2011 VERMONT SMALL GRAIN FORAGE TRIALS
NITROGEN FERTILITY AND HARVEST DATE

INTRODUCTION

Cool season annual forages such as cereal grains can provide early season grazing as well as high quality stored feed. The goal of this project was to determine yields and quality of annual cool season forages harvested at various growth stages and under different fertility regimes. In addition, the fatty acid profile and concentration were determined for treatments. Enhancing beneficial fatty acids in cattle feed may result in enhanced nutritional quality of milk. This includes potential increases in Omega-3 fatty acids that are touted to be heart healthy. The data presented here is from one replicated research trial in Vermont. Crop performance data from additional tests in different locations and often over several years should be compared before you make conclusions. This project was supported through the Organic Valley Farmers Advocating For Organic Fund.

METHODS

In 2011, an organic small grain forage trial was conducted at Choinere Family Farm in Highgate Center, VT. The farm is certified organic by Vermont Organic Farmers, LLC. The previous crop in was a legume/grass sod. The seedbed was prepared by conventional tillage methods. A mixture of oats (*Avena sativa* L.) and triticale (*Triticale hexaploide* Lart.) were planted with a six-inch grain drill on May 14, 2011. The experimental design was a randomized complete block with split plots. The main plots were fertilizer type/rate and the split plots were harvest time. Plots measuring 5' X 20' were fertilized with two different organic fertilizers (Pro-Booster and Chilean nitrate) at two application rates (50 and 100 lbs. N acre^{-1}). The amendments used were Pro-Booster (10% N) and Natural Nitrate of Soda (16% N). The OMRI approved 'Pro Booster' is a fertilizer manufactured for North Country Organics in Bradford, VT. The blended fertilizer is composed of vegetable and animal meals and natural nitrate of soda. It has a guaranteed analysis of 10-0-0. The OMRI approved Natural Nitrate of Soda is more commonly known as 'Chilean Nitrate'. It is mined from Northern Chile. It has a guaranteed analysis of 16-0-0. The use of Natural Nitrate of Soda is allowed, however, it will be removed from the NOP list of approved materials in the near future. In this trial it was used to represent a 100% soluble source of nitrogen fertility. An unfertilized treatment served as a control.

Biomass samples were collected at four stages of small grain forage development: vegetative (Feekes stage 4), boot (Feekes 10.5.2), milk (Feekes 11.1), and soft dough (Feekes 11.2). Subsamples of approximately 2.5 ft^2 were cut to the ground, dried at 40^{o}C, and weighed to determine dry matter yield. Oven dry samples were coarsely ground with a Wiley mill (Thomas Scientific, Swedesboro, NJ) and sent to Cumberland Valley Analytical Services, Inc. (Maugansville, MD) for quality analysis. Results were analyzed with an analysis of variance with SAS (Cary, NC).

Table 1. Organic small grain forage trial information 2011.

Trial Information	Choinere Family Farm, Highgate, VT
Soil type	Georgia stoney loam
Previous crop	Sod
Row width (in.)	6
Planting date	14-May
Harvest dates:	
Vegetative	27-June
Boot	7-July
Milk	25-July
Soft Dough	3-August
Seeding rate	125 lbs acre^{-1}
Manure applications	10 tons acre^{-1} solid - fall 2010 5000 gallons acre^{-1} liquid - spring 2011

SILAGE QUALITY

Silage quality was analyzed by Cumberland Valley Analytical Forage Laboratory in Hagerstown, Maryland. Plot samples were dried, ground and analyzed for crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), and various other nutrients. The Nonstructural Carbohydrates (NSC) and Total Digestible Nutrients (TDN) were calculated from forage analysis data. Performance indices such as Net Energy Lactation (NEL) were calculated to determine forage value. Mixtures of true proteins, composed of amino acids, and nonprotein nitrogen make up the crude protein (CP) content of forages. The bulky characteristics of forage come from fiber. Forage feeding values are negatively associated with fiber since the less digestible portions of the plant are contained in the fiber fraction. The detergent fiber analysis system separates forages into two parts: cell contents, which include sugars, starches, proteins, non-protein nitrogen, fats and other highly digestible compounds; and the less digestible components found in the fiber fraction. The total fiber content of forage is contained in the neutral detergent fiber (NDF). Chemically, this fraction includes cellulose, hemicellulose, and lignin. Recently, forage testing laboratories have begun to evaluate forages for NDF digestibility. Evaluation of forages and other feedstuffs for NDF digestibility is being conducted to aid prediction of feed energy content and animal performance. Research has demonstrated that lactating dairy cows will eat more dry matter and produce more milk when fed forages with optimum NDF digestibility. Forages with increased NDF digestibility (dNDF) will result in higher energy values, and perhaps more importantly, increased forage intakes. Forage NDF digestibility can range from 20 to 80%. The NSC or non-fiber carbohydrates (NFC) include starch, sugars, and pectins.

Fatty acid content and profile of the feed samples were analyzed using a modified version of the direct transesterification method developed by Sukhija and Palmquist (1988). In brief, 1 mL of internal standard (1 mg C13:0 TAG/mL acetone), 2 mL of toluene, and 2 mL of 2% methanolic H_2SO_4 acid were added to 500 mg of ground feed composites samples. The solution was heated at 50°C overnight. After cooling the samples to room temperature, 5 mL of 6% $KHCO_3$ solution and 1 mL of hexane were added. The samples were mixed and centrifuged at 500 x *g* for 5 min. The resulting hexane layer was dried and cleaned over a mixture of Na_2SO_4 and charcoal. An aliquot of the solution, containing the fatty acid methyl esters (FAME), was taken for GLC analysis. The analysis of FAME extracts was performed on a GC-2010 gas chromatograph (Shimadzu, Kyoto, Japan) equipped with a split injector, a flame ionization detector, an autosampler (model AOC-20s; Shimadzu), and a 100 m CP-Sil 88 fused-silica capillary column (100 m × 0.25 mm i.d. × 0.2 μm film thickness; Varian Inc., Palo Alto, CA) The injector and detector were both maintained at 250°C. Hydrogen was used as carrier gas at a linear velocity of 30 cm/sec. The sample injection volume was 1 μL at a split ratio of 1:50. The oven program used was: initial temperature of 45°C held for 4 min, programmed at 13°C/min to 175°C held for 27 min, then programmed at 4°C/min to 215°C held for 35 min. Integration and quantification was based on the FID response and achieved with GC solution software (version 2.30.00, Shimadzu, Kyoto, Japan). Identification of FAME was accomplished by comparison of relative retention times with commercial FAME standards. Total fatty acid content was determined using C13:0 as an internal standard. The fatty acid results were expressed as percentages (weight/weight) of fatty acids detected with a chain length between 10 and 24 carbon atoms. The lowest level of detection was <0.001g/100g fatty acids and is reported as not detectable (ND).

LEAST SIGNIFICANT DIFFERENCE (LSD)

Variations in yield and quality can occur because of variations in genetics, soil, weather, and other growing conditions. Statistical analysis makes it possible to determine, whether a difference among varieties is real or whether it might have occurred due to other variations in the field. At the bottom of each table a LSD value is presented for each variable (i.e. yield). Least Significant differences (LSD's) at the 10% level of probability are shown. Where the difference between two treatments within a column is equal to or greater than the LSD value at the bottom of the column, you can be sure in 9 out of 10 chances that there is a real difference between the two varieties. Treatments that were not significantly lower in performance than the highest value in a particular column are indicated with an asterisk. In the example below A is significantly different from C but not from B. The difference between A and B is equal to 1.5 which is less than the LSD value of 2.0. This means that these varieties did not differ in yield. The difference between A and C is equal to 3.0 which is greater than the LSD value of 2.0. This means that the yields of these varieties were significantly different from one another. The asterisk indicates that B was not significantly lower than the top yielding variety.

Variety	**Yield**
A	6.0
B	7.5*
C	9.0*
LSD	**2.0**

RESULTS AND DISCUSSION

Seasonal precipitation and temperature recorded at a weather station in close in proximity to Highgate Center, VT is reported in Table 2. This season started off with above average precipitation in April and May. However, precipitation was below average during each harvest date. Growing Degree Days (GDD) for the small grain season in Highgate Center was 4015, which was 113 GDD above the 30-year average.

Table 2. Seasonal weather data collected near Highgate Center, VT 2011.

Highgate Center, VT	May	June	July	August
Average Temperature (F)	56.0	65.0	70.0	68.0
Departure from Normal	0.00	-0.50	0.00	-0.50
Precipitation (inches)	7.57	2.18	2.58	5.42
Departure from Normal	4.64	-1.03	-0.83	1.57
Growing Degree Days (base 32)	729	1023	1163	1100
Departure from Normal*	-15.5	60.0	32.6	35.7

* Historical averages are for 30 years of data (1971-2000)

<u>Harvest Stage</u>

The small grains were harvested at the vegetative (8-10 inches in height), boot, milk, and soft dough stages.

Yield and quality of the oat/triticale mixture varied significantly by harvest stage. Yields increased with maturity, averaging 7152 lbs acre^{-1} dry matter in the soft dough stage (Table 3). Crude protein levels were highest in the vegetative stage. Acid Detergent Fiber (ADF), Neutral Detergent Fiber (NDF), Net Energy of Lactation (NEL) and Total Digestible

Nutrients (TDN) were all most favorable in the vegetative stage (Figure 1). The highest forage quality is generally seen during the leafy, vegetative stage of growth, and the results of this study follow that trend (Figure 4). However, this is also the period of lowest yield. The NDF, the percent of cell wall material in the forage, is negatively correlated with intake potential in ruminants, and therefore, a lower number is desirable, which we saw in the vegetative stage. ADF, the percentage of highly indigestible plant material in the forage, is negatively correlated with digestibility, and a number below 35% is desirable. The average ADF value in this trial was below 35% for the vegetative, milk, and soft dough harvests, indicating that the oats and triticale are a good option for forage when harvested at these stages.

The vegetative stage would represent forage available for pasture. In terms of stored feed small grains are usually harvested in the boot or soft dough stage. The advantages of harvesting in the boot stage included increased CP and dNDF. Boot stage forage quality is often similar to first cut perennial forage grasses. Harvesting in the soft dough stages will provide the highest yields but generally the lowest CP. The primary reason to harvest in the soft dough stage is to have higher starch in the forage. The soft dough forage had a starch content of 51.2%. However, the fiber content increases due to the stem and stalks beginning to maturate. Overall, as the grain begins to fill with starch this causes a dilution effect on other fiber components.

Table 3. Spring forage yield and quality results averaged across treatments.

Harvest Stage	DM Yield lbs acre	Moisture %	CP %	ADF %	NDF %	NEL %	dNDF %	NSC %	TDN %	Starch %	NFC %
Vegetative	1665	68.8	**22.1***	**28.5***	**49.1***	**0.670***	35.8	10.9	**64.7***	10.9	19.7
Boot	3898	**76.7***	16.7	38.6	61.3	0.594	**39.5***	6.5	58.0	18.1	13.7
Milk	5871	62.1	12.6	34.7	57.6	0.626	26.8	15.1	60.7	38.1	21.4
Soft Dough	**7152***	58.0	11.4	32.5	56.0	0.638	24.3	**18.9***	61.8	**51.2***	**24.9***
Trial Mean	4647	66.4	15.7	33.6	56.0	0.632	31.6	12.9	61.3	29.6	19.9
LSD	1092	2.67	0.69	0.97	1.09	0.008	0.69	0.86	0.70	2.38	0.95

* Varieties with an asterisk indicate that it was not significantly different than the top performer
NS - None of the varieties were significantly different from one another

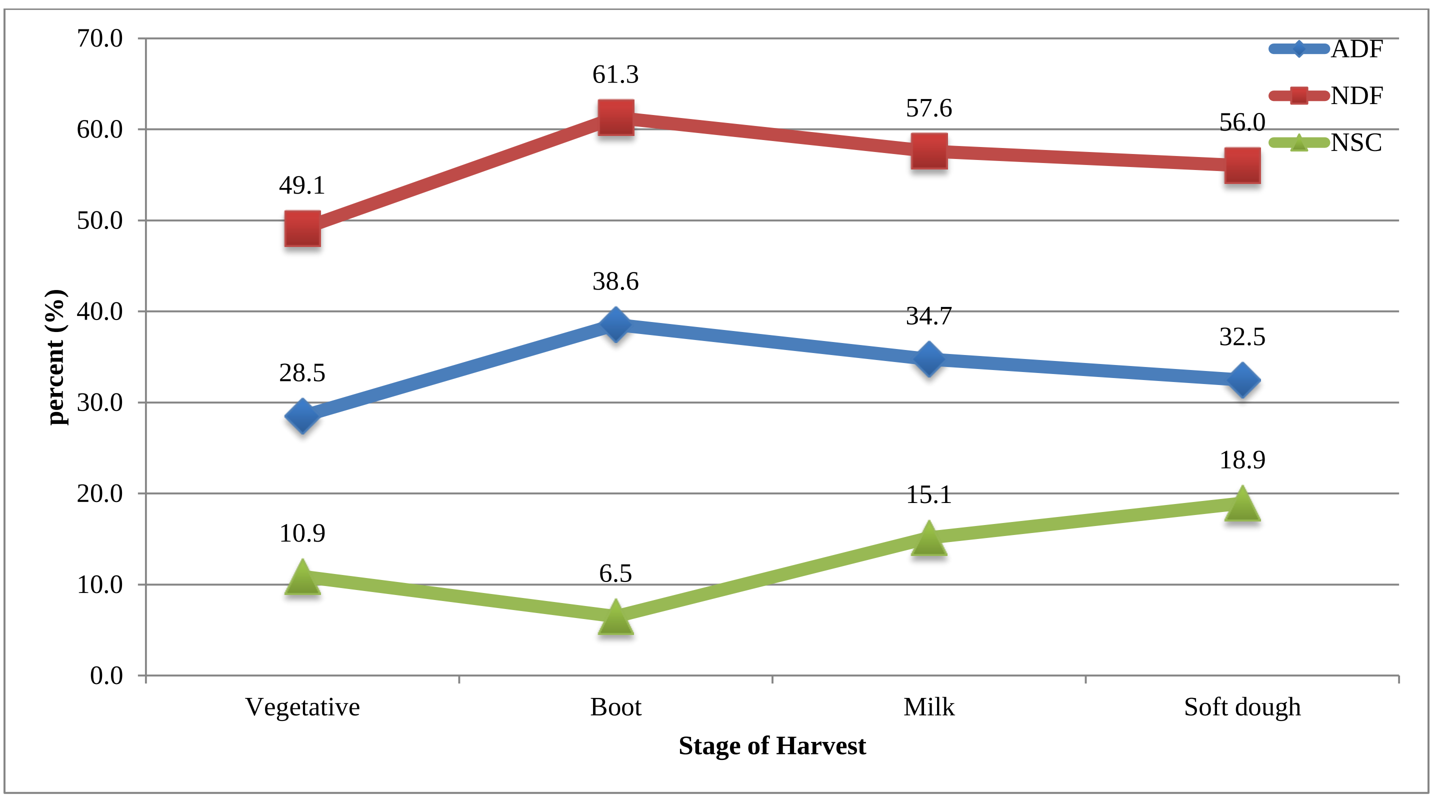


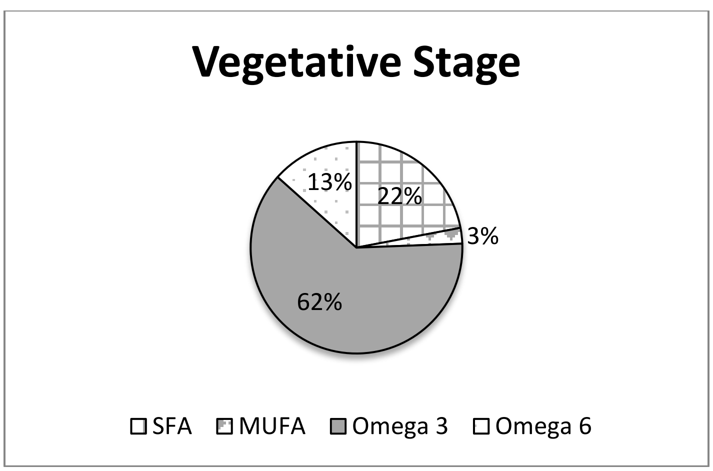
Figure 1. Neutral detergent fiber (NDF), acid detergent fiber (ADF), and non-structural carbohydrate (NSC) levels of oats and triticale forage at four different harvest times.

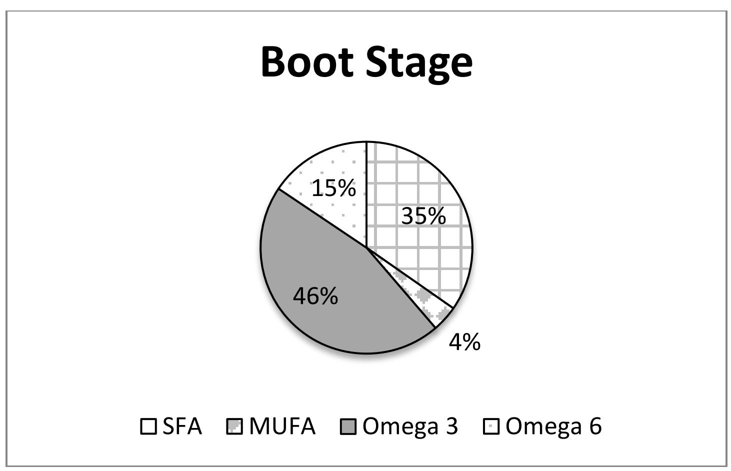
The forage fatty acid (FA) profile and concentrations varied significantly depending on the stage of harvest (Table 4). Figure 2 depicts the change in forage fatty acid profile at four harvest stages. Omega 6s (gray dots) and Omega 3s (in solid gray) make up the poly-unsaturated fatty acids (PUFAs). PUFAs make up the majority of the FA during the vegetative stage (75%) but decrease to 51% of total FA by the soft dough harvest. Omega 3 FAs decrease dramatically with forage maturity. The highest levels of Omega 3 FAs are seen during the vegetative stage, when they make up 62% of total FA. The increase in the ratio of Omega 6 to Omega 3 FA from vegetative to soft dough harvest is due both to the decrease of Omega 3 FAs and increase of Omega 6 FAs with forage maturity. The levels of saturated fatty acids (gray squares) stay relatively constant, with a slight increase during the boot stage, whereas the amount of mono-unsaturated fatty acids (gray diamonds) increased about 20% when the forage reached the milk and soft dough stage. Overall, total concentrations of fatty acids were highest during the vegetative and milk stages. Total FA concentrations during the vegetative stage were 2.5 times greater than the boot stage.

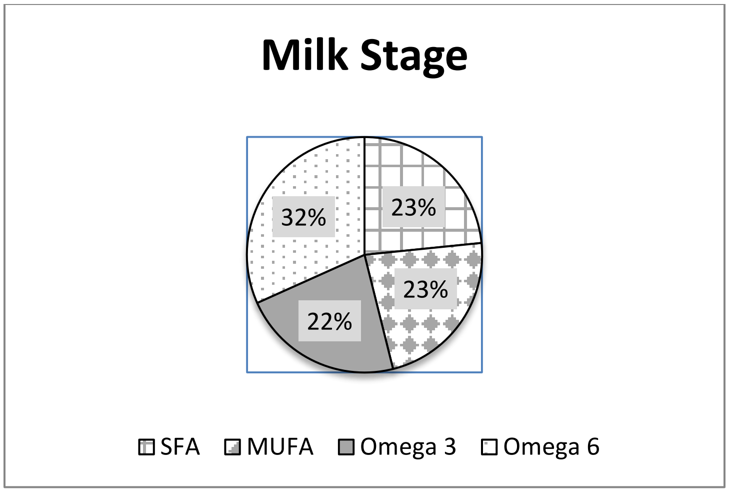
Table 4. Average forage fatty acid profile (%- in grey) and concentration (mg g^{-1}-in white) at three harvest stages.

	Vegetative	Boot	Milk	Soft Dough	Trial Mean	LSD
SFA (%)	22.0	**34.7***	23.4	25.2	26.3	0.92
SFA (mg g^{-1})	6.20*	3.80	**6.20***	5.60	5.40	0.55
C16 (%)	16.8	**23.2***	17.9	19.8	19.4	0.98
C16 (mg g^{-1})	4.70*	2.50	**4.90***	4.40	4.10	0.47
MUFA (%)	2.40	4.00	22.7*	**23.6***	13.2	1.54
MUFA (mg g^{-1})	0.70	0.40	**6.30***	5.40*	3.20	0.88
PUFA (%)	**75.6***	61.3	53.9	51.1	60.5	1.59
PUFA (mg g^{-1})	**21.7***	6.90	14.2	11.5	13.6	1.44
C18:2 LA (%)	13.3	15.4	31.6	**39.3***	24.9	1.21
C18:2 LA (mg g^{-1})	3.80	1.70	8.50*	**8.90***	5.70	1.00
C18:3 LNA (%)	**62.1***	45.6	22.2	11.8	35.4	2.58
C18:3 LNA (mg g^{-1})	**17.8***	5.20	5.60	2.60	7.80	0.86
Omega 3 FA (%)	**62.2***	45.7	22.2	11.8	35.5	2.59
Omega 3 FA (mg g^{-1})	**17.8***	5.20	5.60	2.60	7.80	0.86
Omega 6 FA (%)	13.4	15.6	31.7	**39.3***	25.0	1.21
Omega 6 FA (mg g^{-1})	3.80	1.70	8.60*	**8.90***	5.80	1.01
Total FA (mg g^{-1})	**28.5***	11.1	26.6*	22.5	22.2	2.70
Ratio Omega 6: Omega 3 FA	0.21	0.34	1.52	3.43	1.38	

SFA Saturated Fatty Acids, MUFA mono-unsaturated fatty acids, PUFA poly-unsaturated fatty acids, LA linoleic acid, LNA linolenic acid. * Varieties with an asterisk indicate that it was not significantly different than the top performer in row.







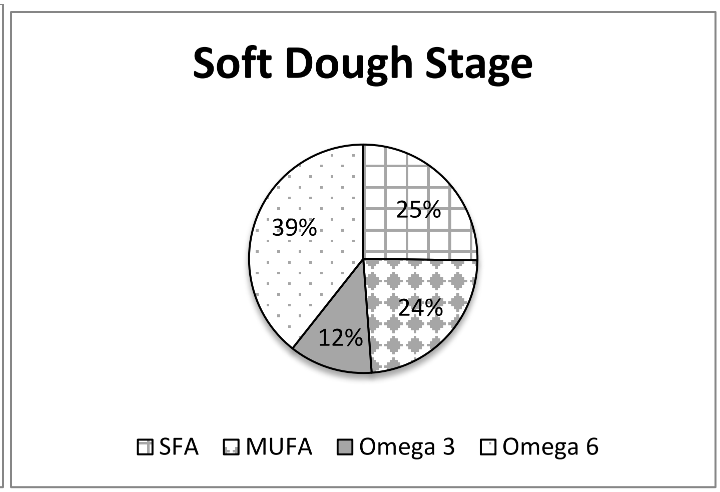


Figure 2. Average fatty acid profile of oat/triticale small grain forage at four harvest stages.

Fertility Type and Amount

Overall, fertility type/rate did not significantly impact yield and most quality parameters of small grains grown for forage. A few exceptions were CP, which was higher than the control when fertilized with Pro-Booster at 100 or 50 lbs acre^{-1} or Chilean Nitrate at 50 lbs acre^{-1} (Table 5). Digestible NDF was also highest with Pro-Booster fertilizer at a rate of 50 lbs acre^{-1}. Increasing nitrogen fertility generally will increase the concentration of CP in forages. However, too much nitrogen can cause other issues such as environmental pollution, increases soluble protein in feed, and lodging issues.

Table 5. Spring forage yield and quality results averaged across harvest stage.

Treatment	DM Yield lbs acre	Moisture %	CP %	ADF %	NDF %	NEL %	dNDF %	NSC %	TDN %	Starch %	NFC %
Pro-Booster 50	4806	67.7	16.1*	34.0	56.4	0.628	**32.4***	12.0	61.0	27.6	19.2
Pro-Booster 100	4984	67.5	**16.6***	33.8	56.2	0.628	31.6*	12.4	61.0	28.8	19.4
Chilean nitrate 50	4481	67.2	15.9*	33.1	55.2	0.638	30.6	13.3	61.8	30.9	20.4
Chilean nitrate 100	4862	67.5	15.6	33.8	56.3	0.633	31.7*	12.9	61.3	29.9	19.9
Control	4373	64.2	15.0	33.4	55.9	0.633	31.6*	13.2	61.4	30.1	20.4
Trial Mean	4647	66.4	15.7	33.6	56.0	0.632	31.6	12.9	61.3	29.6	19.9
LSD (p<0.10)	NS	NS	0.85	NS	NS	NS	0.84	NS	NS	NS	NS

* Varieties with an asterisk indicate that it was not significantly different than the top performer
NS - None of the varieties were significantly different from one another

Overall, there were no significant differences in the fatty acid profile or concentrations when the fertility type and amount were averaged across harvest dates (Table 6). Other research has shown that nitrogen deficient forages would also be lower in fatty acids. The large amount of manure applied to the field many have impacted the ability for us to observe any fertility treatment impacts on fatty acid concentrations.

Table 6. Forage fatty acid profile (% in grey) and concentration (mg g^{-1} in white) of different fertility treatments and application rates (lbs acre^{-1}).

	Pro-Booster 50	Pro-Booster 100	Chilean nitrate 50	Chilean nitrate 100	Control	Trial Mean	LSD
SFA (%)	26.9	26.8	25.4	26.0	26.4	26.3	NS
SFA (mg g^{-1})	5.30	5.30	5.60	5.60	5.40	5.40	NS
C16 (%)	19.9	19.7	18.4	19.5	19.5	19.4	NS
C16 (mg g^{-1})	4.00	4.00	4.30	4.30	4.10	4.10	NS
MUFA (%)	12.1	12.7	14.1	13.6	13.4	13.2	NS
MUFA (mg g^{-1})	2.80	2.80	3.50	3.60	3.20	3.20	NS
PUFA (%)	61.0	60.5	60.6	60.4	60.2	60.5	NS
PUFA (mg g^{-1})	13.1	13.0	14.0	14.2	13.5	13.6	NS
C18:2 LA (%)	23.9	24.2	25.3	25.4	25.3	24.9	NS
C18:2 LA (mg g^{-1})	5.30	5.20	6.00	6.20	5.80	5.70	NS
C18:3 LNA (%)	36.9	36.1	35.1	34.8	34.8	35.4	NS
C18:3 LNA (mg g^{-1})	7.80	7.80	8.00	7.90	7.70	7.80	NS
Omega 3 FA (%)	36.9	36.2	35.2	34.9	34.9	35.5	NS
Omega 3 FA (mg g^{-1})	7.80	7.80	8.00	7.90	7.70	7.80	NS
Omega 6 FA (%)	24.0	24.3	25.4	25.5	25.4	25.0	NS
Omega 6 FA (mg g^{-1})	5.30	5.20	6.00	6.30	5.80	5.80	NS
Total FA (mg g^{-1})	21.3	21.1	23.1	23.4	22.2	22.2	NS
Ratio Omega 6: Omega 3 FA	0.69	0.67	0.76	0.79	0.76	0.73	

SFA Saturated Fatty Acids, MUFA mono-unsaturated fatty acids, PUFA poly-unsaturated fatty acids, LA linoleic acid, LNA linolenic acid.
* Varieties with an asterisk indicate that it was not significantly different than the top performer in row.

REFERENCE

Sukhija, P. S., and D. L. Palmquist. 1988. Rapid method for determination of total fatty-acid content and composition of feedstuffs and feces. *J. Agric. Food Chem.* 36: 1202-1206.

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