Nutrient deficiencies in soybeans

This time of year, soybeans may begin showing signs of chlorosis or other leaf discoloration in all or parts of the field. There may be many causes of discoloration. Nutrient deficiencies are one possibility.

The following is a brief description of the symptoms of some of the most common nutrient deficiencies in soybeans.

**Nutrient deficiency symptoms**

**Nitrogen.** Lower leaves are chlorotic or pale green. Within the plant, any available nitrogen (N) from the soil or from nitrogen fixation within nodules on the roots goes to the new growth first. Soybeans prefer to take up N from the soil solution as much as possible, since this requires less energy than the nitrogen fixation process. Both sources of N are important for soybeans since they are a big user of N.

**Iron.** Iron chlorosis, occurs in calcareous soils with high soil pH. The classic symptom is chlorosis (yellowing) between the veins of young leaves. Iron is not mobile within the plant. A side effect of iron deficiency can be N deficiency, since iron is necessary for nodule formation and function. If iron is deficient, N fixation rates may be reduced. Iron deficiency occurs on calcareous soils because at high levels of calcium, iron molecules become tightly bound to the soil particle and unavailable for plant uptake.
Iron chlorosis. The upper leaves become chlorotic. (Photo by Bill Schapaugh, K-State)

**Magnesium.** Lower leaves will be pale green, with yellow mottling between the veins. At later stages, leaves may appear to be speckled bronze. This deficiency may occur on very sandy soils.

**Manganese.** Stunted plants with interveinal chlorosis. Can be a problem in soils with high pH (>7), or on soils that are sandy or with a high organic matter content. Manganese activates enzymes which are important in photosynthesis, as well as nitrogen metabolism and synthesis. Symptoms are hard to distinguish from iron chlorosis.
Manganese deficiency symptoms are similar to symptoms of iron chlorosis in soybeans. (Photo by Dave Mengel, K-State)

**Molybdenum.** Plants turn a light green color due to lack of nitrogen fixation. This deficiency is not common, but can occur on acidic, highly weathered soils.

Molybdenum deficiency in soybeans. Symptoms are similar to nitrogen deficiency. (Photo by Dave Mengel, K-State)
**Phosphorus.** Phosphorus deficiency may cause stunted growth, dark green coloration of the leaves, necrotic spots on the leaves, a purple color to the leaves, and leaf cupping. These symptoms occur first on older leaves. Phosphorus deficiency can also delay blooming and maturity. This deficiency may be noticeable when soils are cool and wet, due to decrease in phosphorus uptake.

**Potassium.** Soybean typically requires large amounts of potassium. Like phosphorus deficiency, potassium deficiency occurs first on older leaves. Symptoms are chlorosis at the leaf margins and between the veins. In severe cases, all but the very youngest leaves may show symptoms.

![Potassium deficiency: chlorosis of the lower leaves. (Photo by Dave Mengel, K-State)](image)

**Sulfur.** Stunted plants, pale green color, similar to nitrogen deficiency except chlorosis may be more apparent on upper leaves. Plant-available sulfur is released from organic matter. Deficiency is most likely during cool wet conditions or on sandy soils with low organic matter content.

**General considerations**

*Mobile Nutrients:* These nutrients can be transfer from older tissues to youngest tissues within the plant. Symptoms are noticeable first on lower, oldest leaves.
  - Nitrogen
  - Phosphorus
  - Potassium
  - Magnesium

*Immobile Nutrients:* These nutrients are not easily transfer within the plant. Therefore, symptoms occur first on upper, youngest leaves.
  - Boron
- Calcium
- Copper
- Iron
- Manganese
- Molybdenum
- Sulfur
- Zinc

Possible causes of nutrient deficiencies:
1. Low soil levels of the nutrient.
2. Poor inoculation (in the case of nitrogen deficiency).
3. Unusually low or high soil pH levels.
4. Roots are unable to access sufficient amounts of the nutrients. This can be due to poor growing conditions, excessively wet or dry soils, cold weather, or soil compaction.
5. Root injury due to mechanical, insect, disease, or herbicide injury.
6. Genetics of the plant.

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2. Plant analysis for testing nutrient levels in soybeans

If soybeans are showing possible symptoms of nutrient deficiency, one way to test this is through plant analysis. As with corn, wheat, and other crops, there are two primary ways plant analysis can be used: as a routine monitoring tool to ensure nutrient levels are adequate in the plant, and as a diagnostic tool to help explain some of the variability in soybean growth and appearance we see in fields.

Also as with other crops, sampling leaf tissue under stress conditions for monitoring purposes can give misleading results, and is not recommended.

For monitoring purposes, collect 20-30 sets of the upper, fully developed trifoliate leaves, less the petiole, at random from the field anytime between flowering and initial pod set (growth stages R1-3). The top fully developed leaves are generally the dark green leaves visible at the top of the canopy, which are attached at the second or third node down from the top of the stem. Sampling later, once seed development begins, will give lower nutrient contents since the soybean plant begins to translocate nutrients from the leaves to the developing seed very quickly.

The sampled leaves should be allowed to wilt overnight to remove excess moisture, placed in a paper bag or mailing envelope, and shipped to a lab for analysis. Producers should not place the leaves in a plastic bag or other tightly sealed container, as they will begin to rot and decompose during transport, and the sample won't be usable.

The data returned from the lab will be reported as the concentration of nutrient elements, or potentially toxic elements in the plants. Units reported will normally be in percent for the
primary and secondary nutrients (N, P, K, Ca, Mg, and S) and ppm, or parts per million, for the micronutrients (Zn, Cu, Fe, Mn, B, Mo, and Al).

Most labs/agronomists compare plant nutrient concentrations to published sufficiency ranges. A sufficiency range is simply the range of concentrations normally found in healthy, productive plants during surveys.

Plant analysis is an excellent diagnostic tool to help understand some of the variation seen in the field. When using plant analysis to diagnose field problems, producers should try to take comparison samples from both good/normal areas of the field, and problem spots. Collect soil samples from the same good and bad areas, and don’t wait for flowering to sample soybeans. Early in the season collect whole plants from 15 to 20 different places in the sampling areas. Later in the season, collect 20-30 sets of top, fully developed leaves. Handle the samples the same as those for monitoring, allowing them to wilt to remove excess moisture and avoiding mailing in plastic bags.

The following table gives the range of nutrient content considered to be "normal" or "sufficient" for top fully developed soybean leaves at flowering. Keep in mind that these are the ranges normally found in healthy, productive soybeans.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Units</th>
<th>Growth Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>%</td>
<td>Top, fully developed leaves at flowering</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Sulfur</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>ppm</td>
<td></td>
</tr>
<tr>
<td>Iron</td>
<td>ppm</td>
<td></td>
</tr>
<tr>
<td>Manganese</td>
<td>ppm</td>
<td></td>
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<tr>
<td>Zinc</td>
<td>ppm</td>
<td></td>
</tr>
<tr>
<td>Boron</td>
<td>ppm</td>
<td></td>
</tr>
<tr>
<td>Molybdenum</td>
<td>ppm</td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td>ppm</td>
<td></td>
</tr>
</tbody>
</table>

In summary, plant analysis is a good tool producers can use to monitor the sufficiency of soil fertility levels and inoculant effectiveness, and a very effective diagnostic tool. Producers should consider adding this to their toolbox.

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3. The role of nitrogen fertilizer in soil pH levels

Acid soils are becoming an important issue in Kansas, even in the western reaches of the state where most people think of high pH as a bigger issue. The primary reason for our soils becoming more acid over time is the use of nitrogen (N) fertilizers containing ammonium-N, also including mono and diammonium phosphates, 11-52-0 and 18-46-0. As the ammonium-N in fertilizers nitrifies, acidity is released.

In the first step of nitrification, ammonia-oxidizing bacteria oxidize ammonia to nitrite according to the following equation:

\[ \text{NH}_3 + \text{O}_2 \rightarrow \text{NO}_2^- + 3\text{H}^+ + 2e^- \]

*Nitrosomonas* is the most frequently identified genus associated with this step.

In the second step of the process, nitrite-oxidizing bacteria oxidize nitrite to nitrate according to the following equation:

\[ \text{NO}_2^- + \text{H}_2\text{O} \rightarrow \text{NO}_3^- + 2\text{H}^+ + 2e^- \]

*Nitrobacter* is the most frequently identified genus associated with this second step.

Hydrogen (H⁺) is released in the process of nitrification, and free hydrogen ions increase acidity. The higher the percentage of ammonium (or urea) in the fertilizer, the greater the acidification potential.

Another reason that NH₄⁺ increases acidity has to do with plant uptake. As plant roots absorb NH₄⁺ they secrete H⁺ ions into the soil solution to maintain a chemical charge balance.

One common way to express the relative acidifying effects of N fertilizers is the pounds of Effective Calcium Carbonate, ECC, required to neutralize the acidity from 1 pound of actual N. That value varies from 3.6 to 7.2 for the fertilizers we commonly use. The table below shows the actual pounds of ECC needed to neutralize the acidity produced by the N from common fertilizer materials.

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>N Concentration</th>
<th>Pounds of ECC needed as lime to neutralize the acidity from 1 lb. of actual N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium nitrate</td>
<td>34% N</td>
<td>3.6</td>
</tr>
<tr>
<td>Anhydrous ammonia</td>
<td>82% N</td>
<td>3.6</td>
</tr>
<tr>
<td>Urea</td>
<td>46% N</td>
<td>3.6</td>
</tr>
<tr>
<td>UAN Solutions</td>
<td>28-32% N</td>
<td>3.6</td>
</tr>
<tr>
<td>Ammonium Sulfate</td>
<td>21% N</td>
<td>7.2</td>
</tr>
<tr>
<td>Monoammonium Phosphate</td>
<td>11% N</td>
<td>7.2</td>
</tr>
<tr>
<td>Diammonium Phosphate</td>
<td>18% N</td>
<td>5.4</td>
</tr>
</tbody>
</table>
Strictly speaking, soil acidity is a measure of the concentration of H\(^+\) ions in the soil. But the greatest injury to crop growth from low pH soils comes not from the H\(^+\) ions, but from the release of aluminum into the soil solution at low pH levels.

As the pH decreases below 5.5, the availability of aluminum and manganese increase and may reach a point of toxicity to the plant. Excess Al in the soil solution interferes with root growth and function, as well as restricting plant uptake of certain nutrients, namely, Ca and Mg. Liming acid soils reduces the activity of Al and Mn.

**Categories of nitrogen fertilizers**

* Acidification potential: Neutral
  Potassium nitrate (13% N)
  Calcium nitrate (15.5% N)

  Because all of the nitrogen in these fertilizers is in the nitrate form, these fertilizers are not acidifying so there is no need to apply lime to neutralize acidity.

* Acidification potential: Moderate
  Anhydrous ammonia (82% N)
  Urea (46% N)
  Ammonium nitrate (34% N)
  Urea ammonium nitrate solutions (32% and 28% N)

  These products are acidifying because they contain ammonium, or produce ammonium when applied to the soil. But they are less acidifying than DAP, MAP, or ammonium sulfate. Unlike DAP and MAP, anhydrous ammonia and urea do not leave any phosphoric acid residue remaining after they dissolve in soil solution. Ammonium sulfate leaves sulfuric acid residue as it dissolves. With ammonium nitrate and UAN solutions, only part of the total N is in the ammonium form, so these products result in less nitrification than fertilizers in which all the N is in the ammonia or ammonium form.

* Acidification potential: Moderately high
  Diammonium phosphate (DAP) (18% N, 46% P\(_2\)O\(_5\))

  Diammonium phosphate has a moderate acidifying effect when applied.

* Acidification potential: High
  Ammonium sulfate (21% N, 24% S)
  Mono-ammonium phosphate (MAP) (11% N, 52% P\(_2\)O\(_5\))

  These fertilizers are very acidifying. Ammonium sulfate not only results in acidification through the process of nitrification, but one of the dissolution byproducts in sulfuric acid.

This may raise some other questions, though, such as:
A. Why is anhydrous ammonia less acidifying than MAP and DAP if they are all applied at the same N rate?

When anhydrous ammonia (NH₃) is applied to the soil, it reacts with water to form ammonium-N and the hydroxide ion, which is basic.

\* NH₃ + H₂O → NH₄⁺ + OH⁻

This reaction initially raises the pH of the soil. It is only after the NH₄⁺ undergoes nitrification that it begins to acidify the soil (through the release of H⁺). These two reactions (the basic effect of ammonia reacting with water vs. the acidifying effect of nitrification) don’t entirely balance each other out. The end result is an acidifying effect.

B. Why is urea less acidifying than MAP and DAP, if they are all applied at the same N rate?

In soil solution, urea first reacts with water and free H⁺ ions to form ammonium-N and bicarbonate.

\* (1) CO(NH₂)₂ + 2H₂O + H⁺ → 2NH₄⁺ + HCO₃⁻

This reaction is immediately followed by another reaction that takes H⁺ ions out of soil solution:

\* (2) HCO₃⁻ + H⁺ → CO₂ + H₂O

Both these reactions “soak up” free H⁺ ions in soil solution, which reduces acidity. This reduction in acidity is more than balanced out by the acidifying reaction of the nitrification of ammonium-N. As with anhydrous ammonia, the overall net effect is acidifying.

C. Why is MAP slightly more acidifying than DAP when applied at the same N rate?

Ammonium phosphates, such as MAP and DAP fertilizers, are extremely soluble in soil solution, and dissolve easily. Knowing what happens to each product after it dissolves helps explain this effect.

**MAP.** The pH of MAP in saturated solution is 3.5. MAP contains one ammonium-N and one H₂PO₄⁻ ion. The reaction in soil solution is:

\* NH₄H₂PO₄ → NH₄⁺ + H₂PO₄⁻

This reaction does not use up any H⁺ ions in soil solution, so the full acidifying effect of nitrification impacts the soil pH level.

**DAP.** The pH of DAP in saturated solution is 8.0. DAP contains two ammonium-N ions and one HPO₄⁻² ion. In soil solution, DAP initially undergoes the following reaction:
* (1) \((\text{NH}_4)_2\text{HPO}_4 \rightarrow 2\text{NH}_4^+ + \text{HPO}_4^{2-}\)

If the soil solution pH is greater than 7.0, the orthophosphate ion will be stable and not react any further. If the soil solution pH is less than 7.0, the orthophosphate ion will react with the free hydrogen ions and reduce the acidity somewhat.

* (2) \(\text{HPO}_4^{2-} + \text{H}^+ \rightarrow \text{H}_2\text{PO}_4^-\)

To the extent that it occurs, the second reaction balances some of the acidifying effect of the nitrification of the ammonium-N ions. That's why DAP has a slightly less dramatic acidifying effect on the soil than MAP.

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4. Agronomy Field Day highlights agriculture’s solutions to global change

Food vs. fuel. Climate change solutions vs. food shortages and high prices. Is there a way out of this dilemma?

Researchers at K-State’s Department of Agronomy are working on getting answers to these questions. Come to K-State in late August and see how new cropping systems and methods of farming are reshaping the global landscape.

You can see many of the latest research projects first-hand at K-State’s Agronomy Field Day in Manhattan on August 22. There is no charge to attend the Field Day, and a complimentary lunch is provided. The event will be held at the Agronomy North Farm, which is located just north of Bill Snyder Family Stadium on Kimball Ave.

The Field Day begins with registration at 8 a.m. The field tours begin at 8:30 a.m. and last through 2:30 p.m. Participants come and leave whenever they wish during those times. The demonstrations will be repeated often during the day, allowing people to choose whatever they are most interested in.

Transportation will be available to take people around the farm to the various demonstration areas. Be prepared to walk between presentations in each area. Personal transportation will be available for those with disabilities.

Some of the presentations that K-State agronomists will be making at the Field Day include:

* Bioenergy cropping systems
* Energy crop processing
* Perennial native grasses for bioenergy
* Soil carbon sequestration
* Rotational oilseed crops for Kansas
* New herbicide-resistant types of sorghum
* Cover crop species and mixtures
* Improving water quality

In addition to the field demonstrations, participants can bring their questions on crop production to the “Ask the Experts” booth with Jim Shroyer, Extension Agronomy State Leader and other K-State Agronomy extension specialists and faculty. “You might call this session ‘Stump the Chumps,’ but we’ll give every question our best effort,” said Shroyer. These experts will be available in the main equipment shed at the North Farm all day to answer your questions, or get stumped trying.

The equipment shed will also have commercial exhibits, and information for new and prospective students on the benefits of majoring or minoring in Agronomy at K-State.

For more information, contact your local Extension office, or contact Kraig Roozeboom at 785-532-5776, kraig@ksu.edu. The complete Field Day schedule is at: http://www.agronomy.ksu.edu/DesktopDefault.aspx?tabid=891

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5. New Extension Nutrient Management Specialist

Dorivar Ruiz Diaz joins the Agronomy faculty this month as the Extension Nutrient Management Specialist, taking the position formerly held by Dale Leikam. Dorivar was raised on a farm in Paraguay. He recently received his PhD in Soil Fertility from Iowa State University.

His research interests include the efficient use of fertilizer, and land application of waste material (manure and biosolids) with emphasis on crop-available nitrogen. His research has also involved the assessment of environmental risk associated with nutrient management and tillage.

Dorivar was named the outstanding graduate student at the 2005 North Central Region Extension-Industry Soil Fertility Conference.

For your crop nutrient questions, contact Dorivar at 785-532-6183, or ruizdiaz@ksu.edu.

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These e-Updates are a regular weekly item from K-State Extension Agronomy and Steve Watson, Agronomy e-Update Editor. All of the Research and Extension faculty in Agronomy will be involved as sources from time to time. If you have any questions or suggestions for topics you’d like to have us address in this weekly update, contact Steve Watson, 785-532-7105 swatson@ksu.edu, or Jim Shroyer, Research and Extension Crop Production Specialist and State Extension Agronomy Leader 785-532-0397 jshroyer@ksu.edu