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TENNESSEE SOYBEAN PRODUCTION HANDBOOK

CHAPTER 5: Soil Fertility and Nutrient Management in Soybean

Nutifafa Adotey, Assistant Professor
Department of Biosystems Engineering and Soil Science, UT Extension

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SOIL TESTING

The only practical way to determine the nutritional needs in a field to prescribe appropriate lime and fertilizer recommendations is with a reliable soil test. A regional soil testing laboratory is recommended for a robust soil testing program, considering it will be familiar with your local soil conditions to avoid misleading interpretation of soil test results. Although soil samples may be collected at any time, it is best to sample months ahead of planting to allow for planning. The reliability of soil test results depends on the quality of the sample submitted to the soil testing laboratory so it is important to collect representative soil samples using proper sampling procedures. A well represented sample will consist of appropriate subsamples taken at the correct depth and some form of systematic sampling method is necessary to assess accurate fertility. The recommended soil sampling depth for determining soil pH, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) micronutrients and organic matter in Tennessee is 0-6 inches. Information, submission sheet, and sample box are available at your local county UT Extension office or visit the UTIA Soil, Plant and Pest Center website for additional information.[1]

SOIL PH AND LIMING

Fertilizers will be most effective and soybean performs best when soil pH is from 6.2 to 6.8 in mineral soils. Soils with pH < 5.8 decrease the availability of several nutrients that may result in significant yield penalty. Liming is recommended for fields with soil pH < 6.0, and the lime requirement should be based on soil test result to prevent over application. Over-application of lime may result in very high soil pH, thus inducing phosphorus and some micronutrient deficiencies, particularly manganese (Mn) and iron (Fe). In addition, high soil pH can influence the extent of yield loss due to soybean cyst nematodes. Liming materials should be applied at least four months prior to planting to allow enough time for lime to react and effect pH change in the soil, especially within the no-till production system.

FERTILIZER RECOMMENDATIONS

Fertilizer application, particularly P, K, S and molybdenum (Mo), are vital for optimal soybean yields. It is important to apply these recommended nutrients at rates suited to crop needs to prevent unnecessary expenses and decrease nutrient losses to the environment.

PHOSPHORUS

Phosphorus (P) is important particularly during the early stage of growth and development. It is involved in photosynthesis, energy storage and root development. Plants use most of their P in the orthophosphate ($H_2PO_4^-$) form. Smaller amounts of PO_4^{3-} and HPO_4^{2-} are also taken up. Historically phosphorus fertilizer sales are reported as P_2O_5 equivalence, or 2.29 times the elemental P value.

Phosphorus fertilizer application rate should be based on a soil test. In Tennessee, P fertilizer recommendations are based on the Mehlich I or double acid extraction procedure because it correlates well with the soils in Tennessee. Detailed information on how UT recommendation were developed is addressed in "University of Tennessee Fertilizer Recommendation Development" publication.[2] If you are using soil test analyses from laboratories that are using the Mehlich III extraction, the conversion to Mehlich I is described in the "UT Fertility Recommendations for Tennessee Row Crops" publication.[3]

Phosphorus is generally applied preplant in soybean, either in the fall or in the spring prior to planting. Phosphorus loss can occur via soil erosion, leaching in deep sandy soils, or P may be highly retained or even fixed in certain soil types. Phosphorus fertilizer sources are equal in their ability to supply P if correctly applied, even though studies have found polyphosphate promotes

[1] See "Soil, Plant and Pest Center."

[2] See L. Duncan et al. "University of Tennessee Fertilizer Recommendation Development."

[3] See L. Duncan et al. "UT Fertility Recommendations for Tennessee Row Crops."

Table 5-1. *Soil test phosphate interpretation and recommendation for soybean production in TN.*

RANKINGS	SOIL TEST P (lb P a^{-1})		APPLICATION RATES
	MEHLICH-I	MEHLICH-III	(lb P_2O_5 a^{-1})
Low	0 – 18	0 – 30	40
Medium	19 – 30	31 – 60	20
High	31 – 119	61 – 210	0
Very High	≥ 120	≥ 211	0

†Ranges are based on Mehlich I

Source: L. Duncan et al. "UT Fertility Recommendations for Tennessee Row Crops."

Table 5-2. *Soil test potash interpretation and recommendation for soybean production in TN.*

RANKINGS	SOIL TEST K (lb K a^{-1})		APPLICATION RATES
	MEHLICH-I	MEHLICH-III	(lb K_2O a^{-1})
Low	0 – 90	0 –114	80
Medium	91 – 160	115 – 203	40
High	161 – 319	204 – 405	0
Very High	≥ 320	≥ 406	0

†Ranges are based on Mehlich I

Source: L. Duncan et al. "UT Fertility Recommendations for Tennessee Row Crops."

more root growth than orthophosphate. The International Plant and Nutrition Institute (IPNI) developed one-page fact sheets on the various granular and liquid P fertilizer sources[4] and gave a review on their use. Soil test phosphorus interpretation and recommendation for soybean production in Tennessee is summarized in ***Table 5-1***. Application of P is not recommended on high- or very high–test soils.

POTASSIUM

Potassium (K) (also called potash) is a macronutrient that plays an important role in protein and starch formation in the grain, transport of water, nutrients and carbohydrate within the plant, cell wall strength, stomata closure and stalk strength. Thus, soybean plants with inadequate K are susceptible to drought stress and diseases. Plants uptake and use K in the potassium ion (K^+) form. Historically, potassium fertilizer sales are reported as K_2O equivalence, or 1.2 times the elemental K value.

Potassium fertilizer application rate should be based on soil test. Potassium is generally applied preplant in soybean, either in the fall or in the spring prior to planting. Potassium fertilizer sources are equal in their ability to supply K if correctly applied. IPNI developed one-page fact sheets on the various K fertilizer sources[5] (potassium sulfate, potassium nitrate and muriate of potash) and gave a review on their use. Application of K is not recommended on high- or very high–testing soils. Soil test potash interpretation and recommendation for soybean production in Tennessee is presented in ***Table 5-2***.

SULFUR

The UT "Sulfur and Tennessee Row Crops" publication[6] provides an excellent review on sulfur (S) as well as response of row crops to S application. Recent studies in TN did not show significant soybean yield response to S fertilizer application. Current extraction methods are not reliable in predicting soybean yield response to S level in soil, as a result, S application is based on field conditions and past cropping history where crops have exhibited visual sulfur deficiency confirmed by tissue testing. Plants use S in the sulfate (SO_4^{2-}) form.

Sulfur is typically applied near or at planting in soybean in the spring because S in the sulfate form is prone to leaching. IPNI developed a one-page fact sheet on some S fertilizer sources.[7] On soils having a coarse-textured subsoil, 10 pounds of S per acre as part of the fertilizer

[4] See IPNI. "Nutrient Source Specifics."
[5] Ibid.
[6] See T. Raper et al. "Sulfur and Tennessee Row Crops."
[7] See IPNI. "Nutrient Source Specifics."

blend may benefit yield, especially where deficiency symptoms have been observed in soybean in the past or where plant tissue tests have suggested sulfur deficiency.

MOLYBDENUM

Nitrogen (N) fertilizer is not recommended since nitrogen fixation by soybean will usually supply adequate N for optimum yield. Nitrogen fertilizer provides either no yield increases or poor return on fertilizer investment. Low pH soil can reduce molybdenum (Mo) availability, which is required by the bacteria that form nodules for N fixation. Molybdenum deficiency in turn induces nitrogen deficiency, resulting in significant yield penalty. Treat soybean seed with two tenths (0.2) of an ounce of molybdenum per bushel when soil pH is 6.5 or below. Apply either half (0.5) of an ounce of sodium molybdate per bushel or follow the product label for liquid hopper-box applied sources containing fungicides.

NUTRIENT DEFICIENCY

Generally, a nutrient deficiency occurs because of low soil nutrient levels; however, prevailing environmental conditions, soil properties, growth conditions and root diseases may restrict nutrient uptake and induce deficiencies in crops even if soil nutrient levels are estimated sufficient for optimum yield. For example, low or high soil pH, soil compaction and excessively wet or dry soil may prevent nutrient uptake. A handy diagnostic tool to identify nutrient deficiency in crops is via visual observation of symptoms. Nevertheless, this tool may not always provide a definite diagnosis of the nutrient status of the plant. Keep in mind other conditions are capable of inducing symptoms that closely resemble those of nutrient deficiencies. To address this, visual symptoms should be corroborated with plant tissue and soil testing, as well as examination of the history of nutrient applications to the field. Adequate knowledge of visual symptoms and tissue testing may help guide corrective actions in-season or

Table 5-3. *Visual nutrient deficiency symptoms and plant-tissue deficiency levels for soybean.*

NUTRIENT	DEFICIENCY SYMPTOMS AND PLANT/LEAF TISSUE DEFICIENCY LEVELS FOR SOYBEAN
	MACRONUTRIENTS
Nitrogen (N)	**Plant:** Pale green plants. **Leaf:** Appear first on older (lower) leaves. Pale yellow leaves leading to brown, older leaves; veins are prominent. Deficiency is diagnosed when tissue N @ flowering is < 3.25% (Table 5-4).
Phosphorus (P)	**Leaf:** Dark green to bluish leaves with interveinal, small lesions. Appear first on older (lower) leaves. Deficiency is diagnosed when tissue P @ flowering is < 0.3% (Table 5-4).
Potassium (K)	**Leaf:** Appear first on older (lower) leaves. Yellowing along leaf margin progressing to browning; veins remain green. Deficiency is diagnosed when tissue K @ flowering is < 1.5% (Table 5-4).
Magnesium (Mg)	**Plant:** Pale green plants. **Leaf:** Initially expressed as interveinal pale mottling of leaves followed by interveinal necrosis. Appear first on older (lower) leaves. Deficiency is diagnosed when tissue Mg @ flowering is < 0.25% (Table 5-4).
Sulfur (S)	**Plant:** Pale green to yellow plants. **Leaf:** Pale green to yellowing of leaves without prominent vein or necrosis. Appear first on younger (upper) leaves. Deficiency is diagnosed when tissue S @ flowering is < 0.25% (Table 5-4).
	MICRONUTRIENTS
Zinc (Zn)	**Plant:** Pale green plants. **Leaf:** Pale yellow leaves leading to brown, older leaves; veins are prominent. Appear first on younger (upper) leaves. Deficiency is diagnosed when tissue Zn @ flowering is < 21 ppm (Table 5-4).
Boron (B)	**Leaf:** Distorted uppermost leaves. Waxy leaf surface. Appear first on younger (upper) leaves. **Flower:** Abortion of flower. Deficiency is diagnosed when tissue B @ flowering is < 20 ppm (Table 5-4).

Source: IPNI, "Nutrient Source Specifics."

preventive action in the following season to avoid yield loss. Nutrient deficiency in soybeans is rare in Tennessee. ***Tables 5-3*** and ***5-4*** and ***Figure 5-1*** provide information on identifying N, P, K, Mg, S, Zn and B nutrient deficiencies in soybean using visual symptoms.

REFERENCES AND RESOURCES

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Table 5-4. Nutrient sufficiency ranges for recently matured trifoliate soybean leaf at early growth and flowering. Source: R. Campbell, 2013.

GROWTH STAGE	N	P	K	Ca	Mg	S	B	Fe	Mn	Cu	Zn
EARLY GROWTH	3.5–5.5%	0.30–0.60%	1.7–2.5%	1.1–2.2%	0.30–0.60%	-	-	-	-	-	-

Figure 5-1*. Visual N, P, K, Mg, S and B deficiency symptoms for soybean*

NITROGEN (N) DEFICIENCY

Fig. 5-1a. *Healthy soybean plants (Dark green plant on left and right) and N deficient plant (middle). The leaves of N deficient plants are yellowish-green in color. Symptoms appears first on older (lower) leaves. Source: Slaton et al., 2013.*

PHOSPHORUS (P) DEFICIENCY

Fig. 5-1b*. Healthy soybean plants (left) and P deficient plant (right). Phosphorus deficient plant with stunted growth, lack of canopy and upright leaves. Phosphorus deficient leaves may be dark green to bluish leaves with small lesions. Symptoms appear first on older or lower leaves. Source: Unknown photographer, Nebraska Institute of Agriculture and Natural Resources.*

POTASSIUM (K) DEFICIENCY

Fig. 5-1c. *Soybean plant with K deficient leaves. Potassium deficiency is associated with interveinal chlorosis that begins from the leaf tip and margins. Chlorosis then progresses to necrosis (browning). Symptoms appear first on older (lower) leaves. Source: Unknown photographer, Mississippi State University Extension.*

MAGNESIUM (Mg) DEFICIENCY

Fig. 5-1d. *Soybean plants with Mg deficient leaves. Magnesium deficient plant with interveinal mottling of leaves and interveinal necrosis. Symptoms appears first on older (lower) leaves. Source: Unknown photographer, Nebraska Institute of Agriculture and Natural Resources.*

SULFUR (S) DEFICIENCY

Fig. 5-1e. *Soybean plants with S deficient leaves. The leaves of S deficient plant are yellowish-green in color with reduced leaf size. Symptoms appears first on younger (upper) leaves. Location of deficiency is useful in differentiating between N and S deficiency. Source: Unknown photographer, Mississippi State University Extension.*

BORON (B) DEFICIENCY

Fig. 5-1f. *Soybean plants with B deficient leaves. The leaves of S deficient plant are darker green in color and distorted/deformed. Plants may show waxy leaf surface. Symptoms appears first on younger (upper) leaves. Source: Slaton, et al., 2013.*

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