# FOLIAR-APPLIED NITROGEN FERTILIZERS IN SPRING WHEAT PRODUCTION

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Some research results indicated that application of nitrogen (N) fertilizer to the leaves is more efficient because the many possible pathways for N loss associated with the application of nutrients to the soil are avoided (Mosali et al., 2006). The primary incentive for foliar N fertilization in wheat is improved quality – specifically increased protein content in grain. Previous studies in winter wheat showed that protein content was increased from 10.8% to 21% (Finney et al., 1957) and from 14.9% to 16.5% (Woolfolk et al., 2002). Most success in protein increase is reported when foliar application was done just prior to flowering (Woolfolk et al., 2002) or immediately post flowering (Gholami et al.,

2011; Blandino and Reyneri, 2009). Many wheat growers in the Great Plains who are using or considering using foliar products are in need of up-to-date and unbiased information on marketed foliar N fertilizers. When evaluating use efficiency of spring wheat production systems, combining yield and protein into protein yield, as proposed by Jackson (2001) makes sense because N is vital to both yield and protein production.

This study aimed to answer the following questions: 1) Are liquid urea (LU) (20-0-0) and highNRG-N (27-0-0-1) superior to urea ammonium nitrate (UAN) (28-0-0) in improving spring wheat grain yield, grain protein content, and protein yield; and 2) What is the optimum dilution ratio of foliar fertilizers and the threshold at which spring wheat grain yield is reduced due to leaf burn. The field study was

# USING ZINC TO REDUCE CADMIUM IN DURUM GRAIN

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Cadmium (Cd) is a nonessential heavy metal that can cause kidney problems. Diet is the main source of Cd for nonsmokers, with cereal products, including pasta, accounting for up to 20% of the daily intake of Cd. The current official standard for maximum level of Cd in durum wheat grain as stated by the Codex Alimentarius Commission is 0.2 ppm. The European Union has

adopted this level as the maximum allowed in domestic and imported durum, and may lower their accepted level to 0.15ppm. Other durum buyers may also adopt this level.

Cadmium is found naturally in some soils, and is a contaminant of some phosphorus fertilizers. Durum grown on soil with lower pH takes up more Cd than durum grown on soil with higher pH. Higher soil salinity as measured by chloride content can also cause increased Cd uptake.

Accumulation of Cd in durum grain is caused by a single recessive gene. By chance, most durum genotypes grown in Montana accumulate Cd in the grain. Breeding programs in the United States and Canada are developing durum varieties with the low Cd accumulation trait, but until those varieties are readily available, management practices that reduce Cd in durum grain will be useful to durum producers to make their crop more attractive

to European and other foreign markets.

This study was grown at two experimental sites, one dryland and one irrigated, at the Eastern Agricultural Research Center. Nitrogen and phosphorus were applied uniformly as determined by soil tests. Two varieties of durum were used, one that accumulates Cd in the grain (Alzada) and one that does not (Strongfield).

Treatments were:

1) Zinc (Zn) applied with the seed in the form of zinc sulfate at a rate of 1 lb. Zn/ac.;

2) Zn applied with the seed in the form of zinc sulfate at a rate of 1 lb. Zn/ac. plus Zn applied foliarly at the boot stage as chelated Zn at a rate of 1 gal./ac.;

3) no applied Zn.

There were four replications of each treatment. At harvest, durum grain was measured for yield, quality, and content of Cd and Zn in the grain.

Data were analyzed across three years for each site. The Zn treatments had no effect on grain yield, test weight or grain protein content on either the dryland or irrigated sites (Table 1). Zinc applied with the seed had no effect on grain Cd or Zn content. Chelated Zn ap-

plied foliarly at the boot stage reduced grain cadmium content by about 25% at the dryland site and by about 13% at the irrigated site. Grain Cd content was reduced in the variety with the low accumulation gene, Strongfield, by the same percentage as the reduction of grain Cd in Alzada, the variety with high accumulation.

Irrigation and rain water were collected throughout the growing season. In two years, rain water was rather acidic, with average pH values of 5.87 and 6.18. The pH of rain water was 7.19 in the third year. Average pH of irrigation water in all three years was about 7.8. Irrigation water had 1.5 to 2 times as much chloride as rain water.

Zinc treatments did not affect pH, Zn, chloride or Cd content of the soil following harvest. The irrigated site had higher pH and greater chloride and cadmium content in the top six inches than the dryland site. The lower pH of the dryland soil probably contributed to the higher Cd content of the grain under the dryland condition. The low pH of the rain water contributed to the lower pH of the dryland soil, while the more alkaline irrigation water contributed to a higher soil pH at the irrigated site.

**Table 1. Grain yields, test weights, grain protein, grain cadmium and zinc contents of durum grown at the dryland and irrigated sites and averaged across three years (2007-2009).**

| Treatment | variety | % grain protein | test wt, lb/bu | yield, bu/ac | Cd, ppm | Zn, ppm | % grain protein | test wt, lb/bu | yield, bu/ac | Cd, ppm | Zn, ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Dryland site** | | | | | | **Irrigated site** | | |
| Zn with seed | | 14.1 | 60.8 | 46.1 | 0.248b | 23.6a | 15.8 | 60.4 | 74.6 | 0.196b | 31.4a |
| Zn with seed + foliar Zn | | 14.0 | 60.6 | 45.0 | 0.177a | 26.0b | 15.7 | 60.3 | 76.4 | 0.158a | 34.4b |
| No Zn | | 14.1 | 60.9 | 44.7 | 0.245b | 22.9a | 15.7 | 60.5 | 78.3 | 0.182b | 30.5a |
| LSD 0.05 | | ns | ns | ns | 0.038 | 1.2 | ns | ns | ns | 0.025 | 2.0 |
| | Alzada | 13.7a | 60.9 | 44.8 | 0.290b | 23.8 | 15.4a | 60.2a | 73.1a | 0.217b | 31.9 |
| | Strongfield | 14.4b | 60.6 | 45.8 | 0.157a | 24.6 | 16.0b | 60.6b | 79.8b | 0.141a | 32.3 |
| LSD 0.05 | | 0.3 | ns | ns | 0.031 | ns | 0.2 | 0.3 | 4.6 | 0.021 | ns |

Different letters in the same column indicate significant difference at p <0.05. ns indicates no significant difference.

# *Foliar-Applied Nitrogen Fertilizers, cont. from pg 1*

initiated in spring of 2012 using Choteau spring wheat. Three experimental sites were established: One dryland site at Western Triangle Agricultural Research Center (WTARC) (near Conrad, MT), one dryland site in a cooperating producer's field (Jack Patton, Knees, MT), and one irrigated site at Western Agricultural Research Center (WARC) (near Corvallis, MT). Preplant N rate of 80 lb N ac$^{-1}$ was applied as sidebanded urea. At growth stage Feekes 5, topdress N was foliar applied utilizing an ATV-mounted stream bar sprayers (Figure 1) using three N sources – UAN, liquid urea, and highNRG-N. All foliar N treatment were applied at the same topdress rate of 40 lb N ac$^{-1}$. Three dilution ratios were evaluated (100/0, 66/33, and 33/66 (% fertilizer / % water). Each treatment was replicated 4 times in a randomized complete block design.

There were no differences in yield of protein content associated with the ratio of product/water at any of experimental sites. The UAN treatment produced significantly lower yields than highNRG-N at both dryland sites and significantly lower yields than liquid urea (LU) at the Conrad dryland site (Figure 2). At the irrigated site, the LU treated plots produced significantly lower yields than UAN and highNRG-N (Figure 2). Liquid urea treatment produced significantly higher grain protein content in comparison to highNRG-N and UAN at the irrigated Corvallis site, yet produced significantly lower grain protein contents in comparison to these same treatments at the Knees dry-

**Figure 1.** Applying foliar N fertilizers to spring wheat plots using an ATV-mounted stream bar sprayer, Western Triangle Agricultural Research Center, Conrad, MT, 2012.
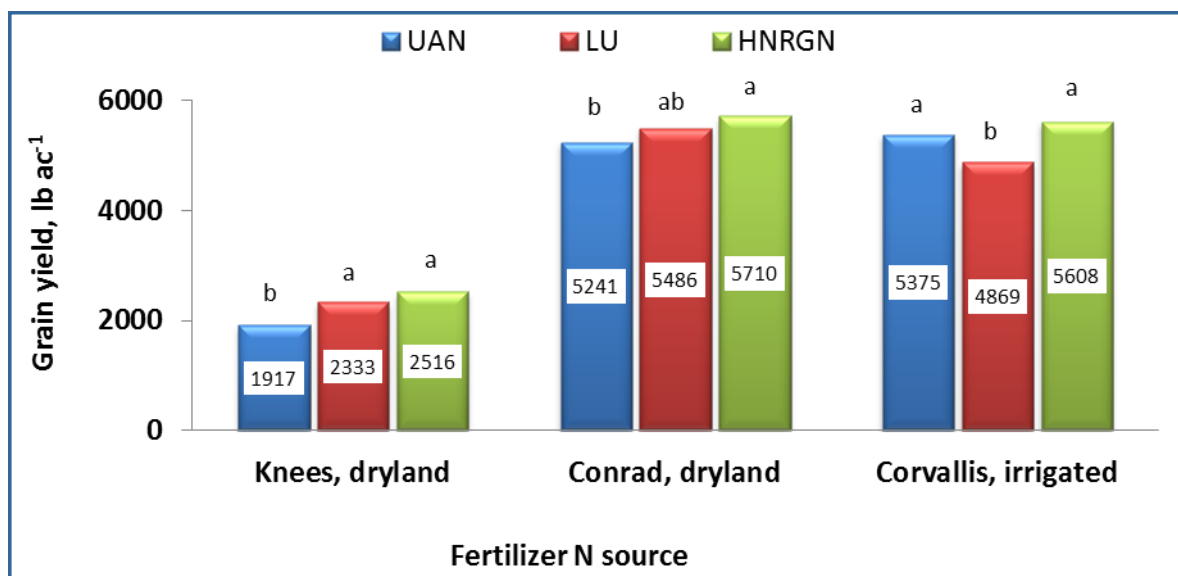




**Figure 2.** Fertilizer N source effect on spring wheat grain yield, Knees, Conrad, and Corvallis, 2012.

land site (Figure 3). At both dryland sites, highNRG-N protein yields were significantly higher than UAN protein yields, while all three fertilizer N sources performed similarly at the irrigated site (Figure 4). Nitrogen use efficiency (NUE) was significantly greater for LU and highNRG-N treated plots than UAN treated plots at both dryland sites, while there was no significant N source effect on NUE at the irrigated site (Figure 5). Overall, the results indicated that in dryland environments, in-season applications of highNRG-N or LU may produce better yields and a have higher NUE than UAN for spring wheat grown when applied at the same N rate, while in an irrigated environment, there does not appear to be a clear difference between these three products. This project is being conducted for one more growing season (2013) at the same experimental locations to verify these preliminary find-ings.
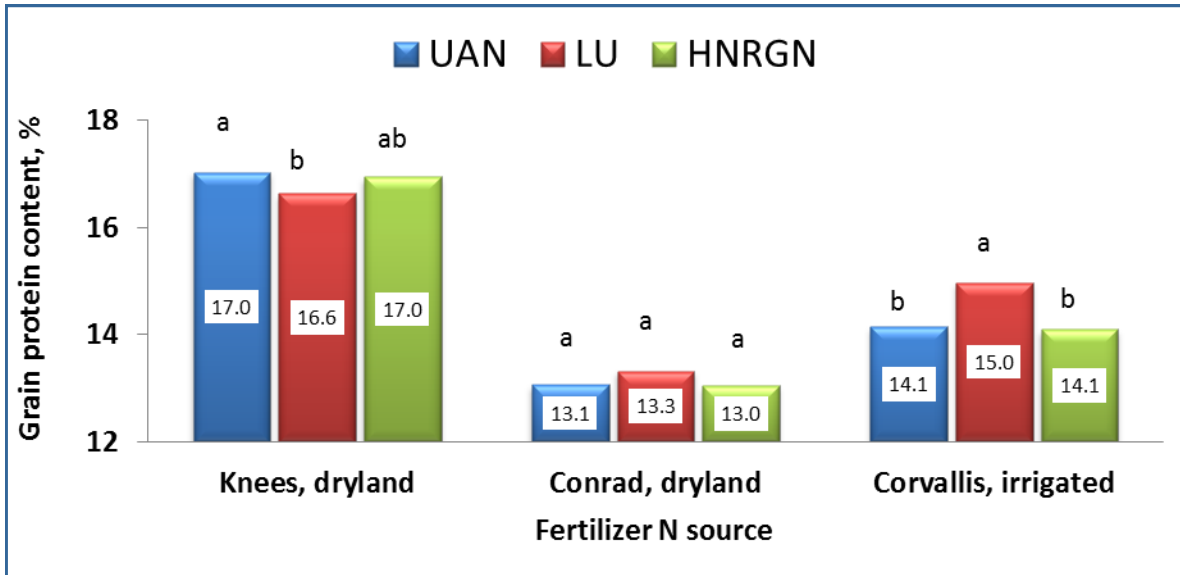
**Figure 3.** In-season N source effect on spring wheat grain protein content at three locations in Montana in 2012. UAN – Urea Ammonium Nitrate. LU – Liquid Urea. HighNRGN – Specialty foliar N product. All sources applied at a rate of 40 lb N ac$^{-1}$.



**Figure 4.** In-season N source effect on spring wheat protein yield at three locations in Montana in 2012. UAN – Urea Ammonium Nitrate. LU – Liquid Urea. HighNRGN – Specialty foliar N product. All sources applied at a rate of 40 lb N ac$^{-1}$.
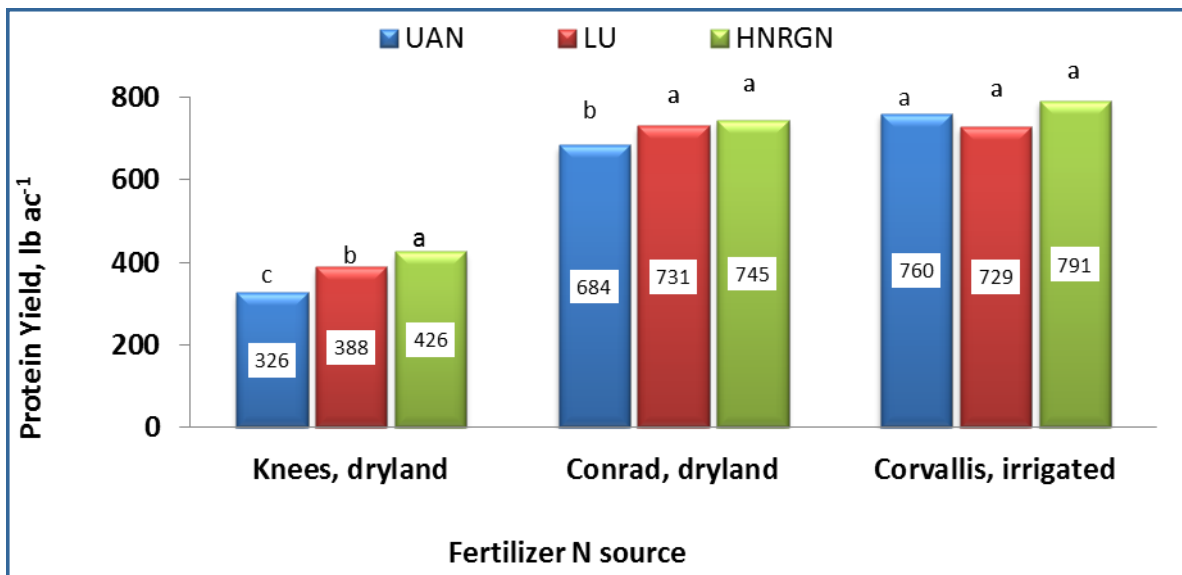
**Figure 5.** Inseason N source effect on nitrogen use efficiency in spring wheat at three locations in Montana in 2012. UAN – Urea Ammonium Nitrate. LU – Liquid Urea. HighNRGN – Specialty foliar N product. All sources applied at a rate of 40 lb N ac$^{-1}$.
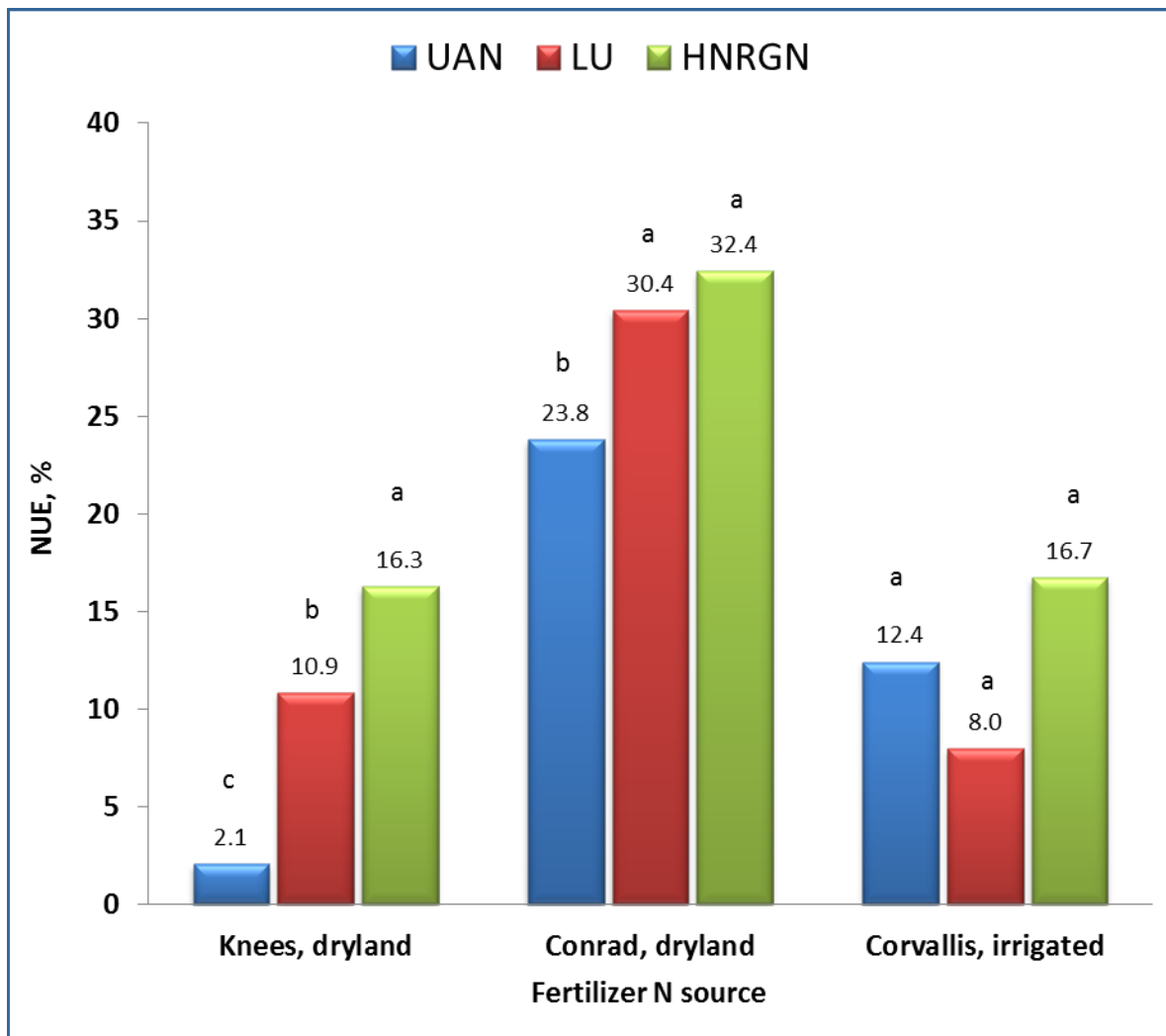
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# Sulfur for Plant Nutrition

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Sulfur is an essential macronutrient for plants and animals, and is required for many important metabolic functions. Plants are able to convert sulfate ($SO_4^{2-}$) into organic compounds, but animals must consume S-containing amino acids (methionine and cysteine) for their dietary requirement. While most S in soils is present in organic matter, soluble sulfate is present in most soils and is the primary source of S nutrition for plants. It is actively transported into the root, especially in the root hair region, and moves into plant cells through a variety of sulfate transporters. Within the plant, sulfate moves in the transpiration stream until it is stored in cell vacuoles or participates in a variety of biochemical reactions. Leaves are also able to assimilate sulfur dioxide ($SO_2$) from the atmosphere, but this amount is usually no more than 1 to 2 lb S/A /yr.

Most of the sulfate taken up by roots is converted to cysteine in leaf chloroplasts. Cysteine is the primary starting point from which most other organic S compounds in plants are formed. This synthesis process begins with sulfate reduction to adenosine phosphosulfate and ultimately to various S-containing organic compounds (Figure 1). Sulfate reduction requires considerable plant energy. Other important S amino acids include the amino acids cystine (a linkage of two cysteine molecules), and methionine (Figure 2). Smaller amounts of S are incorporated into important molecules such as co-enzyme A, biotin, thiamine, glutathione, and sulfolipids.

Once sulfate is converted to organic compounds, they are exported through the phloem to the sites of active protein synthesis (esp. root and shoot tips, fruits and grains) and then become largely immobile within the plant. The symptoms of S deficiency occur first in the younger tissues and are seen as leaves and veins turning pale green to yellow. These chlorosis symptoms look similar to those that occur with N deficiency, but because of its higher internal mobility a low N supply becomes first visible in the older leaves. When S deficiencies are first observed, some crops may not entirely recover the lost growth following S fertilization.

There are a large number of secondary S compounds that provide biochemical benefit to specific plant species. Some crops (e.g. brassicas such as canola and mustard) have a relatively high S requirement and produce glucosinolate compounds. Members of the Allium species (e.g. garlic and onions) produce alliin compounds that may contain >80% of the total plant S. The characteristic flavor and smell of onions and garlic related to these volatile S compounds are enhanced when plants are grown in high S soil. These and other S-containing compounds are linked with resistance to various pests and environmental stress.

**Crop Sulfur Requirement**

Crops differ widely in their S requirement, with plant dry matter concentrations typically between 0.1 and 1% S. The S requirement is typically greatest for brassicas (such as cabbage, broccoli and rapeseed), followed by legumes, and then by cereal grasses.

The S demand will vary during the growing season. For example, S demand for canola is greatest during flowering and seed set. Uptake of S by corn is fairly constant through out the growing season, with grain accounting for >50% of the total S accumulation. Each crop species needs to be examined for its specific nutrient requirement. Removal of S during crop harvest is typically in the range of 10 to 30 lb S/A depending on the crop and yield, but total plant uptake can be as high as 75 lb S/A for some brassica species.

Studies have demonstrated that supplying S to deficient pastures increased yields, N use efficiency, and lowered N losses from the soil. Due to the close linkage between S and N, Schnug and Haneklaus (2005) estimated that one unit of S deficit to meet plant demand can result in 15 units of N that are potentially lost to the environment. They calculated that S deficiencies in Germany might be contributing to an annual loss of over 600 million lb of N (or 10% of the total N fertilizer consumption of the country).

An adequate supply of S is required for sustaining crop yields and quality. Inadequate S will reduce protein synthesis and will result in poor utilization of applied N and less $N_2$ fixation by legumes. Application of the 4R Nutrient Stewardship principles will identify the need for supplemental S to overcome potential limitations to plant nutrition.