NEWS & VIEWS

Dr. C.S. Snyder,
Midsouth Director
May 2000

Raise Soybean Yields and Profit Potential with Phosphorus and Potassium Fertilization

Phosphorus (P) enhances the photosynthesis rate, enzymatic activity, energy transfer, root development, uptake and transfer of other nutrients, nodulation and nitrogen (N)-fixation by symbiotic bacteria, water use efficiency, reproductive growth and maturation, seed number, seed size, and seed germination. It also works with potassium (K) in decreasing damage from several plant diseases.

Potassium regulates several plant processes including: water and nutrient transport across cell walls, regulation of water vapor and carbon dioxide (CO_2) exchange through stomates, and uptake and transfer of other nutrients. It does not reduce damage from soybean cyst nematode, but does help maintain the plant's defense against the damaging effects from the nematode in minimizing yield loss.

In short, P and K help increase farmer profit primarily through increased soybean yields.

How much P and K do soybeans need?

The uptake of P_2O_5, K_2O, magnesium (Mg), and sulfur (S) by soybeans is shown in **Table 1.**

Table 1. Soybeans take up large quantities of nutrients.

Yield, bu/A	N	P_2O_5[1]	K_2O[1]	Mg	S
	lb/A taken up				
40	220	38	140	16	14
55	290	53	190	22	18
70	360	67	220	28	22

[1]P and K expressed in oxide terms, to better relate to fertilizer equivalents.

The relative N, P and K uptake patterns are illustrated in **Figure 1.** Maximum daily uptake rates by soybeans have been reported as:

N	6.9 lb/A/day
P	0.4 (0.9 lb/A P_2O_5)
K	4.1 (4.9 lb/A K_2O)
Ca	2.8 lb
Mg	1.5 lb

The majority of the above-ground nutrient accumulation occurs after the mid-vegetative growth stages (V6-V9). Studies with the southern maturity groups indicate that about 60 percent of the total N and K uptake occurs after flowering (R1-R2). Nutrient shortages during the most rapid uptake periods can result in significant yield loss, often with no visible tissue symptoms.

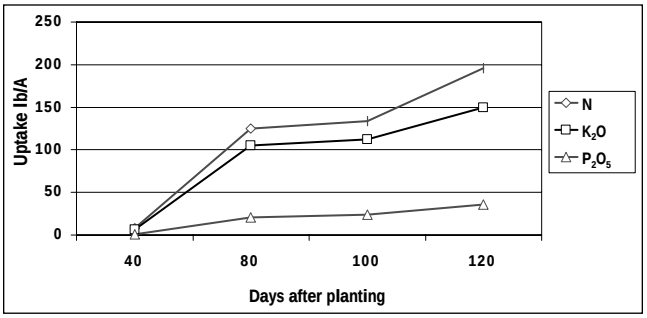
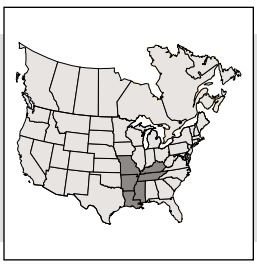


Figure 1. N, P_2O_5, K_2O uptake by a 50 bu/A soybean crop.

There is a sizeable removal of N, P and K by soybeans in the seed harvest. By maturity, soybean seed contain about 65 percent of the N, 73 percent of the P, and 55 percent of the K taken up during the season. Each harvested bushel of soybeans removes about 4 lb of N, 0.8 lb of P_2O_5, and 1.4 lb of K_2O from the field. A 50-bushel soy-

Agronomic market development information provided by:
Dr. C.S. (Cliff) Snyder, Midsouth Director
Potash & Phosphate Institute (PPI)
P.O. Drawer 2440, Conway, AR 72033-2440
Phone: (501) 336-8110; Fax (501) 329-2318
E-mail: csnyder@ppi-far.org



bean crop removes 200 lb of N, 40 lb of P_2O_5, and 70 lb of K_2O. If fields planted to soybeans are not fertilized adequately with P and K, nutrient removal can take a toll on soil fertility levels and reduce the yields of successive soybean crops and other crops in rotation.

How does the soil supply soybean P and K needs?

Sandy and silt loam soils will usually be the first to exhibit deficiencies of P and K. Clayey soils tend to have higher native soil P and exchangeable K levels than the coarser textured soils. However, increasing clay content and an increasing soil test P level do not always go hand in hand. Research reports indicate that most of the P and K uptake by soybeans and other plants occurs through the process of diffusion: movement from an area of high concentration to one of lower concentration. Because K is more soluble than P, it tends to travel farther by diffusion than does P. Root interception of nutrients and mass flow via the soil water are also important, but contribute much less proportionately (less than 20 percent) to uptake. It has been estimated that crop roots typically contact only 1 to 3 percent of the soil in the surface 6 inches. This illustrates how critical it is to provide good season-long soil P and K levels throughout the root zone. If soil test P and K levels are not maintained in the medium to high range, diffusion could be impaired, nutrient uptake could be limited, and yields could decline.

The only way to accurately estimate the P and K supplying power of a soil is with a soil test, based on a representative soil sample, collected from the upper root zone (usually the 0 to 6-inch depth). The rate of P_2O_5 and K_2O to apply depends on the soil test level, the soil type, P and K removal in the harvested crop, and the specific soil fertility objectives of the farmer. If soil test levels are in the low and medium range, most farmers elect to replace those nutrients and add more to raise soil test levels over a reasonable period of time. If crop removal is greater than the rate of application, and the soil test is not in the high range, an increase in the P and K application rate is probably warranted. Other factors such as disease pressure, soil acidity, and compaction can also limit root growth, reduce moisture and nutrient uptake efficiency, and increase the need for fertilization.

What are the optimum soil test P and K levels for soybeans and what is the relative yield at levels below optimum (without P or K fertilization)?

The optimum soil test level often varies with the soil texture (cation exchange capacity, CEC) and clay chemistry. However, for most soils and cropping systems, the data in **Table 2** on relative soybean yields can be used as an approximate guide. Because soybeans are rotated with other crops, and the optimum soil test P and K level varies somewhat for different crops, the practical approach is to strive for soil test P and K levels that would not limit the most demanding crop in rotation. For many fields, soil test levels of about 60 to 70 lb/A of Bray-Kurtz P-1 or Mehlich 3 P and 250 to 300 lb/A of ammonium acetate or Mehlich 3 K would be optimal for many field crops. For high yield goals (i.e. greater than 60 to 70 bu/A), soil test levels greater than these may be necessary.

Table 2. Relative soybean yields at different soil test P and K levels on silt loam soils, based on selected university interpretation.

Soil test	Mehlich 3 extractant		Bray-Kurtz P-1 extractant			Soil test	Mehlich 3 extractant		Ammonium acetate extractant		
P	AR	KY	MO	IA	IL	K	AR	KY	MO	IA[1]	IL
lb/A	—Relative soybean yield, % —					lb/A	—Relative soybean yield, % —				
5	—	46	21	20	42	120	60	85	65	85	60
10	—	63	40	38	55	140	70	89	72	89	66
20	—	78	69	70	81	160	80	93	79	92	74
30	72	86	89	90	95	180	90	96	85	94	80
40	90	92	99	96	98	200	92	97	90	96	85
50	95	95	100	98	99	220	95	98	94	97	90
60	100	97	100	100	100	240	98	99	97	98	95
70	100	99	100	100	100	260	100	100	99	99	97
—	—	—	—	—	—	280	100	100	100	100	98
—	—	—	—	—	—	300	100	100	100	100	99
—	—	—	—	—	—	320	100	100	100	100	100

[1]The data reflect ammonium acetate analysis of field moist samples. Analyses on air-dry samples may result in different interpretations.

Note: Correlation/calibration research is on-going in several states, making the numbers in the table subject to change. Consult state university research and Extension agronomists for more specific information.

What soybean yield is possible with good fertility management?

Back in 1983, Dr. Roy Flannery, Rutgers University, produced 118 bu/A in research plots. Dr. Dick Cooper, USDA-ARS scientist at Wooster, Ohio, has produced 80 to 90 bu/A of soybeans fairly consistently in his high yield systems research program. With early, warm springs, which lead to earlier flowering and an extension of the reproductive period, Dr. Cooper has produced yields over 100 bu/A. If fertility had not been high in these studies, it would not have been possible to benefit as greatly from the favorable growing conditions.

Many farmers are now reporting yields above 70 bu/A. Using yield monitors and global positioning systems, locations within fields are frequently being identified where yields exceed 80 bu/A. These experiences indicate that soybeans will respond to good management and favorable weather.

Could soil fertility be limiting yield increases for many farmers? Summaries of soil test data in the U.S. (across crops), prepared by PPI, with the cooperation of state and private labs, show that 46 percent of the sampled soils test

medium or lower in P and 44 percent test medium or lower in K. Low crop prices in recent years have resulted in the neglect of fertility needs on many fields. Based on the trend for increasing yields nationally **(Figure 2)**, many farmers have the opportunity to raise production and lower per unit costs with improved fertility management.

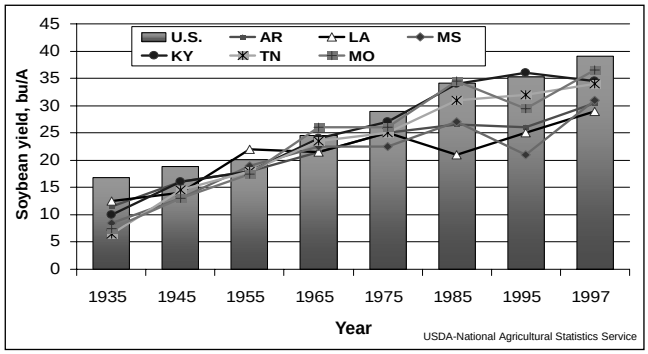


Figure 2. U.S. soybean yields have increased.

What kind of response might be expected with moderate P and K fertilization on low to medium testing soils?

A moderate rate of P_2O_5 and K_2O for soybeans might be 0-40-60. More aggressive rates such as 0-60-90 or 0-80-120 are often necessary for higher yields or to build soil tests. Research by Dr. Don Howard in west Tennessee on a low P and K soil, using soybean cyst nematode-resistant and susceptible varieties, showed that yield responses up to 11 bu/A with P and K are possible with non-irrigated, no-till soybeans **(Figure 3)**. Work in Arkansas has also demonstrated non-irrigated soybean yield increases of more than 11 bu/A with P, on a soil testing 30 lb/A in Mehlich 3 P **(Figure 4)**. Recent tillage (chisel vs. no-till), row spacing (7 vs. 30 inches), and placement (broadcast vs. banded) research in Minnesota (personal communication, Rehm) found yield responses from 11 to 16 bu/A with 92 lb P_2O_5/A on a low P soil.

Opportunities for increased yields and profits with P and K fertilization are within reach on many fields, depending on soil test P and K levels. According to the majority of research published to date, fertilizer placement is less important with soybeans than is the appropriate rate of P and K.

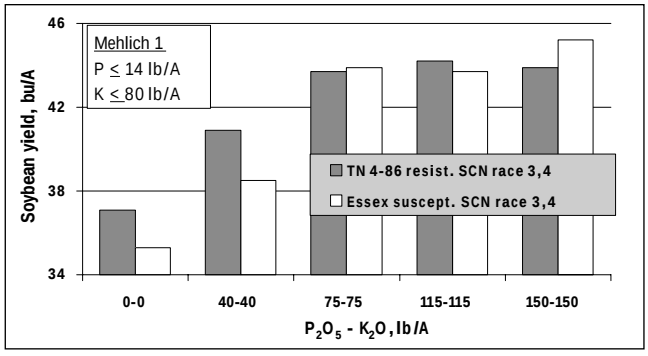


Figure 3. P and K increase no-till soybean yields in Tennessee: 1987-1992. (Howard et al. 1998. Agron. J. 90:518-522)

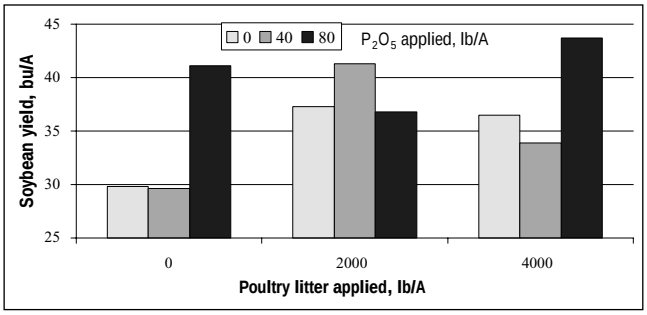


Figure 4. Soybean response to poultry litter and phosphorus.
(4 yr. ave.) Muir and Hedge. 1999. AR Soil Fert. Studies 1998.

The response needed to pay back the investment in P and K, at different soybean prices and assumed P and K costs, is illustrated in **Table 3.** An important point to remember is that P and K rates higher than the current soybean crop removal (a 50-bu/A yield removes 40 lb P_2O_5 and 70 lb K_2O/A) are likely to pay dividends for successive crops by raising soil fertility levels and crop yield potential.

Table 3. Soybean yield increase necessary to cover expenses for soybean fertilization.

Soybean	Example fertilizer rate (lb/A N – P_2O_5 – K_2O)		
Price, $/bu	0-40-60	0-60-90	0-60-120
	——— yield, bu/A ———		
5.00	3.52	5.28	5.88
5.50	3.20	4.80	5.35
6.00	2.93	4.40	4.90
6.50	2.70	4.06	4.52

Assumed costs. P_2O_5 @ $0.23/lb and K_20 @ $0.14/lb. Application cost not included.

How much P and K does it take to raise soil tests?

Soil test levels can be raised if rates of P_2O_5 and K_2O exceed the rates of crop removal. A general rule of thumb is: 6 to 14 lb of P_2O_5 above crop removal are required to raise the soil test P level one lb/A. It takes about 4 to 8 lb of K_2O above crop removal to raise soil test K one lb/A. Research by Dr. Bill Thom in Kentucky is a good example of the buildup in soil test P and K that can result from different fertilizer additions **(Table 4)**.

Table 4. Rates of application in excess of crop removal required to change soil test P or K (lb nutrient/lb of soil test) at a given soil test, Belknap silt loam.

Soil test P, lb/A	P_2O_5 required, lb P_2O_5/lb soil test P	Soil test K, lb/A	K_2O required, lb K_2O/lb soil test K
10	14.5	100	6.4
20	10.3	150	5.4
30	8.4	200	4.7
40	7.3	250	4.2
50	6.5	300	3.8

Source: Thom, W.O. 1990. The Nature and Value of Residual Soil Fertility. AGR-144. University of Kentucky, Cooperative Extension Service.

Many agronomists believe that farmers should consider a four to eight-year approach in raising soil test P and K to optimum levels. It is possible to raise levels more quickly, but the economics are often less attractive, and the risk of possible runoff losses of P during intense rainstorms should be considered.

What are the optimum tissue nutrient levels for soybeans?

The optimum ranges for nutrient levels in the uppermost mature trifoliate leaves at first bloom are:

N	3.6 to 4.7%	Iron (Fe)	50 to 350 parts
P	0.3 to 0.5%		per million (ppm)
K	1.5 to 2.5%	Manganese (Mn)	17 to 100 ppm
S	0.2 to 0.6%	Copper (Cu)	5 to 30 ppm
Ca	0.6 to 1.4%	Zinc (Zn)	21 to 50 ppm
Mg	0.3 to 0.8%		

If nutrient abnormalities are suspected before bloom, whole plant or trifoliate samples may be collected to diagnose problems, depending on the plant size. The plant analysis laboratory should be consulted to obtain sampling and submission instructions. Plant tissue analysis is a relatively inexpensive way to determine if soil test levels and soil fertility management are adequate for high yields.

Conclusion

Managing soybeans at higher soil test P and K levels provides many benefits:

- It allows farmers to capitalize on good weather years
- It minimizes yield loss risks during bad weather years
- It helps raise soil productivity
- It generally increases the yield potential of all crops in the rotation
- It improves grower profit potential
- It ensures that fertility does not limit the return on investment from other crop production inputs.

Efficient management is the goal of all farmers, especially in times of low crop prices. Phosphorus and K fertilization are an important part of reaching that goal. Strive to make higher, more profitable yields with an investment in soil fertility that pays dividends, this year and into the future. ■

RN 20094

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May 2000

Potash & Phosphate Institute (PPI)
655 Engineering Drive, Suite 110
Norcross, GA 30092-2837