SDSU Extension

iGrow Wheat

BEST MANAGEMENT PRACTICES

Chapter 13: Phosphorus, Potassium, Sulfur, and Chloride Requirements

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In South Dakota wheat yields can be limited by phosphorus, potassium, sulfur, and chloride. The purpose of this chapter is to provide an overview of each nutrient as well as provide guidance on how to reduce yield losses due to these nutrient deficiencies.

Phosphorus

Phosphorus is required for root development, tillering, winter survival, and grain filling. If the soil does not contain an adequate amount of P, deficiencies can reduce yields 50% or more. Three basic approaches can be used to minimize P deficiencies.

The first approach relies on *rotations* to increase mycorrhizae populations. These fungi can increase P uptake efficiency by increasing the effective length of the root system. The importance of these organisms is discussed in Chapter 17.

The second approach relies on *mass balance calculations* where soil nutrient mining is estimated (Chapter 12). In this approach, inputs are compared with outputs. For P, outputs consist of the P removed in the harvested grain and straw. For example, a bushel of wheat and ton of wheat straw contains approximately 0.60 and 3.3 lbs of P_2O_5, respectively (Clay et al. 2010), whereas inputs are the P contained in manure and fertilizer. Examples for calculating a mass balance are provided in Chapter 12 and information on commonly used fertilizers is provided in Chapter 10.

Common P fertilizers used in South Dakota are di-ammonium phosphate (DAP, 18-46-0), mono-ammonium phosphate (MAP, 11-52-0), and ammonium polyphosphate (10-34-0, 11.7 lbs/gal). DAP and MAP are solid fertilizers, while ammonium polyphosphate is a liquid fertilizer. If manure is applied, the analyzed manure P content is estimated as 90 to 100% plant available.

The third approach relies on soil sampling to determine the fertilizer recommendation. Soils contain P in several different forms (Fig 13.1). Approximately 1% of the total soil P is in a plant-available form with the remainder as inorganic P (mineral or absorbed on clay surfaces), or tied up in crop residues and/or organic matter. Both inorganic and organic P forms can be converted to plant-available forms through chemical/physical or microbiological processes. No matter which approach is used, soil sampling should be used to track changes in soil nutrient bioavailability.

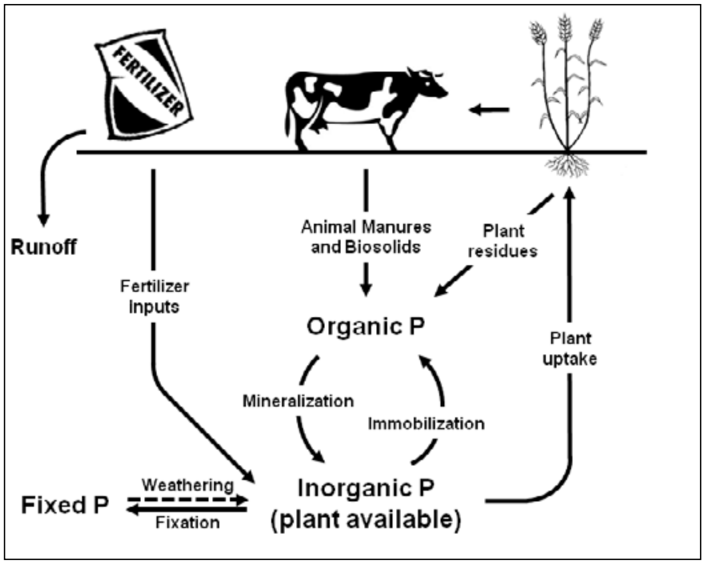

Figure 13.1. Phosphorus cycle in agricultural soils. (Source: Sang Lee, SDSU)

P deficiency symptoms

In plants, P is considered a mobile nutrient and, therefore, deficiencies are generally observed in lower leaves. The most common symptoms are purpling or the development of a light green color (Fig. 13.2). In some situations, P deficiencies can be confused with N deficiencies. Other symptoms include reduced tillering and growth and overall non-vigorous plant growth. Phosphorus soil test summaries for South Dakota reveal that about 2/3 of the state's soils require additional P for adequate wheat growth (Gelderman and Ulvestad 2009).

Figure 13.2. Phosphorus deficiency in wheat.
(Source: http://www.cropkare.com/whycropkare.html and http://www.smallgrains.org)

Soil-based P recommendations

South Dakota phosphorus fertilizer recommendations are based on the soil test P level and wheat yield goal (Table 13.1). Three different extractants, Olsen, Bray-1 or Mehlich III, can be effectively used to determine soil test P levels in the top 6 inches of soil (Gerwing and Gelderman 2005). The Bray-1 and Mehlich III methods are typically used in acid soils (pH less than 7), while the Olsen P method can be used for both low and high pH soils. The Bray-1 method is not recommended for basic (pH greater than 7) soils because this method underestimates plant available P.

An additional test, the Bray P-2 test, has not been adequately correlated to wheat's response to P fertilizer in South Dakota. The soil test results represent index values that coincide with relative yield increases to added P. The critical level for South Dakota wheat is 16 ppm (Olsen method). Research conducted at 33 sites in South Dakota shows that P fertilizer application increased yield by 36% in the very low soil test P level (0-3 ppm) soils. In soils with high (12-15 ppm) to very high P (>16 ppm), responses are less likely.

For soil test P recommendations, soil samples from the surface 6 inches should be collected. A composite sample from a field should contain at least 15 to 20 individual cores. It recommended that sampling should not include cores from waterways, terraces, and other unusual areas or from old homesteads, feedlots or fencerows.

Applying P

Time of P application is not critical as long as the recommended P rate is applied before crop uptake. Applying recommended P for two crop years has also been shown to be an effective practice. Banding with or near the seed is considered the most efficient approach to apply P. Compared to broadcast applications, similar yield responses can be obtained with 1/3 less P when band applied. However, reducing the P rate can result in a gradual decrease in the soil test P level. Banding too much fertilizer with the seed can cause seed or seedling injury from fertilizer salts and decrease seed germination.

Table 13.1. Sample P fertilizer calculations for wheat.

OLSON P METHOD

$$\frac{\text{Recommended } P_2O_5}{\text{acre}} = \left[1.071 - \left(0.067 \times \text{STP}\right)\right] \times \text{RYG}$$

Where :

STP is the soil test value in ppm, and RYG is the realistic yield goal in bu per acre.

Example, Soil test P = 8 ppm, the yield goal is $\frac{\text{60 bu}}{\text{acre}}$, and MAP (11 - 52 - 0) is the P source

$$\frac{\text{Recommended } P_2O_5}{\text{acre}} = \left[1.071 - \left(0.067 \times 8\right)\right] \times 60 = \frac{\text{32 lbs } P_2O_5}{\text{acre}}$$

$$\frac{\text{32 lbs } P_2O_5}{\text{acre}} \times \frac{\text{1 lb MAP}}{\text{0.52 lbs } P_2O_5} = \frac{\text{62 lbs MAP}}{\text{acre}}$$

BRAY-1 P METHOD AND **MEHLICH III METHOD**

$$\frac{\text{Recommended } P_2O_5}{\text{acre}} = \left[1.071 - \left(0.054 \times \text{STP}\right)\right] \times \text{RYG}$$

Example, Soil test P = 8 ppm, and the yield goal is $\frac{\text{60 bu}}{\text{acre}}$, and DAP (18 - 48 - 0) is the P source

$$\frac{\text{Recommended } P_2O_5}{\text{acre}} = \left[1.071 - \left(0.054 \times 8\right)\right] \times 60 = \frac{\text{38 lbs } P_2O_5}{\text{acre}}$$

$$\frac{\text{38 lbs } P_2O_5}{\text{acre}} \times \frac{\text{1 lb DAP}}{\text{0.48 lbs } P_2O_5} = \frac{\text{79 lbs DAP}}{\text{acre}}$$

A spreadsheet by Gelderman (2009) can be used to estimate maximum amounts of common fertilizers that can be applied with wheat at seeding. http://www.sdstate.edu/ps/service-labs-orgs/soil-test-lab/loader.cfm?csModule=security/getfile&PageID=788496

Phosphorus in the environment

Phosphorus is a non-mobile soil nutrient. This means that as a soil nutrient, it generally does not leach to the groundwater. Although P is an essential nutrient for wheat, surface runoff from fields can contain P, which can have detrimental effects on water quality (e.g., eutrophication) in lakes and streams. Phosphorus losses from fields are primarily influenced by soil erosion, P content in the soil, the application method for fertilizer or the type of manure used for P sources. Tillage methods and cover crops can play an essential role in limiting soil erosion and thus inhibiting P movement to water bodies. Lower soil P values and subsurface P placement will also limit soluble P movement.

To limit P movement/loss via surface water, either inject P, till into soil or utilize band placement. Manure should be tilled in or injected, but not applied to frozen or snow-covered soils. Phosphorus in soils is attached to soil particles and contained in organic matter. When soil particles are carried to lakes or streams, P can be released into the water. Cropping systems that reduce soil erosion will also reduce P loss. Therefore, the use of conservation tillage or no-tillage can be expected to reduce total P loss. Ground cover is essential to limit erosion, and planting of cover crops after wheat can also reduce P loss. Vegetative filter strips on hillsides and well-placed vegetative buffer zones along streams can be effective in filtering out sediments and some nutrients before they enter surface waters.

Potassium

Plants require potassium (K) for protein synthesis and photosynthesis. Most agricultural soils in South Dakota have relatively high K levels. However, soils in northeast South Dakota are relatively low in this element.

Potassium deficiency in wheat appears on the lower leaves as necrosis on the tip and edges and developing toward the leaf base (Fig. 13.3). Death of older leaves occurs more rapidly than leaves with N deficiency, and plants may appear to be suffering from drought stress. Only 0.34 lb K_2O is removed with a bushel of wheat; baling of the straw will, however, remove another 1.2 lb K_2O/bu (Clay et al. 2010). Approximately 3.3 lbs K_2O are contained in each ton of wheat straw.

Soil test K

Potassium levels in soil are measured with the ammonium acetate test on a 0-6 inch depth soil sample (Gerwing and Gelderman 2005). The critical level for South Dakota wheat is 160 ppm K. Potassium fertilizer recommendations for wheat are based on the soil K test and the yield goal (Table 13.2).

Applying K

Potassium chloride (0-0-60) is the primary K fertilizer available in South Dakota. Low soil temperature and high clay content can decrease K availability. Banding K is an effective application method; K starter banding has shown increases in K efficiency in Montana soils (Korb et al. 2005). Although higher rates of 0-0-60 can safely be banded with the seed (Gelderman 2009), it is usually not practical to do so. Application rates above 20-30 lbs K_2O/a should be broadcast.

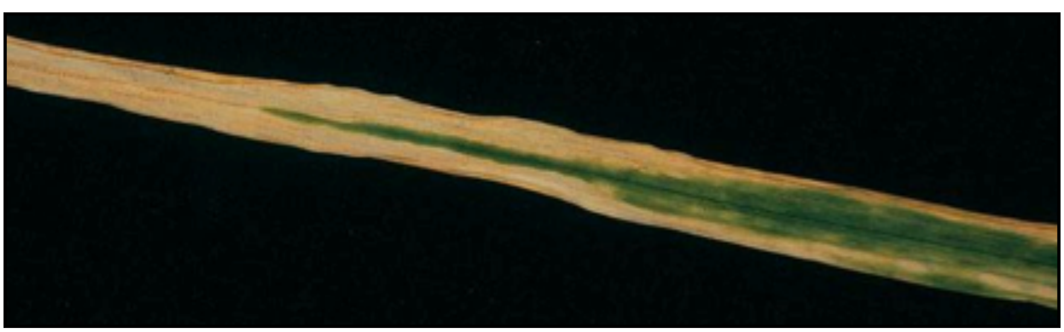

Figure 13.3. Potassium deficiency symptom. (Source: CIMMYT)

Table 13.2. Potassium fertilizer recommendation. (Gerwing and Gelderman 2005)

Where:

$$\frac{\text{Recommended } K_2O}{\text{acre}} = [2.71–(0.017 \text{ x STK})] \text{ x RYG}$$

STK is the soil test K value in ppm, and RYG is the realistic yield goal in bu per acre.

Example, Soil test K = 100 ppm, and the yield goal is $\frac{60 \text{ bu}}{\text{acre}}$

$$\frac{\text{Recommended } K_2O}{\text{acre}} = [2.71–(0.017 \text{ x } 100)] \text{ x } 60 = \frac{61 \text{ lbs } K_2O}{\text{acre}}$$

Sulfur

Wheat requires sulfur (S) to synthesize proteins that impact grain quality. In the past, atmospheric deposition of S provided much of the plant's requirement. However, air quality improvements have reduced S depositions, which have contributed to S deficiencies. In addition, less tillage (less organic matter mineralization) and higher yields (more S removal) also have led to more S deficiencies.

Sulfur deficiencies are similar to nitrogen deficiencies in that the leaves appear yellow (Fig. 13.4). These deficiencies should not be confused with herbicide injury, which also can cause chlorotic symptoms. Unlike N, S deficiency appears first on younger leaves because S is not as mobile in the plant as N. Sulfur deficiency in wheat is difficult to diagnose in the field and thus, plant or soil analysis should be used to verify the diagnosis.

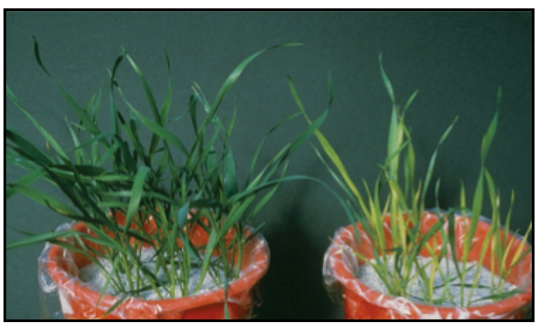

Figure 13.4. Sulfur deficiency symptom (right) compared to healthy wheat (left). (Source: CIMMYT)

Sulfur deficiency is more common in: 1) wheat grown using no-tillage, and 2) wheat grown on coarse-textured soils low in organic matter. Often S deficiency is found on the more eroded parts of the landscape (side hills), while the lower areas of the field are unaffected.

The recommended S rate is based on the soil test, texture, and tillage systems (Table 13.3). Since the sulfate ion is somewhat mobile in soils, soil should be sampled to 2 feet. Sulphur is not subject to volatilization; therefore, surface applications can be used. Commonly used S fertilizers are ammonium sulfate (21-0-0-24 S), ammonium thiosulfate (26% S, 11.4 lb/gal), gypsum (18% S), and potassium sulfate (17% S). If band applied near the seed, avoid using ammonium thiosulfate. Dry sulfur fertilizer materials can be applied with the seed at rates of 10-15 lb S/a. Elemental sulfur should be applied well before wheat is planted because the material requires 1 to 3 months in warm soil before it is completely available to be absorbed by plants. The P fertilizers MAP and DAP may also contain 1-1.5% S (Chapter 10).

Table 13.3. Sulfate recommendations for South Dakota wheat. (Gerwing and Gelderman, 2005).

Sulfate soil value (based on a 2-foot sample)	Relative level	Soil Texture			
		Coarse		Medium/Fine	
		Tilled	Strip-till or no-till	Tilled	Strip-till or no-till
Lbs SO_4-S/acre		lb S/a			
0 – 9	Very low	25	25	25	25
10 – 19	Low	5	25	15	25
20 – 29	Medium	15	25	0	15
30 – 39	High	15	15	0	15
≥ 40	Very high	0	0	0	0

Chloride

Chloride (Cl) is a critical component in the opening and closing of stomata and in photosynthesis. Leaf spotting is a deficiency symptom in wheat (Fig. 13.5) that can appear with very low soil chloride levels. Although Cl- is a required nutrient, it is needed in very small amounts. Deficiencies have been shown to limit wheat growth in South Dakota. In Cl- deficient soils, fertilizer applications can increase yields up to 15 bu/a.

Figure 13.5. Chloride deficiency (spotting) symptom (left) compared to healthy plant (right, with 24 lb Cl/a).
(Source: International Plant Nutrition Institute)

Chloride response has been related to a pre-plant soil Cl test (Table 13.4). South Dakota studies have shown a high probability of yield response from Cl fertilization when the soil test level is below 30 lb Cl/a. Little yield response was observed when it exceeds 60 lbs/a. In many fields, the response is due to the suppression of leaf disease. Chloride application rates are determined by subtracting the chloride soil test level (from the top 2 feet of soil) from 60 lbs/a, with a minimum recommendation of 15 lbs Cl/a (Table 13.5).

In general, fields that are poorly drained or have had a recent history of manure application, irrigation and/or potash (KCl) fertilization will have adequate soil chloride levels. Some recent research indicates that Cl may be cultivar-dependent. Chloride is most economically applied as potash, KCl (0-0-60), and should be surface broadcast.

Additional information and references

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Table 13.4. South Dakota soil test Cl recommendations.
(Gerwing and Gelderman 2005)

Chloride soil value	Relative level
Lbs Cl/acre	
0-15	Very Low
16-30	Low
31-45	Medium
46-60	High
60	Very High

Table 13.5. Sample calculation for Cl fertilizer recommendations.

Determine Cl in soil

$$3\ ppm = \frac{3\ lb\ Cl}{10^6\ lb\ soil} \quad \text{so} \quad \frac{3\ lb\ Cl}{10^6\ lb\ soil} \times \frac{2 \times 10^6\ lb\ soil}{Acre\ 6\ lb\ soil} = \frac{6\ lb\ Cl}{Acre\ 6\ inch\ soil}$$

$$\frac{4\ lb\ Cl}{10^6\ lb\ soil} \times \frac{6 \times 10^6\ lb\ soil}{Acre\ 18\ inch\ soil} = \frac{24\ lb\ Cl}{Acre\ 18\ inch\ soil} \quad \text{and} \quad \frac{6\ lb\ Cl}{Acre\ 6\ inch\ soil} + \frac{24\ lb\ Cl}{Acre\ 18\ inch\ soil} = \frac{30\ lb\ Cl}{Acre\ 24\ inch\ soil}$$

Assume that threshold is 60 lb Cl, then determine needed Cl

$$\frac{60\ lb\ Cl}{Acre\ 24\ inch\ soil} - \frac{30\ lb\ Cl}{Acre\ 24\ inch\ soil} = \frac{30\ lb\ Cl}{Acre\ 24\ inch\ soil} \quad \textit{Then}\ \text{determine KCl recommendation}$$

$$\frac{30\ lb\ Cl}{Acre\ 24\ inch\ soil} \times \frac{1\ lb\ KCl}{0.47\ lb\ Cl} = \frac{64\ lb\ KCl}{Acre\ 24\ inch\ soil} \quad \textit{Or}\ \text{you could say 64 lb KCl/acre}$$

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Acknowledgements

Support for this chapter was provided by South Dakota State University, South Dakota Drought Tolerance Center, South Dakota Wheat Commission, and South Dakota Soybean Board.

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