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The Effects of Topdressing Organic Nitrogen Hard Red Winter Wheat

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The UNIVERSITY of VERMONT EXTENSION

2010 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 12-14%. Higher protein levels generally improve baking characteristics. In 2010, 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.

WEATHER DATA

Seasonal precipitation and temperature recorded at weather stations in close proximity to the 2010 sites are shown in Table 1 and Table 2. This growing season's weather was ideal for growing wheat. Due to the warm spring the wheat got off to an early start and continued to be at least a week early in reaching major developmental stages.

Table 1. Temperature and precipitation summary for Bridport, VT, 2010.

Bridport, VT	Sep. 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)	823	444	279	557	8768	1026	1279
Departure from Normal	-23.5	-68.0	144	186	96.0	26.0	96.0

Table 2. Temperature and precipitation summary for Alburgh, VT, 2010.

South Hero (Alburgh)	Sep. 09	Oct. 09	Mar.	Apr.	May	Jun.	Jul.
Average Temperature (F)	57.7	44.1	37.8	49.3	59.6	66.0	74.1
Departure from Normal	-2.7	-4.7	7.0	5.8	3.0	0.2	3.0
Precipitation (inches)	4.01	5.18	2.79	2.76	0.92	4.61	4.30
Departure from Normal	0.55	0.79	0.73	0.25	-2.01	1.40	0.89
Growing Degree Days (base 32)	771	396	229	521	854	1019	1305
Departure from Normal	-81.0	-125	113	176	91.5	4.5	94.6

*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

Gleason Grains – Bridport, VT:

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 3). The plots were seeded with winter wheat (var 'Redeemer') on September 13, 2009. The prior crop in 2009 was soybeans and in 2008 a sweet clover cover crop.

Table 3. General plot management of the winter wheat trial, Bridport, VT.

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 ac^{-1})	140
Replicates	4
Planting date	Sep. 13, 2009
Harvest date	Aug. 2, 2010
Harvest area (ft.)	5 x 20
Tillage operations	Fall chisel plow, & spike-tooth 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 topdressed with one of 3 organic N amendments. The amendments used were; 'Cheep Cheep' (4% N), 'ProBooster' (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 '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 the flag leaf stage or a split application with ½ the rate at both growth stages. On April 5 2010, the tillering amendments were applied and the flag leaf application was on May 20, 2010.

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.

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 4). Approximately two weeks before planting, composted dairy manure was applied at 70 lbs of available N per acre to all plots, except the unamended controls. 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, 2009. The prior crop in 2009 was winter rye harvested for grain.

Table 4. General plot management of the winter wheat trials, Alburgh, VT

Trial Information	Winter wheat variety trial
Location	Alburgh, VT Borderview Farm
Soil type	Benson rocky silt loam
Previous crop	Rye
Row spacing (in.)	6
Seeding rate (lbs ac^{-1})	150
Replicates	4
Planting date	Sep. 15, 2009
Harvest date	Jul. 12, 2010
Harvest area (ft.)	5x20
Tillage operations	Fall plow, disc, & spike-tooth harrow

The experimental design was a randomized complete block design with six 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 13, 2009 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 at the boot stage. On April 1 2010, the tillering amendments were applied, the flag leaf application was on May 19, 2010, and the boot amendments were applied on May 26, 2010.

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. The plots were harvested with an Almaco SP50 plot combine on July 12, 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.

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 crude protein (CP), falling number, and mycotoxin levels. Grains were analyzed for crude CP 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.

All data was analyzed using a mixed model analysis where replicates were considered random effects. The LSD procedure was used to separate treatment means 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

Borderview Farm, Alburgh, VT:

The treatments differed significantly in winter wheat yield (Table 5 and Figure 1). When 'Cheep Cheep' was applied at either flag leaf or boot stage, it resulted in yields significantly higher than the unamended control plots. However, 'Cheep Cheep' applied at the tillering stage did not result in a yield increase over the control. 'Chilean Nitrate' applied at all of the different application times; tillering, flag leaf, and boot growth stages, yielded significantly higher than the unamended control plots. The boot stage applied 'Chilean Nitrate' treatment yielded the highest with 4100 lbs ac^{-1}; the control was the lowest yielding with 2915 lbs ac^{-1}. The fall manure amended plots did not increase yields significantly over the unamended control or the 'Cheep Cheep' topdressed at the tillering stage. Based on this first year of data it appears that winter wheat yields can be increased if small amounts of additional N are applied at later developmental stages.

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

Feritility Type	Timing of Aplication	Harvest		Quality		
		Test weight	Yield	Crude protein @ 14% moisture	Falling number @ 14% moisture	DON
		lbs/ bu	lbs ac^{-1}	%	seconds	ppm
'Cheep Cheep'	Tillering	59.0	3198	8.63	337	0.18
'Cheep Cheep'	Flag leaf	58.1	3504	8.48	317	0.28
'Cheep Cheep'	Boot	59.1	3875*	9.00	349	0.23
'Chilean Nitrate'	Tillering	58.6	3501	8.88	330	0.15
'Chilean Nitrate'	Flag leaf	59.4	3804*	9.38	348	0.25
'Chilean Nitrate'	Boot	59.0	**4100***	**10.15***	352	0.10
Manure	Fall 2009	58.8	3261	8.05	317	0.28
Control	None	58.1	2915	8.00	329	0.40
LSD (0.10)		NS	519	0.70	NS	NS
Trial means		58.8	3520	8.82	335	0.23

*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 varieties were significantly different from one another.

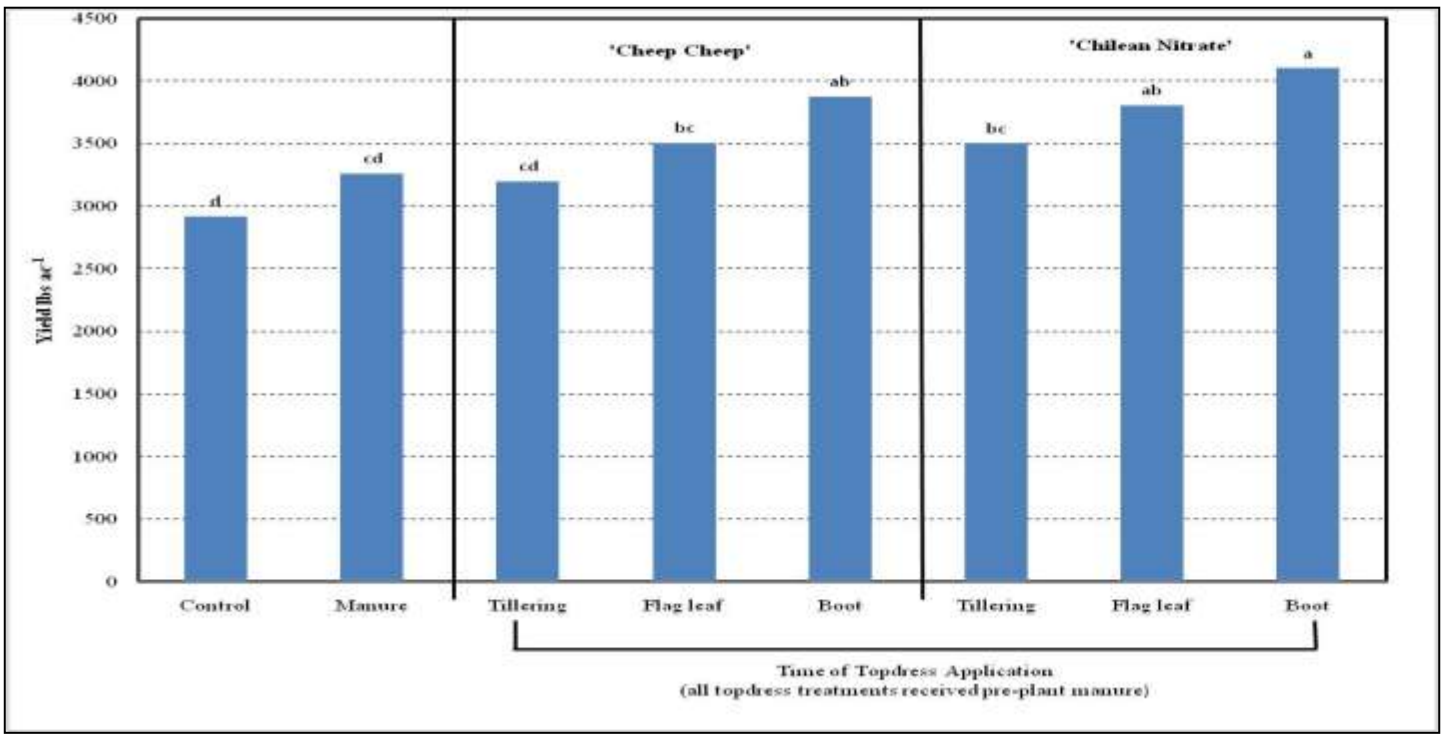

Figure 1. Yield impact of topdressing organic N sources at critical wheat developmental stages, Albugh, VT.
*Varieties with the same letter did not differ significantly in yield

The treatments also differed in winter wheat CP concentration (Table 5; Figure 2). 'Chilean Nitrate' applied at all of the application times; 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, but was not significantly different when applied at the tillering and flag leaf growth stages. This is presumably due to the slow release nature of the amendment. The boot applied 'Chilean Nitrate' had the highest protein level at 10.2%; the lowest was the control with a protein content of 8.0%. The other grain quality tests measured were; test weight, falling number and DON levels. None of these additional tests differed significantly among treatments.

The first year of data suggests that organic N sources applied at the boot stage had significantly higher protein levels and yields than the manure and the control plots. Interestingly, 'Chilean Nitrate' applied at the boot stage resulted in protein levels that were two percentage points higher, and 1000 lbs ac^{-1} greater yield than the manure and control plots. Wheat that received topdress amendments always resulted in higher protein levels than the fall applied dairy manure and the unamended controls. Across all treatments the 'Chilean Nitrate' applied at the boot stage resulted in the highest yields and protein levels. These preliminary results indicate that 'Chilean Nitrate' 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.

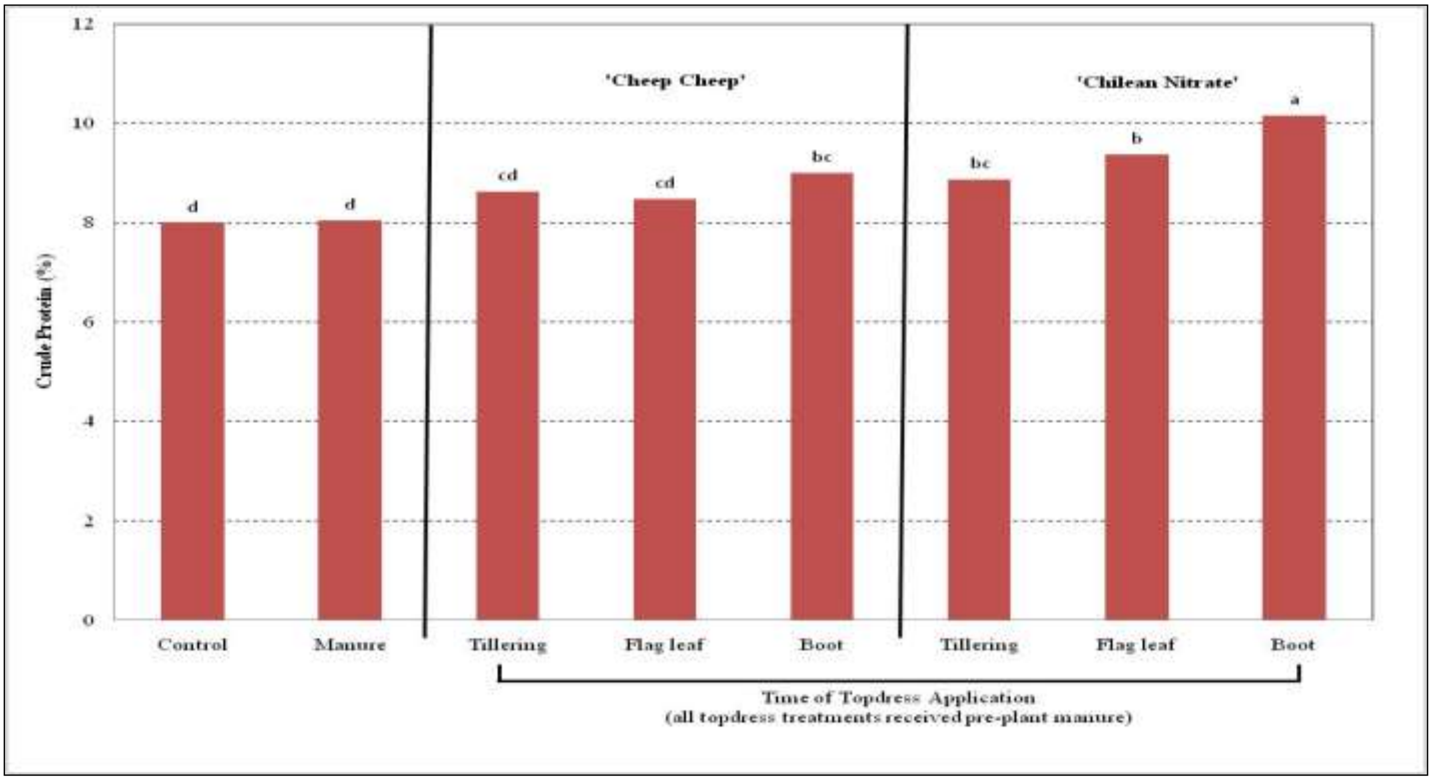

Figure 2.The impact of topdressing organic N sources at critical wheat developmental stages on crude protein concentrations, Albrugh, VT.

*Varieties with the same letter did not differ significantly in yield

RESULTS

Gleason Grains, Bridport, VT:

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 slowly 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. In addition, at these stages, 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.

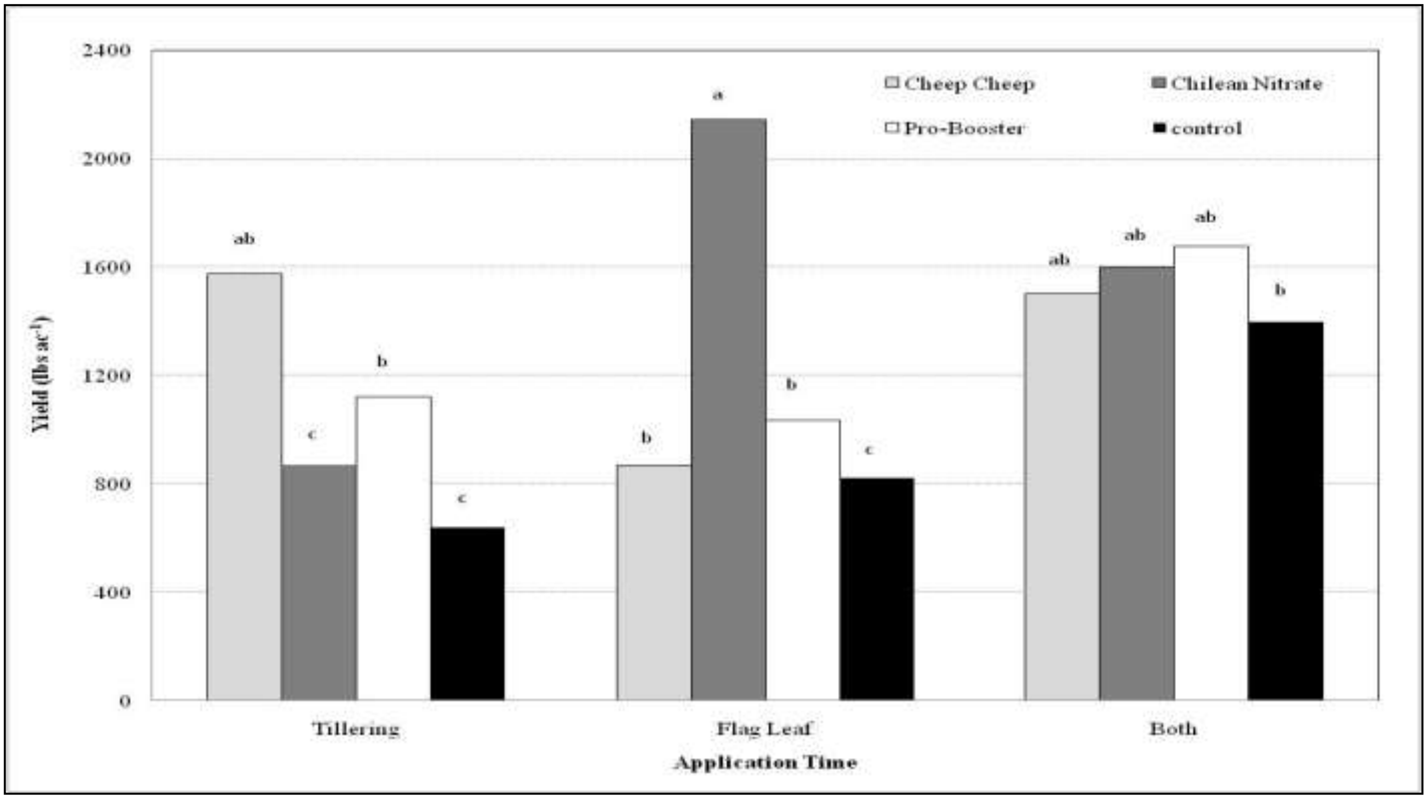

Figure 3. The interaction of application timing and amendment on winter wheat yield, Bridport, VT.
*Varieties with the same letter did not differ significantly in yield

A fertility source x application time interaction was observed for CP 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 CP as compared to the control. The 'ProBooster' application at the flag leaf stage resulted in the highest CP concentrations. When the N application was split, increases in CP 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.

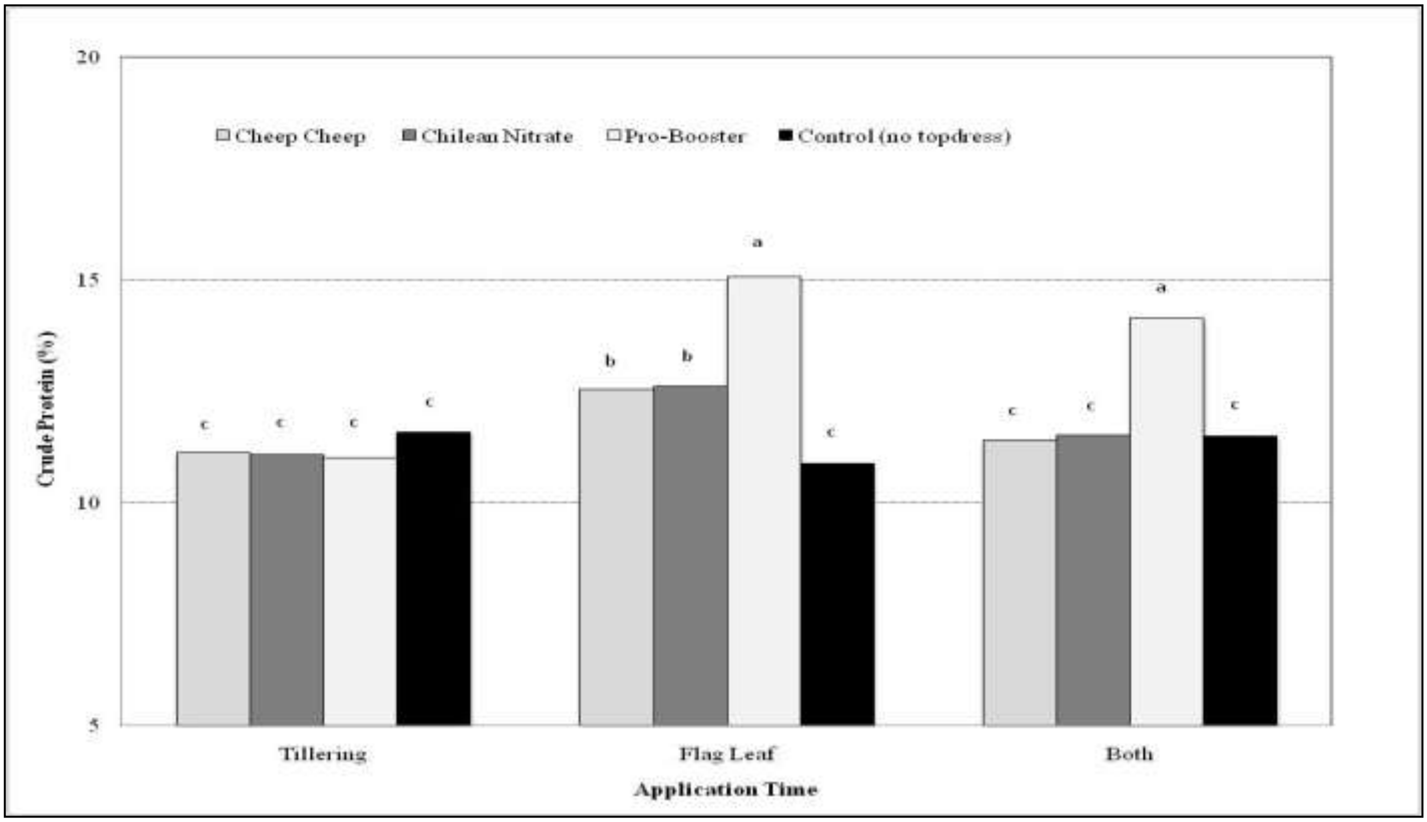

Figure 4.The interaction of application timing and amendment on winter wheat crude protein concentrations, Bridport, VT. *Varieties with the same letter did not differ significantly in yield

Differences among fertilizer types were observed for yield and CP in this experiment (Table 6 and Figure 5). The ‘Chilean Nitrate’ product resulted in significantly higher yields than the control. The ‘Cheep Cheep’ and ‘ProBooster’ did not differ significantly in yield. 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 6).

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

Fertility Type			Grain Quality		
	Moisture	Yield	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.

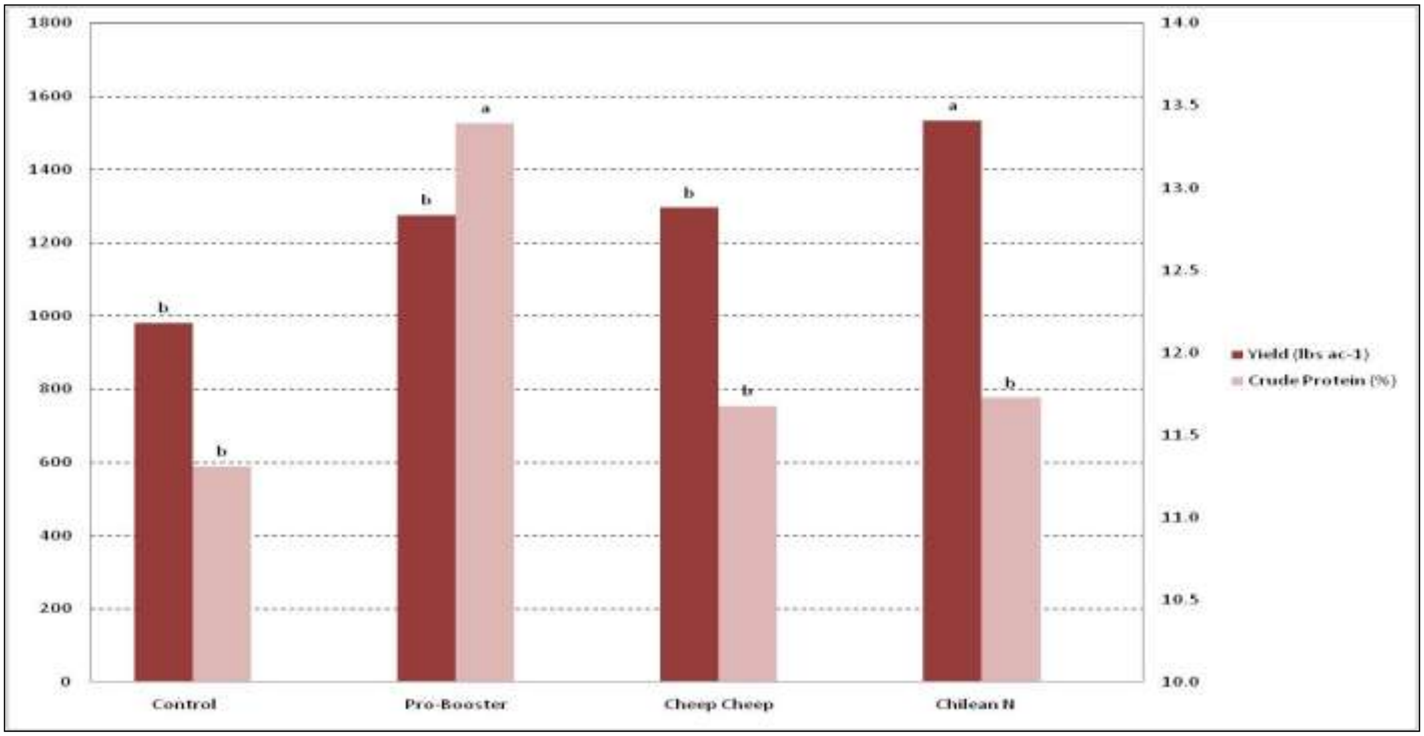

Figure 5. The impact of organic fertility treatments on winter wheat yield and CP concentrations, Bridport, VT.
*Varieties with the same letter did not differ significantly in yield.

The timing of the organic N fertilizer application had a significant impact on yield and CP concentrations of winter wheat (Table 7 and Figure 6). 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 CP 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 7).

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, 'ProBooster' 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 'ProBooster' had the highest protein level of 13.4%.

Table 7. 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	8.96	1076b	11.2c	**333**	0.30
Flag Leaf	8.81	1215b	**12.8a**	302	**0.32**
Both	**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.

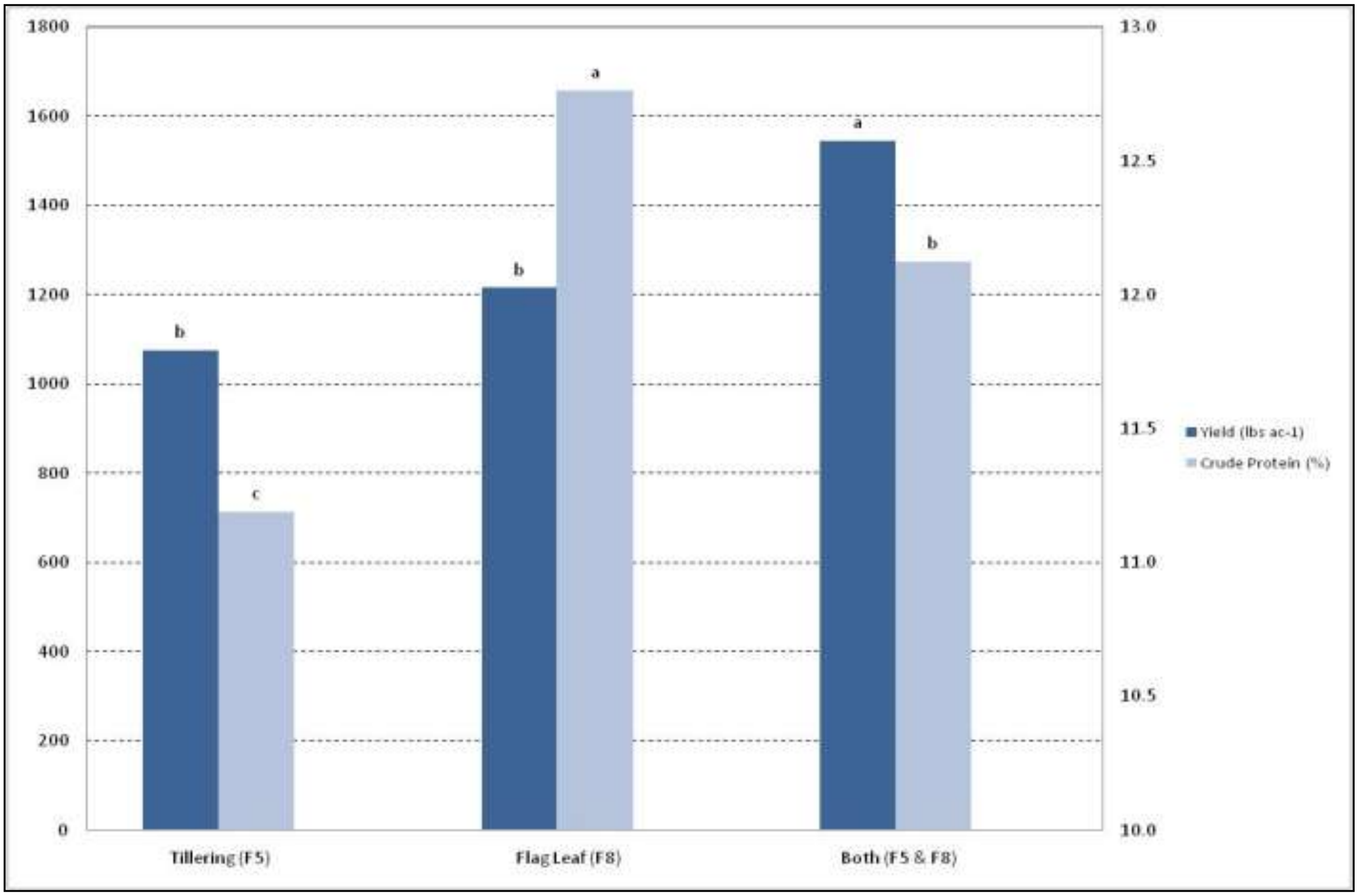

Figure 6. Impact of organic N fertility application time on winter wheat yield and CP concentration, Bridport, VT.
*Varieties with the same letter did not differ significantly in yield.

DISCUSSION

General observations across both winter wheat topdressing studies indicate that organic certified N amendments can be applied to increase both yield and protein levels. Preliminarily it seems as though N sources such as 'ProBooster' 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 he 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 potentially yield and protein increases. More research must be conducted to verify the first year results.

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