Durum Quality is Related to Water and Nitrogen Management

M. J. Ottman and T. A. Doerge

Introduction

The quality of the durum crop this year was worse than any year in recent memory. The minimum standards of durum acceptable to the grain trade is 13% protein and 90% HVAC (Hard Vitreous Amber Count or kernels without yellow berry). Durum below these standards can be blended with high quality grain if available, exported to certain foreign markets not interested in high quality pasta products, or sold as feed. Production of sub-standard durum is undesirable to the grower who is docked for not delivering a specified quality of grain and may be disastrous to the grain companies who are trying to build their reputation on the ability to deliver a specified quantity of high quality durum.

Grain Protein and HVAC are Indicators of Grain Quality

Grain protein and HVAC are convenient indicators of grain quality and can be measured rapidly by local grain companies. A complete durum quality analysis is time-consuming and requires specialized equipment. Yellow berry refers to a kernel with a starchy area encompassing a small portion of the kernel or the entire kernel. Yellow berry kernels are non-vitreous, and light does not pass through them. Vitreous kernels are literally glass-like in composition. The starchy areas in yellow berry kernels are low in protein. Low HVAC count is related to low protein in a general way. However, some varieties are more susceptible to yellow berry than other varieties even at similar grain protein levels. Also, a variety may form a yellow berry under certain environmental conditions but not others despite equivalent grain protein content. Kernel protein is related to durum quality but other factors are also important such as color and milling characteristics. Kernel protein is not as important as the composition of the protein and especially the presence of gluten. The strength of the gluten holds the pasta product together if cooked too long or reheated. Strong gluten also allows for thinner pasta products which can be cooked quicker than thicker-walled products.

Causes of Low Protein and HVAC

Yellow berry and low protein content are related to many factors such as the variety, temperature, rainfall, plant density, phosphorus, calcium, sulfur, soil type, location, irrigation, and fertilizer practices. Nitrogen supply is the single most important factor in limiting grain protein. Nitrogen is a component of amino acids, which are the building blocks of proteins. Applications of nitrogen fertilizer near anthesis can help insure adequate protein levels. However, over-irrigation after this time can leach the nitrogen or make it unavailable due to lack of oxygen in the soil. Oxygen is required by the roots for energy to take up nitrogen and for the bacteria in the soil to convert nitrogen to plant available forms. Saturated soil conditions can also lead to gaseous losses of nitrogen from the soil by the process of denitrification.

Nitrogen Remobilization to the Grain

The major factor contributing to grain protein content is soil nitrogen availability followed by the ability of the plant to remobilize nitrogen from vegetative portions of the plant. Phosphorus plays a role in nitrogen remobilization in the plant and is required for acceptable quality of grain to be produced. Most of the nitrogen that ends up in the grain is remobilized from the vegetative portion of the plant. If nitrogen is deficient in the soil, virtually all the nitrogen in the grain will have been remobilized from the plant. Under other conditions, remobilization may account for only half the nitrogen in the grain. Therefore, nitrogen uptake from the soil during grain fill can make the difference between acceptable and unacceptable grain protein concentration. The time span between one irrigation may be required for soil- or water-applied fertilizer to become completely available to the plant. Foliar applications of urea have a more immediate effect and have been known to increase grain protein concentration.

Nitrogen Accumulation in the Kernel

The concentration of nitrogen in the kernel decreases as the kernel develops due to dilution by an increasing amount of starch. Therefore, protein content is often higher if the grain fill period is abbreviated by water stress, disease, or some other factor. Alternatively, if the grain fill period is lengthened by favorable weather or if yields are extraordinarily high, protein concentration is often lower due to a higher proportion of starch to protein.

Nitrogen Fertilization

A total nitrogen application of 150 to 300 pounds of nitrogen per acre is usually required for optimum yields and protein depending on native soil nitrogen, fertilizer application efficiency, nitrogen uptake efficiency of the crop, irrigation practices, yield potential, and other factors. The timing of the nitrogen application is as important as the total amount applied. Application of 25 to 50 pounds of nitrogen fertilizer with each post-emergence irrigation until anthesis is advised. The following nitrogen fertilizer program will usually result in optimum yields and acceptable quality: 75 pounds of nitrogen per acre preplant, 40 pounds at tillering, 40 pounds at early jointing, 40 pounds at boot, and 25 pounds near anthesis. However, excess water application during grain fill or extremely high yields may result in yellow berry problems.

Water Use

The wheat plant uses about 26 inches of water in the low elevation deserts in Arizona but water use can range from 22 to 30 inches. Assuming and irrigation efficiency of 70% and assuming no effective rainfall, then 36 inches of irrigation water should be applied. If irrigation water applications average 6 inches then 6 irrigations should be applied. The optimum timing of these irrigations is: planting, early jointing, heading, anthesis, milk, and soft dough. This schedule corresponds to applying the first postplant irrigation in late February, the second in mid-March, and the remaining three in 2 week intervals thereafter. Irrigations are often applied during the tillering stage to supply nitrogen even though water may not be needed. Higher rates of preplant nitrogen can often eliminate this need and rainfall during this time may supply plant water requirements. An additional irrigation after flowering is sometimes needed for full season varieties. A total of seven 6-inch irrigations may not be excessive, but eight or more certainly is. Durum protein and HVAC can be decreased by excessive water applications during grain fill. Two or three 6-inch irrigation during grain fill is usually sufficient.

Nitrogen Uptake by Durum

The amount of nitrogen that is contained in the straw and grain of durum is highly influenced by yield and protein content of the grain (see table below). For example, to achieve a grain protein concentration of 13%, an 8000 pound per acre crop will remove 273 pounds of nitrogen per acre from the soil while a 6000 pound per acre crop will remove 205 pounds of nitrogen per acre from the soil. The nitrogen taken up by the plant does not all have to be supplied by fertilizer since some nitrogen can be supplied by the irrigation water, residual nitrogen from the previous crop, or from native soil nitrogen.

Crop nitrogen content varies depending on grain yield and grain protein.

Grain Yield	Grain Protein (% based on 14% moisture)				
	11	12	13	14	15
lbs/acre	------------ Crop nitrogen content* (lbs N/acre) ------------				
4000	116	126	137	147	158
5000	145	158	170	184	197
6000	173	189	205	221	237
7000	202	220	239	258	276
8000	231	252	273	294	315
9000	260	284	307	331	355

* These figures were calculated assuming nitrogen and dry matter ratios of grain and straw are constant across yield and protein levels.

Nitrogen Fertilizer Guidelines for Wheat and Barley

The level of nitrogen (N) fertility has more influence on the growth and yield of small grains than any other single plant nutrient because it is the nutrient most often deficient in Arizona soils. The amount of fertilizer N required will vary depending on the yield potential of the crop, the amount of residual N in the soil prior to planting, the amount and type of crop residues previously incorporated, the soil texture and the type of irrigation system that is used. With good management, a total of about 150 to 300 lbs. N per acre is usually needed for optimum production. Preplant soil analysis and plant tissue analysis during the season can be very useful in establishing the nitrogen needs of the crop.

The following fertilizer recommendations apply to all durum wheat, bread wheat and full-season barley varieties grown in Arizona and are based on a yield potential of 6000 to 7000 lbs. grain per acre. Rates may need to be adjusted for significantly different yield goals. Suggested N rates assume that basin, border-flood or other surface irrigation methods are used. Well managed drip or sprinkler irrigated small grain crops may require somewhat less N than indicated.

Early season nitrogen

Applications of N before or at planting should be based on a preplant soil test for NO_3-N as shown in the following table.

Suggested preplant N fertilizer rates for small grains based on soil NO_3-N content.

Preplant NO_3-N SoilTest Value	Apply this Amountof N*
ppm	lbs./acre
0 to 5	50 to 75
5 to 10	0 to 50
above 10	0

*Add 15 lbs. N per acre per ton of non-legume residue recently incorporated, up to an additional 50 lbs. N per acre. These rates assume plant nitrogen status will be assessed at tillering and corrected if necessary at this time; otherwise, preplant nitrogen rates should be increased substantially.

Nitrogen can be broadcast applied prior to planting and shallowly incorporated, injected into the surface soil or placed with the seed at planting. On sandy soils, ammonium containing fertilizers such as ammonium sulfate (21-0-0), monoammonium phosphate (11-53-0), ammonium phosphate-sulfate (16-20-0) or solution ammonium polyphosphate (10-34-0) should be used rather than predominately nitrate or urea sources. Rates of banded N above 30 lbs. N per acre increase the risk of injury to germinating seedlings. Placement of urea (46-0-0) with or near the seed is not recommended due to the risk of seedling damage from ammonia toxicity. Anhydrous or aqua ammonia should be injected 6 to 9 inches below the soil surface prior to planting and should never be placed near the seed zone.

Mid-season nitrogen

At the 3- to 4-leaf stage of growth, collection of lower stem samples for NO_3-N analysis should begin. The stem tissue between ground level and the seed should be sampled prior to the jointing stage and the 2 inches of stem above the ground level should be collected thereafter. Do not sample stems from damaged or unrepresentative plants. About 25 to 50 lower stems are adequate for analysis, depending on the size of the plants at the time of collection. The number of samples tested from each field depends on the uniformity of the field. Stem samples should be collected from randomly selected plants within uniform areas representing portions of a field that can be fertilized separately. Samples should be placed in a paper bag and dried at about 150^{o}F (65^{o}C) or refrigerated as soon as possible and submitted to a laboratory for NO_3-N analysis.

Most N is broadcast applied to the soil just prior to an irrigation or injected into the irrigation water. For this reason it is suggested that stem samples be collected 7 to 10 days prior to each surface irrigation event before anthesis so that laboratory results will be available to guide mid-season N applications as shown in the following table.

Recommended sampling dates and interpretation of lower stem NO_3-N levels for intensive nitrogen management of surface irrigated small grains in Arizona.

Stem Sampling Dates	Stem NO_3-N Levels	Suggested N Fertilizer Rates*
Growth stage	ppm	lbs./acre
3-4 Leaves	>5000	None**
	2000 - 5000	0 - 50
	<2000	50 - 100
Joint	>3000	None
	1000 - 3000	0 - 50
	<1000	50 - 75
Boot	>3000	None
	1000 - 3000	0 - 30
	<1000	30 - 60

*Decrease N rates by 20% for barley crops of if expected wheat yields are less than 5400 lbs. grain per acre.
**Apply 30 lbs. N per acre regardless of the stem NO_3-N content at the 3-4 leaf stage if the preplant soil test for NO_3-N was below 10 ppm.

A timely application of N fertilizer can prevent or slow the decline of stem nitrate. If the NO_3-N level is below 2000 ppm prior to jointing or below 1000 ppm prior to heading, then application of a nitrate or urea source is recommended. These forms of N move readily in soil solution and are immediately available to plant roots with the first irrigation after the fertilizer has been applied. This decreases the time necessary for recovery from a nitrogen deficiency. At higher levels of stem NO_3-N, the nitrogen source is of less importance because nitrification of ammonium (NH_4) sources can take place rapidly enough to permit the resulting NO_3 to be moved into the root zone to supply the needs of the plants.

All forms of N are equally effective after the mid-tillering stage if the same amounts of actual N are applied. This assumes sound management is practiced with respect to the N form used and that severe N deficiencies have not occurred. However, caution should be used when applying ammonium sources of N such as anhydrous or aqua ammonia in order to avoid plant injury from ammonia toxicity, especially on very sandy soils.

An application of 30 lbs. N per acre in conjunction with the irrigation event occurring closest to the anthesis stage is effective in reducing the incidence of yellowberry and boosting grain protein levels. However, N applications at this time will rarely increase grain yield. Nitrogen applications are not normally needed after anthesis except perhaps on very sandy soils.

<u>Nutrient removal</u>
A harvest of 6700 lbs. of durum wheat per acre will contain about 175 lbs. N. The entire crop will contain about 230 lbs. N per acre.

<u>Nitrogen uptake patterns</u>
Nitrogen uptake in small grains proceeds very slowly until tillering begins. Nitrogen flux increases to a maximum of over 2.5 lbs. N per acre per day during the jointing stage. The N flux then decreases rather gradually over the remainder of the growing season, averaging between 0.5 and 1.5 lbs. N per acre per day during the grain filling period.

<u>Summary</u>
The current University of Arizona guidelines that relate to nitrogen fertilizer management for small grain crops have two major goals in mind. The first is to supply the minimum amount fertilizer N needed to obtain maximum grain yield, grain quality and grower profit. The second is to minimize leaching losses of nitrates which reduce grower profits and can lead to groundwater pollution. This involves the intentional utilization of residual soil N from previous fertilizer applications or crop residues that have been incorporated into the soil.

These guidelines also make several key assumptions. The first is that the grain yield potential is about 6000 to 7000 lbs. per acre. Yield goals above or below this range will require somewhat more or less N fertilizers accordingly. The second assumption is that reasonably efficient basin, border-flood, or furrow irrigation methods will be used. Well managed drip or sprinkler irrigation systems will require less N while excessive irrigation from any type of delivery system will result in inefficient utilization of N. The third assumption is that in-season N application decisions will be based on feedback from soil and stem nitrate tissue tests. Directions for when and how to take these samples and interpret the results are given above. Where high grain protein content is desired, an application of 30 lbs. N per acre at the anthesis stage is also recommended regardless of the stem tissue-nitrate concentration at that time.