MISSISSIPPI SOYBEAN PROMOTION BOARD

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SOYBEAN TISSUE/SEED ANALYSIS TO DETERMINE PLANT NUTRIENT STATUS

The goal of a soil fertility program is to match the nutrient application to soil with the crop nutrient requirements for an intended yield or for a target potential yield. It is a foregone conclusion regarding fertility needs of any growing crop that proper soil sampling and testing is the most reliable way to determine the soil's ability to provide nutrients to a growing crop. This approach is the proven best management practice for maintaining adequate fertility.

Tissue testing is a tool that can be used to assist in identifying nutrient deficiencies that may be limiting crop growth and yield in the field. The nutrients in the plant at a given time as measured by tissue analysis reflect what the plant has been able to obtain from the soil vs. what nutrients are available in the soil reservoir. The nutrient concentration of a particular plant tissue can be compared to a known critical nutrient concentration [click here for critical values] to determine if sufficient nutrients are present in the plant to achieve optimum performance.

Plant analysis or tissue testing can be used as a **monitoring tool** to ensure that plant nutrient levels are adequate, and as a **diagnostic tool** to aid in explaining some of the variability in appearance of soybean plants that may be visible in different areas of a field. When used as a diagnostic tool, producers should take samples from both the "good" and "bad" or problem areas of a field so that the nutrient levels in plants from each area can be compared.

Results from tissue testing likely cannot be used to correct nutrient deficiencies during the current growing season, but rather can be used in planning for future nutrient applications, or to validate the current fertility program for a specific crop. Thus, tissue testing for nutrient sufficiency or deficiency should be used in conjunction with soil tests.

Advances in tissue testing guidelines may enhance its capability of being used to assess nutrient deficiencies that limit soybean performance. The following narrative summarizes the known information as presented in recent publications.

An article in Iowa State University's ICM News titled "Value of Soybean Tissue Testing for Phosphorus and Potassium" authored by Dr. Antonio Mallarino sheds new light on using tissue testing as a tool for making phosphorus [P] and potassium [K] fertilization decisions for soybeans.

- In an extensive study that included 86 site-years [34 for P and 52 for K]) on 17 soil series in Iowa, tissue tests were used to evaluate P and K concentrations in the aboveground portion of soybean plants at the V5-V6 growth stage, and in upper fully mature trifoliate leaves at the R2-R3 stage. Relative soybean seed yield for each site-year was calculated as a percentage of the maximum observed yield.
- Initial soil test levels of P and K across site-years ranged from very low to very high, and seed yield ranged from 22 to 73 bu/acre. Statistically significant yield increases occurred in 22 of the 34 P site-years and in 22 of the 52 K site-years.
- Yield increased with increasing P and K tissue concentrations, but the relationships were not statistically high. **The relatively poor relationships between P and K tissue concentrations and yield indicate that tissue testing for these two elements is not an acceptable way to predict the magnitude of yield response that can be expected**.
- The author concluded that tissue tests can be used to assess the in-season sufficiency of P and K in soybean, but the results also indicate that tissue testing is not better than soil testing as a diagnostic tool. The author also concluded that tissue testing is of doubtful value as a tool for correcting P and K deficiencies in a soybean crop.
- Finally, the author concludes that tissue testing should be used to complement but not substitute for soil testing as the primary method for making fertilization decisions for a soybean crop. Its primary value is likely for confirming soil P and K deficiencies in field areas that exhibit poor performance.

Information that appeared in the article "Research lacking to back claims for foliar-applied fertilizers" should be considered. Key points from that article follow.

- Producers who are considering the application of foliar-applied fertilizers should ask 1) what is the frequency of crop response, and 2) what is the expected average yield increase, and will this increase pay for the applied product? The answers to these questions should be based on valid, verifiable research.
- Recommendations to producers for foliar application of nutrients are usually based on tissue analysis. The tissue values that are used to define nutrient sufficiency or deficiency
- are not always based on research,
- there is inadequate published information that defines the relationship between crop yield increase and the tissue values for many nutrients,
- there is inadequate information to define the exact nutrient concentration that is needed to verify a yield response to foliar feeding,
- many of the cited critical nutrient concentrations are specific to a particular plant part and growth stage, and
- there is not usually a single tissue nutrient concentration that can be used to define nutrient sufficiency or deficiency for the duration of the growing season.

Click here to access a White Paper titled "Foliar Fertilization of Soybeans" that appears on this website. Pertinent points from that article follow.

- A few studies have shown small yield increases resulting from the application of foliar fertilizers to soybeans. However, the yield increases were either not economical or their profitability was not determined.
- Application of a foliar fertilizer to soybeans should be considered only to correct a confirmed in-season nutrient deficiency.
- Even though nutrient deficiencies may sometimes occur during the growing season, the best remedy is to apply the correct amount of fertilizer based on soil test results before planting the next crop.
- Application of deficient nutrients on the plant's foliage during the growing season will not likely result in sufficient uptake of those nutrients in an amount that will provide a profitable yield response because leaf surfaces are not conducive to absorption of fertilizer nutrients.
- The macronutrients N, P, and K should not be considered for foliar application.
- If a foliar fertilizer is applied, maximum benefit will be realized only if there is maximum interception of the product by plant foliage, and only if all leaves of the target plants are thoroughly wetted.

Results reported in two recent journal articles and a PMN webinar provide additional information that can be used to assess tissue testing as a management tool for soybean.

In an article titled "Soybean yield components and seed potassium concentration responses among nodes to potassium fertility", authors Parvej, Slaton, Purcell, and Roberts of the Univ. of Arkansas provide the following results from research.

- The premise for the research was that soybean yield loss from K deficiency is common, especially for soybean grown on soils with low K fertility, but the distribution of that loss among nodes has not been reported.
- The objective of the research was to evaluate soybean seed yield, weight of individual seeds, number of pods and seeds, seed abortion, and the concentration of K in seed among nodes of an indeterminate and a determinate soybean variety grown on soils with different K fertility levels. Plants for analysis were collected at maturity.
- The research was conducted on a silt loam soil near Colt Ark. [35°07' N lat.] in 2012 and 2013 using varieties grown on soils with low, medium, and high soil-K availability as determined by annual soil tests and maintained with yearly fertilization K rates.
- K deficiency symptoms were observed shortly before R1 in the low-K treatment, and became more common thereafter. K deficiency symptoms were never visible in the medium- and high-K treatments.
- Regardless of K fertility level for the indeterminate variety, the largest proportion of the seed yield was produced on the middle nodes of plants.
- Regardless of K fertility level for the determinate variety, the greatest proportion of the seed yield was produced on the bottom-most nodes of plants. This was attributed to the branches that were produced from the bottom two main-stem nodes.

- These results coupled with results from previous research indicate that the largest proportion of seed yield/plant comes from the middle and upper-middle nodes of the indeterminate plants and the combination of the bottom node [due to branching] plus the nodes on the top one-half of the determinate plants.
- On both indeterminate and determinate plants, number of pods and seeds increased on the top five nodes as K fertility increased. On both plant types, increasing K fertility resulted in increases in both pod and seed numbers.
- The largest proportion of pod and seed numbers came from the middle nodes of the indeterminate plants, and from the bottommost nodes of determinate plants. Thus, K fertilization influenced number of pods and seeds on the nodes that produced the largest seed yield differences.
- Regardless of growth habit, seed K concentration increased with increasing K fertility level and decreased from the top to the bottom of the plants. These results indicate that seeds produced on the lower nodes received K preferentially, and that the range in seed-K concentrations on soybean plants can be decreased or eliminated by increasing K availability. This has led to the thought that foliar feeding of K during late reproductive development may be useful in minimizing these top-to-bottom differences, but the amount of foliar-applied K that will be required or that can be absorbed by leaves may be impractical.
- The rapid decline in seed-K concentration toward the upper canopy is likely an explanation for the visible K deficiency symptoms that appear on plants that are grown in conditions with low-K availability.
- The authors concluded that 1) yield loss from K deficiency was greatest on nodes that produced the largest proportion of seed yield for each growth habit, 2) yield loss on the top-most nodes due to K deficiency was from fewer pods and seeds, reduced seed weight, and increased seed abortion, 3) seed-K concentration was greatest in seed produced on the bottom nodes and was least for seed produced on the top-most nodes, and 4) maintaining medium to high soil K fertility minimized the seed-K gradient among nodes and increased seed-K concentration.

In an article titled "Critical trifoliolate leaf and petiole potassium concentrations during the reproductive stages of soybean", authors Parvej, Slaton, Purcell, and Roberts of the Univ. of Arkansas provide the following results.

- The premise of the research was that characterization of the change in soybean leaf- and petiole-K concentrations across time and soybean growth stages would be of value in diagnosing the K nutritional status of soybean at more than a single growth stage, and this knowledge could then be used to relate the K concentration to soybean yield.
- The research was conducted near Colt Ark. in 2012-2014 and at Stuttgart Ark. in 2014 using indeterminate and determinate varieties grown on soils with a range of soil- and annual fertilizer-K rates.
- Leaf samples [fully expanded leaves] used for tissue analysis were collected from one of the top three nodes of plants at 6- to 15-day intervals starting at the V5 stage and continuing to the R7 stage.
- Regardless of soybean variety or K fertilization rate, the K concentration in the sampled leaves increased linearly or plateaued up to the R1-R3 stages, and then declined linearly throughout the remainder of the reproductive period. This pattern was attributed to translocation of K to the developing seed.
- The linear pattern of decline in leaf-K concentration was independent of variety or K availability. This suggests that predicting critical leaf-K concentrations beyond the R2 stage is possible.
- Peak leaf-K concentrations ranged from 1.23% to 2.18%, which represents K concentrations considered deficient to optimal. A peak leaf-K concentration of 1.9% was deemed sufficient from the results of this study.
- The calculated lower and upper leaf-K concentration boundaries in these studies were 1.26% and 1.76% at R3, 1.06% and 1.5% at R4, 0.87% and 1.31% at R5, 0.67% and 1.11% at R5.5, and 0.47% and 0.91% at R6.
- Leaf-K concentration at the R2 stage and beyond was significantly and positively related to relative yield.
- The K concentration pattern of petioles from

vegetative stage to R1-R2 and then to R7 followed the same pattern as that of the leaves.
- Peak petiole-K concentrations at R1-R2 ranged from 2.28% to 5.37%, which is about a two-fold increase over peak leaf-K concentrations.
- Petiole-K concentration at a particular time or reproductive stage increased with each increase in K fertilization rate.
- Petiole-K concentration at the R2 stage and beyond was significantly and positively related to relative yield.
- Peak petiole-K concentrations at R2 ranged from 3.01% to 3.83%, which were more than double the critical leaf-K concentrations. Values within this range were considered sufficient. The upper end of the critical range declined to 0.80% at R6.
- Deficient petiole-K concentrations were estimated to be 2.45% at R3, 1.89% at R4, 1.33% at R5, 0.77% at R5.5, and 0.22% at R6. The authors state that additional research is needed to validate these proposed critical petiole-K concentrations across soybean reproductive stages.
- The results indicate that soybean petioles may be an equally good or better tissue than trifoliolate leaves for monitoring K nutritional status of soybean during reproductive growth.
- The estimates of critical leaf- and petiole-K concentrations reported from this study represent the first proposed critical tissue-K concentrations for soybean across multiple growth stages.

In a PMN Webcast titled "Plant Analysis as a Nutrient Management Tool", Dr. Dave Mengel of Kansas State Univ. provides an excellent summary of all the points gleaned from the above references. A summary of the major points in this webcast follow.
- Tissue analysis provides an assessment to determine if a designed and followed nutrient management plan is working.
- Plant analysis is a valuable diagnostic tool that can be used to assess nutrient deficiency issues observed in the field.
- Collect tissue samples from specific areas in a field that are normally used for soil sampling.
- Know the critical level or concentration of a particular nutrient in the plant in order to determine deficiency or sufficiency of that nutrient. A table showing the critical level and sufficiency range of major plant nutrients in soybean leaves at about R3 is shown.

The following points and guidelines should be considered when plant tissue analysis is to be used for determination of plant nutrient status.
- A soil test indicates which nutrients are available in the soil for crop use, whereas tissue analysis shows which nutrients the growing plants have actually obtained and are using at a particular time/growth stage.
- Sample when the plants are obtaining the greatest quantity of nutrients from the soil, then compare the measured concentrations at that time to a set of standards to determine if nutrient concentrations in the plant indicate sufficiency or deficiency. These results can then be used to modify nutrient applications for next year's crop.
- Sample parts from plants that most closely represent the conditions of the field or field area of interest and that presumably will have a predictable concentration of nutrients. Within those areas, collect samples from healthy plants.
- Collect the proper amount of samples from the proper plant part. This requirement will be given by the particular diagnostic lab used for the test.
- Handle the samples properly–e.g. label sample bags and document the field or field area they came from. Send promptly or refrigerate until sent.

Remember, tissue testing is neither a substitute nor a replacement for a sound program of soil sampling and testing, followed by the consistent replacement of nutrients that are removed from the soil by a crop.

The concentration of a particular nutrient in mature soybean seeds might also be used to determine the sufficiency of soil nutrients for achieving a desired yield.

In a report published in Soil Sci. Soc. of America Journal 80:1231-1243 (2016), Arkansas scientists used data from 100 site-years of replicated field research that had been conducted in Arkansas, Indiana, Iowa, Missouri, Tennessee, Virginia, and Canada to determine soybean yield response to K fertilization. Their objective was to determine the relationships between seed- and soil-K concentrations and relative soybean yield, and use these findings to develop potential seed-K concentration thresholds that can be used to diagnose soil-K deficiency as a yield-limiting factor of soybean. This objective was based on the premise that the K concentration in mature soybean seed might provide an additional tool that can be used to explain lower-than-expected seed yields when K-deficiency symptoms are not obvious. Results from the Arkansas observations follow.

- Average yield [irrigated] from sites that received no fertilizer K and sites that received fertilizer K averaged 58 bu/acre and 64 bu/acre, respectively.
- Soybean seed-K concentration accounted for 66% of the variability in relative yield.
- Relative yield increased linearly as seed-K concentrations increased, and plateaued when seed-K concentration reached 1.63%.
- The critical range of seed-K concentration was determined to be 1.56% to 1.70%. Thus, seed-K concentrations <1.55% were considered deficient, and those >1.71% were considered sufficient.
- 93% of the sites that produced seed with K concentrations deemed deficient produced significant yield responses from added K fertilizer that averaged 9.1 bu/acre. Absolute yield difference attributed to fertilizer K was greatest at sites that produced seed with deficient seed-K and least for sites that produced seed with sufficient seed-K concentrations.
- The difference in seed-K concentration decreased as soil-test K concentration increased, with seed-K difference plateauing when soil-test K concentration was equal to or greater than about 87 ppm [this equates to about 180 lb/acre K].

For the combined North American data, the following results were obtained.

- Soybean seed-K concentration accounted for 60% of the variability in relative yield of unfertilized soybean, and the critical seed-K concentration was predicted as 1.71%, with a 95% confidence limit of 1.65% to 1.77%. Thus, using the entire data set provided results similar to those obtained from using only data from Arkansas.
- 77% of the sites that produced seed with a deficient seed-K level showed a significant yield benefit from fertilizer K that averaged 7.2 bu/acre. This compares to 93% of the Arkansas sites and a yield increase of 9.1 bu/acre.
- Seed-K concentration of soybean receiving no fertilizer K increased linearly as soil-test K concentration increased to about 179 ppm, and seed-K concentration plateaued at 1.88%. Soil-test K concentration explained 40% of the variability in seed-K concentration of soybean that received no K fertilizer.
- For soybean receiving K fertilizer, seed-K concentration increased linearly until soil-test K concentration reached about 170 ppm, and seed-K plateaued at 1.91%. Soil-test K concentration explained only 24% of seed-K variability when K fertilizer was applied.
- The relationships between seed-K and soil-test K concentrations suggest that both fertilizer- and soil-K availability influence soybean seed-K concentration when soil-test K concentrations are less than about 170 to 179 ppm [this equates to about 340 to 360 lb/acre K].

These relationships led the authors to the following conclusions.

- The proposed deficient seed-K concentration of <1.65% correctly identified fields that responded to fertilizer K 77% of the time. Thus, soybean seed-K concentration can be used to diagnose soil-K deficiency for soybean production.
- When soil-K availability is less than about 180 ppm, both fertilizer- and soil-K availability influence soybean seed-K concentration.
- Seed analysis cannot be used to correct K deficiency during the growing season, but can be used as a post-harvest tool for diagnosing reasons for low seed yield and for correcting soil K deficiency for a subsequent crop.

All of the above results indicate that both tissue testing and testing for seed-K concentration can be used to assess the in-season sufficiency or deficiency of K in soybean. However, both of these tests should be used to complement soil testing for making fertilization decisions for a subsequent soybean crop. Their primary value is likely for confirming nutrient deficiencies in a soybean crop that has performed poorly.

These cited results indicate that tools are available that can be used to definitively determine if K deficiency is a contributor to lower-than-expected yields from a particular production site. Also, these tools can be used to determine if K fertilizer recommendations resulting from properly conducted soil tests were indeed sufficient to ensure adequate soil K fertility for an intended or expected soybean yield.

April 2025 Update

Preliminary research at the Univ. of Illinois has determined the following.

- Newer leaves near the top of the soybean plant tend to have a higher concentration of nutrients that older leaves lower in the canopy.
- The concentration of nutrients in leaves can vary over time and by nutrient. This is especially so since nutrients vary in their ability to be mobilized to the developing seed.
- Until more definitive guidelines can be determined, a producer might experiment with sampling one trifoliate lower than the designated trifoliate that is also sampled.

Two publications that should be consulted for guidelines about tissue testing are:

1. Southern Cooperative Series Bulletin No. 394 titled "Reference Sufficiency Ranges for Plant Analysis in the Southern Region of the United States", and
2. Soybean Tissue Sampling from Clemson Univ. Extension.

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