IOWA STATE UNIVERSITY
Extension and Outreach

Soybean Nutrient Needs

Building a sustainable soybean and corn cropping system that consistently produces high yields isn't easy but it is possible. It begins with improving soybean and corn yield using proven management strategies. Obtaining maximum yield is only possible when the plant's nutritional requirements are met and environmental stress is limited. Maintaining a fertile growing environment is a risk management strategy that produces higher yield and healthier plants that are often better suited to withstand the yield-robbing effects of biotic and abiotic stress. A well planned soil fertility program is a management strategy that leads to profitable soybean production. A knowledge of what the nutrients do, which ones are needed, how much to apply, and when to apply them is an important part a successful management strategy.

NUTRIENT REQUIREMENT OF SOYBEAN

Soybeans respond to fertile soils. It is a common production practice in Iowa to fertilize the corn crop and let the rotational soybean crop utilize residual soil nutrients the following year. This is a good management practice, when coupled with a regular soil testing program, to provide enough nutrients to produce two high-yielding crops.

High yielding soybeans require large amounts of nitrogen (N), phosphorus (P), and potassium (K) as well as a smaller amount of sulfur (S) and some micronutrients. Although soybean requires considerably less P and S than N or K, all are important for plant growth and development.

Soybean grown in Iowa does not require an application of N fertilizer. Leguminous crops, like soybean, meet their demand for N through a process called biological N fixation. Soybean forms a symbiotic relationship with soilborne rhizobia bacteria (*Bradyrhizobium japonicum*) to convert, or 'fix' atmospheric N gas to ammonia (NH_3) N, a form usable by the plant. The rhizobia bacterium attaches to new soybean roots just behind the root tip then colonizes the plant. In response to bacterial chemical signals, plant root cells form nodules, which help protect the bacteria from oxygen. Nodules grow very rapidly and will continue to supply N to the plant for approximately six weeks. Nodules begin supplying N during the early vegetative growth

Table 1. Average nutrient removal rates for soybean and corn grown in the Midwest.

	N	P_2O_5	K_2O	S
	pounds/bushel of grain			
Soybean grain	3.8	0.80†	1.50†	0.10
Soybean stover	1.1	0.24	1.0	0.17
Total	4.9	1.04	1.50	0.27
Corn grain	0.90††	0.375†	0.30†	0.08††
Corn stover	0.45††	0.16††	1.10††	0.07††
Total	1.35	0.54	1.40	0.15

Source: Heatherly, L.G and R.W. Elmore (5) except where noted; †Iowa State University Extension publication PM 1688 (17); †† International Plant Nutrition Institute; Amounts base on market moisture phase (V2-V3) and will continue through seed fill (R5-R6).

What is the demand for soil nutrients from one rotation cycle of average soybean and corn crops? A bushel of soybeans removes about 3.8 pounds of N, 0.8 pounds of P (P_2O_5) and 1.5 pounds of K (K_2O) (Table1).

Yield is the primary factor determining soil nutrient removal (10). Nutrient requirements for all crops increase concomitantly with yield. Average soybean and corn yields in Iowa during the 2001 to 2011 period were 48 and 168 bushels per acre, respectively (19). A soybean crop yielding 48 bushels per acre would remove approximately 182 pounds N, 38 pounds P_2O_5 and 72 pounds K_2O per acre from the field. Nutrient removal in the grain from a single two-year cycle of soybean-corn rotation producing average yields would be 333 pounds N, 63 pounds P_2O_5 and 122 pounds K_2O per acre. A portion of these amounts will be supplied from soil nutrient reserves and N fixation by the soybean roots. The remainder will need to be added through decomposition of crop residue and the application of fertilizers and animal manure.

FERTILIZING FOR HIGH-YIELDING SOYBEANS

Iowa State University recommends fertilizer applications be based on soil test levels and estimates of nutrient removal by the grain (17). Studies show a strong linear relationship between grain yield level and P_2O_5 and K_2O removal with grain harvest. Studies also show a good relationship between estimates of P_2O_5 removal in grain to soil test levels over several years. The relationship between K_2O removal and soil test K levels is more variable but studies show a long-term soil K decrease of 3.0 ppm/year (10). Soil K levels appear to be highly influenced by K loss from standing maturing plants and crop residues, a process highly influenced by rainfall (9,10). The rate of P loss is much less because most plant P is organic and less soluble in water than K, which is found as a free cation in plant tissue. They also reported that P and K recycling of soybean is rapid because most P and K are in the leaves, which drop from the plant and quickly decompose on the moist soil.

Opportunities for increased yield with P and K fertilization are likely on some fields depending on soil test levels. For best results, P and K should be applied when the chance of a yield increase is significant and the expected yield increase is sufficient to pay for the applied nutrients.

The only way to accurately estimate the P and K supplying power of a soil is with a series of properly collected soil tests over years.

Understanding the Iowa State University soil test interpretation categories is an important step in the process of determining P and K fertilization. The likelihood that application of these nutrients will produce a positive yield response within each soil test interpretation category is:

Table 2. Likelihood of increasing soybean yield from fertilizer application to soil with varying soil test levels.

P and K Soil Test Level[1]	**Likelihood of Yield Increase**
Very low	80%
Low	65%
Optimum	25%
High	5%
Very high	<1%

[1]The rates recommended for these soil test categories are based on field response trials and attempt to optimize long-term profitability by avoiding yield losses where responses are large and very likely, and provide a high probability of maximized profits at current prices. Source: Sawyer et al. (17)

Critical soil test and plant tissue test concentrations of secondary nutrients such as calcium (Ca), magnesium (Mg), and S; and micronutrients such as iron (Fe), zinc (Zn), copper (Cu), and molybdenum (Mo) and their relationships with soybean yield response to fertilization are not available for Iowa farmers. This is mainly because no deficiencies have been observed in the past. Suggested optimal concentrations for soil or plant tissue tests for soybean suggested in a few Corn Belt states may not be applicable to Iowa conditions, and researchers in those states emphasize the poor reliably of these guidelines. Prediction of potential yield response from micronutrient application cannot be predicted well based on concentrations in soils or soybean tissues. However, Mallarino and colleagues at Iowa State University began a project in 2012 to assess soybean yield response to several micronutrients and, if deficiencies are found, calibrate soil and plant tissue tests.

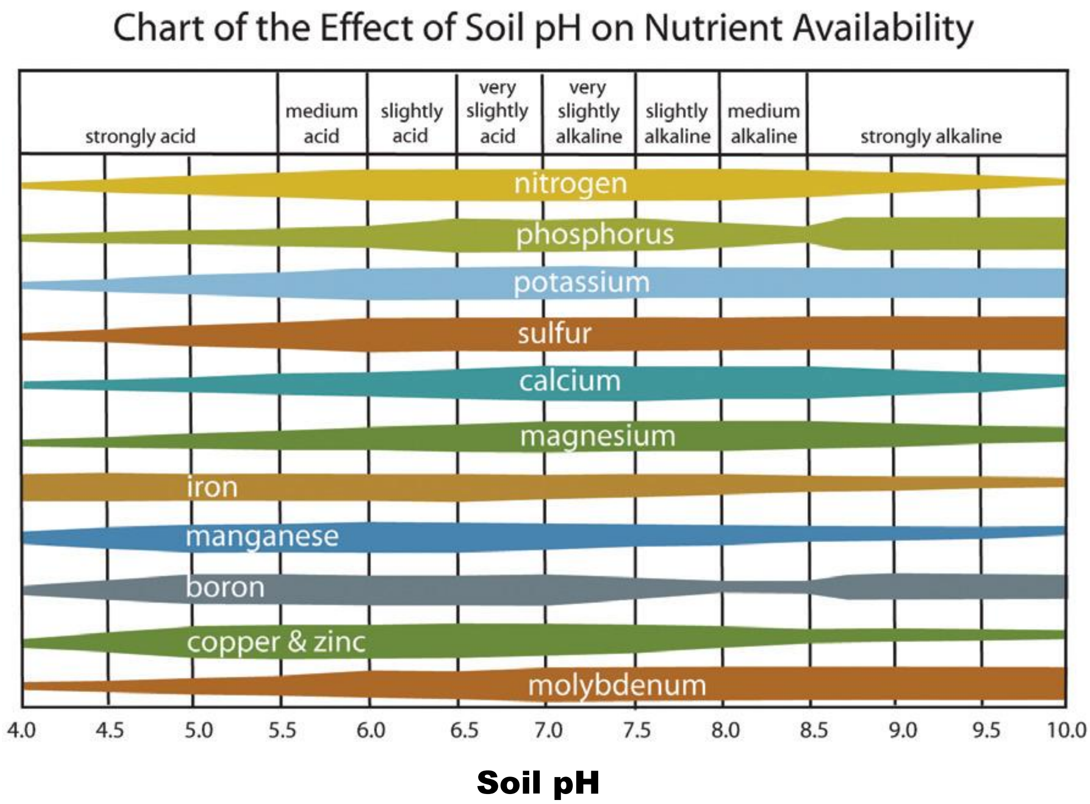
FOLIAR FERTILIZATION

Efforts to increase soybean yield through foliar application of N, P, K, S and various micro-nutrients began in the 1970's when Iowa research by Garcia and Hanway (2) reported increased yields from a specific N, P, K, S combination applied at late reproductive stages. Subsequent testing conducted across a wide geographic region showed however, that soybean yield response to foliar applied fertilizers was variable, inconsistent (18), and occasionally reduced yield (3).

An extensive research project that looked at the yield benefits of a 3-8-15 (N-P-K) foliar fertilizer application to soybean was conducted by researchers at Iowa State University between 1994 and 1996 at 48 Iowa locations. Haq and Mallarino (4) reported inconsistent performance, both positive and negative yield responses, from 3-18-18 (N-P_2O_5-K_2O) foliar fertilizer applications. Their results were similar to those reported by Sesay and Shibles from research conducted in the late 1970s (18). However, Haq and Mallarino also reported that when averaged over 48 farm research locations, foliar fertilization increased soybean yield by 0.80 bushels per acre. The few higher yield responses tended to occur with low early P uptake, high soil cation exchange capacity, and/or deficient rainfall in spring and midsummer. In subsequent research at 26 fields that included other nutrient mixtures, Mallarino and Haq (11) concluded that soybean response to foliar fertilization across all production conditions will seldom offset fertilization costs. More recent research by Mallarino and Kaiser at five fields (8) that included spraying N or N, P, K foliar fertilizers alone or in mixture with a fungicide showed that only the fungicide increased yield, and the N foliar fertilizer decreased yield.

INFLUENCE OF SOIL pH ON NUTRIENT AVAILABILITY

Soil pH is an indication of the general chemical environment in a soil. It is a measure of the relative acidity or alkalinity. A soil pH of 7.0 is neutral, with a value below 7.0 being acidic and above 7.0 alkaline. The availability of most nutrients is greatest at slightly acidic to near neutral soil pH. Soil pH seldom affects plant growth directly in Iowa soils. Rather, it affects the availability of plant nutrients and microbial activity, including atmospheric N fixation by nodules. In most Iowa soils, the pH ranges from about 5.5 to 7.4, and many other soil properties can affect nutrient availability in this pH range. In Iowa the only nutrients with availability clearly related to soil pH are Fe and Zn, where availability to plants is low in alkaline (high pH), calcareous (carbonate containing) soils (12). The measurement of soil pH is needed to determine if lime is needed, and the measurement of soil buffer pH is needed to determine the amount of lime to apply to raise pH to a desirable level. An



Soil pH affects the availability of plant nutrients. The thicker the bar, the more the nutrient is available. The best overall balance is between pH 6.0 and 7.0 (8).

ongoing large Iowa on-farm lime research project that began in 2007 conducted by Mallarino and students has shown significant soybean response to lime below pH 6.0 in soil associations with high-pH subsoil and below pH 6.5 in other soils (7). These results are in general agreement with guidelines published in Iowa State University Extension publication PM 1688 (17).

PLANT NUTRITION IMPACTS SOYBEAN PLANT HEALTH

The influence of plant nutrition on susceptibility and tolerance of soybean to diseases and insects is an important aspect of plant growth. Plants under nutrient stress can be predisposed to attack or are more readily affected by pathogens and insects. Several studies have shown that plants grown under high levels of N are more susceptible to attack by diseases. Similarly, plants suffering from low levels of K are more susceptible to infection by fungal pathogens (16). In Iowa studies, soil applied K was shown to decrease the incidence of several fungal diseases of soybean (1). Although the disease response to K application in these studies was variable among years and locations, some yield increases were observed. Potassium deficiency of plants has also been associated with thin cell walls, smaller, thinner and shorter roots, lower sugar accumulation in the foliar tissue, and accumulation of inorganic N not used for protein biosynthesis (16).

Potassium is also involved in numerous functions in the plant such as enzyme activation, cation/anion balance, stomatal movement, phloem loading, assimilate translocation, and turgor regulation (15).

Insufficient K in soybean causes a pale leaf color which is particularly attractive to the soybean aphid, a sap-sucking insect found throughout the Midwest. Myers and Gratton (13) found that naturally colonizing populations of soybean aphids had significantly higher peak abundance and rate of population increase on K deficient soybean. Because of this, fields or areas within a field low in K may reach the economic threshold for treatment of soybean aphids more quickly than fields with optimum K soil test levels. Moreover, yield loss may occur in these areas if the aphids exceed with economic threshold and are untreated.

IMPACT OF SOIL pH ON SOYBEAN CYST NEMATODE AND OTHER PATHOGENS

Soil pH governs the distribution of soybean cyst nematode (SCN) in fields. Pedersen and coworkers (14) reported that SCN numbers were higher in soils with a pH of 7.0 or greater. They conducted their studies in Iowa and Wisconsin on soils with a broad range of soil types and pH levels and with a diverse set of SCN-resistant and SCN susceptible cultivars. They reported that a high population density of SCN at planting can be expected in field areas with soil pH 7.0 to 8.0 compared with areas of soil pH 5.9 to 6.5. They hypothesized that soil pH may have an indirect effect on SCN biology and/or behavior or the soil pH may affect the suitability or susceptibility of the soybean plant to serve as a host to the nematode.

Soil pH also affects the soybean plants susceptibility to disease. The greatest levels of brown stem rot foliar and stem symptoms are observed in areas of the field where soil pH is 6.5 or lower (6).

CONCLUSIONS

Higher yields through improved management are fundamental to lowering the cost of production and generating higher profit per acre. Maximum yield is possible when the plant's nutritional requirements are met and environmental stress is limited. Any restriction in root growth, decline in photosynthesis caused by diseases or above-ground insects, or serious nutrient shortage can prevent soybean from achieving high yields. A basic knowledge of what nutrients do and how much to apply is part of an important management program for a high-yielding soybean crop.

Iowa State University recommends that P and K fertilizer applications be based on soil testing. When soil test levels are in the optimum category P_2O_5 and K_2O applications should be based on estimates of nutrient removal. Studies show a strong linear relationship between grain yield level and the P_2O_5 and K_2O removal with grain harvest. Lime application also should be applied on the basis of soil testing.

Understanding the Iowa State University soil test interpretation categories, as well as appreciating the difficulty of precisely predicting a yield increase from fertilization, is an important step in the process of deciding P and K fertilization. For best results, apply these nutrients where the chance of a yield increase is significant and the expected yield increase is sufficient to at least pay for the applied nutrients.

ADDITIONAL RESOURCES

Soybean Field Guide, 2nd edition. Iowa State University, University Extension, CSI 0010.

A General Guide for Crop Nutrient and Limestone Recommendations in Iowa. Iowa State University Extension, PM 1688.

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