AGR-213

University of Kentucky
College of Agriculture, Food and Environment
Cooperative Extension Service

Soybean Nutrient Management in Kentucky

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Soybean grows best on fertile soils. For decades, the University of Kentucky has conducted field studies to establish the relationship between soil nutrient supplies and soybean yield. Adequate soil fertility must be present so that yields are not limited. Soybean removes a large amount of nutrients in the seed relative to other annual crops. For each bushel of soybean produced, 3 lb N, 0.7 lb P_2O_5, and 1.1 lb K_2O will be removed in the seed, but considerably more is required to supply the leaves, stems and pods that are not removed during harvest (Table 1).

Table 1. Nutrient uptake and removal with a 50 bushel per acre soybean grain yield.

	Nutrient content (lb/A)		
Total nutrient (lb/A)	**N**	**P_2O_5**	**K_2O**
Total above ground biomass uptake[1]	270	54	119
Removed in seed[2]	150	35	55

[1] Adapted from Purdue Extension publication *Corn and Soybean Field Guide* (ID-179).
[2] Adapted from University of Kentucky Extension publication *Lime and Nutrient Recommendations* (AGR-1).

Soybean Nutrient Management Tools

Soil nutrition levels are assessed by soil sampling and testing. Soil samples should be collected over a field area no larger than 10 acres so as to characterize soil pH and nutrient levels. Larger areas can be sampled if uniform nutrient status is confirmed by soil sampling and crop management practices are the same. Soil samples should be collected to a depth of 4 inches for no-tilled (NT) soils and 6 inches for tilled soils. Seasonal variation in soil test values can occur, particularly in soil pH and bioavailable potassium (K). For this reason soil samples should be collected at the same time each year (e.g. fall or spring). Monitor soil test trends over time to identify whether soil test values are increasing or decreasing. If a clear trend is identified then adjust soil fertility additions appropriately to address the deviation. Ideally, fields should be sampled yearly, but biennial sample collection is acceptable. When applying nutrients for multiple crops and making one application, P and K nutrient recommendations can be added together and applied prior to planting the first crop. Nutrient recommendations will differ depending on cropping sequence. Soybean P and K recommendations are presented below in Table 2. When double cropping wheat and soybean, the P recommendation for small grain and the K recommendation for soybean (Table 2) should be followed. Guidelines relating soil test P and K levels and the associated P and K fertilizer rate recommendations are available in *Lime and Nutrient Recommendations* (AGR-1).

Plant tissue analysis is an acceptable method for determining the nutrient status of soybean at the time the sample is collected but may not be well correlated to soil test values for the same nutrient. Tissue analysis can identify nutrients that might be limiting soybean growth, development and yield, but plant analysis alone will not identify potential contributing factors such as general or sidewall compaction, a soil pH or water drainage problem, or weather events that might have influenced plant nutrient composi-

Table 2. Phosphate and potash rate recommendations for soybean (lbs/A).[1]

	Full season soybean		Double crop soybean[2]		Full season and double crop soybean[2]	
Soil test category	**Soil test P:**	**P_2O_5 needed**	**Soil test P:**	**P_2O_5 needed**	**Soil test K:**	**K_2O needed**
High	>60	0	>60	0	>300	0
Medium	40-60	30	48-60	30	242-300	30
	34-39	40	45-47	40	226-241	40
	28-33	50	41-44	50	209-225	50
			38-40	60	191-208	60
			34-37	70		
			31-33	80		
Low	22-27	60	24-30	90	173-190	70
	16-21	70	17-23	100	155-172	80
	11-15	80	10-16	110	136-154	90
	9-10	90			118-135	100
	7-8	100			100-117	110
	6	110				
Very low	1-5	120	<10	120	82-99	120
					64-81	130
					46-63	140
					<46	150

[1] Adapted from University of Kentucky Extension publication *Lime and Nutrient Recommendations* (AGR-1).
[2] Assumes fertilizer P and K will be applied before the wheat crop and is adequate for both the wheat and double crop soybeans.

Table 3. Nutrient sufficiency ranges for soybean, at early growth and at flowering, when taking the uppermost fully developed trifoliate leaf for the sample.

Nutrients concentration reported (%)						Nutrient concentration reported (ppm)					
N	**P**	**K**	**Ca**	**Mg**	**S**	**Fe**	**Mn**	**Zn**	**Cu**	**B**	**Mo**
Early growth											
3.5-5.5	0.3-0.6	1.7-2.5	1.1-2.2	0.03-0.6	0.3-0.8	ND*	ND	ND	ND	ND	ND
Flowering											
3.25-5.0	0.3-0.6	1.5-2.25	0.8-1.4	0.25-0.7	0.25-0.6	25-300	17-100	21-80	4- 30	20-60	0.1-2.0

*ND—A sufficiency range for these nutrients has not been determined.

tion. Nutrient sufficiency ranges for plant tissue samples are reported in Table 3. These ranges are good guidelines but are not absolute. If tissue sample analysis results fall within the reported ranges, deficiencies should not occur. However, values slightly above or below these ranges do not mean that plant growth or yield will be limited. Values that deviate greatly from the reported ranges should be investigated further to understand potential yield limiting factors.

Fertilizer applications should be based on soil test results, since plant tissue analysis does not indicate the amount of available soil fertility. Plant analysis is useful in diagnosing nutritional problems during the growing season. For best results, plant tissue analysis should be done in conjunction with regular soil testing. Useful plant nutrient analysis results start with properly taken samples, so follow guidelines found in *Sampling Plant Tissue for Nutrient Analysis* (AGR-92).

Soil pH

Soybean performs best when soil pH is between 6.2 and 6.8. Higher soil pH values can reduce the availability of phosphorus and manganese to soybean; lower soil pH values can cause reduced phosphate or molybdate availability, and/or toxic levels of aluminum or manganese. Low soil pH can also reduce nodulation and biological nitrogen fixation. Most soils in Kentucky are acidic and will need to be limed at some point.

Agricultural lime is either calcitic (mostly calcium carbonate) or dolomitic (calcium-magnesium carbonate), and these carbonates neutralize soil acidity. Agricultural lime should be applied at least six months prior to soybean planting to gain most of the lime benefit. Fall application allows enough time for the lime to react, and soils are typically drier in the fall, reducing the risk of compaction during lime application. If fall application is not possible, then lime can be applied in the spring, if soils are suitable for traffic. A spring application may not allow for the full benefit of lime application if the soil pH is very acid but is better than no application at all.

When the soil pH is too high (above 7.2) soybean producers might wish to add a soil amendment to acidify the soil, but this practice has not proven practical for row crops. The nutrients most likely to be deficient for soybean on high pH soil can be dealt with by maintaining adequate soil test levels (phosphorus) or with timely foliar applications (manganese). When soybeans are in a rotation with corn, or corn and wheat, the fertilizer N added to these crops will typically lower soil pH over time.

Macronutrients, Primary and Secondary

Macronutrients for soybean include the primary nutrients: nitrogen (N), phosphorus (P), and potassium (K); and the secondary nutrients: calcium (Ca), magnesium (Mg), and sulfur (S). If a soybean field is properly inoculated, N fixation will supply adequate N. The only two nutrients that need to be added to soil on a regular basis are P and K. To date, no University of Kentucky research has documented soybean yield increases to fertilizer Ca, Mg or S applications. Common fertilizer sources used in Kentucky soybean production are found in Table 4.

Table 4. Nutrient ion forms available to the plant and the common fertilizer sources used in Kentucky soybean production.[1]

Nutrient	Ion forms available to soybean	Common fertilizer sources	Nutrient analysis	Comments
Phosphorus (P)	$H_2PO_4^-$, HPO_4^{2-}	DAP, diammonium phosphate ($(NH_4)_2HPO_4$)	18-46-0	
		MAP, monoammonium phosphate ($NH_4H_2HPO_4$)	11-52-0	
Potassium (K)	K^+	Muriate of potash (KCl)	0-0-60	
Manganese (Mn)	Mn^{2+}	Manganese sulfate ($MnSO_4$)	24% Mn	Soil pH > 7.2 increases risk for Mn deficiency
		Manganese chelate (Mn EDTA)	12% Mn	Foliar Mn application is superior to soil applied Mn
Molybdenum (Mo)	MoO_4^{2-}	Sodium Molybdate (Na_2MoO_4)	38-40% Mo	Soil pH < 5.8 increases risk for Mo deficiency

[1] Only nutrients with a predicted yield response from field research in Kentucky are included in this table. Nitrogen (N) was not included because acceptable inoculation with *B. japonicum* is assumed.

Nitrogen

Nitrogen (N) is important to photosynthesis and the synthesis of amino acids, which are the building blocks of protein. Soybean seed is relatively high in protein, increasing the crop's relative N requirement for yield. There is about three (3) pounds of N in every bushel of soybean seed. Of course, more N than this is needed to grow the stems, leaves and pods that are needed to produce yield. Fortunately, soybean has a symbiotic relationship with *Bradyrhizobium japonicum*, a relationship which causes all necessary N to be fixed and made available to the crop. If soil pH is maintained at a proper level and nodulation is adequate, there is no need to apply fertilizer N to soybean. Numerous root nodules (Figure 1) are an indication that the soybean-bacteria association will fix sufficient N for high yield.

Figure 1. Soybean roots with excellent (left) and poor (right) nodulation.

Figure 2. Areas of this soybean field that are lighter green in color are N deficient because of poor nodulation.

Because soybean's N demand is high, *B. japonicum* inoculation is a much less expensive way to provide the crop's N nutrition than fertilizer N. The *B. japonicum* typically remains in the soil at adequate populations when the field is in a corn–soybean rotation. If soybean is not grown for three to five years, the seed should be inoculated with fresh *B. japonicum* inoculant prior to planting to insure biological N fixation. If the previous soybean crop exhibited poor nodulation, seed for the next crop should be inoculated. There is limited evidence that fields saturated for extended periods during winter have lower populations of *B. japonicum*. Soybean planted into these fields could benefit from fresh seed inoculation.

Symptoms of nitrogen deficiency in young soybean include slow growth and pale green leaves (Figure 2). If N deficiency occurs over a longer period, the pale green leaves will occur over most of the plant, older leaves will turn yellow and leaf senescence (defoliation) will start early. The most common cause of N deficiency in soybean is a lack of nodulation. If N deficiencies are detected early and there are no restrictions on root development, fertilizer N should be applied. Approximately 200 to 250 pounds of N per acre will be needed for a normal yield of full season soybean. Nitrogen deficiency can be induced by molybdenum deficiency, usually due to low soil pH.

Phosphorus

Phosphorus (P) is critical for energy storage and transfer during plant development. Phosphorus, like nitrogen, is also crucial for root development. Soybean P deficiency results in stunted plants, delayed maturity, lack of canopy, and upright leaves (Figure 3). As the crop ages the color may shift toward a bluish pale-green color. Applications of fertilizer P generally result in yield increases when soil P test levels for P are very low to low. The most common form of fertilizer P in Kentucky is diammonium phosphate (DAP, 18-46-0), although monoammonium phosphate (MAP, 11-52-0) is also used. Phosphorus fertilizers should be applied to the soil in the spring prior to planting soybean. The P fertilizer may be applied in the fall after harvest of the previous crop, though this timing is less desirable due to P fixation and loss.

Potassium

Potassium (K) is critical for enzyme activation, osmotic pressure to draw water into roots, photosynthesis, and energy relationships within the plant. Potassium is mobile within the plant, so K deficiency appears first as yellowing near the margins of older leaves; in severe cases, symptoms will progress to brown necrotic (dead) tissue (Figure 4). An observation of soybean K deficiency does not necessarily indicate that the soil is K deficient. Soil compaction or other factors that limit soybean root growth (soybean cyst nematode) can reduce K uptake and result in K deficiency symptoms in the crop.

Applications of fertilizer K generally result in yield increases when soil tests for K are very low to low. The most common form of K fertilizer sold in Kentucky is muriate of potash (KCl, 0-0-60). Potassium fertilizers should be applied prior to seeding soybean, either in the previous fall or in the spring. When double cropping small grains and soybean, the soil test based K recommendation should come from the soybean and the P recommendation should come from the small grain. This information is summarized in Table 2. Both P and K should be applied prior to seeding the small grain in the fall.

Figure 3. Soybean exhibiting P deficiency, with stunted growth, delayed maturity, lack of canopy, and upright leaves.

Micronutrients

Micronutrient elements include boron (B), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), molybdenum (Mo), chloride (Cl) and nickel (Ni). Soil organic matter (SOM) is the "storehouse" for several micronutrient elements. Most SOM-borne micronutrients are in plant-available forms. Soils in Kentucky usually supply adequate micronutrients for maximum soybean yield when the soil pH is maintained between 6.2 and 6.8. Deficiencies in Mo and Mn have been observed in some Kentucky soybean fields and both are related to soil pH. Micronutrients are only needed in very small amounts by plants and the difference between sufficient and toxic plant tissue concentrations is typically small. Care must be exercised in order to avoid over-application and subsequent plant toxicity. Micronutrient applications can be made to soil or foliage. The soil application of micronutrients is almost always superior to foliar application, except when Mn is needed to avoid deficiencies on high pH soils. Foliar macronutrient applications are not recommended.

Figure 4. Soybean potassium deficiency is associated with chlorosis and necrosis at the margins of the oldest leaves. In this field, K deficiency was due to soil compaction that restricted root growth.

Molybdenum

Molybdenum (Mo) is necessary for N fixation by *Bradyrhizobium japonicum.* A lack of Mo for these bacteria results in soybean N deficiency. Soil pH values below 5.8 are associated with reduced Mo availability, and Mo deficiencies normally do not occur when soil pH is at or above 6.2. This means that the best way to maintain adequate Mo is to keep the soil pH above 6.2. In a rescue situation, Mo can be applied as sodium molybdate at 1 to 2 ounces per acre (0.4 to 0.8 ounces of Mo per acre) as a seed treatment. If the soybean seed is inoculated with *B. japonicum* and treated with Mo, the seeds must be planted immediately or the inorganic sodium molybdate may greatly reduce the viability of *B. japonicum*. Another rescue option is to apply sodium molybdate at 1 to 2 ounces per acre as a soil or foliar application.

Manganese

Manganese (Mn) functions as an enzyme activator for photosynthesis. Manganese deficiency in Kentucky has occurred on medium and fine-textured soils with a pH of 6.5 or greater (especially if greater than 7.2), particularly in the Lower Green River region. The combination of high soil pH and poor drainage increases the likelihood of soybean Mn deficiency. Since Mn is relatively immobile in soybean, deficiency symptoms occur first as interveinal chlorosis (leaf veins are green, but areas between the veins are yellow) on younger leaves. Foliar Mn application to Mn deficient soybean improves yields and is more effective than soil-applied Mn. More than one application may be required if the Mn deficiency is severe. Chelated Mn and Mn sulfate are good sources of foliar Mn.

Conclusions

Proper soil pH and adequate nutrient availability are critical to soybean yield. The proper pH (6.2 to 6.8) maximizes the availability of most soil-borne nutrients. Soil testing in 10-acre increments will help identify which fields/areas need amendments to correct soil pH and/or raise soil nutrient levels. In most all cases, soil-applied fertilizer at rates recommended according to soil test results is the most cost effective method for ensuring adequate nutrient availability to the soybean crop.

Resources

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Images:
Figures 1, 2, and 4: Chad Lee; Figure 3: John Grove

Issued 4-2014