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NUTRIENT MANAGEMENT FOR SOYBEAN PRODUCTION

Soybean requires 16 elements to complete the metabolic processes necessary for growth and reproduction. Regardless of the system of production, lack of an adequate supply of any of these elements will decrease plant growth and potential yield, as well as result in soil nutrient depletion that decreases productivity. To minimize a decrease in soybean yield caused by a lack of any of these nutrients, or to avoid applying nutrients that have a low probability of economically increasing yield, producers should develop and use a nutrient management plan.

Fertile soil supports vigorous plant growth that covers the soil surface early in the growing season. The increased soil cover will decrease soil moisture evaporation, decrease wind and water erosion, and maximize the amount of plant residue remaining after harvest to minimize erosion during the offseason. Vigorously growing plants are more resistant to biotic and abiotic stresses, including diseases and insects, weeds, and adverse weather conditions.

The contents of this White Paper present a short description of and links to resources that can be accessed to provide guidance for making decisions about soil fertility management for optimum economical soybean production in the Midsouth.

NUTRIENT MANAGEMENT PLAN

An effective nutrient management plan identifies the amount, source, time of application, and placement of nutrients needed to sustain economic viability of crops, while simultaneously protecting the environment. Development of a nutrient management program begins with collecting soil samples from a production unit or field, followed by a soil test.

Sampling protocol is important to ensure accuracy of results and proper application of test recommendations to a field unit. Because most fields are variable in topography, slope, and soil series, nutrient levels will vary considerably within a field. Samples must be collected in a systematic manner across a field, or within variable units within a field.

Click here to access an MSSOY White Paper titled "Sampling Soil for Fertility and Nematodes" that covers all aspects of soil sampling to assess fertility status. Click here for an MSU Extension Service publication entitled "Useful Nutrient Management Planning Data" that provides data and conversion factors that will be helpful in the setup and conduct of a nutrient management plan. Click here for a USDA-NRCS publication titled "Conservation Practice Standard for Nutrient Management" that addresses the conservation of soil nutrients for plant production and minimizing nonpoint source pollution that can be attributed to mismanagement in the application and use of soil nutrients.

NITROGEN [N]

Click here to access an MSSOY White Paper titled "Nitrogen Fertilizer for Soybeans" that is a comprehensive treatise on nitrogen fertilization pertaining to soybean. The contents of the White Paper cover N fertilizer applied to soybean in a high-yield environment, N fertilizer applied to replace fixed N, starter N fertilizer, and N fertilizer applied during reproductive development. A summary that is up-to-date with current literature is also included.

PHOSPHORUS [P]

Soybean removes approximately 0.90 pound of phosphate [P_2O_5] or about 0.40 pound of actual P for each bushel of seed harvested. On most fields, at least this removal amount should be applied to maintain adequate P fertility. Because P application is not needed every year, it is most economical to apply an ammoniated material ahead of the corn crop in a biennial soybean–corn rotation. This practice results in the most economical application of P by cutting applications and associated costs in half. Growers can select from straight P materials such as triple superphosphate or from liquid or dry formulations of ammoniated phosphates.

Click here to access an MSU Extension publication titled "Phosphorus in Mississippi Soils" that gives soil test indices for P for all crops, as well as a list of common P-containing fertilizers and their analysis.

Presently, the primary source of P fertilizers is rock phosphate [RP]. However, this P source is finite–in fact, some sources estimate that it will be gone in 50 years. Also, the U.S. has only a small reserve of RP. Most [~80%] of this P source is in northern Africa, which means that its availability to U.S. farmers is subject to the vagaries of world politics.

Recently, there has been increased interest in reclaiming P from wastewater sources to provide a sustainable source of P-fertilizer as well as reduce P enrichment in surface waters. Struvite [$MgNH_4PO_4 \cdot 6H20$–magnesium ammonium phosphate] is the common name for a P-containing material that can be created from P-containing wastewater, and it is surmised that this P source could have value as an agricultural fertilizer. That is the premise behind research with struvite that was conducted by scientists at the Univ. of Arkansas to determine if this material can replace commonly-used fertilizers as a P source for crops. Results from that research are reported in the following articles.

- "Corn and soybean response to wastewater-recovered and other common phosphorus fertilizers" by Ylagan et al. Results from this research that was conducted in a greenhouse to determine how struvite compared to other forms of P fertilizers point to 1) using struvite as a recycled P-fertilizer, 2) improving wastewater quality by removing the struvite-P, and 3) using struvite-P to provide a sustainable P-fertilizer source.
- "Soybean growth and production as affected by struvite as a phosphorus source in eastern Arkansas" by Omidire et al. Results from this research that was conducted in a field comprised of a P-deficient silt loam soil to determine how struvite affected soybean growth and development when compared to that resulting from fertilization with other P sources support the findings of the greenhouse study in the previously-cited article–i.e., struvite has the potential to be a viable alternative P-fertilizer for soybean production in the Midsouth.
- "Wastewater-recycled struvite as a phosphorus source in a wheat-soybean double-crop production system in eastern Arkansas" by Omidire and Brye. Results from this research that was conducted to determine the effect of struvite on wheat and soybeans grown in a doublecrop system substantiate the use of struvite as a potential alternative P-fertilizer for Midsouth crop production.

Articles titled "Agronomic response to struvite as an alternative fertilizer-phosphorus source" by Leslie Johnson and "Struvite seen as good alternative for phosphate in crop fertilizer in Arkansas field study" by John Lovett provide summaries of the results reported in the above articles, comments by the reports' authors about the potential utility of struvite as a P-fertilizer source for Midsouth crops, and a list of publications that report results from myriad Arkansas studies with struvite.

The positive results from research with struvite-P reported in the above-cited articles lead to the following questions. 1) Can struvite-P be economically created in an amount/at a scale that will provide a viable and stable source of P-fertilizer for Midsouth crops? 2) Will the creation and use of struvite-P be cost competitive in both the short- and long-term with that of common P-fertilizer sources now being used? 3) Will wastewater treatment facility managers and operators be willing to invest in and install the necessary apparatuses to create enough struvite to meet the P demands of agricultural producers? The answers to these questions will determine if/when struvite-P will or will not be a viable alternative to current P-fertilizer sources. However, since current P-fertilizer sources are finite, there likely will be a time in the near future when it is decided that struvite-P will necessarily become a significant P-fertilizer source for crop production.

POTASSIUM [K]

Soybean removes approximately 1.20 pounds of potash [K_2O] or 1 to 1.25 pounds of actual K per bushel of seed produced. Continued removal of K without replacement will lower the soil supply to a level that will not support optimum yield. Soil test levels may change considerably from one sampling time to the next. Thus, soil K should be monitored over time, and variable test values should be used with caution.

There are several materials available to supply K to the soil. Potassium chloride (muriate of potash) is the most economical form, and can be applied in the fall or spring preceding the soybean crop, except on sandy, low-CEC soils where it is subject to overwinter loss. If magnesium is also needed for the soybean crop, potassium-magnesium sulfate is a good K source.

Click here for an MSU Extension publication entitled "Potassium in Mississippi Soils" that gives soil test indices for K for all crops. Click here for updated soil test-based K fertility recommendations for Mississippi soybeans.

CALCIUM, MAGNESIUM, & SULFUR

Calcium [Ca], Magnesium [Mg], and Sulfur [S] are essential plant nutrients. They are referred to as secondary nutrients because they are required in smaller quantities than N, P, and K, but in larger quantities than the micronutrients. Details about the importance and function of these secondary plant nutrients to and in crop plants can be found in MSU-ES Information Sheet 1039.

The amount of these nutrient elements is usually adequate in Mississippi soils that have favorable pH and organic matter levels. Conversely, inadequate amounts of these elements likely will occur in acid soils, or coarse-textured soils that generally have low organic matter content.

The most pertinent information about these nutrients follows.

- Calcium's primary function is to provide structural support for plant cell walls.
- Magnesium is a component of chlorophyll, and thus it is involved in photosynthesis.
- Both Ca and Mg are supplied to soil in lime products.

Sulfur nutrition for plants has become a hot topic because of the 1) reduction in atmospheric S deposition resulting from reduced S emissions from factories and power plants, 2) increased crop removal of S because of higher yields, and 3) long-term decreases in soil organic matter. Click here for a summary of S fertility for soybeans. Click here for a summary of results from Midsouth research with sulfur fertilization of soybeans.

Pertinent points to consider for S nutrition in soybeans follow.

- Sulfur is a component of the amino acids methionine and cysteine, and these two essential amino acids are often insufficient in protein derived from soybeans.
- Sulfur is essential for protein synthesis as well as for nodulation and nitrogen fixation in soybeans.
- Soybean grain removes about 1.7 lb of S per 10 bushels of grain, or about 10 lb/acre for a 60 bu/acre yield.
- The sulfate ion (SO_4) is the form primarily absorbed by plants. Sulfate-S is mobile in most soils; thus, it is subject to leaching, especially from sandy soils.
- Coarse-textured and low-organic matter soils are those most likely to be sulfur-deficient.
- Organic matter is the main source of soil S in Mississippi soils. Thus, if fertilizer S in not applied to the soil, the main source of S will be the mineralization of organic matter by soil microbes.
- Sulfur levels are generally considered low at 0-5 ppm, moderate at 6-8 ppm, and high at >8 ppm.
- Traditional soil testing is not a good predictor of S deficiency because of the transient nature of S availability, its mobility away from the crop root zone prior to crop need, and the lack of calibration of soil tests to S deficiency in plants. Also, commonly-used soil tests likely will identify fields that have sufficient sulfur, but are not very good at identifying those fields that will benefit from added sulfur.
- If S fertilizer application is needed, apply the necessary amount before corn in a corn-soybean rotation for the most benefit.
- Since the plant-available form of S is sulfate (SO_4), apply a SO_4-containing fertilizer for an immediate crop response–i.e. these products should be applied close to crop demand to reduce loss by leaching. If a fertilizer containing elemental S is used, it must be applied well in advance of the crop's need.
- Ammonium sulfate (21-0-0-24S), ammonium thiosulfate (12-0-0-26S), and calcium sulfate or

gypsum (0-0-0-17S) are the most commonly used sulfate fertilizers. Potassium sulfate (0-0-50-18S) is a fertilizer that contains both K and S.

- Tissue testing of the appropriate plant tissue at the appropriate time is recommended to definitively identify an S deficiency.
- There is anecdotal evidence that sulfur fertilization in the late growing season will result in higher seed protein content. This needs further investigation.
- Preliminary data indicate that a 1 to 1.5 bu/acre yield increase resulting from S fertilization will pay for the fertilizer amount that will normally be applied to S-deficient soils.
- Presently, the best recommendations are to 1) consider S fertilizer application to coarse-textured soils with low OM, 2) apply a SO_4-containing fertilizer close to the time of peak plant need, and 3) use tissue testing during critical growth stages to determine S sufficiency in appropriate soybean plant tissues. Click here for S sufficiency level in soybeans.

SOIL pH AND LIMING

Midsouth soils used for soybean production often require lime to correct or control soil acidity. A soil test is the only tool that can determine soil pH, and the pH of a sampled soil should be a component of the results provided in the soil test report.

Details about the quality of the various materials used for liming to correct soil pH are given in MCES Information Sheet 873 titled “Soybeans: Liming and Fertilization”. Additional information can be found in MCES Information Sheet 1587 titled “Agricultural Limestone’s Neutralizing Value” authored by Drs. Oldham and Jones. A few basic points gleaned from these publications follow.

- The value of lime depends on the size of individual particles and the purity of the lime.
- Calcium carbonate equivalent [CCE] is the measurement of lime purity.
- Sieve analysis and CCE of lime material are used to calculate the Relative Neutral Value [RNV], or effective CCE.
- Mississippi Lime Regulations require the label, sales invoice, delivery ticket, or bulk ticket to show the RNV. Lime sold in Mississippi must have a minimum RNV of 63%. Example calculations of this value can be found in the above linked document.
- Read the label to ensure maximization of lime effectiveness and economic value.

Research [Soil pH Influences Soybean Disease Potential] shows that soil pH greater than about 7.0 was associated with high initial soybean cyst nematode [SCN] egg density. Soil pH is also related to iron deficiency chlorosis [IDC] severity [see below section].

IRON AND IRON DEFICIENCY CHLOROSIS [IDC]

The element iron [Fe] is required to form chlorophyll, the green pigment in plants. When iron uptake from the soil is limiting to plants, plants become iron-deficient. The most common symptom is interveinal chlorosis in newly developed leaves, where the leaf tissue turns yellow while the veins remain green. This deficiency, termed iron deficiency chlorosis or IDC, can cause moderate to severe yield reductions in soybeans.

Click here to access a comprehensive treatment of IDC–how it affects soybean and how it can be remedied. Click here to access links to company varietal trait data that include IDC ratings for many varieties.

MICRONUTRIENTS

Micronutrients are essential for crop production, but are required and used by plants in lesser amounts than those of the macro and secondary nutrients. Critical plant processes are limited if required micronutrients are limited or lacking. If a necessary micronutrient is limited or unavailable, plant abnormalities, reduced growth, and lower yield will result. Micronutrient deficiencies can be detected by visual symptoms and by testing soil and plant tissue.

Micronutrients used by plants include boron [B], chlorine [Cl], copper [Cu], iron [Fe], manganese [Mn], molybdenum [Mo], and zinc [Zn]. The amount of these micronutrients is usually sufficient in most soils to meet crop needs.

Most micronutrients are weakly mobile or immobile in plants. Thus, deficiency symptoms will usually appear most severely in the newest plant tissues; e.g. the newest trifoliate in soybean.

Soil and plant analysis are both useful for determining levels of micronutrients in soil and plant tissue, respectively. However, soil tests for them are not as precise as those for pH, P, and K.

Plant tissue analysis can reliably determine the level of most micronutrients in the sampled plant part, and the results can aid in diagnosing a visual problem. Regrettably, once a micronutrient deficiency is detected, the plant has already suffered irreversible yield loss. Thus, results from these analyses can only be used to prevent such deficiencies in a future crop.

Deficiency of micronutrients in soybean production systems is an oft-discussed topic. However, this topic does not receive the attention accorded to deficiencies of the macronutrients N, P, K, and S, probably because there is not a wealth of evidence showing that micronutrient deficiencies are soybean yield limiters in the manner of the macronutrients. In fact, current dogma is that yield increases would not be expected from applying micronutrient fertilizers to the vast majority of soils or plants growing on them. Of course, if a rarely-seen deficiency of a particular micronutrient is documented, then that deficiency must be addressed by the addition of that micronutrient in a form used by plants.

In an article titled "Soybean Response to Broadcast Application of Boron, Chlorine, Manganese, and Zinc", authors Sutradhar, Kaiser, and Behnken present results from a four-year study conducted on 35 sites in Minnesota to evaluate soybean response to broadcast applications of B, Cl, Mn, and Zn. The objectives of the study were to determine how applications of these micronutrients affected soybean tissue nutrient concentration and grain yield, and the relationships between soil and plant tissue tests.

In the studies, soil samples were collected from the 0 to 6-in. depth and analyzed appropriately for P, K, B, Cl, Mn, and Zn. The newest fully developed soybean trifoliate leaf with petiole was sampled for tissue nutrient analysis when soybean was at the R1 growth stage. Concentrations of B, Cl, Mn, and Zn in the tissue samples were determined with appropriate analysis procedures.

Findings from this research follow.

- Plant tissue nutrient concentrations indicated that micronutrient levels in soils at the study sites were sufficient for maintaining soybean yield.
- Concentrations of micronutrients in sampled leaf tissue were all well above defined sufficiency levels, thus indicating that the soil reservoir of each micronutrient was sufficient without additional fertilization.
- Tissue micronutrient concentrations of B, Mn, and Zn were seldom increased by micronutrient fertilization compared to a non-fertilized control.
- There was no significant effect of micronutrient fertilization on soybean seed yield compared to non-fertilized controls.
- The results indicate that a yield response to direct application of micronutrients is unlikely for soybeans.
- Increasing soybean seed yield resulted in greater removal of the tested micronutrients from soil. Thus, a continuing period of above-average yields will likely result in the removal of micronutrients at a pace that exceeds the heretofore perceived normal rate.
- Trifoliate B, Mn, and Zn concentrations were not appreciably related to their respective soil test results or to seed yield. Thus, tissue micronutrient concentration should not be used to determine when micronutrient fertilizers should be applied.
- Soil-test B, Cl, and Zn levels were not related to soybean seed yield when each micronutrient was not applied. Thus, soil tests for these minerals will not be a good predictor of deficiency.
- The authors concluded that soybean seed yield may respond to Mn application if soil-test Mn is less than 20 ppm.

Click here for an article titled "Micronutrients for Soybean Production in the North Central Region" by Mallarino, Kaiser, Ruiz-Diaz, Laboski, Camberato, and Vyn [North Central Soybean Research Program] to access a summary of knowledge about specific micronutrients in soybeans. Key points about each micronutrient from that article follow.

Boron [B). Soil OM is the primary source and it becomes available to plants mainly through microbial activity. It can be leached from coarse-textured soils or soils that are irrigated. Drought can decrease B availability because of its negative effect on OM decomposition. Yield increases from B fertilization are documented only in isolated cases; however, excess B can be detrimental to soybean. B fertilization is recommended only in verified cases of B deficiency.

Copper [Cu]. Soybean is considered one of the least susceptible crops to Cu deficiency. Thus, documented Cu deficiencies in soybean are rare to non-existent.

Chlorine [Cl]. Soybean is considered one of the least susceptible crops to Cl deficiency. Thus, documented Cl deficiencies in soybean are rare to non-existent, as are positive responses to Cl fertilization. Certain potash fertilizers supply large amounts of Cl to soil.

Iron [Fe]. Soybeans are one of the most sensitive crops to Fe deficiency. Fe deficiency symptoms are referred to as Iron Deficiency Chlorosis [IDC], which is a condition that is related to Fe in the soil being unavailable to plants rather than Fe deficiency in the soil. Past knowledge of IDC symptoms in a field and measurements of affecting soil properties are typically used to identify fields or areas of fields that are prone to IDC in soybeans.

Manganese [Mn]. Mn deficiency symptoms in soybeans may look similar to Fe or Zn deficiencies because the deficiency is usually related to a soil property or properties that render Mn in the soil unavailable to the plant. Broadcast applications of Mn to the soil rapidly become unavailable. Thus, foliar-applied Mn will likely be the most effective method to alleviate a deficiency. Since Mn is immobile in the plant, multiple foliar applications may be necessary. Fertilization with Mn will not be economical if visual deficiency symptoms are not obvious. Click here for a White Paper that provides indepth information about Mn fertility for soybeans.

Molybdenum [Mo]. Mo deficiency can show as an N deficiency in soybeans since it is required for N fixation. Mo deficiencies can usually be corrected by liming soils to the proper pH level since its availability decreases in soils with a low pH. The most common Mo fertilization practice is to treat seed with an Mo-containing product.

Zinc [Zn]. Soybeans have low to moderate susceptibility to Zn deficiency; thus Zn deficiency in the crop is not common. Since Zn is moved to the plant roots primarily via diffusion in soil water, Zn deficiency in soybeans is more likely to occur on sandy soils that dry quickly [i.e. have limited available water most of the time]. Because Zn has low mobility in the plant, deficiency symptoms that do occur will show in the upper plant in the newest leaves.

Take Home Message about Micronutrients

Results referenced in several of the above-linked articles may not be totally applicable to Midsouth soils and the Midsouth soybean production environment. However, they do paint a consistent picture of soybean response, or rather lack of response, to micronutrient fertilization when soil levels of these nutrients are determined to be adequate according to accepted soil tests.

Most soils have inherently adequate levels of most micronutrients needed for optimum soybean production. However, with increasing yields from irrigated soybean in the Midsouth, producers likely should become more aware of micronutrient levels in their soils, and be vigilant for micronutrient deficiency symptoms.

- Click here to access a White Paper on this website that provides a detailed discussion about tissue testing and how it can be used in conjunction with soil test results to determine proper fertilization for high soybean yields.
- Click here for a Pioneer article titled "Micronutrients for Crop Production" that provides details about availability of micronutrients by soil pH level, their estimated uptake by high-yielding soybeans, and a narrative description of general micronutrient deficiency symptoms.

Excess Micronutrients

There are circumstances that can result in an excess of a particular micronutrient. This can lead to a toxic condition that may reduce soybean performance. A case in point is chlorine.

Research studies have been conducted to explore the potential soybean yield reduction that might result from excessive Cl in the soil. This condition can occur where large amounts of potassium fertilizer in the form of potassium chloride [KCl] have been applied.to address soil K deficiency.

- Potassium chloride is the cheapest source of fertilizer K. However, high soil Cl concentrations can result when high rates of KCl are applied.
- Research has shown that the amount of KCl applied ahead of a soybean crop should be limited to no more than about 100 lb/acre. However, this can vary from field to field.
- If soil test K is very low, higher rates should be considered since the yield reduction due to insufficient K is greater than yield reductions that might result from higher rates of KCl.
- When chloride toxicity is a concern, consider applying potassium sulfate as the K fertilizer.
- The effect of too much Cl will be worse on poorly drained soils in years with low rainfall since Cl will not move out of the root zone.
- Two important points should be considered when managing this issue. 1) Apply K fertilizer only where it is needed. 2) Apply K fertilizer annually when needed so the rate that is applied will be relatively low each year.

TISSUE SAMPLING/TESTING

Tissue testing is a tool that can be used to assist in identifying nutrient deficiencies in soybean plants 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 to determine if sufficient nutrients are present in the plant to achieve optimum performance and/or yield.

Results from tissue testing 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.

Click here to access a White Paper on this website that provides information about tissue testing, plus guidelines for using this tool to assess the nutrient status of soybean.

GENERAL INFORMATION

Click here for a Univ. of Missouri article that gives details for diagnosing nutrient deficiencies in plants. Click here for an MSU Extension publication titled "Soil Fertility and Fertilizers" that covers most subjects pertaining to soil fertility and fertilizers. An Iowa State Univ. publication titled "Soybean Nutrient Needs" is a good source for information specifically about soybean.

Slaton, Roberts, and Ross of the Univ. of Ark. published "Fertilization and Liming Practices" (Chapter 5–updated in 2013) in the Arkansas Soybean Production Handbook. The contents of this chapter include a review of soil test-based fertilizer recommendations for soybean production sites, a description of the symptoms of nutrient deficiencies or toxicities in soybean, and research- and/or experience-based insights pertaining to nutrient management strategies for the crop. This is probably the most thorough treatment of the subject matter of this White Paper.

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