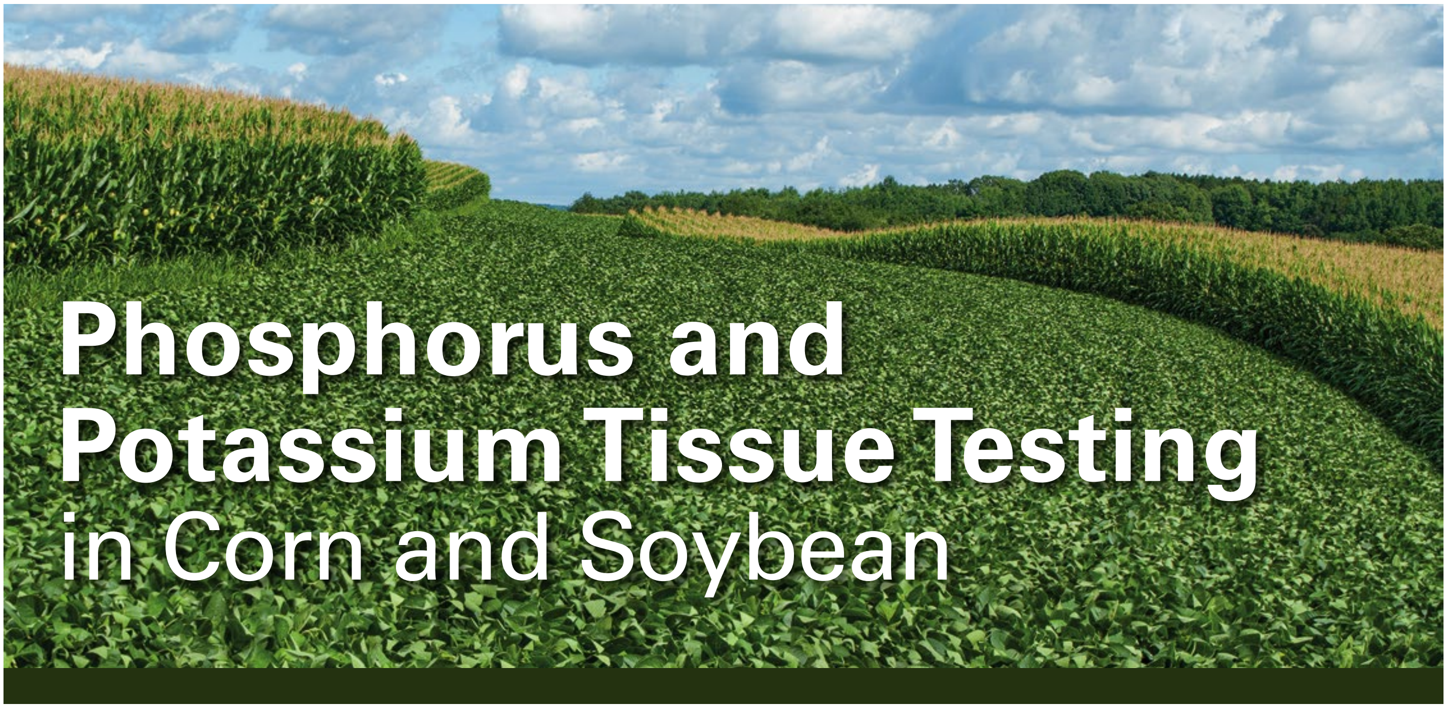

Phosphorus and Potassium Tissue Testing in Corn and Soybean

Iowa farmer and crop consultant interest in the use of tissue testing for phosphorus (P) and potassium (K) diagnostics in corn and soybean has increased in recent years. Some are using interpretations that were not derived from correlations of tissue test results with crop response or that were developed for other geographic regions. Iowa research since the 1950s has continuously investigated the relationships between crop yield response and soil test P and K with various test methods. That ongoing research has resulted in soil test interpretations that have been updated over time as needed and are reliable.

However, to date there has been no P or K tissue test interpretations published by Iowa State University Extension and Outreach for corn and soybean.

Tissue nutrient concentrations, including P and K, vary greatly not only with soil nutrient supply, but also with the plant growth stage, plant part sampled, growing conditions, and hybrids or varieties. In addition, diagnosis by tissue testing occurs during the growing season, when the success of corrective measures for the sampled crop by fertilization to the soil or foliage is low and uncertain. To be useful in corn and soybean production, tissue test interpretations must be developed for specific regions and across a wide range of cultivars and growing conditions as well as for specific plant parts and growth stages.

Iowa tissue testing research for P and K

Although many experiments from the 1970s until the 1990s measured the effect of fertilization on P or K concentrations of different corn and soybean plant parts, the data was not sufficient to establish reliable tissue test interpretations. This was because there were insufficient number of trials in different years and soils with necessary ranges of grain yield response or plant tissue concentrations. Therefore, new field correlation research was conducted from 2003-14 to evaluate the value of tissue testing for P and K in corn and soybean. There were 66 site-years for P (32 for corn and 34 for soybean) and 119 site-years for K (67 for corn and 52 for soybean). Research data from previous years (1990 or older) were not combined with the new data so that interpretations would be relevant to current yield levels and modern hybrids or varieties.

The research evaluated tissue tests for early vegetative and early reproductive growth stages that had been used by previous research in Iowa and other states. The plant part sampled for the tissue test at the early vegetative stage was the entire aboveground plant cut one inch from ground level at the V5-V6 growth stage of corn (Figure 1) or soybean (Figure 2). The corn plant part sampled for the tissue test at the early reproductive stage was the blade portion of the leaf opposite and below the primary ear (not including the leaf sheath) at the R1 (silking) stage (Figure 3), which is commonly known as the ear leaf test.

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The soybean plant parts sampled for the tissue test at the early reproductive stage were the three top trifoliate leaves with leaflet borders not touching (including the trifoliate leaf petioles) at the R2-R3 stage (Figure 4). The corn and soybean growth staging system used in Iowa can be found with detailed descriptions in ISU Extension and Outreach publications ***Corn Growth and Development*** (PMR 1009) (https://store.extension.iastate.edu/Product/6065) and ***Soybean Growth and Development*** (PM 1945) (https://store.extension.iastate.edu/Product/6451). The total P or K concentration was measured for the young plant test and the leaf test in both crops.

Figure 1. Corn plant at the V6 growth stage. The sixth leaf is the oldest leaf with the collar fully visible. The aboveground plant parts were sampled (cut one inch from the ground).

Figure 2. Soybean plant at the V6 growth stage. The plant has six trifoliate leaves with leaflets fully unrolled (borders not touching). The aboveground plant parts were sampled (cut one inch from the ground).

Figure 3. Corn plant at the R1 growth stage. The sampled part was the blade of the leaf opposite and below the ear (not the sheath).

Figure 4. Soybean plant at the R2 growth stage. The sampled parts were the three top trifoliate leaf having leaflets with borders not touching, including the petioles.

Figures 5-8 show correlation data from the recent Iowa studies in which the corn or soybean grain yield response is expressed relative (percentage) to yield with non-limiting P or K fertilization. The corn and soybean yield response to P and K decreased (the relative yield values increased) with increasing tissue P or K concentrations from low values up to a plateau level with high concentrations. The P and K concentrations for both crops were higher for young plants sampled at the V5-V6 growth stage than for leaves sampled at the early reproductive stage, although the difference was much larger for corn than for soybean. Phosphorus deficiency symptoms such as purple coloring of leaves were not observed in plots not fertilized with P at any site, and reduced plant height was obvious at sites with some of the lowest plant or leaf P concentrations. Potassium deficiency symptoms, including yellow to necrotic edges of older leaves and reduced growth, often were observed in plots receiving no K fertilization at sites with some of the lowest plant or leaf K concentrations. However, the K deficiency symptoms were observed more frequently at the leaf sampling stage (R1 in corn and R2-R3 in soybean) than at the V5-V6 stage.

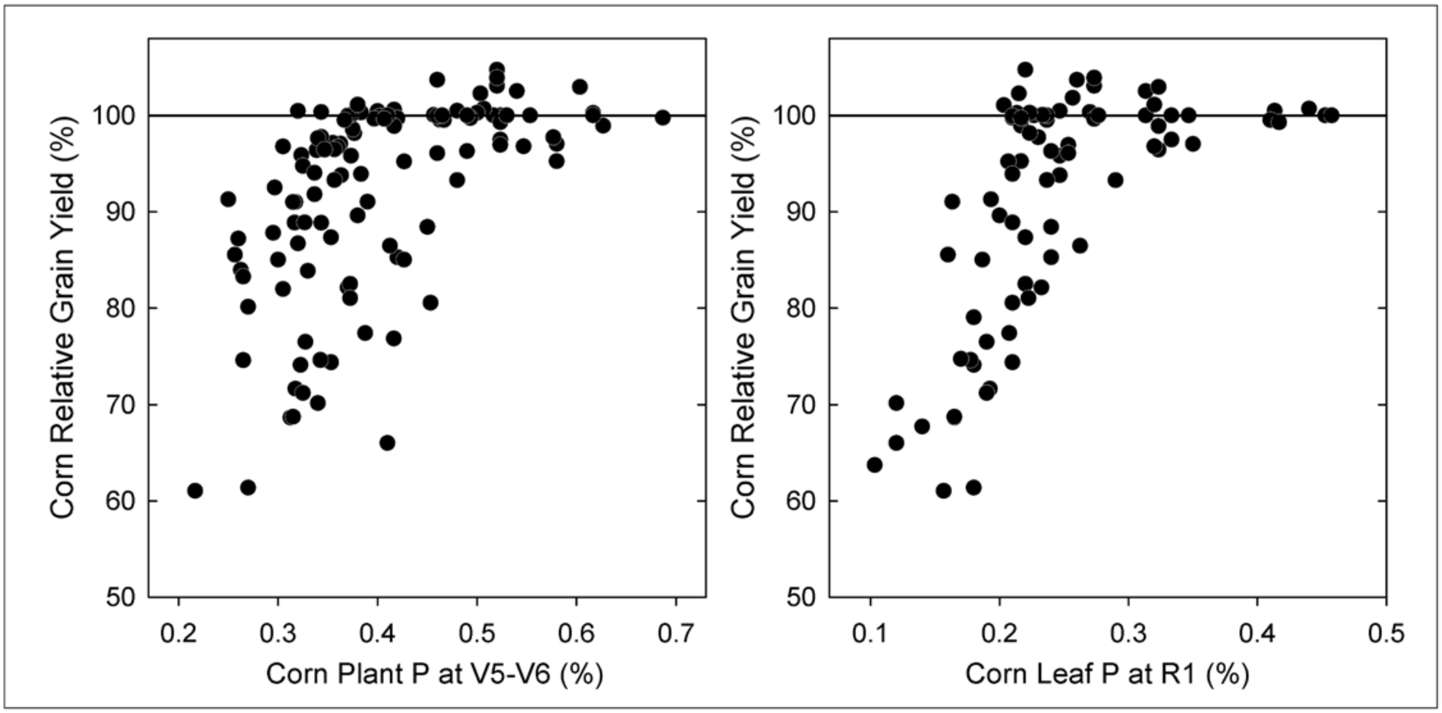

Figure 5. Relationship between corn relative grain yield response and the P concentration in whole plants at the V5-V6 growth stage and in the ear leaves at the R1 growth stage.

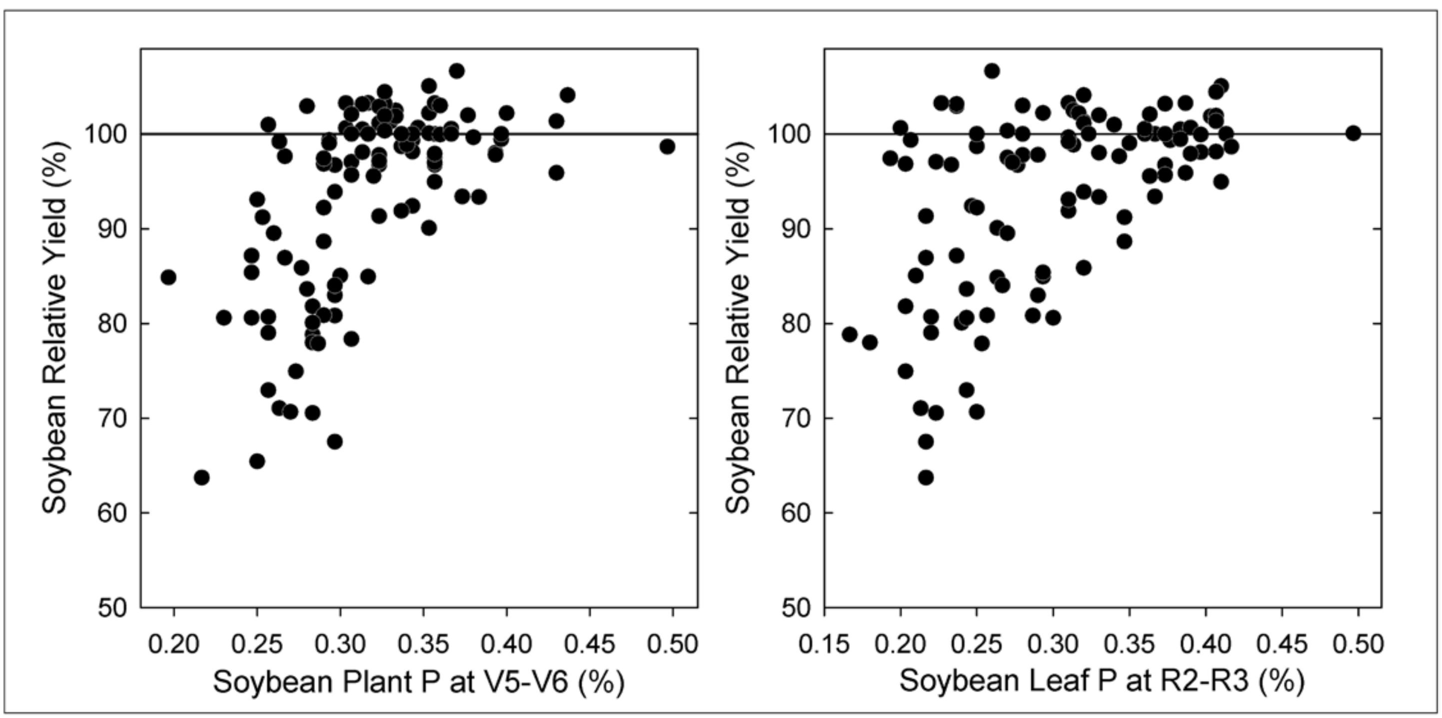

Figure 6. Relationship between soybean relative grain yield response and the P concentration in whole plants at the V5-V6 growth stage and in the top trifoliate leaves at the R2-R3 stage.

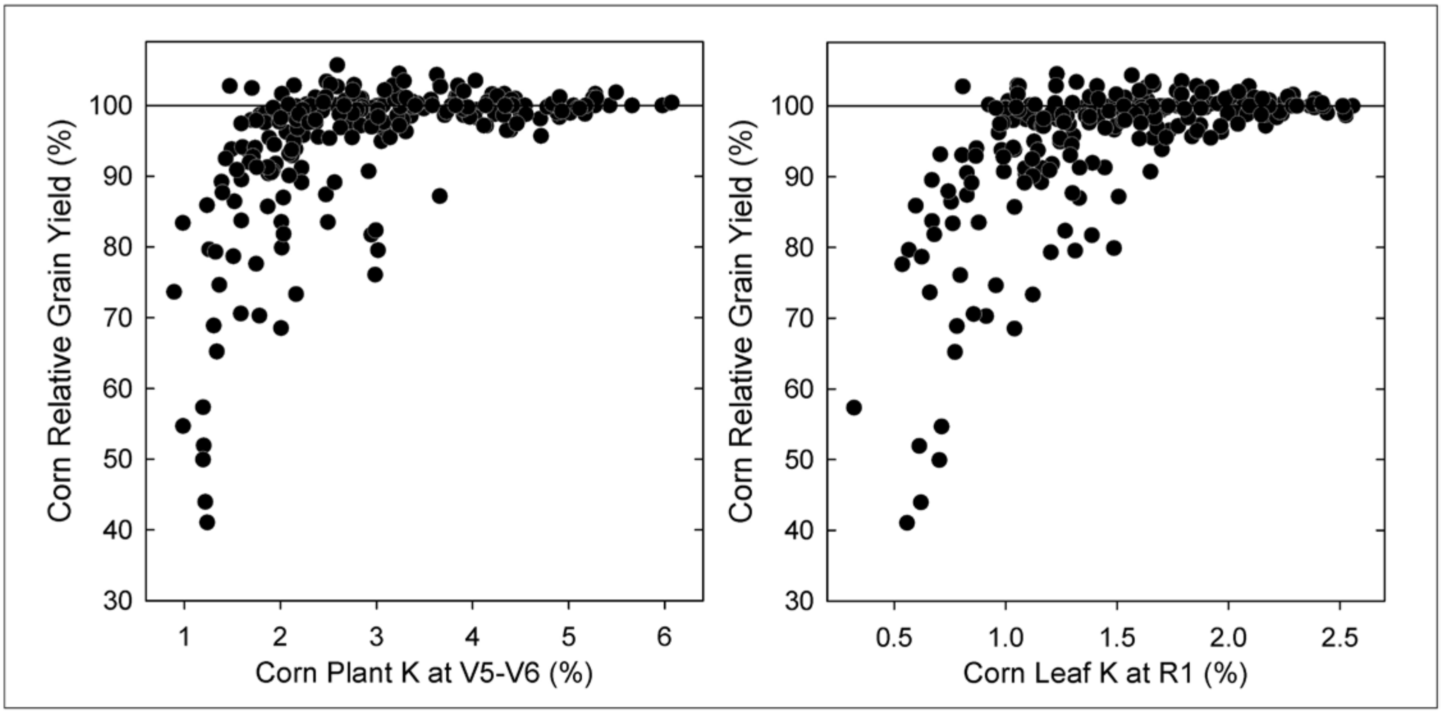

Figure 7. Relationship between corn relative grain yield response and the K concentration in whole plants at the V5-V6 growth stage and in the ear leaves at the R1 growth stage.

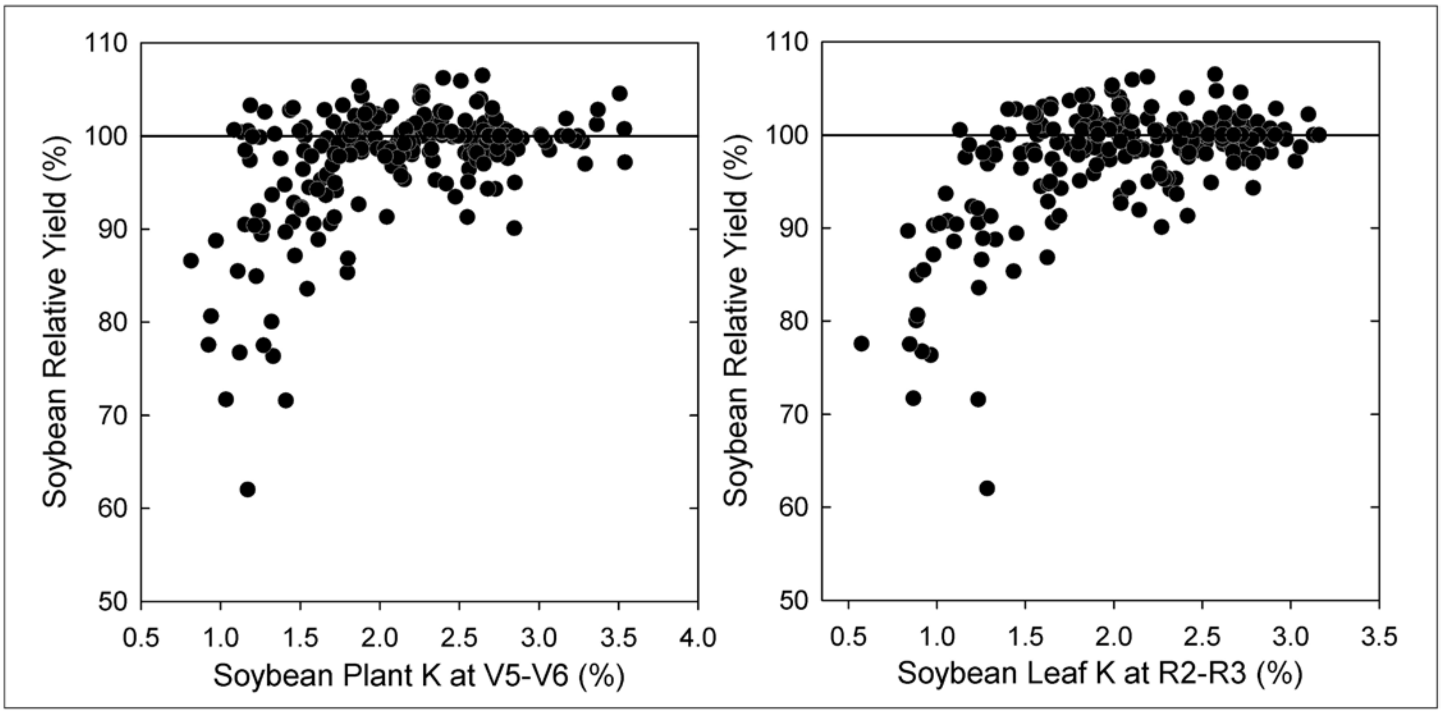

Figure 8. Relationship between soybean relative grain yield response and the K concentration in whole plants at the V5-V6 growth stage and in the top mature trifoliate leaves at the R2-R3 stage.

The distribution of data points in the figures show that the variation in relative yield for approximately similar nutrient concentrations was smaller in some cases than in others. Also, a few data points in most graphs seem to depart from the general relationships, which is commonly seen in tissue or soil test correlation research. Available information for growing conditions (soils, weather, and hybrids or varieties used) for the trials could not fully explain reasons for these non-conforming data points.

The unexplained variation of the relationship between the corn young plant P test and yield response was larger than the variation for the ear leaf P test (Figure 5), which means the young plant test has a lower capability to predict the magnitude of response to P supply than the ear leaf test. The variation in the relationship between the soybean leaf P test and yield response was larger than the variation for the soybean young plant test (Figure 6), which indicates that the soybean leaf P test has a lower capability to predict P response than the young plant test. For all the P tissue tests, however, the distribution of the data points shows a break between the concentration zone with likely yield response and the zone with unlikely response, which is useful for the test diagnostic. The graphs for soybean plant and leaf K (Figure 8) show a wider range of relative yield values around the plateau level than for other tests, which indicates a lower capability to identify concentrations that would result in small yield increases and decreases at high concentration levels.

The variation observed for the relationships between crop yield response to P and K fertilization and the young plant or leaf test results for both crops was similar to or larger than the variation that has been observed in relationships between yield response and soil test methods for these nutrients.

The high variation in relationships for the corn young plant P test (Figure 5), soybean leaf P test at R2-R3 (Figure 6), and both soybean K tissue tests (Figure 8) has not been observed for correlations of yield response with soil test results. The variation in relationships for the other tissue tests is approximately similar to variation observed for correlations of yield response with soil test results.

Tissue test interpretation categories

There are no widely accepted procedures for developing interpretations for soil or tissue test results. Published research typically provides an estimation of critical concentrations. Critical concentrations of soil or tissue test results distinguish between conditions of nutrient deficiency with likely crop response to fertilization from situations with adequate nutrient supply and unlikely response. A critical concentration range often is determined by using two or more mathematical response models instead of a single value. This is because soil and tissue testing are not free of error or uncertainty, mainly due to often large spatial variability, laboratory bias, and difficulties accounting for conditions that limit yield response to fertilization or induce a higher than expected response. Although critical concentration ranges are useful to develop interpretation categories for implementing a test in production agriculture, other considerations, some subjective, also are used. These include judgement of the bias imposed by different response models and assumed risk of using too low or too high of a critical concentration or range.

Table 1 indicates the three interpretation categories of Low, Sufficient, and High suggested for P and K tissue tests in corn and soybean based on research results shown in Figures 5-8.

Tissue testing and these interpretations should be used as a diagnostic tool to estimate the P and K status of corn and soybean, and not to predict yield levels or yield response to in-season fertilizer application. Like any test, there is always a certain degree of uncertainty about the meaning of a test result, as data in the figures show.

There is a high probability that test results within the Sufficient category indicate P and K levels are adequate to attain maximum yield or maximum economic yield.

In all cases, the average relative yield value for test results within the Sufficient category was 99-100 percent. Test results in the Low category indicate likely deficiency. Test results in the High category indicate a high probability of

Table 1. Interpretation categories of P and K tissue tests for corn and soybean based on two growth stages and plant parts.

Nutrient	Crop	Stage	Plant Part	Low	Sufficient	High
				- - - - - - - - Nutrient Concentration (%) - - - - - - - -		
Phosphorus	Corn	V5-V6	Plant†	< 0.48	0.48-0.58	≥ 0.59
		R1	Ear leaves‡	< 0.25	0.25-0.32	≥ 0.33
	Soybean	V5-V6	Plant†	< 0.33	0.33-0.41	≥ 0.42
		R2-R3	Trifoliate leaves§	< 0.35	0.35-0.42	≥ 0.43
Potassium	Corn	V5-V6	Plant†	< 2.5	2.5-3.8	≥ 3.9
		R1	Ear leaves‡	< 1.4	1.4-2.0	≥ 2.1
	Soybean	V5-V6	Plant†	< 1.9	1.9-2.7	> 2.8
		R2-R3	Trifoliate leaves§	< 1.8	1.8-2.5	> 2.6

† Cut one inch from ground level.
‡ Blade of the leaf opposite and below the primary ear.
§ Top three trifoliate leaves with untouching leaflet border per plant including petioles.

P or K supply beyond amounts needed to maximize yield or to attain maximum economic yield, but not necessarily excessive supply. The research used to develop these interpretations showed no yield decrease from even the highest tissue P and K concentrations.

Considerations for plant tissue sampling

To ensure appropriate use of the suggested interpretations, it is important to sample the same corn or soybean plant parts at the same time as done in the research to ensure accurate results. The tissue P and K concentrations will not vary much for the growth stages V5-V6 for both crops, R2-R3 for soybean, and for corn ear leaves as long as silks are not brown.

Each sample should be a composite from at least ten corn or soybean plants (ten plants at the V5-V6 stage, ten corn ear-leaf blades at the R1 stage, or three top trifoliate soybean leaves from ten plants at the R2-R3 stage) to ensure the test result represents an average for the collection area.

As is the case for soil testing, zone or grid sampling approaches can be used for tissue testing, although dense grid sampling is not practical for sampling plant tissue at the reproductive stages. Research has shown that tissue P and K concentrations can vary across a field as much as P and K soil test values.

Separate samples should be collected when different planting dates are used within a field because the appropriate growth stages may occur at different times. Use of different hybrids or varieties within a field can introduce additional variation due to potentially different development rates and genotype differences that may affect nutrient concentrations.

The actual impact of different hybrids or varieties on nutrient concentrations at a similar growth stage has not been well quantified, however. Therefore, even if the growth stage is approximately the same for different hybrids or varieties within a field, separate sampling is recommended.

To reduce the risk of sample decay and loosing dry matter or fluids, put the samples in paper bags and submit them to a laboratory as soon as possible.

Use of sealed plastic bags is not recommended because the samples can get hot and will decay. Freezing the samples is not recommended because major plant decomposition and fluid loss can occur if samples thaw during transport. The samples can be air-dried before submitting them to a laboratory by placing them exposed on a clean area with a fan blowing air across them, or with care can be dried in an oven at 140°F (60°C) or less.

Caution when using tissue test interpretations

Research has demonstrated that tissue testing can be used as an in-season tool to assess P and K sufficiency in corn and soybean. The results showed, however, that variation in correlation between tissue test results and crop yield responses is similar or higher than for soil testing. In addition, tissue testing is of doubtful value to correct P and K deficiencies for that sampled crop.

Therefore, tissue testing should be used to complement and not substitute for recommended soil testing in making fertilization decisions.

A particularly useful approach for tissue testing is when normal and poor growth areas exist in a field that may be related to P or K nutrient supply. In such situations, collect and analyze both soil and plant tissue from the areas to help diagnose deficiencies. Any stress, such as drought, excess moisture, pests or diseases, and deficiencies of other nutrients can influence plant growth and nutrient uptake and can increase or decrease nutrient concentrations. Therefore, careful interpretation of tissue test results is always needed, but especially when test results are much lower or higher than normal. A comparison of tissue and soil test results along with consideration of field history information is helpful for detecting and understanding potential nutritional problems.

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