Chapter 5

Fertilization and Liming Practices

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Fertilizer and lime applications should be based on current, accurate soil tests. The only direct cost associated with soil testing is the time to take good samples and deliver them to your county Extension agent's office. Soil tests can pinpoint fields, or areas within fields, where lime and/or fertilizer needs are the most critical and must be corrected to attain a desirable yield.

University of Arkansas soil test recommendations assume dryland yield potentials of 20 to 30+ bu/A and irrigated yield potentials of 40 to 50+ bu/A. Under optimal environmental conditions, higher yields will be attained using current recommendations.

Lime

Economic yield reductions due to soil acidity generally occur on sandy and silt loam soils at pH values of less than 5.5. Fields with pH values below 5.3 require close attention. If soil pH values are 5.0 or less, liming should take priority over fertilizing. Soybeans may tolerate pH values as low as 5.2 on many alluvial clayey soils without significant yield loss; however, crops in rotation with soybeans such as wheat may suffer from aluminum (Al) and manganese (Mn) toxicities associated with low pH. (See Table 5.1.)

Table 5.1. Expected Yield Reductions Due to Soil Acidity

Soil pH	Yield Reduction Expected[1]	
	Upland Soils	Alluvial Soils Along Major Rivers and Streams
	%	%
4.6 - 5.0	30 - 50	15 - 20
5.1 - 5.4	20 - 30	10 - 15
5.5 - 5.7	10 - 20	5 - 10
5.8 - 6.0	0	0

[1]Reduction in yield relative to yield at an optimum pH level of approximately 6.0 to 6.5. Expressed as a percentage of potential yield.

Molybdenum

Molybdenum (Mo) is a micronutrient required by the bacteria that form nodules on soybean roots and take nitrogen from the soil air to supply the plant needs. When lime cannot be applied to sandy or silt loam soils with pH values below 5.8, always apply Mo to the seed at planting. In fact, treat seed with Mo whenever the pH is 7.0 or below or if lime has been applied within the last year. On some clayey soils with a pH below 5.8, response to Mo has been nearly as good as response to lime alone or a lime and Mo combination with yield increases up to 6 bushels/acre.

Without adequate molybdenum, yield response to recommended phosphate and potash may not occur or may be limited. With adequate molybdenum, recommended rates of phosphate and potash fertilizer have a great chance of increasing soybean yields.

Phosphorus and Potassium

The tables on the following page include current University of Arkansas phosphate and potash fertilizer recommendations for soybeans alone or not doublecropped. If soybean yields exceed 50 bushels per acre, consider soil sampling yearly to better monitor nutrient needs.

Much greater and more frequent response has been obtained from potassium (K) than from phosphorus (P) fertilizer in Arkansas field experiments. On most silt loam soils, yield reductions may be expected, provided that other soil factors are not limiting. When soil acidity and low soil test K levels occur at the same time, significant yield reductions occur.

If potassium deficiencies occur prior to early seed development (before R5), or if recommended potassium was not applied, potash (0-0-60) may still be applied and watered in with prompt irrigation or a rain. The University of Arkansas has measured yield increases of 6 bushels or more per acre on a soil testing low in potassium (below 90 pounds of K per acre) when 0-0-60 was applied near seed-filling, irrigated into the soil and the field was not allowed to drought-stress afterward.

Table 5.2. Phosphate and Potash Recommendations for Irrigated Alluvial Soils

Soil Test P (Lbs/A)	Soil Test K (lbs/A)		
	Above 220	150-220	Below 150
	--- Recommended N-P_2O_5-K_2O --- Per Acre		
Above 60	0-0-0	0-0-60	0-0-90
60 and Below	0-45-0	0-40-60	0-45-90

Table 5.3. Phosphate and Potash Recommendations for Irrigated Loessial Soils and Nonirrigated Alluvial or Bottomland Soils

Soil Test P (Lbs/A)	Soil Test K (Lbs/A)			
	Above 220	150-220	90-150	Below 90
	--- Recommended N-P_2O_5-K_2O --- Per Acre			
Above 40	0-0-0	0-0-60	0-0-90	0-0-120
40 and Below	0-45-0	0-40-60	0-45-90	0-60-120

Table 5.4. Phosphate and Potash Recommendations for Nonirrigated Loessial Soils

Soil Test P (Lbs/A)	Soil Test K (lbs/A)		
	Above 200	125-200	Below 125
	--- Recommended N-P_2O_5-K_2O --- Per Acre		
Above 40	0-0-0	0-0-60	0-0-90
25-40	0-0-0	0-40-60	0-45-90
25 and Below	0-45-0	0-40-60	0-45-90

Figure 5.1. Potash deficiency can occur, especially on loessial soils, if soil test recommendations are not followed.

Nitrogen

Neither soil nor foliar fertilizer nitrogen (N) has increased yields economically in hundreds of experiments in Arkansas and other states; therefore, do not apply N fertilizer for soybeans. There is little effect from N fertilizer when applied; it is simply a cost that produces no increase in grain yield.

Seed Inoculation with Rhizobia Bacteria

The only time seed should be inoculated with rhizobia is on land where soybeans have not been grown in the previous three to five years, or where previous soybean crops have had poor nodulation.

Fertilization of Rotations

The increasing intensity of production has resulted in the frequency of rice in the rice-soybean rotation and increased acreage of the wheat-soybean doublecrop. Therefore, fertilizing each crop as recommended is imperative. The wheat-soybean doublecrop can be adequately fertilized with P and K prior to the wheat crop as an alternative to fertilizing each crop. However, due to the anaerobic-aerobic soil environment in a rice-soybean rotation, fertilization of each crop is preferred to fertilizing only once in this rotation.

Fertilizer Management With Reduced Tillage

Before converting to reduced-tillage or no-tillage operations, apply recommended rates of lime, phosphate and potash, and mix with the top 6 inches of soil, especially lime. Over time, with a lack of tillage, nutrients tend to stratify or accumulate near the soil surface. But, with with reduced tillage and plant residue accumulation on the surface, root activity may increase near the soil surface. This is why broadcast surface applications of phosphate and potash have generally been just as good as placing phosphate and potash in surface bands or in subsurface bands near the row at planting or shortly afterward. If soil test phosphorus levels are below 20 to 30 pounds of extractable-P per acre, banding phosphorus 2 inches below and 2 inches to the side of the seed at planting will increase yields more than a broadcast application. However, the benefit from subsurface-band placement of phosphorus is seldom enough to justify new equipment expense. Regardless of application method, apply phosphorus as near to planting time as possible to allow maximum opportunity for plant uptake and to reduce P from being tied-up by the soil in less available forms. **Note on soil sampling reduced tillage:** For P, K or limestone recommendations, sample the 2- to 8-inch soil depth.

Special Note on Lime and Fertilization Practices

If a field has a P test level of 40 lbs/A, a K test level of 130 lbs/A and a pH of 5.2, the first action recommended is treating the seed with the recommended rate of molybdenum at planting. If soil test manganese (Mn) levels are below 200 lbs/A, then the money left over after providing the molybdenum seed treatment should be spent on potash. At this soil test manganese level (below 200 lbs/A), manganese toxicity may pose little threat and the benefits from liming may be limited, provided that seeds are treated with molybdenum. If the soil test levels of manganese are high (200+ lbs/A) **and the soil is not clayey**, the best choice is to lime and treat seed with molybdenum. With a minimum lime rate of 1 ton/A, the cost will vary from $15-$25/A per ton applied at different locations in the state.

If soil pH is 5.5 or above, and both P and K are needed but the cost exceeds cash on hand, apply K and leave off P when a choice must be made between the two.

Fertility goals must be accomplished with the aid of a good soil test. Applying fertilizer or lime without a good soil test is not good management. Your county Extension agent will help you sort through the possible options once you have a soil test. A 45-bushel/A soybean crop may remove above 65 percent of the total 220 to 300 pounds of nitrogen per acre accumulated in the aboveground plants. In addition, 30 to 35 pounds of P_2O_5 and 50 to 60 pounds of K_2O may be removed in the harvested seed. Failure to fertilize for several consecutive years severely lowers P and K soil test values on sandy loam and silt loam soils.

Poultry Litter on Leveled and Salt-Affected Soils

Response of soybeans to poultry litter on recently cut or leveled soils has been similar to responses by rice on the same soils. Rates of either composted or raw litter, ranging from 1,000 to 2,000 pounds per acre, may help to restore soil productivity and increase yields. Repeated applications for several years may be necessary to achieve the most benefit. Research on the interaction between phosphate and potash fertilizer and poultry litter rate indicates that the response from litter is not entirely from the phosphate and potash but some other factor. Therefore, when applying litter, apply the soil test recommended rates of phosphate and potash.

No-till soybean yields on a sloping, eroded, acid soil have been increased by more than 5 bushels per acre with a ton of poultry litter. However, on an eroded, high-sodium soil, rates of composted or raw litter up to 2,000 pounds per acre failed to increase soybean yields. At this site, there was a significant 4-bushel response to recommended rates of phosphate and potash, whether litter was applied or not. A three-year study on a leveled, irrigated soil on the Pine Tree Experiment Station at Colt showed that 2,000 pounds of fresh litter yearly and 6,000 pounds of litter the first year only provided 5 to 6 bushels per acre per year more than lower yearly rates of fresh or composted litter and the control.

Chloride Toxicity

On certain Arkansas soils where significant amounts of chloride are delivered in the irrigation water, soybean plants may show leaf scorching symptoms and yields may be reduced. At present, the only practical way to avoid chloride toxicity is to select a “chloride-excluding” variety. Chloride-excluding varieties do not readily translocate chloride from plant roots to the tops where it is more damaging.

If soil tests show need for potassium, muriate of potash (0-0-60), which is potassium chloride, may

Figure 5.2. Chloride toxicity symptoms in a soybean leaflet.

still need to be applied to provide adequate potassium. Other potassium sources such as potassium magnesium sulphate (Sul-Po-Mag, K-Mag) and potassium sulfate have lower chloride levels than muriate of potash and may be used, but they are considerably more expensive per unit of potassium or K_2O. To accurately diagnose a potential chloride toxicity problem:

1. Collect soil samples from both 0- to 6-inch and 6- to 12-inch depths,

2. Analyze plant leaves for both potassium and chloride levels, and

3. Test irrigation water for total salt content (electrical conductivity) and chloride levels. If irrigation water has higher chloride levels, its use may need to be limited or discontinued to protect soil productivity. If the soil and plants show elevated chloride, plant only chloride-excluding soybean varieties. Refer to the Cooperative Extension Service, University of Arkansas soybean variety selection guide or the computerized *SOYVA* program for appropriate variety selection. Consult county Extension agents regarding diagnostic soil, plant and water tests for chloride toxicity assessment.

Diagnostic Sampling

The recommended sample is the uppermost mature trifoliate leaf (without petiole). The sufficient ranges of nutrient levels at bloom for soybeans in Arkansas are shown in Table 5.5. Even though a nutrient level drops below the desirable range, this does not necessarily imply a need for that plant nutrient. Other factors such as drought, nematodes, diseases and insect damage may be the real problem. Follow a thorough diagnostic procedure that includes soil, plant and any irrigation water analyses, along with root and aboveground observations, for accurate diagnosis of plant nutrition problems.

Plant and soil samples taken for diagnostic purposes should include a separate sample from the normal area of the field and a separate sample from the abnormal or problem area of the field. This sampling procedure allows for an in-field comparison plus comparison to published nutrient levels.

Tissue analyses during the vegetative growth of the plant, while helpful, do not have good predictive value in assessing nutrient limitation. As much as 60 percent or more of the plant's total nutrient uptake occurs after bloom (R2). The desired nutrient levels (Table 5.5) may be used before bloom but only as a general reference to detect gross nutrient imbalances.

Table 5.5. Suggested Critical Ranges (Sufficiency Level) of Nutrients in Soybean Leaf at the Flowering Stage of Growth
(Sabbe, et al.)

Range Values	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	B
	%						ppm				
Low	3.25	0.25	1.5	0.8	0.25	0.25	25	17	21	4	20
High	5.00	0.60	2.3	1.4	0.70	0.60	300	200	80	30	60

Figure 5.3. A soil sampling tube containing a core of soil to be analyzed.

Phosphate and Potassium

The fertilizer recommendations have been developed over many years through extensive University of Arkansas research. Soybean yields above 50 bushels per acre have been attained with these recommendations. When yields are 45 bushels per acre or lower, these phosphate and potash rates should assure good yields and modest increases in soil test levels over the course of several years.

Some producers desire to apply phosphate and potash even when soil tests do not indicate a need and the likelihood of a yield response is small. Such a philosophy is called "maintenance fertilization" and is based on the concept of replacing the nutrients removed in the crop harvest. While this approach is not usually economically justified, some consider it good stewardship of the soil resource. The maintenance approach is most useful when the soil test values are just above the critical level (i.e., soil test value when fertilizer is recommended). The nutrient removal by 45 bu/A soybeans in various cropping systems (Tables 5.6 and 5.7) illustrates the necessity of frequent and careful monitoring of the soil's fertility to maintain adequate nutrients for optimum production of all crops in a specific rotation.

Sulfur

Research in Arkansas has not shown a significant response to sulfur addition. On rare occasions on deep sandy soils when sulfur is limited, 10 to 20 pounds of sulfate (sulfur) may be beneficial. Deficiencies may show up initially as pale green to yellow leaves in the top of the plant. As deficiency progresses, the entire plant may turn green to yellow. Prolonged S deficiency results in plant symptoms similar to prolonged N deficiency.

Magnesium

If soil tests indicate exchangeable Mg levels below 75 pounds per acre, providing Mg from resources such as sulfate of potash magnesia (Sul-Po-Mag, K-Mag), magnesium sulfate (epsom salts) or dolomite limestone when lime is recommended to correct low soil pH may be beneficial.

Iron, Zinc, Copper, Manganese and Boron

Soil tests, plant tissue analysis and research by the University of Arkansas have not identified the need for or general response to application of these nutrients for commercial soybean production. Limited response to manganese addition has been measured with soybean growth on some eastern Arkansas silty clay soils where soil test Mn levels were below 20 pounds per acre. Plant tissue analyses confirmed low tissue Mn levels also.

Unless plant tissue analyses indicate deficiencies of these nutrients (Table 5.6), their application is not recommended.

Table 5.6. Nutrient Removal in Soybean Grain in a 45-Bushel Per Acre Yield (Sabbe)

Nutrient										
N	P_2O_5	K_2O	Ca	Mg	S	Fe	Mn	Zn	Cu	B
Lbs/Acre										
180	36	63	5.5	5.9	7.7	0.14	0.12	0.12	0.04	0.07

Table 5.7. Major Nutrient Removal by Soybean and Selected Crops in Rotational Systems

		N	P_2O_5	K_2O
		------------- Lbs/A -------------		
I.	Soybean: Soybean			
	Soybean, 45 bu	180	36	63
	Soybean, 45 bu	180	36	63
	2-Year Total	360	72	126
II.	Soybean: Wheat: Double-Crop Soybean			
	Soybean, 45 bu	180	36	63
	Wheat, 50 bu	58	28	17
	Soybean, 45 bu	180	36	63
	2-Year Total	418	100	143
III.	Rice: Soybean			
	Rice, 120 bu	66	35	22
	Soybean, 45 bu	180	36	63
	2-Year Total	246	71	85
IV.	Corn: Soybean			
	Corn, 150 bu	113	66	34
	Soybean, 45 bu	180	36	63
	2-Year Total	293	102	97
V.	Cotton: Soybean			
	Cotton, 2 bale	64	28	40
	Soybean, 45 bu	180	36	63
	2-Year Total	244	64	103
VI.	Rice: Soybean: Soybean			
	Rice, 120 bu	66	35	22
	Soybean, 45 bu	180	36	63
	Soybean, 45 bu	180	36	63
	3-Year Total	426	107	148
VII.	Rice: Soybean: Rice			
	Rice, 120 bu	66	35	22
	Soybean, 45 bu	180	36	63
	Rice, 120 bu	66	35	22
	3-Year Total	312	106	107