2011 VERMONT SMALL GRAIN FORAGE TRIALS

INTRODUCTION

Spring cereal grains such as oats, barley, triticale, wheat, and spelt could have the potential to provide high yield and quality feed for livestock. These cool season annuals can provide early season grazing as well as high quality stored feed. Spring grains are planted in mid to late April and can be harvested at various stages of development. The objective of this project was to evaluate yield and quality of various spring grain species harvested in the vegetative, milk, or soft dough stage. 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 overall goal of this project is to help organic dairy producers reduce their reliance on expensive concentrates through the production of a variety of high quality annual forages. In addition, we were interested in investigating the value of combining brassica forage with these cool season annuals. 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 Borderview Research Farm in Alburgh, VT (Table 1). The research area is certified organic by Vermont Organic Farmers, LLC. The previous crop was organic corn silage. The seedbed was prepared by conventional tillage methods. Plots were planted with a six-inch grain drill on May 13, 2011. The oats, barley, spelt, and triticale were planted at 125 lbs/acre. The Barkant turnips were planted at 8 lbs/acre. The varieties and seed source are listed in Table 2. Plot size was 5' x 20' and were fertilized with Pro-Booster organic fertilizer at a rate of 70 lbs. N $acre^{-1}$ on June 28, 2011. Each treatment was harvested at three development stages, vegetative stage, milk stage, and soft dough stage. Subsamples of approximately 2.5 ft^2 were cut to the ground, dried at 40^oC, 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. (Hagerstown, MD) for quality analysis. Results were analyzed with an analysis of variance with SAS (Cary, NC).

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 GCsolution 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).

Table 1. General plot management.

Trial Information	Borderview Farm, Alburgh, VT
Soil type	Benson rocky silt loam
Previous crop	Corn silage
Row width (in.)	6
Planting date	13-May
Harvest dates:	
Vegetative	27-June
Milk	13-July (Barley) 14-July (Wheat 25-July (Spelt, Oats, Triticale)
Soft Dough	26-July (Barley and Wheat) 8-August (Spelt, Oats, Triticale)
Seeding rate	125 lbs/acre
Tillage methods	Mold board plow, disk, and spike tooth harrow
Fertilizer applications	ProBooster 70 lbs. N/acre on 28-June

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 – 80%. The NSC or non-fiber carbohydrates (NFC) include starch, sugars, and pectins.

Table 2. Spring cereal grain and turnip variety and source.

Type	Variety	Company
Forage Oats	Everleaf	King's AgriSeeds
Barley	Robust	Lakeview Organics
Wheat	AC Barrie	SeCan
Triticale	Tritical® 718	King's AgriSeeds
Spelt	VNS	Lakeview Organics
Forage Turnip	Barkant	Barenbrug

VNS – variety not stated

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 Alburgh, VT is reported in Table 3. This season started off with above average rain in April and May. This delayed cereal grain planting into mid-May. Ideally planting would have been completed by April. Precipitation was below average during each harvest date.

Table 3. Seasonal weather data collected near Alburgh, VT 2011.

South Hero (Alburgh)	May	June	July	August
Average Temperature (F)	58.7	67.1	74.4	70.4
Departure from Normal	2.1	1.3	3.3	1.6
Precipitation (inches)	8.67	3.52	3.68	10.23
Departure from Normal	5.35	0.09	-0.29	6.38
Growing Degree Days (base 32)	826	1088	1314	1121
Departure from Normal	63.6	74.1	104	-26.3

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

Harvest Stage x Grain Species Interaction

For each parameter reported, there was a significant grain species by harvest stage interaction. This indicates that grain species did not perform the same across harvest stages. Yield increased for each treatment with later harvest stages except for spelt and triticale, where yield decreased from milk to soft dough. We would expect yield to increase as plants become more mature. A decline in yield may be attributed to drought conditions experienced in the summer months. Crude protein decreased with later harvest stages, except for barley and wheat, where protein levels stayed level from milk to soft dough. Fiber concentrations (ADF and NDF) were lowest during the vegetative stage for all the treatments except barley and wheat, where the lowest levels were seen in soft dough. This may be due to faster maturation of barley and wheat. These species may have been further along with fully developed grains when the treatments were sampled, which increased the overall quality.

Harvest Stage

Comparing treatments across harvest stage, forage yields were greatest 4396 lbs dry matter acre^{-1}, when harvested at soft dough (Table 4). Protein levels were highest during the vegetative stage. The lowest ADF levels were seen from the soft dough and vegetative harvest. Fiber content generally increases as plants mature but the formation of starch in the soft dough harvested grains may dilute the fiber content. The fiber digestibility (dNDF) was highest in the vegetative stage. The nonstructural carbohydrates were highest in the soft dough stage again a result of grain fill in the heads. There was no difference in the NeL (Mcal/lb) between vegetative and soft dough harvested forages. The additional starch from grain formation improves the overall quality of cereal grains harvested in the soft dough stage.

Table 4. Cereal grain yield and quality compared across harvest stages.

Stage	Moisture %	Yield lbs/acre	CP %	ADF %	NDF %	dNDF %	TDN %	NeL Mcal/lb	NSC %
Vegetative	81.7	1409	**14.1**	30.9*	**50.2**	**68.8**	**63.7**	**0.658***	14.6
Milk	65.0	3724	10.7	33.8	56.5	48.7	61.6	0.635	17.1
Soft Dough	**51.7**	**4396**	10.0	**30.7***	55.0	45.2	62.9	0.650*	**21.1***
Trial Mean	66.1	3176	11.6	31.8	53.9	54.2	62.7	0.647	17.6
LSD (0.10)	1.70	367	0.48	1.25	1.76	1.35	0.77	0.0087	0.99

* Varieties with an asterisk indicate that it was not significantly different than the top performer (in bold).

The forage fatty acid (FA) profile and concentrations varied significantly depending on the stage of harvest (Table 5). Amounts of the FA Linolenic acid (C18:3, an omega 3 FA) in the forage decreased markedly with maturation from 51.8% of FA at the vegetative harvest down to 8.3% at the soft dough harvest. Another main poly-unsaturated fatty acid, Linoleic (C18:2, an omega 6 FA) increased in the forage from 16.5% at vegetative harvest to 46.2% at the soft dough harvest. Interestingly, mono-unsaturated fatty acids (MUFAs) also increased from 3.3% at the vegetative stage to 18.8% of FA at the soft dough stage. The ratio of omega 6 to omega 3 FA was the lowest (0.32) and presumably the most favorable (as a lower ratio is more favorable for human diets) during the vegetative stage.

Table 5. Average forage fatty acid profile (%- in grey) and concentration (mg g^{-1}-in white) at three harvest stages.

	Vegetative	Milk	Soft Dough	Trial mean	LSD
SFA (%)	**28.1***	28.1*	26.6	27.6	0.8242
SFA (mg g^{-1})	4.9*	4.3	**5.0***	4.7	0.3308
C16 (%)	20.2	**21.3***	20.7	20.7	0.5098
C16 (mg g^{-1})	3.5	3.3	**3.9***	3.6	0.2642
MUFA (%)	3.3	13.1	**18.8***	11.7	1.9973
MUFA (mg g^{-1})	0.6	2.4	**4.0***	2.3	0.6641
PUFA (%)	**68.6***	58.8	54.6	60.7	1.5819
PUFA (mg g^{-1})	**12.3***	9.1	10.4	10.6	0.7985
C18:2 LA (%)	16.5	32.2	**46.2***	31.6	1.2646
C18:2 LA (mg g^{-1})	2.9	5.2	**8.9***	5.7	0.6811
C18:3 LNA (%)	**51.8***	26.5	8.3	28.8	1.9043
C18:3 LNA (mg g^{-1})	**9.3***	4.0	1.5	4.9	0.3878
Omega 3 FA (%)	**51.9***	26.5	8.3	28.9	1.9077
Omega 3 FA (mg g^{-1})	**9.4***	4.0	1.5	4.9	0.3878
Omega 6 FA (%)	16.7	32.3	**46.3***	31.7	1.2628
Omega 6 FA (mg g^{-1})	3.0	5.2	**8.9***	5.7	0.6812
Total FA (mg g^{-1})	17.8*	15.8	**19.4***	17.6	1.6543
Ratio Omega 6: Omega 3 FA	0.3	1.3	**6.0***	2.5	0.3892

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.

Grain Species

Comparing treatments across species, forage oats yielded the highest at 4657 lbs dry matter acre^{-1} (Table 6). Triticale, wheat, and spelt had the highest crude protein levels, between 11.6-12.3%. The barley treatments had the lowest ADF levels and the highest total digestible nutrients (TDN), net energy of lactation (NEL), and non-structural carbohydrates (NSC). Fiber digestibility (dNDF) was greatest for the oat treatments. The addition of turnip into the seeding did not appear to impact quality. Overall, yields were similar or lower when turnips were added to the mix. A higher proportion of turnips may have resulted in higher CP and less fiber concentration but would also further decrease dry matter yields. Future work on seed mixes would help us better understand if this combination of forages is viable for the dairy community.

Table 6. Cereal grain yield and quality compared across species.

Treatment	Moisture %	Yield lbs/acre	CP %	ADF %	NDF %	dNDF %	TDN %	NeL Mcal/lb	NSC %
Barley	66.9	3668	11.1	28.0*	51.5	54.1	64.5*	0.667*	20.4*
Barley and Turnip	64.9	3661	10.7	**27.4***	51.1	54.4	**65.2***	**0.676***	**21.6***
Oats	**72.1***	**4657**	11.1	33.5	55.5	**58.9***	62.8	0.651	14.8
Oats and Turnip	69.6*	3465	10.7	32.7	54.3	58.3*	63.5	0.658	16.7
Spelt	66.0	2508	11.6*	33.6	55.5	53.2	61.5	0.635	16.3
Spelt and Turnip	63.9	2490	12.1*	33.6	54.9	54.1	61.6	0.633	16.3
Triticale	64.1	2932	12.0*	33.1	55.7	53.4	61.6	0.634	16.0
Triticale and Turnip	66.8	3032	**12.3***	32.0	54.1	52.6	62.0	0.638	16.6
Wheat	63.5	2587	12.1*	31.9	52.7	51.8	62.1	0.641	18.7
Wheat and Turnip	63.6	2761	12.0*	31.8	53.7	51.3	62.3	0.642	18.6
Overall Mean	66.1	3176	11.6	31.8	53.9	54.2	62.7	0.647	17.6
Treatment LSD (0.10)	3.11	670	0.87	2.28	NS	2.47	1.40	0.0159	1.79

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

The grain species had a significant impact on the forage FA profile and concentrations when results were averaged across harvest stages (Table 7). Triticale and spelt had the highest concentrations of linolenic acid, C18:3 of any forage species (6.22 and 5.22 mg g^{-1} respectively). Because LNA is the main Omega 3 FA, triticale and spelt also had the highest concentrations of Omega 3 FAs. Total concentrations of FAs were highest in oats-21.86 mg g^{-1}, but the lowest ratio of Omega 6 to Omega 3 FA was seen in spelt and triticale.

Table 7. Average forage fatty acid profile (%- in grey) and concentration (mg g^{-1}-in white) of spring grains with or without turnip.

	Barley	Barley and Turnip	Oats	Oats and Turnip	Spelt	Spelt and Turnip	Trit	Trit and Turnip	Wheat	Wheat and Turnip	Trial Mean	LSD
SFA (%)	28.0	27.9	28.0	27.7	28.0	27.9	26.4	27.6	27.2	27.6	27.6	NS
SFA (mg g^{-1})	4.60	4.9	**5.9***	5.3*	4.40	4.90	4.50	4.70	3.90	4.1	4.70	0.604
C16 (%)	21.0	21.0	20.9	20.9	20.9	20.8	19.7	20.5	20.7	21.0	20.7	NS
C16 (mg g^{-1})	3.50	3.7	**4.4***	4.1*	3.30	3.70	3.30	3.50	3.00	3.1	3.60	0.482
MUFA (%)	11.4	11.7	16.2	13.8	10.8	11.4	10.5	10.9	10.8	9.9	11.7	NS
MUFA (mg g^{-1})	2.10	2.30	**4.10***	3.40*	1.70	2.10	1.80	2.30	1.80	1.50	2.30	1.21
PUFA (%)	60.7*	60.4*	55.8	58.6	61.2*	60.8*	**63.1***	61.5*	62.0*	62.5*	60.7	2.89
PUFA (mg g^{-1})	10.1	10.8*	**11.9***	11.4*	10.0	11.0*	11.5*	10.7*	9.00	9.60	10.6	1.45
C18:2 LA (%)	32.0*	34.0*	29.6	30.7	31.2	29.9	31.7	30.2	32.9*	**34.1***	31.6	2.31
C18:2 LA	5.70*	6.50*	**6.80***	6.50*	4.80	5.50	5.30	5.30	4.90	5.30	5.70	1.24
C18:3 LNA (%)	28.5	26.3	26.0	27.7	29.8	30.7	31.2	31.1	28.9	28.2	28.8	NS
C18:3 LNA	4.40	4.20	5.10	4.90	5.20	5.50*	**6.20***	5.30	4.00	4.30	4.90	0.708
Omega 3 (%)	28.6	26.3	26.1	27.8	29.9	30.8	31.3	31.2	29.0	28.3	28.9	NS
Omega 3 (mg g^{-1})	4.40	4.20	5.10	4.90	5.20	5.50*	**6.20***	5.30	4.10	4.30	4.90	0.708
Omega 6 (%)	32.1*	34.1*	29.7	30.8	31.3	30.0	31.8	30.3	33.1*	**34.2***	31.7	2.31

Omega 6 (mg g^{-1})	5.80*	6.60*	**6.90***	6.50*	4.80	5.50	5.30	5.30	5.00	5.30	5.70	1.24
Total FA (mg g^{-1})	16.9	18.0	**21.9***	20.2*	16.2	18.0	17.8	17.6	14.7	15.3	17.6	0.020
Ratio Omega 6:Omega 3 FA	2.80*	3.20*	3.02*	**3.22***	2.09	2.09	2.14	2.32	2.40	2.65	2.59	0.711

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 (in bold).

Vegetative Stage Harvest

The vegetative stage harvest was to document the value of small grains as a potential early season grazing crop. The addition of turnip to the small grains had no statistical effect on the yield and quality parameters. At the vegetative stage harvest, the highest yielding treatments were barley + turnip (2294 lbs dry matter acre^{-1}), wheat, and barley (Table 8 and Figure 1). Barley is the fastest maturing spring grain and some of the yield differences in the vegetative stage may be due the advanced barley maturity. Triticale and spelt had the highest protein levels, over 15% concentration. Oats and triticale had the lowest ADF (Figure 2). ADF indicates the percent of highly indigestible plant material and values under 35% are desirable. The wheat treatments had the lowest digestible NDF values, whereas the oat treatments had the highest total digestible nutrients (TDN) and net energy of lactation (NeL) levels.

Table 8. Cereal grain yield and quality when harvested in the vegetative stage, June 27, 2011.

Vegetative stage	Moisture %	Yield lbs acre^{-1}	CP %	ADF %	NDF %	dNDF %	TDN %	NeL Mcal/lb	NSC %
Barley	83.3	1920*	12.7	33.0	56.3	63.5	62.3	0.640	13.6
Barley and Turnip	**79.4**	**2294***	12.4	33.1	56.7	63.7	62.6	0.648	14.0
Oats	84.8	1417	13.4	28.4*	46.1*	**78.2***	**66.6***	**0.693***	15.1
Oats and Turnip	84.4	1452	13.3	**28.3***	**45.1***	77.7*	66.1*	0.685*	**15.6**
Spelt	81.5	1220	15.2*	30.7	48.3	69.3	63.3	0.658	14.3
Spelt and Turnip	80.3	976	15.5*	30.8	48.3	70.1	63.4	0.655	14.2
Triticale	81.8	682	**16.1***	29.1*	47.5	72.0	64.7	0.668	14.7
Triticale and Turnip	81.5	1195	15.3*	29.3*	46.0*	70.0	64.0	0.663	15.2
Wheat	80.5	1692*	13.7	33.2	53.1	62.2	61.7	0.635	14.3
Wheat and Turnip	79.8	1237	13.2	33.1	54.9	61.2	62.0	0.638	14.7
Veg. Stage Mean	81.7	1409	14.1	30.9	50.2	68.8	63.7	0.658	14.6
Treatment LSD (0.10)	NS	610.4	1.50	1.25	1.83	1.87	1.27	0.0145	NS

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

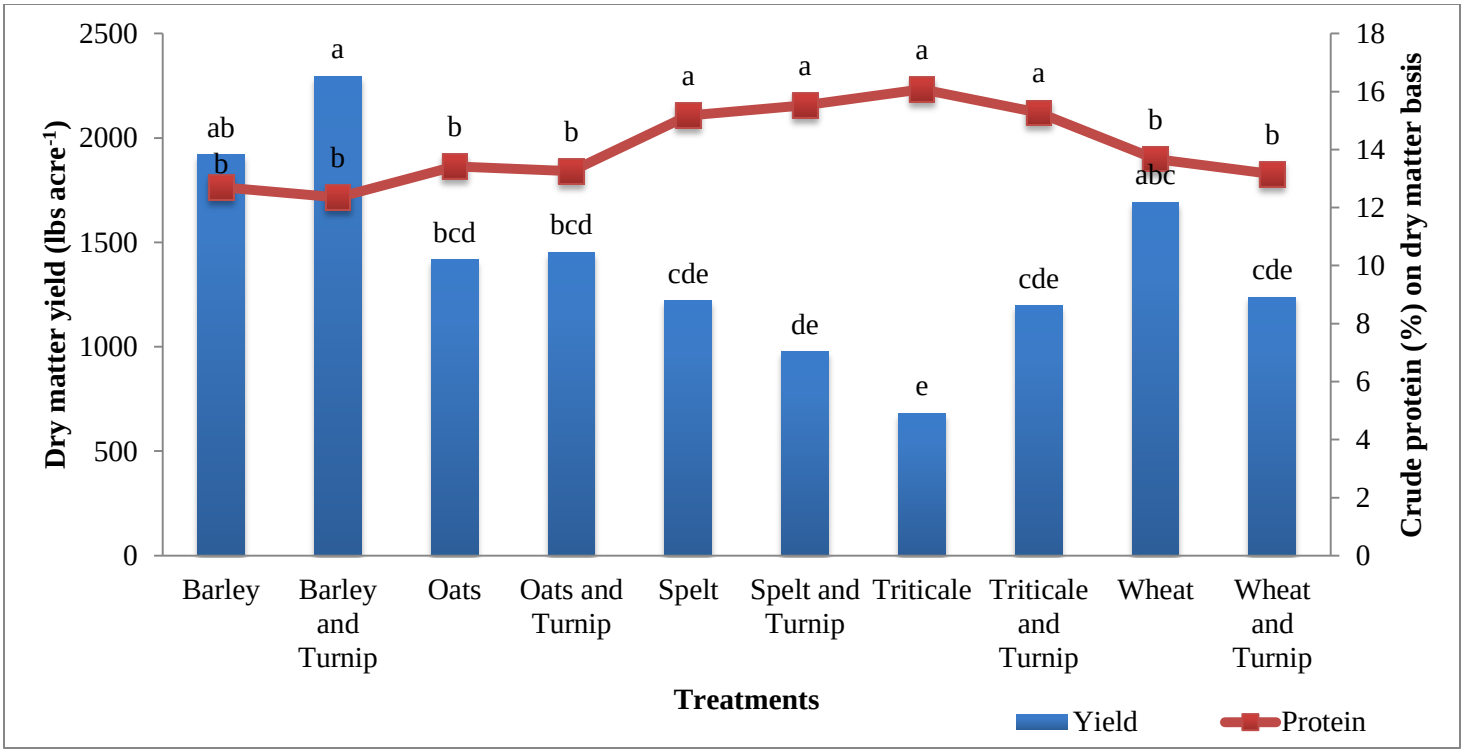

Figure 1. Yield and protein of small grain forage and small grain/brassica mixtures harvested in the vegetative stage.
Treatments with the same letter did not differ significantly.

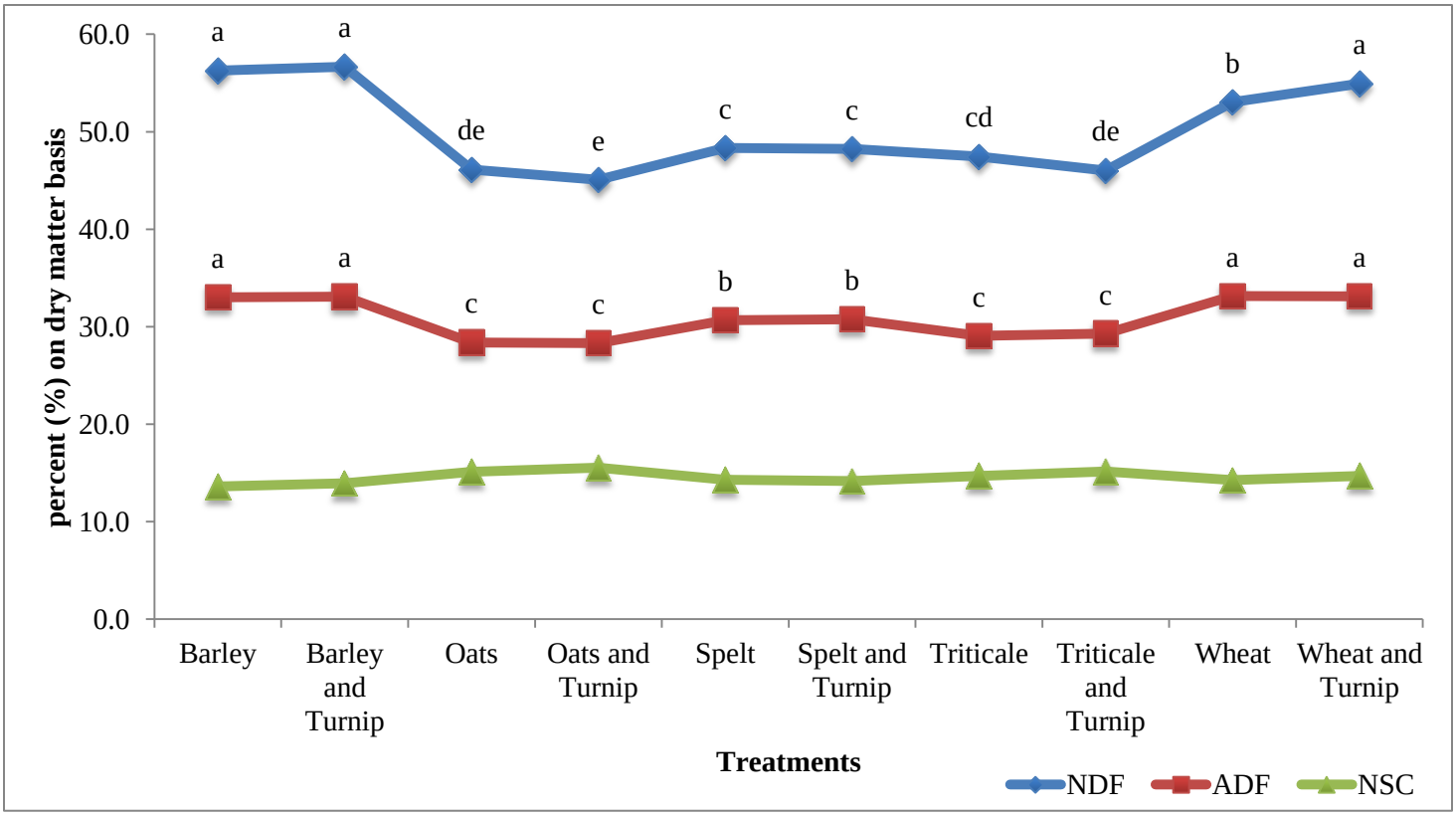

Figure 2. Neutral detergent fiber (NDF), acid detergent fiber (ADF), and non-structural carbohydrate (NSC) concentration of small grain forage harvested in the vegetative stage. *Treatments with the same letter did not differ significantly.*

During the vegetative stage, the FA profile of linolenic acid, C18:3 averaged 51.8% (Table 9; Figure 7). Triticale and spelt had the greatest concentrations of Omega 3 FA, 13.6 and 10.4 mg g^{-1} respectively. Interestingly, total concentrations of FA in the triticale (23.5 mg g^{-1}) were much higher than any other treatments. Spelt and turnip had the second highest concentrations of total FA (19.4 mg g^{-1}). The lowest ratio of Omega 6 to Omega 3 FA was seen with the triticale and spelt treatments.

Table 9. Vegetative stage fatty acid profile (% in grey) and concentration (mg g^{-1} in white).

	Barley	Barley and Turnip	Oats	Oats and Turnip	Spelt	Spelt and Turnip	Trit	Trit and Turnip	Wheat	Wheat and Turnip	Stage Mean	LSD
SFA (%)	29.8*	30.3*	**30.4***	30.0*	28.1	27.5	23.1	26.1	28.2	28.0	28.1	2.2328
SFA (mg g^{-1})	4.3	4.5	5.6*	**5.7***	5.2*	5.2*	5.4*	4.7	3.8	4.3	4.9	0.5223
C16 (%)	20.9*	21.3*	**22.2***	21.6*	20.1	19.6	16.8	18.9	20.3	20.4	20.2	1.3522
C16 (mg g^{-1})	3.0	3.2	4.1*	**4.1***	3.7*	3.7*	3.9*	3.4	2.8	3.2	3.5	0.4023
MUFA (%)	4.3*	**4.7***	3.1	3.6*	2.4	2.6	3.3	2.5	3.0	3.3	3.3	1.1381
MUFA (mg g^{-1})	0.6*	0.7*	0.6*	0.7*	0.5	0.5	**0.8***	0.4	0.4	0.5	0.6	NS
PUFA (%)	66.0	64.9	66.5	66.4	69.5	70.0	**73.5***	71.4*	68.8	68.7	68.6	2.4181
PUFA (mg g^{-1})	9.8	9.9	12.7	12.8	13.2	13.7	**17.4***	13.2	9.6	10.8	12.3	2.2970
C18:2 LA (%)	16.2	16.5	17.3	17.3	14.6	15.0	15.8	14.5	18.3*	**19.6***	16.5	1.5633
C18:2 LA (mg g^{-1})	2.4	2.5	3.3*	3.3*	2.8	2.9	**3.8***	2.7	2.6	3.1	2.9	0.5983
C18:3 LNA (%)	49.4	48.2	48.9	48.7	54.7*	54.8*	**57.6***	56.7*	50.2	48.7	51.8	3.4153
C18:3 LNA (mg g^{-1})	7.3	7.3	9.4	9.4	10.4	10.7	**13.5***	10.5	7.0	7.7	9.3	1.8856
Omega 3 (%)	49.5	48.3	49.1	49.0	54.8*	54.9*	**57.7***	56.8*	50.3	48.8	51.9	3.3915
Omega 3 (mg g^{-1})	7.3	7.3	9.4	9.5	10.4	10.7	**13.6***	10.5	7.0	7.7	9.4	1.8865
Omega 6 (%)	16.4	16.6	17.4	17.4	14.7	15.1	15.9	14.6	18.6*	**19.9***	16.7	1.5636
Omega 6 (mg g^{-1})	2.4	2.5	3.3*	3.4*	2.8	2.9	**3.8***	2.7	2.6	3.1	3.0	0.6004
Total FA (mg g^{-1})	14.7	15.1	18.8	19.2	18.9	19.4	**23.5***	18.4	13.8	15.7	17.8	2.8393
Ratio Omega 6:Omega 3 FA	0.33	0.34	0.35	0.35	0.27	0.27	0.28	0.26	0.37	0.40	0.32	

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 (in bold).

Milk Stage Harvest

Oats alone had the greatest dry matter yields when harvested in the milk stage, 5620 lbs dry matter $acre^{-1}$ (Table 10 and Figure 3). Wheat, triticale and oats had the highest milk stage protein levels, from 11.1 – 11.7%. The barley treatments had the lowest milk stage ADF and NDF levels (Figure 4), while oat, barley, and spelt had the highest digestible NDF levels. The barley treatments also had the highest total digestible nutrients, net energy of lactation and non-structural carbohydrates. Addition of turnips into the grain mix did not seem to impact forage quality.

Table 10. Small grain forage yield and quality harvested in the milk stage, mid-July, 2011.

Milk stage	Moisture %	Yield lbs $acre^{-1}$	Protein %	ADF %	NDF %	dNDF %	TDN %	NeL Mcal/lb	NSC %
Barley	68.1*	4144	10.2	26.4*	49.9*	49.6*	65.4	0.680*	**22.9***
Barley and Turnip	68.1*	3610	9.90	**25.4***	**49.0***	48.8	**66.3**	**0.688***	24.3*
Oats	70.0*	**5620**	11.1*	36.8	60.1	**51.5***	60.2	0.623	11.7
Oats and Turnip	**70.1***	3947	9.9	37.3	60.9	50.3*	60.3	0.623	13.8
Spelt	62.6	3451	10.2	36.6	59.4	48.6	60.3	0.620	15.6
Spelt and Turnip	64.9	2877	10.4	37.8	60.1	49.8*	59.2	0.605	14.4
Triticale	60.2	4259	10.6	37.0	60.2	46.7	59.3	0.610	14.5
Triticale and Turnip	63.4	4021	11.3*	35.6	59.0	45.2	59.9	0.613	14.9
Wheat	61.3	2398	11.4*	32.4	53.1	48.1	62.3	0.643	19.8
Wheat and Turnip	61.4	2908	**11.7***	32.4	53.4	48.2	62.5	0.645	19.4
Milk Stage Mean	65.0	3724	10.7	33.8	56.5	48.7	61.6	0.635	17.1
Treatment LSD (0.10)	2.09	952	1.09	1.46	1.72	2.26	0.886	0.011	1.45

* Varieties with an asterisk indicate that it was not significantly different than the top performer in column.

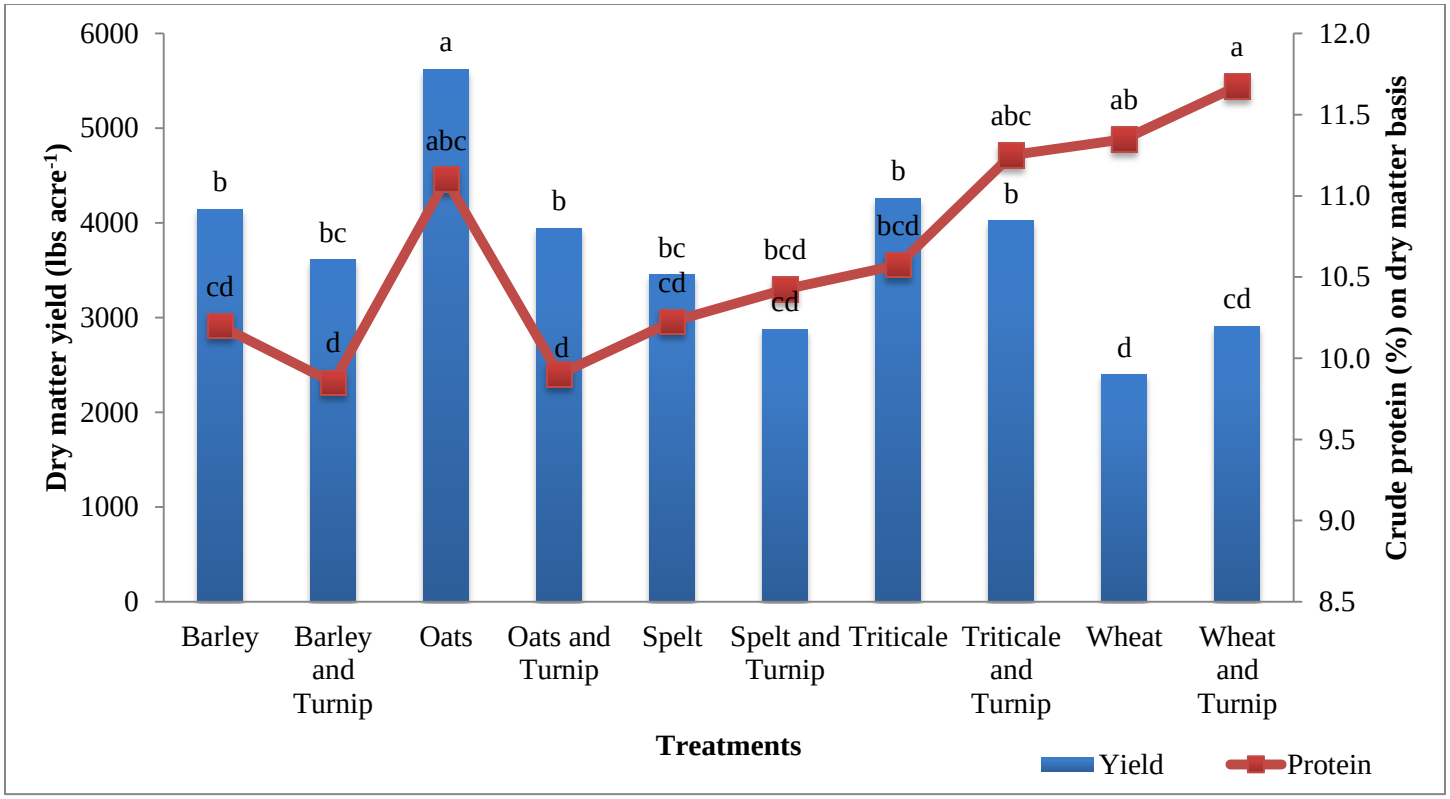

Figure 3. Yield and protein of small grain forage and small grain/brassica mixtures at the milk stage. **Treatments with the same letter did not differ significantly.*

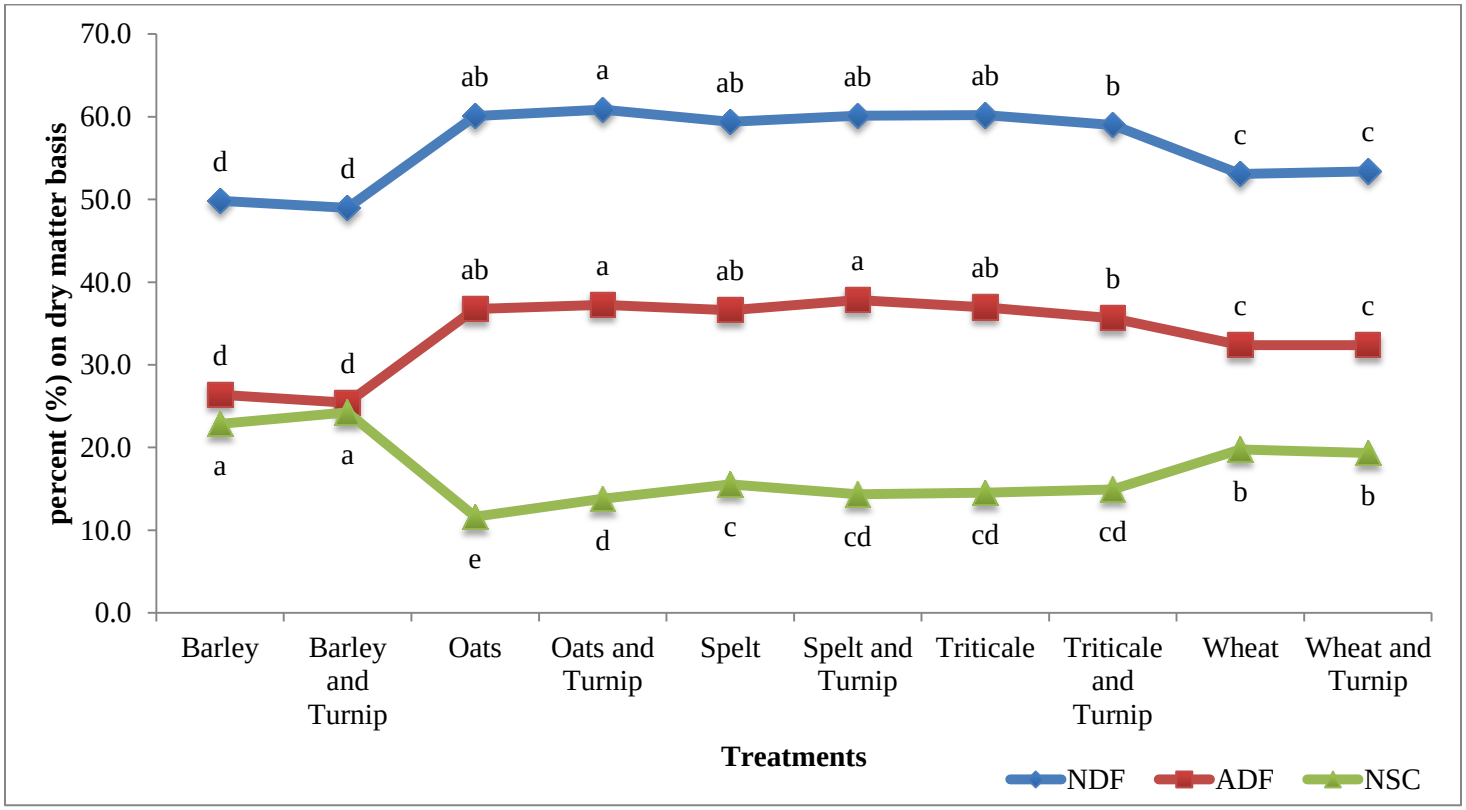

Figure 4. Neutral detergent fiber (NDF), acid detergent fiber (ADF), and non-structural carbohydrate (NSC) concentrations of small grain forage harvested in the milk stage. **Treatments with the same letter did not differ significantly.*

Interestingly, during the milk stage harvest, there were no significant differences for forage fatty acid profile or concentrations between species (Table 11; Figure 7). Average total FA concentrations decreased slightly from the vegetative stage from 17.7 mg g^{-1} to 15.8 mg g^{-1} in the milk stage.

Table 11. Milk stage fatty acid profile (% in grey) and concentration (mg g^{-1} in white).

	Barley	Barley and Turnip	Oats	Oats and Turnip	Spelt	Spelt and Turnip	Trit	Triticale and Turnip	Wheat	Wheat and Turnip	Stage Mean	LSD
SFA (%)	28.0	26.6	28.1	28.9	26.5	28.3	28.2	29.6	27.6	29.4	28.1	NS
SFA (mg g^{-1})	4.4	4.5	5.2	3.9	4.2	4.2	4.0	4.6	4.0	4.1	4.3	NS
C16 (%)	21.4	20.5	21.4	22.0	20.5	21.1	21.1	22.0	21.2	22.1	21.3	NS
C16 (mg g^{-1})	3.3	3.4	3.9	3.0	3.2	3.1	3.0	3.5	3.1	3.1	3.3	NS
MUFA (%)	12.4	15.3	15.4	9.6	13.7	13.6	14.0	13.3	13.4	10.2	13.1	NS
MUFA (mg g^{-1})	2.4	3.0	3.2	1.3	2.4	2.3	2.2	2.7	2.6	1.5	2.4	NS
PUFA (%)	59.6	58.1	56.5	61.5	59.8	58.1	57.9	57.1	58.9	60.3	58.8	NS
PUFA (mg g^{-1})	9.3	9.8	10.6	8.4	9.5	8.7	8.3	9.3	8.8	8.7	9.1	NS
C18:2 LA (%)	30.7	34.3	33.1	32.4	34.5	30.3	31.8	30.5	31.4	32.7	32.2	NS
C18:2 LA (mg g^{-1})	5.0	6.0	6.3	4.6	5.5	4.7	4.6	5.3	5.0	4.8	5.2	NS
C18:3 LNA (%)	28.8	23.7	23.3	28.9	25.2	27.6	26.0	26.6	27.4	27.5	26.5	NS
C18:3 LNA (mg g^{-1})	4.3	3.8	4.3	3.9	3.9	4.0	3.6	4.0	3.8	3.9	4.0	NS
Omega 3 (%)	28.9	23.7	23.4	28.9	25.2	27.7	26.0	26.6	27.5	27.5	26.5	NS
Omega 3 (mg g^{-1})	4.3	3.9	4.3	3.9	3.9	4.0	3.6	4.0	3.8	3.9	4.0	NS
Omega 6 (%)	30.7	34.4	33.2	32.6	34.6	30.5	31.9	30.5	31.5	32.8	32.3	NS
Omega 6 (mg g^{-1})	5.0	6.0	6.3	4.6	5.5	4.7	4.7	5.3	5.0	4.8	5.2	NS
Total FA (mg g^{-1})	16.1	17.3	19.0	13.7	16.1	15.2	14.5	16.6	15.5	14.4	15.8	NS
Ratio Omega 6:Omega 3 FA	1.15	1.55	1.48	1.18	1.40	1.17	1.29	1.33	1.30	1.22	1.31	

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 (in bold).

Soft Dough Stage Harvest

Similar to the milk stage, oats alone were the highest yielding treatment when harvested during the soft dough stage (Table 12 and Figure 4). Oats yielded close to 7000 lbs dry matter $acre^{-1}$, which is about 2000 lbs $acre^{-1}$ more than the next highest yielding treatment, barley + turnip. Barley, spelt + turnip, triticale + turnip, and the wheat treatments had the highest protein levels of the soft dough harvest. The barley treatments were the highest quality treatments with the lowest ADF, NDF, and highest dNDF, TDN, NeL and NSC. Barley appears to be a good choice for high quality forage when harvested in the milk or soft dough stage. Oats were the highest yielding small grain forage when harvested in the milk or soft dough stage. In most cases turnips did not seem to provide much quality benefit to the forage. There was a slight decline in fiber concentrations but mostly not significant.

Table 12. Cereal grain yield and quality harvested at the soft dough stage, late-July, early-August 2011.

Soft dough stage	Moisture %	Yield lbs acre^{-1}	Protein %	ADF %	NDF %	DNDF %	TDN %	NeL Mcal/lb	NSC %
Barley	49.3	4941	10.4*	24.6*	48.5*	49.4*	65.7*	0.680*	24.7*
Barley and Turnip	47.2	5079	9.9	**23.8***	**47.5***	**50.6***	**66.8***	**0.693***	**26.5***
Oats	**61.6***	**6935**	8.8	35.3	60.4	47.0	61.6	0.638	17.6
Oats and Turnip	54.2*	4996	8.9	32.5	57.1	47.0	64.0	0.665	20.6
Spelt	53.9*	2853	9.5	33.7	58.8	41.9	61.0	0.628	19.0
Spelt and Turnip	46.4	3618	10.4*	32.3	56.3	42.5	62.1	0.640	20.5
Triticale	50.3	3853	9.3	33.4	59.5	41.6	60.8	0.625	18.7
Triticale and Turnip	55.6*	3879	10.3*	31.1	57.2	42.6	62.0	0.640	19.8
Wheat	48.6	3672	**11.4***	30.1	52.0	45.2	62.4	0.645	22.0
Wheat and Turnip	49.6	4136	11.3*	29.8	52.7	44.3	62.6	0.643	21.8
Soft Dough Mean	51.7	4396	10.0	30.7	55.0	45.2	62.9	0.650	21.1
Treatment LSD (0.10)	7.76	1261	1.19	3.55	3.78	2.19	2.34	0.026	3.06

* Varieties with an asterisk indicate that it was not significantly different than the top performer in column.

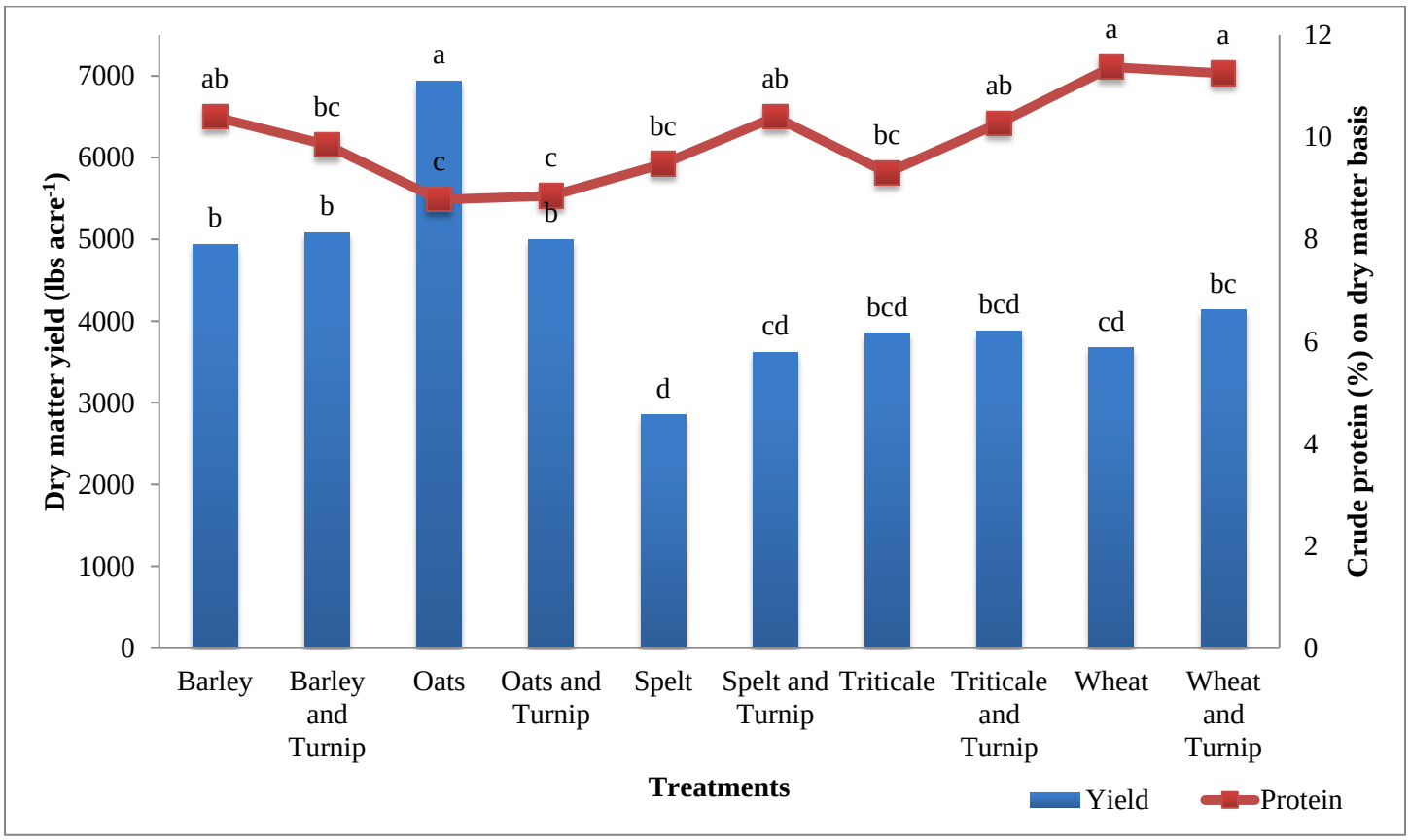

Figure 5. Yield and crude protein (CP) of small grain forage and small grain/brassica mixtures harvested in the soft dough stage.
Treatments with the same letter did not differ significantly.

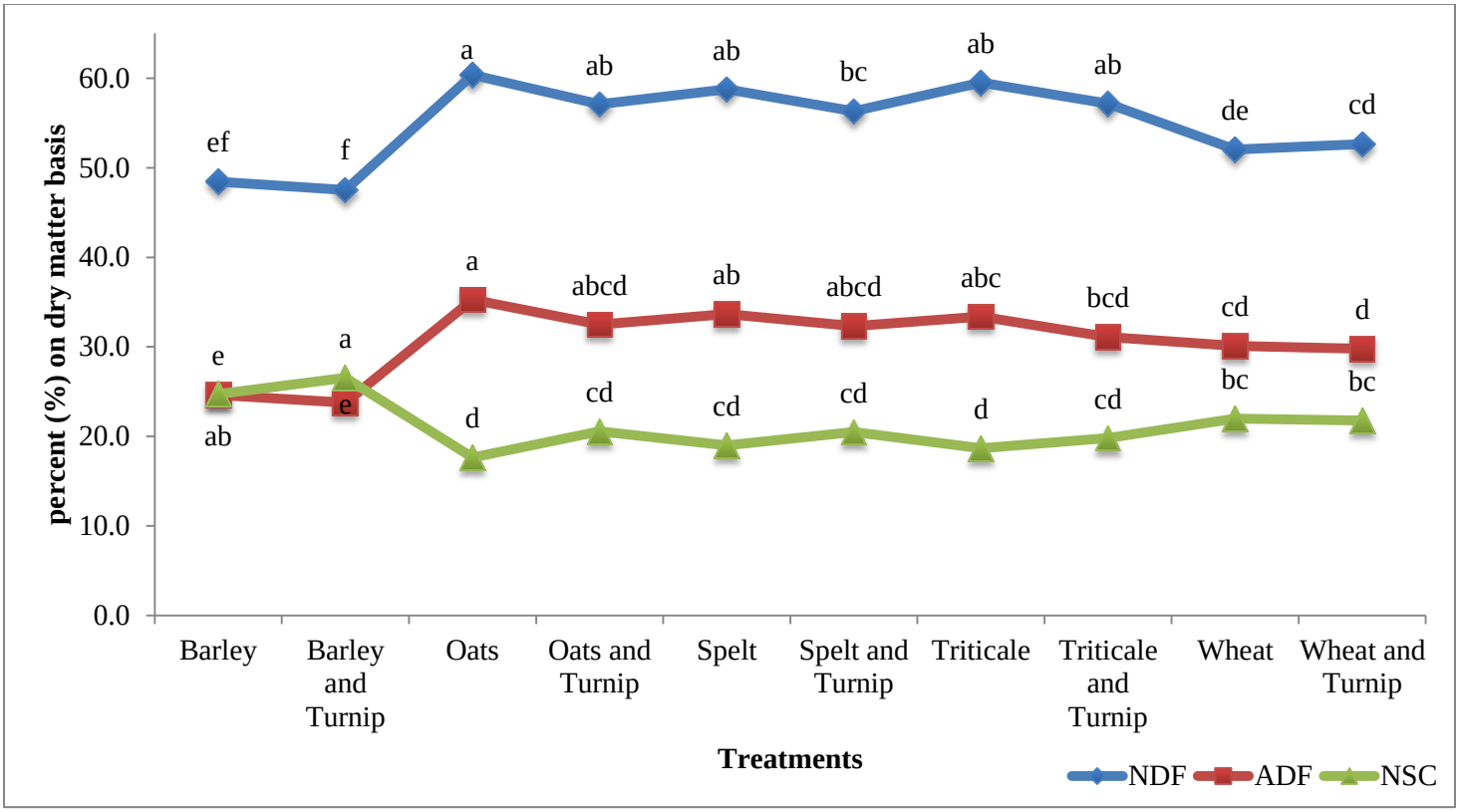

Figure 6. Neutral detergent fiber (NDF), acid detergent fiber (ADF), and non-structural carbohydrate (NSC) concentrations of small grain forage harvested in the soft dough stage. **Treatments with the same letter did not differ significantly.*

During the soft dough harvest, levels of the Omega 3 FA, LNA, decreased significantly from earlier harvests (Table 13; Figure 7). However, the triticale and spelt treatments had higher amounts of LNA than the other species (Table 13; Figure 7). Barley and turnip had the next highest amount of total FA with 21.7 mg g^{-1}.

Table 13. Soft dough stage fatty acid profile (% in grey) and concentration (mg g^{-1} in white).

	Barley	Barley and Turnip	Oats	Oats and Turnip	Spelt	Spelt and Turnip	Trit	Triticale and Turnip	Wheat	Wheat and Turnip	Species Mean	LSD
SFA (%)	26.1	26.6	25.5	24.1	**29.3***	27.8*	27.9*	27.2*	25.7	25.3	26.6	3.32
SFA (mg g-1)	5.10	5.70*	**6.80***	6.50*	3.90	5.40	4.10	4.60	3.70	3.90	5.00	1.36
C16 (%)	20.6	21.3*	19.3	19.1	**22.2***	21.7*	21.2*	20.6	20.4	20.5	20.7	1.24
C16 (mg g-1)	4.10	4.60*	**5.20***	5.10*	3.00	4.2*	3.10	3.50	3.00	3.20	3.90	1.1476
MUFA (%)	17.4	15.2	**30.1***	28.0*	16.4	17.9	14.1	17.0	15.9	16.2	18.8	5.03
MUFA (mg g)	3.40	3.30	**8.50***	8.10*	2.20	3.5	2.30	3.60	2.40	2.60	4.00	2.48
PUFA (%)	56.5*	58.1*	44.4	47.8	54.2	54.2	58.0*	55.9*	58.3*	**58.5***	54.6	3.99
PUFA (mg g)	11.3*	12.7*	12.5*	**13.0***	7.40	10.6*	8.90	9.60	8.70	9.20	10.4	3.19
C18:2 LA	49.2*	**51.1***	38.5	42.3	44.4	44.4	47.6	45.7	49.1*	50.0*	46.2	3.45
C18:2 LA	9.90*	11.1*	11.0*	**11.6***	6.10	8.8*	7.40	8.00	7.30	7.90	8.90	3.10
C18:3 LNA (%)	7.30	6.90	5.80	5.50	9.70*	9.7*	**10.2***	10.0*	9.10*	8.40*	8.30	2.36
C18:3 LNA (mg g)	1.40	1.50	1.50	1.40	1.30	1.8	1.50	1.60	1.30	1.30	1.50	NS
Omega 3 FA (%)	7.30	6.90	5.80	5.50	9.80*	9.7*	**10.2***	10.1*	9.10*	8.40*	8.30	2.38
Omega 3 FA (mg g)	1.40	1.50	1.50	1.40	1.30	**1.8***	1.50	1.60*	1.30	1.30	1.50	NS
Omega 6 FA (%)	49.2*	**51.2***	38.6	42.3	44.5	44.5	47.8*	45.8	49.2*	50.1*	46.3	3.46
Omega 6 FA (mg g)	9.90*	11.2*	11.0*	**11.6***	6.10	8.8*	7.40	8.00	7.30	7.90	8.90	3.10
Total FA (mg g)	19.9	21.7*	**27.8***	27.7*	13.5	19.5	15.3	17.8	14.8	15.7	19.4	6.74
Ratio Omega 6:Omega 3 FA	6.85	7.43	7.09	8.11	4.62	4.75	4.94	5.09	5.51	5.95	6.03	

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 (in bold).

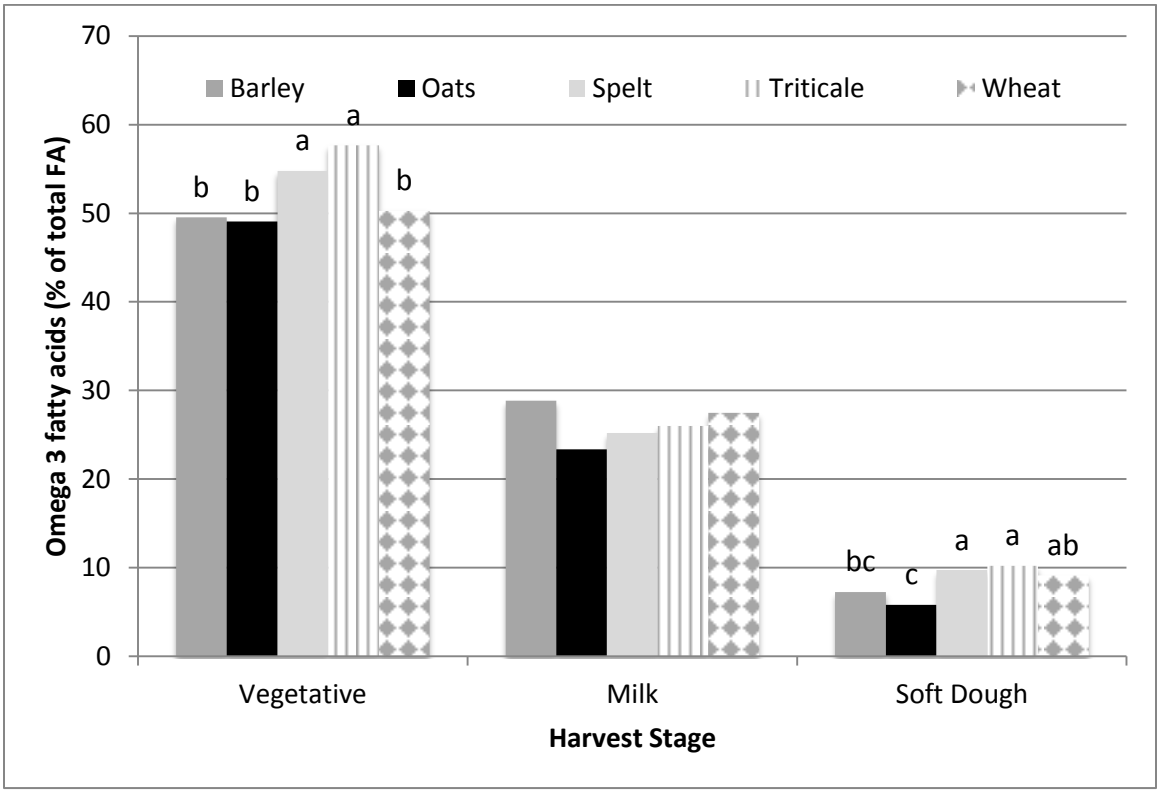

Figure 7. Omega 3 fatty acid profile of small grain forages at three harvest stages.

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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