SDSU Extension

iGrow Corn

BEST MANAGEMENT PRACTICES

Chapter: 29

Evaluating the Success of N, K, and P Fertilizer Applications

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To assess whether the fertilizer investment is adequate, it is important to conduct a periodic assessment of your corn soil fertility program (Table 29.1). This assessment could consider changes in the soil nutrient level or the amount of nutrients harvested by the crop. This chapter discusses and provides examples on how to conduct P, K, and N assessments.

Table 29.1 Steps for improving a fertilizer program:

1. Collect soil samples from your field following appropriate protocols.
2. Conduct a visual scouting of the production field.
    a. Consider collecting plant samples and soil samples from problematic areas. Have these samples been analyzed for the nutrients in question? Compare your nutrient concentration with optimum plant nutrient concentrations. If the sample nutrient concentration is below the critical level, this does not necessarily mean that your plants are nutrient-limited. The critical levels were defined many years ago and they should be used only as a benchmark for comparison. Plant nutrient concentrations should be compared with soil test results and previous yields.
3. Assess the N rate by measuring stalk nitrate and the residual N content at the end of the growing season.
4. Calculate changes in soil N by converting soil organic matter contents to organic N.
5. Track changes in soil P and K over the past several years. How do your soil P and K nutrient levels compare with the optimum soil nutrient levels?
6. Develop a P and K budget. In this calculation, consider removal and additions.
7. Based on your results, revise the N, P, and K recommendations.

Preparing to Conduct N and P Fertility Assessments

1. Soil Sample Collection

The goal for a nutrient assessment is to provide information for a valid comparison over time. This requires that the samples be collected in the same location and relative date (Chapter 21). Due to plant uptake during the growing season, N, P, and K soil test results are often lower in following harvest than prior to planting. To the best of our knowledge, an appropriate sampling time for

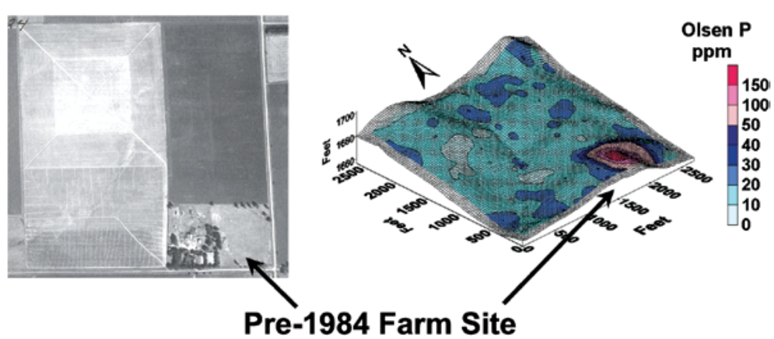

Figure 29.1 An aerial image and field soil test P contour map. Very high P levels can be found in old homestead sites. (Courtesy of authors)

long-term fertilizer assessments has not been reported. Our recommendation is to use either spring or fall samples for assessments, not both.

Sample Preparation for Shipping

After the samples are collected they should be prepared for shipping to an appropriate laboratory. When selecting a soil testing laboratory, consider the reliability of the results as well as the turnaround time. Selection of a precise and accurate laboratory is essential in terms of data quality and reliability. Precision and accuracy represent two different terms. Precision is a measure of repeatability, while accuracy is a measure of correctness of the reported value. Laboratories can be precise and inaccurate as well as imprecise and inaccurate. Where possible, select laboratories that are precise and accurate. The Soil Science Society of America sponsors the North American Proficiency Testing (NAPT) program that provides a certification of laboratories. A list of certified laboratories is available online at naptprogram.org. Ask your laboratory if it participates in a sample exchange program. Once a laboratory is selected, follow its recommendations for submitting samples. Many soil testing laboratories recommend that the samples be cooled and submitted for analysis as soon as possible. Do not leave moist soil samples in the truck for several days or in direct sunlight. Check with the laboratory about its recommendations for sample preparation.

2. Scouting fields

When scouting the field, it is important to note the date, determine the plant growth stage, visually inspect the plants for nutrient deficiencies (Table 29.1), measure the plant population, and travel beyond the field boarders (Fig. 29.2). Different protocols may be adopted for N, K, and P assessments, and in many situations, problems can be remediated only in next year's crop

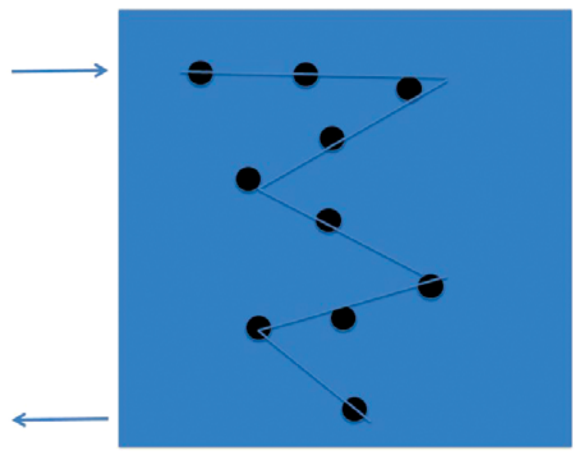

Figure 29.2 During scouting, walk in the field at least 10 steps from the field edge and examine 10 plants at every black dot.

Once the analytical and scouting results are obtained, the data should be stored for future reference. To facilitate this analysis, yield data, associated cultural practices, images, pest problems, personal notes, sampling dates, sampling protocols, and soil test results should be placed into long-term storage. Choices for long-term storage include:

- Printed hard copies of all data from a given field.
- On-farm storage of digital records. This is complicated by computer systems that routinely change.
- Off-farm storage by a data management company.
- Routinely update data to current data storage formats.

3. Tissue Sampling

Tissue sampling can be used for in-season assessment of nutrient shortages. Tissue samples collected from a prescribed location and different protocols are used for different plants and crop growth stages. For example, in soybeans at the seedling growth stage, collect the entire plant, whereas for plants between the R1 to R3 growth stages, collect 30 to 50 of the most recently mature trifoliates (Kaiser et al., 2013).

For corn at the seedling growth stage, 15 to 20 whole plants should be collected, whereas for plants between 12 inches tall (30 cm) to tasseling, 15 to 20 of the first fully developed leaves from the top of the plant should be collected. For plants between tasseling and silking, collect 12 to 20 of the leaves directly below the ear (Kaiser et al., 2013). Again, care should be followed to make sure the plants do not mold. The expected ranges for selected nutrients are provided in Tables 29.3 and 29.4.

Table 29.2 General plant deficiency symptoms that can be observed when scouting a field.

Nutrient	Symptom	Plant part	Solution
Nitrogen	General yellowing.	Older parts first.	In legume, treat seed with Bradyrhizobium or apply N fertilizer.
Phosphorus	Dark green or reddish purple leaves.	Older parts first.	Apply P fertilizer, check soil P level.
Potassium	Wilting, interveinal chlorosis, and scorching of leaf margins starting at the edge (see Chapter 23).	Older parts first.	Apply K fertilizer, check soil K levels.
Sulfur	General yellowing (see Chapter 27).	Younger leaves first.	Apply S fertilizer, check soil S level.
Iron	Yellowing of veins of the leaves generally found in high pH soils. Whole leaf may turn white.	Younger leaves first.	Use Fe efficient cultivars and treat seed with Fe.
Zinc	Pale green plants; interveinal mottling (or interveinal chlorosis in drybean) of older leaves leading to bronze necrosis; green veins.	Younger leaves first.	Apply Zn fertilizer.

Table 29.3 Expected ranges for soybean trifoliates collected between R1 and R3. (Kaiser et al., 2013)

Plant Nutrient	Unit	Expected Range
Nitrogen	%	4.26-5.5
Phosphorus	%	0.26-0.50
Potassium	%	1.71-2.50
Calcium	%	0.36-2.00
Magnesium	%	0.26-1.00
Iron	ppm	51-350
Zinc	ppm	20-50
Boron	ppm	21-55
Copper	ppm	10-30
Manganese	ppm	21-100

Table 29.4 Expected ranges of selected nutrients for corn collected at three growth stages. Images of corn growth stages are available in Chapter 5.

Nutrient	Unit	Seedling	Vegetative	Tasseling to Silking
Nitrogen	%	4.0-5.0	3.5-4.5	2.76-3.75
Phosphorus	%	0.4-0.6	0.35-0.50	0.25-0.50
Potassium	%	3.0-5.0	2.0-3.5	1.75-2.75
Calcium	%	0.51-1.6	0.20-0.80	0.30-0.60
Magnesium	%	0.3-0.6	0.20-0.60	0.16-0.40
Sulfur	%	0.18-0.40	0.18-0.40	0.16-0.40
Iron	ppm	40-500	25-250	50-250
Zinc	ppm	25-60	20-60	17-75
Boron	ppm	6-25	6-25	5.1-40
Manganese	ppm	40-160	20-150	50-250
Copper	ppm	6-20	6-20	3-15

Conducting an N Assessment

Assessing the effectiveness of the N fertilizer rate is more difficult than assessing the phosphorus fertilizer program. The differences between the nitrogen and phosphorus assessment approaches are that nitrate is rapidly lost from soil, whereas phosphate is retained by soil. Annual N fertilizer assessments can be conducted by using a stalk nitrate test to determine the amount of nitrate-N contained in stalks 2 or 3 weeks prior to black layer.

4. Stalk Nitrate Test – Annual Assessment

The cornstalk nitrate test has been used as an end-of-season tool to assess the N program. However, it is important to point out that many external values may influence the interpretation. For example, a drought can result in elevated values (Sawyer, 2010). In this test, 2 or 3 weeks prior to black layer, the section of the plant between 6 and 14 inches above the ground collected and analyzed (Camberato and Nielsen, 2014). Previous research has shown that high nitrate concentration is the result of N availability exceeding the plant requirement. Research conducted in Indiana suggests that a concentration < 450 ppm represents low availability, between 450 and 2000 ppm represents optimal availability, and > 2000 ppm excessive availability (Camberato and Nielsen, 2014). Slightly different values are suggested for Minnesota, where the adequate levels are defined between 700 and 2000 ppm (Kaiser et al., 2013). Stalk nitrate-N concentrations for South Dakota have not been defined.

5. Changes in Soil C and N – Long-term Assessment

Long-term changes in the soil organic C and N can be used to assess temporal changes in soil health and the N supplying power. Increases in soil organic matter have been linked to increased plant-available water and N mineralization. Sample calculations are provided in Example 29.1. This assessment shows that 488 lbs of organic N/acre have been added to the soil. There have been numerous attempts to develop a soil chemical test that will predict how much of the organic N will be available to the growing crop in the next growing season. In spite of these efforts, a simple chemical test is not available. Different states have integrated soil organic matter into the N recommendation differently. For example, in Nebraska soil organic matter is integrated into the calculation. However, in South Dakota soil organic matter is not integrated into the calculation. Nitrogen contained in the soil organic matter can be made available to the plant only through N mineralization.

Example 29.1 If your soil organic matter in the surface 6 inches (15 cm) has increased from 2% to 2.5%, how much additional C and N is stored in the soil? In this calculation, assume that the surface 6 inches contains 1,673,000 lbs of soil/acre, and the C/N ratio is 10. This soil has a bulk density of 1.25 g/cm^3.

Step 1. Determine the amount of soil organic matter (SOC) in the soil. In this calculation, it was assumed that 1 acre of soil 6 inches deep contained 1.68 million lbs soil.

$$\frac{(0.025\text{-}0.02\ lb)}{lb\ soil} \times \frac{1{,}680{,}000\ lbs\ soil}{acre} = 8{,}400\ lbs\ SOM/acre$$

Step 2. Convert SOM to organic C

$$\frac{8400\ lbs\ SOM}{acre} \times \frac{0.58\ lbs\ C}{1\ lb\ organic\ matter} = 4870\ lbs\ C/acre$$

Step 3. Calculate change in soil N

$$\frac{4870\ lbs\ C}{acre} \times \frac{0.1\ lbs\ N}{1\ lb\ C} = 488\ lbs\ N/acre$$

Determining P and K Removal

6. Temporal Changes in Soil Nutrients

Nutrient assessments are based on comparing changes in the soil test value with fertilizer additions and the amount of nutrient removed in harvested crops. Factors that influence the effectiveness of these calculations include:

1. That soil test values are often lower in the fall following harvest than the spring. Temporal differences resulting from overwinter recharge increase soil nutrient concentrations.
2. Field-moist samples often have lower K concentrations than dried and ground samples.
3. Soil test P can increase under anaerobic conditions and decrease under aerobic conditions. This change is attributed to changes in the oxygen concentration and associated changes in the relative amounts of Fe^{+2} (anaerobic) and Fe^{+3} (aerobic) contained in the soil solution.

Determine P Removal

Yield monitor data, when combined with average nutrient levels in grain and tissue samples, can be used to track P removal. The basic approach for converting yield monitor data to nutrient removal maps is to use data in Table 29.5. Because the yield monitor data contains erroneous information, it must be cleaned prior to analysis. Several approaches for cleaning yield monitor data are provided in Pierce and Clay (2007).

Table 29.5 Estimates of nutrient removal of N, P_2O_5, K_2O, Mg, and S by major South Dakota crops. (Clay et al., 2011)

Crop	Plant Part	Unit	N	P_2O_5	K_2O	Mg	S
Corn	Grain	lbs/bu	0.9	0.38	0.27	0.09	0.08
	Stover	lbs/ton	16	5.8	40	5	3
Soybean	Grain	lbs/bu	3.8	0.84	1.3	0.21	0.18
	Stover	lbs/ton	40	8.8	37	8.1	6.2
Wheat	Grain	lbs/bu	1.5	0.6	0.34	0.15	0.1
	Straw	lbs/mt	14	3.3	24	2	2.8

When developing a P budget, all crops used in the rotation must be considered. Removal rates for selected crops are provided in Table 29.5. The amount of nutrient removed from a field is determined by summing the amount of nutrients removed over several years, while additions are determined by summing the nutrient additions, including manure (Example 29.1). Removal can be converted from P to P_2O_5 by dividing the removal value by 0.436 and K can be converted to K_2O by dividing the removal value by 0.83.

7: Determine Nutrient Inputs

Nutrient inputs are determined by summing all of the nutrients contained in the fertilizer and the manure. For example, if 100 lbs/a of diammonium phosphate (DAP) is applied every other year, then over a 6-year period 300 lbs of DAP will be applied. Based on a fertilizer grade of 18-48-0 (N, P_2O_5, K_2O), 144 lbs of P_2O_5/a or 62.9 lbs P/acre have been applied. If 115 lbs P_2O_5 are removed annually then more P is removed than added. Under these conditions, the soil test value should decrease. An additional example is provided below (Example 29.4).

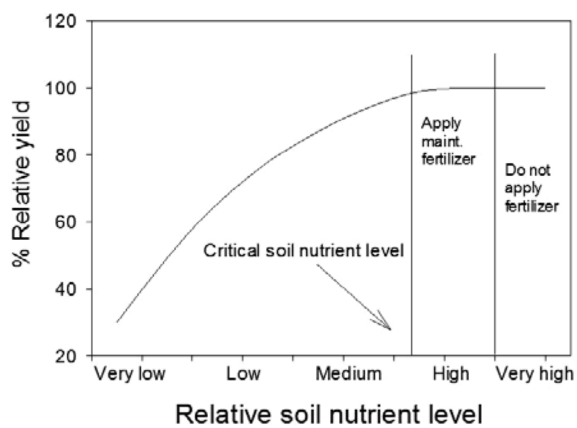

Figure 29.3 A conceptual relationship between relative yield and relative soil nutrient level. This chart shows the relationship between the critical soil nutrient level, maintenance fertilizer applications, and where not to apply any additional fertilizer.

If analysis suggests that mining has occurred (outputs>inputs) and soil test values have decreased below the critical nutrient level, consider increasing the fertilizer rate (Fig. 29.3). If the soil value is much higher than the critical level, consider reducing the fertilizer rate. In some situations, environmental considerations necessitate decreasing or eliminating additional P applications. The potential impact of increasing or decreasing the fertilizer rate can be tested by placing side-by-side fertilizer strips in the field.

Meeting Environmental and Production Goals

In the past, fertilizer recommendations were based on the plants economic responses to specific nutrients. Agronomists are now asked to consider both production and environmental goals simultaneously. Achieving this goal may require that fertilizer Best Management Practices become aligned with the 4-R program (Fixen, 2007). The 4-R program is the application of fertilizers using the right source, at the

Example 29.2 Estimating crop P and K removal in a corn and soybean rotation.

1. Calculate the amount of P_2O_5 and K_2O removed by 60 bu/acre soybean crop and 200 bu/acre corn crop.

Pounds of P_2O_5 /acre removed by a 60 bu/a soybean crop

$$= \frac{60 \text{ bu}}{\text{acre}} \bullet \frac{0.84 \text{ lbs } P_2O_5}{\text{bu}} = \frac{50.4 \text{ lbs. } P_2O_5}{\text{acre}}$$

Pounds of P_2O_5 /acre removed by a 200 bu/acre corn crop

$$= \frac{200 \text{ bu}}{\text{acre}} \bullet \frac{0.38 \text{ lbs } P_2O_5}{\text{bu}} = \frac{76 \text{ lbs. } P_2O_5}{\text{acre}}$$

Total removal is 126 pounds of P_2O_5 /acre

Pounds of K_2O /acre removed by a 60 bu/a soybean crop

$$= \frac{60 \text{ bu}}{\text{acre}} \bullet \frac{1.3 \text{ lbs } K_2O}{\text{bu}} = \frac{78 \text{ lbs. } K_2O}{\text{acre}}$$

Pounds of K_2O /acre removed by a 200 bu/acre corn crop

$$= \frac{200 \text{ bu}}{\text{acre}} \bullet \frac{0.27 \text{ lbs } K_2O}{\text{bu}} = \frac{54 \text{ lbs. } K_2O}{\text{acre}}$$

Example 29.3 Determine the amount of N and P2O5 harvested in a 200 bu/acre corn crop. A 200 bu corn crop produces approximately 9464 lbs of dry stover [(200 bu/acre)×(47.32 lbs dry grain/bu grain)×(1 lb stover/lb dry grain)]. This calculation assumes a harvest index [HI= dry grain/(grain + stover)] = 0.50

N and P2O5 in the grain + stover

$$\text{Corn N} = \frac{200 \text{ bu}}{\text{a}} \times \frac{0.9 \text{ lbs N}}{\text{bu}} + \frac{9464 \text{ lbs. stover}}{\text{a}} \times \frac{\text{ton}}{2000 \text{ lbs}} \times \frac{16 \text{ lbs}}{1 \text{ ton}} = \frac{256 \text{ lbs N}}{\text{a}}$$

$$\text{Corn } P_2O_5 = \frac{200 \text{ bu}}{\text{a}} \times \frac{0.38 \text{ lbs } P_2O_5}{\text{bu}} + \frac{9464 \text{ lbs. stover}}{\text{a}} \times \frac{\text{ton}}{2000 \text{ lbs}} \times \frac{5.8 \text{ lbs}}{1 \text{ ton}} = \frac{103 \text{ lbs}}{\text{a}}$$

Example 29.4 Calculate the amount of P_2O_5 added to a soil if 50 gal/acre of ammonium polyphosphate (10-34-0, density = 11.7 lbs/gal) are applied annually for 3 years.

$$3 \text{ years} \times \frac{50 \text{ gal}}{\text{acre}} \times \frac{11.7 \text{ lbs}}{1 \text{ gal}} \times \frac{34 \text{ lbs. } P_2O_5}{100 \text{ lbs fert}} = 597 \text{ lbs } P_2O_5/\text{a}$$

Determine the amount of K_2O that has been applied if 125 lbs of potassium chloride (0-0-62) is applied annually for 3 years.

$$3 \text{ years} \times \frac{125 \text{ lbs}}{\text{acre}} \times \frac{62 \text{ lbs. } K_2O}{100 \text{ lbs fert}} = 232 \text{ lbs } K_2O/\text{a}$$

right rate, at the right time, and at the right place. This basic concept is designed to increase yields while having a minimal impact on the environment. Worldwide research is being conducted to achieve this goal. To further improve fertilizer recommendations, new knowledge, new diagnostic techniques, routing scouting, and improved record keeping needs to be integrated into our assessment and recommendation protocols. A critical component of improving fertilizer efficiency may include changing our conceptual understanding of fertilizer response and converting static fertilizer algorithms to dynamic algorithms that consider changes in climatic conditions.

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