



**NATIONAL ASSOCIATION OF WHEAT GROWERS FOUNDATION  
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# UTILIZING SOIL TESTING FOR GREATER WHEAT PROFITABILITY<sup>1</sup>

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## ABSTRACT

Soil testing is probably the most effective way of assessing the current soil nutrient status and determining fertilizer needs of wheat. Water, N, and P are generally the dominant yield limiting factors for wheat in the United States. Potassium, S, and micronutrients are generally not as limiting for wheat production and their needs can be assessed and predicted by soil testing. Water greatly influences yield potential, particularly in the semiarid wheat growing areas. Therefore, the quantity of soil water plus growing season precipitation needs to be assessed. The level of water and native and residual plant nutrients in the soil will influence the level of nutrients that need to be applied to optimize yields and economic returns. Only those nutrients needed to optimize wheat yields and quality should be applied for maximum profitability.

## SOIL SAMPLING

Maximizing the profitability of fertilizer applications for wheat requires that needed nutrients be applied only in sufficient quantity to obtain optimum economic yields. Soil testing is essential if accurate, maximum profit potential, fertilizer recommendations are to be made. Soil testing success depends on collection of a representative soil sample and an accurate laboratory analysis. Numerous soil samples, from the appropriate depth, need to be collected from representative areas of the field. Divide the field, avoiding odd or problem areas, into about 20 to 40 acre lots (100 acre lots may be more practical but less desirable) and collect 10 to 15 subsamples from each lot for a good composite sample. Sample different or special problem areas separately and have these samples analyzed separately. A non-representative sample can be misleading and may be worse than no sample at all. A list of suggested soil tests needed to make accurate crop management decisions are given in Table 1 along with the suggested depth for soil sampling and the frequency that soil tests should be conducted. A complete initial assessment of all root zone nutrients would be useful for better nutrient management in intensively managed wheat systems.

## SOIL TEST vs YIELD POTENTIAL AND FERTILIZER NEEDS

### Available Soil Water

Most soil testing laboratories do not routinely determine field water content of samples sent to them. Samples are usually dried immediately after collection or are dried as soon as received by the lab to minimize changes in nutrient status caused by microbial and mineralization processes. Separate samples

should be collected from the potential wheat root zone to assess the quantity of plant-available water. Soil texture influences plant-available water held by a soil. Sandy soils generally hold about 0.75 to 0.8 inches of water per foot of soil depth, loam soils about 1.2 to 1.5 inches/ft, and clay loam soils about 2 inches/ft. Thus, soil texture influences wheat yield potential by the amount of water a soil will hold. Black and Bauer (1986) showed (Fig. 1) that wheat yield potential increases as the crop's available water supply (soil water plus growing season precipitation) increases. Halvorson and Kresge (1982) and Leholm and Vasey (1983) used available soil water plus growing season precipitation to predict maximum wheat yield potentials in the northern Great Plains.

Available soil water can be estimated in the field by knowing the soil texture and probing for the depth of moist soil. A soil moisture probe can be simply a 3/8 inch stainless steel rod with a handle at one end and a ball bearing (1/2 inch) welded to the other end. A probe can be pushed easily into the soil when it is at or near field capacity. When dry soil is encountered, the probe becomes very difficult to push deeper, which provides a usable estimate of moist soil depth. Multiplying moist soil depth by inches of available water held per foot of moist soil gives an estimate of inches of available soil water.

In humid regions of the U.S., knowing soil water holding capacity and the distribution and amount of growing season precipitation can be helpful in estimating the loss of mobile nutrients due to leaching. Thus, fertilizer N rates and time of application can be adjusted for efficient use and profitability.

#### Phosphorus

Soil Tests: Available P must be present in sufficient amounts to optimize responses to available water supplies and N fertilization. Soil tests for P have been very effective for predicting fertilizer P needs. The Olsen soil test (sodium bicarbonate extraction) has been widely accepted as the test for use on calcareous soils (pH >7.0). The relationship between this test and relative yield potential of wheat grown in annual cropping systems is shown in Fig. 2. These data indicate that a 21 ppm P level is needed to achieve 100% of the yield potential. The Bray-Kurtz P soil test is widely used for acid soils (pH <6.5) with similar soil test P levels required to achieve maximum wheat yield potentials in the north-central Region (Oplinger et al., 1985; personal communications, Dr. Paul Fixen, South Dakota State Univ., Brookings, 1986). These tests have had extensive field calibration with measured crop response to P applications.

The type of relationship shown in Fig. 2 is useful in estimating yield reductions caused by inadequate available P levels, thereby allowing a more accurate estimate of N fertilizer needs. In general, sufficient fertilizer P should be applied to bring the soil test level to approximately 21 ppm to optimize wheat yields and response to N fertilization. Halvorson and Black

(1985) found adequate levels of P were needed to obtain optimum response to N fertilization (Table 2). As more intensive wheat management systems are adapted, higher soil test P levels may be required to optimize yields. Halvorson (1986) reported a soil test P level of about 26 ppm was needed to achieve 100% of the yield potential of wheat grown in a crop-fallow system on a loam soil in northeastern Montana.

When P fertilizer is added to most soils in the Great Plains, an increase can be expected in soil test P levels. the amount of increase will be dependent upon soil texture and other soil characteristics. Halvorson and Kresge (1982) used this approach to estimate the amount of broadcast and incorporated P fertilizer needed to optimize yields. If less P fertilizer was applied than recommended, wheat yield potentials were reduced. They estimated that 8 to 10 lb  $P_2O_5$ /acre was needed to raise the soil test P level 1 ppm.

P Placement: Phosphorus application method will affect utilization efficiency. Banding fertilizer P is very efficient at very low soil test levels (Peterson et al., 1981). Therefore, when P is banded, lower rates can be applied and still achieve optimum yield potential. However, the response to residual fertilizer P may be less for future crops because of the smaller amount of P applied.

The short- and long-term economics of P fertilization needs to be considered. The long-term economics of a large one time application of P fertilizer can be profitable (Jose, 1981; Halvorson et al., 1986; Wagar et al., 1986). However, the short-term profitability is marginal for a one-time large P application. Wheat and fertilizer price and current soil test P level will govern how much P can be profitably applied in a given year. The investment in P fertilizer may need to be amortized over several years, similar to machinery, in order to optimize wheat yields and responses to N fertilization. Application of adequate fertilizer P to bring the soil test P level to about 21 ppm followed by smaller annual P applications to maintain this soil test level may result in optimum wheat yields and optimum short- and long-term profitability.

### Nitrogen

Once the plant-available water supply and P needs have been identified, potential yield and total N requirements can be estimated. The N needs of wheat vary with wheat type (Hard Red or Soft White) and geographic location (Halvorson, Alley, and Murphy, 1986). In general, 2.0 to 2.5 lb N/bu is needed to optimize wheat yields and quality in the U.S. As the yield level increases, the total N requirements per bushel may increase because of a decrease in N use efficiency. A value of 2.3 to 2.5 lb N/bu would be a good estimate to use for predicting N requirements of Hard Red wheats. The following equations can be used to estimate fertilizer N needs for wheat:

a) Total N Needs (lb/A) = Yield (bu/A) x N Required (lb N/bu)

b) Fert N Needs (lb/A) = Total N - Residual Soil N - Other N

where Other N in equation "b" is the contribution of N expected from soil organic matter mineralization (approximately 20 lb N/A per 1% organic matter), manure applications (3 to 5 lb N/ton applied), and/or from legumes grown in the rotation. The Residual Soil N term refers to the residual soil nitrate-N in the root zone of the growing wheat crop (i.e., soil surface to 4 ft depth). Most Great Plains states recommend sampling to a minimum depth of at 2 to 3 feet to assess residual soil nitrate-N. Deeper sampling (>3 ft) is suggested to more accurately assess the distribution and amount of nitrate-N available for crop uptake. Without subsoil sampling for residual nitrate-N, N fertilizer needs could be substantially over or under estimated with negative financial results.

Many of the Eastern and some of the Corn Belt states do not recommend soil testing for residual soil N (Oplinger et al, 1985). However, testing the soil profile (0 to 4 ft) for residual nitrate-N could improve N management programs in these areas, as well as improve profitability and reduce the amount of N reaching the ground water.

#### Potassium, Sulfur, and Other Nutrients

Soil tests for K, S, and micronutrients should be used to evaluate their availability and identify the amount of fertilizer needed. Soil tests for S continue to be improved and field correlated with crop response (Rasmussen and Allmaras, 1986). When a soil is deficient in S, wheat yield and quality can be improved with its application. In time, S may become more critical for wheat as more S is removed from the soil system.

Singh et al. (1986) reported a wheat response to zinc application where high rates of P fertilizer had been applied. Soil testing will help identify nutrient imbalances so that remedial action can be taken.

Fixen et al. (1986) reported progress toward development of a chloride soil test and its correlation with wheat yields and disease resistance. Utilizing soil tests to identify nutrient deficiencies and enhance disease control will increase profitability as we move toward more intensive wheat management systems with higher yield potentials.

#### Soil Acidity - Aluminum Toxicity

The use of larger amounts of N in intensive wheat management will speed the process of soil acidification under both irrigated and dryland conditions in semiarid areas. As the soil pH approaches 5.6 with organic matter degradation and application of acid forming N fertilizers, a soil test for pH and aluminum (Al) becomes very important. These tests are essential for determining lime requirements to alleviate Al toxicity as a

yield limiting factor. Research in Kansas has shown tremendous yield differences between aluminum sensitive and tolerant wheat varieties at soil pH levels near 5.0 (Unruh and Whitney, 1986). Wheat yields were increased more than 3 fold for some varieties with the application of lime.

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Table 1. List of suggested soil test results needed to make crop management decisions and suggested soil sampling depths and frequency of testing.

Soil Test	Suggested Soil Sampling Depth	Suggested Testing Frequency
Water Content	0 to 4 ft or root zone	Each crop year
Nitrate-N	0 to 4 ft or root zone	Each crop year
Sulfate-S	0 to 2 ft	Every 2 to 3 crops
Phosphorus	0 to 6 inch or plow depth	Every 2 to 3 crops
Potassium	0 to 6 inch or plow depth	Every 2 to 3 crops
Chloride	0 to 2 ft	Every 2 to 3 crops
Micronutrients	0 to 6 inch or plow depth	Every 3 to 4 crops
Soil pH	0 to 3 inch or plow depth	Every 2 to 3 crops
Soluble Salts	0 to 6 inch and/or deeper	Every 3 to 4 crops
Organic Matter	0 to 6 inch or plow depth	Every 3 to 4 crops
Lime Requirement	0 to 6 inch and/or deeper	Every 2 to 3 crops
Texture	0 to 6 inch and/or deeper	Every 4 to 6 crops

Note: Soil tests can be run more frequently than indicated to monitor changes resulting from fertilizer application if desired.

Table 2. Response of Spring wheat, grown in a crop-fallow system, to a one-time application of fertilizer P and fertilizer N applied each crop year (Halvorson and Black, 1985).

P <sub>2</sub> O <sub>5</sub> Added lb/A	Soil Test		Average Grain Yield			Cumulative Yield		
	Level P		Per Crop Year			Above Check (6 crops)		
	Crop-1	Crop-6	0-N	40-N	80-N	0-N	40-N	80-N
	----- ppm -----		----- bu/A -----			----- bu/A -----		
0	6	5	26.5	27.3	27.7	0	4	7
46	9	7	29.0	30.3	31.3	16	23	28
92	12	8	31.0	34.8	35.4	27	50	53
183	26	12	32.8	39.6	39.3	38	79	77
366	40	18	34.4	41.5	41.4	48	87	89

Note: 0-N = no N; 40-N = 40 lb N/a; 80-N = 80 lb N/a applied each crop year.

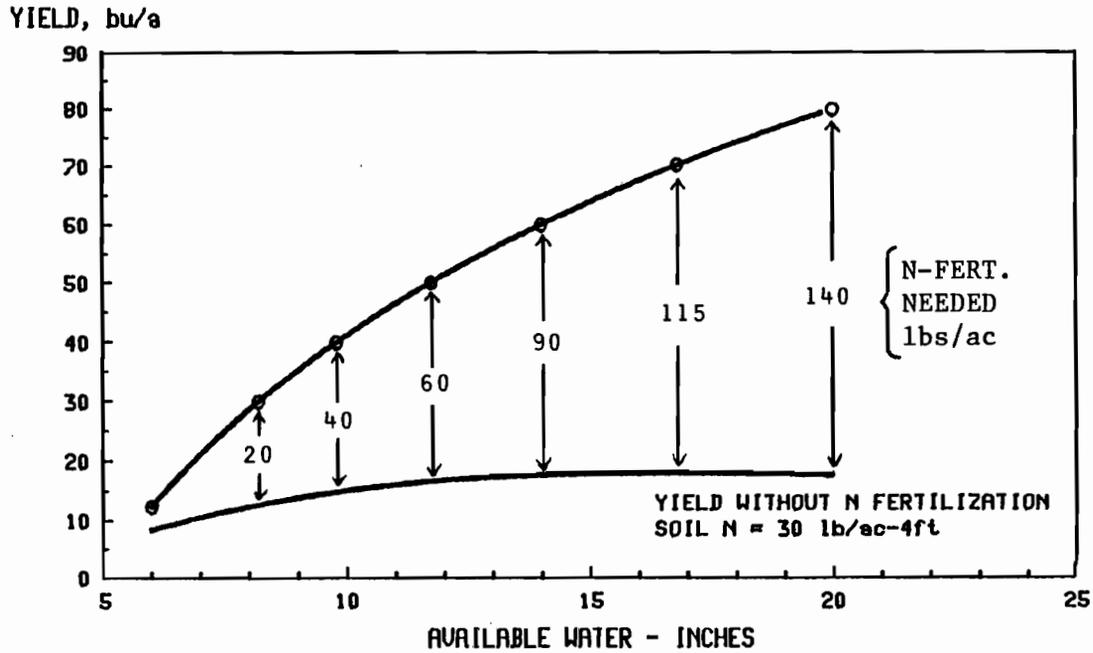


Figure 1. Available water (stored soil water plus growing season rainfall) as related to wheat yields and nitrogen needed for dryland recropping. (Black and Bauer, 1986).

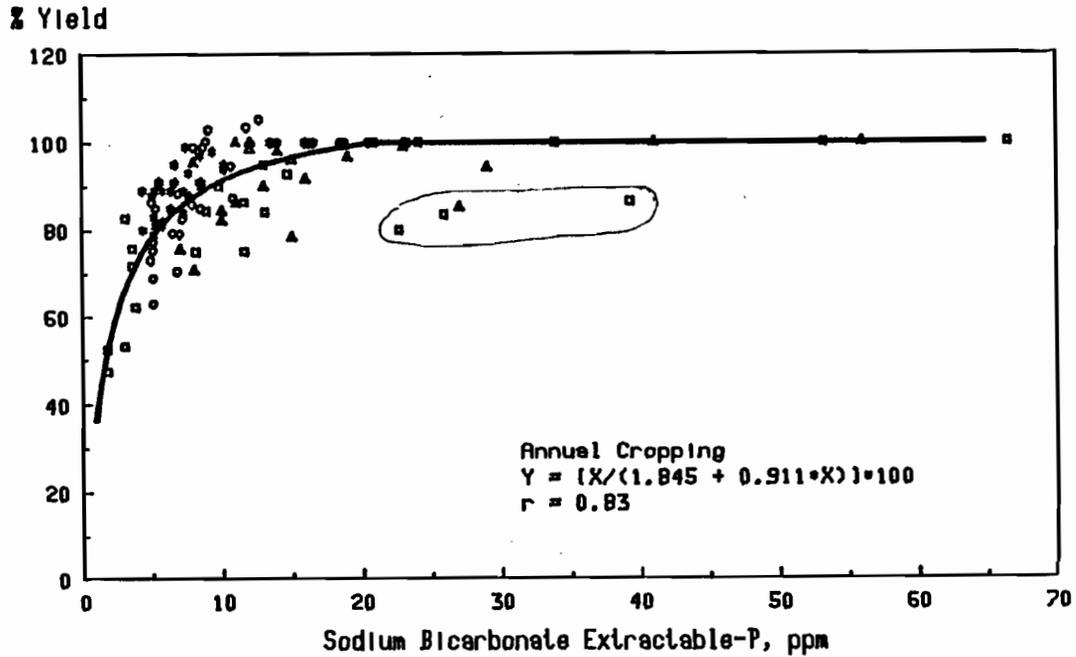


Figure 2. Relative wheat yield potential as a function of soil test P level in annual cropping systems in the northern Great Plains. Circled points excluded in regression analysis. (Halvorson, 1986).