Chapter 7

Soil Fertility and Plant Nutrition for Grain Sorghum

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Grain sorghum production in Texas ranges from unfertilized dryland to high-input full irrigation. Needless to say the soil nutrient status is highly variable. Crop rotation and the frequent producer practice to fertilize only when a certain crop is in rotation means that residual fertility may be more important. Likewise, tillage and fertilizer placement practices will affect the nutrient use efficiency of grain sorghum.

Soil Testing

Many producers do not realize the extent of research and testing that is behind the process of analyzing soil samples for nutrients and the subsequent recommendations they generate. A realistic goal for many producers is to soil sample every three years.

Different Philosophies of Soil Test Recommendations

There are **two** common approaches to soil fertility recommendations for the same crop and production conditions. **Each has its own merits and can be used successfully** although these approaches can generate recommendations that seemingly are at odds with each other.

1. Provide what the crop needs for current-year production. Based on your yield goal, your current soil nutrient status and that nutrient's projected availability to your crop, add the level of nutrients needed to fertilize your crop for this year. This approach in terms of out-of-pocket expenses costs less and it also may reduce potential nutrient losses due to leaching or other means. This is most likely the approach that state labs take.

2. Build-and-maintain soil nutrient status. Most likely this means fertilizing to maintain a higher long-term residual level of nutrients in the soil. Nutrient levels may be in excess of the crop's requirement, but also not at a luxury or wasteful level that squanders money. This approach, provided there are ample nutrients available, may guard against unexpected limitations in nutrient availability or higher crop demand if yields are higher than expected. This philosophy is more likely to be found among private labs.

TIP: If you have a fertilizer dealer, crop consultant, or other third party collect and submit soil samples for you, be sure to obtain a sample of the soil test report itself. Understand what the report is saying, and keep it in your records for the farm or field for up to 15 years so that you may track changes in the soil over time.

Why are there differences between soil sample report recommendations?—

Different methods of soil sample nutrient extraction and analysis
Have you ever submitted samples of the same soil to two different labs? You might have found different recommendations. Although labs within a given region of the country tend to have

uniform testing procedures, this is not always the case. For example, there are different tests for soil P (soil pH may dictate which one should be used). Labs may use a different extractant for the soil, or once they have obtained the extract for nutrient analysis may use a different method of measuring the nutrient in the extract which could be affected by other constituents in the sample. These differences lead to different test values of nutrient measured in your soil.

Different fertilizer recommendations
As noted above there are differences in the philosophy of soil testing. Provided the soil test value for a particular nutrient is the same, then build-and-maintain would likely have a higher fertilizer recommendation. This philosophy may be the normal approach to recommendations by a test lab. Apart from differences in philosophy the calibration curves plotting nutrient requirement for a unit of yield are not necessarily the same. One lab may recommend 2.0 pound of N per cwt. of sorghum yield goal, whereas another recommends 2.5. Or a particular lab's recommendations might include additions or deductions to their calculation that are not factored in by a different lab.

TIP: When your soil test lab, fertilizer dealer, crop consultant, or other third party provides fertilizer recommendations, do the following:

- Ask about their philosophy of soil test recommendations as noted in #1 and #2 above.
- Furthermore, if you are receiving fertilizer application recommendations without the benefit of soil test results, then ask about the guidelines used in arriving at those recommendations.
- Finally, if you receive recommendations without having even provided a yield goal then you need to question the recommendations closely to ensure that at least a minimum agronomic basis and not a pure sales motive alone is guiding fertilizer plans.

Texas A&M University Soil Testing Lab

The College Station lab provides complete fee-based services for soil, plant tissue, and water analyses. Texas AgriLife testing across Texas on grain sorghum (as well as other crops) forms the basis for soil test recommendations for samples. For more information on services, submittal forms, and how to collect and submit representative samples visit http://soiltesting.tamu.edu/

TIP: When choosing a soil test lab, inquire if the lab is accredited by a state agency/certification board, a participant in the North American Proficiency Testing program, or some other testing standard guidelines. This ensures that the lab meets recognized standards and practices that are foundational for providing you with good test values and recommendations.

TIP: If you already use or consider using a soil test lab that is far removed from the region or state where your soil was sampled, call them to ensure they can provide you with results based on suitable test procedures and recommendations for your soil type and your crop (especially if your crop is not grown in that state).

Sorghum Nutrient Requirements

Table 7-1. Approximate nutrient uptake and removal by grain sorghum per acre for major nutrients.

	Nutrient Uptake†			Nutrient Removal‡		
Yield	N	P_2O_5	K_2O	N	P_2O_5	K_2O
	---------------------------------- Pounds per Acre ----------------------------------					
2,000	60	21	55	30	15	8
4,000	120	42	110	60	30	16
6,000	180	63	165	90	45	24
8,000	240	84	220	120	60	32
10,000	300	105	275	150	75	40

†Nutrient uptake at the rate (per cwt.) of 3.0 N, 1.1 P_2O_5, 2.75 K_2O. Nutrient uptake is the total taken up by the crop grain and above ground vegetation. These numbers should be used only as general guideline (Potash & Phosphate Institute).
‡Nutrient removal at the rate (per cwt.) of 1.5 N, 0.75 P_2O_5, 0.4 K_2O

Nitrogen

"You Can't Get Something from Nothing for Very Long"

It is common in West Texas, particularly on dryland, to not fertilize grain sorghum at all, even for nitrogen. To some extent this 'just-get-by' attitude resulted from low grain sorghum prices, but may also reflect poor attitudes and the lack of success on the part of many producers due to too-high seeding rates and little thought in hybrid selection. Sorghum indeed responds to nitrogen. The Texas AgriLife Research Crop Testing program for dryland sorghum performance tests in West Texas routinely adds 40 lbs. N per acre, then producers have difficulty believing our yields in some years that top 3,000 lbs./A. The N was available when conditions were favorable for hybrids to take advantage of it.

Nitrogen is by far the most important nutrient for sorghum to maximize production. For maximum yields relative to the available water, N should not be lacking or grain development will be reduced. The long-standing general nitrogen (N) nutrient requirement for Texas grain sorghum is:

N requirement:

2 lbs. actual N (soil or fertilizer) per acre per 100 lbs. of yield goal

Thus a 5,000-pound grain yield would need about 100 lbs. of N per acre. In Texas this has generally been presented to producers as the amount of N fertilizer to add.

The Texas A&M University soil test lab recommendations, however, use the above rule but deduct nitrate-N from a soil test in the top 6".

Texas A&M recommendation:

(Fertilize 2 lbs. actual N per acre per 100 lbs. of yield goal) minus (soil N at 0-6"*****)

Hence for the same yield goal noted above, but with a soil test report showing 9 ppm NO_3-N for a 6-inch deep sample (which is ~2 million lbs. of soil), the calculated N fertilizer addition is:

Fertilizer N to add:

(2 lbs. N/acre) X (50 cwts./A yield goal) – (2 X 9 ppm) = 82 lbs. N per acre

This N recommendation, particularly when the profile N is deducted, is more conservative (lower) that what is normally generated in other states such as Kansas or Oklahoma which each use a more complicated formula or include other adjustments, but AgriLife Extension recommends Texas producers maintain the simple rule of thumb above. *When soil test information is not available this rule will help producers at a minimum to be in the range of meeting the sorghum's N requirement for good yield.*

*****Ideally soil testing for N would use a 24" depth sample (in contrast to 6" for P, which is largely in the surface, or the standard depth noted above in most soil tests). <u>If soil test N is available for depths below 6"</u> then credit that N 100% toward your N requirement thus reducing fertilizer N requirement, e.g. "2 lbs. N per acre per 100 lbs. of yield goal **–** Profile N." Crop rotations may affect residual N and often credits are assigned to soil N if the previous crop was a legume.

Nitrogen Applications after Sorghum Emergence

Side-dress N applications with knives or coulters should be made by ~20-25 days after germination (4 to 5 leaf stage) to ensure good N fertility in advance of initial growing point differentiation (30-35 days after germination) while minimizing any root pruning. Later applications may excessively prune feeder roots and miss the potential benefits to GPD.

Under center pivot irrigation, N fertilizer may be applied several times during the early part of the growing season. Due to the convenience of pivot-applying N, up to 20% of N might be held back until after GPD, but Extension recommends that the final N be applied no later than boot stage which is ~60 days after germination for a full-season hybrid and no later than ~50 days for a medium maturity hybrid. About 70% of the needed N for a grain sorghum crop is already in the plant at boot stage.

Because N is relatively mobile in the soil, fertilizer placement is not as critical for N as it is for most other nutrients. Nitrate-nitrogen, NO_3-N, the form most available to grain sorghum, will move with water and can be readily brought into contact with crop roots for quick absorption.

Ammonium-nitrogen (NH_4, also available to plants) is positively charged and is held by negatively-charged clay and organic matter particles in the soil until converted by soil bacterial action into the nitrate form. The conversion from ammonium to NO_3-N in the soil—nitrification—is most likely to occur when fields are arable. When fields are water-logged, nitrate can be converted to nitrogen gas—denitrification—and lost from the soil by volatilization.

Guidelines for Surface Applied N Fertilizer

Ammonium-based fertilizers are more susceptible to volatilization losses when applied to the soil surface if no rain or irrigation occurs. Three key factors reduce the effectiveness of the surface-applied N leading to volatilization losses, particularly when acting together:

- Moist or wet soil
- pH > 7
- Increased temperature, windy conditions

Extension always recommends where possible that producers using broadcast N fertilizer apply to dry soil. Furthermore, applying N prior to a predicted rain or scheduled irrigation is particularly advantageous.

Starter Fertilizer & Salt Injury Potential—Suggestions for Grain Sorghum

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Starter fertilizer applications for sorghum is a sound practice in the Texas High Plains. Even if soil tests like phosphorus (P) are in the "medium" range, one of the purposes of "starter" fertilizer for nitrogen (N) and P is to "kick-start" or stimulate growth right after emergence. Starter fertilizer research, especially in Kansas has shown that rooting and early growth is promoted by starter fertilizer applications in the 2" x 2" configuration (from the seed, 2 inches to the side and 2 inches below). Starter fertilizer can be applied with the seed, the so-called "pop-up" fertilization, but at rates much less than the 2" x 2" placement. A common concern is potential salt injury and ammonia damage if the rate of starter fertilizer is too high.

- Salt injury comes from N, potassium (K), and sulfur (S).
- Pounds per acre of N+K+S applied will determine injury potential, but K and S fertilization is rare on the High Plains due to our high K and S native soil fertility.
- N fertilizers that contain or readily form ammonia, NH_3, can be toxic to seed (see below).
- Phosphorus fertilizer (e.g., triple superphosphate, 0-46-0, etc.) does not cause injury to seedlings, but most P fertilizers used in West Texas contain N (e.g. 11-52-0, 10-34-0), so follow the below guidelines for N.

Table 7-2. Suggested maximum fertilizer salt amounts (lbs. N-K_2O-S/acre) for seed row fertilizer placement, row spacing, and soil type.

	Loamy-Clayey Soil				Sandy Soil			
Fertilizer	Row spacing (inches)							
Placement	15	20	30	40	15	20	30	40
Pop-up (with seed)	10-15	8-12	5-8	6	10	8	5	4
2" X 2" pattern	80	60	40	30	40	30	20	15

More salt-forming N and K fertilizers can be applied to loamy and clayey soils than to sandy soils. Narrower rows spacings allow more N and K as well. Pop-up starter fertilizer rates are much lower than starter fertilizer 2 inches from the seed. If the total amount of N fertilizer applied to your sorghum is 60 lbs. N/A, and you are on 20-inch rows, than the entire dose could be applied as a 2" X 2" starter on loamy and clayey soils. However, in most cases, the balance of the N fertilizer will have to be sidedressed. This can be as 32-0-0 either dribbled or knifed in 6 to 10 inches off the row without the threat of injury, applied through a pivot, or using a broadcast spreader.

Some starter N fertilizers have potential for injury from ammonia (NH_3) because they either contain NH_3 or an N form that quickly converts to NH_3 gas. This is primarily a concern with pop-up fertilization. For pop-up applications with the seed producers should avoid urea ammonium nitrate (32-0-0 or 28-0-0), mixtures of 32-0-0 and ammonium thiosulfate (28-0-0-5S), solid urea (46-0-0), mono-ammonium phosphate, or MAP (11-52-0), and diammonium phosphate DAP (18-46-0).

For sample calculations as well as additional row spacings consult "Starter and In-Furrow Fertilizer & Salt Injury Potential," (Bronson) at http://lubbock.tamu.edu/sorghum

Phosphorus (P_2O_5)

It is difficult to gauge needed P requirements for grain sorghum or any crop without soil test information for P in the 0-6" depth. Table 7-3 notes soil test P levels and their relative designation such as very low, low, and moderate (20-50 ppm, a very wide range). Soil test P levels above 50 ppm are high. In most of Texas response to fertilizer P is inconsistent between 30 to 40 ppm (the transition zone of soil P response) using the Mehlich III soil test method, and measurable yield differences are not demonstrated above 40 ppm soil P.

When growing conditions are cool or wet early in the season, especially where producers might be planting early to minimize sorghum midge potential, seedlings may show temporary P-deficiency symptoms. This particular situation as well as P nutrition in general lends itself well to either banded or in-furrow application of P. Fertilizer P itself is not salt forming or toxic to plants at higher levels of P, but see comments above on allowable banded and pop-up P fertilizer rates when N is a component of the P fertilizer.

Since soil P is relatively immobile, or "fixed" in soils, placement in a concentrated form is particularly important in low to medium testing soils. Research has shown that plants obtain a higher proportion of their needed P from soil reserves. Only about 30 percent of applied P is used by the crop following fertilization in the current year, even though it may have been banded.

Table 7-3. Phosphorus recommendations for grain sorghum in West Texas.

Soil test	Yield Goal, bu/A (lbs./A)†				
Mehlich 3	40 (2,240)	80 (4,480)	120 (6,720)	160 (8,960)	200 (11,200)
(ppm)	Lbs. recommended P_2O_5/A				
0-5 (Very low)	35-40	65-70	80	80	80
5-10 (Very low)	30-35	60-65	80	80	80
10-15 (Low)	25-30	50-60	80	80	80
15-20 (Low)	20-25	45-50	70-80	80	80
20-25 (Moderate)	15-20	35-45	60-70	80	80
25-30 (Moderate)	15-20	30-35	45-60	60-80	80
30-35 (Moderate-High)‡	---	20-30	35-45	45-60	60
35-40 (Moderate-High)‡	---	---	20-35	30-45	50
40-45 (Moderate-High)*	---	---	---	15-30	30

†P_2O_5 rates are capped at 80 lbs. In severely depleted P soils, yield could potentially respond at higher rates of P. Visit with your Extension agronomist under severely depleted soil P conditions where a high yield goal is desired.

‡West Texas soil research suggests that 30-40 ppm soil test P is a "transition level" at which yield responses to additional fertilizer P are inconsistent.

+West Texas soil research suggests P fertilizer additions at this level of soil test P does not demonstrate measurable yield differences.

Texas AgriLife does not offer a general rule of thumb for P_2O_5 needs for grain sorghum. When soil test P levels are very low, however, tables from several states' Extension soil test guidelines cite a P_2O_5 requirement for fertilizer that is approximately 50% of that of N (and 40% for low soil test P, 25% for moderate soil test P). This would reflect the fact that much P comes from residual sources.

TIP: If you don't know your soil P status, don't have a soil test, but are willing to band P then consider a P_2O_5 rate that is about one-fourth to one-third of the N rate. Increase the target rate of P if you believe your residual soil P is low.

TIP: Fertilizer P applied in a band is more efficient than broadcast P. As a general rule of thumb producers may be able to reduce P applications by as much as 20% if fertilizer is applied in a band due to relative increased availability of P.

Potassium (K_2O, or Potash)

Soil K levels in West Texas are generally high and unless soil K levels have been diminished greatly, it is likely that only top end grain sorghum yields would consider K additions. Texas A&M University soil test guidelines project the K requirement at 2 lbs. K_2O/A per cwt., however, the soil test levels are normally sufficient (if not well in excess) to preclude fertilizing with potassium.

Iron (Fe) and Zinc (Zn)

Two other important nutrients for grain sorghum production in West Texas are iron and zinc. Zinc is not commonly an issue in sorghum in this region (it is for corn), but iron deficiency related to caliche soils and outcroppings in West Texas (usually pH $\geq$ 7.9) is a particular concern for sorghum. Chalky soils that appear whitish across the field should probably never have grain sorghum, and it is prohibitively expensive to correct it. Many fields, however, simply experience some degree of iron deficiency, the classical condition of interveinal chlorosis where the veins of the younger leaves remain green and the leaves are yellow between the veins (Figure 7-1). In the worst of cases, the leaves are almost completely bleached out and the plants do not grow. Iron deficiency can be induced temporarily due to water-logged conditions. Where modest cases where iron deficiency occurs as the root volume expands iron deficiency diminishes.

Fig. 7-1. Iron deficiency in West Texas grain sorghum compounded by wet soil.

Iron deficiency compared to N deficiency. Iron deficiency is normally expressed mostly on newest leaves, and iron is immobile within the plant. When iron becomes available again, newly emerging leaves will again be dark green. Older chlorotic leaves will not green up unless they receive a direct foliar feed. In contrast, N is mobile in the plant, and will move to the youngest leaves from older plant tissues (which may express N deficiency) and shows no striping symptoms.

Most soil tests will flag Fe < 4 ppm as deficient. Currently, there are no economical sources of soil-applied Fe available. Therefore, the only options for correcting Fe deficiencies are to apply foliar Fe sprays in-season or to apply manure for long-term correction. If iron chlorosis has been observed during previous years in a field, iron fertilizer materials may be applied preemptively to the foliage through multiple sprayings early in the season. Table 7-4 gives suggested foliar treatments to correct iron as well as zinc deficiencies.

Table 7--4. Suggested sources, rates, and timing of iron or zinc foliar sprays.

Deficiency	Product*	Product/100 gals water	Product/ Acre	Timing
Iron	Iron sulfate (20% Fe)	20 lbs (2.5% solution)	1 lb. then 2-3 lbs.	10-14 days after emergence - 5 gals/A over crop row. Follow with 2 apps. @ 10-14 day interval @ 10-15 gals/A
	Iron chelate (10% Fe)	8 lbs. (1%)	0.4-0.5 lbs	Same as above
Zinc	Zinc sulfate (30% Zn)	2 lbs. (0.5%)	0.2 - 0.4 lbs	10-20 gals/A in first 30 days
	Zinc chelate (9% Zn)	2 qts (0.1%)	1 pint	10-20 gals/A in first 30 days

*Include a surfactant or other wetting agent. Product composition may vary. Select similar products or adjust mixing ratios to achieve comparable rates of nutrient application.

Source: Updated information based on research results and recommendations through the Texas AgriLife Extension Service Soil, Water and Forage Testing Laboratory.

For further information about iron consult 'Correcting Iron Deficiencies in Grain Sorghum' L-5155, from Texas AgriLife Extension (http://agrilifebookstore.org, or contact your local county Extension office).

Zinc: Where soil P is 'very high' or 'high' and zinc levels are low then further P application may induce zinc deficiency particularly when soil pH is high. If soil test results indicate a possible zinc deficiency (< 1 ppm Zn), zinc fertilizer may be broadcast and incorporated preplant with other fertilizers or ideally banded near the seed at planting. Chelates are up to five times more effective than inorganic sources, but price will determine which product is a better choice.

Other Nutrients in Texas Sorghum

Unless you have had a particular problem in the past with sulfur, calcium (all West Texas soils are high), manganese, etc. there is no fertility correction likely needed. Noting other nutrients and their levels in soil test reports is probably sufficient for keeping an eye on possible imbalances.

Foliar Feeding Major and Minor Nutrients

In general foliar feeding is expensive. Extension does not recommend that producers rely on foliar feeding for N due to the far higher per unit cost of N. Foliar feeding of micronutrients is more common, and many products will have a package of micronutrients and simply may be the most convenient means to use if you have a known deficiency with an individual nutrient. Otherwise, significant amounts of micronutrient sprays are used that probably provide little if any benefit ('feel good' or 'catch all' treatments?). Micronutrient deficiencies other than iron are hard to diagnose without experience and/or a tissue test. Non-chelated sources if available and applied with a good sticking agent can be quite effective and perhaps a better buy.