THESIS

GRASS AND GRASS-LEGUME MIXES FOR IRRIGATED PASTURE USING ORGANIC PRODUCTION METHODS

Submitted by

Matthew R. Booher

Department of Soil and Crop Sciences

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISON BY MATTHEW R. BOOHER ENTITLED GRASS AND GRASS-LEGUME MIXES FOR IRRIGATED PASTURE USING ORGANIC PRODUCTION METHODS BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

Committee on Graduate Work

Jessica Davis

Paul Meiman

Advisor: Joe Brummer

Department Head: Gary Peterson

ABSTRACT OF THESIS

GRASS AND GRASS-LEGUME MIXES FOR IRRIGATED PASTURE USING ORGANIC PRODUCTION METHODS

Species selection and fertility management are two of the greatest challenges facing producers of organic pasture. The objectives of this study were to:

1. Identify irrigated grass and grass-legume mixtures that possess the productivity, durability, and forage quality to meet the needs of organic dairies in the western US.
2. Evaluate the use of legumes and compost as nutrient sources for pastures being managed in accordance with organic protocols.

Research was conducted for two years at the Agricultural Research, Development, and Education Center located about 4 km south of Wellington, CO. Four grass mixes: tall fescue (TF), hybrid wheatgrass-tall fescue-hybrid brome (HWG-TF-HB), orchardgrass-meadow brome-smooth brome (OG-MB-SB), and orchardgrass-meadow brome-Kentucky bluegrass (OG-MB-KB), were established in fall 2007. In 2008, plots received either a compost treatment of 22.4 Mg ha^{-1}, or were part of a control set that received no compost. Plots were harvested six times in 2008 to simulate rotational grazing, and dry matter (DM) yield, crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF) were determined at each cutting. Fertility (compost) had no effect in 2008. Total DM yield of TF (10,864 kg ha^{-1}) was higher than OG-MB-SB (9,241 kg ha^{-1}) and OG-MB-KB (8,079 kg ha^{-1}). Dry matter yield of TF in late-September was 120% higher

than the other grass mixes. In general, forage contained higher CP and lower NDF and ADF as the season progressed, resulting in increased forage quality over time. Averaged across cutting date, CP of TF (19.8 %) was 9% lower than the other grass mixes; however, CP remained adequate to meet most ruminant needs for all grass mixes at all cutting dates. In 2009, the 22.4 Mg ha^{-1} compost fertility treatment was divided to include an 11.2 Mg ha^{-1} treatment and a 0 Mg ha^{-1} control, in an effort to observe nitrogen mineralization from previous compost applications. Also in 2009, alfalfa, birdsfoot trefoil, sainfoin, and white clover were interseeded into the 2008 control plots to observe legume effects on yield and forage quality. Yield and quality data were taken for five cuttings in 2009. As a result of a low level of nitrogen in the compost, fertility had no effect on yield or quality in 2009. Total DM yield in 2009 averaged about 45% less than in 2008. Total DM yields of TF and HWG-TF-HB averaged 23% higher than the other grass mixes. Crude protein content averaged about 6 percentage points lower in 2009 than in 2008, most likely due to nitrogen deficiency. Similar to 2008, TF was lower in CP than the other grass mixes. In general, forage quality improved over the season. On average, TF (56.2 %) and HWG-TF-HB (56.9 %) had a 4% higher NDF content than the other grasses, while all grass mixes had a similar average ADF content of around 32%. Because legumes did not significantly contribute to harvested yield until cuttings 4 and 5 in 2009, cuttings 1-3 were not included in analyses of the legume treatments. The alfalfa treatment had 25% higher DM yield than the other legume treatments, due to the greater presence of alfalfa in the plots. Mix and cutting date affected CP content of the sward within the legume treatments. Similar to the results observed in the compost treatments, tall fescue had lower average CP content than the other grass mixes within the legume treatment, while OG-MB-SB averaged higher than the other grass mixes. Cutting effects for the legume treatment were similar (decreasing CP) to the compost treatment for the period analyzed (cuttings 4 and 5). NDF was affected by legume species, probably due to the greater abundance of alfalfa in the plots. The OG-MB based mixes in the legume treatments averaged 6% lower in NDF content than the other grass mixes. The management implications of this study vary based on the relative importance of pasture in an animal's diet. Tall fescue tended to yield higher than the other grass mixes in the study, but had lower CP content. While this difference may be statistically significant, levels of CP for all grasses (including TF) were adequate for most animal needs. In addition, digestible fiber content was highest in mixes containing TF, making this grass an excellent choice for producers desiring high yields, durability, and overall good quality. Conversely, the OG-MB-SB mix, while showing a moderate yield and CP content, had a higher proportion of indigestible fiber than all other mixes. This appears to be a product of the smooth brome component in the mix, and presents a case for avoiding this species if high digestibility is desired. In general, forage quality of all grass mixes improved over the growing season, peaking in late summer and fall. This study found that the addition of legumes to grass-based pasture is an excellent tool for increasing forage quality, especially crude protein content. Additionally, nitrogen management (i.e. compost testing) is vital to forage productivity and quality when using organic fertility sources.

Matthew R. Booher
Department of Soil and Crop Sciences
Colorado State University
Fort Collins, CO 80523
Spring 2010

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INTRODUCTION

Consumer demand and economic pressures are forcing more and more animal operations to increase their use of improved pasture (Martz et al., 1999; White et al., 2002). The organic dairy industry, with typically higher input costs and an inherent susceptibility to public scrutiny, is under pressure to increase its reliance on grazed forages. Proponents of increased grazing cite both the advantages of lower input costs associated with grazed forages, as well as the potential sustainability of perennial pasture-based agroecosystems (Cederberg and Mattsson, 2000; de Boer, 2003; Weller and Bowling, 2007). From an agronomic standpoint, pasture systems are an excellent option to provide protein and energy to ruminants. However, they do require proper management to remain productive and nutritious.

Soil fertility and species selection are two of the greatest challenges facing pasture managers, especially when managing under organic protocols (Emily Prisco, Aurora Organic Dairy, personal communication, 2009). In a conventional production setting, inorganic fertilizers often provide the bulk of nutrients to satisfy pasture fertility requirements. Conversely, the fertility needs of organic pasture are often met by utilizing manures, composts, or legumes. Nutrient release from organic sources such as these often vary widely based on climatic factors, physical and chemical properties of the sources, and biotic factors. Additionally, long-term release of organically-bound nutrients introduces another level of complexity to organic fertility management (Gagnon and Simard, 1999; Eghball, 2000). While the use of organic fertilizers is a necessity for organic producers, the benefits of these tools can be realized in conventional systems as well. Composts and manures make valuable use of on-farm nutrients, and are often less expensive than commercial nutrient sources (Butler and Muir, 2006).

Legumes are also a common source of nutrients in organic pasture systems. Mixed grass-legume pastures have many advantages over straight grass mixes, including nitrogen fixation and increased protein content and digestibility (Dougherty and Rhykerd, 1985; Broderick, 1995). From an economic point of view, the use of pasture legumes translates into decreased fertilizer costs and increased value of the forage resource.

For producers managing straight grass or grass-legume mixes using organic practices, choosing the appropriate species to include in a pasture mix can be difficult. Along the Front Range of Colorado, semi-arid conditions and soils with low organic matter create unique challenges to the establishment and maintenance of perennial, cool-season grasses and legumes. Additionally, forage species must withstand relatively frequent defoliation while remaining productive and nutritious. For organic dairies, these requirements must be met while adhering to organic protocols (e.g. organic fertility sources, organic weed control, etc.). The objectives of this study were to:

1. Identify grass and grass-legume mixtures that possess the productivity, durability, and forage quality to meet the needs of organic dairies in the western US., and
2. Evaluate the use of legumes and compost to supply nutrients to pastures being managed in accordance with organic protocols.

MATERIALS AND METHODS

This study was conducted during the 2008 and 2009 growing seasons at the Colorado State University Agricultural Research, Development, and Education Center located about 4 km south of Wellington, CO (40°39´ N 104°59´ W, elevation 1,554 meters). Average annual precipitation is 33 cm with about 88% falling from April through October. Average monthly temperatures are 0°C in January and 22°C in July. The study site was located on a Fort Collins loam soil (fine-loamy, mixed, mesic Aridic Haplustalf).

The previous crop was alfalfa, which was killed in summer 2007. The field was clean-tilled, and a blanket compost application of 22.4 Mg ha^{-1} (0.62 % total N) was incorporated prior to planting. This compost application provided approximately 13.4 kg ha^{-1} of immediately available nitrogen and 128 kg ha^{-1} of organically bound nitrogen. Roughly 25 kg ha^{-1} (~20%) of this organic fraction would have become available during the 2008 growing season (Eghball, 2000). The nitrogen fractions for each of the composts used in this study are reported in Table 1.

Table 1. Nitrogen fractions of three compost applications used in the study.

Application	Total- N	Organic- N	Ammonia- N	Nitrate- N
	-------------Concentration (as is)-------------			
Fall 2007	0.62	0.57	0.00	0.06
Spring 2008	1.07	1.01	0.01	0.05
Fall 2008	0.29	0.26	0.03	0.00

Four grass mixes, comprised of one or more grass species, were seeded on September 5, 2007 with a no-till drill (Model 3P605NT, Great Plains Mfg., Inc., Salina, KS) fitted with a cone seeder attachment (Kincaid Equipment Manufacturing, Haven, KS) and set at a 17-cm row spacing. Plots receiving a legume treatment were simultaneously planted with one of four legumes. The grass mixes and legumes used are shown in Table 2. Plots measured 3 by 12 m and were arranged in a randomized complete block design with three replications.

<u>2008 Field Season</u>

On April 22, 2008, a fertility treatment was imposed in which half of the plots were fertilized with dairy compost at a rate of 22.4 Mg ha^{-1} (1.07% total N according to Table 1). This compost application would have provided about 13.5 kg ha^{-1} of immediately available nitrogen and 45 kg ha^{-1} of mineralized nitrogen available over the 2008 growing season (Eghball, 2000). A visual evaluation conducted in spring 2008 revealed legume presence to be insufficient for the needs of the study. Legumes were interseeded in April 2008 in an attempt to establish the legume treatments; however, grass competition and water issues resulted in seeding failure, leaving a 0 Mg ha^{-1} control. As a result, the only fertility treatments evaluated during the 2008 season were the 0 Mg ha^{-1} control and 22.4 Mg ha^{-1} compost treatment.

Forage was collected from the plots on six cutting dates in 2008. The first harvest was taken on June 3rd when plants were relatively mature to allow for more complete establishment of the grasses. Subsequent harvests occurred when plant heights reached approximately 38 cm, or around 21 days following the previous harvest, in an attempt to simulate rotational grazing. Total rainfall from April to October measured 20.8 cm, with more than half occurring in the month of August.

Table 2. Species, varieties, and seeding rates of grasses and legumes used in the study.

Species	Scientific Name	Variety	Seeding Rate (kg ha^{-1})
Grass mix 1			
Hybrid wheatgrass	*Elymus hoffmainni*	'Newhy'	9.0
Tall fescue	*Festuca arundinacea*	'Fawn' Endophyte-free	7.3
Hybrid brome	*Bromus inermis x beibersteinii*	'Bigfoot'	10.1
Grass mix 2			
Orchardgrass	*Dactylis glomerata*	'Crown Royale'	4.5
Meadow brome	*Bromus biebersteinii*	'Paddock'	11.2
Kentucky bluegrass	*Poa pratensis*	'Ginger'	1.1
Grass mix 3			
Orchardgrass	*Dactylis glomerata*	'Crown Royale'	3.3
Meadow brome	*Bromus biebersteinii*	'Paddock'	11.2
Smooth Brome	*Bromus inermis*	'Lincoln'	5.6
Grass mix 4			
Tall fescue	*Festuca arundinacea*	'Fawn' Endophyte-free	16.8
Legumes			
Alfalfa	*Medicago sativa*	'Ranger'	9.0
Birdsfoot trefoil	*Lotus corniculatus*	'Leo'	4.5
Sainfoin	*Onobrychis viciaefolia*	'Sandhills'	22.4
White clover	*Trifolium repens*	'Durana'	2.2

<u>2009 Field Season</u>

Legumes were interseeded again in March of 2009, and initially established well as seedlings. However, it became apparent by midsummer that grass competition prohibited the legumes from becoming a significant component in most plots. By cuttings 4 and 5, alfalfa, and to a lesser extent white clover, had established and become a substantial component in many plots, although their abundance across plots was inconsistent. The presence of the other legume species remained at a level that did not contribute to harvestable yield. Volunteer alfalfa contaminated some plots in the other legume treatments, and in some cases, contributed to the harvested yield of those plots. Table 3 shows the abundance and contribution of the four legume species in this study at cuttings 4 and 5. Because of the late appearance of a legume component, only cuttings 4 and 5 were used to conduct quality analyses. Additionally, the single compost treatment from 2008 was divided in 2009 to create three compost rates: 0, 11.2, and 22.4 Mg ha^{-1}. Compost was applied on October 23, 2008 for the 2009 growing season. Poor compost (0.3% total N) was inadvertently used in this application, resulting in insufficient available nitrogen for the 2009 season (5.8 and 11.5 kg ha^{-1} of available N at the 11.2 and 22.4 Mg ha^{-1} compost rates, respectively). Consequently, all treatments were nitrogen deficient during the 2009 season; however, data was collected in a manner similar to 2008. Total rainfall from April to October measured 26.7 cm, with more than half occurring from April through July. Because of the relative similarity in nitrogen content of the three compost rates, only the 0 and 22.4 Mg ha^{-1} rates were chosen for quality analyses. Quality analyses for these compost treatments were conducted for all five cuttings in 2009.

Harvest and Sample Preparation

Harvests were performed using a Lacerator Green Chopper (Gruett's, Potter, WI) with an attached weigh bin to collect forage from a 1.5 by 12 m area in the center of the plot. Plots were harvested at a 10-cm cutting height. A subsample of approximately 400 g was collected from each plot as harvested material entered the weigh bin. All forage subsamples were dried to a constant weight at 55°C for at least 72 hours and weighed to determine forage dry matter content. Yield data taken at harvest were adjusted to report yield on a dry matter (DM) basis. Dry weight samples were then ground, first through a sheer mill (Wiley Model 4, Arthur H. Thomas Co., Philadelphia, PA) equipped with a 2 mm screen, and then through a cyclone mill (Cyclotec Model 1093, Foss Corp., Eden Prairie, MN) using a 2 mm screen, before determination of forage quality.

Forage Quality Analyses

Total nitrogen concentration of samples was measured using the Dumas combustion method (Etheridge et al., 1998) with a Leco C and N analyzer (Model CN 2000, Leco Corp., St. Joseph, MI). Crude protein was estimated by multiplying forage nitrogen concentration by 6.25.

Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined as described by Van Soest et al. (1991) using the ANKOM filter bag procedure. In the ANKOM procedure, forage samples are processed in individual filter bags and digested using an ANKOM Fiber Analyzer (Model No: ANKOM 200, Ankom Technology, Macedon, NY) in accordance with the manufacturer's protocols. An estimate of dry matter intake (DMI) as a percent of bodyweight was calculated from NDF using the equation: DMI %= 120/NDF %. Acid detergent fiber was used to determine dry matter digestibility (DMD) using the equation: DMD % = 88.9 – (0. 779 x ADF %). Relative feed value (RFV) was calculated as an additional index using both DMD and DMI. Relative feed value combines potential intake and digestibility into one number for an easy method to evaluate and compare forage quality. Relative feed value was calculated using the formula: RFV= (DMD % X DMI %)/1.29.

In addition to the yield and quality parameters tested in 2009, two other procedures were performed in an effort to quantify the legume, weed, and grass composition of each plot. To help quantify the contribution-by-mass of legumes, plant separations were performed for each plot at all five cuttings in 2009. This was accomplished by taking a second subsample at time of harvest, which was then frozen and later separated into grass, legume, and weed fractions. These fractions were dried to obtain dry matter weight and used to calculate the individual makeup of each plot on a percent basis.

Table 3. Abundance, contribution to yield, and contamination by alfalfa of four legumes during cuttings four and five in 2009.

Legume	No. of plots contributing to harvested yield	Avg. contribution of intended legume to harvested yield (%)	No. of plots contaminated with alfalfa	Avg. contribution of all legumes to harvested yield (%)
Cutting 4				
Alfalfa	11 out of 12	21.9	N/A	21.9
Birdsfoot trefoil	0 out of 12	0	10 out of 12	3.8
Sainfoin	0 out of 12	0	8 out of 12	3.1
White clover	3 out of 12	8.6	8 out of 12	4.3
Cutting 5				
Alfalfa	10 out of 12	14.0	N/A	14.0
Birdsfoot trefoil	0 out of 12	0	8 out of 12	3.4
Sainfoin	0 out of 12	0	5 out of 12	1.6
White clover	5 out of 12	6.3	4 out of 12	6.7

Additionally, point counts were performed at cutting 5 to quantify the species composition of each plot. Twenty-five points were randomly chosen within each plot using a modified step-point frame (Owensby, 1973). The species of grass, legume, or weed closest to each point was recorded. Percent species composition was calculated by dividing individual species totals for each plot by the total number of points (25) and then multiplying by 100.

Soil Sampling and Test Methods

All plots were sampled on October 23, 2008, prior to the October 30 application of compost at rates of 11.2 and 22.4 Mg ha^{-1}. Plots were sampled again on May 6, 2009 in an attempt to observe nutrient mineralization that may have occurred since the previous soil sampling period. Eight to ten cores were taken from each plot at a depth of about 15 cm, combined into one composite sample, and allowed to air dry. Each sample was then analyzed for the following soil properties: pH, organic matter (OM), soluble salts, nitrate (NO_3^-), ammonium (NH_4^+), phosphorus (P), and potassium (K). Nitrate and ammonium were determined using a 2N potassium chloride extract (Keeney and Nelson, 1982). Phosphorus was determined using Olsen's sodium bicarbonate test (Olsen et al., 1954), and potassium was extracted using NH_4OAc-EDTA (Chapman and Kelly, 1930).

Statistical Analysis

Data were analyzed using PROC MIXED (SAS Institute, 2009) to evaluate the interaction and main effects of grass mix, cutting date, and compost rate or legume species. Fixed effects included grass mix, cutting date, compost rate, and legume species. Block and any block interactions were considered to be random. Effects were considered significant when the probability was less than or equal to 0.05. When the above effects were significant for any of the following variables: DM yield, CP, NDF, ADF, DMI, DMD, and RFV, means were separated using LS MEANS (SAS Institute, 2009). Years were tested separately due to differences in treatment application (i.e. compost rates and slow legume establishment) that occurred between years. In 2009, compost and legume treatments were analyzed separately due to the large variability associated with the legume treatments. Within the legume treatments, cuttings 4 and 5 were analyzed separately from cuttings 1 through 3 due to the increased abundance of legumes in those later cuttings. Several dependent forage quality variables, (CP, NDF, and ADF), were regressed linearly against legume abundance (independent variable) data taken from cuttings 4 and 5 to look at the influence of legumes on overall forage quality of the stand. These regressions were performed in Microsoft Excel (Microsoft, 2007). R^2 values were used to gauge strength of the relationships, and p-values were used to determine significance ($p \leq 0.05$) of the slopes. Soil variables (organic matter, nitrate, ammonium, phosphorus, and potassium) associated with the fall 2008 samples were tested for differences among grass mixes and compost treatments (0 and 22.4 Mg ha^{-1}). Soil analysis results from the spring 2009 sampling period were also tested for differences among grass mixes and compost treatments (0, 11.2, and 22.4 Mg ha^{-1}). However, for this sampling period, the three rates represented compost applied in the fall of 2008 to plots that had received 22.4 Mg ha^{-1} in the spring of 2008. These treatments were compared to control plots (represented by legume plots) which did not receive any compost in the spring of 2008.

RESULTS AND DISCUSSION

Forage Yield

2008

Fertility did not affect yield; therefore, all results were averaged across compost treatments. It is speculated that mineralized nitrogen from tillage and the previous alfalfa crop, combined with slowly available nitrogen from the initial blanket compost application, may have negated any response to the 2008 compost treatment compared to the 0 Mg ha^{-1} control. The first cutting in 2008 was taken relatively late in an effort to promote continued establishment of the grasses. At cutting 1, OG-MB-SB and HWG-TF-HB yielded higher than the other grass mixes. The second cutting occurred too soon, resulting in low yields for that cutting (Fig. 1).

However, forage yields fell significantly after the first cutting for all grass mixes, irrespective of the premature harvest at cutting 2. Yields of all grass mixes remained relatively low throughout midsummer, and tended to increase in late summer, in agreement with typical cool-season grass growth curves (Wolf et al., 1979). However, yields of TF increased significantly in late summer, and yielded 120% higher than the other grass mixes at cutting 6 (Fig. 1). Cutting 6 yields for the HWG-TF-HB, OG-MB-KB, and OG-MB-SB mixes remained similar to cutting 5 yields and appeared to be on a decreasing plane.

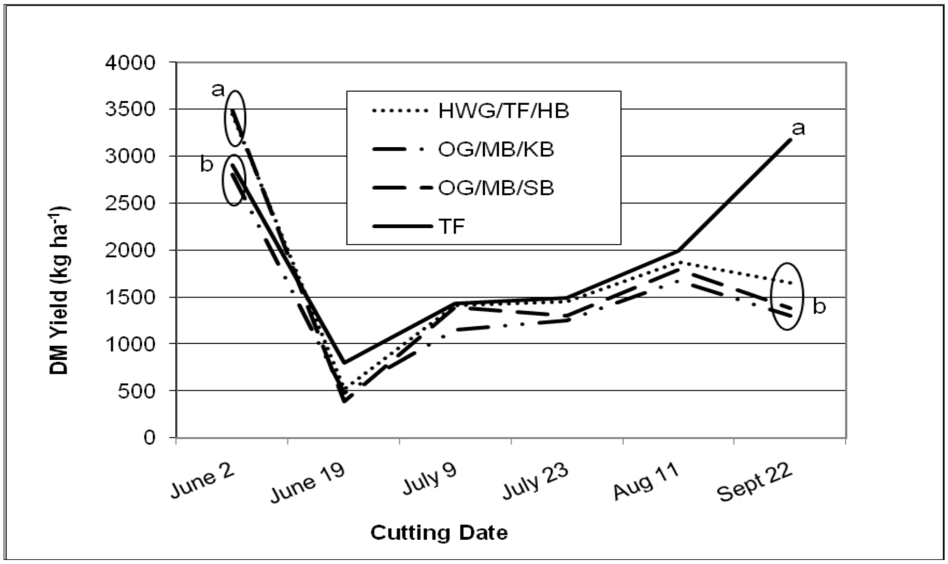

Figure 1. Dry matter (DM) yield of four grass mixes at six cutting dates across the 2008 growing season. For grass mixes within a cutting date, means adjacent to different lowercase letters are different at the 0.05 probability level.

Tall fescue's superior late season growth potential is well known (Schuster and de Leon Garcia, 1973; Taylor and Templeton, 1976; Ocumpaugh and Matches, 1977), and it is often chosen for late fall and winter stockpiled forage for this reason. Such excellent late-season growth makes TF a good option for operations in which fall forage for grazing is critical. In this study, visual observations in mid-October verified the possibility of an additional, seventh cutting of TF.

Total annual DM yields of TF (10,864 kg ha^{-1}) were significantly higher than those of OG-MB-SB (9,241 kg ha^{-1}) and OG-MB-KB (8,079 kg ha^{-1}), and higher than HWG-TF-HB (9,714 kg ha^{-1}) at a 0.06 level of significance. A study by Waldron et al. (2002) that looked at yields of grasses including tall fescue, meadow brome, smooth brome, and orchardgrass, also reported that TF had superior annual yields regardless of irrigation level. Visual observations revealed that TF often dominated the sward in the

HWG-TF-HB mix. This may help to explain the similar performance of this mix in relation to straight TF.

2009

Compost treatments

Although there was a fertility main effect for yield (P=0.02), a detailed look at the differences among means showed that the least fertile compost treatment (0 Mg ha^{-1}) yielded the same as the most fertile treatment (22.4 Mg ha^{-1}), while both were higher than the intermediate treatment of 11.2 Mg ha^{-1}. The poor compost used in 2009 created a situation in which nitrogen content was so low that the three fertility treatments were basically the same from an agronomic standpoint. Additionally, the forage nitrogen content (2.8-3.4% N) for nearly all plots in 2009 indicated a season-long deficiency (Dougherty and Rhykerd, 1985). Due to the low nitrogen content of the compost and the resulting N deficiency in the grasses, all results of yield and quality were averaged across compost treatments.

Forage yields in 2009 were greatly compromised by nitrogen deficiency. As previously stated, the compost applied in the fall of 2008 was exceptionally low in nitrogen (Table 1). As a result, grasses were largely reliant upon organic-nitrogen mineralization from previous compost applications in 2007 and 2008. Forage yields across the five cutting dates in 2009 decreased significantly over time for all grass mixes (Table 4). While forage yields at cutting 1 appeared somewhat normal compared to 2008, we predict that the pool of available nitrogen was soon exhausted, and nitrogen mineralization could not keep up with grass needs. Grass plants appeared pale-green throughout much of the season, and regrowth was abnormally slow. The resulting yields from cuttings 2 through 5 were lower than expected. Although not tested statistically, total DM yield in 2009 averaged about 45% less than in 2008 (6,522 vs. 9,475 kg ha^{-1}).

A further look at total yield in 2009 revealed significant differences among grass mixes. Tall fescue (7,315 kg ha^{-1}) and HWG-TF-HB (7,083 kg ha^{-1}) yielded more than OG-MB-SB (5,709 kg ha^{-1}) and OG-MB-KB (5,982 kg ha^{-1}). The apparent superiority of TF under conditions of adequate nitrogen as well as under nitrogen deficiency is an interesting finding with real-world applications. Grass mix also affected average DM yield in a similar manner, with the TF and HWG-TF-HB mixes averaging higher than the OG-MB based grass mixes (Table 4).

Table 4. Dry matter (DM) yield of four grass mixes across five cutting dates in 2009.

	Cutting					
	1	2	3	4	5	
Grass mix*	May 18	June 19	July 20	Aug 17	Oct 1	Avg.
	------------------------**DM yield** (kg ha^{-1})------------------					
TF	3180 §	1334	1221	711	870	**1464 a**†
HWG/TF/HB	3107	1309	1286	660	726	**1384 a**
OG/MB/SB	2790	1000	965	484	472	**1142 b**
OG/MB/KB	2496	1081	1231	634	541	**1197 b**
Avg.	**2893 A**‡	**1180 B**	**1176 B**	**622 C**	**652 C**	

* TF=tall fescue
HWG-TF-HB=hybrid wheatgrass-tall fescue-hybrid brome
OG-MB-SB=orchardgrass-meadow brome-smooth brome
OG-MB-KB=orchardgrass-meadow brome-Kentucky bluegrass
§The interaction of cutting date by grass mix was not significant (p=0.28). Interaction means are shown only for reference purposes.
† For species averages, means followed by the same lowercase letter are not different at the 0.05 probability level.
‡ For cutting date averages, means followed by the same uppercase letter are not different at the 0.05 probability level.

Legume treatments

Legume species significantly affected DM yields in 2009. This was most likely a reflection of the smaller overall presence of legumes in the sainfoin plots (Table 3). Average yield at cutting 5 (Oct. 1) was not different than cutting 4 (Aug. 17).

Table 5. Dry matter (DM) yield of forage as affected by legume species averaged across grass mixes at two cutting dates in 2009.

	Cutting		
	4	5	
Legume species	Aug 17	Oct 1	Avg.
	------------**DM yield** ($kg\ ha^{-1}$)	-----------	
Alfalfa	630.5 §	665.2	**647.9 a** †
White clover	473.3	628.61	**550.9 ab**
Birdsfoot trefoil	449.09	635.1	**542.1 ab**
Sainfoin	435.6	490.4	**463.0 b**
Avg.	**497.1 A** ‡	**577.9 A**	

§The interaction of cutting date by legume species was not significant (p=.39). Interaction means are shown only for reference purposes.
† For species averages, means followed by the same lowercase letter are not different at the 0.05 probability level.
‡ For cutting date averages, means followed by the same uppercase letter are not different at the 0.05 probability level.

Soil Test Results

<u>Phosphorus</u>

In fall 2008, the 22.4 $Mg\ ha^{-1}$ compost treatment had a significantly higher soil phosphorus (P) level than the control, which received no compost (Table 6). In spring 2009, there was no difference in soil P among compost treatments; however, all compost treatments were higher than the control plots (with legumes) (Table 7). In spring 2009, the OG-MB based mixes tended to have higher soil P than the TF dominated mixes, especially the straight TF. This trend may be due to increased root activity and P uptake in early spring by the mixes containing TF, resulting in less P in the soil nutrient pool at the time of sampling.

Table 6. Effect of grass mix and compost application on soil Olsen phosphorus (P) levels in fall 2008.

	Compost rate (Mg ha^{-1})		
Grass mix*	0 ¶	22.4	Avg.
	---------------mg kg^{-1} P---------------		
TF	15.2 §	23.6	**19.4 a** †
HWG-TF-HB	14.1	26.9	**20.5 a**
OG-MB-SB	15.8	27.6	**21.7 a**
OG-MB-KB	17.8	24.1	**20.9 a**
Avg.	**15.7 B** ‡	**25.5 A**	

* TF=tall fescue
HWG-TF-HB=hybrid wheatgrass-tall fescue-hybrid brome
OG-MB-SB=orchardgrass-meadow brome-smooth brome
OG-MB-KB=orchardgrass-meadow brome-Kentucky bluegrass
§The interaction of compost rate by grass mix was not significant (p=0.51). Interaction means are shown only for reference purposes.
† For species averages, means followed by the same lowercase letter are not different at the 0.05 probability level.
‡ For compost rates, means followed by the same uppercase letter are not different at the 0.05 probability level.
¶All compost treatments received 22.4 Mg ha^{-1} of compost in spring 2008, followed by a fall 2008 application at the rate indicated.

Table 7. Effect of grass mix across compost treatments on soil Olsen phosphorus (P) levels in spring 2009.

		Compost rate (Mg ha^{-1})			
Grass mix*	Control ¶	0	11.2	22.4	Avg.
	------------------------ mg kg^{-1} P------------------------				
TF	11.2§	21.7 §	23.7	23.0	**19.9 a** †
HWG-TF-HB	11.1	33.3	18.0	32.0	**23.6 a**
OG-MB-SB	13.9	25.0	28.7	32.7	**25.1 a**
OG-MB-KB	15.1	32.0	34.3	38.0	**29.9 a**
Avg.	**12.8 B** ‡	**28 A**	**26.2 A**	**31.4 A**	

* TF=tall fescue
HWG-TF-HB=hybrid wheatgrass-tall fescue-hybrid brome
OG-MB-SB=orchardgrass-meadow brome-smooth brome
OG-MB-KB=orchardgrass-meadow brome-Kentucky bluegrass
§The interaction of compost rate by grass mix was not significant (p=0.71). Interaction means are shown only for reference purposes.
†Species means followed by the same lowercase letter are not different at the 0.05 level.
‡ For compost rates or legume treatment, means followed by the same uppercase letter are not different at the 0.05 probability level.
¶The control (legume plots) did not receive compost in spring or fall of 2008.
Compost treatments received 22.4 Mg ha^{-1} of compost in spring 2008, followed by a fall 2008 application at the rate indicated.

Nitrate

Fall 2008 and spring 2009 soil nitrate (NO_3^-) levels were uniformly low with no differences among grass mixes or among compost treatments and control plots (Tables 8 and 9).

Table 8. Effect of grass mix and compost application on soil nitrate (NO_3^-) levels in fall 2008.

	Compost rate (Mg ha^{-1})		
Grass mix*	0 ¶	22.4	Avg.
	--------------- mg kg^{-1} NO_3^--------------		
TF	1.4	1.5	**1.4**
HWG-TF-HB	1.4	1.5	**1.5**
OG-MB-SB	1.4	1.5	**1.4**
OG-MB-KB	1.4	1.4	**1.4**
Avg.	**1.4**	**1.5**	

* TF=tall fescue
HWG-TF-HB=hybrid wheatgrass-tall fescue-hybrid brome
OG-MB-SB=orchardgrass-meadow brome-smooth brome
OG-MB-KB=orchardgrass-meadow brome-Kentucky bluegrass
The main effects of grass mix (p=0.82) and compost rate (p=0.20) were not significant, nor was the interaction of grass mix by compost rate (p=0.83). Main effect and interaction means are shown only for reference purposes.
¶All compost treatments received 22.4 Mg ha^{-1} of compost in spring 2008, followed by a fall 2008 application at the rate indicated.

Potassium

The compost treatment in fall 2008 had significantly higher soil potassium (K) than the control. There were no differences among grass mixes (Table 10). In spring 2009, all compost treatments had higher soil K than the legume treatments which received no compost in either spring 2008 or fall 2008; however, there were no differences among compost treatments (Table 11). All soil K levels in this study were considered to be adequate for crop growth.

Table 9. Effect of grass mix across compost treatments on soil nitrate (NO_3^-) levels in spring 2009.

Grass mix*	Control ¶	Compost rate (Mg ha^{-1}) 0	11.2	22.4	Avg.
	------------------------	**mg kg^{-1} NO_3^-**	------------------------		
TF	1.4	2.4	1.6	1.6	**1.8**
HWG-TF-HB	1.9	1.3	1.6	1.9	**1.7**
OG-MB-SB	1.9	2.2	1.5	1.7	**1.8**
OG-MB-KB	1.7	1.9	3.0	1.8	**2.1**
Avg.	**1.7**	**1.9**	**1.9**	**1.8**	

* TF=tall fescue
HWG-TF-HB=hybrid wheatgrass-tall fescue-hybrid brome
OG-MB-SB=orchardgrass-meadow brome-smooth brome
OG-MB-KB=orchardgrass-meadow brome-Kentucky bluegrass
The main effects of grass mix (p=0.47) and compost rate (p=0.79) were not significant, nor was the interaction of grass mix by compost rate (p=0.22). Main effect and interaction means are shown only for reference purposes.
¶The control (legume plots) did not receive compost in spring or fall of 2008.
All compost treatments received 22.4 Mg ha^{-1} of compost in spring 2008, followed by a fall 2008 application at the rate indicated.

Table 10. Effect of grass mix and compost application on soil potassium (K) levels in fall 2008.

Grass mix*	Compost rate (Mg ha^{-1}) 0 ¶	22.4	Avg.
	---------------- **mg kg^{-1} K** ----------------		
TF	313.5§	413.8	**363.4 a** †
HWG-TF-HB	330.4	430.8	**380.6 a**
OG-MB-SB	321.7	406.1	**363.9 a**
OG-MB-KB	334.6	420.0	**377.3 a**
Avg.	**325.1 B** ‡	**417.7 A**	

* TF=tall fescue
HWG-TF-HB=hybrid wheatgrass-tall fescue-hybrid brome
OG-MB-SB=orchardgrass-meadow brome-smooth brome
OG-MB-KB=orchardgrass-meadow brome-Kentucky bluegrass
§The interaction of compost rate by grass mix was not significant (p=0.51). Interaction means are shown only for reference purposes.
† For species averages, means followed by the same lowercase letter are not different at the 0.05 probability level.
‡ For compost rates, means followed by the same uppercase letter are not different at the 0.05 probability level.
¶All compost treatments received 22.4 Mg ha^{-1} of compost in spring 2008, followed by a fall 2008 application at the rate indicated.

Table 11. Effect of grass mix across compost treatments on soil potassium (K) levels in spring 2009.

		Compost rate (Mg ha^{-1})			
Grass Mix*	Control ¶	0	11.2	22.4	Avg.
		------------------------- **mg kg^{-1} K** -------------------------			
TF	310.3 §	416.0	429.7	426.7	**395.7 a** †
HWG-TF-HB	326.7	442.7	409.7	483.3	**415.6 a**
OG-MB-SB	338.7	405.0	469.3	467.0	**420.0 a**
OG-MB-KB	334.6	457.7	474.7	433.7	**425.2 a**
Avg.	**327.5 B** ‡	**430.3 A**	**445.8 A**	**452.7 A**	

* TF=tall fescue
HWG-TF-HB=hybrid wheatgrass-tall fescue-hybrid brome
OG-MB-SB=orchardgrass-meadow brome-smooth brome
OG-MB-KB=orchardgrass-meadow brome-Kentucky bluegrass
§The interaction of compost rate or legume by grass mix was not significant ($p=0.71$). Interaction means are shown only for reference purposes.
† For species averages, means followed by the same lowercase letter are not different at the 0.05 probability level.
‡ For compost rates, means followed by the same uppercase letter are not different at the 0.05 probability level.
¶The control (legume plots) did not receive compost in spring or fall of 2008.
All compost treatments received 22.4 Mg ha^{-1} of compost in spring 2008, followed by a fall 2008 application at the rate indicated.

Organic Matter

The compost treatment in fall 2008 was significantly higher in soil OM than the control (Table 12). There were no differences among grass mixes. In spring 2009, all compost treatments were higher in soil OM than the legume treatments which received no compost in either spring 2008 or fall 2008. Additionally, the compost treatment at the 22.4 Mg ha^{-1} rate was higher in soil OM than the 11.2 Mg ha^{-1} rate and higher than the compost control (0 Mg ha^{-1})(Table 13).

Table 12. Effect of grass mix and compost application on soil organic matter (OM) content in fall 2008.

	Compost rate (Mg ha^{-1})		
Grass mix*	0 ¶	22.4	Avg.
	------------------OM (%)-----------------		
TF	2.16 §	2.21	**2.18 a** †
HWG-TF-HB	2.18	2.22	**2.20 a**
OG-MB-SB	2.16	2.23	**2.20 a**
OG-MB-KB	2.13	2.20	**2.16 a**
Avg.	**2.16 B** ‡	**2.22 A**	

* TF=tall fescue
HWG-TF-HB=hybrid wheatgrass-tall fescue-hybrid brome
OG-MB-SB=orchardgrass-meadow brome-smooth brome
OG-MB-KB=orchardgrass-meadow brome-Kentucky bluegrass
§The interaction of compost rate by grass mix was not significant (p=0.95). Interaction means are shown only for reference purposes.
† For species averages, means followed by the same lowercase letter are not different at the 0.05 probability level.
‡ For compost rates, means followed by the same uppercase letter are not different at the 0.05 probability level.
¶All compost treatments received 22.4 Mg ha^{-1} of compost in spring 2008, followed by a fall 2008 application at the rate indicated.

Table 13. Effect of grass mix across compost treatments on soil organic matter (OM) content in spring 2009.

		Compost rate (Mg ha^{-1})			
Grass mix*	Control ¶	0	11.2	22.4	Avg.
	-------------------------OM (%)-------------------------				
TF	2.52 §	2.87	2.70	2.70	**2.69 a** †
HWG-TF-HB	2.61	2.63	2.63	2.80	**2.67 a**
OG-MB-SB	2.57	2.67	2.73	2.87	**2.71 a**
OG-MB-KB	2.56	2.67	2.60	2.87	**2.67 a**
Avg.	**2.56 C** ‡	**2.71 ABC**	**2.66 B**	**2.81 A**	

* TF=tall fescue
HWG-TF-HB=hybrid wheatgrass-tall fescue-hybrid brome
OG-MB-SB=orchardgrass-meadow brome-smooth brome,
OG-MB-KB=orchardgrass-meadow brome-Kentucky bluegrass
§The interaction of compost rate or legume by grass mix was not significant (p=0.19). Interaction means are shown only for reference purposes.
† For species averages, means followed by the same lowercase letter are not different at the 0.05 probability level.
‡ For compost rates, means followed by the same uppercase letter are not different at the 0.05 probability level.
¶The control (legume plots) did not receive compost in spring or fall of 2008.
All compost treatments received 22.4 Mg ha^{-1} of compost in spring 2008, followed by a fall 2008 application at the rate indicated.

Crude Protein (CP)

2008

Fertility treatments had no significant affect on CP content; therefore, results were averaged across compost treatments. Averaged across cutting dates, tall fescue was lower in crude protein than all other grass mixes (Table 14).

Table 14. Crude protein (CP) of four grass mixes across six cutting dates in 2008.

	Cutting						
	1	2	3	4	5	6	
Grass mix*	June 2	June 19	July 9	July 23	Aug 11	Sept 11	Avg.
	---------------------------**CP** (%)----------------------------						
OG/MB/KB	19.4 §	21.5	22.2	25.4	24.7	21.9	**22.5 a** †
OG/MB/SB	18.9	21.1	18.4	24.2	25.4	22.5	**21.7 ab**
HWG/TF/HB	18.6	21.2	21.5	22.3	23.1	19.0	**21.0 b**
TF	17.8	20.6	21.1	21.1	21.1	17.3	**19.8 c**
Avg.	**18.7 C** ‡	**21.1 B**	**20.8 B**	**23.2 A**	**23.6 A**	**20.1 B**	

* TF=tall fescue
HWG-TF-HB=hybrid wheatgrass-tall fescue-hybrid brome
OG-MB-SB=orchardgrass-meadow brome-smooth brome
OG-MB-KB=orchardgrass-meadow brome-Kentucky bluegrass
§The interaction of cutting date by grass mix was not significant ($p=0.07$). Interaction means are shown only for reference purposes.
† For species averages, means followed by the same lowercase letter are not different at the 0.05 probability level.
‡ For cutting date averages, means followed by the same uppercase letter are not different at the 0.05 probability level.

In general, CP increased over the season (Table 14). The decrease in average CP at cutting 6 is most likely a result of plant senescence and nutrient translocation associated with decreasing temperature and day length (Robson, 1967). In TF, the decrease in protein at cutting 6 may also be due to dilution from continued fall growth. Abdalla et al. (1988) also reported that concentrations of CP increased over the grazing season. However, findings from that study showed that high protein levels were maintained through September, perhaps due to the milder climate at their location

(Harford, NY). A study by Lassiter et al. (1956) found yearly average CP values for tall fescue-, orchardgrass-, Kentucky bluegrass-, and smooth brome-based pastures similar to those observed in this study. All mixes at all cutting dates in this study contained relatively high concentrations of CP that meet or exceed requirements for most classes of ruminants (NRC, 2001). It is important to note that the individual needs of producers dictate what is considered adequate forage quality. For example, high-producing dairy cows fed mainly through a total mixed ration may require much less CP from pasture than an operation in which animals depend on pasture for the bulk of their nutrition. In view of the adequacy of CP displayed by all grasses in this study, yield of CP may be a more important measure than concentration in evaluating the value of a grass mix. For example, total yield of CP for TF (1,448 kg ha^{-1}) in 2008 was significantly higher than for OG-MB-SB (993 kg ha^{-1}), the mix with the highest concentration of CP.

<u>2009</u>

Compost treatments

Fertility treatments did not affect crude protein in 2009; therefore, data were averaged across compost treatments. Grass mix and cutting date significantly affected CP content (Table 15). Results related to grass mix were similar to those obtained in 2008, with TF containing significantly less CP, on average, than the other mixes. Additionally, OG-MB-SB had higher average CP values than the other grass mixes. Crude protein decreased over the season in a manner very similar to 2008 (Tables 14 and 15). Although not tested statistically, crude protein values in 2009 appeared to be distinctly lower than in 2008, presumably because of nitrogen deficiency and subsequent plant stress (Buxton et al., 1996).

Table 15. Crude protein (CP) content of four grass mixes across five cutting dates for the compost treatments in 2009.

	Cutting					
	1	2	3	4	5	
Grass mix*	May 18	June 19	July 20	Aug 17	Oct 1	Avg.
	----------------------------**CP** (%)------------------------					
OG/MB/SB	15.2 §	16.9	16.5	19.4	18.8	**17.4 a** †
OG/MB/KB	13.9	14.5	14.9	17.6	17.3	**15.6 b**
HWG/TF/HB	12.3	14.4	14.7	16.8	15.8	**14.8 b**
TF	10.1	13.1	14.1	15.7	14.8	**13.7 c**
Avg.	**13.1 D** ‡	**14.7 C**	**15.0 BC**	**17.4 B**	**16.7 A**	

* TF=tall fescue
HWG-TF-HB=hybrid wheatgrass-tall fescue-hybrid brome
OG-MB-SB=orchardgrass-meadow brome-smooth brome
OG-MB-KB=orchardgrass-meadow brome-Kentucky bluegrass

§The interaction of cutting date by grass mix was not significant (p=0.06). Interaction means are shown only for reference purposes.

† For species averages, means followed by the same lowercase letter are not different at the 0.05 probability level.

‡ For cutting date averages, means followed by the same uppercase letter are not different at the 0.05 probability level.

Legume treatments

Legume species, cutting date, and grass mix all affected crude protein content of the sward. Again, the legume effect is probably a direct reflection of the greater abundance of alfalfa in the plots (Table 3). Crude protein was higher on average for cutting 5 compared to cutting 4 (Table 16). This may be due to the trend of increasing yield during this period; however, it is most likely due to physiological changes as grasses prepared for winter (Marschner, 1995; Power, 1986).

Similar to results for the compost treatments (Table 15), tall fescue in the legume treatments had a lower average CP content than the other grass mixes, while OG-MB-SB had the highest CP content (Table 16). These findings suggest that grass mix was the overriding factor determining quality in 2009.

Table 16. Crude protein content of four grass mixes across two cutting dates for the legume treatments in 2009.

	Cutting		
	4	5	
Grass mix*	Aug 17	Oct 1	Avg.
	----------------**CP** (%)----------------		
OG/MB/SB	20.0 §	18.9	**19.4 a** †
OG/MB/KB	18.5	18.2	**18.4 b**
HWG/TF/HB	17.8	16.7	**17.2 c**
TF	17.0	15.7	**16.3 d**
Avg.	**18.3 A** ‡	**17.4 B**	

* TF=tall fescue
HWG-TF-HB=hybrid wheatgrass-tall fescue-hybrid brome
OG-MB-SB=orchardgrass-meadow brome-smooth brome
OG-MB-KB=orchardgrass-meadow brome-Kentucky bluegrass

§The interaction of cutting date by grass mix was not significant (p=0.48). Interaction means are shown only for reference purposes.

† For species averages, means followed by the same lowercase letter are not different at the 0.05 probability level.

‡ For cutting date averages, means followed by the same uppercase letter are not different at the 0.05 probability level.

Because alfalfa establishment was variable in 2009, a regression relationship was developed between percent alfalfa in the sward and CP of the overall mix using data from cutting 5 (Fig. 2). From an animal nutrition standpoint, it appears that small additions of alfalfa to a pasture sward can significantly improve overall CP content. For example, some high-producing dairy cows may have dietary requirements in excess of 20% crude protein (NRC, 2001). A pasture that may not contain sufficient protein as a pure grass could meet these requirements with the inclusion of as little as 25% alfalfa.

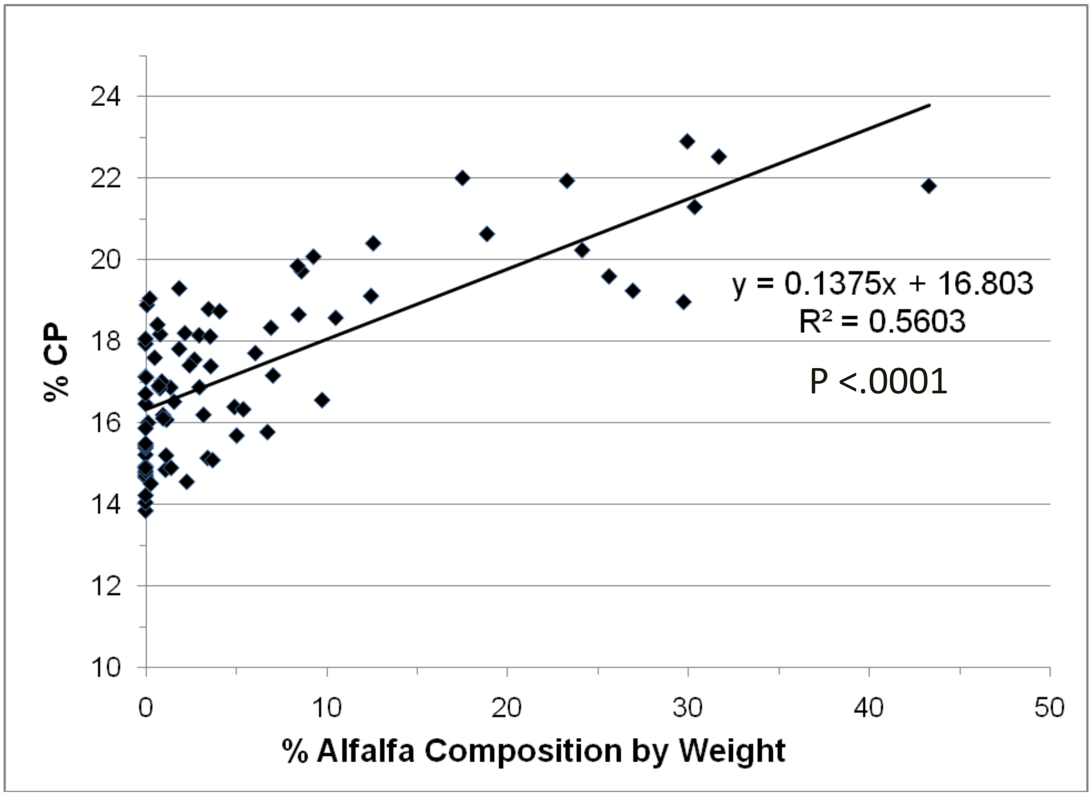

Figure 2. Effect of alfalfa composition on crude protein (CP) content of grass-based pasture in 2009.

Neutral Detergent Fiber (NDF)

2008

Fertility did not significantly affect NDF; therefore, results were averaged across compost treatments. Neutral detergent fiber is a measure of total fiber, and is comprised of cellulose, hemicellulose, and lignin. Averaged across all grass mixes, NDF declined (higher quality) throughout the growing season (Table 17). Similar results were observed by Abdalla et al. (1988) where NDF values peaked in June and July before declining through the rest of the season. Abdalla et al. (1988) describes NDF as a function of leaf-to-stem ratio, in which the proportion of leaf generally decreases as plants mature. Because C_3 grass stems contain more fiber than do leaves, by mature forage results in

Table 17. Percent neutral detergent fiber (NDF) of four grass mixes across six cutting dates in 2008.

	Cutting						
	1	2	3	4	5	6	
Grass mix*	June 2	June 19	July 9	July 23	Aug 11	Sept 11	Avg.
				----------------------------**NDF** (%)------------------------			
OG/MB/KB	61.1 §	59.6	57.2	59.1	52.4	52.2	**56.9 a** †
HWG/TF/HB	61.7	58.6	60.5	61.1	55.4	53.9	**58.5 b**
OG/MB/SB	65.0	57.9	60.1	59.8	54.0	52.5	**58.2 b**
TF	61.4	59.3	60.4	59.7	55.0	54.5	**58.4 b**
Avg.	**62.3 C** ‡	**58.9 B**	**59.5 B**	**59.9 B**	**54.2 A**	**53.3 A**	

* TF=tall fescue
HWG-TF-HB=hybrid wheatgrass-tall fescue-hybrid brome
OG-MB-SB=orchardgrass-meadow brome-smooth brome
OG-MB-KB=orchardgrass-meadow brome-Kentucky bluegrass
§The interaction of cutting date by grass mix was not significant (p=0.39). Interaction means are shown only for reference purposes.
† For species averages, means followed by the same lowercase letter are not different at the 0.05 probability level.
‡ For cutting date averages, means followed by the same uppercase letter are not different at the 0.05 probability level.

a higher total fiber (NDF) content as plants mature. Work by Gustavsson et al. (2004) found that dry matter accumulation is a good predictor of NDF, and indeed this viewpoint fits the findings of this study fairly well. However, yield does not completely explain variations in NDF, especially under conditions where forages remain relatively immature throughout the season (e.g. rotational grazing). Day length and temperature may also have an influence on NDF through their modification of grass morphology, for example, leafy fall growth (Briske, 1991; Laude, 1953). Orchardgrass-meadow brome-Kentucky bluegrass had lower NDF content than all other grass mixes (Table 17). The NDF values measured in this study during 2008 may be higher (lower quality) than the recommended amount for some dairy cattle, based on NRC guidelines (NRC, 2001). However, concerns related to NDF vary based on production goals, the overall nutrient requirements of grazing animals, and the amount of the diet comprised of pasture forage.

2009

Compost plots

Fertility treatments did not significantly affect NDF; therefore, results were averaged across compost treatments. Main effects of grass mix and cutting date were significant. Despite very different fertility conditions (i.e. nitrogen deficiency) between 2008 and 2009, similar differences among grass mixes were observed between the two years (Tables 17 and 18). Cutting date trends, in which NDF decreased across the season, were also similar to those seen in 2008. Again, quality inversely followed yield fairly closely.

Table 18. Percent neutral detergent fiber (NDF) of four grass mixes across five cutting dates in 2009.

	Cutting					
	1	2	3	4	5	
Grass mix*	June 2	June 19	July 9	July 23	Aug 11	Avg.
	------------------------**NDF** (%)------------------------					
OG/MB/SB	62.9 §	55.4	57.1	49.7	46.2	**54.3 a** †
OG/MB/KB	62.7	55.5	57.5	51.4	47.8	**54.9 a**
HWG/TF/HB	63.2	58.4	58.5	53.7	50.5	**56.9 b**
TF	62.7	59.1	58.4	54.1	46.8	**56.2 b**
Avg.	**62.8 D** ‡	**57.0 C**	**57.8 C**	**52.2 B**	**47.8 A**	

* TF=tall fescue
HWG-TF-HB=hybrid wheatgrass-tall fescue-hybrid brome
OG-MB-SB=orchardgrass-meadow brome-smooth brome
OG-MB-KB=orchardgrass-meadow brome-Kentucky bluegrass
§The interaction of cutting date by grass mix was not significant (p=0.22). Interaction means are shown only for reference purposes.
† For species averages, means followed by the same lowercase letter are not different at the 0.05 probability level.
‡ For cutting date averages, means followed by the same uppercase letter are not different at the 0.05 probability level.

Legume plots

Legume species and grass mix significantly affected NDF in the legume plots. The plots with alfalfa had lower NDF content (higher quality) than the other legume treatments (Table 19), probably due to the lower abundance of legumes in those plots (Table 3). Averaged across legume species, the OG-MB-SB and OG-MB-KB mixes had lower NDF content than the other grass mixes (Table 20). This is in agreement with

Table 19. Percent neutral detergent fiber (NDF) of four legume species averaged across grass mixes at two cutting dates in 2009.

	Cutting		
	4	5	
Legume species	Aug 17	Oct 1	Avg.
	---------------**NDF** (%)--------------		
Alfalfa	47.7 §	45.8	**46.7 a** †
White clover	52.0	47.9	**49.9 b**
Birdsfoot trefoil	51.3	49.4	**50.3 b**
Sainfoin	52.3	49.0	**50.6 b**
Avg.	**50.8 A** ‡	**48.0 A**	

§The interaction of legume species by cutting date was not significant (p=0.92). Interaction means are shown only for reference purposes.
† For species averages, means followed by the same lowercase letter are not different at the 0.05 probability level.
‡ For cutting date averages, means followed by the same uppercase letter are not different at the 0.05 probability level.

Table 20. Percent neutral detergent fiber (NDF) of four grass mixes averaged across legume species at two cutting dates in 2009.

	Cutting		
	4	5	
Grass mix*	Aug 17	Oct 1	Avg.
	----------------**NDF** (%)--------------		
TF	51.6 §	50.4	**51.0 a** †
HWG-TF-HB	51.8	49.7	**50.7 a**
OG-MB-SB	49.3	45.9	**47.6 b**
OG-MB-KB	50.6	46.1	**48.3 b**
Avg.	**50.8 A** ‡	**48.0 A**	

* TF=tall fescue
HWG-TF-HB=hybrid wheatgrass-tall fescue-hybrid brome
OG-MB-SB=orchardgrass-meadow brome-smooth brome
OG-MB-KB=orchardgrass-meadow brome-Kentucky bluegrass
§The interaction of grass mix by cutting date was not significant (p=0.24). Interaction means are shown only for reference purposes.
† For mix averages, means followed by the same lowercase letter are not different at the 0.05 probability level.
‡ For cutting date averages, means followed by the same uppercase letter are not different at the 0.05 probability level.

results discussed previously in the study. Unlike results for the compost plots, NDF did not decrease during the period analyzed (cuttings 4 and 5). This is perhaps due to the influence of legumes; however, the two treatment groups were not directly compared. A regression relationship was developed between percent alfalfa in the sward and NDF content of the overall mix at cutting 5 (Fig. 3). Similar to its effect on CP content, small additions of alfalfa to pure grass mixes appears to improve forage quality, in this case, lowering total fiber content of the overall mix.

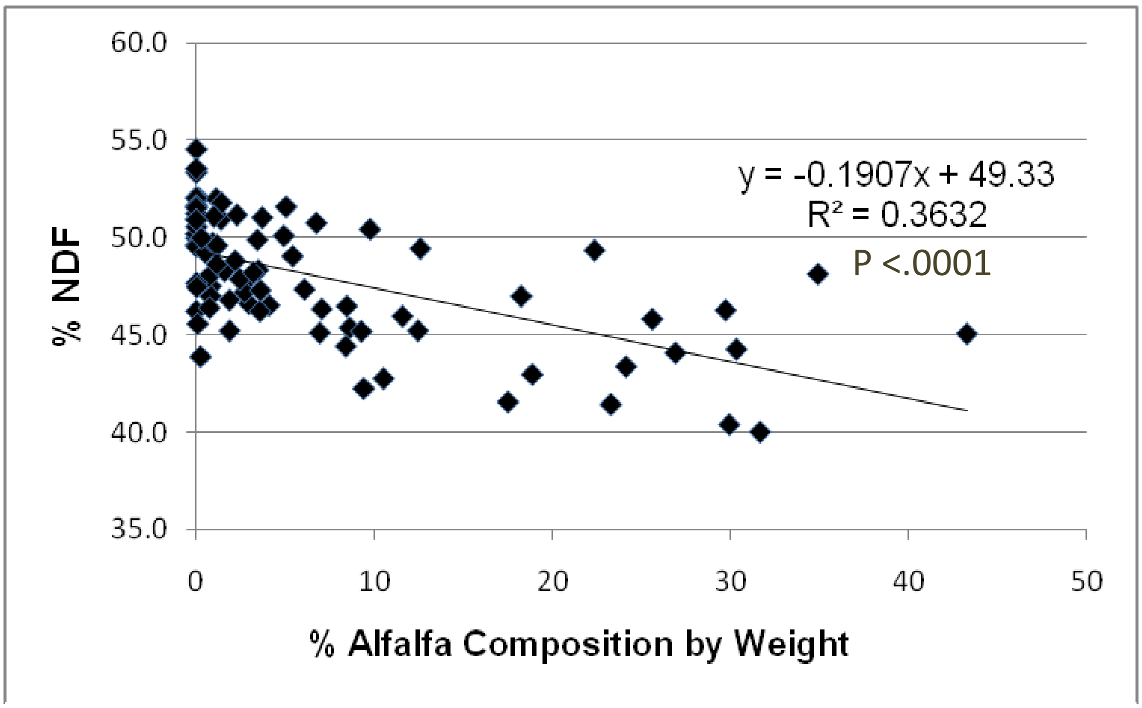

Figure 3. Effect of alfalfa composition on neutral detergent fiber (NDF) content of grass-based pasture at cutting 5 in 2009.

Acid Detergent Fiber (ADF)

2008

The general trend in ADF was similar to that of NDF (decreased over time). ADF is a measure of the indigestible lignin and cellulose components of plant fiber which, like total fiber, increase with plant maturation. Consequently, one might expect lignin and cellulose to increase proportionately to total fiber. However, the lignin and cellulose measured by ADF is more highly influenced by environmental factors such as day length and temperature than by dry matter accumulation (Van Soest, 1988). These influences are evident in the spring and fall cuttings. ADF at cutting 1 remained fairly low despite high yields and subsequently high NDF values. ADF values during fall cuttings (cooler temperatures and shorter days) were the lowest of the season. While ADF is comprised of both cellulose and lignin, several findings related to lignin might help to explain the dynamics of ADF over the season. According to Van Soest (1988), there is a negative relationship between total fiber and lignin in forages grown during the spring. Conversely, there is a positive relationship between total fiber and lignin in the fall. During midsummer, there is little or no association between total fiber and lignin. A multi-year study of seasonal trends in pasture digestibility by Crampton and Jackson (1944) found seasonal trends similar to this study. The Crampton and Jackson (1944) study showed that lignin content followed a bell-shaped curve which peaked in midsummer. Variations that occurred between the three years of that study directly reflected local climatic conditions of moisture and temperature.

Tall fescue and HWG-TF-HB appeared to have higher hemicellulose contents than OG-MB and OG-MB based mixes, as implied by the difference between their NDF and ADF contents. As a result, the grass mixes that appeared to be of poorer quality based on NDF actually possessed a higher proportion of digestible fiber.

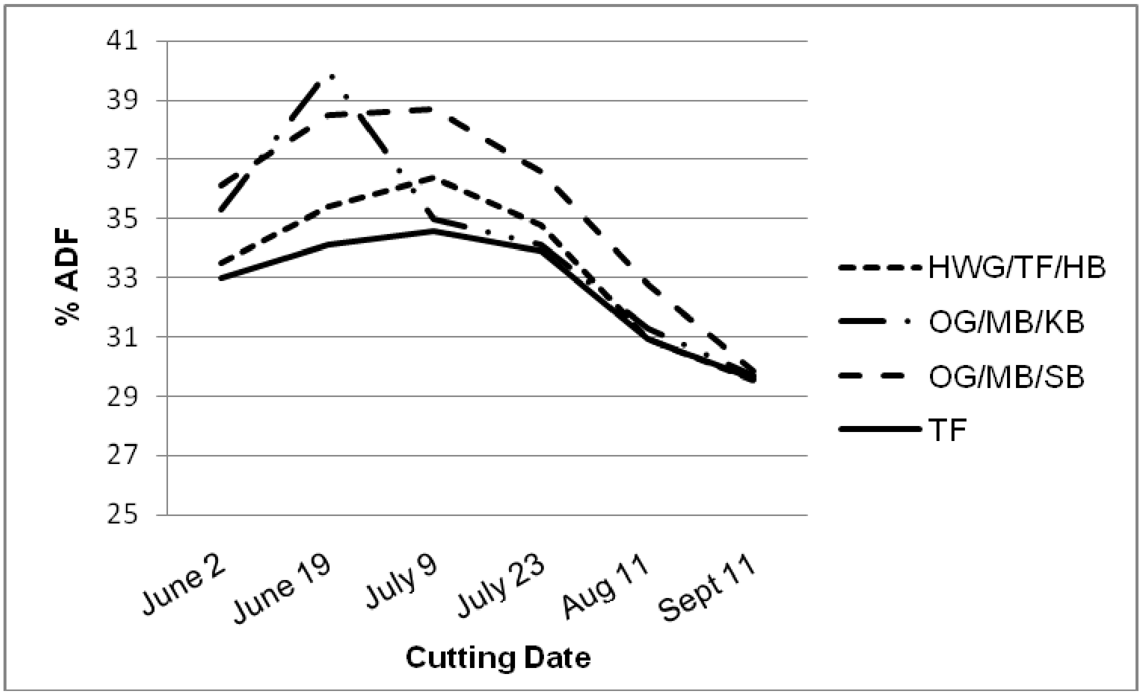

Figure 4. Percent acid detergent fiber (ADF) of four grass mixes across 6 cutting dates in 2008.

There was a grass mix by cutting date interaction for ADF (Fig. 4). This interaction is difficult to explain. In light of work by Buxton and Redfearn (1997) which shows relative tissue proportions among several cool-season grasses used in this study (smooth brome, orchardgrass, and tall fescue), it is reasonable to assume that species differences caused this interaction. For example, Buxton and Redfearn (1997) found that smooth brome has nearly twice as many sclerenchyma cells (which make up highly lignified tissue) as tall fescue. In this study, the smooth brome component in the OG-MB-SB mix might have caused the higher ADF content of that mix compared to TF. Wedin and Huff (1996) state that Kentucky bluegrass, because of early, rapid maturation, may be of lower digestibility than other cool-season perennial grasses. Therefore, an increase in the Kentucky bluegrass component of the OG-MB-KB mix could be responsible for the rapid increase in ADF during the second cutting for that mix.

2009

Compost plots

Fertility and grass mix did not significantly affect ADF in 2009. The main effect of cutting date suggests that ADF at cutting 5 was lower than at the other cutting dates (Table 21). Although not tested statistically, ADF content (especially in spring) generally appeared to be lower than in 2008, presumably because of decreased growth due to nitrogen deficiency in 2009.

Table 21. Percent acid detergent fiber (ADF) of four grass mixes across five cutting dates in 2009.

	Cutting					
	1	2	3	4	5	
Grass mix*	May 18	June 19	July 20	Aug 17	Oct 1	Avg.
	-----------------------**ADF** (%)-----------------------					
OG/MB/SB	33.3 §	32.8	34.2	32.3	27.8	**32.1 a** †
OG/MB/KB	34.3	32.1	34.6	33.1	28.2	**32.0 a**
HWG/TF/HB	33.8	33.1	33.2	32.1	28.2	**32.1 a**
TF	34.4	33.4	32.2	32.5	28.8	**32.2 a**
Avg.	**33.9 B** ‡	**32.9 B**	**33.5 B**	**32.5 B**	**28.2 A**	

* TF=tall fescue
HWG-TF-HB=hybrid wheatgrass-tall fescue-hybrid brome
OG-MB-SB=orchardgrass-meadow brome-smooth brome
OG-MB-KB=orchardgrass-meadow brome-Kentucky bluegrass
§The interaction of cutting date by grass mix was not significant (p=0.24). Interaction means are shown only for reference purposes.
† For species averages, means followed by the same lowercase letter are not different at the 0.05 probability level.
‡ For cutting date averages, means followed by the same uppercase letter are not different at the 0.05 probability level.

Legume plots

There was a legume species by cutting date interaction for ADF, which is not easily explainable (Fig. 5). From the graph, it appears that the interaction was caused primarily by the slower rate of decline in ADF in the birdsfoot trefoil plots. However, there was very little if any birdsfoot trefoil in either cutting that contributed to yield

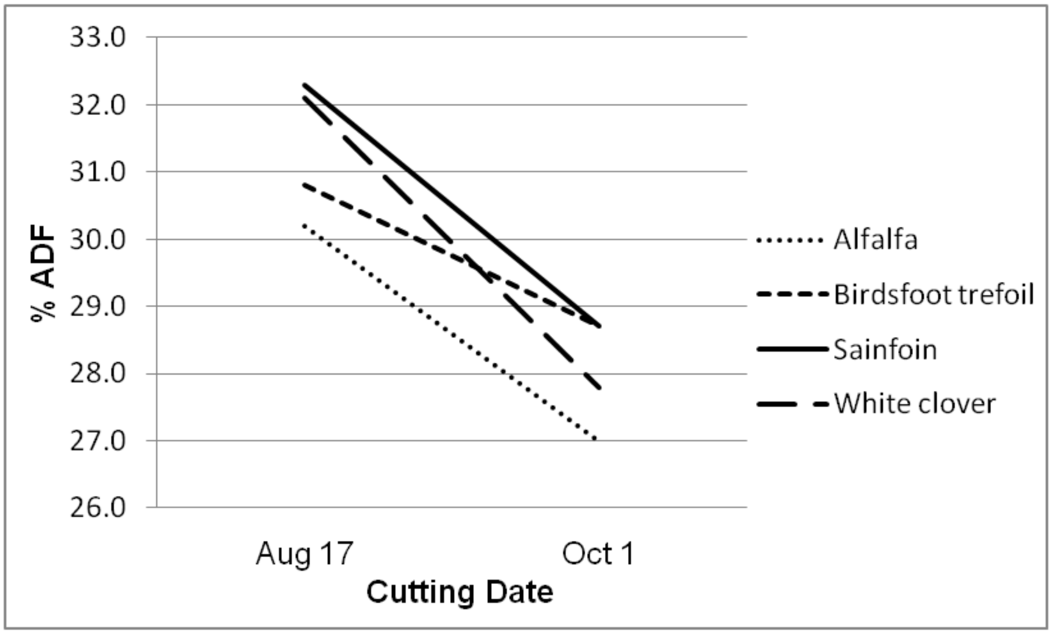

Figure 5. Acid detergent fiber (ADF) of four legume species averaged over grass mix across two cutting dates in 2009.

and only small amounts of alfalfa (<4%) which would not explain this slower rate of decline. In general, the effect of cutting date appeared very similar to that observed in the compost plots in 2009, with average ADF decreasing from 31.4% in cutting 4 to 28.0% in cutting 5. This difference is presumably due to environmental and morphological factors discussed previously. An additional interaction of grass mix by cutting date showed that the ADF content of OG-MB dominated mixes had a steeper rate of decline than the grass mixes with TF in them during the period analyzed (Fig. 6). As shown by the regressions of alfalfa composition with CP and NDF, legumes can have a positive effect on forage quality as the legume component of a sward increases. A similar, but weaker relationship existed between alfalfa composition and ADF content of the grass sward (Fig. 7).

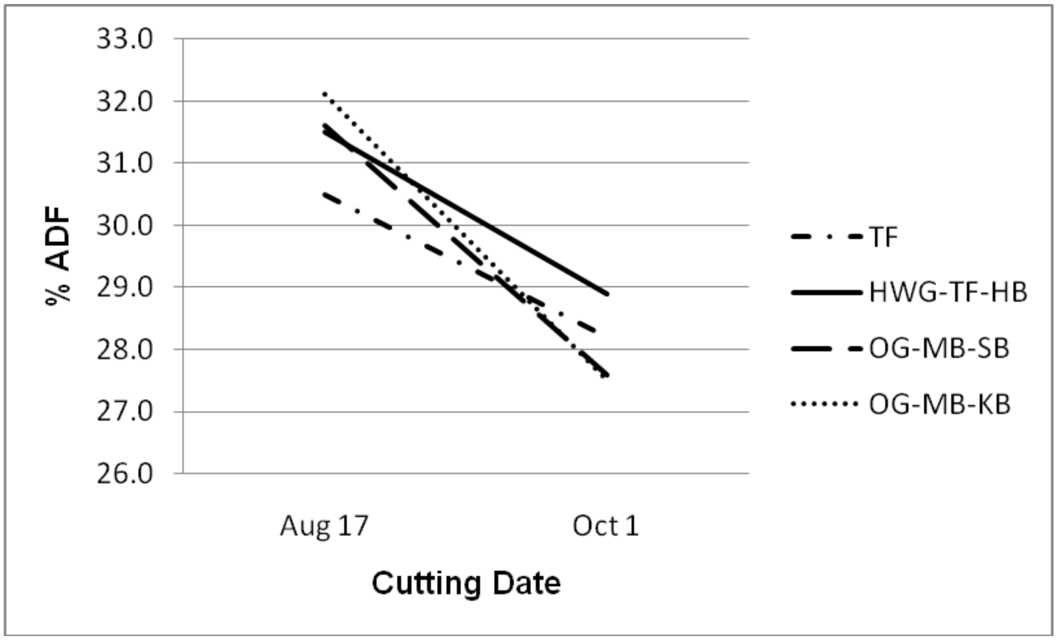

Figure 6. Acid detergent fiber (ADF) of four grass mixes across two cutting dates in 2009.

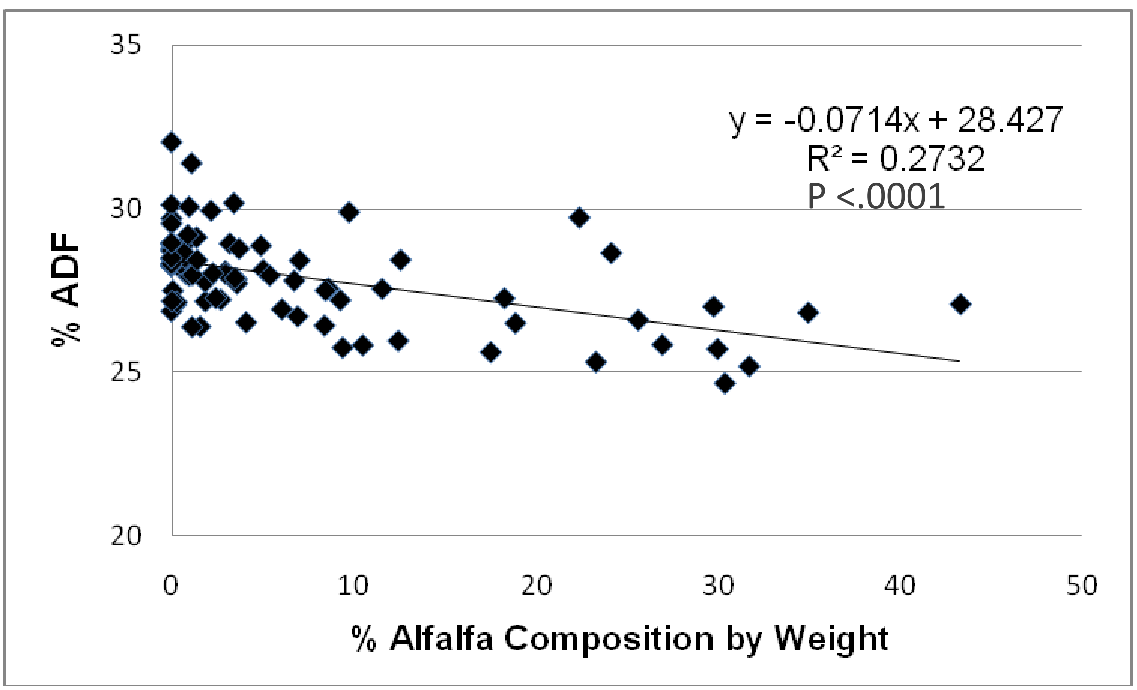

Figure 7. Effect of alfalfa composition on acid detergent fiber (ADF) content of grass-based pasture in 2009.

Calculated Forage Quality Indices

Dry matter Intake (DMI)

Neutral detergent fiber, as a measure of total fiber content, is often used to predict the dry matter intake (DMI) potential of forage. Because DMI is calculated directly from NDF, changes in NDF over the season result in corresponding changes in DMI, where DMI inversely follows NDF. Cutting date significantly affected DMI in 2008, with the highest predicted DMI occurring during late-summer and fall (Table 22).

Table 22. Dry matter intake (DMI) of four grass mixes across six cutting dates in 2008.

	Cutting						
	1	2	3	4	5	6	
Grass mix*	June 2	June 19	July 9	July 23	Aug 11	Sept 11	Avg.
	-----------------------------DMI (% of bodyweight)--------------------------						
OG/MB/KB	1.97 §	2.02	2.10	2.03	2.29	2.30	**2.12 a †**
HWG/TF/HB	1.92	2.10	1.99	1.97	2.17	2.23	**2.10 b**
OG/MB/SB	1.85	2.08	2.00	2.01	2.22	2.29	**2.10 b**
TF	1.96	2.03	1.99	2.02	2.18	2.20	**2.10 b**
Avg.	**1.93 C ‡**	**2.04 B**	**2.02 B**	**2.01 B**	**2.22 A**	**2.25 A**	

* TF=tall fescue
HWG-TF-HB=hybrid wheatgrass-tall fescue-hybrid brome
OG-MB-SB=orchardgrass-meadow brome-smooth brome
OG-MB-KB=orchardgrass-meadow brome-Kentucky bluegrass
§The interaction of cutting date by grass mix was not significant (p=0.39). Interaction means are shown only for reference purposes.
† For species averages, means followed by the same lowercase letter are not different at the 0.05 probability level.
‡ For cutting date averages, means followed by the same uppercase letter are not different at the 0.05 probability level.

Averaged across cutting dates, OG-MB-KB was significantly higher in DMI than the other grass mixes. While relative differences in DMI may seem minor when compared directly, real-world differences at the production scale may prove significant. For example, the difference in average predicted intake between the June 2nd and Sept. 11th cutting dates is roughly 8.8 kg per day for a 454 kg cow. Multiplied by an entire herd, this difference can translate to thousands of kilograms of additional forage consumed. Diets in which total NDF concentration is too high may limit daily feed intake and subsequent intake of CP and energy. Typically, operations in which pasture comprises the majority of animals' diets would be most likely to encounter NDF-limited intake.

Dry Matter Digestibility (DMD)

Grass mix and cutting date effects were significant in 2008, with a mix by cutting interaction. In general, dry matter digestibility improved over the season, with the highest forage digestibility occurring at cutting 6. The mix by cutting date interaction mimics that of ADF in 2008, and resulted in a sharp decline in digestibility for the OG-MB-KB mix at cutting 2 (Fig. 8).

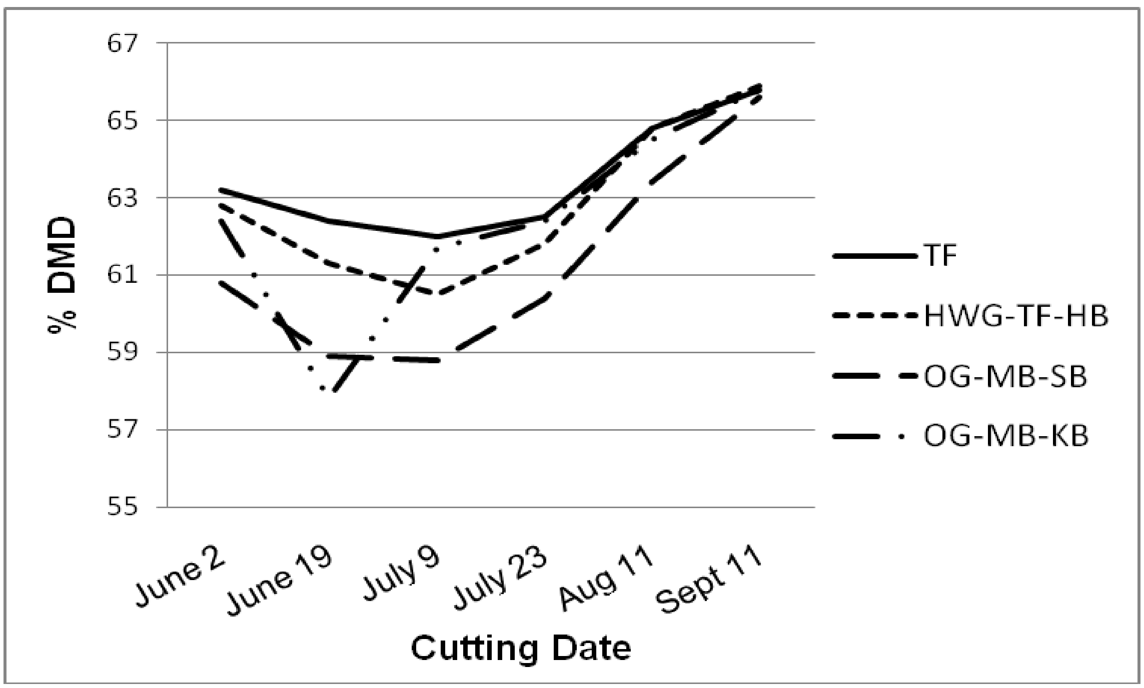

Figure 8. Percent dry matter digestibility (DMD) of four grass mixes across six cutting dates in 2008.

Relative Feed Value (RFV)

Relative feed value is calculated using both NDF and ADF. Consequently, some results emerged which would not be predicted on the basis of NDF or ADF alone, giving a picture of fiber-related forage quality across cuttings and among grass mixes as it relates to their relative nutritional value. Averaged across cutting dates, OG-MB-SB had a lower RFV than OG-MB-KB and TF (Table 23). Relative feed value generally improved across the season, with the majority of improvement occurring in cuttings 4 and 5, presumably in conjunction with similar improvements (decreases) in NDF and ADF.

Table 23. Relative feed value (RFV) of four grass mixes across six cutting dates in 2008.

	Cutting						
	1	2	3	4	5	6	
Grass mix*	June 2	June 19	July 9	July 23	Aug 11	Sept 11	Avg.
	------------------------------**RFV**------------------------------						
OG/MB/KB	94.0 §	90.6	100.4	98.4	114.6	117.3	**102.6 a** †
TF	95.9	97.9	95.8	97.7	109.7	112.5	**101.1 a**
HWG/TF/HB	94.9	97.8	93.4	94.4	108.9	113.8	**100.6 ab**
OG/MB/SB	87.6	94.9	91.2	94.0	109.2	116.4	**98.9 b**
Avg.	**93.1 C** ‡	**95.3 C**	**95.2 C**	**96.1C**	**110.6 B**	**115.0 A**	

* TF=tall fescue
HWG-TF-HB=hybrid wheatgrass-tall fescue-hybrid brome
OG-MB-SB=orchardgrass-meadow brome-smooth brome
OG-MB-KB=orchardgrass-meadow brome-Kentucky bluegrass
§The interaction of cutting date by grass mix was not significant (p=0.17). Interaction means are shown only for reference purposes.
† For species averages, means followed by the same lowercase letter are not different at the 0.05 probability level.
‡ For cutting date averages, means followed by the same uppercase letter are not different at the 0.05 probability level.

MANAGEMENT IMPLICATIONS

This study found all grass mixes to be fairly productive when compared to yield estimates for pasture in other areas of Colorado managed using conventional practices (Pearson, 2004abc; Bosley et al., 2005). Tall fescue tended to yield higher than the other grass mixes in the study, especially during the late summer and fall. Crude protein of tall fescue was lower relative to the other grass mixes, but still remained adequate in terms of most ruminant needs. Smooth brome, which yielded well in early spring and had good CP values, had relatively low fiber quality. In general, forage quality improved over the growing season, peaking in late summer and fall.

Assessments of pasture yield and quality are largely dependent on its intended use. Lactating dairy cows generally have the greatest nutrient requirements of any production animal. For this reason, most dairies tend to meet their animal's nutritional needs through high-concentrate rations, and a relatively small portion of daily intake comes from pasture. In this case, producing an adequate quantity of pasture forage is relatively more important than producing high quality pasture. For operations in which grazing accounts for a significant portion of daily intake (i.e. if ration intake has been depressed by grazing), pasture quality becomes an important factor. Depending on individual needs and management practices, differences in forage quality among grass mixes may be unimportant; or they may be of great importance. For producers needing high yields and relatively good quality, tall fescue would provide a good combination of both. Alternatively, producers desiring higher CP, intake, and palatability should select one of the OG-MB-based mixes. It is important, however, to evaluate forage quality from the standpoint of both nutrient concentration and nutrient yield. A lower-quality but higher-yielding mix may produce more protein or digestible fiber per unit area, thus providing more value to a producer. Additionally, this study found that the addition of legumes to grass-based pasture is an excellent tool for increasing forage quality, especially crude protein content.

Nitrogen management is vital to forage productivity when using organic fertility sources. Variable nitrogen contents in composts used in this study resulted in unintended nitrogen deficiencies and subsequent yield and quality losses, reinforcing the importance of knowing the nutrient content and mineralization rates of organic fertility sources prior to their use. The nitrogen deficiency in 2009 seemed to have large effects on crude protein.

The establishment of legumes in this study proved difficult on multiple occasions due to factors including seeding depth, irrigation availability, and competition from established grasses. It is therefore important to view legume establishment, especially into established grasses, as a challenging, and sometimes lengthy process.

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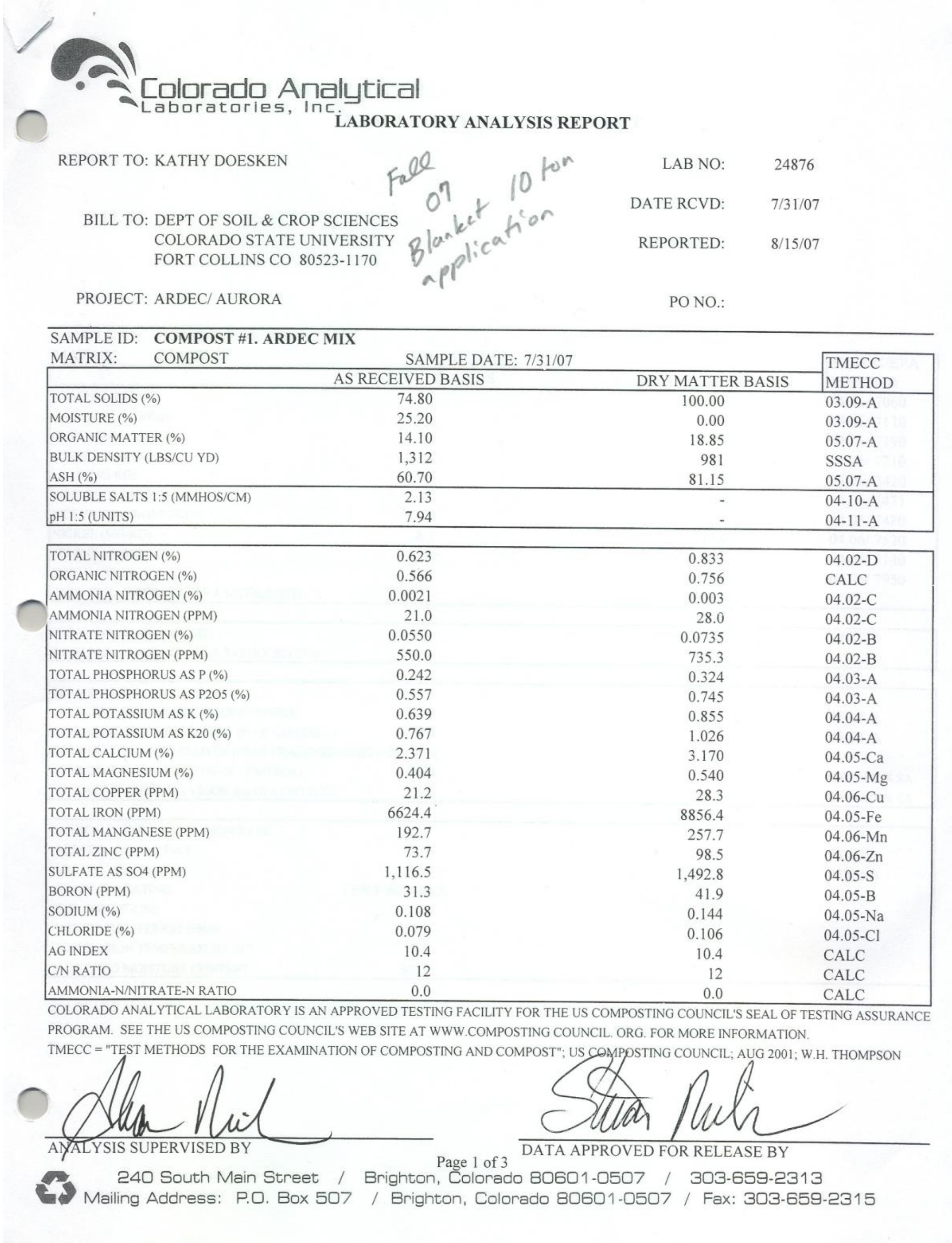
APPENDIX A - COMPOST ANALYSES



Colorado Analytical Laboratories, Inc.

LABORATORY ANALYSIS REPORT

REPORT TO: KATHY DOESKEN

Fall 07 Blanket 10 ton application

LAB NO: 24876

DATE RCVD: 7/31/07

BILL TO: DEPT OF SOIL & CROP SCIENCES
COLORADO STATE UNIVERSITY
FORT COLLINS CO 80523-1170

REPORTED: 8/15/07

PROJECT: ARDEC/ AURORA

PO NO.:

SAMPLE ID: **COMPOST #1. ARDEC MIX**
MATRIX: COMPOST
SAMPLE DATE: 7/31/07

	AS RECEIVED BASIS	DRY MATTER BASIS	TMECC METHOD
TOTAL SOLIDS (%)	74.80	100.00	03.09-A
MOISTURE (%)	25.20	0.00	03.09-A
ORGANIC MATTER (%)	14.10	18.85	05.07-A
BULK DENSITY (LBS/CU YD)	1,312	981	SSSA
ASH (%)	60.70	81.15	05.07-A
SOLUBLE SALTS 1:5 (MMHOS/CM)	2.13	-	04-10-A
pH 1:5 (UNITS)	7.94	-	04-11-A
TOTAL NITROGEN (%)	0.623	0.833	04.02-D
ORGANIC NITROGEN (%)	0.566	0.756	CALC
AMMONIA NITROGEN (%)	0.0021	0.003	04.02-C
AMMONIA NITROGEN (PPM)	21.0	28.0	04.02-C
NITRATE NITROGEN (%)	0.0550	0.0735	04.02-B
NITRATE NITROGEN (PPM)	550.0	735.3	04.02-B
TOTAL PHOSPHORUS AS P (%)	0.242	0.324	04.03-A
TOTAL PHOSPHORUS AS P2O5 (%)	0.557	0.745	04.03-A
TOTAL POTASSIUM AS K (%)	0.639	0.855	04.04-A
TOTAL POTASSIUM AS K20 (%)	0.767	1.026	04.04-A
TOTAL CALCIUM (%)	2.371	3.170	04.05-Ca
TOTAL MAGNESIUM (%)	0.404	0.540	04.05-Mg
TOTAL COPPER (PPM)	21.2	28.3	04.06-Cu
TOTAL IRON (PPM)	6624.4	8856.4	04.05-Fe
TOTAL MANGANESE (PPM)	192.7	257.7	04.06-Mn
TOTAL ZINC (PPM)	73.7	98.5	04.06-Zn
SULFATE AS SO4 (PPM)	1,116.5	1,492.8	04.05-S
BORON (PPM)	31.3	41.9	04.05-B
SODIUM (%)	0.108	0.144	04.05-Na
CHLORIDE (%)	0.079	0.106	04.05-Cl
AG INDEX	10.4	10.4	CALC
C/N RATIO	12	12	CALC
AMMONIA-N/NITRATE-N RATIO	0.0	0.0	CALC

COLORADO ANALYTICAL LABORATORY IS AN APPROVED TESTING FACILITY FOR THE US COMPOSTING COUNCIL'S SEAL OF TESTING ASSURANCE PROGRAM. SEE THE US COMPOSTING COUNCIL'S WEB SITE AT WWW.COMPOSTING COUNCIL. ORG. FOR MORE INFORMATION.
TMECC = "TEST METHODS FOR THE EXAMINATION OF COMPOSTING AND COMPOST"; US COMPOSTING COUNCIL; AUG 2001; W.H. THOMPSON

ANALYSIS SUPERVISED BY

DATA APPROVED FOR RELEASE BY

Page 1 of 3

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Mailing Address: P.O. Box 507 / Brighton, Colorado 80601-0507 / Fax: 303-659-2315

Figure 9. Compost analysis for compost used in preplant application.

Colorado Analytical Laboratories, Inc.

first STW spring 2008 application

LABORATORY ANALYSIS REPORT

REPORT TO: ADDY ELLIOTT

LAB NO: 25255.03

DATE RCVD: 4/18/08

BILL TO: DEPT OF SOIL & CROP SCIENCES
COLORADO STATE UNIVERSITY
FORT COLLINS CO 80523-1170

REPORTED: 5/2/08

PROJECT: AURORA PROJECTS

PO NO.: NA/WILL PAY INVOICE

SAMPLE ID: **COMPOST**
MATRIX: COMPOST

SAMPLE DATE: 4/17/08

	AS RECEIVED BASIS	DRY MATTER BASIS	TMECC METHOD
TOTAL SOLIDS (%)	71.38	100.00	03.09-A
MOISTURE (%)	28.62	0.00	03.09-A
ORGANIC MATTER (%)	17.20	24.10	05.07-A
ASH (%)	54.18	75.90	05.07-A
SOLUBLE SALTS 1:5 (MMHOS/CM)	5.14	-	04-10-A
pH 1:5 (UNITS)	8.62	-	04-11-A
TOTAL NITROGEN (%)	1.074	1.504	04.02-D
ORGANIC NITROGEN (%)	1.011	1.416	CALC
AMMONIA NITROGEN (%)	0.0127	0.018	04.02-C
AMMONIA NITROGEN (PPM)	127.2	178.2	04.02-C
NITRATE NITROGEN (%)	0.0503	0.0704	04.02-B
NITRATE NITROGEN (PPM)	502.7	704.3	04.02-B
TOTAL PHOSPHORUS AS P (%)	0.505	0.708	04.03-A
TOTAL PHOSPHORUS AS P2O5 (%)	1.162	1.628	04.03-A
TOTAL POTASSIUM AS K (%)	1.321	1.851	04.04-A
TOTAL POTASSIUM AS K20 (%)	1.585	2.221	04.04-A
C/N RATIO	8	8	CALC
AMMONIA-N/NITRATE-N RATIO	0.3	0.3	CALC

TO CONVERT % TO PPM MULTIPLY BY 10,000. TO CONVERT % TO LBS/TON MULTIPLY BY 20.

COLORADO ANALYTICAL LABORATORY IS AN APPROVED TESTING FACILITY FOR THE US COMPOSTING COUNCIL'S SEAL OF TESTING ASSURANCE PROGRAM. SEE THE US COMPOSTING COUNCIL'S WEB SITE AT WWW.COMPOSTING COUNCIL. ORG. FOR MORE INFORMATION.

TMECC = "TEST METHODS FOR THE EXAMINATION OF COMPOSTING AND COMPOST"; US COMPOSTING COUNCIL; AUG 2001; W.H. THOMPSON

ANALYSIS SUPERVISED BY

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Page 1 of 1

240 South Main Street / Brighton, Colorado 80601-0507 / 303-659-2313
Mailing Address: P.O. Box 507 / Brighton, Colorado 80601-0507 / Fax: 303-659-2315

Figure 10. Compost analysis for compost used in spring 2008 application.

04/29/2009 10:31 3036592315 COLORADO ANALYTICAL PAGE 06/07

2nd Stuth
fall 2008
application

Colorado Analytical Laboratories, Inc.

LABORATORY ANALYSIS REPORT

REPORT TO: JESSICA DAVIS 25420.01

BILL TO: DEPT OF SOIL & CROP SCIENCES
COLORADO STATE UNIVERSITY
FORT COLLINS CO 80523-1170

DATE RCVD: 9/9/08

REPORTED: 9/22/08

PROJECT:

PO NO.:

SAMPLE ID: COMPOST
MATRIX: COMPOST SAMPLE DATE: NONE

	AS RECEIVED BASIS	DRY MATTER BASIS	TMECC METHOD
TOTAL SOLIDS (%)	79.56	100.00	03.09-A
MOISTURE (%)	20.44	0.00	03.09-A
ORGANIC MATTER (%)	6.84	8.60	05.07-A
ASH (%)	72.72	91.40	05.07-A
SOLUBLE SALTS 1:5 (MMHOS/CM)	2.66	-	04-10-A
pH 1:5 (UNITS)	9.09	-	04-11-A
TOTAL NITROGEN (%)	0.291	0.366	04.02-D
ORGANIC NITROGEN (%)	0.258	0.324	CALC
AMMONIA NITROGEN (%)	0.0325	0.041	04.02-C
AMMONIA NITROGEN (PPM)	325.5	409.1	04.02-C
NITRATE NITROGEN (%)	0.0007	0.0008	04.02-B
NITRATE NITROGEN (PPM)	6.7	8.5	04.02-B
TOTAL PHOSPHORUS AS P (%)	0.107	0.134	04.03-A
TOTAL PHOSPHORUS AS P2O5 (%)	0.245	0.308	04.03-A
TOTAL POTASSIUM AS K (%)	0.465	0.584	04.04-A
TOTAL POTASSIUM AS K20 (%)	0.558	0.701	04.04-A
C/N RATIO	12	12	CALC
AMMONIA-N/NITRATE-N RATIO	48.4	48.4	CALC

TO CONVERT % TO PPM MULTIPLY BY 10,000. TO CONVERT % TO LBS/TON MULTIPLY BY 20.

COLORADO ANALYTICAL LABORATORY IS AN APPROVED TESTING FACILITY FOR THE US COMPOSTING COUNCIL'S SEAL OF TESTING ASSURANCE PROGRAM. SEE THE US COMPOSTING COUNCIL'S WEB SITE AT WWW.COMPOSTING COUNCIL. ORG. FOR MORE INFORMATION.

TMECC = "TEST METHODS FOR THE EXAMINATION OF COMPOSTING AND COMPOST"; US COMPOSTING COUNCIL; AUG 2001; W.H. THOMPSON

ANALYSIS SUPERVISED BY DATA APPROVED FOR RELEASE BY

Page 1 of 1

240 South Main Street / Brighton, Colorado 80601-0507 / 303-659-2313
Mailing Address: P.O. Box 507 / Brighton, Colorado 80601-0507 / Fax: 303-659-2315

Figure 11. Compost analysis for compost used in fall 2008 application.

APPENDIX B - PLOT MAPS

Rep 1

HWG - TF - HB Alfalfa **4**	HWG - TF - HB Sainfoin **3**	OG - MB - Smooth Brome Sainfoin **2**	OG - MB - Smooth Brome Alfalfa **1**
OG - MB - Kentucky BG Birdsfoot Trefoil **5**	OG - MB - Kentucky BG Sainfoin **6**	Tall Fescue White Clover **7**	OG - MB - Smooth Brome White Clover **8**
HWG - TF - HB Alfalfa **12**	OG - MB - Smooth Brome Birdsfoot Trefoil **11**	OG - MB - Kentucky BG White Clover **10**	HWG - TF - HB Sainfoin **9**
HWG - TF - HB White Clover **13**	OG - MB - Kentucky BG White Clover **14**	Tall Fescue White Clover **15**	Tall Fescue Sainfoin **16**
OG - MB - Kentucky BG Birdsfoot Trefoil **20**	HWG - TF - HB White Clover **19**	OG - MB - Smooth Brome Alfalfa **18**	OG - MB - Smooth Brome Sainfoin **17**
OG - MB - Kentucky BG Sainfoin **21**	OG - MB - Smooth Brome White Clover **22**	OG - MB - Kentucky BG Alfalfa **23**	Tall Fescue Sainfoin **24**
Tall Fescue Birdsfoot Trefoil **28**	HWG - TF - HB Birdsfoot Trefoil **27**	OG - MB - Smooth Brome Birdsfoot Trefoil **26**	OG - MB - Kentucky BG Alfalfa **25**
Tall Fescue Alfalfa **29**	HWG - TF - HB Birdsfoot Trefoil **30**	Tall Fescue Birdsfoot Trefoil **31**	Tall Fescue Alfalfa **32**

Rep 2

HWG - TF - HB Alfalfa **36**	HWG - TF - HB White Clover **35**	OG - MB - Kentucky BG Alfalfa **34**	Tall Fescue Birdsfoot Trefoil **33**
OG - MB - Smooth Brome Sainfoin **37**	Tall Fescue White Clover **38**	OG - MB - Smooth Brome White Clover **39**	Tall Fescue Alfalfa **40**
Tall Fescue Birdsfoot Trefoil **44**	OG - MB - Smooth Brome Alfalfa **43**	OG - MB - Smooth Brome Sainfoin **42**	HWG - TF - HB White Clover **41**
HWG - TF - HB Sainfoin **45**	Tall Fescue Sainfoin **46**	HWG - TF - HB Birdsfoot Trefoil **47**	OG - MB - Kentucky BG Sainfoin **48**
OG - MB - Smooth Brome White Clover **52**	OG - MB - Smooth Brome Alfalfa **51**	HWG - TF - HB Birdsfoot Trefoil **50**	OG - MB - Kentucky BG White Clover **49**
OG - MB - Kentucky BG Birdsfoot Trefoil **53**	Tall Fescue White Clover **54**	OG - MB - Smooth Brome Birdsfoot Trefoil **55**	HWG - TF - HB Alfalfa **56**
OG - MB - Kentucky BG Alfalfa **60**	HWG - TF - HB Sainfoin **59**	OG - MB - Kentucky BG Sainfoin **58**	OG - MB - Smooth Brome Birdsfoot Trefoil **57**
Tall Fescue Alfalfa **61**	OG - MB - Kentucky BG Birdsfoot Trefoil **62**	Tall Fescue Sainfoin **63**	OG - MB - Kentucky BG White Clover **64**

Rep 3

HWG - TF - HB White Clover **68**	OG - MB - Smooth Brome White Clover **67**	HWG - TF - HB White Clover **66**	OG - MB - Kentucky BG Birdsfoot Trefoil **65**
OG - MB - Smooth Brome Sainfoin **69**	Tall Fescue White Clover **70**	OG - MB - Kentucky BG White Clover **71**	Tall Fescue Birdsfoot Trefoil **72**
OG - MB - Kentucky BG Alfalfa **76**	Tall Fescue Sainfoin **75**	HWG - TF - HB Alfalfa **74**	OG - MB - Kentucky BG Sainfoin **73**
Tall Fescue Birdsfoot Trefoil **77**	OG - MB - Smooth Brome Sainfoin **78**	OG - MB - Smooth Brome Alfalfa **79**	OG - MB - Smooth Brome White Clover **80**
OG - MB - Kentucky BG Alfalfa **84**	OG - MB - Smooth Brome Birdsfoot Trefoil **83**	OG - MB - Smooth Brome Birdsfoot Trefoil **82**	HWG - TF - HB Birdsfoot Trefoil **81**
OG - MB - Kentucky BG White Clover **85**	OG - MB - Kentucky BG Birdsfoot Trefoil **86**	Tall Fescue Alfalfa **87**	Tall Fescue White Clover **88**
HWG - TF - HB Sainfoin **92**	Tall Fescue Sainfoin **91**	OG - MB - Smooth Brome Alfalfa **90**	Tall Fescue Alfalfa **89**
HWG - TF - HB Alfalfa **93**	HWG - TF - HB Birdsfoot Trefoil **94**	HWG - TF - HB Sainfoin **95**	OG - MB - Kentucky BG Sainfoin **96**

(shaded)	**Compost treatment**	**HWG**	**Hybrid Wheatgrass**
		TF	**Tall Fescue**
		HB	**Hybrid Brome**
(unshaded)	**Legume treatment**	**OG**	**Orchardgrass**
		KB	**Kentucky Bluegrass**
		SB	**Smooth Brome**

Figure 12. 2008 Plot map.

Rep 1			
HWG - TF - HB Alfalfa **Plot 4**	HWG - TF - HB Sainfoin **Plot 3**	OG - MB - Smooth Brome Sainfoin **Plot 2**	OG - MB - Smooth Brome Alfalfa **Plot 1**
OG - MB - Kentucky BG Birdsfoot Trefoil **Plot 5**	OG - MB - Kentucky BG **Plot 6 11.5 Mg ha-1**	Tall Fescue White Clover **Plot 7**	OG - MB - Smooth Brome White Clover **Plot 8**
HWG - TF - HB Alfalfa **Plot 12**	OG - MB - Smooth Brome Birdsfoot Trefoil **Plot 11**	OG - MB - Kentucky BG White Clover **Plot 10**	HWG - TF - HB **Plot 9 22 Mg ha-1**
HWG - TF - HB **Plot 13 0 Mg ha^{-1}**	OG - MB - Kentucky BG **Plot 14 0 Mg ha-1**	Tall Fescue **Plot 15 22 Mg ha-1**	Tall Fescue **Plot 16 11.5 Mg ha-1**
OG - MB - Kentucky BG **Plot 20 10 Mg ha-1**	HWG - TF - HB White Clover **Plot 19**	OG - MB - Smooth Brome Alfalfa **Plot 18**	OG - MB - Smooth Brome **Plot 17 22 Mg ha-1**
OG - MB - Kentucky BG Sainfoin **Plot 21**	OG - MB - Smooth Brome **Plot 22 0 Mg ha-1**	OG - MB - Kentucky BG Alfalfa **Plot 23**	Tall Fescue Sainfoin **Plot 24**
Tall Fescue **Plot 28 0 Mg ha-1**	HWG - TF - HB Birdsfoot Trefoil **Plot 27**	OG - MB - Smooth Brome **Plot 26 11.5 Mg ha-1**	OG - MB - Kentucky BG Alfalfa **Plot 25**
Tall Fescue Alfalfa **Plot 29**	HWG - TF - HB **Plot 30 11.5 Mg ha-1**	Tall Fescue Birdsfoot Trefoil **Plot 31**	Tall Fescue Alfalfa **Plot 32**
Rep 2			
HWG - TF - HB Alfalfa **Plot 36**	HWG - TF - HB **Plot 35 22 Mg ha-1**	OG - MB - Kentucky BG Alfalfa **Plot 34**	Tall Fescue Birdsfoot Trefoil **Plot 33**
OG - MB - Smooth Brome Sainfoin **Plot 37**	Tall Fescue **Plot 38 22 Mg ha-1**	OG - MB - Smooth Brome White Clover **Plot 39**	Tall Fescue Alfalfa **Plot 40**
Tall Fescue **Plot 44 0 Mg ha-1**	OG - MB - Smooth Brome Alfalfa **Plot 43**	OG - MB - Smooth Brome **Plot 42 22 Mg ha-1**	HWG - TF - HB White Clover **Plot 41**
HWG - TF - HB Sainfoin **Plot 45**	Tall Fescue Sainfoin **Plot 46**	HWG - TF - HB Birdsfoot Trefoil **Plot 47**	OG - MB - Kentucky BG **Plot 48 11.5 Mg ha-1**
OG - MB - Smooth Brome **Plot 52 0 Mg ha-1**	OG - MB - Smooth Brome Alfalfa **Plot 51**	HWG - TF - HB **Plot 50 11.5 Mg ha-1**	OG - MB - Kentucky BG White Clover **Plot 49**
OG - MB - Kentucky BG Birdsfoot Trefoil **Plot 53**	Tall Fescue White Clover **Plot 54**	OG - MB - Smooth Brome Birdsfoot Trefoil **Plot 55**	HWG - TF - HB Alfalfa **Plot 56**
OG - MB - Kentucky BG Alfalfa **Plot 60**	HWG - TF - HB **Plot 59 0 Mg ha-1**	OG - MB - Kentucky BG Sainfoin **Plot 58**	OG - MB - Smooth Brome **Plot 57 11.5 Mg ha-1**
Tall Fescue Alfalfa **Plot 61**	OG - MB - Kentucky BG **Plot 62 22 Mg ha-1**	Tall Fescue **Plot 63 11.5 Mg ha-1**	OG - MB - Kentucky BG **Plot 64 0 Mg ha-1**
Rep 3			
HWG - TF - HB White Clover **Plot 68**	OG - MB - Smooth Brome **Plot 67 0 Mg ha-1**	HWG - TF - HB **Plot 66 22 Mg ha-1**	OG - MB - Kentucky BG **Plot 65 11.5 Mg ha-1**
OG - MB - Smooth Brome Sainfoin **Plot 69**	Tall Fescue **Plot 70 0 Mg ha-1**	OG - MB - Kentucky BG White Clover **Plot 71**	Tall Fescue **Plot 72 11.5 Mg ha-1**
OG - MB - Kentucky BG Alfalfa **Plot 76**	Tall Fescue Sainfoin **Plot 75**	HWG - TF - HB Alfalfa **Plot 74**	OG - MB - Kentucky BG **Plot 73 0 Mg ha-1**
Tall Fescue Birdsfoot Trefoil **Plot 77**	OG - MB - Smooth Brome **Plot 78 22 Mg ha-1**	OG - MB - Smooth Brome Alfalfa **Plot 79**	OG - MB - Smooth Brome White Clover **Plot 80**
OG - MB - Kentucky BG Alfalfa **Plot 84**	OG - MB - Smooth Brome Birdsfoot Trefoil **Plot 83**	OG - MB - Smooth Brome **Plot 82 11.5 Mg ha-1**	HWG - TF - HB **Plot 81 11.5 Mg ha-1**
OG - MB - Kentucky BG **Plot 85 22 Mg ha-1**	OG - MB - Kentucky BG Birdsfoot Trefoil **Plot 86**	Tall Fescue Alfalfa **Plot 87**	Tall Fescue White Clover **Plot 88**
HWG - TF - HB Sainfoin **Plot 92**	Tall Fescue **Plot 91 22 Mg ha-1**	OG - MB - Smooth Brome Alfalfa **Plot 90**	Tall Fescue Alfalfa **Plot 89**
HWG - TF - HB Alfalfa **Plot 93**	HWG - TF - HB Birdsfoot Trefoil **Plot 94**	HWG - TF - HB **Plot 95 0 Mg ha-1**	OG - MB - Kentucky BG Sainfoin **Plot 96**

	Compost treatment	**HWG**	**Hybrid Wheatgrass**
		TF	**Tall Fescue**
	Legume treatment	**HB**	**Hybrid Brome**
		OG	**Orchardgrass**
		KB	**Kentucky Bluegrass**
		SB	**Smooth Brome**

Fig 13. 2009 Plot map.

APPENDIX C - POINT SAMPLING DATA

Table 24. Average abundance of grasses, legumes, and weeds in mixes used in the study in 2008.

Mix		HWG	TF	HB	alfalfa	sainfoin	birdsfoot trefoil	white clover	weed
Grass(es)	Legume species	Average abundance (%)							
HWG-TF-HB	alfalfa	16.0	57.3	16.0	5.3	0.0	0.0	0.0	1.3
HWG-TF-HB	birdsfoot trefoil	22.7	42.7	12.0	0.0	0.0	22.7	0.0	0.0
HWG-TF-HB	sainfoin	9.3	74.7	12.0	0.0	2.7	0.0	0.0	0.4
HWG-TF-HB	white clover	14.7	44.0	12.0	0.0	0.0	0.0	28.0	1.8
HWG-TF-HB		19.5	62.0	15.0	0.0	0.0	0.0	0.0	1.0
TF	alfalfa	0.0	86.7	0.0	8.0	0.0	0.0	0.0	1.3
TF	birdsfoot trefoil	0.0	74.0	0.0	0.0	0.0	21.3	0.0	2.2
TF	sainfoin	0.0	85.3	0.0	2.7	5.3	0.0	0.0	0.9
TF	white clover	0.0	80.0	0.0	0.0	0.0	0.0	14.0	0.0
TF		0.0	94.7	0.0	0.0	0.0	0.0	0.0	3.6

Table 25. Average abundance of grasses, legumes, and weeds in mixes used in the study in 2009.

Mix		OG	MB	SB	KB	alfalfa	sainfoin	birdsfoot trefoil	white clover	weed
Grass(es)	Legume species	Average abundance (%)								
OG-MB-KB	alfalfa	16.0	50.7	0.0	14.7	12.0	0.0	0.0	0.0	0.0
OG-MB-KB	birdsfoot trefoil	8.0	34.7	0.0	24.0	0.0	0.0	21.3	0.0	1.8
OG-MB-KB	sainfoin	9.3	37.3	0.0	17.3	10.7	1.3	0.0	0.0	1.3
OG-MB-KB	white clover	12.0	26.0	0.0	8.0	4.0	0.0	0.0	2.7	0.0
OG-MB-KB		13.6	32.8	0.0	22.4	1.2	0.0	0.0	4.4	2.2
OG-MB-SB	alfalfa	24.0	18.7	44.0	0.0	6.7	0.0	0.0	38.0	0.9
OG-MB-SB	birdsfoot trefoil	6.7	22.7	40.0	0.0	0.0	0.0	20.0	0.0	0.0
OG-MB-SB	sainfoin	29.3	21.3	40.0	0.0	0.0	5.3	0.0	0.0	2.2
OG-MB-SB	white clover	12.0	26.7	41.3	0.0	1.3	0.0	0.0	17.3	1.7
OG-MB-SB		24.0	15.3	50.7	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX D - ANALYSIS OF VARIANCE TABLES

Table 26. Analysis of variance for soil phosphorus in fall 2008.

	Degrees of freedom	F value	P value
grass mix	3	0.31	0.8216
treatment	1	32.27	<.0001
treatment * mix	3	0.77	0.5133

Table 27. Analysis of variance for soil phosphorus in spring 2009.

	Degrees of freedom	F value	P value
grass mix	3	2.67	0.0691
treatment	3	12.07	<.0001
treatment * mix	9	0.69	0.7129

Table 28. Analysis of variance for soil nitrate in fall 2008.

	Degrees of freedom	F value	P value
grass mix	3	0.31	0.8213
treatment	1	1.70	0.1963
treatment * mix	3	0.30	0.8273

Table 29. Analysis of variance for soil nitrate in spring 2009.

	Degrees of freedom	F value	P value
grass mix	3	0.86	0.4740
treatment	3	0.35	0.7862
treatment * mix	9	1.43	0.2262

Table 30. Analysis of variance for soil potassium in fall 2008.

	Degrees of freedom	F value	P value
grass mix	3	1.71	0.1724
treatment	1	186.48	<.0001
treatment * mix	3	0.43	0.7322

Table 31. Analysis of variance for soil potassium in spring 2009.

	Degrees of freedom	F value	P value
grass mix	3	2.76	0.0537
treatment	3	92.02	<.0001
treatment * mix	9	2.06	0.0625

Table 32. Analysis of variance for soil organic matter in fall 2008.

	Degrees of freedom	F value	P value
grass mix	3	0.43	0.7337
treatment	1	5.03	0.0279
treatment * mix	3	0.11	0.9547

Table 33. Analysis of variance for soil organic matter in spring 2009.

	Degrees of freedom	F value	P value
grass mix	3	0.28	0.8421
Treatment	3	13.34	<.0001
treatment * mix	9	1.45	0.1856

Table 34. Analysis of variance for 2008 total annual dry matter yield.

	Degrees of freedom	F value	P value
grass mix	16	7.59	0.0022
Fertility	16	2.38	0.1426
fertility * mix	16	0.88	0.4719

Table 35. Analysis of variance for 2008 dry matter yield.

	Degrees of freedom	F value	P value
grass mix	3	7.59	0.0022
Fertility	1	2.38	0.1426
fertility *mix	3	0.88	0.4719
cutting	5	67.34	<.0001
grass mix *cutting	15	3.41	0.0003
fertility * cutting	5	1.49	0.2093
fertility * grass mix * cutting	15	0.51	0.9272

Table 36. Analysis of variance for 2009 dry matter yield of compost treatments.

	Degrees of freedom	F value	P value
Fertility	2	4.11	0.0191
grass mix	3	9.22	<.0001
fertility *mix	6	1.29	0.2659
cutting	4	81.62	<.0001
fertility *cutting	8	0.58	0.7916
grass mix * cutting	12	1.21	0.2829
fertility * grass mix * cutting	24	0.89	0.6206

Table 37. Analysis of variance for 2009 dry matter yield of legume treatments.

	Degrees of freedom	F value	P value
Fertility	3	4.27	0.0084
grass mix	3	0.99	0.4028
fertility *mix	9	1.55	0.1505
cutting	1	4.99	0.0892
fertility *cutting	3	1.03	0.3877
grass mix * cutting	3	0.74	0.5303
fertility * grass mix * cutting	9	1.05	0.4133

Table 38. Analysis of variance for 2008 crude protein.

	Degrees of freedom	F value	P value
grass mix	3	6.67	0.0042
Fertility	1	3.23	0.0918
fertility *mix	3	1.09	0.3836
cutting	5	14.01	<.0001
grass mix *cutting	15	1.72	0.0689
fertility * cutting	5	0.56	0.7316
fertility * grass mix * cutting	15	1.29	0.2316

Table 39. Analysis of variance for 2009 crude protein of compost treatments.

	Degrees of freedom	F value	P value
Fertility	1	0.09	0.7698
grass mix	3	56.61	<.0001
fertility *mix	3	2.85	0.0436
cutting	4	98.52	<.0001
fertility *cutting	4	0.84	0.5058
grass mix * cutting	12	1.84	0.0588
fertility * grass mix * cutting	12	0.77	0.6792

Table 40. Analysis of variance for 2009 crude protein of legume treatments.

	Degrees of freedom	F value	P value
Fertility	3	27.29	<.0001
grass mix	3	30.69	<.0001
fertility *mix	9	1.01	0.4400
cutting	1	8.49	0.0435
fertility *cutting	3	0.26	0.8540
grass mix * cutting	3	0.84	0.4791
fertility * grass mix * cutting	9	0.33	0.9624

Table 41. Analysis of variance for 2008 neutral detergent fiber.

	Degrees of freedom	F value	P value
grass mix	3	3.77	0.0347
Fertility	1	0.25	0.6263
fertility *mix	3	0.89	0.4708
cutting	5	50.82	<.0001
grass mix *cutting	15	1.08	0.3888
fertility * cutting	5	0.36	0.8745
fertility * grass mix * cutting	15	1.60	0.8677

Table 42. Analysis of variance for 2009 neutral detergent fiber of compost treatments.

	Degrees of freedom	F value	P value
Fertility	1	2.37	0.1280
grass mix	3	3.64	0.0166
fertility *mix	3	0.76	0.5226
cutting	4	67.85	<.0001
fertility *cutting	4	0.59	0.6740
grass mix * cutting	12	1.33	0.2240
fertility * grass mix * cutting	12	0.79	0.6596

Table 43. Analysis of variance for 2009 neutral detergent fiber of legume treatments.

	Degrees of freedom	F value	P value
Fertility	3	18.12	<.0001
grass mix	3	13.49	<.0001
fertility *mix	9	0.41	0.9239
cutting	1	3.20	0.1484
fertility *cutting	3	1.45	0.2376
grass mix * cutting	3	2.49	0.6888
fertility * grass mix * cutting	9	0.49	0.8776

Table 44. Analysis of variance for 2008 acid detergent fiber.

	Degrees of freedom	F value	P value
grass mix	3	13.06	<.0001
Fertility	1	0.05	0.8301
fertility *mix	3	0.06	0.9804
cutting	5	47.89	<.0001
grass mix *cutting	15	2.07	0.0203
fertility * cutting	5	0.77	0.5749
fertility * grass mix * cutting	15	0.94	0.5211

Table 45. Analysis of variance for 2009 neutral detergent fiber of compost treatments.

	Degrees of freedom	F value	P value
Fertility	3	13.69	<.0001
grass mix	3	2.62	0.0588
fertility *mix	9	0.35	0.9551
cutting	1	38.17	0.0035
fertility *cutting	3	3.20	0.0297
grass mix * cutting	3	5.35	0.0025
fertility * grass mix * cutting	9	1.91	0.0680

Table 46. Analysis of variance for 2009 acid detergent fiber of legume treatments.

	Degrees of freedom	F value	P value
Fertility	1	2.31	0.1331
grass mix	3	0.49	0.6892
fertility *mix	3	0.11	0.9518
cutting	4	83.44	<.0001
fertility *cutting	4	2.13	0.0867
grass mix * cutting	12	1.29	0.2443
fertility * grass mix * cutting	12	1.00	0.4592

Table 47. Analysis of variance for 2008 dry matter intake.

	Degrees of freedom	F value	P value
grass mix	3	4.64	0.0182
Fertility	1	0.37	0.5529
fertility *mix	3	0.93	0.4515
cutting	5	55.29	<.0001
grass mix *cutting	15	1.09	0.3860
fertility * cutting	5	0.35	0.8778
fertility * grass mix * cutting	15	0.63	0.8391

Table 48. Analysis of variance for 2008 dry matter digestibility.

	Degrees of freedom	F value	P value
grass mix	3	13.06	<.0001
Fertility	1	0.05	0.8301
fertility *mix	3	0.06	0.9804
cutting	5	47.89	<.0001
grass mix *cutting	15	2.07	0.0203
fertility * cutting	5	0.77	0.5749
fertility * grass mix * cutting	15	0.94	0.5211

Table 49. Analysis of variance for 2008 relative feed value.

	Degrees of freedom	F value	P value
grass mix	3	2.90	0.0478
Fertility	1	0.30	0.5854
fertility *mix	3	0.57	0.6361
cutting	5	61.55	<.0001
grass mix *cutting	15	1.41	0.1669
fertility * cutting	5	0.29	0.9173
fertility * grass mix * cutting	15	0.84	0.6360