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The Effects of Topdressing Organic Nitrogen on Hard Red Winter Wheat

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The UNIVERSITY of VERMONT EXTENSION

2011 VERMONT ORGANIC NITROGEN TOPDRESSING OF WINTER WHEAT

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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 winter wheat currently produced in Vermont has protein levels below what most commercial mills would consider suitable for flour production. Commercial mills prefer to buy wheat with CP concentrations of 12-15%. Higher protein levels generally improve baking characteristics. In 2011, the University of Vermont Extension in collaboration with Gleason Grains (Bridport, VT) and Borderview Farm (Alburgh, VT) established trials to evaluate if winter wheat yield and protein could be improved by topdressing with various organic nitrogen (N) sources at key developmental stages. 2011 was the second trial year at both locations.

MATERIALS AND METHODS

Borderview Farm – Alburgh, VT:

The seedbed at the Alburgh location was prepared by conventional tillage methods. All plots were managed with practices similar to those used by producers in the surrounding areas (Table 1). The plots were seeded with a John Deere 750, 6 inch spacing double disc opener 13 foot grain drill. The plots were seeded with hard red winter wheat (var 'Harvard') on September 15, 2010. The prior crop in 2010 was spring wheat.

Table 1. General plot management of the winter wheat topdressing trials, Alburgh, VT.

Trial Information	Winter wheat variety trial
Location	Alburgh, VT Borderview Farm
Soil type	Benson rocky silt loam
Previous crop	Spring wheat
Row spacing (in.)	6
Seeding rate (lbs ac^{-1})	130
Replicates	4
Planting date	Sep. 15, 2010
Harvest date	Jul. 19, 2011
Harvest area (ft.)	5x25
Tillage operations	Fall plow, disc, & spike-toothed harrow

The experimental design was a randomized complete block design with seven treatments replicated 4 times. The treatments included an unamended control as well as a fall manure amended treatment. These treatments represented standard winter wheat production practices of local farms. The composted cow manure was applied on September 3, 2010, two weeks prior to planting. The compost was applied at a rate to provide 70 lbs of plant available N for the wheat crop. The other treatments included organic N topdress treatments of 'Cheep Cheep' or 'Chilean Nitrate' applied at tillering, flag leaf stage, or the boot stage. On April 22, 2011, the tillering amendments were applied, the flag leaf application was on May 11, 2011, and the boot amendments were applied on May 31, 2011.

The product 'Cheep Cheep' is an OMRI approved and widely available dehydrated poultry litter product that has a guaranteed analysis of 4-3-3. The OMRI approved Natural Nitrate of Soda is more commonly known as 'Chilean Nitrate' 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 topdress fertilizer source. 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. 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 and the 'Cheep Cheep' at 1000 lbs per acre.

Image 1. Plant and soil sampling, Alburgh, VT

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. 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 for analysis. All soil was analyzed at University of Vermont's Agricultural and Environmental testing laboratory in Burlington, VT. Plant samples were sent to Cumberland Valley Analytical Services in Hagerstown, MD for analysis.

Plots were harvested with an Almaco SP5C0 plot combine on July 19th, 2011; the harvest area was 5' x 25'. 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.

<u>Gleason Grains – Bridport, VT</u>:

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 18, 2010. Prior crop in 2010 was clover. In addition to clover, the trial area had chickens pasturing on it throughout the 2010-growing season.

Table 2. General plot management of the winter wheat topdressing trial, Bridport, VT.

Trial Information	Winter wheat topdress trial
Location	Bridport, VT Gleason Grains
Soil type	Farmington loam
Previous crop	Clover
Row spacing (in.)	6
Seeding rate (lbs ac^{-1})	140
Variety	Redeemer
Replicates	4
Planting date	Sept.18, 2010
Harvest date	July 20, 2011
Harvest area (ft.)	5 x 20
Tillage operations	Fall chisel plow, & spike-toothed harrow

In early April of 2011 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 '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 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 'Pro Booster') 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 'Pro Booster'. 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 19, 2011, the tillering (F5) amendments were applied and the flag leaf (F8) application was on May 19, 2011.

Image 2. Tillering application of organic N amendments, Bridport, VT.

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. 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 for analysis. All soil was analyzed at University of Vermont's Agricultural and Environmental testing laboratory in Burlington, VT. Plant samples were sent to Cumberland Valley Analytical Services in Hagerstown, MD for analysis.

Plots were harvested with an Almaco SPC50 plot combine on July 20th, 2011; the harvest area was 5' x 20'. 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.

Wheat Quality Assessment:

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 12-15% 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 ($P < 0.10$).

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 (e.g. yield). Least Significant Differences (LSD's) at the 10% level of probability are shown. Where the difference between two varieties 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. Wheat varieties that were not significantly lower in performance than the highest variety in a particular column are indicated with an asterisk. In the example below variety A is significantly different from variety C but not from variety B. The difference between A and B is equal to 725 which is less than the LSD value of 889. This means that these varieties did not differ in yield. The difference between A and C is equal to 1454 which is greater than the LSD value of 889. This means that the yields of these varieties were significantly different from one another. The asterisk indicates that variety B was not significantly lower than the top yielding variety.

Variety	Yield
A	3161
B	3886*
C	**4615***
LSD	**889**

RESULTS

Seasonal precipitation and temperature recorded at weather stations in close proximity to the 2011 sites are shown in Table 2. This growing season brought extreme weather conditions. Between April and May 16 inches of rain fell, 10 inches above normal rainfall amounts in both trial site locations. The increased moisture delayed wheat growth, especially in clay or compacted areas where water pooled and stayed wet for extended amounts of time. In addition, the heavy rainfall increased nutrient leaching. From one extreme to the other; in June and July, there were several weeks with very little rain and higher than normal temperatures causing drought like conditions and putting further stress on the wheat. Just prior to harvest a violent thunderstorm with high winds caused severe lodging of several plots in the first rep at the Bridport location. From planting to harvest in Alburgh there was an accumulation of 5506 Growing Degree Days (GDD), 685 GDDs higher than the 30 year average and in Bridport there was an accumulation of 5016 Growing Degree Days (GDD), 217 GDDs higher than the 30 year average.

Table 3. Temperature and precipitation summary for Alburgh, VT, 2011.

Alburgh	Sept. 2010	Oct. 2010	Nov. 2010	April	May	June	July
Average Temperature (F)	64.0	50.6	39.9	46.6	58.7	67.1	74.4
Departure from Normal	3.60	1.80	2.20	3.10	2.10	1.30	3.30
Precipitation (inches)	4.32	6.73	2.93	7.88	8.67	3.52	3.68
Departure from Normal	0.86	3.75	0.00	5.00	5.35	0.09	-0.29
Growing Degree Days (base 32)	990	578	243	465	826	1088	1314
Departure from Normal	138	57.4	63.4	120	63.6	74.1	104

Table 4. Temperature and precipitation summary for Bridport, VT, 2011.

Bridport	Sept. 2010	Oct. 2010	Nov. 2010	April	May	June	July
Average Temperature (F)	61.9	47.9	36.7	43.7	57.8	65.0	72.3
Departure from Normal	1.70	-0.60	0.30	-0.70	0.60	-0.40	2.10
Precipitation (inches)	3.52	9.79	*	7.88	8.67	3.52	3.68
Departure from Normal	-0.56	6.41	*	5.00	5.35	0.09	-0.29
Growing Degree Days (base 32)	897	493	189	363	800	1023	1251
Departure from Normal	93.0	18.6	189	17.7	37.2	9.00	40.3

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)
*missing data

Borderview Farm, Alburgh, VT:

Soil & Plant Nitrogen

Soil and plant biomass nitrogen analysis have yet to be completed. The samples are currently at the lab and data will be completed by the termination of this project.

Wheat Yield and Quality

The treatments did not differ significantly in winter wheat yield (Table 5; Figure 1). The average yield of the trial was 4,592 lbs ac^{-1}. The treatments differed in winter wheat CP concentration (Table 5; Figure 2). 'Chilean Nitrate' applied at tillering, flag leaf, and boot growth stages, had significantly higher protein levels than the fall applied manure and unamended control plots. In addition, 'Cheep Cheep' applied at the boot stage had significantly higher protein levels in comparison to the manure and control plots. The tillering and boot applied 'Chilean Nitrate' had the highest protein level at 10.9%; the lowest was the control with a protein content of 9.50%. Treatments did not differ significantly in falling number or DON.

Table 5. The results of fertility type and application timing on wheat harvest and quality.

Fertility Type	Time of Application	Yield lbs ac^{-1}	Moisture %	Test weight bu ac^{-1}	Quality Crude protein %	 Falling number seconds	 DON ppm
Cheep Cheep	Tillering (F5)	4713	12.7	61.3	10.1	384	0.35
Chilean Nitrate	Tillering (F5)	4983	13.4*	**62.9**	**10.9***	372	0.43
Cheep Cheep	Flag Leaf (F8)	4318	**13.9***	62.3	10.1	**387**	**0.30**
Chilean Nitrate	Flag Leaf (F8)	**5158**	13.3*	62.0	10.8*	371	0.45
Cheep Cheep	Boot (F10)	4614	13.5*	61.5	10.7*	386	0.40
Chilean Nitrate	Boot (F10)	4623	13.7*	62.4	**10.9***	374	0.40
Manure	Fall 2010	4233	13.0	62.3	9.7	369	0.40
None	Control	4098	13.5*	61.8	9.5	355	0.43
LSD (0.1)		NS	0.64	NS	0.71	NS	NS
Trial means		4592	13.4	62.0	10.3	375	0.39

*Wheat that did not perform significantly lower than the top performing treatment in a particular column is indicated with an asterisk.
NS - None of the treatments were significantly different from one another.

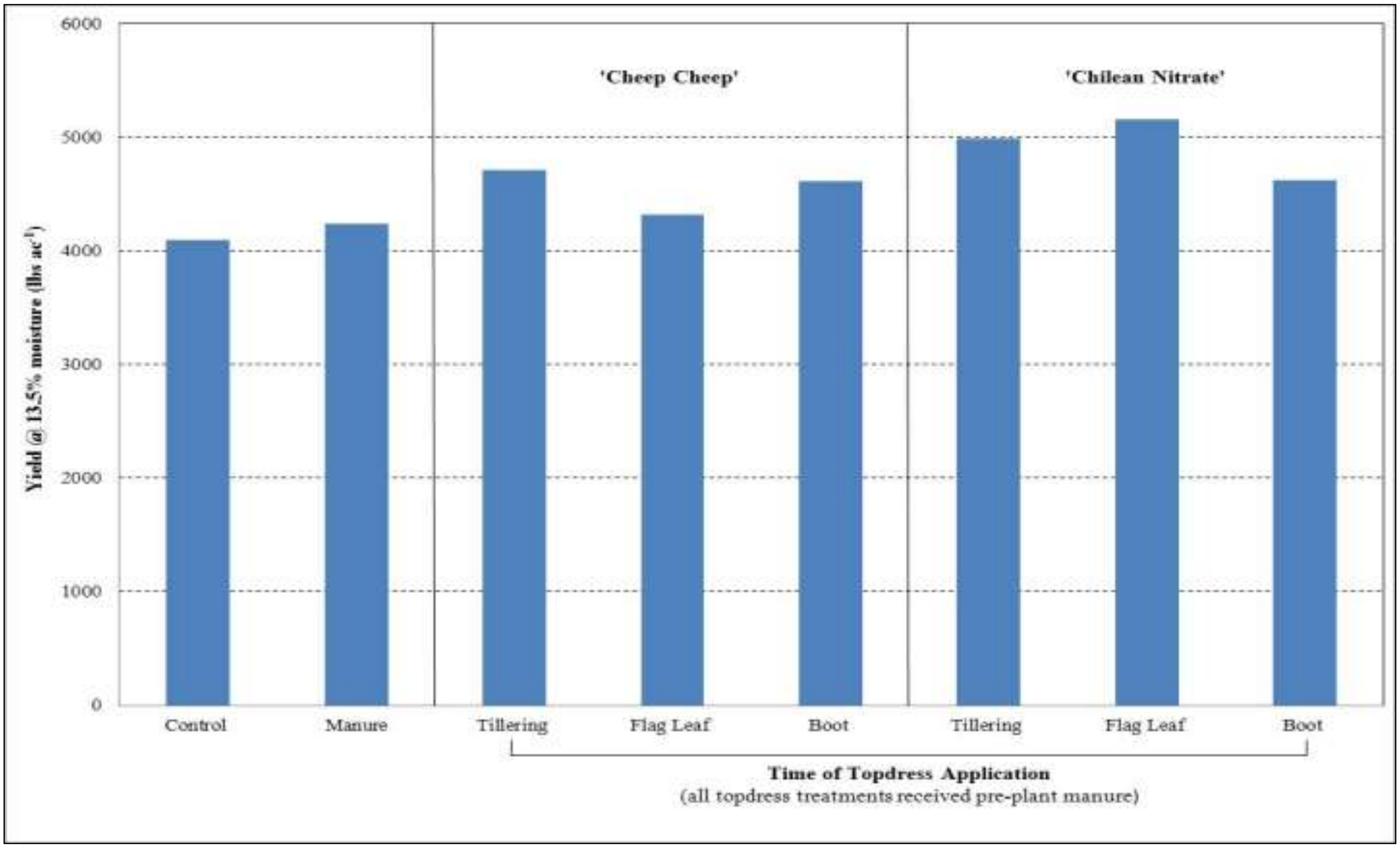

Figure 1. Yield impact of topdressing organic N sources at critical wheat developmental stages, Alburgh, VT.

The data suggests that organic N sources applied at boot stage had significantly higher protein levels than the manure and the control plots. Interestingly, 'Chilean Nitrate' applied at the boot stage resulted in protein levels that were one and a half percentage points higher than the Manure and Control plots. Although 'Cheep Cheep' applied in boot stage increased protein over the manure and control plots addition in the tillering or flag leaf stage did not. These results indicate that a soluble source of nitrogen may be a viable organic fertilizer source for increasing winter wheat protein across several stages.

Image 3. Wheat spike emergence, Alburgh, VT

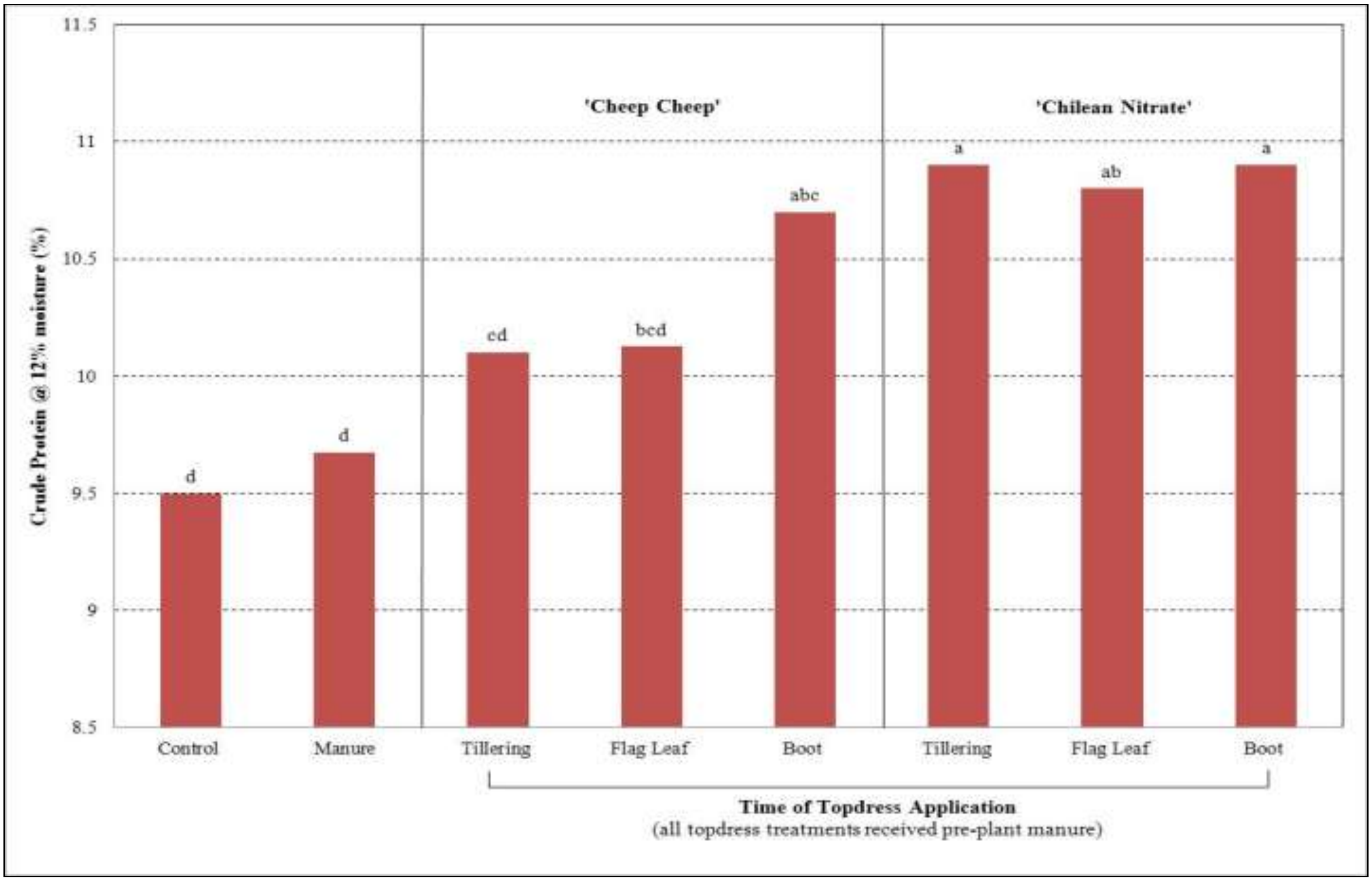

Figure 2.The impact of topdressing organic N sources at critical wheat developmental stages on crude protein concentrations, Albrugh, VT. *Treatments with the same letter did not differ significantly in yield

Gleason Grains, Bridport, VT:

Soil & Plant Nitrogen

Soil and plant biomass nitrogen analysis have yet to be completed. The samples are currently at the lab and data will be completed by the termination of this project.

Image 4. Wheat topdress trial harvest –Bridport, VT

Wheat Yield and Quality

The treatments did not differ significantly in winter wheat yield (Table 6; Figure 3). The trial yield average was 2,524 lbs ac^{-1} this was about half of the Alburgh yield. Low yields may have been the result of adverse weather conditions during the growing season. Treatments also did not differ significantly in test weight, falling number, or DON.

Table 6. Yield and quality results of the different organic amendments

Fertility Type	Time of Application	Yield lbs ac^{-1}	Moisture %	Test weight bu ac^{-1}	Quality: Crude protein %	Quality: Falling number seconds	Quality: DON ppm
Cheep Cheep	Tillering (F5)	2835	14.1	57.0	11.6	**460**	0.43
Chilean Nitrate	Tillering (F5)	2228	14.5	55.0	12.5*	402	0.50
Pro-Booster	Tillering (F5)	2452	15.0	55.9	11.9	398	0.33
Cheep Cheep	Flag Leaf (F8)	2562	15.0	55.0	12.0	432	0.45
Chilean Nitrate	Flag Leaf (F8)	2533	13.8	57.0	12.8*	443	**0.23**
Pro-Booster	Flag Leaf (F8)	2526	**15.3**	55.4	**12.9***	439	0.50
Cheep Cheep	Both (F5 & F8)	2417	14.8	55.9	12.0	459	0.33
Chilean Nitrate	Both (F5 & F8)	**2855**	15.1	55.6	12.7*	453	0.50
Pro-Booster	Both (F5 & F8)	2699	14.5	56.5	**12.9***	456	0.35
None	Control	2138	14.6	**57.3**	12.2*	436	0.26
LSD (0.1)		NS	NS	NS	0.86	NS	NS
Trial means		2524	14.7	56.1	12.3	438	0.39

*Wheat that did not perform significantly lower than the top performing treatment in a particular column is indicated with an asterisk.
NS - None of the treatments were significantly different from one another.

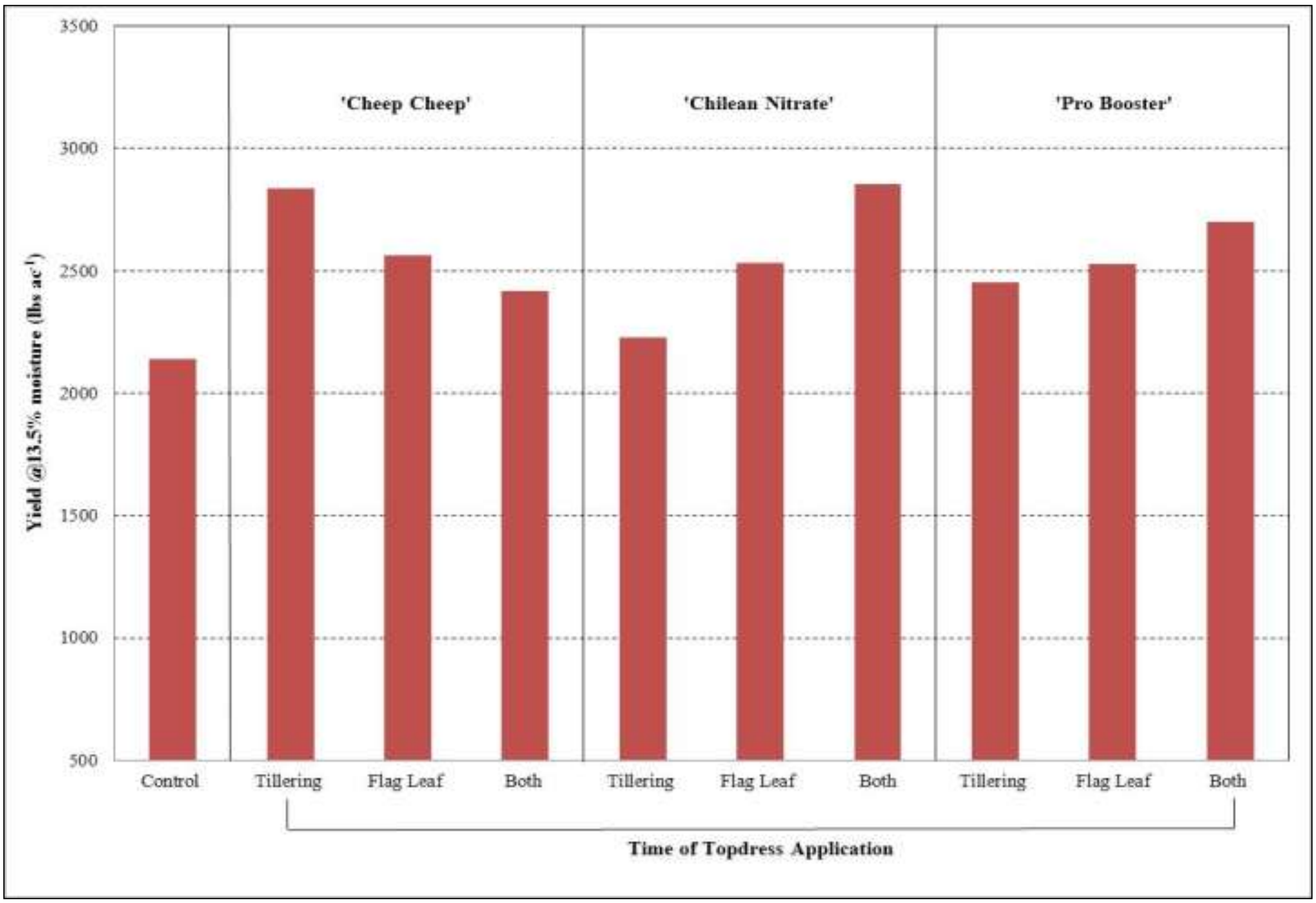

Figure 3. Yield impact of topdressing organic N sources at critical wheat developmental stages, Bridport, VT.

The treatments differed significantly in winter wheat crude protein concentration (Table 6; Figure 4). ‘Pro Booster’ applied at either the flag leaf or both (tillering and flag leaf) growth stages had the highest protein level at 12.9%. ‘Pro Booster’ applied at the flag leaf or both growth stages had significantly higher protein levels than all of the ‘Cheep Cheep’ application times. Overall, the application of ‘Pro Booster’ or ‘Chilean Nitrate’ at the flag leaf or both (tillering and flag leaf) growth stages resulted in improved CP.

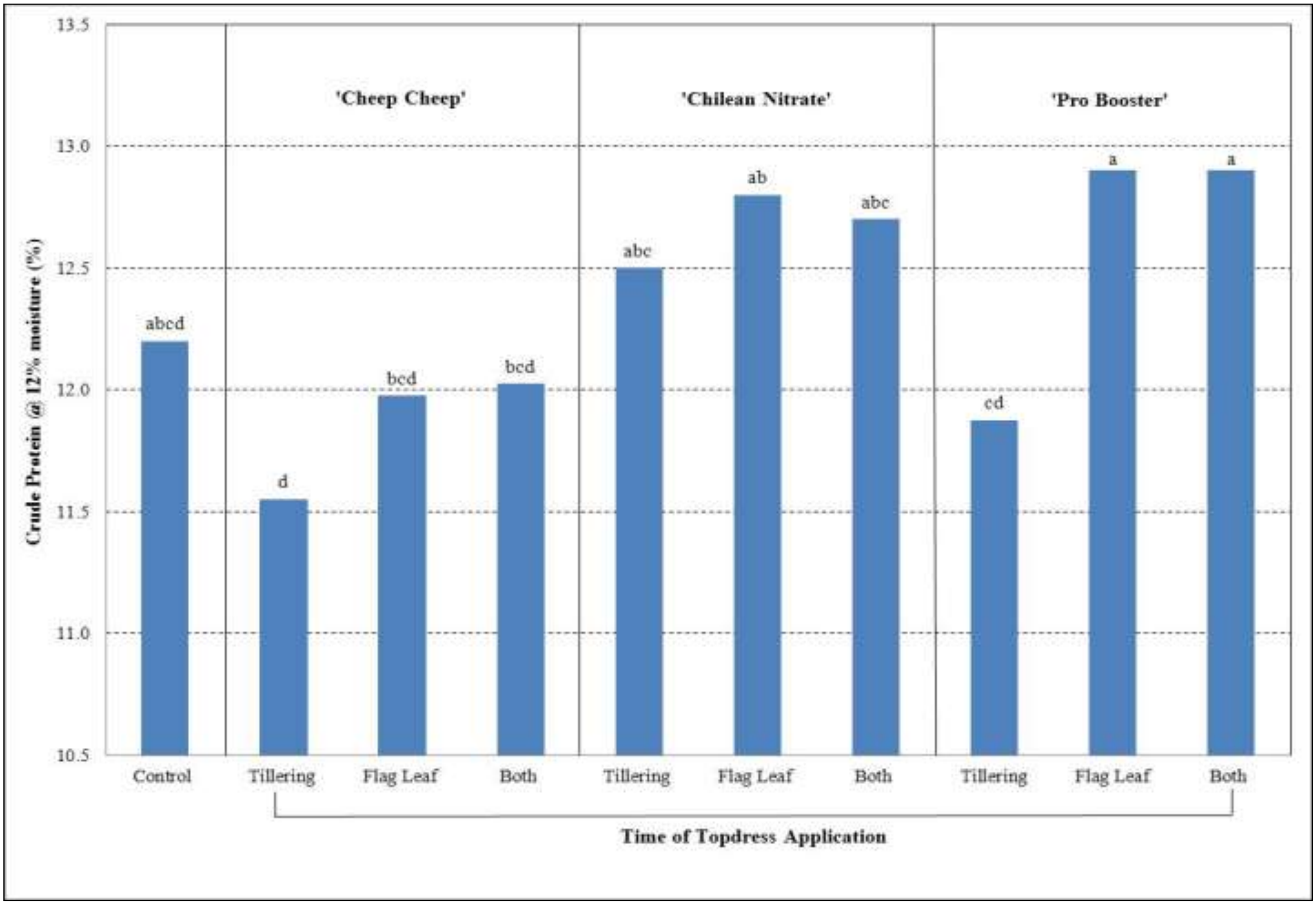

Figure 4. The impact of topdressing organic N sources at critical wheat developmental stages on crude protein concentrations, Bridport, VT. *Treatments with the same letter did not differ significantly in yield

DISCUSSION

In 2011, the growing season was highly variable with a very wet spring and dry summer resulting in poor wheat yields throughout the state. The trial area also experienced much of this unfavorable weather. However, some general observations can be made; both winter wheat topdressing studies indicate that organic certified N amendments can be applied to increase both yield and protein levels. It appears as though N sources such as 'Pro Booster' with both soluble and slow release N sources may more easily meet the N needs of the plant. Slow release N products such as composted poultry manure will need to have properly timed applications so that the N has enough time to be mineralized into plant available N sources. This may require applications prior to rapid uptake periods. In the case of soluble N products such as 'Chilean Nitrate' application time will need to be timed at the time of rapid uptake. This will allow the plant to access N at the critical stages hence resulting in potential yield and protein increases. It is important to note that 'Chilean Nitrate' may be removed from the USDA NOP list of approved materials. Further studies should be conducted to determine N release rates of organic approved materials.

The UVM Extension Crops and Soils Team would like to thank Gleason Grains and Borderview Farm for their generous help with the trial and acknowledge the USDA NE SARE Partnership grant program and USDA Organic Research and Education Initiative for their financial support. Any reference to commercial products, trade names, or brand names is for information only, and no endorsement or approval is intended.

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