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In-Season Potassium Management in Arkansas Soybean

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Potassium (K) is often the most yield-limiting nutrient in soybean and must be added as fertilizer in greater amounts than other plant essential nutrients for adequate plant growth. Plants use K for energy production and water regulation, which influence photosynthesis and many other essential plant processes. Potassium deficiency in soybean is known to increase disease susceptibility, worsen the effects of drought stress, and significantly reduce grain yield. Previous work done in Arkansas has measured as much as **32 to 40 percent yield loss** due to K deficiency. While proper soil testing and preplant fertilization is the best way to avoid in-season deficiencies, these can be corrected to produce a full yield goal when managed properly. Soybean can suffer from K deficiency at any time during the growing season, but K deficiency after the R2 (full flower) developmental stage may cause irreversible seed yield loss.

The concentration of K in soybean tissues changes with plant development. Soybean plants accumulate dry matter and K rapidly after the onset of reproductive growth reaching the maximum dry matter and K accumulation near the R6-R7 growth stage. The rapid uptake and allocation of K among plant structures (leaves, stem, seed, etc.) also changes during reproductive growth and results in the dynamic nature of plant tissue-K concentrations across time. The changes in tissue-K concentrations with plant development should be considered in critical concentrations across time to accurately define sufficiency or deficiency. Potassium is highly mobile in plants and is never incorporated as part of the chemical structure of plants but remains in the liquid portion of the plant.

Most literature defines the critical-K concentration of soybean leaves at the R2 growth stage when leaf-K concentrations have peaked. The use of a single critical concentration across all soybean growth stages may result in misdiagnosis of K deficiency or sufficiency for mid and late reproductive growth stages when leaf-K concentrations are declining. For accurate diagnosis, tissue-K concentration from the uppermost fully expanded trifoliolate should be compared to the dynamic critical concentration curve to account for the natural decline in leaf-K with reproductive development, shown in Figure 1.

Deficiency Symptoms and Hidden Hunger

When K is not available in sufficient amounts, soybean plants may exhibit visual deficiency symptoms or suffer from hidden hunger. Hidden hunger occurs when plants show no visual K deficiency symptoms while plant K concentrations are low enough to negatively affect plant growth and reduce seed yield. Significant yield loss can occur even in the absence of visible deficiency symptoms. Hidden hunger can only be detected using tissue nutrient analysis provided the tissue nutrient concentration is correlated to seed yield and can be interpreted for the tissue sampled and plant development stage.

Management Tip: Do not rely on visual symptoms to identify and treat a potential K deficiency, obtain tissue sample and confirm with a tissue test.

As nutrient availability becomes more limiting, nutrient deficient plants are more likely to express visual symptoms that can be used to diagnose a nutrient deficiency. Potassium is a mobile nutrient in the plant. When K deficiency symptoms do appear, the symptoms don't always appear in the traditional manner in which we would expect mobile nutrient deficiencies to be expressed, especially in indeterminate soybean cultivars.

Typically, the deficiency symptoms of mobile nutrients like K appear first in the oldest leaves low in the canopy. Immobile nutrient deficiency symptoms usually appear first in the newest, upper leaves. Potassium deficiency in soybean is an exception to this rule. Potassium deficiency symptoms during soybean reproductive growth are frequently observed on the middle and upper (young) leaves rather than the lower, older leaves. This difference in the appearance of symptomology is based on the fact that K is preferentially allocated to pods and seeds at the bottom of the plant instead of the newer growth at the top of the plant, resulting in a shortage of K in the upper portion of the plant canopy. Often by the time these symptoms appear in mid to late reproductive growth, yield potential may have already been lost through aborted flowers, pods, or seeds.

Management Tip: K deficiency symptoms appear as marginal chlorosis of leaves and often appear in the upper canopy during reproductive growth.

Dynamic Critical Potassium Concentration Thresholds

Critical concentrations determine the nutrient status, below which is considered deficient and yield limiting, and above which is considered sufficient. University of Arkansas System Division of Agriculture scientists developed dynamic critical-K concentration curves for soybean trifoliolate leaf samples during reproductive growth. Tissue analysis and interpretation using the dynamic critical concentration curves have two major benefits including the ability to detect hidden hunger and to quantify the degree of deficiency. Figure 1 shows the **dynamic critical-K concentration curves** for soybean predicted to produce 95 percent, 85 percent, and 75 percent of maximum yield. The critical concentration curves can help determine when K nutrition is limiting and when in-season potash applications may be beneficial to correct K deficiency in soybean.

We recommend proactive and routine tissue sampling before signs of K stress appear as the best way to monitor nutrient status and avoid yield loss associated with K deficiency and hidden hunger. Samples of the **uppermost fully expanded trifoliolate leaf (trifoliate leaflets without the petiole)** should be taken and sent to the Fayetteville Agricultural Diagnostic Lab or a commercial lab that performs tissue analysis.

Tissue sampling and analysis can be done at any time during the growing season. However, the predictive ability of the tissue concentration thresholds is strongest beginning with the full R2 growth stage (10-20 days after R1) and the sufficient K concentration to produce near maximum yield should be considered across time using the 95 percent maximal yield critical concentrations shown in Figure 1 (red line).

Potassium (K) Deficiency Symptoms in Soybean Plants

From left to right, first three photos display severe K deficiency symptoms at the V4, R2, and R5 growth stages in soybean plants. The fourth photo shows a soybean plant 30 days after the R1 growth stage that has no visual K deficiency symptoms, but has a leaf-K concentration of 1.25 percent K. The dynamic critical concentration curve (Figure 1) estimates these soybeans will yield below 85 percent of the maximum yield potential if no corrective potash application is made. An immediate application of 60 lb K_2O/acre is likely to correct the deficiency and produce near-maximal yield potential.

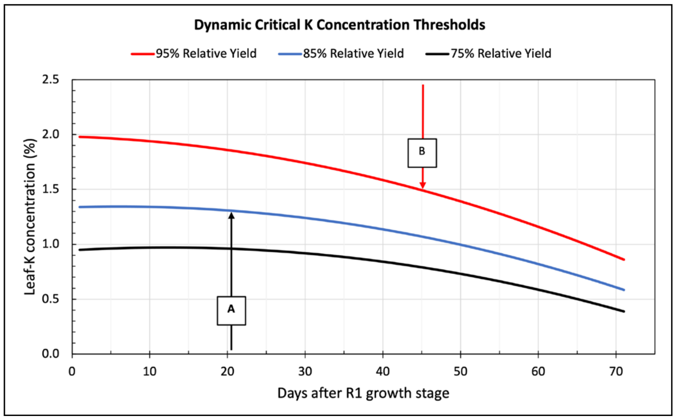

Figure 1. The dynamic critical potassium (K) concentration thresholds for the uppermost fully expanded trifoliolate leaf during soybean reproductive development to produce 95 percent (red), 85 percent (blue), and 75 percent (black) of maximal yield. The black arrow (point A) represents the end of the critical window to correct moderate to severe K deficiency (visible early-season symptoms) and the red arrow (point B) represents the end of the critical window to correct hidden hunger (few to no visible symptoms) and expect a full yield response.

Avoid collecting tissue samples during vegetative growth and the R1 and early R2 stages, especially for indeterminate cultivars (generally MG IV or lower). Corrective potash applications should be made as soon as a K deficiency is diagnosed. Fortunately, there is a relatively large window of time to apply corrective potash to K-deficient soybean to achieve a positive yield response. The window of opportunity to rescue K deficient soybean is based on the severity of the deficiency and the relative days after the first flower, or R1 growth stage. If this is unknown, computer modeling tools such as SoyMap and SoyStage are available to help estimate this and other key growth stages using your geographic location, planting date, cultivar and maturity group.

Management tip: Record the date of first flower, or R1 growth stage, for every soybean field. The interpretation of the tissue-K concentrations consider the K concentration changes during reproductive growth for diagnosis.

Soybean Tissue Sampling for Potassium Management:

1. Always sample the uppermost fully expanded trifoliolate leaf which consists of the three leaflets and their petiolules (trifoliate leaf without the petiole; Figure 2). This will be the leaf below leaves that have not unfurled or are small from recent emergence. In soybean that is still growing vegetatively, there will often be a difference in color between the newly emerged leaves and the fully expanded leaves.

2. Always remove the petiole from the three leaflets and submit only the leaflets. During early and mid reproductive growth, the trifoliolate leaf has a much lower K concentration (1-2 percent) than the petiole (3-5 percent). If the petiole is included, the K concentration results will be different and prevent proper interpretation of the tissue-K concentration using the curves in Figure 1.

3. Include 12-15 trifoliolate leaflets in each sample.

   a. **Proactive Tissue Sampling** is used to identify hidden hunger or make sure K nutrition is not limiting. Sample fields in management zones similar to stratified random sampling techniques.

   b. **Reactive Tissue Sampling** is used to diagnose problem fields. Always include leaf samples from a good and a bad area of the field. Comparing tissue nutrient concentrations in representative samples collected from good and bad areas will facilitate the proper identification of potential nutrient deficiencies.

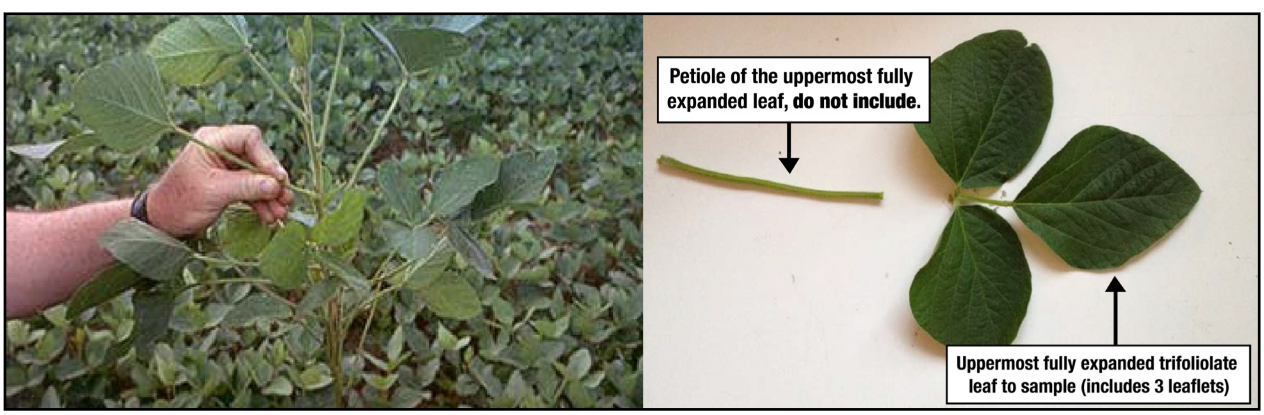

Figure 2. Selecting the correct plant part. When picking the leaf to sample start at the top of the plant and move down until you identify the uppermost fully expanded trifoliate leaf (usually the third leaf from the top). The uppermost expanded leaf will usually have a darker color green and coarser texture compared to the younger leaves. For this trifoliate leaf, **sample only the three leaflets, called the trifoliolate, and exclude the petiole.**

Steps to Correcting an In-Season Potassium Deficiency

If tissue tests confirm a deficiency, follow the 4 R's of nutrient management to correct the deficiency.

The 4 "R"s of In-Season Potassium Management

Right Time

The window of opportunity depends on the severity of the situation:

- Within 20 days after R1 when symtpoms are visible and severe
- Within 45 days after R1 when hidden hunger is suspected or subtle deficiency symtpoms are observed

Right Source

Granular potash sources such as muriate of potash (MOP) should be used.

Note: Foliar applications of K will not likely be sufficient to correct a deficiency. Research shows about 3 lbs K_2O is needed to produce each bushel of soybean.

Right Rate

If a K deficiency is confirmed the current recommendation is to apply 60 to 120 lbs K_2O/acre, depending on the severity of the deficiency as soon as possible up until the R4 growth stage.

Right Place

Broadcast application.

Note: When applying potash the soil can be wet or dry without loss concerns. However, K fertilizer must be incorporated with irrigation or rainfall to move the K from the soil surface to the root zone for plant uptake.

Window of Opportunity to Correct a Deficiency

The severity of K deficiency influences the window of opportunity for correction and restoration of yield potential assuming adequate soil moisture for plant uptake. When visible K deficiency symptoms are observed during vegetative and early reproductive growth potash should be applied within 20 days after the R1 growth stage. When tissue analysis diagnoses hidden hunger potash can be applied within 45 days after the R1 growth stage, shown in Figure 3. The yield response of K-deficient soybean to potash fertilization diminishes as fertilization is delayed beyond these critical periods. Potash fertilizer applied beyond these two critical times may still provide a positive yield response with the understanding that some yield potential has already been lost.

As the plant continues to progress under K deficiency, additional yield potential is lost through flower, pod and seed abortion (e.g., unfilled pods), which cannot be recovered with added K. Soybean normally aborts some flowers and pods but their abortion can be exacerbated by K deficiency. Very little yield potential can be recovered past the R5 (beginning seed) growth stage. By the R5 stage, pod set is complete and application of K fertilizer to correct a K deficiency can only influence seed development and final seed weight. An in-season application of 60 to 120 lbs K_2O/acre may fulfill the in-season needs of soybean in most situations. It is important to note that surface-applied granular K fertilizer requires moisture from rainfall or irrigation to move the K to roots for uptake. If the soil is dry and irrigation cannot be accomplished with 10 days of irrigation, then the likelihood of correcting K deficiency with ground applied K fertilizer diminishes. Arkansas research showed that applied K fertilizer is taken up quickly (within 2 weeks) on silt loam soils following K application and irrigation.

Management tip: When visible K deficiency symptoms are observed during vegetative and early reproductive growth potash should be applied within 20 days after the R1 growth stage. When tissue analysis diagnoses hidden hunger potash can be applied within 45 days after the R1 growth stage, shown in Figure 3.

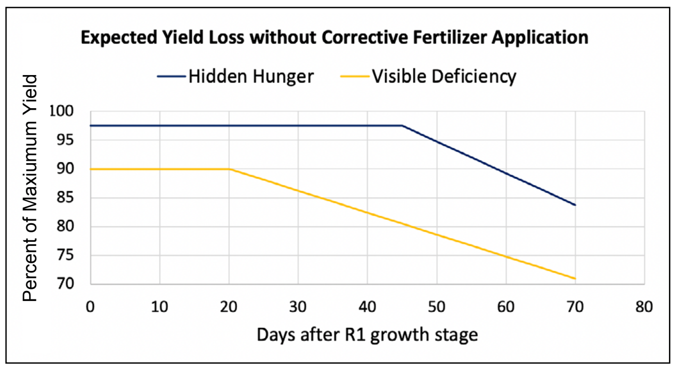

Figure 3. The yield decline in K deficient soybean without a corrective potassium (K) fertilizer application as reproductive growth progresses. The flat bar represents the window of opportunity to expect a full yield response to a fertilizer application, 20 days after R1 for severe deficiencies (yellow) and 45 days after R1 for hidden hunger situations (blue). After this point, irreversible yield loss is expected.

Ongoing Research

Current research intends to correlate the trifoliolate leaf-K concentration to soybean grain yield and identify the correct rate of potash needed to restore full yield potential to K deficient soybean from the R1 to R4 growth stage. The economics of in-season rate recommendations will be considered to determine if it is financially justifiable based on the application method, fertilizer costs, price of soybean, and the anticipated yield benefit at the time of K application. Additional research intends to develop a sampling protocol for large production fields to best capture the field nutrition status.

Key Points

- K is often the most limiting nutrient for soybean in silt loam and sandy loam soils in Arkansas
- K deficiency can be yield-limiting before symptoms appear and is referred to as a hidden hunger
- Trifoliolate leaf samples when combined with the dynamic critical-K concentration during reproductive growth can determine the need for additional potash applications
- Corrective applications of 60 to 120 lbs K_2O/acre must be made before R4 (full pod) for a meaningful yield response
- Routine soil testing and proper preplant fertilization remains the best way to avoid in-season deficiencies

References for Further Reading

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