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IMPROVING WINTER GRAIN YIELDS, QUALITY, AND NITROGEN USE EFFICIENCY USING ADAPTIVE MANAGEMENT

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Small grains have gained importance in New England agriculture over the last decade due to expanding demand for local sources for food and feed. Growers are particularly interested in grains that are planted in the fall (winter wheat, spelt, triticale, rye) because they provide numerous rotational benefits, produce high yields, scavenge residual soil nitrogen (N), and protect the soil from winter erosion. Recent grower surveys indicate that N fertility management is a key production challenge for winter grains, which involves providing enough N at the right times to optimize yields and, in the case of bread wheat, grain protein. Readily available N applied at planting is subject to over winter losses via leaching and volatilization; and mineralization of organic N sources is difficult to predict and lags behind crop demand in the early spring. The goal of this project is to develop an adaptive N management strategy to improve N-use efficiency, reduce environmental N losses, and increase revenue for winter grain production. The adaptive N procedure uses early season tiller counts to determine N needs of the wheat crop. This approach is used successfully in other humid regions of the U.S. and has shown promise in local preliminary trials. On-farm trials are being conducted to develop this new N management tool for New England grain farmers. Therefore, in April 2014, the University of Vermont Extension-Northwest Crop and Soils Program established an on-farm trial at Four Star Farms in Northfield, MA.

MATERIALS AND METHODS

The seedbeds in Northfield were prepared by conventional tillage methods. All plots were managed with practices outlined in Table 1. The plots were seeded with a Great Plains, 7.5 inch spacing double disc opener 7 foot grain drill. The trial was seeded with the hard red winter wheat (var 'Zorro') on 24-Sep 2013 at a seeding rate of 120lbs ac^{-1}. One week after planting the plots were fertilized at a rate of 200 lbs ac^{-1} with 19-19-19.

Table 1. General plot management of the 2014 winter wheat and spelt on-farm N management trials, Northfield, MA.

Trial Information	Winter Wheat and Spelt
Location	Four Star Farms Northfield, MA
Soil type	Hadley silt loam
Tillage operations	Moldboard plow and harrow
Row spacing (in.)	7.5
Seeding rate (lbs ac^{-1})	120
Variety	Zorro
Replicates	3
Fall fertilization (lbs ac^{-1})	200 (19-19-19)
Planting date	24-Sep 2013
Trial Establishment	23-Apr 2014
GS25 fertilization date	23-Apr 2014
GS30 fertilization date	14-May 2014
Harvest date	31-Jul 2014
Harvest area (ft.)	5 x 20

The experimental design was a randomized complete block design with ten treatments replicated 3 times (Table 2). Ammonium sulfate (24-0-0) was used as the soluble nitrogen source. These N topdress treatments were applied at spring green-up (GS25), pre-stem extension (GS30), or at both these growth stages. On 23-Apr 2014 the GS25 amendments were applied, and on 14-May 2014 the GS30 treatments were applied. At the time of the applications, plots were amended with potash (0-0-62) and ammonium phosphate (11-52-0) to match the fertilization plan used by the farm. In addition, sulfur (90%) was added to the control plots account for the sulfur added to the plots in the ammonium sulfate.

Plots were sampled for plant nitrogen concentration prior to N applications and at key developmental stages until the wheat reached physiological maturity. Plant samples were taken to determine total nitrogen concentration by combustion analysis. The tissue samples consisted of 8 rows of wheat top growth, and 6 inches in length selected randomly within each plot. Samples were put into clean paper bags, kept cool, and transported directly to the UVM Horticultural Research Farm where samples were placed in a dryer. Once dried, plant samples were weighed and ground in a Wiley Laboratory Mill, Standard Model No.3. Samples were then sent to the UVM Agricultural and Environmental Testing Laboratory for analysis.

Table 2. Application rates and timings of nitrogen amendments and total amount of N applied, Northfield, MA.

Treatments	Spring greenup (GS25)	Pre-stem extension (GS30)	Total N applied
	lbs ac^{-1}	lbs ac^{-1}	lbs ac^{-1}
1	0	0	0
2	0	30	30
3	0	60	60
4	0	90	90
5	30	90	120
6	30	0	30
7	30	30	60
8	30	60	90
9	60	0	60
10	90	0	90

On 23-Apr, the numbers of tillers were counted in three 12-inch segments randomly selected within each plot in order to determine tiller density (tillers per square foot).

On 9-Jul, after the wheat had reached physiological maturity and was in the process of drying down, the number of spikes was counted from a plant biomass sampling of 4 randomly selected 12-inch segments per plot.

Prior to harvest the plant heights were measured, excluding awns, percent lodging and the severity of lodging was recorded based on a visual rating with a 0 – 5 scale, where 0 indicates no lodging and 5 indicates severe lodging and a complete crop loss. Plots were harvested with an Almaco SPC50 plot combine on 31-Jul 2014; the harvest area was 5' x 20'. At the time of harvest, grain moisture, test weight, and plot yields were measured.

Following harvest, seed was cleaned with a small Clipper cleaner (A.T. Ferrell, Bluffton, IN). 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 and the resulting flour was evaluated for its protein content using the Perten Inframatic 8600 Flour Analyzer. Grain protein affects gluten strength and loaf volume. Most commercial mills target 12-15% protein.

All data was analyzed using a mixed model analysis where replicates were considered random effects. The Least Significant Difference (LSD) procedure was used to separate cultivar means when the F-test was significant ($P< 0.10$). There were significant differences among the two locations for most parameters, and therefore data from each location is reported independently.

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) 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 following example, 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 2013 and 2014 site is shown in Table 3. The growing season this year was marked by lower than normal temperatures in November and April and higher than normal rainfall in May, June, and July. There was an accumulation of 4923 Growing Degree Days (GDDs), which is 5 GDDs above the 30 year average.

Table 3. 2013 and 2014 temperature and precipitation summary for Four Star Farms.

Greenfield, MA	Sep-13	Oct-13	Nov-13	Apr-14	May-14	Jun-14	Jul-14
Average temperature (°F)	60.3	50.7	36.5	45.6	56.7	65.6	69.8
Departure from normal	0.10	1.90	-2.80	-0.60	0.50	0.20	0.50
Precipitation (inches)	4.31	2.24	4.19	3.29	4.93	5.82	7.55
Departure from normal	0.10	-2.42	0.15	-1.24	0.87	1.59	3.24
Growing Degree Days (base 32°F)	849	581	137	407	767	1010	1172
Departure from normal	4.50	60.5	-82.5	-19.5	17.1	7.50	17.1

Based on National Weather Service data from cooperative observation stations in Greenfield, MA. Historical averages are for 30 years of NOAA data (1981-2010) from Greenfield, MA.
Data taken from Tully Lake, MA when Greenfield data was not available.

***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.

***Hard Red Winter Wheat*:**

There were significant differences in the number of spikes, plant height, lodging, and lodging severity between treatments (Table 4). Spike counts were highest when over 60 lbs of N were applied at GS25, GS30 or with split applications (Table 4, Figure 1). The lowest spike counts were exhibited when no fertilizer was applied.

Table 4. The impact of N topdress treatments on winter wheat tiller and spike counts, plant height, and lodging, Northfield, MA.

Treatments	**Time of Application**	**Total N applied**	**Spike counts**	**Plant height**	**Lodging**	**Severity**
		lbs ac^{-1}	ft^2	cm	%	0-5
Control	None	0	29	85.4	**0.00***	**0.00***
0-30	GS30	30	37	96.4	**0.00***	**0.00***
0-60	GS30	60	42*	99.2	46.7	2.00*
0-90	GS30	90	44*	104*	60.0	3.67
30-90	GS25 & GS30	120	41*	105*	81.7	3.67
30-0	GS25	30	36	**110***	38.3*	2.33
30-30	GS25 & GS30	60	44*	108*	63.3	3.00
30-60	GS25 & GS30	90	44*	105*	76.7	3.67
60-0	GS25	60	**48***	108*	90.0	4.67
90-0	GS25	90	45*	107*	91.7	4.67
LSD (0.1)			9	9.41	45.1	2.04
Trial means			41	103	54.8	2.77

Values shown in **bold** are of the highest value or top performing.
* Treatments that did not perform significantly lower than the top performing variety in a particular column are indicated with an asterisk.

Wheat was shortest when no N fertilizer was applied or GS30 applications at 30 and 60 lbs N per acre. Lodging was severe in all treatments that received over 30 lbs of N per acre (Figure 2). Ninety pounds of N applied at GS25 resulted in the highest percent of plant lodging (91.7%) and was the most severe (4.67).

Table 5. The results of fertility rate and application timing on hard red winter wheat harvest and quality.

Treatments	Time of application	Total N applied	Yield @ 13.5% moisture	Moisture	Test weight	Crude protein @ 12% moisture
		lbs ac^{-1}	lbs ac^{-1}	%	lbs bu^{-1}	%
Control	None	0	1598	18.0	51.0*	10.4
0-30	GS30	30	2223	18.0	49.8	11.7
0-60	GS30	60	2541	17.5	49.7	11.4
0-90	GS30	90	**3147***	17.0	50.0	12.7*
30-90	GS25 & GS30	120	2775*	16.9	48.5	**13.6***
30-0	GS25	30	2855*	17.3	**52.2***	10.8
30-30	GS25 & GS30	60	2920*	17.4	51.0*	12.5
30-60	GS25 & GS30	90	2399	17.2	48.2	12.8*
60-0	GS25	60	3054*	16.6*	50.7*	11.4
90-0	GS25	90	2963*	**15.7***	49.0	12.6*
LSD (0.1)			412	1.14	1.55	1.01
Trial means			2648	17.2	50.0	12.0

Values shown in **bold** are of the highest value or top performing.
* Treatments that did not perform significantly lower than the top performing variety in a particular column are indicated with an asterisk.

The treatments differed significantly in yield, harvest moisture, test weight, and protein (Table 5; Figure 3). Adding nitrogen to the winter wheat at GS25, GS30, or both (split applications) increased yields significantly compared to the control. The highest yielding treatment was 90lbs of N applied at GS30 (3147 lbs ac^{-1}). Statistically similar yields were obtained from the following treatments; 60lbs of N applied at GS25 (3054 lbs ac^{-1}), 90lbs of N applied at GS25 (2963 lbs ac^{-1}), 30lbs of N applied at both GS25 and GS30 (2920 lb ac^{-1}), 30lbs of N applied at GS25 (2855 lbs ac^{-1}), and the split application of 30lbs of N applied at GS25 and 90lbs of N applied at GS30 (2775 lbs ac^{-1}).

All of the treatments had moistures above 14%, necessary for optimal grain storability, and therefore all treatments had to be dried down. The treatment with the highest test weight was 30lbs of N applied at GS25 (52.2 lbs bu^{-1}). None of the treatments attained the optimal 56 to 60 lb bu^{-1} test weight for wheat. The addition of nitrogen to winter wheat at GS25, GS30, or both (split applications) increased protein content compared to the unamended control. The treatment with the highest protein level was the split application of 30lbs GS25 and 90 lbs of N applied at GS30 (Table 5; Figure 3). Split applications or single applications where at least 90lbs of N were applied had the greatest impact on protein content. These treatments had protein levels that met industry standards of 12-15%.

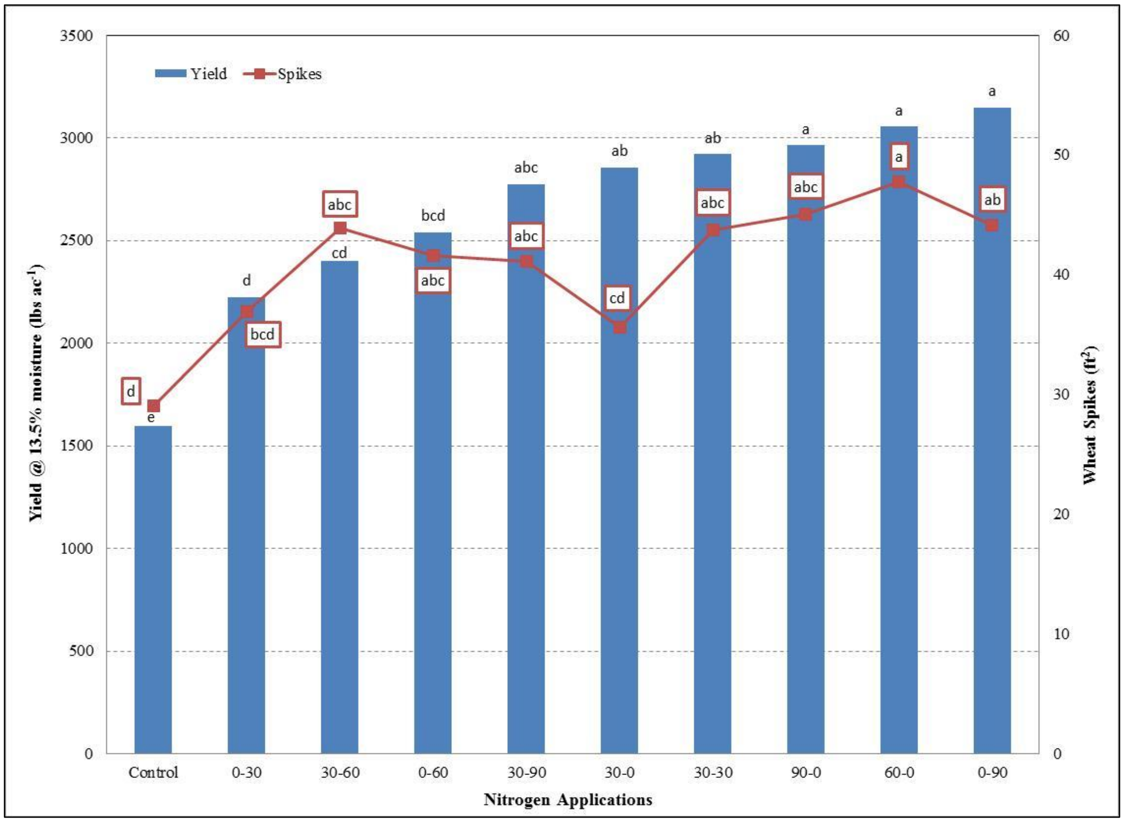

Figure 1. Comparison of the impact of topdressing N at critical wheat developmental stages on yield and spike counts, Northfield, MA.
Treatments with the same letter did not differ significantly.

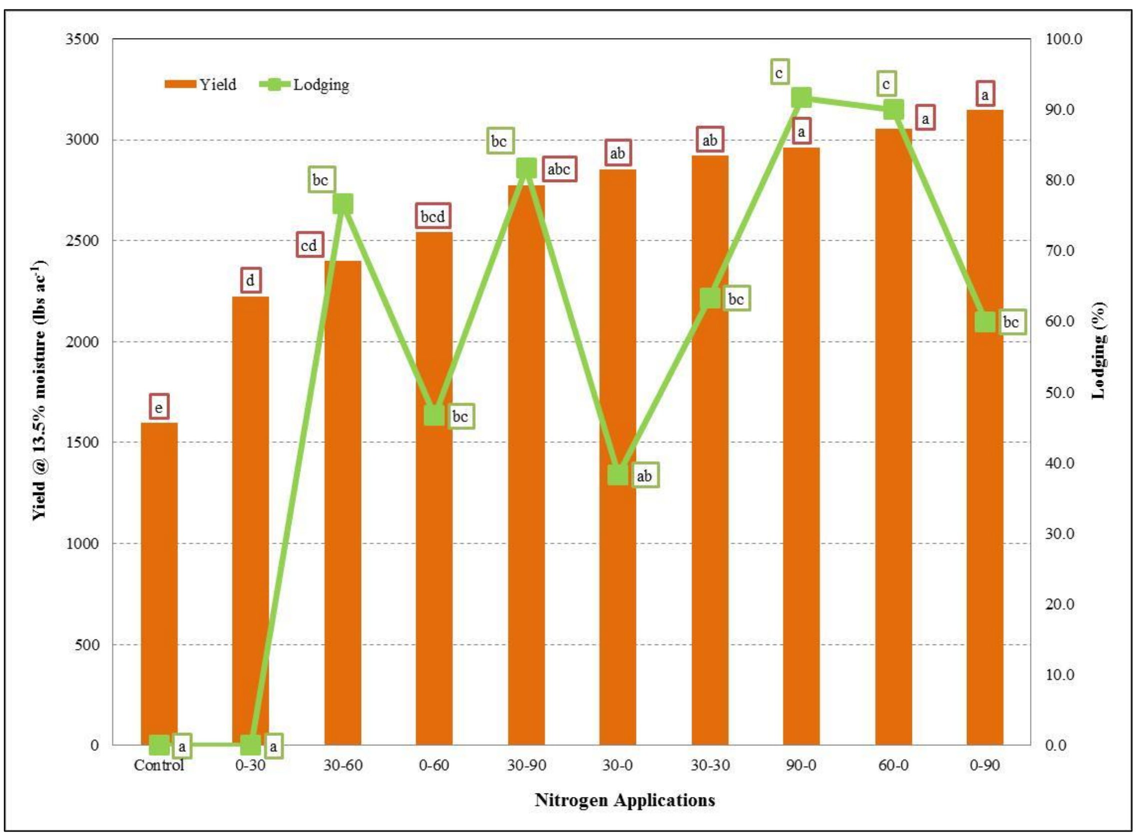

Figure 2. Comparison of the impact of topdressing N at critical wheat developmental stages on yield and percent lodging, Northfield, MA.
Treatments with the same letter did not differ significantly.

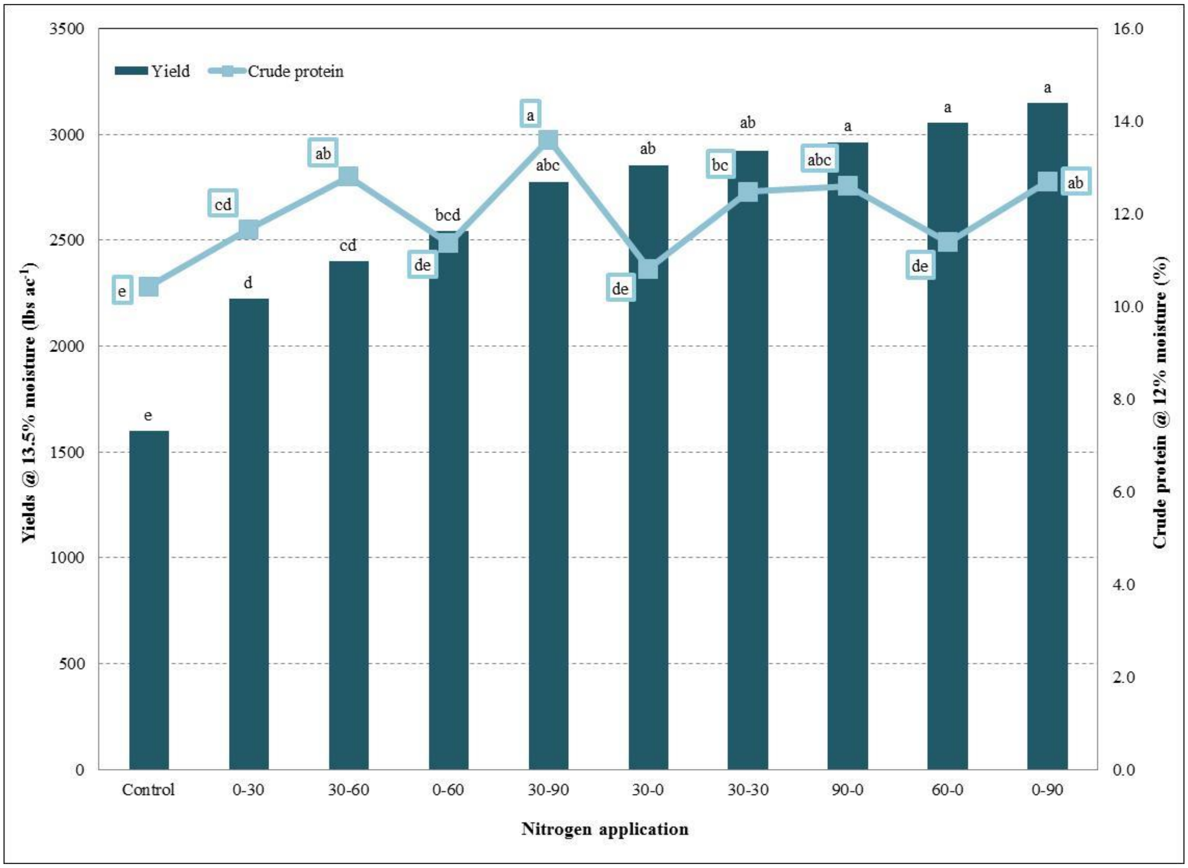

Figure 3. Comparison of the impact of topdressing N at critical wheat developmental stages on yield and protein concentration, Northfield, MA.
Treatments with the same letter did not differ significantly.

DISCUSSION

It's important to remember these results are from one year of data collection. The average winter wheat tiller count was 71 at Four Star Farms. Using the Virginia Coop Extension's N management tool, 40lbs of N is the recommended topdress at spring green-up (GS25) (Figure 4). However, this year's trial results indicate that adding 60lbs or more N had a greater impact on increasing grain yields.

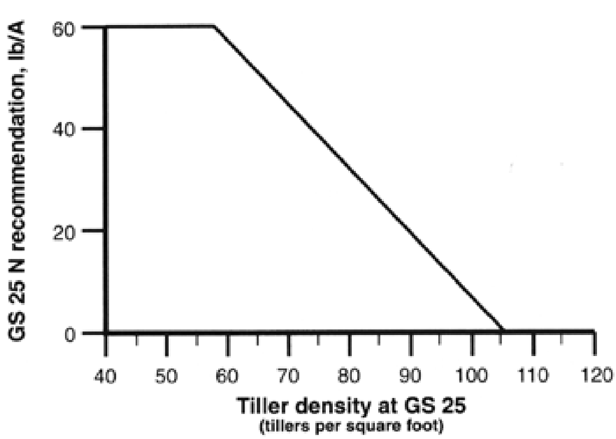

Figure 4. Nitrogen recommendation for the first application in a split based on tiller density.
From "N Management for Winter Wheat: Principles and Recommendations,"
Virginia Coop Extension.

Split applications or a single application (GS25 or GS30) of 90lbs or greater of nitrogen significantly influenced grain protein concentrations. The treatment with the highest protein level was 3.4% higher than the unamended control (10.4%).

Using the tiller counts to guide N applications for winter wheat could be useful, but more trial sites and years are required to better estimate critical tiller numbers. In addition, more research needs to be done on the timing and rate of nitrogen topdressing to increase winter wheat protein concentrations. One year of data is not adequate to confidently recommend that farmers begin changing fertility practices. Therefore, we intend to establish additional on-farm trials on winter grains in 2015.

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