow/d more than that of the WCC and WTR mixtures respectively.

These predictions, however, were limited due to the fact that a southern hemisphere model was utilized to predict to milk production of northern hemisphere grazing dairy systems. The weather patterns in New Zealand are more mild and do not reach neither the low or high temperatures observed throughout the year. Average temperatures in Northland, NZ (where the farm models were set to be located) ranged from 11°C to 20°C throughout the grazing season (worldweatheronline.com) while temperatures averaged in western Kentucky and eastern Tennessee (locations of farms utilized in Chapter 1) ranged from 9.8 to 26.4°C throughout the grazing season (Chapter 1, Table 1.1). Rainfall was also different, with average rainfall/month totally from 47.7-297.3 mm in Kentucky and Tennessee (Chapter 1, Table 1.1), while rainfall in Northland, NZ averaged from 25-160 mm/month.

In addition, the FARMAX Dairy Pro model utilizes cattle based out of New Zealand, which may have genetics different than those many producers utilize in the US. Therefore, it may be on interest to compare the grazing performance under similar conditions of dairy cattle of similar breeds with different genetics to analyze the potential differences in production on similar conditions.

Conclusion

Mixture quality, breed, and input type had predicted effects on milk, milk protein, and milk fat yields. Predicted lactation curves for all systems were similar to those of pasture based dairy systems. However, the high-input systems, especially the J-HI system, were estimated to plateau off in many of the parameters instead creating a parabola shaped lactation curve instead of increasing in the fall similar to other systems. When analyzing across all farms, the mixture that predicted the highest yields pf milk, milk fat, and milk protein was the CS mixture. This may be due to the consistent high quality observed in this mixture from spring into fall. While the warm season mixtures may have exceeded the CS mixture in certain quality parameters randomly throughout the year, the consistency of the CS mixture helped to maintain the milk and milk component yield estimates of farms in this simulation. Therefore, when analyzing the estimations made by this model, mixture CS was the forage mixtures that allowed the highest predicted milk production. Although mixture CS was the lowest yielding in DM, its increased quality throughout the season helped this mixture to maintain higher estimated yearly production totals.

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Appendix

Table 2.1 Species composition of brassicas and cool and warm season legumes and/or grasses of four forage mixtures entered in model to predict forage mass and nutrient production used in inputs for 2017 FARMAX simulation

Mixture	Species
CS	Alfalfa, Red Clover, Orchard Grass, and Tall Fescue
WRC	Annual Ryegrass, Red Clover, Crab Grass, and Annual Lespedeza
WCC	Annual Ryegrass, Crimson Clover, Sorghum-X Sudan-grass Hybrid, and Cowpea
WTR	Turnip, Rape, Oats, Annual Ryegrass, Sorghum-X Sudan-grass Hybrid, and Cowpea

Table 2.2 Inputs for yields of dry matter (metric ton DM/ha) and metabolizable energy (ME, MJ/kg DM), as well as percent neutral detergent fiber (NDF) and digestibility (in vitro digestibility at 48h; IVTD48H) of mixtures grazed in 2017 FARMAX simulation

Mixture[1]	Dry Matter	ME	NDF	CP
Spring				
WRC	16.1	10.12	47.39	16.5
WCC	14.9	10.22	47.02	16.2
CS	9.4	10.42	43.93	20.2
WTR	14.6	10.24	46.83	15.9
Summer				
WRC	7.3	9.44	52.58	17.7
WCC	8.1	9.06	58.51	14.9
CS	8.3	10.07	46.54	18.9
WTR	9.6	9.00	58.03	14.8
Fall				
WRC	-	10.80	36.6	26.5
WCC	-	11.04	34.81	23.8
CS	-	10.59	44.41	22.0
WTR	-	10.78	37.83	19.2

[1]Mixtures A (Annual Ryegrass, Red Clover, Crab Grass, and Annual Lespedeza), B (Annual Ryegrass, Crimson Clover, Sorghum-X Sudan-grass Hybrid, and Cowpea), C (Alfalfa, Red Clover, Orchard Grass, and Tall Fescue), and D (Turnip, Rape, Oats, Annual Ryegrass, Sorghum-X Sudan-grass Hybrid, and Cowpea).

Table 2.3 Inputs for farm simulations in 2017 FARMAX simulation

Farm System	Breed	Breeding Worth	Body Weight, kg	BCS	Average Stocking Rate (Cows/ha)
HF-HI	Holstein Friesian	241	498	3	2
HF-LI	Holstein Friesian	241	498	3	2
J-HI	Jersey	243	369	3	2
J-LI	Jersey	243	369	3	2

Table 2.4 Inputs of dry matter (DM) intake implemented to conduct 2017 FARMAX simulations (kg DM/d)

Farm System	HF-HI	HF-LI	J-HI	J-LI
Test Mixture Pasture	12	16	9	12
Corn Grain	2.7	2.7	2.7	2.7
Annual Ryegrass Hay- Winter	9	2.7	12	0.5
Annual Ryegrass Hay- Grazing Season	0.5	0	0.5	0
Corn Silage	7	0	4	0

Table 2.5 Average daily milk, milk protein, and milk fat yields on each farm system: Holstein Friesian High-Input (HF-HI), Holstein Friesian Low-Input (HI-LI), Jersey High-Input (J-HI), and Jersey Low-Input (J-LI) consuming 4 test plot forages mixtures[1] in 2017 FARMAX simulations

	FARM SYSTEM				
Predicted Yields, kg/cow/d for each forage mixture	**HF-HI**	**HF-LI**	**J-HI**	**J-LI**	**AVERAGE**
Milk					
CS	23.7	20.0	18.9	16.7	19.8
WRC	24.1	20.0	18.1	13.5	18.9
WCC	23.3	19.2	17.4	14.7	18.7
WTR	23.3	19.3	17.1	14.5	18.6
Milk Protein					
CS	1.04	0.89	1.13	0.91	0.99
WRC	1.06	0.89	0.98	0.73	0.91
WCC	0.88	0.71	0.72	0.60	0.90
WTR	1.04	0.86	0.92	0.79	0.90
Milk Fat					
CS	0.89	0.74	0.88	0.70	0.80
WRC	0.91	0.74	0.76	0.55	0.74
WCC	0.88	0.71	0.72	0.60	0.73
WTR	0.87	0.72	0.71	0.60	0.72

[1] **CS** (Alfalfa, Red Clover, Orchard Grass, and Tall Fescue), **WRC** (Annual Ryegrass, Red Clover, Crab Grass, and Annual Lespedeza), **WCC** (Annual Ryegrass, Crimson Clover, Sorghum-X Sudan-grass Hybrid, and Cowpea), and **WTR** (Turnip, Rape, Oats, Annual Ryegrass, Sorghum-X Sudan-grass Hybrid, and Cowpea).

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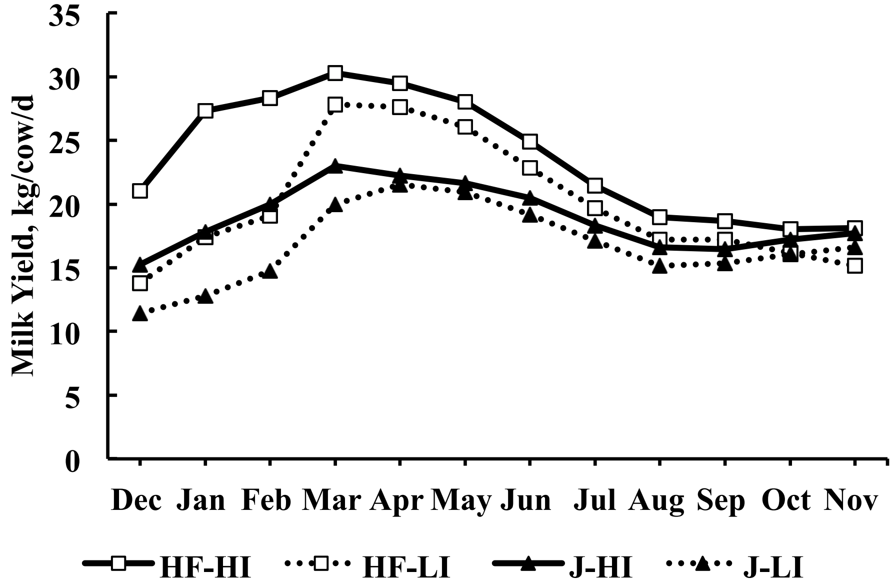

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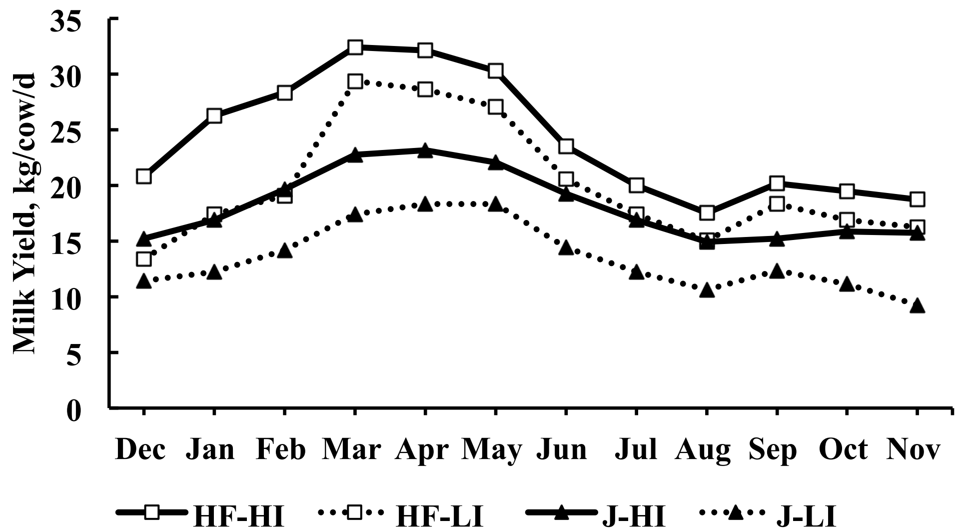
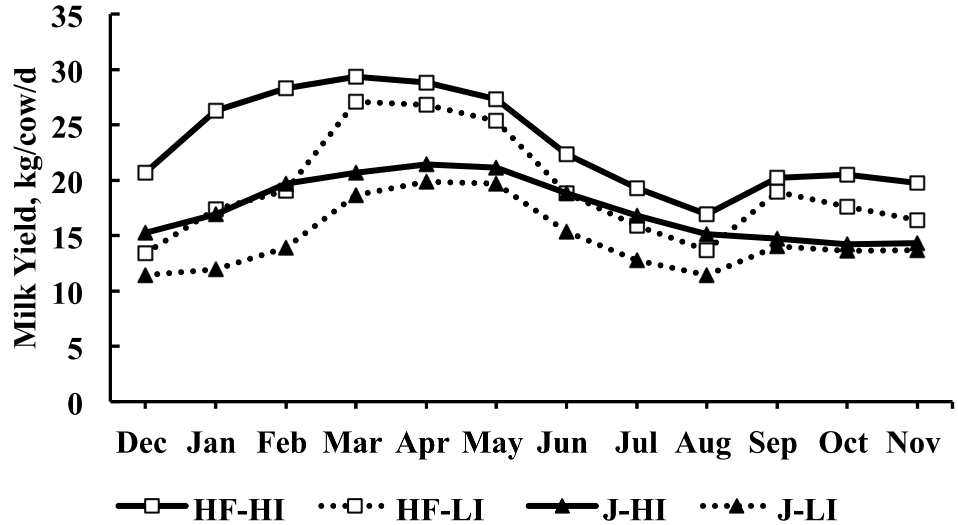


Figure 2.1 (a – d). Predicted milk yields (kg/cow/d) on Holstein Friesian High-Input (HF-HI), Holstein Friesian Low-Input (HI-LI), Jersey High-Input (J-HI), and Jersey Low-Input (J-LI) of cows on pasture consuming 4 test plot forages mixtures [1]

[1]**a)** CS (Alfalfa, Red Clover, Orchard Grass, and Tall Fescue), **b)** WRC (Annual Ryegrass, Red Clover, Crab Grass, and Annual Lespedeza), **c)** WCC (Annual Ryegrass, Crimson Clover, Sorghum-X Sudan-grass Hybrid, and Cowpea), and **d)** WTR (Turnip, Rape, Oats, Annual Ryegrass, Sorghum-X Sudan-grass Hybrid, and Cowpea).

c)



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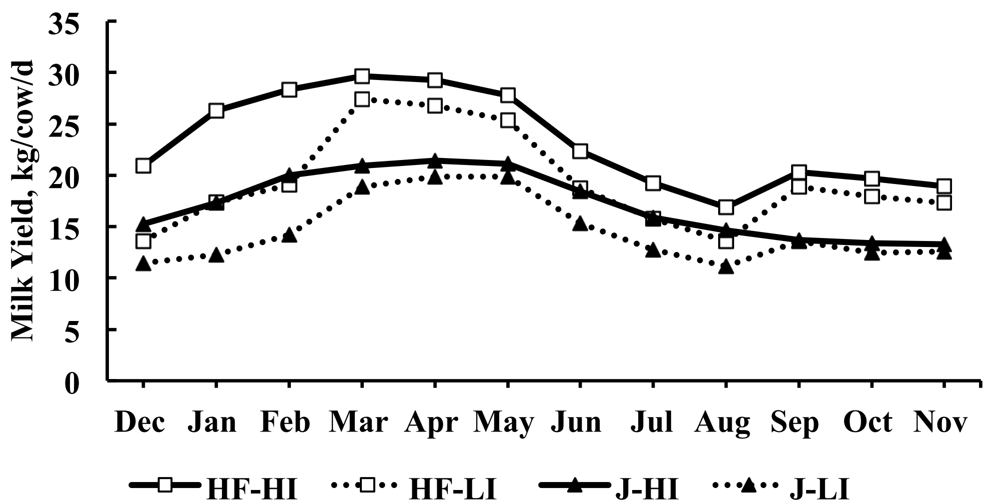
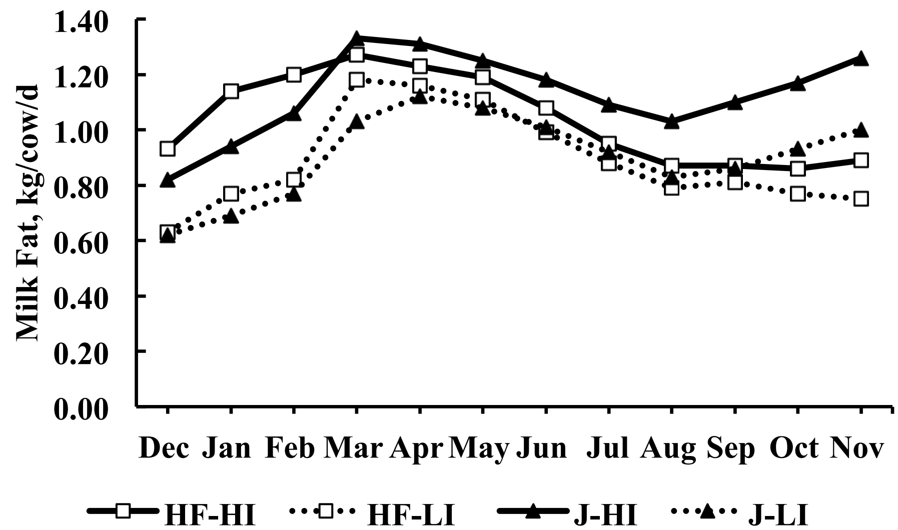


Figure 2.1 continued

a)



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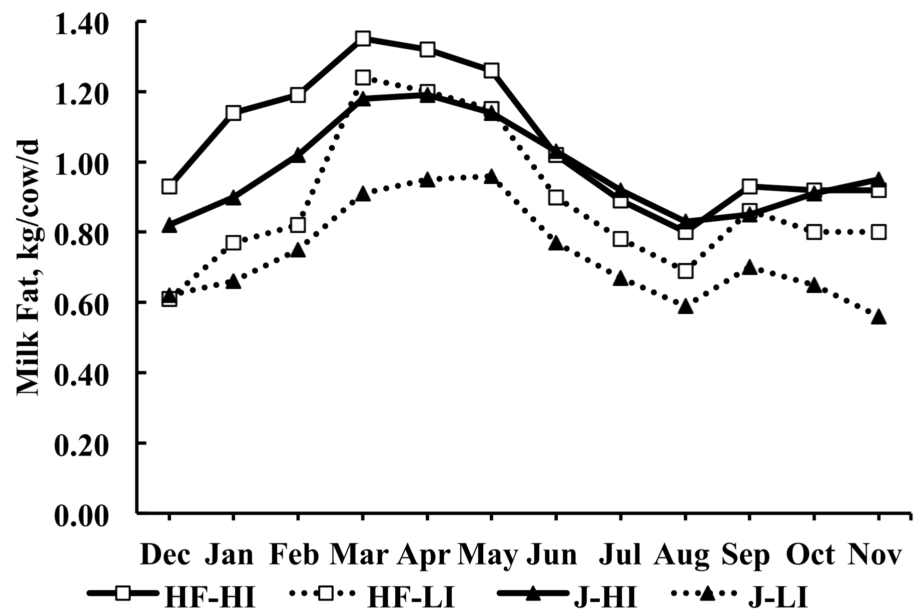
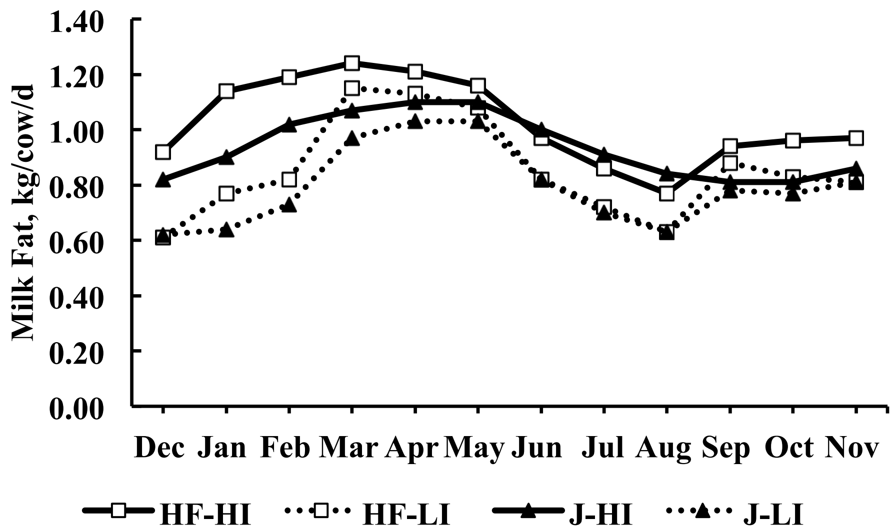


Figure 2.2 (a – d). Predicted milk fat yields (kg/cow/d) on each farm system: Holstein Friesian High-Input (HF-HI), Holstein Friesian Low-Input (HI-LI), Jersey High-Input (J-HI), and Jersey Low-Input (J-LI) of cows on pasture consuming 4 test plot forages mixtures[1]

[1] **a)** CS (Alfalfa, Red Clover, Orchard Grass, and Tall Fescue), **b)**WRC (Annual Ryegrass, Red Clover, Crab Grass, and Annual Lespedeza), **c)**WCC (Annual Ryegrass, Crimson Clover, Sorghum-X Sudan-grass Hybrid, and Cowpea), and **d)** WTR (Turnip, Rape, Oats, Annual Ryegrass, Sorghum-X Sudan-grass Hybrid, and Cowpea).

c)



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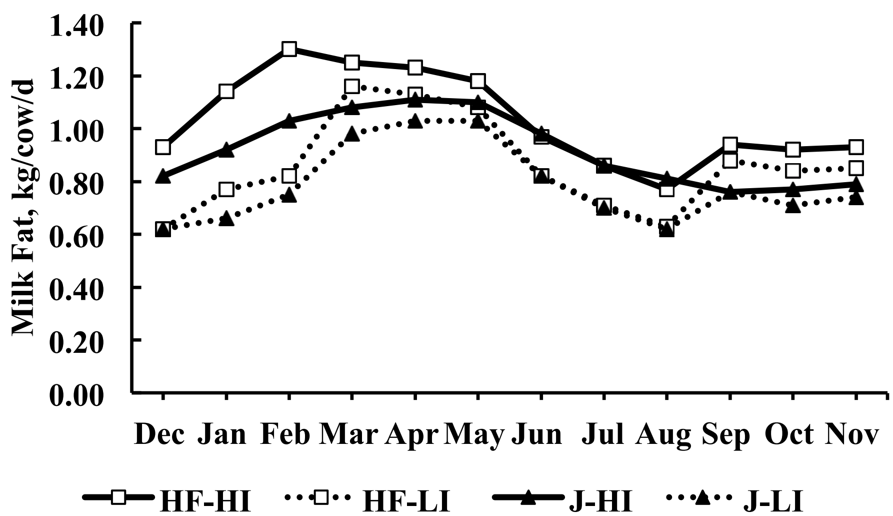
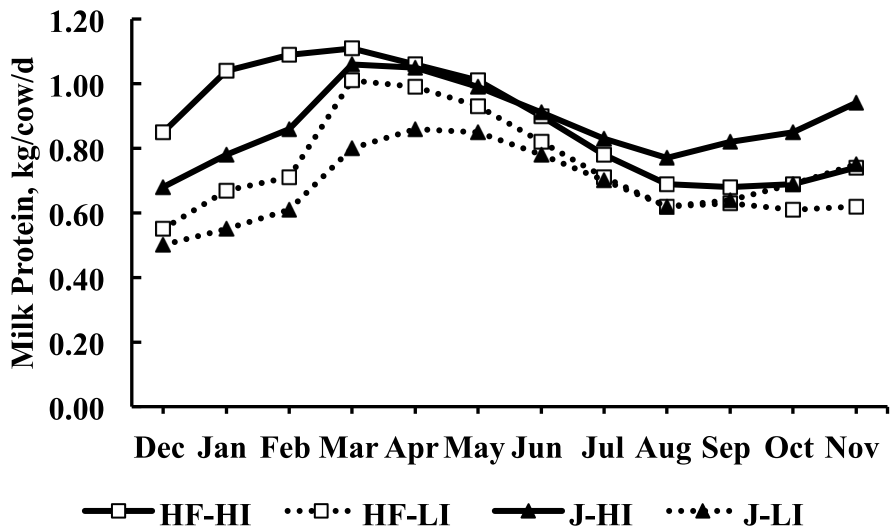


Figure 2.2 continued

a)



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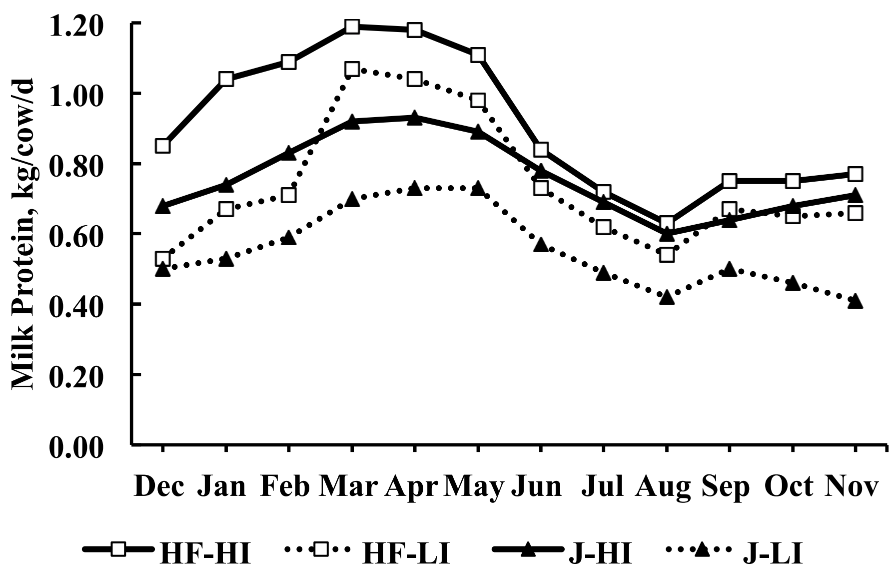
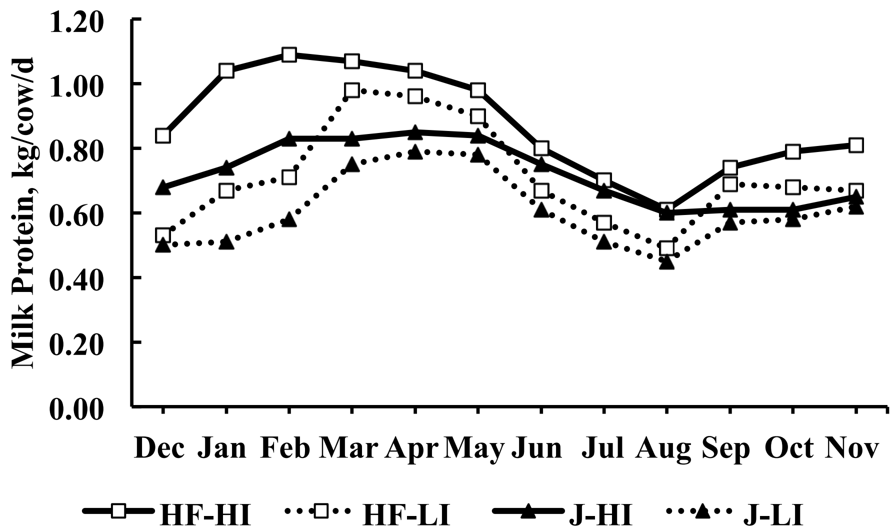


Figure 2.3 (a – d). Predicted milk protein yields (kg/cow/d) on each farm system: Holstein Friesian High-Input (HF-HI), Holstein Friesian Low-Input (HI-LI), Jersey High-Input (J-HI), and Jersey Low-Input (J-LI) of cows on pasture consuming 4 test plot forages mixtures[1]

[1] **a)** CS (Alfalfa, Red Clover, Orchard Grass, and Tall Fescue), **b)**WRC (Annual Ryegrass, Red Clover, Crab Grass, and Annual Lespedeza), **c)**WCC (Annual Ryegrass, Crimson Clover, Sorghum-X Sudan-grass Hybrid, and Cowpea), and **d)** WTR (Turnip, Rape, Oats, Annual Ryegrass, Sorghum-X Sudan-grass Hybrid, and Cowpea).

c)



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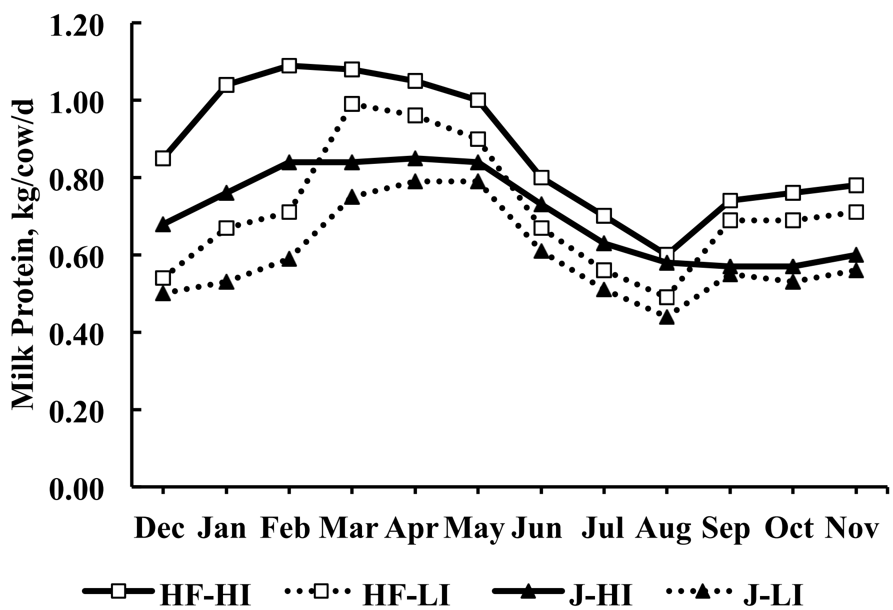

Figure 2.3 continued

CONCLUSION

By incorporating warm season forages in with cool season ones, differences were observed across mixtures. Spring yielded greater DM than summer across all mixtures, however, the incorporation of warm season species did not increase summer yields as predicted. This may be due to decreased summer temperatures. Mixture C, which was composed solely of cool season perennial forages, maintained the highest quality throughout the grazing season (March-November). Therefore results should be repeated again to observe the effects of a summer season with an increased average temperature on forage mixtures.

Farmax predictions were most similar to observed results in summer, however, a large difference was observed in fall and spring. When analyzing the effects of mixtures on each farm, farms with Jersey as the predominate breed did not see a significant difference in production between mixtures, however, Holstein Friesian farms saw decreased milk yield and decreased milk component yields when grazing mixture D. This may be due to the increased fiber found in mixture D and lower digestibly, particularly in spring and summer. Mixture C increased estimated BCS, milk yields, and milk component yields in the summer months for over half of the farms. In conclusion, production of farms on mixtures did not differ greatly across different mixtures. However, levels of fiber did potentially affect DMI and energy intake of cows on pasture, leading to differences in estimated production, particularly in the summer season.

These results are only from one year of data, during an abnormal grazing season. Unseasonably cool and rainy summer months were observed during this time, potentially leading to increased quantity and yield of cool season perennial forages in the summer months. With this, it would be valuable to repeat both studies again to collect more data points. During this time it may also be beneficial to plant larger test plots and to more closely monitor cows on pasture while grazing each plot to assess actual cow production while on each pasture to better understand potential production gains/losses could be observed in each forage mixture.

VITA

Hannah Ruth Bailey was born in Southern, WV. She grew up on a small family farm raising Christmas trees and hay. Once graduating high school, Hannah attended West Virginia University where she received a degree in Agricultural Biochemistry and a minor in Business and Administration. During this time, Hannah fell in love with research as well as dairy cows and wanted to be able to pursue a career in dairy nutrition. Therefore, to be able to follow this dream, Hannah moved to the University of Tennessee to receive her M.S. in Animal Nutrition and Physiology with a focus in dairy nutrition and organic forage management. After completing her degree, Hannah plans to continue her education after gaining more experience in industry.