CROP INSIGHTS

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Basics of Soybean Fertility

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Summary

- Soil testing every three to four years is recommended as a basis for managing soybean fertility.
- Soybeans thrive in the pH range of 6.0 to 6.8. Essential nutrients are readily available and N-fixing rhizobia are favored in this range.
- N fertilization rarely results in agronomic or economic yield increases when nodulation is normal. More research is needed to determine when N fertilization may be warranted.
- P and K must be at high enough levels in the soil to prevent soybean deficiencies. Fertilization beyond this “critical” level generally does not increase yields.
- Sandy, low organic matter soils may show sulfur deficiencies. Atmospheric deposition of sulfate from coal-fired power plants reduces deficiencies in some areas.
- Manganese deficiencies are most likely to occur in coarse, dry, high pH and high organic matter soils. Soil or foliar applications can be used to provide this nutrient.
- Iron deficiency chlorosis is associated with native high pH soils. Variety selection is the first and most important step in managing this problem.

Introduction

Soybean yield increases have not kept pace with those of corn in farmers’ fields in recent years. Consequently, growers are re-examining soybean management practices to look for possible areas of improvement. One such area is soybean fertilization. This is especially true if fertility levels have not been maintained in some fields due to higher crop yields and higher costs for nutrients. In addition, corn and soybean nutrient needs, though similar, are not identical. For these reasons, growers may benefit from a review of basic soybean fertility principles.

Soil Testing

Managing soybean fertility should begin with regular soil testing. Soil testing is a valuable and inexpensive tool for ascertaining the nutrient and pH status of a particular field and guiding field input decisions. Soil tests should be taken every three to four years and sent to reputable labs for analysis; testing in shorter intervals is more costly and unlikely to provide further useful soil information. Instructions for collecting, handling and shipping samples are available from your state Extension service or soil test lab.

Standard soil tests generally measure pH, buffer pH (or lime test index, which is buffer pH x10), available phosphorus (P), exchangeable potassium (K), calcium (Ca), magnesium (Mg), cation exchange capacity (CEC) and organic matter (OM). Note that soil test values may be reported in either pounds per acre (lb/acre) or parts per million (ppm). To convert ppm into lb/acre, multiply ppm by 2.

Micronutrient soil tests will report amounts of the other nutrients (at a greater cost), but these quantities do not always correlate well with nutrient application recommendations in agronomic crops. Tissue testing in-season is recommended for identifying and confirming micronutrient deficiencies indicated by soil tests.

When diagnosing a suspected in-season nutrient deficiency, take soil and tissue samples from a normal area of the field in addition to the affected area. Comparing these reports will give additional insight into possible nutrient issues and increased confidence in diagnosis and confirmation of a nutrient deficiency.

Soil pH

The pH of a soil is a measure of the acidity or concentration of hydrogen ions in the soil solution. Many chemical and biological processes in the soil are affected by pH, and maintaining pH in the proper range will maximize the efficiency of other crop inputs and decrease the risk of yield losses. Soybeans thrive in the pH range of 6.0 to 6.8 (in mineral soils) for a couple of reasons. Figure 1 shows the availability of essential nutrients as a function of soil pH.

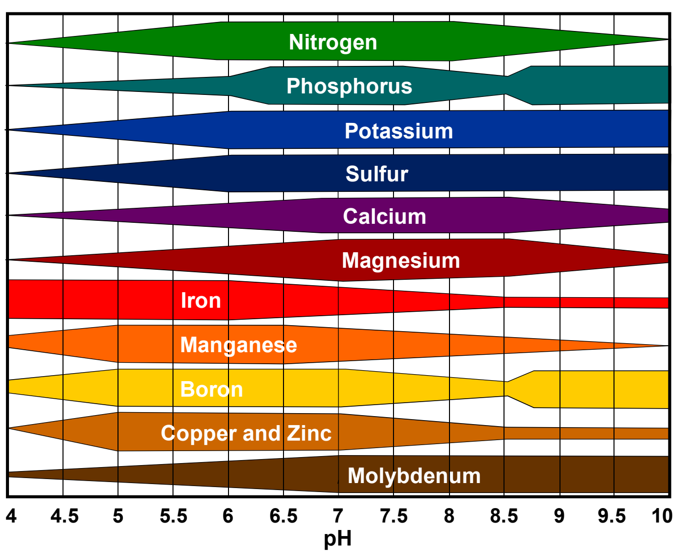

Figure 1. Relative availability of plant nutrients by soil pH[1].

Most of these nutrients are more available within than beyond this optimal pH range. Note also that some nutrients become less available as pH rises above 6.8, so “blanket” applications of lime above this point may be detrimental to the crops. Another reason for keeping pH in the desired range is to support beneficial microorganism activity in the soil, particularly *Bradyrhizobium japonicum*, which is responsible for fixing nitrogen in soybean root nodules.

To raise soil pH, the lime test index or buffer pH value is used to determine the amount of liming material necessary to reach a target pH. Low values of lime test index or buffer pH indicate that more liming materials are necessary to raise pH by a point than in a soil with higher lime test index.

Nitrogen (N)

The soybean is a high-protein crop and requires a large quantity of nitrogen (N) to synthesize amino acids and proteins. As a legume crop, however, soybeans supply most of their own N needs by fixation of atmospheric N_2 into ammonium (NH_4^+), a form that is readily available to the plant. Additional N is scavenged from the soil through organic matter cycling and rainfall deposition to supply N needs not met by the nodulation process.

Research has shown that if ammonium or nitrate is available to be absorbed from the soil when nodules are present, N-fixation will decrease proportionally. For this reason, N fertilization in soybeans rarely results in agronomic or economic yield increases when nodulation is normal, and is generally not recommended. However, research in some irrigated, high-yield environments has demonstrated that N applied during the pod or seed stages of soybean development may increase yield.

Phosphorus (P) and Potassium (K)

Phosphorus (P) and potassium (K) are macronutrients, or nutrients that are needed in relatively large quantities compared to others. The content of both P and K in soybeans is high relative to that of corn and wheat (Table 1).

Table 1. Removal of P and K by various crops. From Vitosh, et al., 1995.

Crop	Unit of yield	Nutrient removed per unit of yield	
		P_2O_5	K_2O
		----- *lb/unit* -----	
Corn - *Feed grain*	bushel	0.37	0.27
Silage	ton	3.30	8.00
Soybeans	**bushel**	**0.80**	**1.40**
Wheat - *Grain*	bushel	0.63	0.37
Straw	bushel	0.09	0.91

A 60 bu/acre soybean crop would remove about 48 lbs P_2O_5 and 84 lbs K_2O from the soil in the grain. This is 33% less phosphorus but 55% more potassium than a 200 bu/acre corn crop removes in the grain.

Soil testing should be used to determine the levels of plant-available P and K. These nutrients must be in high enough quantities in the soil to prevent plant deficiencies, but once this critical level is reached, additional yield gains with higher levels of P and K are generally not realized. University studies put the critical level for P somewhere in the range of 30 to 40 pounds per acre (Table 2). The critical level of K is more variable, and depends on the CEC of the soil (Table 2).

Table 2. Critical soil test levels (CL) for various agronomic crops. From Vitosh, et al., 1995.

Crop	P	K at CEC[1]			
		5	10	20	30
	ppm (lb/acre)	- - - - - - *ppm (lb/acre)* - - - - - - -			
Corn	15 (30)[2]	88 (175)	100 (200)	125 (250)	150 (300)
Soybean	**15 (30)**	**88 (175)**	**100 (200)**	**125 (250)**	**150 (300)**
Wheat	25 (50)	88 (175)	100 (200)	125 (250)	150 (300)

[1] Critical level for ppm K = 75 + (2.5 x CEC) for all crops

[2] Values in parentheses are lb/acre.

Note: A CEC of 15 is used to calculate the K_2O recommendation for calcareous soils (soils with equal to or greater than 7.5 and a calcium saturation of 80 percent or greater) and organic soils (soils with an organic matter content of 20 percent or greater or having a scooped density of less than 0.8 grams per cc).

Symptoms of K deficiency include yellowing of the margins of the leaves, starting with the older, lower leaves (Figure 2).

Figure 2. Potassium deficiency in soybeans. Note the yellowing pattern beginning at the leaf margins. Photo courtesy of Robert Mullen, Ohio State University.

Phosphorus deficiency symptoms include stunting, spindly stems and dark-green to bluish coloration of plant tissue.

Fertilizing on a crop-removal basis with P and K can be a good agronomic practice once the critical levels are reached. In research studies, banding P and K usually does not produce consistently better yield results than broadcast applications. Fertilizers should not be placed with the soybean seed due to risk of seedling injury and stand loss from salt-induced stresses associated with fertilizers.

Sulfur (S) and Magnesium (Mg)

Sulfur (S) is an important plant nutrient that is available in the soil from cycling of organic matter and atmospheric deposition. Sandy, low organic matter soils are associated with S deficiencies. Also, atmospheric deposition of sulfate in the eastern Corn Belt and northeast is typically higher than in the Great Plains and Midwestern states due to the operation of coal-fired power plants. Soybeans with S deficiencies will exhibit pale green-yellow color in topmost leaves.

Soybeans require 20 to 25 pounds of S per year, and in cases of high organic matter soils or manured fields, a high percentage is derived from the soil. Ammonium sulfate, ammonium thiosulfate, gypsum, potassium sulfate, magnesium sulfate and elemental sulfur are potential sources of supplemental S. For more information on sulfur requirements, see the *Crop Insights* on *Sulfur Fertility for Crop Production*.

Magnesium (Mg) deficiencies are relatively uncommon, but may occur in areas of acidic, sandy soils. Interveinal chlorosis and mottling will occur on deficient plants, starting with the lower (older) leaves. These areas may appear bronzed or speckled as the deficiency progresses.

Magnesium is usually reported in standard soil test and tissue test reports. The critical level for exchangeable Mg in the soil is 50 ppm or 100 lb/acre. The simplest method for supplementing soil Mg is by the use of dolomitic limestone, magnesium sulfate or potassium magnesium sulfate. In some cases, excessive K in the soil can hinder the plant's ability to take up Mg.

Micronutrients

Compared to the macronutrients, micronutrients are equally necessary for plant growth and yield, albeit in smaller quantities. Since only small amounts are required, there is a narrow margin between "sufficient" and "toxic" rates for some micronutrients.

Highly productive soils usually contain sufficient micronutrients for optimum crop growth, but specific soil environments or features and weather patterns can result in deficiencies. Soil pH adjustments may increase micronutrient availability in some cases, though some deficiencies are induced by other factors, such as organic matter and texture.

Manganese (Mn) - One of the more common micronutrient deficiencies observed in soybeans is manganese (Mn). Manganese deficiencies are most likely to occur in coarse, dry, high pH and high organic matter soils. Manganese deficiency symptoms include interveinal chlorosis on the newest (topmost) leaves (Figure 3).

Figure 3. Manganese-deficient soybean plants. Uppermost (youngest) leaves show interveinal chlorosis while the veins remain green. Manganese is fairly immobile in the plant rendering symptoms on the newest leaves. (Photo courtesy of Ron Gehl, NC State University).

Consistent field history of Mn deficiencies may guide the decision-making for a soil-applied Mn amendment, but foliar applications are also appropriate for treatment with a Mn product. Test soybean tissue (20 topmost trifoliate leaves with stems or petioles removed) to confirm Mn deficiency before application. Research reports that less than 21 ppm in the tissue indicates low Mn, and crop response may result from foliar Mn treatment from growth stage V6 to R1.

If Mn products are to be tankmixed with glyphosate, use an EDTA-chelated formulation of Mn and add the product to the tank last (after water, AMS and glyphosate). For more information on manganese requirements, see the *Crop Insights* on *Manganese Fertility in Soybean Production*.

Iron (Fe) - Iron deficiency chlorosis (IDC) symptoms are similar to those of manganese, with interveinal chlorosis and severe stunting (Figures 4 and 5), and are usually associated with native high pH soils. This condition is yield-limiting in many soybean fields in the northern and western U.S. Corn Belt including western Minnesota, the Dakotas, Nebraska, Kansas, Iowa and other states. Primary management practices include variety selection, iron chelate treatments and increased soybean seeding rates.

Variety Selection - Because soybean varieties vary widely for tolerance to IDC, variety selection is the first and most important step in managing this problem. Pioneer Hi-Bred has a significant research effort to screen its soybean varieties in areas with IDC (Figure 5). This effort allows Pioneer to rate existing varieties as well as identify new varieties that can help growers overcome yield losses to IDC. Pioneer® brand varieties are rated on a 1 to 9 scale where 1 indicates poor tolerance and 9 indicates excellent tolerance. If growers are planting into an area with a history of IDC, they should select varieties with an IDC score of 6, 7 or 8.

Figure 4. Interveinal chlorosis due to iron deficiency (left). Note the similar appearance to Mn deficiency (Figure 3) and stunted growth (right).

Iron Chelate Treatments – Historically, soil-applied iron chelates could not be justified due to cost, and the value of seed- and foliar-applied treatments was also questionable in Pioneer and University studies. However, a relatively new soil-applied Fe-EDDHA, Soygreen®, is less expensive at about $10 to $15/acre. Pioneer and University studies have shown a profitable response of Soygreen, but in Pioneer studies, Soygreen did not increase yields of tolerant varieties with a rating of "7".

Increased Plant Population – Another management practice that has resulted in higher yields in IDC areas is increased plant population. Scientists suggest increasing plant density to 200,000 plants/acre in 30-inch rows in chlorotic field areas. Using GPS systems to map affected fields, and variable-rate seeding equipment to vary seeding rates in affected vs. non-affected field areas could increase the efficiency of this management strategy.

Figure 5. Pioneer research plot showing extreme varietal differences in iron deficiency chlorosis tolerance.

In areas that do not have native calcareous, high pH soils, IDC is much less common. Liming these soils only when necessary can help avoid Fe deficiencies. Acidifying the soil may increase availability of Fe, and acidification can occur with the use of ammonium and sulfate-containing fertilizers. For more information on iron deficiency, see the *Field Facts* on *Management of Soybeans on Soils Prone to Iron Deficiency Chlorosis*.

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[1] Adapted from E. Truog. 1946. Soil reaction influence on availability of plant nutrients. Soil Science Society of America Proceedings 11, 305-308.

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