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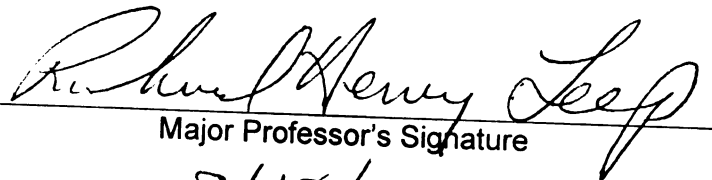
Evaluation of *Medicago sativa* spp. *falcata* in Michigan

presented by

Elysia A Berry

has been accepted towards fulfillment
of the requirements for the

MS degree in Crop and Soil Science


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EVALUATION OF *Medicago sativa* spp. *falcata* IN MICHIGAN

By

Elysia A Berry

A THESIS

Submitted to
Michigan State University
In partial fulfillment of the requirements
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ABSTRACT

EVALUATION OF *Medicago sativa* spp. *falcata* IN MICHIGAN

By
Elysia A Berry

Grazing livestock is an important practice in Michigan to reduce feeding costs of harvested forage. Alfalfa and grass mixtures are commonly used for pastures in the north-central region. Falcata alfalfa (*Medicago sativa* spp. *falcata*) possesses several desirable characteristics for pastures in this region including winter hardiness and prolonged forage quality. This study evaluated forage yield, grazing preference, forage quality, and stand persistence of binary combinations of *Medicago falcata* cv. Yellowhead, *Medicago sativa* cv. ZG9830, and Birdsfoot trefoil (*Lotus corniculatus*) cv. Norcen seeded with one of the following perennial, cool season grass species: meadow fescue, orchardgrass, or timothy. Three stands were sown in May 2005: one in the Upper Peninsula and two in the Lower Peninsula of Michigan. Over the three year data collection period, an average of four grazing events occurred each year. *M. sativa* mixed with each of the grasses produced the greatest forage yield. *M. sativa* averaged almost 2.2 metric tons per hectare of dry matter over *M. falcata* and almost 4.5 metric tons per hectare of dry matter over birdsfoot trefoil. Overall, the cattle have shown no grazing preference for falcata over *sativa*, but a slight trend was seen for the birdsfoot trefoil. Significant differences were found in forage quality, both within and between the three locations. Stand persistence (plant density) varied each year due to sampling error.

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LIST OF ABBREVIATIONS

ADF	Acid Detergent Fiber
BFTFES	Birdsfoot Trefoil and Meadow Fescue
BFTOR	Birdsfoot Trefoil and Orchardgrass
BFTTIM	Birdsfoot Trefoil and Timothy
CP	Crude Protein
DM	Dry Matter
EL	Michigan State University Dairy, East Lansing, MI
FALFES	<i>Medicago sativa</i> spp. <i>falcata</i> and Meadow Fescue
FALOR	<i>Medicago sativa</i> spp. <i>falcata</i> and Orchardgrass
FALTIM	<i>Medicago sativa</i> spp. <i>falcata</i> and Timothy
LC	Lake City Experiment Station, Lake City, MI
NE _L	Net Energy for Lactation
NDF	Neutral Detergent Fiber
RFV	Relative Feed Value
SATFES	<i>Medicago sativa</i> spp. <i>sativa</i> and Meadow Fescue
SATOR	<i>Medicago sativa</i> spp. <i>sativa</i> and Orchardgrass
SATTIM	<i>Medicago sativa</i> spp. <i>sativa</i> and Timothy
TDN	Total Digestible Nutrients
UPES	Upper Peninsula Experiment Station, Chatham, MI

I. INTRODUCTION

Alfalfa is often preferred over other forage legumes in feeding ruminants, due to the high feed value, high forage yields, and drought resistance in areas of livestock production (Dietz, 2003). In 2001, alfalfa represented about 2.5% of the total agricultural hectareage in the US with approximately half of the alfalfa hectareage in the Upper Midwest and northern Great Plains (Riday and Brummer, 2002). In many cases, alfalfa is included in grazing systems to not only increase animal production (Campbell, 1963 and Barker et al., 1999), but to increase pasture and rangeland stand persistence (Berdahl et al, 1986), increase soil organic carbon (Bliss, 2003) in the pasture and rangeland and to provide enough nitrogen to sustain the pasture and rangeland for more years (Mortenson et al., 2004).

Yellow-flowered alfalfa (*Medicago sativa* spp. *falcata*; hereafter *falcata*) was a relatively unknown legume in America until its rediscovery on the Norman “Bud” Smith Ranch in South Dakota in the early 1960’s (Smith, 1997). Since then forage plant geneticists, especially Dr. Arvid Boe of South Dakota State University, have been interested in testing *falcata* to learn how this legume can be incorporated in to today’s grazing and forage production. Many cow/calf operations in the North Central region of the United States function on a narrow profit margin resulting in the need for forage management systems with little costs past those involved in the initial input.

There are many positive characteristics of purple flowered alfalfa (*Medicago sativa* L.; hereafter *sativa*) that are exhibited by *falcata*; even so, additional benefits of prolonged forage quality, greater pest resistance, and increased winterhardiness indicates *falcata* has good potential for use as a pasture legume in the North Central region of the

United States (Boe et al, 1998). Falcata alfalfa maintains forage yield (Boe et al.,1994) and quality longer, as well as being more persistent and shown to be more resistant to potato leafhopper (*Empoasca fabae*) (PLH) than sativa cultivars in the North-central plains (Bortnem et al., 1993). Falcata shows higher grazing tolerance and stand persistence due to the branching roots and prostrate growth habit of the alfalfa (Berdahl et al, 1989, Hendrickson and Berdahl, 2003). Even though sativa forage quality diminishes rapidly after the first bloom due to reduction in vegetative growth, lignification and leaf loss, falcata has been shown to maintain forage quality well-beyond flowering.

Because falcata and sativa are the same species, it is convenient to produce germ crosses of these two subspecies, trying to get the best of both in one plant. The falcata-sativa crosses commonly produce greater forage yields and increased stand persistence compared to falcata or sativa on its own (Berdahl et al., 1986; Riday and Brummer, 2002). This characteristic of falcata could increase the flexibility of grazing and stockpiling in pastures for cow/calf and dairy producers reducing the need and added cost of hay production.

Even with falcata's known benefits, there are a few characteristics which may pose problems in grazing situations. One negative characteristic of the falcata germplasm has been slower regrowth, dormancy during summer drought, and a more decumbent growth habit when stressed by the environment or heavy grazing conditions (Berdahl et al., 1989; Riday and Brummer, 2002). The slower regrowth may actually be attributed to falcata utilizing carbohydrate root reserves to maintain greater stand persistence following grazing (Berdahl et al., 1989). Seed production of falcata is a major issue due to problems with seed production and supply. Falcata has indeterminate growth habit,

thus, each plant in a stand has the ability to produce the sickle-shaped seed pods at different times, causing some pods to be ready before others, increasing the risk of pods shattering while trying to harvest the seed (Boe et al., 1998).

Falcata could be stockpiled in a field after September and fed to cattle during the winter months, if forage yield, quality (which will be lower than non-stockpiled material), and grazing palatability can be maintained. This study will evaluate the forage yield, forage quality, stand persistence, and palatability of falcata, sativa, and birdsfoot trefoil to provide information to farmers on the pasture potential of falcata compared to the sativa and birdsfoot trefoil varieties represented in the market.

Hypothesis and Objectives

The hypothesis that falcata will produce comparable forage yield, forage quality, and palatability to sativa (birdsfoot trefoil being the most palatable) and will have equal or greater stand persistence under rotational grazing compared to sativa or birdsfoot trefoil was the basis for this study.

The objectives of this study were:

- 1) To evaluate palatability of falcata under grazing practices as compared to sativa and birdsfoot trefoil in three locations in Michigan.
- 2) To determine forage yield and stand persistence of falcata as compared to sativa and birdsfoot trefoil under the same grazing practices.
- 3) To determine forage quality and palatability of falcata compared to sativa and birdsfoot trefoil under free-choice grazing by dairy and beef cows.

II. MATERIALS AND METHODS

Site Description

Alfalfa grazing research trials were established at three locations across Michigan in spring 2005: Michigan State University Dairy in East Lansing (EL), Ingham County, Michigan (42°72' N, 84°49' W) on a Marlette fine sandy loam; Lake City Experiment Station in Lake City (LC), Missaukee County, Michigan (44°35' N, 85°18' W) on a Nester soil (fine sandy loam, mixed Typic Eutroboralfs); Upper Peninsula Experiment Station in Chatham (UPES), (46°35' N, 86°92' W) on an Eben soil (sandy loam, very cobbly, mixed, frigid Alfic Haplorthodes). The Lake City Experiment Station is located 140 miles north of East Lansing. The Upper Peninsula Experiment Station is located 370 miles north of East Lansing. Soil pH at the beginning of the trial in East Lansing was 7.3. Soil pH at the beginning of the trial in Lake City was 6.3. Soil pH at the beginning of the trial in Chatham was 7.4.

Legume-Grass Combinations

The three legumes chosen for this study were *Medicago sativa* spp. *falcata* (var. Yellowhead, developed by AG and Agri-Food Canada, Swift Current, Saskatchewan (Hendrickson et al., 2008, hereafter referred to as *falcata*), *Medicago sativa* spp. *sativa* (var. ZG9830, a grazing-type alfalfa, hereafter referred to as *sativa*) and *Lotus corniculatus* (var. Norcen, hereafter referred to as birdsfoot trefoil). Each legume was assigned to three plots: one plot contained the legume mixed with timothy grass (var. Dolina), one plot contained the legume mixed with meadow fescue (var. Laura), and one plot contained the legume mixed with orchardgrass (var. tekapo). Each plot was

duplicated in a split-plot design with the legume as the main plot and the grass combination as the subplot. Each plot consisted of two separate passes with the seeder so destructive sampling (plant digs for stand persistence and grazing palatability) could be obtained from one-half of the plot, while forage quality and forage yield was collected from the undestroyed half of the plot (Appendix Table 1-3). Each legume-grass combination was replicated four times at each trial location.

Establishment and Harvesting

A single soil test (pH, phosphorus, potassium, magnesium, calcium, and cation exchange capacity) at each location was obtained from a subsample from 20 cores (20-25 cm depth) randomly located within the trial area. Soil amendments, if necessary, were made prior to establishment. Conventional tillage (moldboard plowing and fitting with a disc or a drag, followed by cultipacking) was used to prepare the soil for the seeding after weeds were killed using glyphosate. Prior to seeding, alfalfa seed was inoculated with *Sinorhizobium meliloti* and birdsfoot trefoil with *Rhizobium loti* (Urbana Lab., Urbana, IL). A 0.9 m-wide Carter self-propelled nursery cone seeder (Carter Manufacturing, Brookston, IN) was used to seed the plots. All of the trial locations were seeded in spring 2005, while the East Lansing plots were reseeded in August 2005 due to accidental herbicide application which killed the grass in the plots. Seeding rates were as follows: falcata at 7.26 kg/acre, sativa at 5.44 kg/acre, birdsfoot trefoil at 2.72 kg/acre, meadow fescue at 3.63 kg/acre, orchardgrass at 1.81 kg/acre, and timothy at 0.91 kg/acre. These seeding rates were used following the recommendations for each of these species in actual planting for pastures. The plots were harvested, starting in spring 2006, using a

rotary flail harvester (Carter Manufacturing Co. Inc., Brookston, IN) to harvest the 0.9 by 7.6 m plots at a cutting height of 7 to 9 cm from the soil surface.

Data Analysis

Dry Matter Forage Yield

Dry matter content of harvested alfalfa was determined by collecting a subsample of harvested biomass which was weighed wet, dried at 60°C for 72 h, and weighed again.

Dry matter was determined as: $\text{DM content (\%)} = \text{Dry (g)} / \text{Wet (g)} \times 100$.

Forage Quality

Samples of alfalfa used for nutritive evaluation were collected at the time of harvest by clipping ~ 250 g of alfalfa from each plot prior to harvest or by capturing chopped biomass from the harvester. Samples were dried at 60°C for 48 h, and ground to pass through 1 mm screen in a Christy-Turner Lab Mill (Ipswich, Suffolk, UK). A minimum subsample of 20 g was retained for nutritive analysis. Each sample was scanned with a 6500 near-infrared spectrophotometer (NIRS, FOSS NIRSystems, Inc., Eden Prairie, MN) with wavelengths between 800 and 2500 nm. Reflected wavelengths were recorded. Crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) were predicted from equations developed by the NIRS Consortium (Madison, WI) and the MSU Forage Lab. A randomly selected subset of samples was compiled based on the neighborhood and Global H statistic to validate the NIRS prediction of crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF). The Goering and Van Soest (1970) method was used for NDF and ADF determination with the addition of 1 mL of alpha-amylase to the neutral detergent solution for the breakdown of starch. Dry matter (DM) content was determined by

drying 0.5 g of sample in ceramic crucibles at 100°C for 24 h. The samples were ignited in a muffle furnace at 500°C for 6 h to determine ash content. Total digestible nutrients for the NIRS were calculated using the equation:

$$\text{TDN} = \text{dNFC} + \text{dCP} + 2.25 * \text{dFA} + \text{dNDF} - 7$$

where

$$\text{digestible Non-fiber Carbohydrate} = 0.98 (100 - [(\text{NDF} - \text{NDCIP}) + \text{CP} + \text{EE} + \text{Ash}]) * \text{PAF}$$

$$\text{dFA} = \text{digestible Crude Fat}$$

$$\text{digestible Crude Protein} = \text{CP} * \exp[-1.2 * (\text{ADICP} / \text{CP})]$$

$$\text{digestible Neutral Detergent Fiber} = 0.75 * (\text{NDFn} - \text{L}) * [1 - (\text{L} / \text{NDFn})^{0.667}]$$

(National Research Council, 2001 p. 14)

Relative Feed Value (RFV) for the NIRS was calculated using the following formula: $(\text{DDM} * \text{DMI}) / 1.29$, where DDM is the digestible dry matter and DMI is the dry matter intake, estimated from ADF and NDF values, respectively. (Garcia et al., 2003).

Net Energy for Lactation (NE_L) is used to describe the amount of energy used by a cow for body maintenance, milk production, growth, and reproduction measured in megacalories per kilogram (Garcia et al., 2003). It can be calculated from TDN values using the following equation: $0.0245 * \text{TDN} - 0.12$ (National Research Council, 2001, pg. 13).

Stand persistence

Stand persistence was determined after by digging and counting plants in two 0.093 m^2 areas of the “destructive sampling plots” in the fall and spring of each year. In the spring, plots were visually rated for winter kill (scale: 1 to 10, 10-100% of the plot killed).

Palatability

Palatability was rated by using two people standing at opposing ends of each plot in the alleys between replications to assess the percentage of the plot consumed by a scale of 1 to 5 (1=0-20% of the plot consumed; 5=81-100% of the plot consumed). The length of each plot averaged 7.6 m.

Statistical Analysis

All data collected was tested for normality and unequal variances using PROC UNIVARIATE based on the Shapiro-Wilk statistic and data sets not normally distributed will be transformed. Analysis of variance was performed on all data with the PROC GLM procedure software version SAS 9.1 (SAS Institute, 2009) using the Kenward-Roger method for determining degrees of freedom. Means of forage yield, palatability, and weighted means of forage quality were separated by Fisher's Protected Least Significant Difference (LSD) test at the 5% level of significance. If LSD was not able to be obtained due to missing data points, standard error was used instead to determine significant differences.

Normality was not significantly different for any of the tested data once the cutting interactions were taken out of the equations. There were significant interactions between the sub plots, but not between the main effects. The cuttings caused a significant interaction due to the variability between East Lansing (13 cuttings total) and Lake City and Chatham (12 cuttings total each). Once normality was obtained, variances for forage quality were not statistically significant ($\alpha=0.05$) by year or location. Differences in forage yield totals (number of cuttings) between the locations caused the

forage yield data to be significantly different by location, resulting in data being run separately by location for forage yield.

Table 1. ANOVA output for yield.

Type 3 Analysis of Variance

Source	Error		
	DF	F Value	Pr > F
trt	592	5.01	<.0001
Loc	592	60.78	<.0001
Rep	592	0.82	0.4834
Year	592	7.70	0.0005
Cut	592	5.55	0.0009

III. RESULTS AND DISCUSSION

Weather Records

Chatham, MI

The amount of precipitation received between April and October each year was less than the 30 year average, during the three harvest years in Chatham. Chatham averaged 4.1 cm of precipitation less than the 30 year average of 60.3 cm, during the growing season. The total precipitation for the 2006, 2007, and 2008 growing seasons was 51.6 cm, 59.4 cm, and 57.45 cm, respectively (Table 4).

Table 2. Precipitation Data for Chatham, MI (cm).

Chatham					
	Norm*	2006	2007	2008	Deviation
Apr	6.3	5.1	16.3	16.0	6.2
May	8.0	14.5	5.5	9.3	1.8
June	9.2	2.2	5.2	9.4	-3.6
July	9.0	5.4	4.4	4.5	-4.3
Aug	9.0	8.4	2.0	2.7	-4.76
Sept	10.6	6.5	12.7	9.6	-1.0
Oct	8.2	9.6	13.3	5.9	1.4
Total	60.3	51.6	59.4	57.4	-4.1

*30 year average

During the course of the growing season (April to October), Chatham had slightly warmer than normal weather for 2006 and 2007, having a total average of 12.8°C and 14.4°C, respectively (Table 5). The grazing season for 2008 was only slightly below average at 12.3°C. The 30 year average temperature for Chatham (April to October, 1971-2000) was 12.6 °C.

Table 3. Temperature data for Chatham, MI (°C).

Chatham					
	Norm*	2006	2007	2008	Deviation
April	3.9	6.7	2.8	3.9	0.6
May	10.6	10.6	12.8	7.2	-0.4
June	15.6	14.4	17.2	13.9	-0.4
July	18.3	20.6	18.9	17.8	0.7
Aug	17.8	17.8	18.9	18.3	0.6
Sept	13.3	12.8	16.7	15.6	1.7
Oct	8.3	6.7	13.3	9.4	1.5
Average	12.6	12.8	14.4	12.3	0.6

* 30 year average

Table 4. Precipitation Data for Lake City, MI (cm).

Lake City					
	Norm*	2006	2007	2008	Deviation
Apr	7.3	9.3	8.8	8.9	1.7
May	6.8	14.1	5.6	4.5	1.3
June	7.9	12.7	9.5	18.2	5.6
July	8.3	5.5	3.1	10.0	-2.1
Aug	7.7	11.6	6.3	5.5	0.2
Sept	8.3	8.3	4.8	7.5	-1.4
Oct	6.7	11.9	6.2	6.8	1.6
Total	52.9	73.4	44.3	61.4	6.9

*30 year average

Lake City, MI

The amount of precipitation received between April and October in 2006 and 2008 was above the 30 year average, while 2007 was a below average year for precipitation in Lake City. The 30 year average for Lake City is 52.9 cm. In the 2006 and 2008 growing seasons, the amount of precipitation equaled 73.4 and 61.4 cm, respectively. In 2007, the amount of precipitation Lake City received was 44.3 cm.

Overall, the average rainfall during the course of this study was above the 30 year average, having an average of 6.9 cm of precipitation more each year (Table 6).

The average temperature during the course of the growing season (April to October), Lake City had slightly warmer than normal weather for 2006 and 2007, having a total average of 14.1°C and 14.4°C, respectively (Table 7). The grazing season for 2008 was only slightly below average at 13.0°C. The 30 year average temperature for Lake City (April to October, 1971-2000) was 13.3°C.

Table 5. Temperature Data for Lake City, MI (°C)

	Lake City				
	Norm*	2006	2007	2008	Deviation
April	5.0	7.2	4.4	7.2	1.3
May	11.7	13.3	13.9	9.4	0.6
June	16.7	17.2	17.8	16.7	0.6
July	19.4	21.1	18.9	18.9	0.2
Aug	18.3	19.4	18.9	17.2	0.2
Sept	13.9	13.3	15.6	14.4	0.6
Oct	7.8	6.7	11.1	7.2	0.6
Average	13.3	14.1	14.4	13.0	0.5

* 30 year average

East Lansing, MI

The amount of precipitation received each year was an average of 11.73 cm greater than the 30 year average precipitation received from April to October, during the three harvest years in East Lansing. The 30 year average was 50.6 cm. The 2006, 2007, and 2008 growing season precipitation amounts were 68.4 cm, 60.7 cm, and 57.8 cm of precipitation, respectively (Table 8).

The average temperature during the course of the growing season (April to October) for East Lansing was slightly warmer than normal for 2006, 2007, and 2008.

The total averages for each growing season were 15.7°C, 16.8°C, and 16.1°C respectively (Table 9). The 30 year average temperature for East Lansing (April to October, 1971-2000) was 15.2°C.

Table 6. Precipitation Data for East Lansing, MI (cm)

East Lansing					
	Norm*	2006	2007	2008	Deviation
Apr	7.1	5.9	4.7	5.5	-1. 8
May	6.9	14.3	10.6	3. 5	2.5
June	9.0	7.4	14.1	12.2	2.3
July	7. 7	9.4	1.3	9. 5	-1.0
Aug	7.9	14.3	13.2	1.3	1. 7
Sept	6.4	7.5	5.3	21.4	5.1
Oct	5.6	9.7	11.5	4.6	3.0
Total	50.6	68.4	60.7	57.8	11.7

*30 year average

Table 7. Temperature Data for East Lansing, MI (°C)

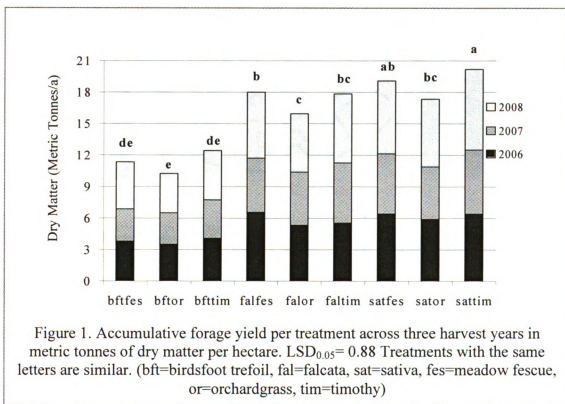
East Lansing					
	Norm*	2006	2007	2008	Deviation
April	7.2	10.0	6.7	10.0	1.7
May	13.9	14.4	16.1	12.8	0.6
June	18.9	18.9	20.6	20.0	0.9
July	21.1	22.8	21.1	21.7	0.7
Aug	20.0	21.1	21.7	20.6	1.1
Sept	15.6	15.0	17.8	17.8	1.3
Oct	10.0	7.8	13.9	9.4	0.4
Average	15.2	15.7	16.8	16.1	1.0

* 30 year average

Forage Yield Results

Chatham

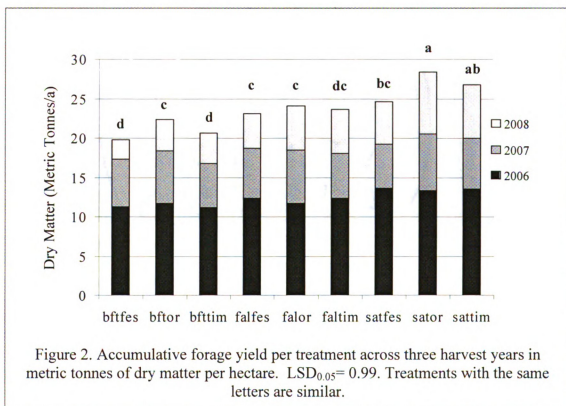
Four grazing events took place in the 2006, 2007, and 2008 grazing seasons. The harvest plots were harvested with the Carter flail harvest within two days of the grazing event. The sativa-timothy combination resulted in the greatest forage yield, with a 3-year total of 20 metric tonnes of DM/a. The significantly lowest yielding combinations across the three years were birdsfoot trefoil-meadow fescue and birdsfoot trefoil-orchardgrass combinations with total forage yields averaging 11 and 10 metric tonnes of DM/a, respectively (Figure 1). The falcata-orchardgrass and falcata-meadow fescue combinations were significantly lower yielding than sativa-timothy combinations, but the falcata-meadow fescue combination was higher than the falcata-orchardgrass, but not different than the sativa-meadow fescue or sativa-orchardgrass combinations. The



birdsfoot trefoil-grass combinations were significantly lower yielding than the falcata-grass and sativa-grass combinations ($\alpha=0.05$). The average total forage yields ranged from 16 metric tonnes of DM/a (falcata-orchardgrass) to 20 metric tonnes of DM/a (sativa-meadow fescue).

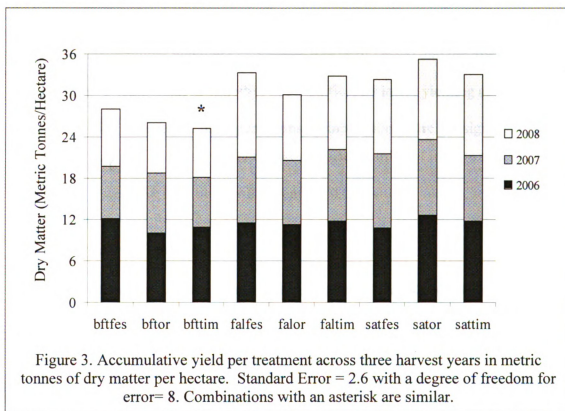
Lake City

Four grazing events took place in the 2006, 2007, and 2008 grazing seasons. The mechanically harvested plots were harvested with the Carter flail harvest within two days of the grazing event. The legume-grass combination with the highest forage yield across



the three grazing years was the sativa-orchardgrass with a total 3-year forage yield of 28 metric tonnes of DM/a; however, this was not significantly different than the sativa-timothy combination. The combinations which had significantly lower total average

forage yield were the birdsfoot trefoil-meadow fescue and birdsfoot trefoil-timothy combinations with total 3-year forage yields of 19.8 and 20.2 metric tonnes of DM/a, respectively (Figure 2). Other than the sativa-orchardgrass and sativa-timothy combinations, the other sativa-grass, falcata-grass, and birdsfoot trefoil-orchardgrass combinations were not significantly different ($\alpha=0.05$) with an average total forage yield ranging from 23 metric tonnes of DM/a (birdsfoot trefoil-orchardgrass) to 28 metric tonnes of DM/a (sativa-meadow fescue).



East Lansing

Five grazing events took place during the 2006 and 2007 grazing seasons and three data collections were taken for the 2008 grazing season. The harvest plots were harvested with the Carter flail harvest within two days of the grazing event. Due to

incomplete data collection during the fifth grazing events in 2006 and 2007, Least Significant Differences were not able to be analyzed, but standard error was used to analyze significant differences across the average total forage yields for the three years. Birdsfoot trefoil-timothy was the lowest yielding combination; an average total forage yield of 25 metric tonnes of DM/a was harvested. This combination is significantly different from the falcata-timothy, sativa-meadow fescue, and sativa-timothy combinations; average total forage yields of 33, 32.5, and 32 metric tonnes of DM/a, respectively (Figure 3). Using the standard error, the sativa-orchardgrass combination was significantly higher yielding (35.5 metric tonnes of DM/a) and the lowest yielding combination (birdsfoot trefoil-timothy) was significantly lower yielding at 25 metric tonnes of DM/a. The rest of the legume-grass combinations were not significantly different ($\alpha=0.05$).

Forage Quality Results

The recommended forage nutritive values for this section are based upon a small framed grazing dairy cow. Table 7 shows the recommended forage nutritive values to maintain the diet of a small framed grazing dairy cow producing 27 kg milk a day.

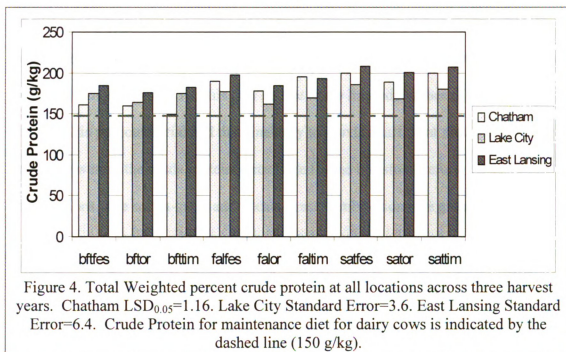
Table 8. Forage Nutritive Values for a grazing dairy cow (Amaral-Phillips et al.)

Crude Protein	Acid Detergent Fiber	Net Energy for Lactation
22%	19%	1.67 Mcal/kg

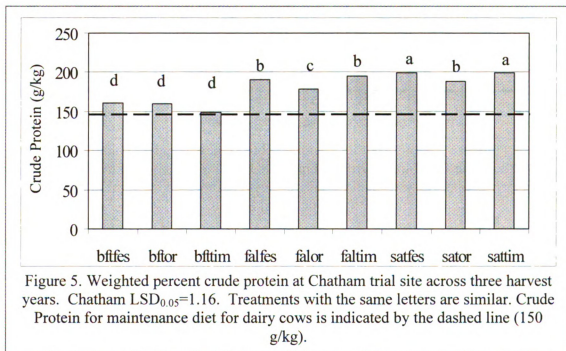
Crude Protein

The recommended minimum crude protein percentage for a maintenance diet for dairy cows is between 150 and 190 g/kg (National Research Council, pg. 50). As seen in

Figure 4, all of the legume-grass combinations (except the birdsfoot trefoil-grass combinations in Chatham) are above the required level for a maintenance diet of a dairy



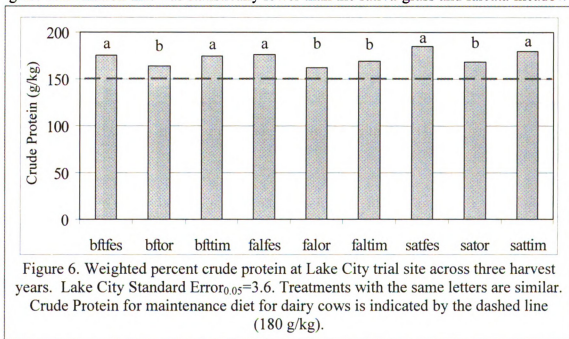
cow for all of the locations across the three grazing years. None of the legume-grass combinations were significantly different from one another between locations, however



statistical significance was seen within each location ($\alpha=0.05$).

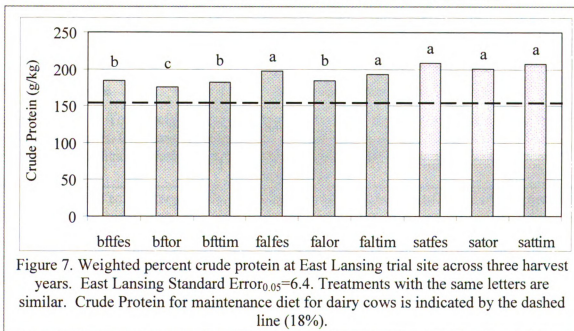
The results of the Chatham crude protein are given in Figure 5. The averages of the weighted percentage for the birdsfoot trefoil-grass combinations are significantly lower than the other legume-grass combinations, but still near the minimum requirements for a small framed dairy cow; this may be due to the limited number of birdsfoot trefoil plants in this particular trial and their inability to provide sufficient nitrogen to the grasses, lowering the crude protein percentage for the birdsfoot trefoil-grass combinations. The sativa-grass and falcata-grass combinations are greater than the birdsfoot trefoil-grass combinations with sativa-meadow fescue and sativa-timothy resulting in the significantly higher crude protein percentage at 199 g/kg each, respectively.

Figure 6 shows the weighted crude protein percentages for Lake City. Standard error was used to determine significant differences ($\alpha=0.05$). The only birdsfoot trefoil-grass combination that was statistically lower than the sativa-grass and falcata-meadow



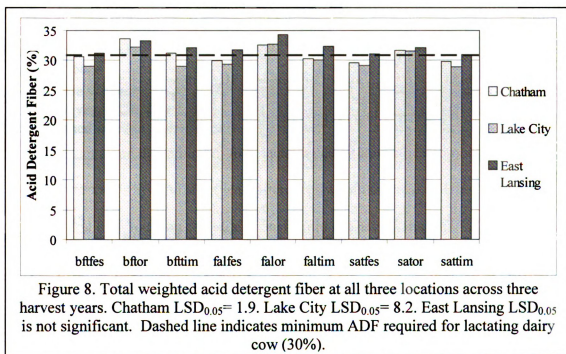
fescue combinations was the birdsfoot trefoil-orchardgrass combination. Of the sativa-grass and falcata-grass combinations, the falcata-orchardgrass and falcata-timothy combinations were statistically lower than the sativa-grass and falcata-meadow fescue combinations. The sativa-orchardgrass combination was also statistically lower than the sativa-meadow fescue and sativa-timothy combinations. In each of the legume-grass combinations, the orchardgrass combinations were each statistically lower than the other grass combinations. This may be due to the orchardgrass maturing slightly faster than the other grasses used in this study, lowering the crude protein percentage at the Chatham trial.

The weighted crude protein percentages for East Lansing show that only the birdsfoot trefoil-orchardgrass and birdsfoot trefoil-timothy combinations were significantly lower in weighted crude protein percentages, with values of 175 g/kg and 182 g/kg, respectively. Birdsfoot trefoil-meadow fescue and all falcata-grass and sativa-grass combinations were not significantly different from each other ($\alpha=0.05$).



Acid Detergent Fiber

The recommended maximum percent of acid detergent fiber from forage easy for a lactating dairy cow is near 30% ADF (Garcia et al., 2003); after 30%, the cow needs to expend energy to break down the ADF. As seen in Figure 8, all of the legume-grass combinations are near the required minimum, even for a maintenance diet for grazing dairy cows, let alone the minimum for a lactating dairy cow at peak production. Both Chatham and Lake City had statistical differences within the acid detergent fiber percentages at their locations, but East Lansing did not have statistical difference. There was no statistical significance seen between the locations ($\alpha=0.05$) (Figure 8).



Percent acid detergent fiber for Chatham is given in Figure 9. All of the birdsfoot trefoil-grass combinations were statistically different from the sativa-grass and falcata-grass combinations. The sativa-grass combinations and falcata-grass combinations were more similar statistically than the birdsfoot trefoil-grass combinations ($\alpha=0.05$). The sativa-timothy and sativa-meadow fescue combinations resulted in the lowest percent

weighted ADF with 29.8% and 29.5%, respectively. The birdsfoot trefoil-orchardgrass combination resulted in the highest percentage of weighted ADF at 33.6% ADF. This may be due to the earlier maturity of the orchardgrass variety compared to timothy and meadow fescue.

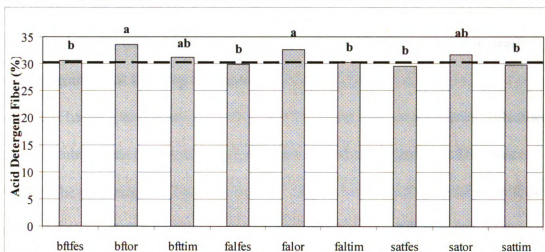


Figure 9. Total weighted acid detergent fiber at Chatham trial site across three harvest years. Chatham $LSD_{0.05} = 1.9$. Treatments with the same letters are similar. Dashed line indicates minimum ADF required for lactating dairy cow (30%).

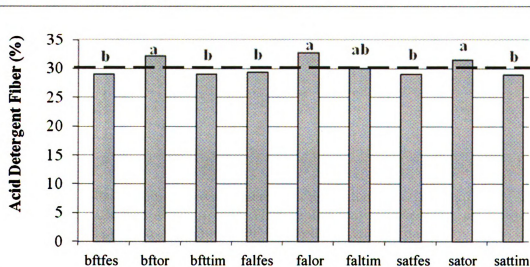
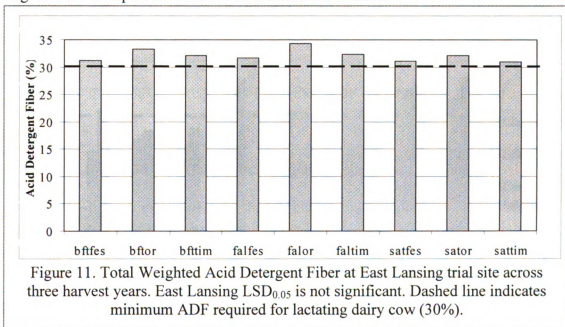


Figure 10. Total weighted acid detergent fiber at Lake City trial site across three harvest years. Lake City $Standard\ Error_{0.05} = 8.2$. Treatments with the same letters are similar. Dashed line indicates minimum ADF required for lactating dairy cow (30%).

The Lake City results are given in Figure 10. The birdsfoot trefoil- meadow fescue, birdsfoot trefoil-timothy, sativa-meadow fescue, and sativa-timothy combinations were statistically significant from the rest of the combinations with percent ADF values of 29.98%, 29.06%, 29.08% and 28.89%, respectively ($\alpha=0.05$). Each of the falcata-grass combinations, sativa-orchardgrass, and birdsfoot trefoil-orchardgrass combinations were not statistically different from one another. All combinations resulted in nearly ideal ADF content for lactating dairy cows.

East Lansing results are given in Figure 11. There were no significant differences between combinations in percentage of weighted ADF (Least Significant Difference $\alpha=0.05$). The percentage of the weighted ADF ranged from 31.02% (birdsfoot trefoil-meadow fescue) to 34.27% (falcata-orchardgrass; Figure 11). The range of ADF content for all locations was near or slightly higher than the ideal 30% ADF values needed for lactating dairy cows. Orchardgrass-legume combinations resulted in the highest ADF compared to all other treatment combinations.



Total Digestible Nutrients

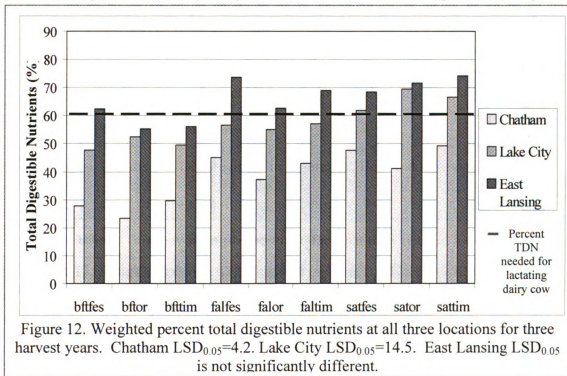
Total Digestible Nutrients were determined using the following formula:

$$\text{TDN} = \text{dNFC} + \text{dCP} + (2.25 * \text{dFA}) + \text{dNDF} - 7$$

(National Research Council, p. 14).

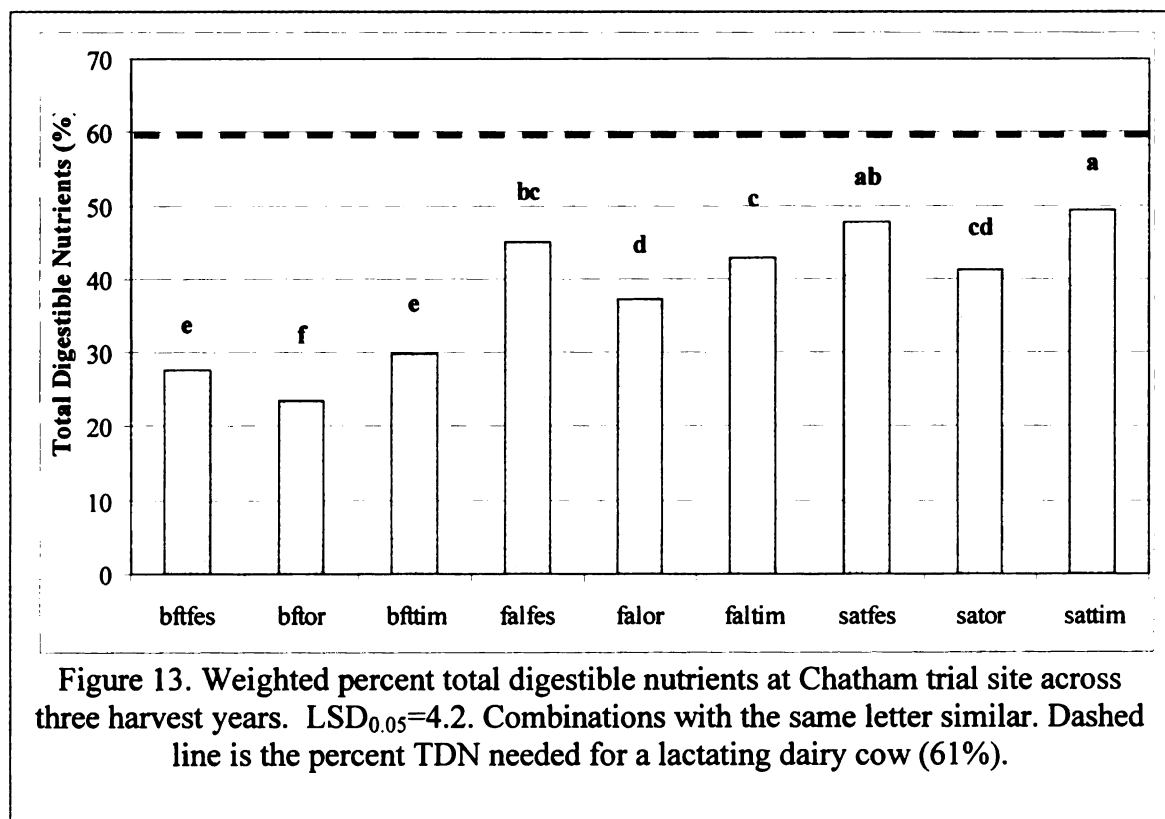
Total Digestible Nutrients takes into account the digestible nonfibrous carbohydrate concentration, digestible crude protein concentration, and the digestible neutral detergent fiber concentration to better understand the amount of energy available to the grazing cow. The recommended minimum percent of total digestible nutrients required to maintain the diet of a lactating dairy cow producing 40 kg of milk per day is 61% (National Research Council, p. 16).

Results of TDN are given in Figure 12. Both Lake City and East Lansing resulted in legume-grass combinations near or above 61%; however, the combinations at Chatham did not. This may be attributed to the fact that the Chatham location had a 30 plus-day rest period between grazing events and with the cooler temperatures, the plants



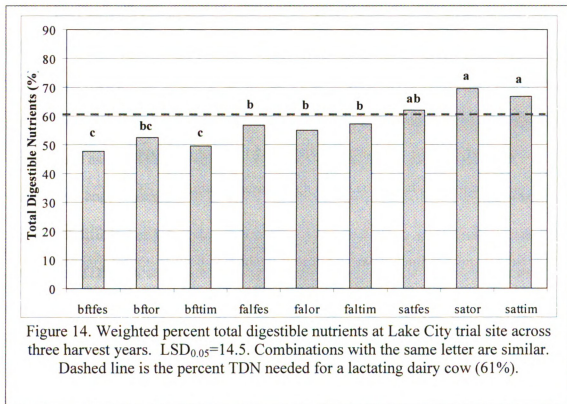
matured much faster than the other two locations, decreasing the crude protein and increasing the NDF fiber content. Lake City was on a 30-day rest period between grazing events, resulting in higher crude protein and lower NDF percentages. East Lansing, overall, had higher TDN values due to the fact that a grazing event occurred every 3-4 weeks (shorter rest period), keeping combinations in a less mature growth stage, resulting in the higher crude protein and lower NDF values. There was no statistical difference between the weighted TDN percentages for each location; however, there was statistical difference within the Chatham and Lake City combinations ($\alpha=0.05$).

None of the legume-grass combinations at Chatham met requirements for maintaining the diet of a lactating dairy cow. Perhaps, due to the fact that Chatham had a longer rest period between grazing events, the plants may have remained in a mature state for longer time, decreasing the crude protein and increasing NDF percentages. Another



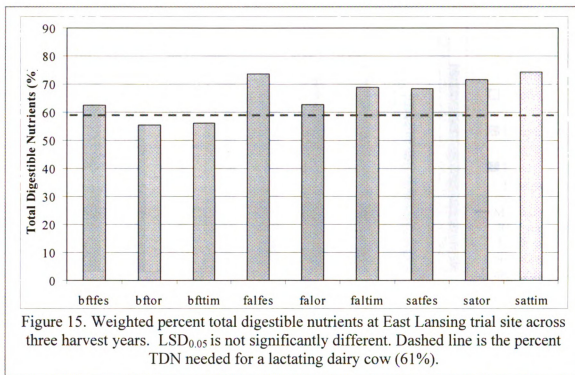
factor may have been a lower legume content compared to the amounts of legume found at the Lake City and East Lansing trial locations. Each of the birdsfoot trefoil-grass combinations were below 30%, with the lowest TDN percentage for Chatham being the birdsfoot trefoil-orchardgrass combination (23.43%) (Figure 13). The sativa-grass and falcata-grass combinations were all statistically similar, except for the falcata-orchardgrass combination with a TDN percentage of 37.3%. The highest TDN percentage was the sativa-timothy combination at 49.4%.

The Lake City plots had a 30-day rest period between grazing events, resulting in slightly lower crude protein and lower NDF percentages; these lower percentages resulted in higher TDN percentages across each of the combinations at Lake City compared to Chatham. Since LSD was not able to be calculated due to missing data points, standard error was used. Standard error indicates all combinations at Lake City



are above the line of required percent TDN to maintain the diet of a lactating dairy cow. Again, the birdsfoot trefoil-grass combinations were statistically lower than the sativa-grass and falcata-grass combinations with TDN percentages of 47.63% (birdsfoot trefoil-meadow fescue), 52.42% (birdsfoot trefoil-orchardgrass), and 49.62% (birdsfoot trefoil-timothy), respectively (Figure 14). The falcata-grass combinations and the sativa-meadow fescue combination were not statistically different from one another; however, the sativa-orchardgrass and sativa-timothy combinations were statistically greater than any of the other combinations at Lake City. The TDN percentages for sativa-orchardgrass and sativa-timothy were 69.55% and 66.76%, respectively. Even though the falcata and sativa combinations were statistically similar, only the sativa combinations had TDN percentages above the 61% requirement for maintaining the diet of a lactating dairy cow.

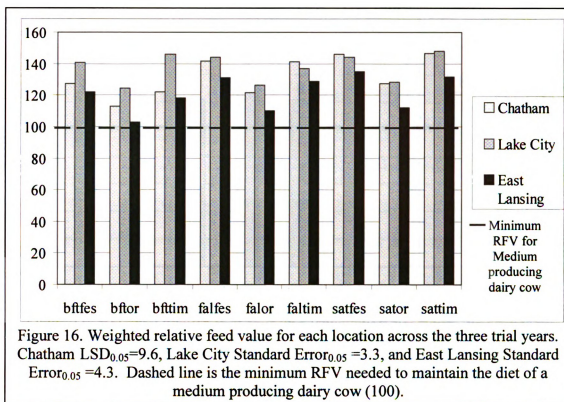
East Lansing forage combinations were grazed on a shorter schedule than the other two locations, allowing only 3-4 weeks of rest before the combinations were grazed again. This may help attribute to the higher TDN percentages seen at East Lansing than the other two locations. By grazing the forage combinations more frequently, the plants did not have as much time to mature, resulting in higher crude protein and NDF percentages and, consequently, higher TDN percentages. There were not any statistically significant differences between any of the forage combinations at East Lansing ($\alpha=0.05$). The lowest TDN percentages were evident in the birdsfoot trefoil-orchardgrass and birdsfoot trefoil-timothy combinations at 55.35% and 56.24%, respectively (Figure 15). The two highest TDN percentages were obtained with falcata-meadow fescue and sativa-timothy combinations at 73.66% and 74.35%, respectively.



Relative Feed Value

Relative Feed Value is an index by which hay and haylages are ranked based in calculations using digestible dry matter and dry matter intake, where $(DDM \cdot DMI) / 1.29 = RFV$ (Garcia et al., 2003). Legumes that are in full bloom will have an RFV of 100; legumes not in bloom will have a higher RFV rating, resulting in better quality hay and haylage. For this paper, an RFV of 100-120 will be used to show the amount of RFV needed to maintain the diet of a medium producing grazing dairy cow (Weiss et al., 1999).

Relative feed value results are given in Figure 16. Each of the locations produced legume-grass DM that was at or above the RFV needed to maintain the diet of a medium producing grazing dairy cow. At each location, the legume-orchardgrass combination had the lowest scoring RFV. This may be due to the orchardgrass maturing faster than the other grasses and legumes, reducing the ADF and NDF values, resulting in



lower DDM and DMI values. RFV was similar among locations, but there were differences within each location.

All of the combinations met the minimum RFV needed to maintain the diet of a medium producing dairy cow (Figure 17) at the Chatham trial location. Within each legume-grass combination, the legume-orchardgrass combination ranked lowest with RFV of 113 (birdsfoot trefoil-orchardgrass), 121 (falcata-orchardgrass), and 127 (sativa-orchardgrass), respectively. This may be due to the orchardgrass maturing a little earlier than the legumes and other grasses, resulting in lower DDM and DMI values. The highest ranking legume-grass combinations were the falcata-meadow fescue, falcata-timothy, sativa-meadow fescue, and sativa-timothy combinations with RFV of 142, 141, 146, and 146, respectively.

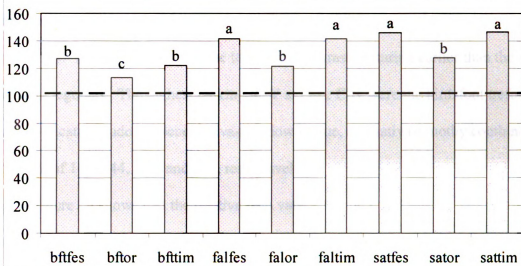


Figure 17. Weighted relative feed value at Chatham trial site across three harvest years. $LSD_{0.05}=9.6$. Combinations with the same letter are similar. Dashed line is the minimum RFV needed for a medium producing dairy cow (100).

Relative feed values at the Lake City trial location also were above the minimum RFV for a medium producing dairy cow, as seen in Figure 18. In each legume-grass

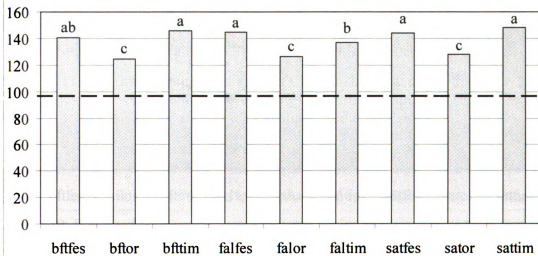
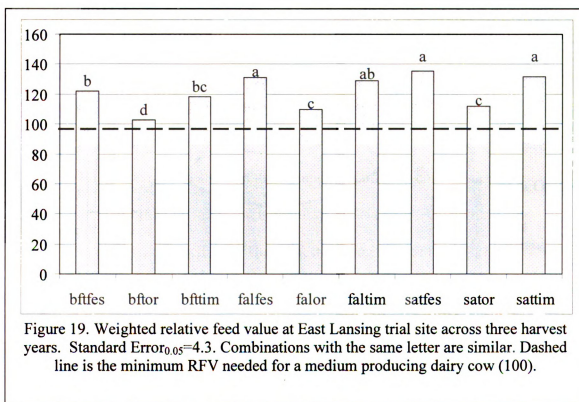


Figure 18. Weighted relative feed value at Lake City trial site across three harvest years. $Standard\ Error_{0.05}=3.3$. Combinations with the same letter are similar. Dashed line is the minimum RFV needed for a medium producing dairy cow (100).

combination, the orchardgrass produced the lowest RFV with values of 124 (birdsfoot trefoil-orchardgrass), 127 (falcata-orchardgrass), and 128 (sativa-orchardgrass), respectively. This may, again, be due to the orchardgrass maturing earlier than the other grasses or legumes. The highest ranking RFV at Lake City were the birdsfoot trefoil-timothy, falcata-meadow fescue, sativa-meadow fescue, and sativa-timothy combinations with RFV of 146, 144, 144, and 148, respectively.

Figure 19 shows that the relative feed values for the East Lansing trial location were also all above the minimum RFV to maintain the diet of a medium producing dairy cow. The East Lansing trial also had the legume-orchardgrass combinations rank lowest with RFV of 103 (birdsfoot trefoil-orchardgrass), 110 (falcata-orchardgrass), and 112 (sativa-orchardgrass), respectively. The highest ranking RFV at the East Lansing trial

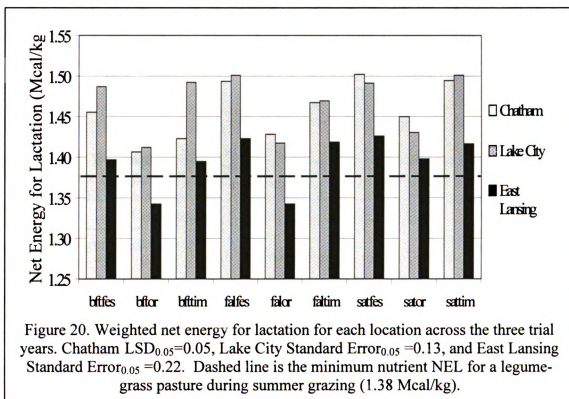


were falcata-meadow fescue, sativa-meadow fescue, and sativa-timothy with values of 131, 135, and 132, respectively.

Net Energy for Lactation

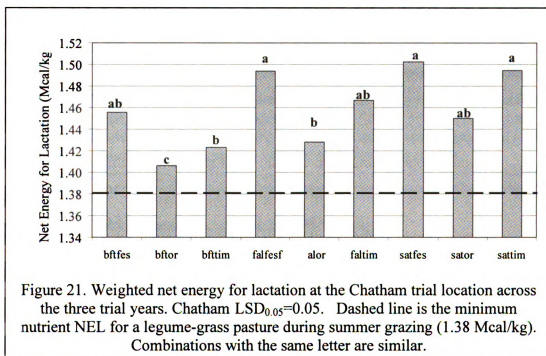
Net Energy for Lactation (NE_L) is used to describe the amount of energy used by a cow for body maintenance, milk production, growth, and reproduction measured in megacalories per kilogram (Garcia et al., 2003). It can be calculated from TDN values using the following equation: $0.0245 \times \text{TDN} - 0.12$ (National Research Council, 2001, pg. 13). For a mixed, mostly grass pasture, during the summer production months, the average NE_L value is 1.38 Mcal/kg (Amaral-Phillips et al., 1997) so that is the value used to compare the combinations with in this study.

The total weighted Net Energy for Lactation for each location is shown in Figure 20. Chatham and Lake City had all legume-grass combinations above the minimum



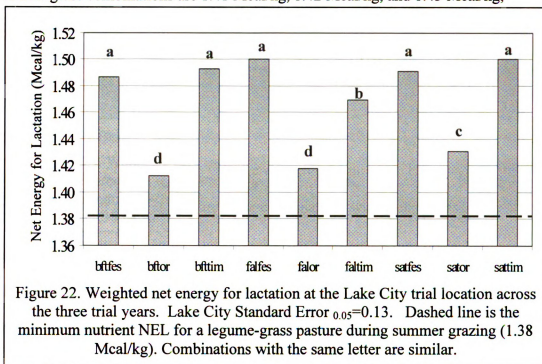
nutrient NE_L for legume-grass pastures; however, East Lansing did not have all combinations above the common nutrient NE_L . This may have been due to the shorter rotational period between grazing events, resulting in the plants not being able to mature as much as the plants at Lake City and Chatham. The grass which had the lowest NE_L was orchardgrass at each location with each legume combination. This may have been due to the orchardgrass maturing faster than the other grasses and legumes.

All of the combinations at the Chatham trial location were above the minimum nutrient NE_L for a legume-grass pasture during the summer grazing months (Figure 21). In each legume-grass combination, the grass with the lowest NE_L was orchardgrass, no



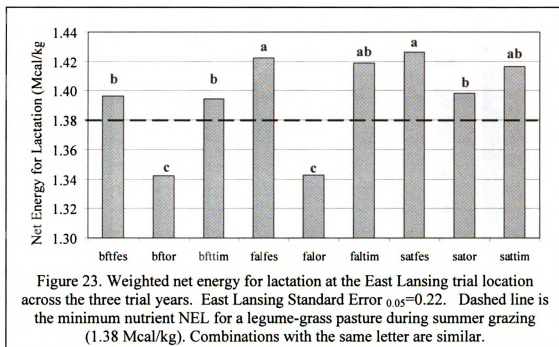
matter the legume combination. The NE_L values for the birdsfoot trefoil-orchardgrass, falcata-orchardgrass, and sativa-orchardgrass combinations were 1.41 Mcal/kg, 1.43 Mcal/kg, and 1.45 Mcal/kg, respectively. The highest NE_L values belonged to the falcata-meadow fescue, sativa-meadow fescue, and sativa-timothy combinations with NE_L values of 1.49 Mcal/kg each, respectively.

The Lake City trial NE_L values are given in Figure 22. The lowest legume-grass combinations for nutrient NE_L are those combinations with orchardgrass. The NE_L values for the birdsfoot trefoil-orchardgrass, falcata-orchardgrass, and sativa-orchardgrass combinations are 1.41 Mcal/kg, 1.42 Mcal/kg, and 1.43 Mcal/kg,



respectively. The rest of the combinations, except for the falcata-timothy combination ($NE_L=1.47$ Mcal/kg), have NE_L values near 1.49 Mcal/kg.

Two of the East Lansing legume-grass combinations were below the minimum nutrient NE_L for grass-legume pastures (Figure 23). This may be due to the shorter resting period between grazing events in East Lansing. The legume-grass combinations did not have as much time to regrow and mature in East Lansing, leading to less energy acquired from the plant when grazed. Even so, looking at each legume-grass combination, the grass with the lowest NE_L values is orchardgrass. Even with the shorter resting period, it appears that the orchardgrass still had time to mature, leading to the smaller NE_L values. The NE_L values for the birdsfoot trefoil-orchardgrass, falcata-

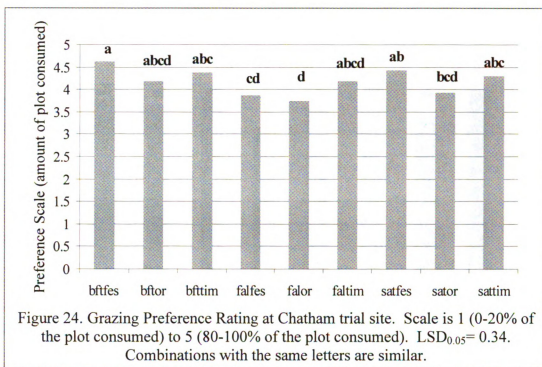


orchardgrass, and sativa-orchardgrass combinations are 1.34 Mcal/kg, 1.34 Mcal/kg, and 1.40 Mcal/kg, respectively. The legume-grass combinations with the greatest nutrient NE_L were falcata-meadow fescue and sativa-meadow fescue with NE_L values of 1.42 Mcal/kg and 1.43 Mcal/kg, respectively.

Palatability

Chatham

Each legume-grass combination was palatable based on the grazing preference rating scale used where 1 equaled 0-20% of the plot consumed and 5 equaled 80-100% of the plot consumed. The legume-grass combinations that were most preferred were birdsfoot trefoil-orchardgrass, birdsfoot trefoil-timothy, and sativa-meadow fescue with average grazing preference ratings of 3.42, 3.4, and 3.38, respectively. The legume-grass combinations that were least preferred were sativa-timothy and falcata-meadow fescue with average grazing preference ratings of 2.67 and 2.66, respectively (Figure 16). These



two may have been least preferred due to having fewer legumes in each of the combinations. Having fewer legumes may have deterred the cows from eating these combinations. All of the other legume-grass combinations were not statistically different ($\alpha=0.05$).

Lake City

Each legume-grass combination was palatable based on the grazing preference rating scale used where 1 equaled 0-20% of the plot consumed and 5 equaled 80-100% of the plot consumed. The legume-grass combination that was most preferred was the sativa-orchardgrass combination with an average grazing preference rating of 3.94. The legume-grass combination that was least preferred was the falcata-meadow fescue combination with an average grazing preference rating of 3.09 (Figure 17). All of the rest of the legume-grass combinations were not statistically different ($\alpha=0.05$).

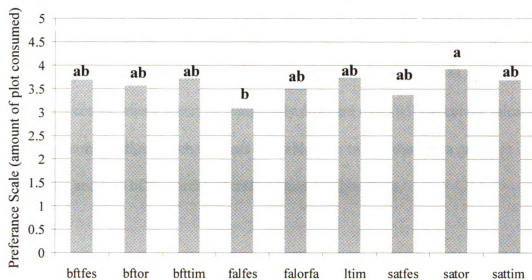


Figure 25. Grazing Preference Rating at Lake City trial site. Scale is 1 (0-20% of the plot consumed) to 5 (80-100% of the plot consumed). $LSD_{0.05} = 0.76$. Combinations with the same letters are similar.

East Lansing

All legume-grass combinations were palatable based on the grazing preference rating scale used where 1 equaled 0-20% of the plot consumed and 5 equaled 80-100% of the plot consumed. The legume-grass combination that was most preferred was the

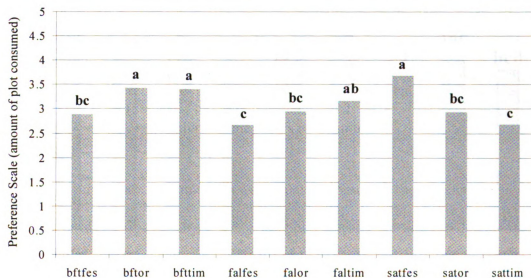
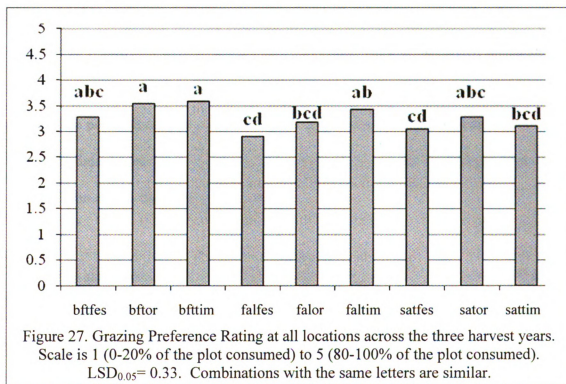


Figure 26. Grazing Preference Rating at East Lansing trial site. Scale is 1 (0-20% of the plot consumed) to 5 (80-100% of the plot consumed). $LSD_{0.05} = 0.54$. Combinations with the same letters are similar.

birdsfoot trefoil-meadow fescue combination with an average grazing preference rating of 4.62. The legume-grass combination least preferred was the falcata-orchardgrass combination with an average grazing preference rating of 3.75 (Figure 18). All other legume-grass combinations were not statistically different ($\alpha=0.05$) except the falcata orchardgrass combination which was less palatable than two of the sativa grass combinations and two of the birdsfoot trefoil grass combinations.

Total

Palatability based on the grazing preference rating scale used where 1 equaled 0-20% of the plot consumed and 5 equaled 80-100% of the plot consumed resulted in legume-grass combinations that were most preferred being birdsfoot trefoil-orchardgrass and birdsfoot trefoil-timothy combinations with average grazing preference ratings of 3.59 and 3.55, respectively. The legume-grass combination least preferred was the



falcata-meadow fescue combination with an average grazing preference rating of 2.91 (Figure 19). The remainder of the legume-grass combinations were not statistically different ($\alpha=0.05$). In each of the legume-grass treatments, the meadow fescue combinations were statistically lower than the other grasses offered. This lower grazing preference may be due to the hairless leaves of the meadow fescue; the cows may not like to feel of the grass as they eat. These grazing preference ratings show that birdsfoot trefoil-grass combinations were slightly preferred over the falcata-grass and sativa-grass combinations, but these two combinations were not significantly different from one another ($\alpha=0.05$).

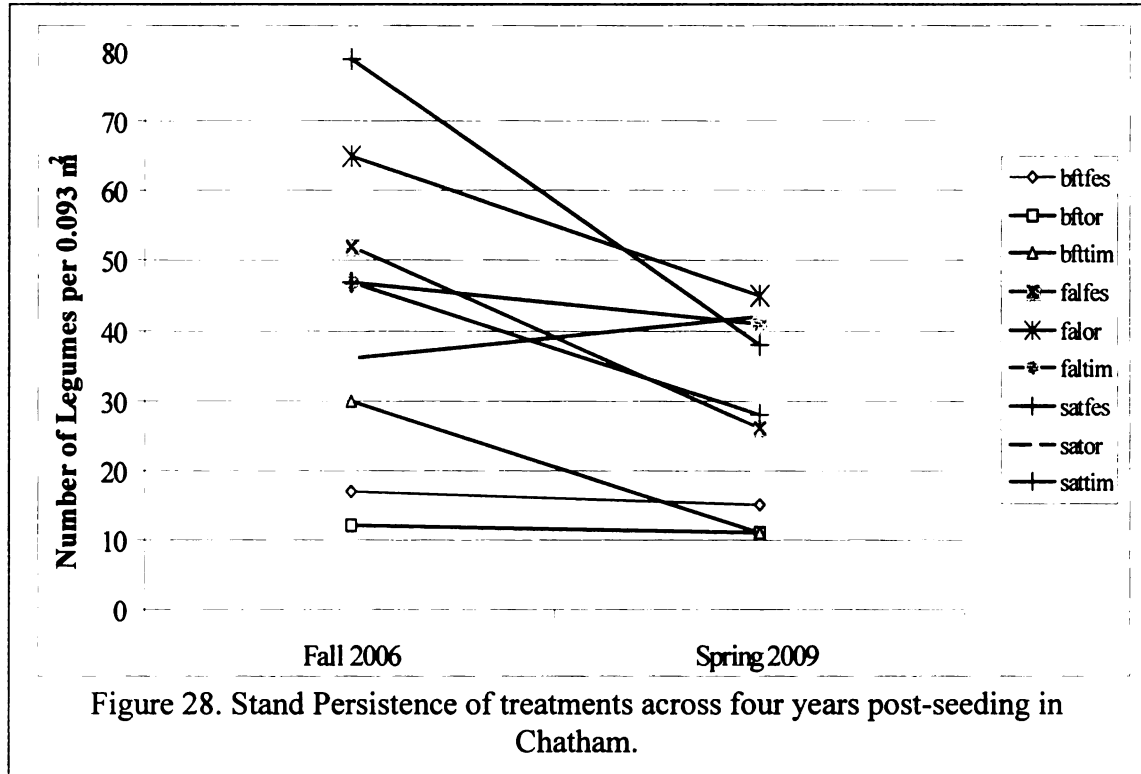
Stand Persistence

“Stand persistence is a complex trait affected by a large number of factors, including grazing, mechanical harvesting equipment, intensity of harvest management, diseases and pests, cold weather, inadequate dormancy, and inter- and intraspecies plant competition (Riday and Brummer, 2006).” This was evident in this study, including sampling error, which resulted in extremely varied stand persistence data, resulting in several data points discarded at each location. Statistics were not performed on remaining data; however, this section shows the trend of estimated stand persistence at each location across the three grazing years.

Chatham

The stand persistence of the combinations from fall 2006 and spring 2009 are shown in Figure 20. There is a trend over the course of three grazing seasons with the number of legumes per two-0.093 m² sampling areas having decreased. The sativa-grass and falcata-grass combinations had initial plant populations ranging from 79 (sativa-

timothy) to 36 (sativa-orchardgrass) legumes per two-0.093 m² area. At the end of the three grazing seasons, falcata-grass and sativa-grass combinations were more similar in numbers of legumes per two-one foot² sampling areas with the range being from 45 falcata-orchardgrass) to 26 (falcata meadow fescue) legumes per two-0.093 m² areas.

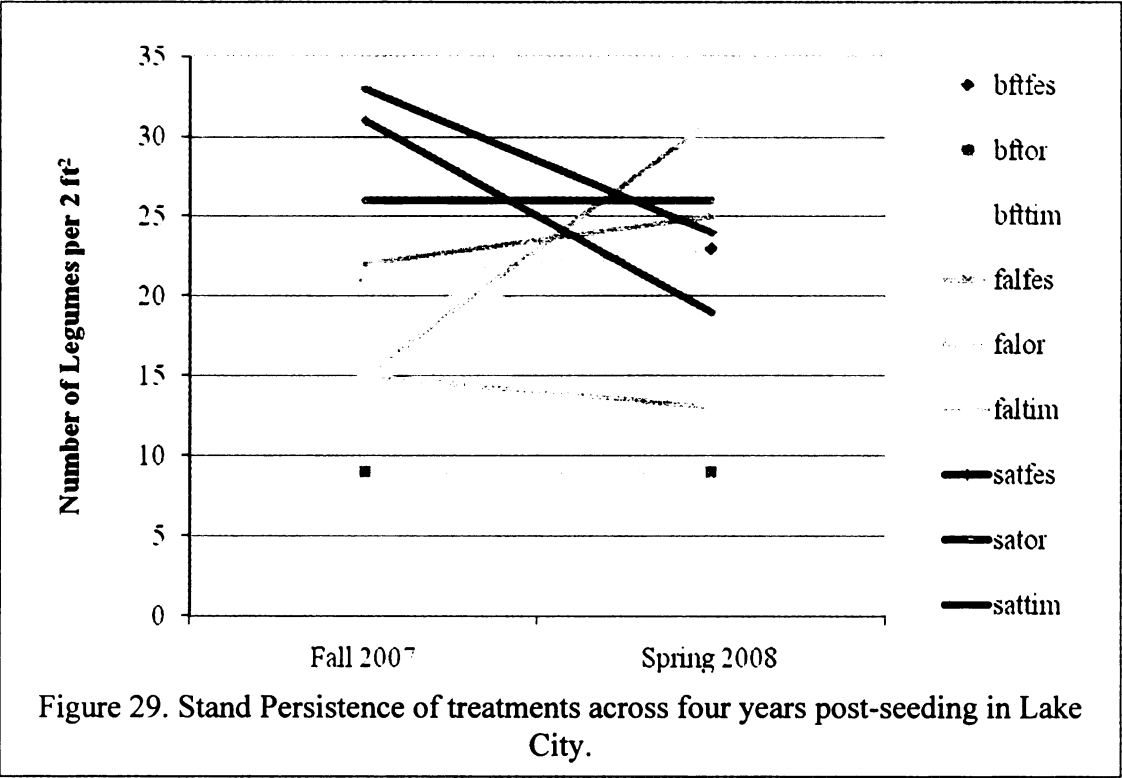


The birdsfoot trefoil-grass combinations had the lowest stand persistence legume numbers ranging from 12 (birdsfoot trefoil-orchardgrass) to 30 (birdsfoot trefoil-timothy) legumes per two-0.093 m² areas at the start of the study; however, the birdsfoot trefoil did not lose as many legumes over the course of the 3 years of grazing, having decreased by only 1 (birdsfoot trefoil-orchardgrass), 2 (birdsfoot trefoil-meadow fescue), and 19 (birdsfoot trefoil-timothy) legumes per two-0.093 m² areas.

Lake City

The stand persistence of the combinations from fall 2006 and spring 2009 are shown in Figure 21. Some of the legume-grass combinations declined, but others

increased dramatically, which is likely a result of the sampling error. At the start of the study (spring 2006), there was no defined difference between each of the legume–grass combinations, with a range from 9 (birdsfoot trefoil-orchardgrass) to 33 (sativa-timothy)

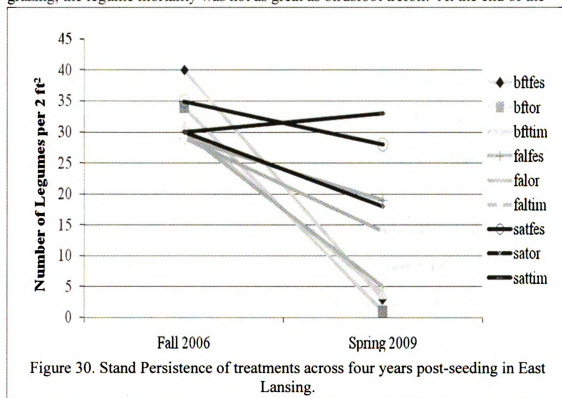


legumes per two-0.093 m² areas. At the end of the three grazing seasons, the range was from 9 (birdsfoot trefoil-orchardgrass) to 36 (sativa-orchardgrass) legumes per two-0.093 m² areas with no defined difference between the stand persistence of the three legumes.

East Lansing

The stand persistence of the combinations from fall 2006 and spring 2009 are shown in Figure 22. There is a trend over the course of three grazing seasons with the number of legumes per two-0.093 m² sampling areas having decreased. Again, each legume-grass combination showed significant variance after the three grazing seasons, but were similar at the start of the study, with a range from 29 (falcata-meadow fescue) to 40 (birdsfoot trefoil-meadow fescue) legumes per two-0.093 m² areas. At the start of the

study, birdsfoot trefoil-grass combinations had the greatest number of legumes; however, after the second year of grazing, the birdsfoot trefoil-grass combinations decreased rapidly in legume numbers. The sativa-grass and falcata-grass combinations were initially similar to the birdsfoot trefoil-grass combinations, but after the entire three years of grazing, the legume mortality was not as great as birdsfoot trefoil. At the end of the



study, the content of sativa per two-0.093 m² area was greater than birdsfoot trefoil, with 1 (birdsfoot trefoil-orchardgrass) to 33 (sativa-timothy) legumes per two-0.093 m² area. The falcata-grass and sativa-grass combinations were similar, except for the falcata-orchardgrass combination, which was more similar to the birdsfoot trefoil-grass combinations at the end of the three grazing seasons.

IV. CONCLUSION

The results of this study support the hypothesis of this study: falcata will produce comparable forage yield, forage quality, and palatability to sativa (birdsfoot trefoil being the most palatable) and will have equal or greater stand persistence under rotational grazing compared to sativa or birdsfoot trefoil. Forage yields from each location indicated that falcata-grass combinations were not statistically different than sativa-grass combinations, except for the sativa-timothy combination at the Chatham and East Lansing trials and the sativa-orchardgrass combination at the Lake City trial. In each location, the birdsfoot trefoil-grass combinations yielded less forage than the falcata-grass or sativa-grass combinations.

The total weighted crude protein data show that combinations with lower than nutritionally required value of 18% were birdsfoot trefoil-grass combinations at Chatham. When analyzed by location, statistical differences were shown between birdsfoot trefoil-grass combinations; birdsfoot trefoil-grass combinations being significantly lower in dry matter forage yield than sativa or falcata-grass combinations. However, there was no statistical difference between the falcata-grass and sativa-grass combinations.

The total weighted ADF results show that all combinations were above the 30% required value for the maintenance diet of dairy cows. There were no statistical differences between locations. When analyzing locations, there were statistical differences at Chatham and Lake City, but not at East Lansing with differences between the falcata-grass and sativa-grass combinations.

Analysis of total weighted TDN results showed most of the combinations at Lake City and East Lansing were above the value required to maintain the diet of a dairy cow

(61%), but at Chatham, the forage combinations were below this value. This was likely due to a longer rotation period between grazing events than at the other two locations. The falcata-grass and sativa-grass combinations showed no statistical difference within each trial location.

Relative feed values showed that all the combinations at each location had an RFV above the minimum requirement for a medium milk producing cow (100 RFV). At each location, the legume-grass combinations with the lowest RFV ratings were those legumes paired with orchardgrass. The lower RFV for orchardgrass may be due to the orchardgrass having been more mature at the grazing date than the other grasses and legumes.

All of the net energy for lactation values at Chatham and Lake City were above the minimum nutrient NE_L for legume-grass pastures (1.38 Mcal/kg); however, East Lansing had two combinations below the common nutrient NE_L . This may have been due to the shorter rotational period between grazing events, resulting in the plants not being able to mature as much as the plants at Lake City and Chatham. The grass which had the lowest NE_L was orchardgrass at each location with each legume combination. This may have been due to the orchardgrass maturing faster than the other grasses and legumes.

Each of the legume-grass combinations were related as palatable at each location. The most preferred combinations were the birdsfoot trefoil-orchardgrass and birdsfoot trefoil-timothy combinations with average grazing preference ratings of 3.59 and 3.55, respectively; the falcata-meadow fescue combination was the least preferred with an average grazing preference rating of 2.9. Stand persistence data was not analyzed due to

sampling error, but each of the legume-grass combinations showed a trend of decreasing legume numbers per two-0.093 m² sampling areas. Birdsfoot trefoil had the least number of legumes after three grazing seasons, while falcata and sativa were more similar.

The results of this study support the hypothesis and objectives stated before the start of the study. In summary, this study showed that *Medicago sativa* spp. *falcata* could be used as a legume in Michigan's grazing systems without sacrificing forage yield or forage quality; however, this data does not show an advantage over *Medicago sativa* spp. *sativa*.

V. APPENDIX

Table 9. East Lansing Plot Map (The light grey areas are seeding errors)

N^	vernal		Vernal		vernal		vernal
101	falfes	201	Faltim	301	bftfes	401	faltim
101	falfes	201	Faltim	301	bftfes	401	faltim
102	falor	202	Bftor	302	falfes	402	bftor
102	falor	202	Bftor	302	falfes	402	bftor
103	faltim	203	Satfes	303	falor	403	satfes
103	faltim	203	Satfes	303	falor	403	satfes
104	bftfes	204	Sator	304	bfttim	404	sattim
304	bfttim	404	Sator	104	bftfes	204	sattim
105	Bftor	205	Bftfes	305	bftor	405	falfes
105	Bftor	205	Bftfes	305	bftor	405	falfes
106	bfttim	206	Sattim	306	faltim	406	sator
106	bfttim	206	Sattim	306	faltim	406	sator
107	satfes	207	Falfes	307	sator	407	falor
107	satfes	207	Falfes	307	sator	407	falor
108	sator	208	Bfttim	308	sattim	408	bftfes
108	sator	208	Bfttim	308	sattim	408	bftfes
109	sattim	209	Falor	309	satfes	409	bfttim
109	sattim	209	Falor	309	satfes	409	bfttim
	vernal		Vernal		vernal		vernal

legume	grass	combination code
yellowhead	Laura	falfes
yellowhead	Dolina	faltim
yellowhead	tekapo	falor
norcen	Laura	bftfes
norcen	Dolina	bfttim
norcen	tekapo	bftor
ZG 9830	Laura	satfes
ZG 9830	Dolina	sattim
ZG 9830	tekapo	sator

Table 10. Lake City Plot Map

N _v	border		border		border		border
109	sattim	209	falor	309	satfes	409	bfttim
109	sattim	209	falor	309	satfes	409	bfttim
108	sator	208	bfttim	308	sattim	408	bftfes
108	sator	208	bfttim	308	sattim	408	bftfes
107	satfes	207	falfes	307	sator	407	falor
107	satfes	207	falfes	307	sator	407	falor
106	bfttim	206	sattim	306	faltim	406	sator
106	bfttim	206	sattim	306	faltim	406	sator
105	bftor	205	bftfes	305	bftor	405	falfes
105	bftor	205	bftfes	305	bftor	405	falfes
104	bftfes	204	sator	304	bfttim	404	sattim
104	bftfes	204	sator	304	bfttim	404	sattim
103	faltim	203	satfes	303	falor	403	satfes
103	faltim	203	satfes	303	falor	403	satfes
102	falor	202	bftor	302	falfes	402	bftor
102	falor	202	bftor	302	falfes	402	bftor
101	falfes	201	faltim	301	bftfes	401	faltim
101	falfes	201	faltim	301	bftfes	401	faltim
	border		border		border		border

Table 11. Chatham Plot Map

N ^A	vernal		vernal		vernal		vernal
	vernal		vernal		vernal		vernal
101	falfes	201	faltim	301	bftfes	401	faltim
101	falfes	201	faltim	301	bftfes	401	faltim
102	falor	202	bftor	302	falfes	402	bftor
102	falor	202	bftor	302	falfes	402	bftor
103	faltim	203	satfes	303	falor	403	satfes
103	faltim	203	satfes	303	falor	403	satfes
104	bftfes	204	sator	304	bfttim	404	sattim
104	bftfes	204	sator	304	bfttim	404	sattim
105	bftor	205	bftfes	305	bftor	405	falfes
105	bftor	205	bftfes	305	bftor	405	falfes
106	bfttim	206	sattim	306	faltim	406	sator
106	bfttim	206	sattim	306	faltim	406	sator
107	satfes	207	falfes	307	sator	407	falor
107	satfes	207	falfes	307	sator	407	falor
108	sator	208	bfttim	308	sattim	408	bftfes
108	sator	208	bfttim	308	sattim	408	bftfes
109	sattim	209	falor	309	satfes	409	bfttim
109	sattim	209	falor	309	satfes	409	bfttim
	vernal		vernal		vernal		vernal
	vernal		vernal		vernal		vernal

Table 12 Average Accumulative forage yield at each location (metric tonnes dry matter per hectare)

(Metric tonnes DM per hectare)	Birdsfoot trefoil	Falcata	Sativa
Chatham	11.3	17.0	19.1
Lake City	20.9	23.6	26.6
East Lansing	26.5	31.8	33.9
Average	19.6	24.1	26.5

Table 13. Stand persistence data for Chatham across four years post-seeding. 2009.

Combination	Fall 2006	Fall 2007	Spring 2009
falfes	52	51	26
falor	65	40	45
faltim	47	42	41
bftfes	17	9	15
bftor	12	8	11
bfttim	30	15	11
satfes	47	27	28
sator	36	32	42
sattim	79	51	38

Table 14. Stand persistence data for Lake City across four years post-seeding. 2009

Combination	Fall 2007	Fall 2008	Spring 2008
falfes	22	19	25
falor	15	18	31
faltim	15	19	13
bftfes	22	11	25
bftor	9	19	9
bfttim	21	30	18
satfes	31	22	19
sator	26	28	26
sattim	33	32	24

Table 15. Stand persistence data for Lake City across four years post-seeding. 2009

Combination	Fall 2006	Fall 2007	Spring 2008	Fall 2008	Spring 2009
falfes	29	16	18	29	19
falor	30	9	15	13	5
faltim	29	15	23	16	14
bftfes	40	11	8	10	3
bftor	34	4	3	7	1
bfttim	31	8	11	15	4
satfes	35	22	30	15	28
sator	30	14	26	20	18
sattim	30	15	29	22	33

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