Applying Liquid Nitrogen In Spring Wheat

Results show highNRG-N has an advantage in terms of protein yield and NUE.

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***Summary:** At both the dryland sites, differences were significant but not statistically at the irrigated site. There were significant differences in yield, protein, protein yield, or nitrogen use efficiency (NUE) associated with fertilizer-to-water-ratio at any of the three experimental sites. Agronomically speaking, highNRG-N is a proprietary fluid product having an analysis of 27-0-0-1S derived from ammonium nitrate, urea, and ammonium sulfate offering an advantage in terms of protein yield and NUE in spring wheat production in Montana.*

Wheat is the principal food grain produced in the United States. Nitrogen (N) is the nutrient that most commonly limits wheat yield and quality. Nitrogen use efficiency is currently only about 40 percent. A considerable increase from the previously estimated 33 percent NUE in the late 1990s is primarily due to advance in nutrient management strategies and cutting edge technologies. Development of efficient N management and improving N recommendations are fundamental issues that must be addressed to maintain or increase the sustainability of wheat production in the future.

While spring wheat's primary value is its quality, represented by high grain protein content, N is vital to both yield and protein production. When evaluating NUE in spring wheat, combining yield and protein into protein yield parameter (calculated as a product of grain yield and percent grain protein) makes sense. Protein yield enables us to calculate the efficacy of a particular treatment (such as fertilizer product or application method) from the perspective of producing a better return on the investment via optimizing grain yield and quality simultaneously.

Foliar application of fluid fertilizer to wheat is not a new concept. The renewed interest of wheat producers in foliar fertilization is partially due to active promotion of fluid products as more efficient when compared to the more traditionally dry granular fertilizers.

Foliar mechanisms

Plants are known to take up water and various nutrients through foliage. Previous studies show that leaf stomata facilitate mineral nutrient uptake. Foliar fertilization can assist in correcting deficiencies or preventing nutrient shortages during critical growth stages due to rapid nutrient absorption and utilization. However, unlike roots, plant leaves are not adapted to attain substantial volumes of nutrients to meet the bulk of nutrient requirements. Research has shown that foliar nutrition has four distinctive consecutive steps:

- Adsorption (adherence to the leaf's surface)
- Movement through the leaf's surface
- Absorption (cellular compartmentalization)
- Translocation and utilization by the plant.

Studies on Bermuda grass, winter wheat, and spring wheat have shown that between 25 and 55 percent of foliar-applied N is taken up through the leaves. The average reported N uptake efficiency is about 30 percent.

It is common practice to blend nutrients into one complex foliar mix. In some cases, one nutrient may enhance or inhibit the uptake of another nutrient; thus, interaction among the nutrients must be taken into account.

Finally, studies demonstrate that foliar fertilizers are likely to be cost effective if the price of foliar products is no more than 15 percent higher than traditional granular fertilizer sources such as urea.

Potential/challenges

Some of the appeal of foliar fertilization, according to market media, includes:

- Immediate benefits
- Prolonged flowering
- Increased yields

- Enhanced growth during dry spells
- Increased cold and heat tolerance
- Increased pest and disease resistance
- Maximized plant health and quality
- Improved internal circulation of the plant.

Foliar application also helps to minimize N mineralization, denitrification, runoff, and leaching--the pathway of loss association with soil-applied fertilizer. It has been suggested that foliar-applied N is readily taken up, translocated, and utilized. Lower risk of N loss and effective N uptake imply that smaller quantities of fertilizer could be sufficient to satisfy crop N requirements and to effectively correct N deficiency mid-season.

Some research results suggest that foliar fertilization could be up to 20 times more efficient than soil application. From the point of view of practicality, the majority of foliar N fertilizers is easy to transport, store, and calibrate. Furthermore, they are compatible with many other fertilizers and chemicals such as herbicides. Combined application of premixed chemicals saves time, labor, and money.

Many studies indicate that foliar fertilization is most useful when soil conditions limit nutrient availability. For example, alkaline soils do not readily release most metallic nutrients such as iron (Fe), manganese (Mn), and zinc (Zn). Foliar application has been successfully used to effectively alleviate these micronutrient deficiencies. Nitrogen is a macronutrient needed in much larger quantities compared to micronutrients. Nitrogen is a highly mobile element, both in the soil and within the plant. Some scientists point out that application of N to the soil targeting root uptake makes much more sense, because leaves may not be able to take up N in amounts adequate to satisfy the entire plant's needs. Furthermore, foliar application of nutrients such as N often results in leaf burn as water evaporates and the fertilizer salts remain behind. Some research suggests that significant ammonia loss may occur following foliar applied N fertilizers, which in fact decreases NUE. Using stream-jet or flood nozzles, mixing the liquid N with additional water, applying less than 65kg N ha-1 per application, and avoiding applications on very warm or very cold windy days were shown to minimize concerns associated with leaf burn.

Foliar N products

Several foliar N fertilizers are currently available on the market. These products vary in analysis and can include N products or mixtures of N plus other macro and micro nutrients. Some of the N foliar fertilizers include:

- Urea ammonium nitrate (UAN)
- Liquid urea (LU)
- NRG

UAN. The most widely used foliar N fertilizer is UAN. Urea ammonium nitrate (28-0-0 or 32-0-0) is a non-pressurized solution that can be used in a variety of application practices. The liquid mix of UAN has been on the market for a long time. It provides a fast acting and long-lasting plant nutrient supply in a combination of three forms of nitrogen:

"Highest NUE achieved with high NRG-N"

- Nitrate-N provides quick response
- Ammonia-N provides a longer lasting response
- Organic N in urea provides sustained feeding.

However, foliar application of UAN has been recognized as the least recommended option for N application by some researchers. Early in the growing season, foliar application of UAN may cause leaf burn, but mid- and late-season applications can reduce grain yields due to burn injury caused to leaves.

Liquid urea is a water-based urea solution (20-0-0). LU's proposed benefits include: slower uptake by the plant, which helps to maintain N levels within the soil plant system. LU is recommended for application during the warm growing months of the year for rapid correction of N deficiency. Research on foliar application of LU to crops is very limited. Generally, it is noted that where dry urea functions effectively, LU should perform equally well or better due to having the advantage of higher uniformity over some dry urea sources.

NRG is a proprietary fluid product having an analysis of 27-0-0-1S derived from ammonium nitrate, urea, and ammonium sulfate. Additionally, it is said to include trace amounts of secondary/micronutrients as well as proprietary flavonol technology.

Montana study

The primary reason for foliar N fertilization in wheat is increased grain yield and improved quality-increased grain protein content. As noted earlier, protein yield represents an important parameter for evaluation of NUE in spring wheat. Previous studies in wheat showed that protein content was increased from 11 to 21 percent and from 15 to almost 17 percent.

Most success in protein increase has been reported when foliar application was done just before or immediately after flowering. Many wheat growers are already using foliar products or considering including them as a part of their nutrient management plan. These producers are in need of up-to-date and unbiased information about currently marketed foliar N fertilizers.

Our study aimed to answer the following questions:

- Are LU and NRG agronomically and economically superior to UAN in improving spring wheat grain yield and protein content?
- What is the optimum dilution ratio of foliar fertilizers and the threshold at which spring wheat grain yield is reduced to leaf burn?

The field study, funded by Montana Fertilizer Tax Advisory Committee, was initiated in the spring of 2012. Three experimental sites were established:

- Two dryland, one at Western Triangle Agricultural Research Center (WTARC) near Conrad, MT, and another in a cooperating producer's field (Jack Patton, Choteau County, MT)
- One irrigated at Western

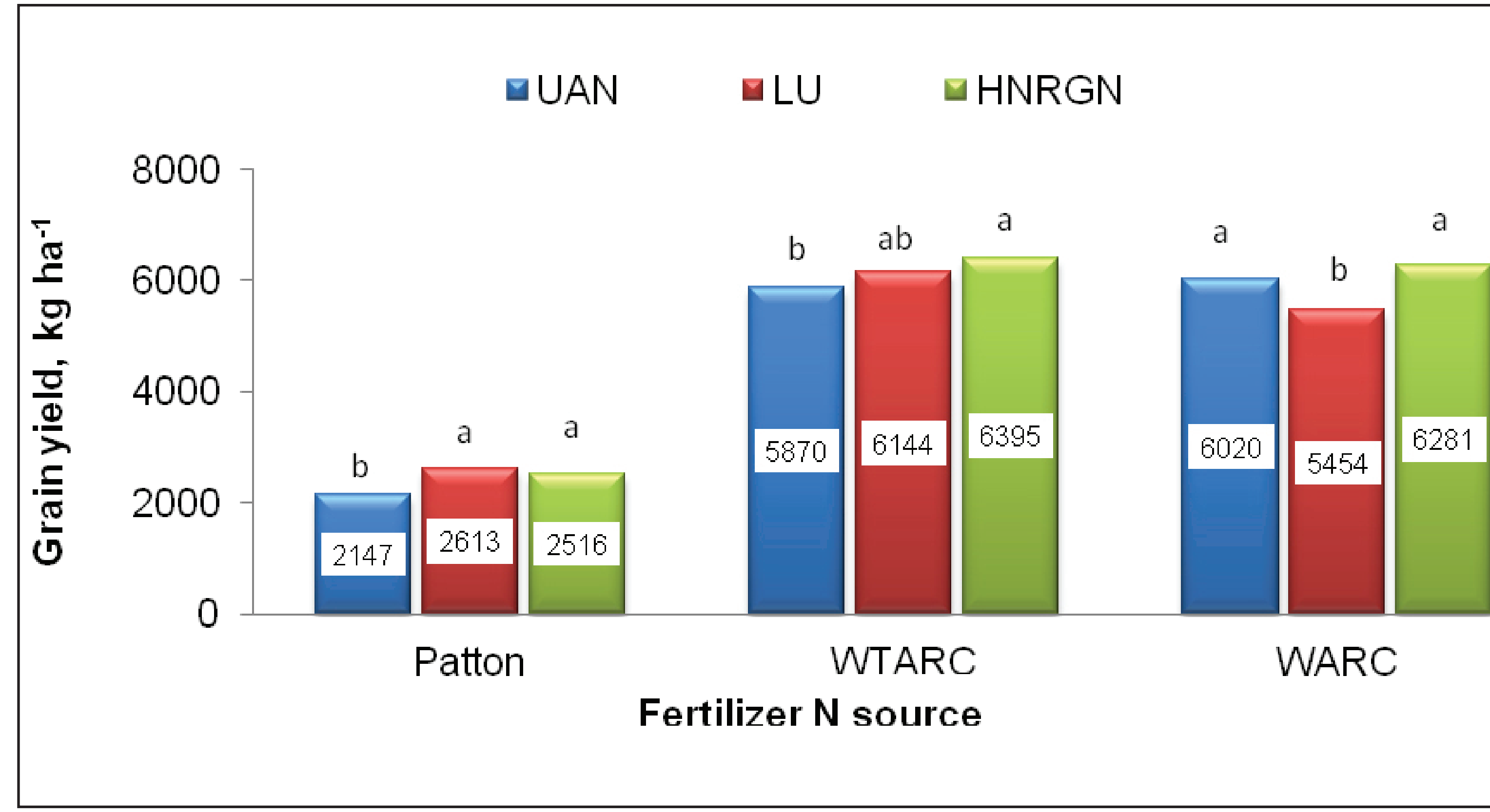

Figure 1. *Fertilizer N source effect on spring wheat grain yield, Patton, WTARC, and WARC, 2012. The means in the same group followed by the same letter are not significantly different, p<0.05.*

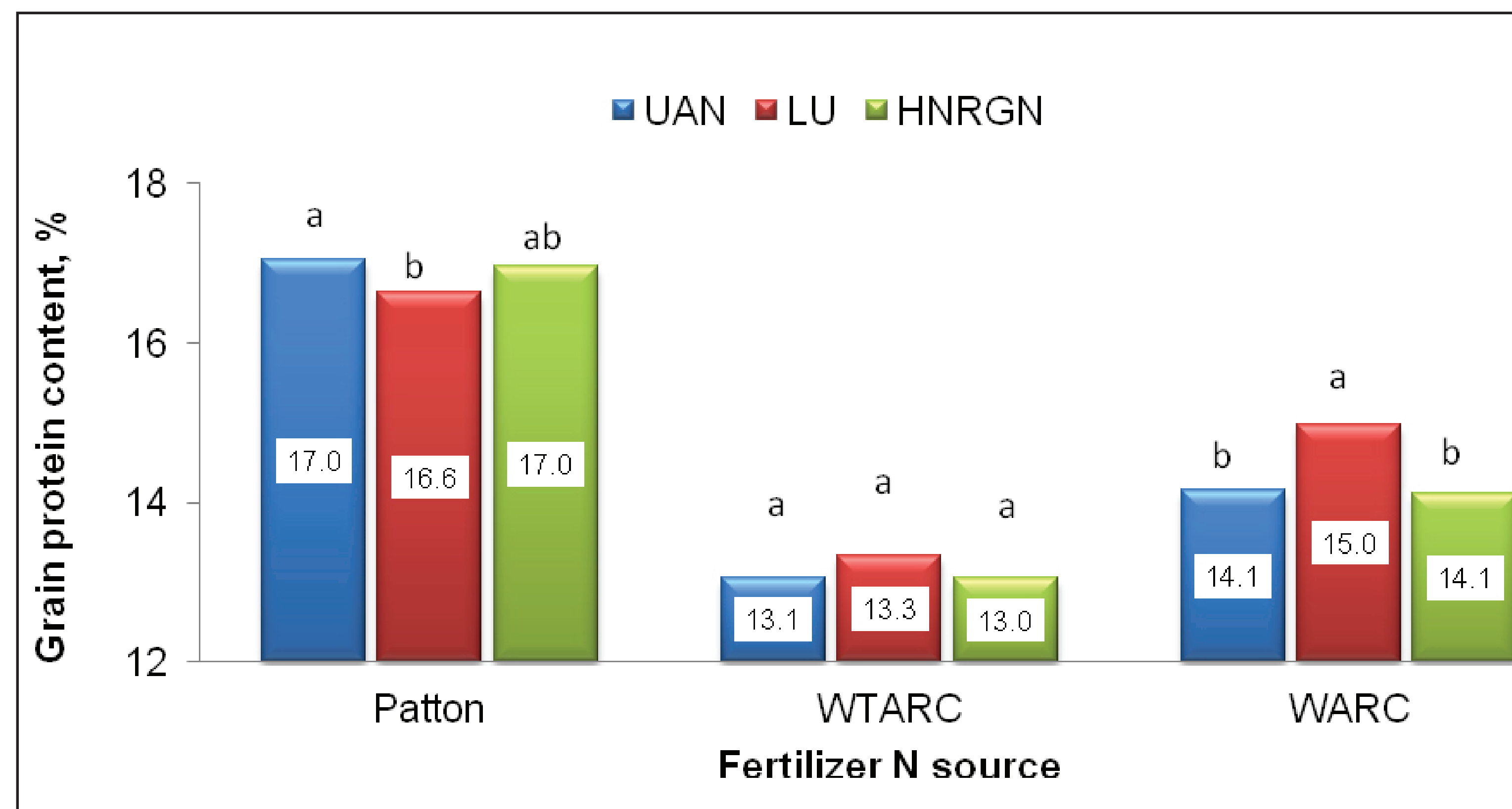

Figure 2. *Fertilizer N source effect on spring wheat grain protein content, Patton, WTARC, and WARC, 2012. The means in the same group followed by the same letter are not significantly different, p<0.05.*

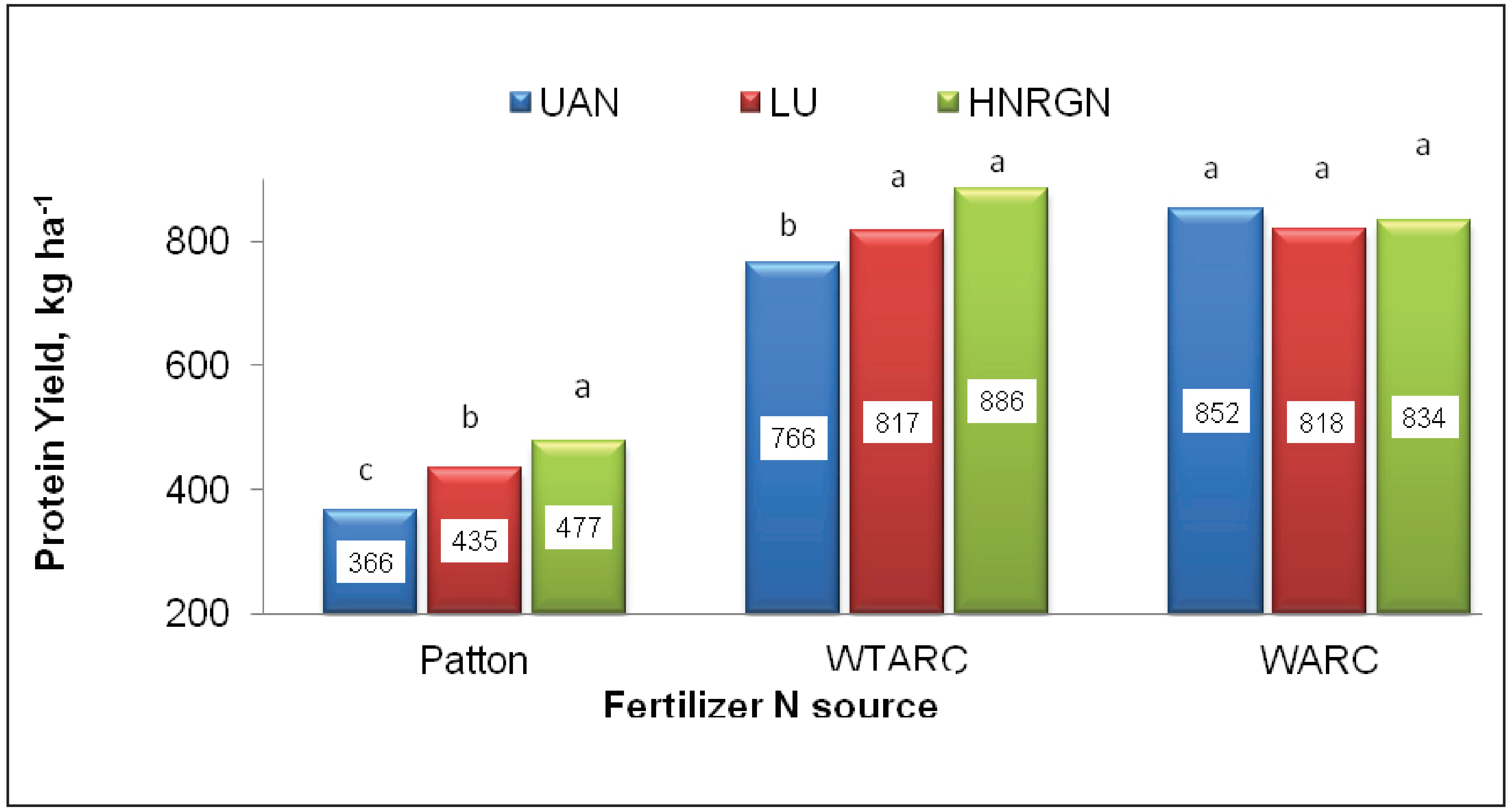

Figure 3. *Fertilizer N source effect on spring wheat protein yield, Patton, WTARC, and WARC, 2012. The means in the same group followed by the same letter are not significantly different, $p<0.05$.*

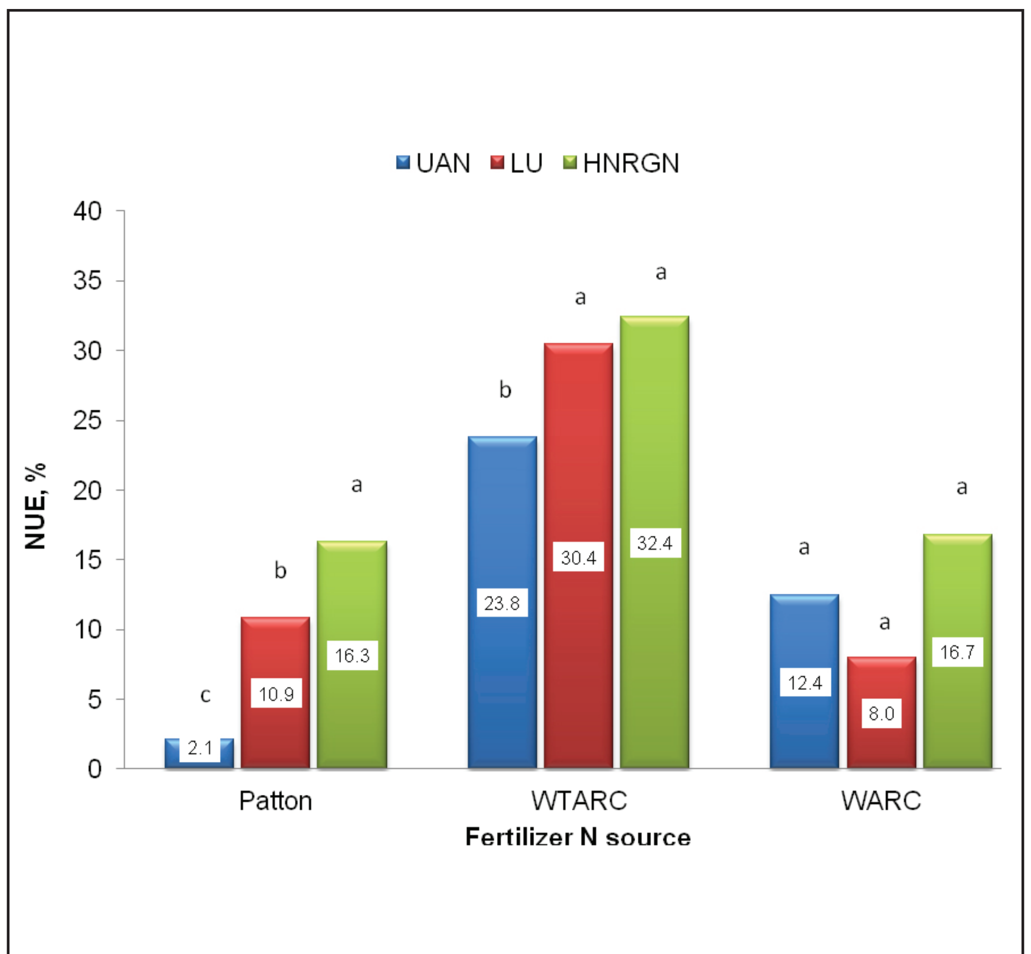

Figure 4. *Fertilizer N source effect on NUE, Patton, WTARC, and WARC, 2012. The means in the same group followed by the same letter are not significantly different, $p<0.05$.*

Agricultural Research Center (WARC) near Corvallis, MT using Choteau spring wheat.

At each location, treatment structure reported in Table 1 was employed. Treatment 1 was established as an unfertilized check plot. Preplant N rate of 90 kg N ha-1 was applied as side-banded urea. At growth stage Feekes 5, topdress N was foliar-applied with an ATV-mounted stream bar sprayer using three N sources: UAN, liquid urea, and NRG.

Topdress rate of 45 kg N ha-1, and 3 dilution rations of 100/0, 66/33, and 33/66 (fertilizer %/water %) were evaluated. Because NRG contains S, Fe, Mg, Mn, and Zn, soil analysis was used to ensure that any one of these nutrients is not deficient and can be corrected prior to topdress application.

Each treatment was replicated four times.

Plot size was 1.5 m by 7.6 m.

Grain yield and protein content were determined at harvest.

Nitrogen use efficiency was determined using "the difference method" by deducting the total N uptake in wheat from the

Table 1. Treatment, structure & mean spring wheat grain yield, Patton WTARC & WARC 2012

Trt	Preplant N Fertilizer (urea) Rate, kg N ha^{-1}	Top-dress N Fertilizer Source	Topdress N Fertilizer Rate, kg N ha^{-1}	Topdress N Fertilizer/ Water Ratio, %	Mean spring wheat grain yield, kg ha^{-1}		
					PATTON	WTARC	WARC
1	0	-	-	-	2526 (bcd)	5370 (c)	5625 (abc)
2	90	UAN	45	100/0	2120 (ed)	5971 (ab)	6008 (abc)
3	90	UAN	45	66/33	2234 (cde)	5804 (bc)	5706 (abc)
4	90	UAN	45	33/66	2087 (e)	5834 (bc)	6346 (ab)
5	90	LU	45	100/0	2575 (bc)	6038 (ab)	5404 (c)
6	90	LU	45	66/33	2579 (bc)	6190 (ab)	5414 (bc)
7	90	LU	45	33/66	2687 (ab)	6204 (ab)	5543 (abc)
8	90	HNRGN	45	100/0	2812 (ab)	6375 (ab)	6415 (a)
9	90	HNRGN	45	66/33	2611 (bc)	6363 (ab)	6283 (abc)
10	90	HNRGN	45	33/66	3029 (a)	6448 (a)	6144 (abc)

The means in the same column followed by the same letter are not significantly different, $p<0.05$.

Table 2. Mean spring wheat grain protein content & protein yield, Patton WTARC & WARC

Trt	Mean spring wheat grain protein content, %			Mean spring wheat protein yield, kg ha^{-1}		
	PATTON	WTARC	WARC	PATTON	WTARC	WARC
1	13.8 (c)	10.8 (c)	13.4 (f)	349 (d)	579 (b)	754 (b)
2	17.2 (a)	12.8 (b)	14.4 (bcde)	365 (d)	764 (a)	862 (ab)
3	16.8 (ab)	13.2 (ab)	13.9 (def)	376 (cd)	769 (a)	792 (ab)
4	17.0 (ab)	13.1 (ab)	14.2 (cde)	355 (d)	766 (a)	901 (ab)
5	16.7 (ab)	13.2 (ab)	15.1 (a)	430 (bc)	800 (a)	817 (ab)
6	16.8 (ab)	13.7 (a)	15.0 (ab)	433 (bc)	845 (a)	809 (ab)
7	16.5 (b)	13.1 (ab)	14.9 (abc)	442 (b)	810 (a)	823 (ab)
8	16.9 (ab)	13.1 (ab)	13.8 (ef)	475 (ab)	833 (a)	882 (ab)
9	17.1 (a)	13.2 (ab)	14.6 (abcd)	447 (b)	841 (a)	916 (a)
10	16.8 (ab)	12.9 (b)	14.0 (def)	510 (a)	829 (a)	859 (ab)

The means in the same column followed by the same letter are not significantly different, $p<0.05$.

Table 3. Mean spring wheat N uptake & NUE, Patton WTARC & WARC 2012

Trt	N Uptake, kg N ha^{-1}			NUE, %		
	PATTON	WTARC	WARC	PATTON	WTARC	WARC
1	60 (d)	99 (b)	129 (b)	-	-	-
2	63 (d)	131 (a)	148 (ab)	2.1 (d)	23.5 (a)	13.8 (a)
3	65 (cd)	132 (a)	136 (ab)	3.4 (cd)	24.1 (a)	4.8 (a)
4	61 (d)	131 (a)	155 (ab)	0.8 (d)	23.8 (a)	18.7 (a)
5	74 (bc)	137 (a)	140 (ab)	10.2 (bc)	28.1 (a)	8.1 (a)
6	74 (bc)	145 (a)	139 (ab)	10.6 (bc)	33.8 (a)	7.1 (a)
7	76 (b)	139 (a)	141 (ab)	11.8 (b)	29.4 (a)	8.8 (a)
8	81 (ab)	143 (a)	151 (ab)	15.9 (ab)	32.2 (a)	16.3 (a)
9	77 (b)	144 (a)	157 (a)	12.4 (b)	33.3 (a)	20.6 (a)
10	88 (a)	142 (a)	147 (ab)	20.5 (a)	31.8 (a)	13.3 (a)

The means in the same column followed by the same letter are not significantly different, $p<0.05$.

N-unfertilized treatment (check plot) from total N uptake in wheat from fertilized plots, and then divided by the rate of N fertilizer applied.

Grain N uptake was calculated by multiplying grain yield by total N concentration. Grain yield, grain protein content, protein yield, N uptake, and NUE were evaluated using statistical procedures. While similar grain yields were obtained with LU and NRG at dryland sites, lowest yields occurred with UAN.

At the irrigated site, UAN and NRG produced similar yields and the lowest yields were obtained with LU (Figure 1).

"NRG is proprietary fluid product"

There was no apparent trend in grain protein content associated with fertilizer N source (Figure 2).

At both dryland sites, high protein yields were observed with NRG, while at the irrigated site all three fertilizer N sources performed similarly (Table 2, Figure 3).

At all three sites, highest NUE was achieved with NRG (Table 3, Figure 4). The differences were significant at both dryland sites, and substantial, while not statistically significant, at the irrigated site.

Summing up

Overall, the results indicated that from the agronomic point of view, NRG has an advantage in terms of protein yield and NUE in spring wheat production in Montana. This project will be conducted for one more growing season at three experimental locations to verify these preliminary findings.

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