SDSU Extension

iGrow Soybean

BEST MANAGEMENT PRACTICES

Chapter 25: Determining Your Soybean Phosphorus Recommendation

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Phosphorus is an essential plant nutrient and is used by soybeans to enhance the root development, photosynthesis, and energy transfer throughout the growing season. Phosphorus is added to the soil by fertilizers and manure and removed from the soil primarily when crops are harvested (Fig. 25.1). Additional, smaller losses of P can occur through runoff and erosion. When added to soil, P generally stays were it is applied, and its uptake is reduced under drought conditions.

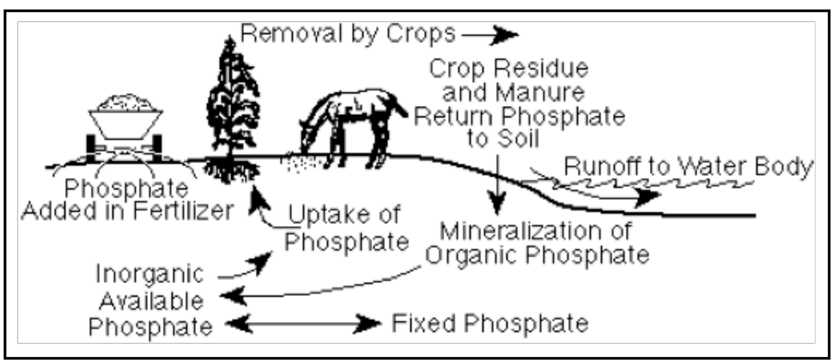

Figure 25.1. Phosphorus cycle in many agricultural soils. (Source: http://www.epa.gov/oecaagct/ag101/printbeef.html)

For many producers, a soil P management program starts with collecting a representative soil sample. This sample is then analyzed, using the Bray-1 and Olsen P tests, to determine your P recommendation. The Bray-1 test was designed for acid soils (pH<7.3) while the Olsen test was designed for basic soil (pH>7.3). The purpose of this chapter is to demonstrate how to determine your current recommendation.

Phosphorus and soybeans

Having a sufficient supply of P is especially important during the early stages of plant development, when the root system is not yet extensive. During early vegetative stages, roots take up P very quickly—much more quickly than they do later in the season (Barber, 1978). The greatest plant demand for P occurs in later vegetative stages (V10) and continues through mid reproductive stages (R5) (Fig. 25.2; Hanway and Weber, 1971). The P taken up during this period accounts for about 75-80% of the total P taken up by the plant by physiological maturity. After about R5 (beginning seed), P is rapidly lost from the leaves, petioles, stems, and pods and is repartitioned into the developing beans. Approximately half of the P in mature seeds comes from these plant fractions. At harvest, approximately 73% of the total P in the plant is in the mature seed.

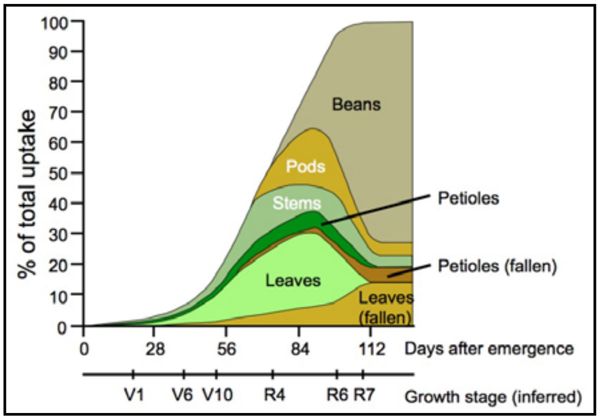

Figure 25.2. The influence of plant growth stage on P partitioning in the plant. (Modified from Hanway and Weber, 1971)

The primary purpose of P is to help soybeans manage energy produced during photosynthesis. When P is limiting, soybeans have a reduced ability to tolerate stress (Monsanto, 2010) and the probability of a response to P fertilizer decreases with increasing soil test P level (Fig. 25.3). When soil P supplies are low, more than 50% of the P in the soybean plant may come from P fertilizer while under high P supplies, fertilizer may contribute less than 30% of total uptake (Bureau et al., 1953).

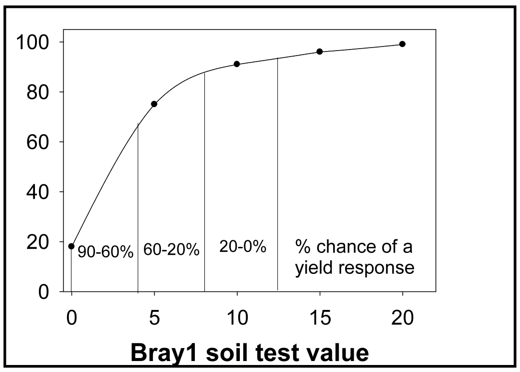

Figure 25.3. Conceptual relationship between soil test value and the probability of a yield increase. (Modified from Ferguson, 2006)

Adequate P nutrition can reduce the susceptibility and or incidence of diseases such as Asian rust and soybean mosaic virus (Pacumbaba et al., 1997; Piccio et al., 1980) and may also help overcome yield limitations from soybean cyst nematodes (Howard et al., 1998). Phosphorus deficiencies in soybeans generally are typified by spindly plants with small leaflets. The leaves may have a dark green or bluish green tint (Chapter 17; Monsanto, 2010). Phosphorus deficiency also adversely affects nitrogen nutrition by impairing the functioning of nodules (Sa and Israel, 1995). Maintaining the soil pH between 5.5 and 7 generally increases P availability.

Phosphorus, soil, and the environment

In soil, P can exist in plant-available and plant-unavailable forms. Plants take up only P that is dissolved in the soil solution. Sources of this solution P come from both inorganic and organic sources. Inorganic sources include P minerals and P chemically bonded to other soil minerals, like iron and aluminum oxides and calcium minerals. P in these inorganic forms is often referred to as being "fixed," even though it can be released into the soil solution over time through weathering and other soil chemical reactions. Organic sources include manures, bio-solids, and crop and animal residues. Phosphorus in organic forms is released into the soil solution through microbial degradation. In both inorganic and organic forms, there is a portion of the P that is more readily released into the soil solution, making it potentially available for crop uptake (Fig. 25.1).

Soil test extractants have been created to access both the solution P and the P that can potentially become plant available. It is important to note that no soil test extractant measures all of the P that is potentially plant available. Consequently, soil test results provide only an index of P availability and not a complete accounting. What makes soil tests useful in production agriculture is the field research that relates specific soil test readings to crop response, as shown in Figure 25.3. The Bray-P1 extractant is designed for soils with a pH <7.3 while the Olsen extractant is designed for soils with a pH>7.3 (Watson and Mullen, 2007; http://infohouse.p2ric.org/ref/17/16690.pdf).

Phosphorus can be transported from production fields to streams and lakes with eroding soils. To minimize transport, the following practices should be followed:

- Use soil sampling to define P fertilizer rates and follow recommendation guidelines.
- Consider manure as an important resource as opposed to a waste product.
- Consider all sources of P when determining P application rates.
- Place P sources below the soil surface.
- Use management techniques that reduce erosion.
- Install vegetative filter strips on hillsides and well-placed vegetative buffer zones along streams.
- Use the 4Rs (right source, right rate, right time, and right place). http://www.ipni.net/4r

Precision P management may also be a high priority in newly tile-drained fields. In these fields, the removal of excess water will likely stimulate the conversion of Fe+2 to Fe+3, which in turn can reduce available P. Until new equilibrium P levels are reached, we recommend careful monitoring. Careful monitoring is also recommended for CRP land that is converted back into farmland (Chapter 14). In these soils, the lack of fertilizer applications for 10 to 15 years may have drastically reduced available P. When P is added following the above recommendations, it will gradually increase. Soil test P values in these fields should be carefully tracked.

Soil sampling

For many producers, a P recommendation program starts with collecting a soil sample (Chapter 18). Soil samples are collected both to estimate nutrient levels in a field and to estimate the amount of residual nutrients contained in the soil. For accurate estimates, representative soil samples must be collected. Accuracy improves by increasing the number of subsamples composited into a bulk sample and by avoiding areas that once were feedlots, farmsteads, and fence lines. Details on soil sampling and sample handling are available in Chapter 18, Clay et al. (2002) and Gelderman et al. (2005). For P, soil samples are collected from the 0-6 inch depth, while for N the samples are collected from two depths (0-6 and 6-24 inches).

Samples can be collected from grid points, grid cells, and whole fields (Chapter 20). Based on grid point and grid cell sampling site-specific fertilizer recommendations can be developed. Grid point or grid cell soil values can be combined with yield monitor data to make more precise decisions.

Table 25.1. General rules of thumb for collecting accurate soil samples.

- Do not sample dead furrow, turn-rows, waterways, old fence line, old farmsteads or any other area that does not represent the field.
- Reduce fertilizer recommendation errors by compositing as many sub-samples as possible.
- In P banded fields, do not oversample the P bands. Over-sampling bands produces a larger fertilizer error error than under-sampling bands.
- Track soil P levels in flooded, new tile drainage lands, and in CRP land converted to row crops.

Understanding your P soil test

If a single soil sample is collected from a field, the soil test P value of that sample represents the average value (Fig. 25.4). If the field had a normal population distribution, half of the field would have a P concentration less than that value. However, many fields have a skewed distribution, resulting in 60 or 70% of the field having a P concentration less than that value. This means that if the Olsen P concentration is 16 ppm then most of the field may require significant amounts of P fertilizer. These fields may warrant precision P management (grid cell sampling).

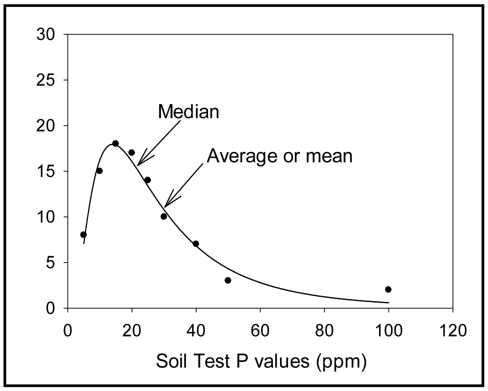

Figure 25.4. The relationship between a soil sample value and the likely P population distribution. (Source: L. Sanghun, SDSU)

P fertilizer recommendations

South Dakota P fertilizer recommendations are calculated based on the soil P test level and the soybean yield goal. Phosphorus is not a mobile nutrient in the soils and thus the movement of P is less than a few inches even in light-textured soils. Therefore, soil samples collected from the surface six inches can be used to determine the soil P level. Soil sampling protocols are provided in Chapter 18. Suggested phosphate fertilizer recommendations for soybean are shown in Tables 25.2 and 25.3.

Table 25.2. Phosphorus fertilizer recommendations for soybean in South Dakota. (Modified from Gerwing and Gelderman, 2005). The Bray-P1 test is routinely used in acid soils (pH,<7.3), while the Olsen test is used in calcareous soils (pH>7.3).

Yield	Bray-P1 Olsen	Soil Test Phosphorus (ppm)				
		VL	L	M	H	VH
		0-5	6-10	11-15	16-20	21+
		0-3	4-7	8-11	12-15	16+
bu/a		P_2O_5 (lb/a)				
30		40	23	10	0	0
40		54	31	10	0	0
50		67	39	11	0	0
60		80	47	13	0	0
70		94	55	15	0	0
80		107	62	18	0	0

Table 25.3. Phosphorus fertilizer recommendations for corn in South Dakota. (Modified from Gerwing and Gelderman, 2005). The Bray test is routinely used in acid soils (<pH,7.3), while the Olsen test is used in calcareous soils (pH>7.3).

Yield	Bray-P1 Olsen	Soil Test Phosphorus (ppm)				
		VL	L	M	H	VH
	Bray-P1	0-5	6-10	11-15	16-20	21+
	Olsen	0-3	4-7	8-11	12-15	16+
bu/a		P_2O_5 (lb/a)				
100		63	46	28	11	0
120		76	55	34	13	0
140		89	64	39	15	0
160		101	73	45	17	0
180		114	82	51	19	0
200		127	92	56	21	0

Problem 25.1. Determine the P_2O_5 recommendation for a soil with a Bray-1 soil test value of 10 ppm and a soybean yield goal of 50 bu/acre and a corn yield goal of 200 bu/acre.

Use the soil test value to determine the two-year P rate, as shown below.

Soybean lbs P_2O_5/a = (1.55 - 0.10 x 10) x 50 = 27.5 lbs P_2O_5/acre

Corn lbs P_2O_5/a = (0.70 - 0.035 x 10) x 200 = 70 lbs P_2O_5/acre

Based on these calculatons, the P recommendation is 97.5 lbs P_2O_5/acre.

Determining P rate for a corn followed by soybean rotation

To take advantage of the N contained in the MAP or DAP fertilizers many producers apply the P fertilizer to corn in the corn followed by soybean rotation. The two-year P_2O_5 recommendation is determined by using the soil test result to determine the P rate for both corn and soybean. The soybean and corn P recommendations are provided in Table 25.4. Sample calculations are provided in Problem 25.1.

Table 25.4. Soybean and corn P recommendation equations and sample calculations.

Soybean Bray-P1 recommendation equation

lbs P_2O_5/acre = (1.55 - 0.10 x BrayP1) x yield goal

Corn Bray-P1 recommendation equation

1 lbs P_2O_5/a = (0.70 - 0.035 x BrayP1) x yield goal

Soybean Olsen P recommendation equation

lbs P_2O_5/acre = (1.55 - 0.14 x OlsenP) x yield goal

Corn Olsen P recommendation equation

lbs P_2O_5/a = (0.70 - 0.044 x Olsen P) x yield goal

Sample soybean fertilizer calculation using Olsen P

Soil test P = 5 ppm (Olsen) and the yield goal is 60 bu/acre

(1.55 - 0.14 x soil test P) x yield goal

lbs P_2O_5/acre = (1.55 - 0.14 x 5) x 60

51 P_2O_5/acre

Selecting a yield goal for P recommendations

There are many different approaches to calculate a yield goal. One of the easiest is to determine the average value from previous years, and then remove any outliers (Table 25.5). These yield estimates can be modified for poor and good soil moisture. For good soil moisture conditions the yield estimates may be increased 10%, while for poor soil moisture conditions the yield estimates are decreased 10%.

Your P program can be fine tuned by routine scouting, tracking nutrient levels, determining P mass balances, and using a more rigorous soil extracting solution. Details on scouting, tracking nutrients, and determining P mass balances are in Chapter 17. Information on the P2 soil test is below.

Table 25.5. An example showing how to estimate a yield goal.

Year	Yield Goal bu/acre	Soil Moisture Conditions
1	40	Good
2	35	Poor
3	45	Good
4	10	Very poor
5	60	Excellent
6	55	Excellent
7	42	Good
8	38	Good
Average	40.625	
Excluding year 4	45	

Estimated yield (bu/acre) = (40+35+45+60+55+42+38)/6=45 bu/acre

Using multiple soil P tests

Some laboratories may also offer the Bray-P2 test. The Bray-P2 test is similar to the P1 test, however it contains a higher concentration of HCl. The difference between the Bray-P2 and Bray-P1 test has been related to active reserves. In South Dakota, research needs to be conducted to better define how the Bray-P2 test can be used to improve P recommendations.

It has been proposed that the Bray-P1 and Bray-P2 tests can be used to assess readily and moderately available P sources. In South Dakota the current P recommendation system is built on the Bray-P1 or Olsen test.

It has been suggested that a Bray-P2 value that ranges from 40 to 60 ppm is desirable. In this interpretation, a high Bray-P2/Bray-P1 ratio (>3) indicates that P fixation is a problem, while a low ratio (<2) indicates that the soil has a low P fixing capacity. Research on the value of the Bray-P2 test for South Dakota needs to be conducted. It has not currently been proven that certain Bray P2 ranges or ratios with Bray P1 values are diagnostic of crop response to P additions in the short term (one season) or long term (multiple seasons).

Banding the fertilizer is an approach used to reduce P fixation. Many farmers band the P two inches below and two inches to the side of the seed. When compared with seed placement, this approach reduces the risk of salt injury. When placed with or near the seed, using MAP rather than DAP can reduce risks of ammonia toxicity to seeds or seedlings, particularly when ammonium forms or urea forms of nitrogen are co-applied, soils are dry, CEC is low, free calcium carbonates exist, and/or soil pH is basic.

Research on the benefits of banding is mixed. Bly et al. (2006) reported that if moisture is adequate, soybean yields have usually been slightly higher for P broadcast than banded treatments. Gelderman et al. (2002) had different results and reported that broadcast incorporated and banded P rates produced similar yields. Rehm et al. (2001) had similar results in Minnesota. Recent research suggests that yields might be increased by banding the fertilizer directly below the seed (Yin and Vyn, 2003).

In some situations, the P effectiveness may be limited by low soil pH. When N fertilizer is applied, soil pH values slowly decrease. In acid soils (pH < 5.5), iron and aluminum minerals react with applied P to form insoluble compounds with limited availability. If the soil pH is less than 5.4, it may be possible to increase soybean yields by adding lime (Bly et al., 2004, 2005).

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