The Effects of Topdressing Organic Nitrogen on Hard Red Winter Wheat Yield and Quality: Part II

SUMMARY

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. Assuring adequate available nitrogen (N) for grain yield and protein are the primary challenges of organic winter wheat production in New England. Topdressing N to increase protein quantity and quality is recommended for conventionally grown wheat, but the effectiveness of topdressing organic N sources needs evaluation.

In 2011, we were awarded a partnership grant titled "The Effects of Topdressing Organic Nitrogen of Hard Red Winter Wheat Quality and Protein Part II", to continue to explore the relationship between topdressing organic nitrogen amendments (composted poultry manure, Chilean nitrate, and Pro-Booster, an available bagged fertilizer), the application times (tillering, flag leaf, and split application at both times), and how these two factors influence the quality and quantity of grain protein, on farm. First year results demonstrated that topdressing can have a positive impact on both yield and quality. However, one year of data is not adequate to confidently recommend that farmers begin changing fertility practices. Therefore our group repeated the study in 2011 to verify our 2010 results.

In 2011, the topdressing of wheat at tillering and flag leaf stage did not increase yields compared to the unamended control. However, crude protein (CP) differed significantly among treatments. Organic nitrogen treatments including Probooster and Chilean nitrate applied at the flag leaf stage resulted in higher CP concentrations than Cheep Cheep applied at flag leaf stage. The control did not differ significantly from that amended treatments. Above average precipitation during the growing season may have resulted in significant N leaching from all treatments.

INTRODUCTION

The desire for local and organic food is on the rise throughout the Northeast. Consumers are asking for bread baked with locally grown wheat. Millers and bakers, however, cannot find enough locally grown organic wheat, and that which is available often does not meet the higher quality standards required bread production. Addressing the quality issue is essential for expanding the bread flour market in the northeast.

One of the major quality issues facing northern grain producers is low protein content of the wheat. Much of the hard red winter wheat currently produced in Vermont has protein levels consistently between 9 and 12%. Many of the commercial flour mills have target protein levels of 14-15%. In general, higher grain protein content results in improved bread baking characteristics of the flour.

Research suggests the amount of soil nitrogen (N) available to the plant during plant growth directly influences the quantity and quality of grain protein. It is relatively easy to obtain acceptable wheat protein levels if N is in a plant available form during periods of critical need. In a conventional system readily available synthetic fertilizers can be added to wheat during these times. However, in organic systems it is more difficult to manage N release rates. In Vermont, organic farmers rely solely on green and animal manures as the source of N for winter wheat crops. Since protein levels of winter wheat average 10% we assume that N is a limiting factor in both yield and quality. Farmers are interested to know if the addition of commercially available organic nitrogen sources during critical wheat development stages will improve the yield and protein content of the wheat crop.

In 2011 we continued to explore the relationship between topdressing organic nitrogen amendments, the application times, and how these two factors influence the quality and quantity of grain protein for a second year.

OBJECTIVES & MILESTONES

The objective of this project is to determine if topdressing wheat with organic N sources during critical uptake periods will improve overall yield and quality. In collaboration with our co-operating farmer, we evaluated the impact of three different organic N sources; composted chicken manure, Chilean nitrate, and Pro-Booster, applied at two different times during the growing season; spring application, application at flag leaf, and a combination of the two on wheat yield and quality.

- In April 19 of 2011 the trial plots at Gleason Grains in Bridport, VT were established.
- Amendments were applied at key developmental stages (tillering and flag leaf).
- Plant biomass and soil nitrate samples were taken throughout plant development and are in the process of being analyzed.
- On July 20, 2011 the plots were harvested and grain yields calculated.
- Fall of 2011, gain quality testing; % grain moisture, test weight, crude protein, falling number and DON analysis, were conducted on the grain from each of the test plots at the University of Vermont's Cereal Testing Laboratory in Burlington, VT. Plant biomass samples were sent to Cumberland Valley Analytical Laboratory.
- On June 9, 2011 a workshop was held at Gleason Grains in Bridport, VT which highlight the N topdressing trial. There were 40 people in attendance.
- On June 21, 2011 a workshop was held at Aurora Farms in Charlotte, VT. The Kenyon family discussed their interest in large scale organic N topdress trials at their farm. There were 50 people in attendance.
- October 7, 2011 an episode of "Across the Fence" aired highlighting the project; http://www.youtube.com/watch?v=dJy5jmG6_lw&list=UUr8rzEUNSC2s5VNWfEZ3Qaw&index=13&feature=plcp
- In January of 2011 a research report was written; hard copies will be handed out at winter conferences and workshops and a pdf version will be posted on both the UVM Extension NorthWest Crops and Soils Team and Northern Grain Growers Association (NGGA) websites.

MATERIALS AND METHODS

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 1). 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.

Image 1. Tillering application of organic N amendments

Table 1. General plot management of the wheat trial.

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	9-18-10
Harvest date	8-2-11
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.

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 for analysis. All soil will be 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.

The plots were harvested with an Almaco SP50 plot combine on August 2, 2011. A wind storm a week prior to harvest resulted in significant lodging in a number of the plots. 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 ($P < 0.10$).

Image 2. Topdress plots during June 9th workshop-Bridport, VT

Image 3. Wheat topdress trial harvest –Bridport, VT

RESULTS AND DISCUSSION/MILESTONES

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. 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 which impacted yields. From planting to harvest in Bridport there was an accumulation of 5016 Growing Degree Days (GDD), 217 GDDs higher than the 30 year average.

Table 2. Temperature and precipitation summary for Bridport, VT, 2011.

Bridport, VT	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	9.8	*	7.88	8.67	3.52	3.68
Departure from Normal	-0.56	6.4	*	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

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 3 and Figure 1). When ‘Cheep Cheep’, Pro Booster or Chilean Nitrate were applied at any of the different application times; tillering, flag leaf, or a split application

at both growth stages, this resulted in higher yields than the unamended Control plots. The split application of 'Chilean Nitrate' treatment yielded the highest with 2855 lbs ac^{-1}; the Control was the lowest yielding with 2138 lbs ac^{-1}.

Table 3. Yield and quality results of the different organic amendments

Time of Application	Fertility Type				Quality		
		Yield	Moisture	Test Weight	Crude Protein	Falling Number	DON
		lbs ac^{-1}	%	bu ac^{-1}	%	seconds	ppm
Tillering (F5)	Cheep Cheep	2835	14.1	57.0	11.6	**460**	0.43
Tillering (F5)	Chilean Nitrate	2228	14.5	55.0	12.5*	402	0.50
Tillering (F5)	Pro-Booster	2452	15.0	55.9	11.9	398	0.33
Flag Leaf (F8)	Cheep Cheep	2562	15.0	55.0	12.0	432	0.45
Flag Leaf (F8)	Chilean Nitrate	2533	13.8	57.0	12.8*	443	**0.23**
Flag Leaf (F8)	Pro-Booster	2526	**15.3**	55.4	**12.9***	439	0.50
Both (F5 & F8)	Cheep Cheep	2417	14.8	55.9	12.0	459	0.33
Both (F5 & F8)	Chilean Nitrate	**2855**	15.1	55.6	12.7*	453	0.50
Both (F5 & F8)	Pro-Booster	2699	14.5	56.5	**12.9***	456	0.35
Control	None	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 varieties were significantly different from one another.

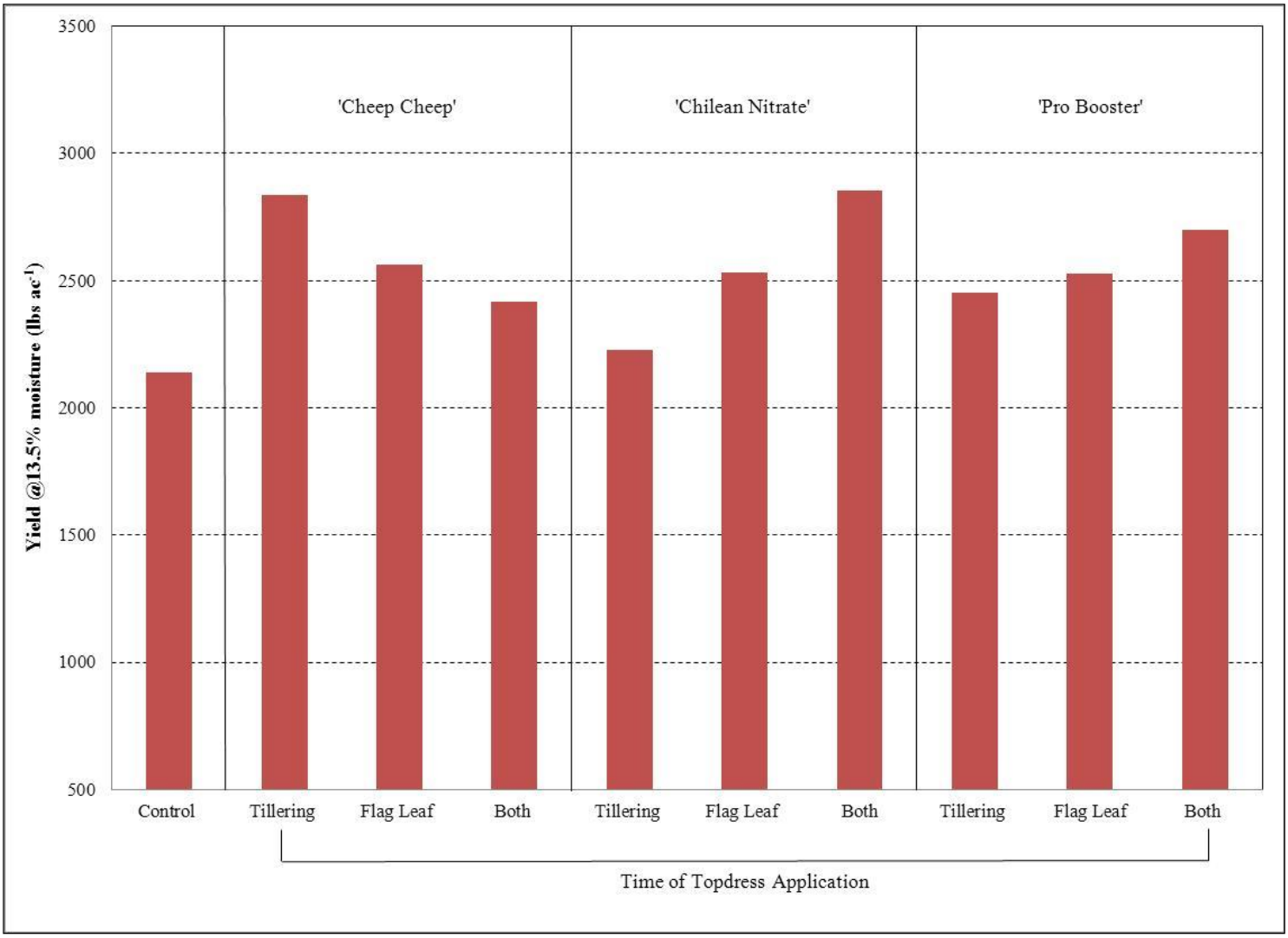

Figure 1. Yield impact of topdressing organic N sources at critical wheat developmental stages.

The treatments did differ significantly in winter wheat crude protein concentration (Table 3 and Figure 2). '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; tillering, flag leaf, or both. 'Cheep Cheep' applied at the tillering stage had the lowest protein level with 11.6%. Interestingly, the control plot did not differ significantly from any of the other treatments. Overall, the application of 'Pro Booster' or 'Chilean Nitrate' at the flag leaf or both (tillering and flag leaf) growth stages resulted in the best chance to improve both wheat protein levels and yields. While 'Cheep Cheep', applied at the same stages did improved protein levels it did not improve yields. 'Cheep Cheep' applied at tillering resulted in the highest yield of the three application times; this is possibly due to the slow N release nature of this product. The other grain quality tests measured were; test weight, falling number and DON levels. None of these additional tests differed significantly among treatments.

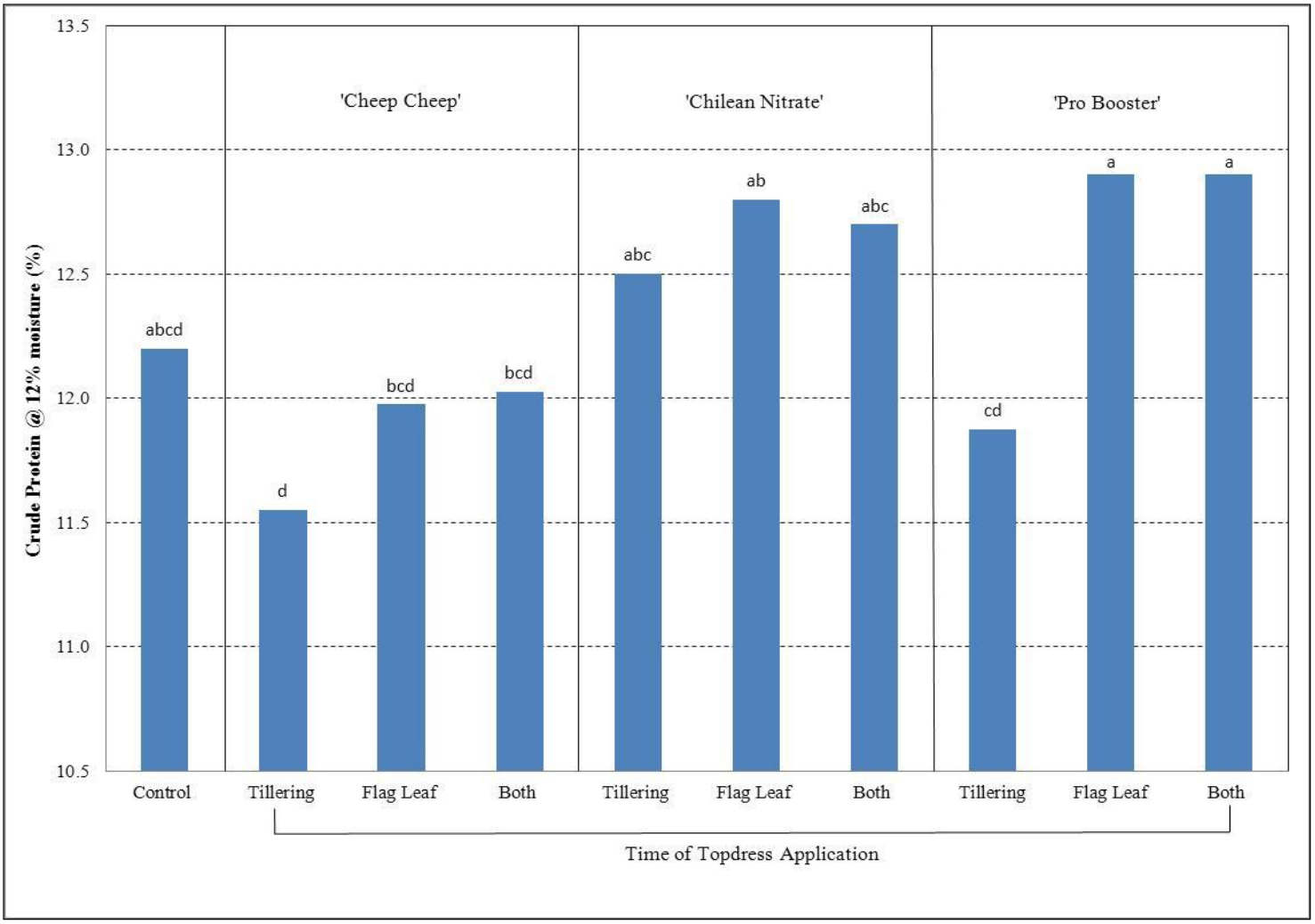

Figure 2. The impact of topdressing organic N sources at critical wheat developmental stages on crude protein concentrations.
*Varieties with the same letter did not differ significantly in protein levels.

DISCUSSION

The second year of research results from the winter wheat topdressing study indicate that organic certified N amendments can be applied to increase protein levels. Preliminarily it seems 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 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. It's important to note that the extreme weather conditions during the 2011 growing season affected both yield and quality.

IMPACT OF RESULTS/OUTCOMES

These second year results demonstrated that topdressing can have an impact on wheat protein concentrations. However, due to weather conditions in 2011 it is difficult to determine if there were any significant impacts on yield. Farms are interested in implementing topdressing as a practice to improve wheat yield and quality. However, the data is still relatively inconclusive. The largest organic wheat producer in the state, located in Charlotte, Vermont, attempted to conduct a larger scale organic nitrogen topdressing trial during the 2011

growing season on some of their winter wheat fields as a result of our 2010 findings. Unfortunately due to the heavy rains and their dense clay soils the fields didn't dry out in time to topdress the wheat. However they plan to try again in the 2012 growing season

PUBLICATIONS/OUTREACH

Producing High Quality Organic Bread Wheat, an on-farm workshop was held June 9, 2011 at Gleason Grains in Bridport, VT. The workshop highlighted the NE SARE funded organic fertility experiment. In addition, Ben Gleason discussed crop rotation and weed control in wheat grown for human consumption. We viewed Ben's wheat processing facility including his seed cleaning, meadows mill, and sifting operation. This event had 40 attendees consisting of farmers, Extension, and other agricultural professionals. Many of the farmers were anxious to view project results.

Production & Processing of Organic Grain: Getting to the Nitty Gritty, an on-farm workshop was held June 21, 2011 at Aurora Farms in Charlotte, VT. The workshop highlighted the Kenyon family's grain production and processing techniques. They discussed their attempt to conduct large scale organic N topdressing trials which results in a very stuck tractor. However, they do plan to establish the trial again next year. This event had 50 attendees consisting of farmers, Extension, and other agricultural professionals.

On October 7, 2011 an episode of *"Across the Fence"* aired highlighting this project;
http://www.youtube.com/watch?v=dJy5jmG6_lw&list=UUr8rzEUNSC2s5VNWfEZ3Qaw&index=13&feature=plcp
This link was posted on both the UVM Extension North West Crops and Soils Team and Northern Grain Growers Association (NGGA) websites.

A research report was written on the results from this topdressing; hard copies were handed out at winter conferences and workshops and a pdf version was posted on both the UVM Extension North West Crops and Soils Team and Northern Grain Growers Association (NGGA) websites.

AREAS NEEDING ADDITIONAL STUDY

Additional information is needed on the rate on N release of organic amendments