IMPACT OF TOPDRESSING ORGANIC NITROGEN ON WHEAT PROTEIN

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The demand for local organic food is steadily increasing throughout Vermont and New England. Consumers are asking for bread baked with locally grown wheat; however bakers have been slow to incorporate local wheat flour because of the challenges associated with obtaining grains that consistently meet bread-baking standards. Addressing the quality issue is essential for expanding the bread flour market in the northeast.

One of the major quality factors facing Vermont grain producers is protein content. Much of the wheat currently produced in Vermont has protein levels below what most commercial mills would consider suitable for flour production.

In March 2010 the University of Vermont Extension was awarded a SARE Partnership grant to establish a trial at Gleason Grains in Bridport, VT. The purpose of this project was to determine whether topdressing organic nitrogen (N) amendments, during key times of wheat development, would increase grain protein and yields. The amount of protein in wheat depends largely on soil nitrogen availability during plant growth. Higher protein levels generally result in improved baking characteristics. Assuring adequate available N for grain yield and protein are the primary challenges of organic winter wheat production.

WEATHER DATA

Seasonal precipitation and temperature recorded at weather stations in close proximity to the 2010 sites are shown in Table 1. This growing season's weather was ideal for growing wheat. Due to the warn spring the wheat got off to an early start and continued to be at least a week early in reaching major developmental stages. From planting to harvest there was 5282.1 Growing Degree Days (GDDs) accumulated, 535.7 GDDs higher than the 30 year average.

Table1. Temperature and precipitation summary, 2010.

Bridport, VT	**Sept. 09**	**Oct.09**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**
Average Temperature (F)	59.4	45.3	38.1	50.5	60.3	66.2	73.2
Departure from Normal	-1.4	-3.2	6.7	6.9	4.0	0.3	3.8
Precipitation (inches)	2.4	3.6	4.12	4.37	2.42	5.35	2.58
Departure from Normal	-1.7	0.2	1.73	1.48	-1.20	1.62	-1.57
GDDs (base 32)	822.5	443.5	279.0	557	8768	1026	1279
Departure from Normal	-23.5	-68.0	144	186	96	26	96

*Based on National Weather Service data from cooperative observer stations in close proximity to field trials. Historical averages are for 30 years of data (1971-2000)

CULTURAL PRACTICES

The seedbed at the Bridport location was prepared by conventional tillage methods. All plots were managed with practices similar to those used by producers in the surrounding areas (Table 2). The plots were seeded with winter wheat (var 'Redeemer') on September 13, 2009. Prior crop in 2009 was soybeans and in 2008 a sweet clover cover crop.

Table 2. General plot management of the wheat trial.

Trial Information	Winter wheat variety trial
Location	Bridport, VT Gleason Grains
Soil type	Vergennes Clay
Previous crop	Soybeans
Row spacing (in.)	6
Seeding rate lbs	140
Replicates	4
Planting date	9-13-09
Harvest date	8-2-10
Harvest area (ft.)	5 x 20
Tillage operations	Fall chisel plow, & spike- toothed harrow

In early April of 2010 the experiment was imposed within the winter wheat field on the Gleason Farm. The experimental design was a randomized complete block in a split plot design. Treatments were replicated four times. The main plots were amended with one of 3 organic N amendments. The amendments used were; 'Cheep Cheep' (4% N), Pro-Booster (10% N), and Natural Nitrate of Soda (16% N). The product 'Cheep Cheep' is an OMRI approved and widely available dehydrated poultry litter product. It has a guaranteed analysis of 4-3-3. The OMRI approved 'ProBooster' 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 is limited to supplying no more than 20% of the crops total N requirements. In the case of wheat it was assumed that an average yield of 4000 lbs would uptake approximately 100 lbs of N per acre. Therefore the allowed application rate of N from 'Chilean Nitrate' would be 20 lbs per acre. The goal was to supply the wheat with 20 lbs of N from each fertilizer source. The organic fertility sources ('Cheep Cheep' and

Image 1. Assessing wheat development after N application at the tillering stage (F5).

‘ProBooster’) contain mostly organic-N and therefore the amount of N available to the plants would be only a percentage of the total applied. Based on past data collection and information from the companies it was assumed that 50% of the total N from the ‘Cheep Cheep’ would be available and 30% from the ‘ProBooster’. The topdress amendments were broadcast applied by hand at the required time. Hence the ‘Chilean Nitrate’ was applied at a rate of 125 lbs per acre, the ‘Cheep Cheep’ at 1000 lbs per acre, and the ‘ProBooster’ at 600 lbs per acre. An unfertilized treatment served as a control.

The split plots were the timing of the N fertilizer application. The plots were fertilized by hand at the tillering stage (Feekes Growth Stage 5, F5), the flag leaf stage (Feekes Growth Stage 8, F8), or a split application with ½ the rate at both growth stages. On April 5 2010, the tillering (F5) amendments were applied and the flag leaf (F8) application was on May 20, 2010.

Plots were sampled for soil nitrates prior to organic N application and at key developmental stages until the wheat reached physiological maturity. From each plot a composite of 10 soil cores (1 inch dia., 12 inch depth) was taken, placed on ice, and transported to the testing laboratory on the day of sampling. Soil nitrates were measured using flow injection analysis. In addition, plant samples were taken to determine total nitrogen concentration by combustion analysis at the same time as soil sampling. The tissue samples consisted of 2 rows of wheat top growth, 12 inches in length, and replicated twice per plot. Samples were put into clean paper bags, placed on ice, and transported directly to the laboratory fo[illegible]sity of Vermont’s Agricultural and Environmental testing laboratory. Plant samples were sent to Cumberland Valley Analytical Services in Hagerstown, MD for analysis.

Image 2. Plant biomass and soil nitrate sampling.

Image 3. Harvesting plots

Due to an inundation of sweet clover, the plots had to be mowed on July 30, 2010 and dried down before harvesting with an Almaco SP50 plot combine on August 2, 2010. Following harvest, seed was cleaned with a small Clipper cleaner. Once cleaned the sample was weighed to determine yield. An approximate one pound subsample was collected to determine quality. Quality measurements included standard testing parameters used by commercial mills. Test weight was measured by the weighing of a known volume of grain. Generally the heavier the wheat is per bushel, the higher baking quality. The acceptable test weight for bread wheat is 56-60 lbs per bushel. Once test weight was determined, the samples were then ground into flour using the Perten LM3100 Laboratory Mill. At this time flour was evaluated for its protein content, falling number, and mycotoxin levels. Grains were analyzed for protein content using the Perten Inframatic 8600 Flour Analyzer. Grain protein affects gluten strength and loaf volume. Most commercial mills target 14-15% protein. The determination of falling number (AACC Method 56-81B, AACC Intl., 2000) was measured on the Perten FN 1500 Falling Number Machine. The falling number is related to the level of sprout damage that has occurred in the grain. It is measured by the time it takes, in seconds, for a stirrer to fall through a slurry of flour and water to the bottom of the tube. Falling numbers greater than 350 indicate low enzymatic activity and sound quality wheat. A falling number lower than 200 indicates high enzymatic activity and poor quality wheat. Deoxynivalenol (DON) analysis was analyzed using Veratox DON 5/5 Quantitative test from the NEOGEN Corp. This test has a detection range of 0.5 to 5 ppm. Samples with DON values greater than 1 ppm are considered unsuitable for human consumption.

Mixed-model analysis was calculated using PROC MIXED procedure of SAS. Mean separation among treatments involving fertilizer source and timing of application were obtained using the LSMEANS procedure when the F-test was significant ($P< 0.10$).

RESULTS

Soil & Plant Nitrogen

There were no significant differences in soil nitrate-N levels at tillering, flowering, or physiological maturity. However, significant variation found between replicates may have reduced the ability to identify differences amongst the treatments. The probooster amendment raised plant nitrate-N levels higher than other organic soil amendments (Table 3). With the exception of probooster, applying organic fertility sources at the tillering stage did not increase plant nitrate-N compared to the control. Application of probooster at tillering and flagleaf stages increased plant nitrate-N compared to the control and other amendments.

Table 3. Soil and plant nitrate-N analysis.

Feritility type	Aplication time	Soil nitrate-N sample date			Plant nitrogen sample date		
		Tillering	Flowering	Physiological maturity	Tillering	Flowering	Physiological maturity
		11-May	27-May	6-Jul	11-May	27-May	6-Jul
		------------------ppm------------------			---------------------%---------------------		
Cheep Cheep	Tillering (F5)	2.76	1.67	2.51	10.7	7.73	6.15
Cheep Cheep	Flag Leaf (F8)		2.24	2.62		7.95	6.88
Cheep Cheep	Both (F5 & F8)	1.96	2.09	2.90	9.48	8.40	6.25
Chilean Nitrate	Tillering (F5)	2.21	1.45	3.11	10.5	8.33	6.63
Chilean Nitrate	Flag Leaf (F8)		13.73	**3.29**		10.0	7.20
Chilean Nitrate	Both (F5 & F8)	1.86	2.69	2.41	10.4	9.03	7.53
Pro Booster	Tillering (F5)	**2.25**	1.57	2.37	**14.3***	10.6	6.60
Pro Booster	Flag Leaf (F8)		**20.04**	2.84		**13.4***	**9.18***
Pro Booster	Both (F5 & F8)	2.08	16.97	2.73	11.5	10.1	7.30
Control	None	2.03	1.76	2.71	9.65	7.90	6.58
LSD (0.10)		NS	NS	NS	1.04	1.38	1.24
Trial means		2.16	6.42	2.75	10.9	9.34	7.03

<u>Wheat Yield and Quality</u>:

Differences among fertilizer types were observed for yield and crude protein (CP) in this experiment (Table 4 and Figure 1). The 'Chilean Nitrate' product resulted in significantly higher yields than the control. The 'Cheep Cheep' and 'ProBooster' had the did not differ significantly in yield as compared to the control plots. The 'ProBooster' amendment resulted in a CP concentration of 13.4% which was signicicantly greater than any of the other treatments. Grain moisture, falling number and DON levels were not significantly different between organic fertility treatments. (Table 4).

Table 4. Yield and quality results of the different organic amendments

Fertility Type	Moisture	Yield	Grain Quality		
			Crude Protein	Falling Number	DON
	%	lbs ac^{-1}	%	seconds	ppm
Cheep Cheep	**9.39**	1296ab	11.7b	304	0.23
Pro-Booster	8.97	1276ab	**13.4a**	309	0.28
Chilean Nitrate	9.35	**1534a**	11.7b	**338**	0.30
Control (None)	8.99	981b	11.3b	315	**0.38**
Probability level	NS	*	***	NS	NS
Trial means	9.18	1277	12.0	316	0.30

Within a column, means followed by the same letter are not significantly different (P < 0.1).
*, **, *** coefficients significant at the 0.1, 0.05, and 0.001 probability levels, respectively
NS, no significant (P < 0.10) coefficients.

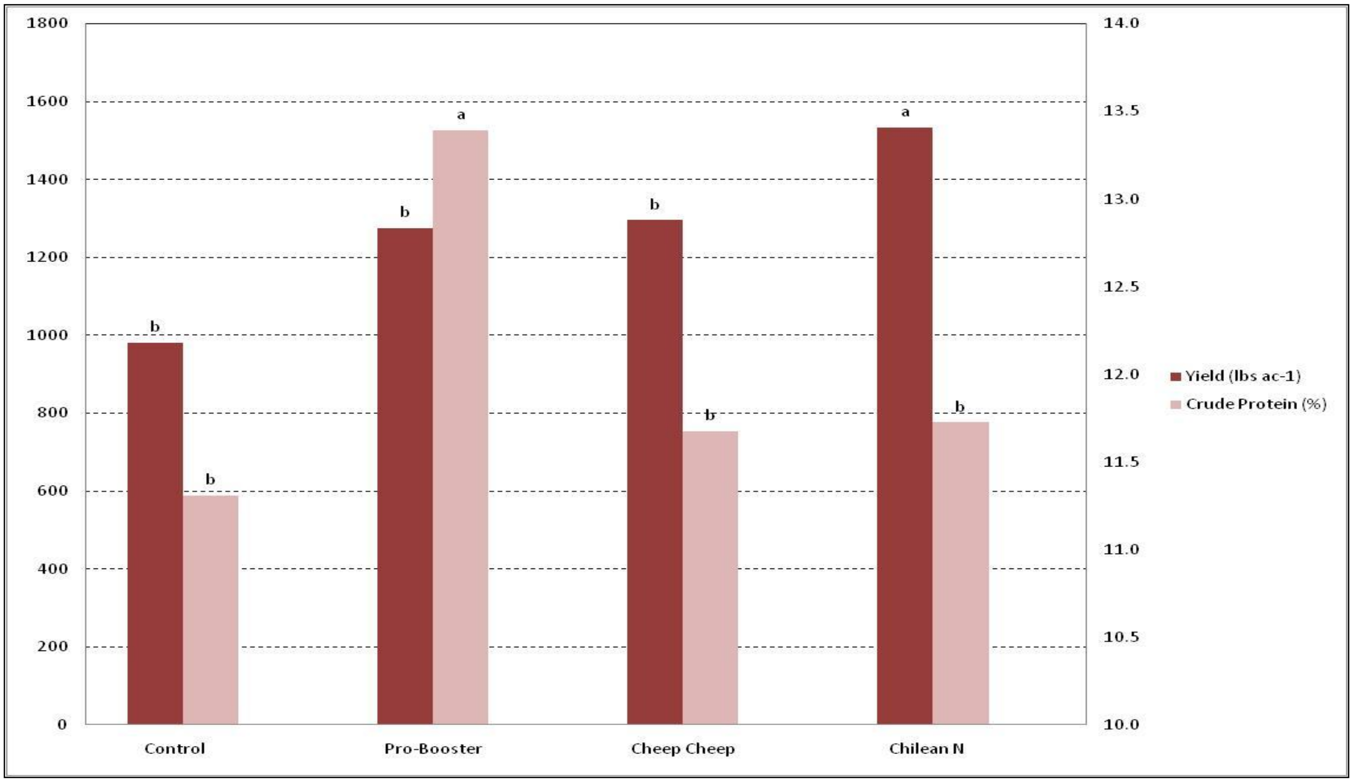
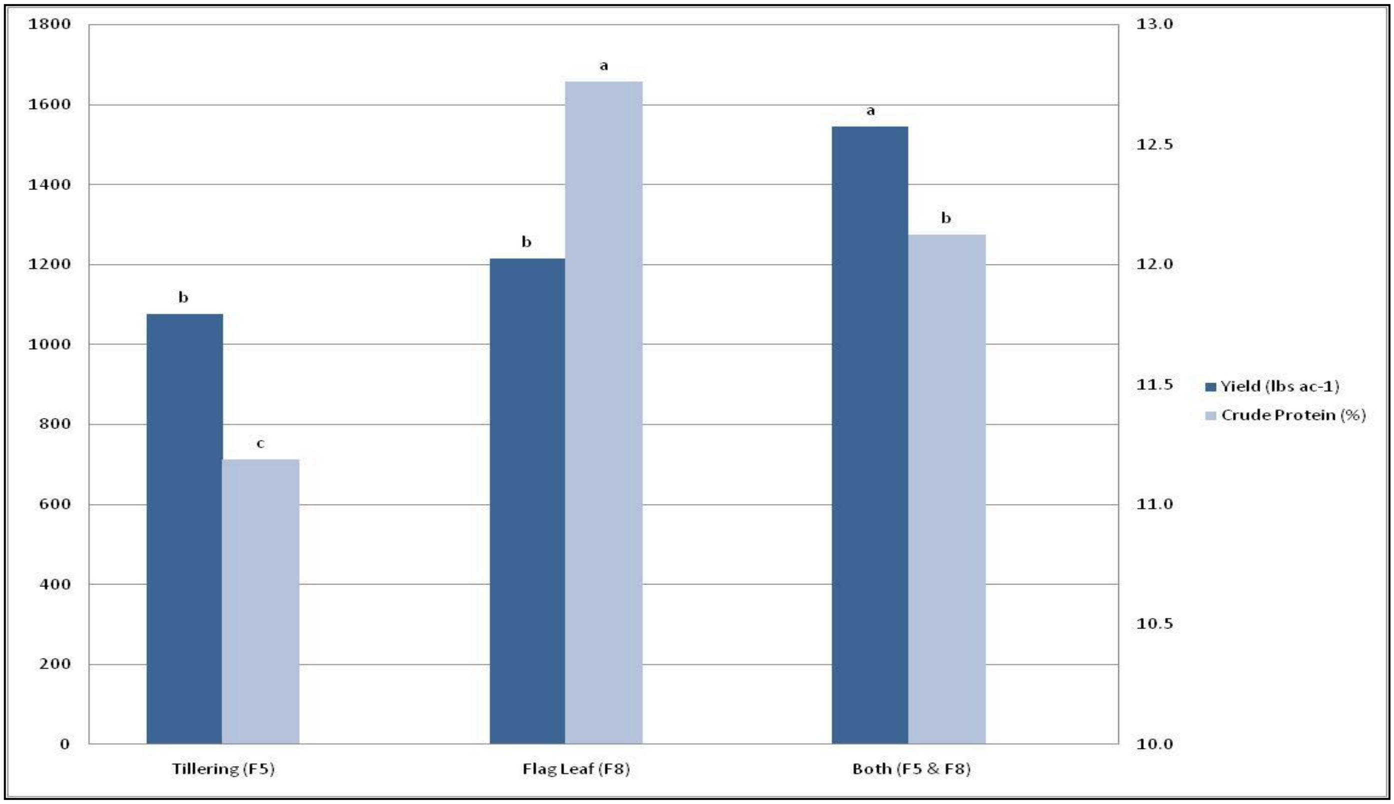


Figure 1. The impact of organic fertility treatments on winter wheat yield and crude protein concentrations.
*Varieties with the same letter did not differ significantly in yield.

The timing of the organic N fertilizer application had a significant impact on yield and crude protein concentrations of winter wheat (Table 4 and Figure 2). A split application of organic N fertilizer at the tillering and flag leaf stage resulted in the highest yields of 1545 lbs ac^{-1}. The highest crude protein concentration was observed when organic N sources were applied at the flag leaf stage. Application of organic N sources at the tillering stage resulted in the lowest crude protein concentration. Grain moisture, falling number and DON levels were not significantly different between the timing applications of the organic amendments (Table 5).

Table 5. Yield and quailty results of each of the application time.

Time of Application			Quality		
	Moisture %	Yield lbs ac^{-1}	Crude Protein %	Falling Number seconds	DON ppm
Tillering (F5)	8.96	1076b	11.2c	**333**	0.30
Flag Leaf (F8)	8.81	1215b	**12.8a**	302	**0.32**
Both (F5 & F8)	**9.75**	**1545a**	12.1b	315	0.28
Probability level	NS	***	***	NS	NS
Trial means	9.18	1277	12.0	316	0.30



Within a column, means followed by the same letter are not significantly different (P < 0.1).
*, **, *** coefficients significant at the 0.1, 0.05, and 0.001 probability levels, respectively
NS, no significant (P < 0.10) coefficients.

Figure 2. Impact of organic N fertility application time on winter wheat yield and crude protein.
*Varieties with the same letter did not differ significantly in yield.

There were significant fertility source x application time interactions observed in the experiment. A fertility source x application time interaction was observed for yield (Figure 3). This suggests that the organic N fertility sources will vary across the range of application times. For example, 'Cheep Cheep' and ProBooster applied at tillering had a significant increase in yields over the 'Chilean Nitrate' or the Control. This presumably has to do with the slow release nature of this amendment potentially supplying N to the plant over a longer period of time. This would be compared to the 'Chilean Nitrate' being more rapidly available. Interestingly when 'Chilean Nitrate' was applied at the flag leaf stage it resulted in significantly higher yields than the other fertility treatments. Interestingly, the 'Cheep Cheep' and 'ProBooster' performed similarly to the Control. Again the slow release nature of the N from these products may have limited the amount of plant available N during this period of rapid uptake. When the applications were split there were no significant differences between treatments.

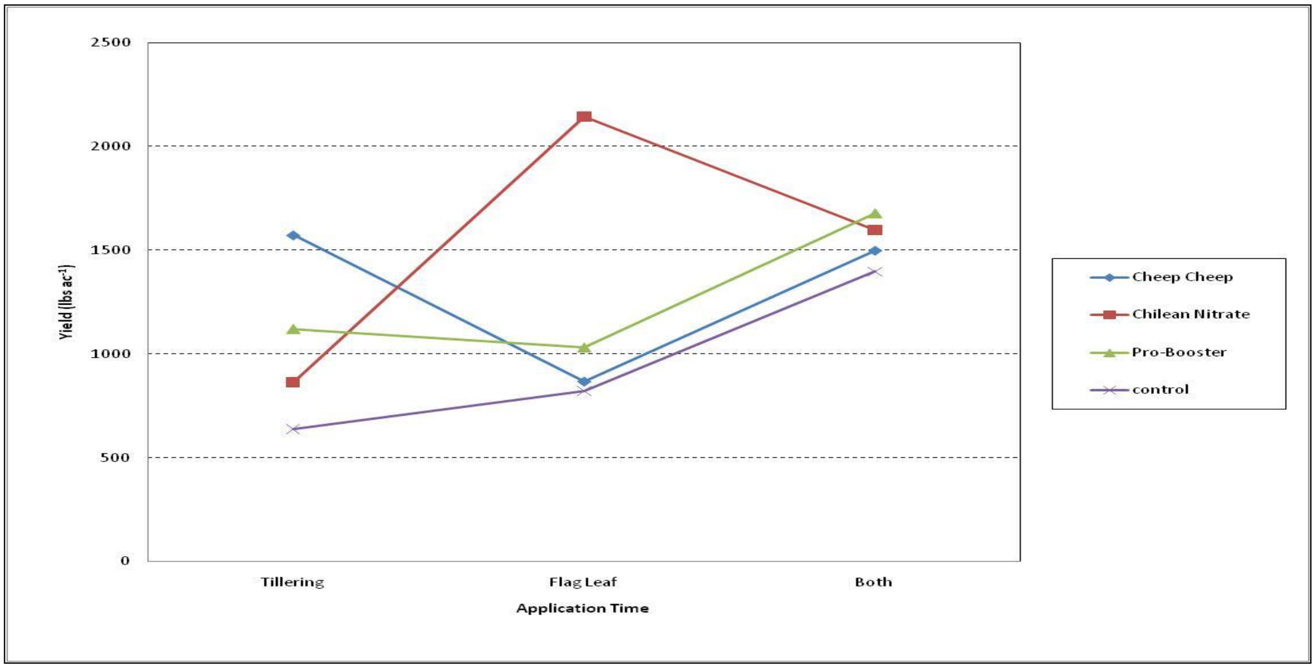


Figure 3. The interaction of application timing and amendment on yield

A fertility source x application time interaction was observed for crude protein concentration (Figure 4). This suggests that the organic N fertility sources will vary across the range of application times. Application of N sources at tillering did not result in protein increases as compared to the control. However, applications of N fertility sources at the flag leaf stages did result in a significant increase in crude protein as compared to the control. The 'ProBooster' application resulted in the highest crude protein concentrations. Increases in crude protein concentrations were only significantly higher than the control in the 'ProBooster' treatments. Overall, the application of organic N sources at the flag leaf stage resulted in the best chance to improve wheat protein levels.

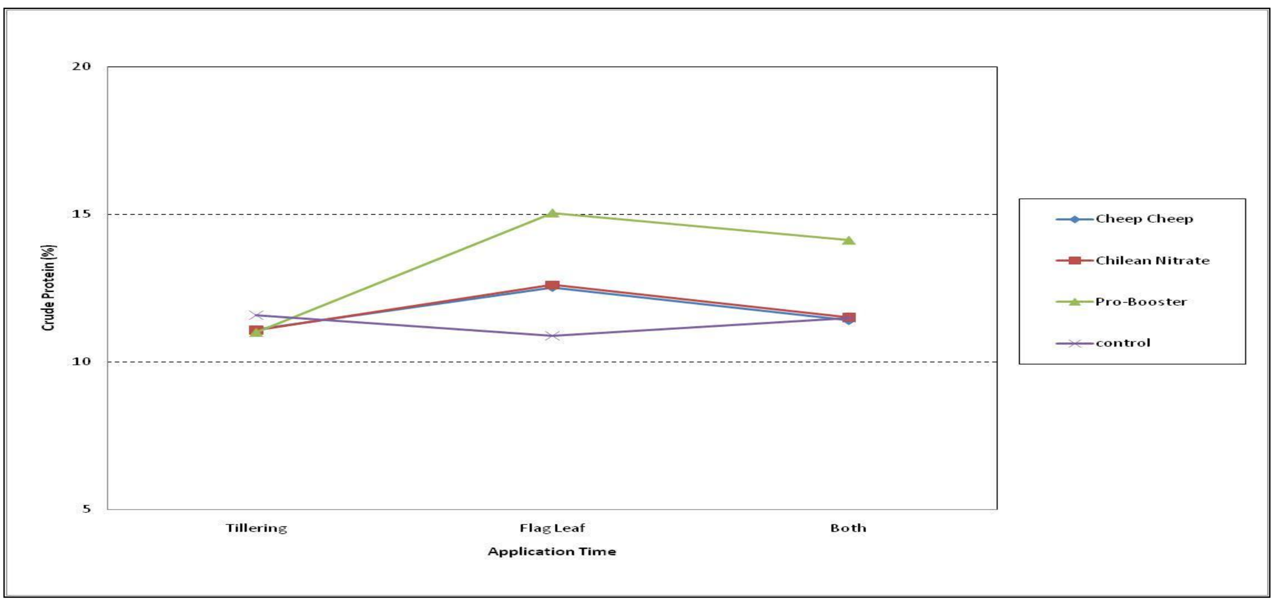


Figure 4.The interaction of application timing and amendment on crude protein

DISCUSSION

The first year of data suggests that organic N sources applied at flag leaf and as split applications at tillering and flag leaf stages had significantly higher protein levels than N just applied at tillering or the control plots. Interestingly, Pro-Booster applied at the flag leaf stage resulted in protein levels that were three percentage points higher than the other fertility treatments applied at this stage. Wheat that received topdress amendments always resulted in higher protein levels than the unamended controls. Across all treatments Pro-Booster had the highest protein level of 13.4%. These preliminary results indicate that Pro-Booster may be a viable organic fertilizer source for increasing winter wheat protein. However, one year of data is not adequate to confidently recommend that farmers begin changing fertility practices. We are resubmitting this grant with the intent to collect a second year of data to verify our results.

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