



FERTILIZING SMALL GRAINS IN ARIZONA

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Nitrogen Content of Crop

Nitrogen is the primary fertilizer nutrient required by wheat and barley. A wheat crop contains 33 to 37 pounds of nitrogen per 1000 pounds of grain in a range of grain protein from 12 to 14%. A barley crop will contain about 20% less nitrogen than wheat at similar yield levels due to lower grain nitrogen concentration. The actual total amount of nitrogen contained in the crop will vary greatly depending on yield level and protein content of the grain (Table 1).

If high yields are expected or high protein content is desired, the grower needs to increase nitrogen fertilizer rate accordingly. The expected crop nitrogen content and optimum nitrogen fertilizer rate are not identical due to nitrogen that may be available in the soil and water or losses of nitrogen fertilizer that may occur throughout the season.

Sources of Nitrogen

Small grains obtain nitrogen not only from fertilizer, but also from the soil and irrigation water. In a study conducted at the Maricopa Agricultural Center with durum, about half of the nitrogen taken up by the crop was from fertilizer and the remainder was from soil and water (Ottman and Pope, 2000). Pounds of nitrogen per acre in the irrigation water can be calculated by multiplying the parts per million of nitrate-N in the water by 0.226 and by the number of acre-inches per acre of water to be applied. Pounds of nitrate-N per acre in the soil potentially available to the crop at any point in time can be estimated by

multiplying parts per million of nitrate-N in each foot of soil by 4. Estimating the total amount of N the soil contributes to the crop is difficult, because nitrogen will be released from the organic matter and soil minerals and become available to the crop throughout the season, and soil nitrogen availability will vary depending on intrinsic soil properties, weather, and crop management.

As an example, if we assume:

- a wheat crop contains 246 lbs N/acre,
- 240 lb N/acre of fertilizer was applied,
- 42 acre-inches/acre of irrigation water was applied containing 3 ppm nitrate-N, and
- the preplant soil nitrate-N content was 8 ppm in the first foot and 2 ppm in the second, third, and fourth one-foot increments,

then, the contribution of the various sources of N is estimated as follows:

- Fertilizer: 240 lbs N/acre \times 0.5 = 120 lbs N/acre
- Irrigation water: 42 acre-inches/acre \times 0.226 \times 3 ppm nitrate-N = 28 lbs N/acre
- Total soil (by difference): 246 lbs N/acre (crop) – 120 lbs N/acre (fertilizer) – 28 lbs N/acre (water) = 98 lbs N/acre
- Preplant soil nitrate: (8 + 2 + 2 + 2) ppm nitrate-N \times 4 = 56 lbs N/acre

Table 1. Nitrogen content of wheat (grain, straw, and roots) at various grain yield and grain protein levels.

Grain yield lbs/acre	Grain protein (%)		
	12	13	14
	Crop N (lbs N/Acre)		
5000	166	176	185
6000	200	211	222
7000	233	246	259
8000	266	281	296

Assumptions: 1) Grain yield on a 7% moisture basis, 2) Grain protein on a 12% moisture basis, 3) Grain N = grain protein/5.7, 4) Grain yield/total above-ground yield = 0.42 (Ottman et al., 2000; Ottman and Pope, 2000), 5) Straw N = 0.34% (Ottman et al., 2000), 6) Root yield = 0.2 \times total above-ground yield (Rajala and Peltonen-Sainio, 2001), and 7) Root N = 1.5% (Hicks, 1928).

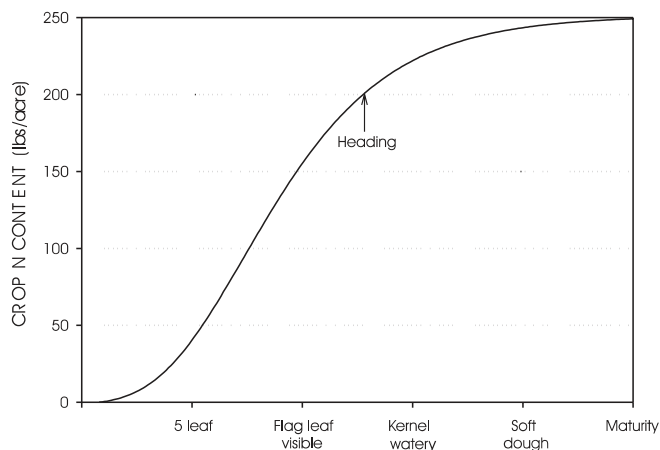


Fig. 1. Generalized small grain N content over the progress of the season.

Optimum Nitrogen Fertilizer Rate

The actual amount of fertilizer nitrogen required for optimum yields varies from 150 to 300 pounds per acre for wheat and 120 to 240 pounds per acre for barley. Additional nitrogen fertilizer is usually needed for wheat after heading to increase grain protein content, but nitrogen fertilizer applied after heading usually does not affect grain yield. Nitrogen fertilizer requirement can be affected not only by yield potential and grain protein content but also by crop residues, soil type, irrigation practices, the efficiency of fertilizer application, and the nitrogen contained in the soil and water. Insufficient nitrogen application reduces grain yield. Excessive nitrogen application increases fertilizer cost, reduces yield, and increases lodging.

Nitrogen Fertilizer Scheduling

Most crop nitrogen uptake occurs between the 5-leaf stage until heading, when crop nitrogen uptake is most rapid (Fig. 1). Therefore, nitrogen fertilizer applications should precede or coincide with crop N needs. Nitrogen applied up to the heading stage has the potential to influence yield, while applications from heading to 2 weeks after flowering will have a minimal effect on yield but can increase protein content of the grain. Nitrogen fertilizer applications can be scheduled ahead of time if approximate irrigation dates are known. An example of a nitrogen fertilizer schedule is contained in Table 2. Excessive

nitrogen applications before planting should be avoided since nitrogen fertilizer efficiency is about 20% less when applied pre-plant compared to during the growing season. However, enough nitrogen fertilizer should be applied pre-plant to supply the crop with nitrogen until the next planned nitrogen application date.

Boosting Grain Protein Content

Durum grain protein content needs to be 13% or greater to meet end-use requirements. Grain protein content of wheat can be increased by nitrogen fertilizer applications between heading and 2 weeks after flowering. Nitrogen fertilizer applications after heading will have minimal effect on grain yield. Thirty pounds of nitrogen per acre applied near flowering will increase grain protein by about 1 percentage point and hard vitreous amber count (HVAC) by 12 percentage points (Table 3). Nitrogen fertilizer application later than 2 weeks after flowering will not increase protein content as effectively as earlier applications. High yielding varieties that tend to have protein levels below 13% are most likely to benefit from late season nitrogen application.

Nitrogen Application Methods

Nitrogen fertilizer can be broadcast, injected into the soil, placed in the irrigation water, or banded with the seed. Rates of banded nitrogen above 30 pounds of nitrogen per acre increase the risk of injury to germinating seedlings. Placement of urea (46-0-0) or diammonium phosphate (18- Table 2. Example of a nitrogen fertilizer schedule for barley (full season) and durum at Maricopa. Fertilizer applications after heading are intended to boost durum grain protein content and are not required for barley. Table 3. The effect of nitrogen fertilizer applied near flowering on yield, protein, and HVAC of durum at Maricopa (Doerge et al., 1989; Doerge and Ottman, 1990, 1991; Ottman et al., 2000). The nitrogen applied before this flowering period averaged 175 lbs N/acre. Grain protein and HVAC are statistically different, but not grain yield. 46-0) with or near the seed is not recommended due to the risk of seedling damage from ammonia toxicity. All types of dry nitrogen fertilizer should be incorporated into the soil or watered in as soon as possible to avoid the risk of loss from volatilization, especially in the case of urea. Response to foliar nitrogen can be quicker than water or soil applied nitrogen, but leaf burn may occur at rates of urea greater than 10 to 20 pounds of nitrogen per acre.

Table 2. Example of a nitrogen fertilizer schedule for barley (full season) and durum at Maricopa. Fertilizer applications after heading are intended to boost durum grain protein content and are not required for barley.

Date	Stage	Fertilizer rate	
		Barley	Durum
		lbs N/acre	
Dec 10	Planting	75	75
Feb 04	5 leaf	40	40
Feb 27	2 nodes	40	40
Mar 16	Pre-boot	40	40
Mar 30	Heading-Flowering	0	30
April 11	Milk	0	30
TOTAL		195	255

Table 3. The effect of nitrogen fertilizer applied near flowering on yield, protein, and HVAC of durum at Maricopa (Doerge et al., 1989; Doerge and Ottman, 1990, 1991; Ottman et al., 2000). The nitrogen applied before this flowering period averaged 175 lbs N/acre. Grain protein and HVAC are statistically different, but not grain yield.

N rate near flowering	Grain Yield	Grain Protein	HVAC
lbs N/acre	lbs N/acre	%	%
0	6818	11.6	79
30	6717	12.7	91
60	6697	13.6	96

Fertilizer Types

A variety of nitrogen fertilizer types can be utilized by wheat and barley. Ammonium forms of nitrogen result in a higher stem nitrate concentration initially than urea or nitrate since ammonium will not leach past the limited root system of the young plant. Nitrate or urea can usually correct a nitrogen deficiency during the season faster than ammonium forms of nitrogen. Aqua or anhydrous ammonia can injure the plants due to ammonia toxicity, particularly on sandy soils.

Soil and Plant Tissue Testing

A combination of pre-plant soil testing and in-season tissue testing is currently recommended by the University of Arizona to guide wheat and barley fertilization. Soil (Table 4) and plant tissue testing guidelines (Table 5) are outlined below. Pre-plant nitrogen application is based on nitrate content of the surface 6 inches of soil. In-season nitrogen applications are based on nitrate content

of the portion of the stem between the seed and soil surface before jointing and, after jointing, on the 2 inches of the stem just above the soil surface. The stems should be collected 7-10 days before a scheduled nitrogen fertilizer application so that the stem nitrate results will be available to guide nitrogen rate decisions. About 25 to 50 stems are necessary to provide a representative sample. Nitrogen fertilizer recommendations are based on the nitrate-N content of an oven-dry stem sample, or a stem sample whose sap has been extracted. The variables that affect optimum nitrogen fertilizer rate, such as soil type, residue, crop growth, etc., are reflected in the nitrate content of the lower stem. A disadvantage of the lower stem nitrate test is that once in the deficient region, lower stem nitrate may not increase significantly with additional fertilizer application. Nevertheless, soil and plant tissue testing are valuable tools for nitrogen fertilizer management.

Table 4. Suggested pre-plant nitrogen fertilizer rates based on nitrate-nitrogen content of the surface 6 inches of soil.

Pre-plant soil nitrate-N	Description	Recommended pre-plant N rate*
ppm		lbs n/acre
<5	Low	50 to 75
5 to 10	Medium	0 to 50
>10	High	0

* Add 15 lbs N/acre per ton of non-legume residue recently incorporated, up to an additional 50 lbs N/acre.

Table 4. Suggested pre-plant nitrogen fertilizer rates based on nitrate-nitrogen content of the surface 6 inches of soil.

Stage Sampled	Stem Nitrate-N	Description	N rate*	Stage to apply fertilizer
	ppm		lbs n/acre	
3 to 4 leaf	>5000	Excess	0**	3 - 4 leaf to jointing
	2000 - 5000	Adequate	0 - 50	
	<2000	Deficient	50 -100	
Jointing to boot	>3000***	Excess	0	Jointing to Heading
	1000 - 3000	Adequate	0 - 50	
	<1000	Deficient	50 -75	
Heading****	>3000	Excess	0	Heading to Milk
	1000 - 3000	Adequate	30 -60	
	<1000	Deficient	60	

* Decrease N rates by 20% for barley or if expected wheat yields are less than 5400 lbs/acre.

** Apply 30 lbs N/acre regardless of stem nitrate-N content at the 3-4 leaf stage if the pre-plant soil test for nitrate-N was below 10 ppm.

*** For malting barley, 2000 ppm is considered excessive between jointing and boot.

**** Nitrogen applications after heading are intended for wheat only, to increase grain protein content.

Table 6. Suggested pre-plant phosphorus fertilizer rates based on sodium bicarbonate extractable phosphorus of the surface 6 inches of soil.

Pre-plant soil phosphorus ppm	Description	Recommended pre-plant P rate lbs n/acre
<7	Low	50 to 100
7 to 13	Medium	0 to 50
>13	High	0

Phosphorus

Phosphorus is the only fertilizer element other than nitrogen usually needed by wheat or barley in Arizona. Phosphorus fertilizer is not always required for optimum yields since some soils contain high levels of phosphorus. Soil phosphorus levels greater than 13 ppm sodium bicarbonate extractable P indicate that phosphorus fertilizer is not needed (Table 6). Phosphorus can be applied as a band near the seed, broadcast, or applied in the irrigation water at planting. Phosphorus rates can be decreased by half if phosphorus is applied in a band rather than broadcast. Monoammonium phosphate (11-52-0) is recommended when banding since ammonia toxicity can result from fertilizers such as diammonium phosphate (18-46-0) and ammonium phosphate sulfate (16-20-0). In any case, phosphorus fertilizer that also contains nitrogen should never be banded at a rate that results in an application of more than 30 pounds of nitrogen per acre. Phosphorus deficiency in small grains is usually expressed as stunted growth and may not be readily apparent. Purpling may occur in extreme cases of deficiency. Tillering is reduced and maturity is delayed. Phosphorus deficiency is most likely in cold soils due to decreased growth of roots to intercept the phosphorus and decreased diffusion of phosphorus to the roots:

Other Nutrients

Deficiencies of nutrients other than nitrogen or phosphorus have not been documented in Arizona, and presumably, application of these nutrients is rarely economically justified. Nevertheless, some of these elements are applied to small grains in the state.

Potassium and the secondary nutrients consisting of sulfur, calcium, and magnesium are plentiful in Arizona soils. Potassium strengthens the straw in cereals and prevents lodging. Potassium deficiency symptoms appear similar to drought stress. The plants are short, the stems are weak and spindly, and the older leaves dry out starting at the tips and progressing to the margins. Potassium deficiency is most likely on sandy soils low in organic matter. Sulfur deficiency consists of leaf yellowing similar Table 6. Suggested pre-plant phosphorus fertilizer rates based on sodium bicarbonate extractable phosphorus of the surface 6 inches of soil. to nitrogen, but is more striking. Leaves of sulfur deficient plants are light green and the older leaves may be bright yellow. The plants are stunted and have few tillers. Sulfur deficiency can occur on sandy, acidic, cold, or low organic matter soils. Calcium deficiency is characterized by reduced or distorted growth of young tissue, withered leaf tips, brown roots, and weak stems. Calcium deficiency usually occurs on acid soils, but can occur on soils with high pH or high sodium content. Magnesium

deficiency has not been reported in North America. Deficiency symptoms include yellowing between leaf veins and a yellow mottling of the leaf, purpling of the older leaf edges, weakened stems, and stunted growth. Magnesium deficiency is most likely on soils that are acidic, sandy, low in organic matter, or high in calcium.

The plant requirement for micronutrients is many times less than other nutrients. Arizona soils generally contain a sufficient amount of micronutrients. Micronutrients include iron, zinc, copper, manganese, boron, molybdenum, and chlorine. A deficiency of iron is characterized by a sharp yellowing between veins of new leaves and stunted growth. Plants deficient in zinc develop yellowing, graying, or bronzing between veins on older leaves in contrast to development of symptoms on younger leaves with iron, manganese, and copper deficiency. Copper deficiency is expressed as stunting, leaf yellowing, wilting, dying of leaf tips, and a graying of leaves. Interveinal yellowing occurs in manganese deficiency, but not as sharply as with iron deficiency. Boron deficiency is characterized by stunted growth. Molybdenum deficiency is exhibited by pale, thick, brittle, withered leaves and a stunted plant. Deficiencies of iron, zinc, manganese, copper, and boron are associated with high pH soils coarse in texture and low in organic matter. Molybdenum deficiency is favored by low soil pH:

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