**SOIL 4234 Laboratory #9**

**Micronutrient Deficiencies (15 points)**

Student

Lab

TA

**Objectives**

1. Know which elements are plant essential micronutrients.
2. Identify visual micronutrient deficiencies.
3. Understand soil testing and tissue testing procedures and interpretations.

**Micronutrients**

The micronutrients are grouped together because they are all required by plants in very small amounts. Some, like molybdenum, are required in such small amounts that deficiencies can be corrected by applying the element at only a fraction of a pound per acre. Similarly, chlorine is needed in such small quantities that when researchers at the University of California were attempting to document its essentiality, they found that touching plant leaves with their fingers transferred enough chlorine from the perspiration on their skin to meet the plant’s requirements. These elements do not function in plants as a component of structural tissues like primary and secondary nutrients. Instead, micronutrients are mainly involved in metabolic reactions as a part of enzymes where they are used over and over without being consumed. Nevertheless, their functions are very specific and cannot be substituted for by some other element. Deficiencies of any of the elements can be corrected by foliar application of solutions containing the element.

**Manganese, Chlorine, Copper, and Molybdenum**

Deficiencies of these nutrients have yet to be documented in Oklahoma, except for chlorine in wheat on a deep sandy soil near Perkins. Each of the elements is adsorbed by plants in the ionic form, manganese and copper as the divalent cations Mn2+ and Cu2+, molybdenum as the oxyanion MoO42-, and chlorine as the simple Cl- anion. Of these four nutrients, molybdenum and chlorine are probably the most likely to receive attention. Molybdenum functions in plants in the enzyme nitrate reductase, which is very important in nitrogen metabolism in legumes. Availability is reduced in acid soils and often if molybdenum availability is marginal it can be increased to adequate levels by simply liming the soil. Where large seeded legumes are grown, like soybeans or peanuts, obtaining seed that was grown with a good supply of molybdenum will avoid the deficiency because normal levels of molybdenum in the seed will be enough to meet the plant needs.

Soil fertility research in the Great Plains has occasionally shown small grain response to fertilizers containing chlorine. Often the response has been the result of disease suppression rather than correction of an actual nutrient deficiency in the plant, and usually it has been in areas that do not commonly apply potassium fertilizers containing chloride (such as muriate of potash or potassium chloride, 0-0-62).

**Boron**

Boron is absorbed by plants as uncharged boric acid, B(OH)3, the chemical form also present in soil solution. Boron is believed to function in plants in the translocation of sugars. Because boron is uncharged in soil solution and it forms slightly soluble compounds, it is also relatively mobile in soils and can be leached out of the surface soil. This is sometimes critical in peanut, production because of the very sandy, porous soils peanuts are produced in. As a result, boron deficiency has been reported in peanuts. The deficiency manifests itself as a condition known as "hollow heart" whereby the center of the nut is not completely filled and an inferior crop is harvested. Although alfalfa has an annual requirement twice that of peanuts, the deficiency of boron has never been documented in alfalfa. The reason for this is likely because alfalfa is usually grown in deep, medium textured soils and because alfalfa has an extensive root system even at lower depths in the soil profile. Whenever boron deficiencies are suspected, and if boron fertilizer is applied, care should be exercised as toxicities can be created by simply doubling the recommended rate.

**Iron and Zinc**

Iron and zinc deficiencies both occur in Oklahoma and are associated with unique soil and crop situations. Zinc is absorbed as the divalent cation Zn2+, while iron is absorbed as a "plant provided" chelated Fe3+ complex by grass type plants and as the "plant-reduced" divalent cation Fe2+ by broad-leaved plants.

Corn is sensitive to moderately low soil zinc levels and deficiencies may occur at DTPA soil test values below 0.8 ppm. Winter wheat, on the other hand, has been grown in research experiments near Woodward, Oklahoma where the soil test zinc value was less than 0.15 ppm without showing any deficiency or responding to zinc fertilizer. Zinc deficiency has yet to be found in winter wheat in Oklahoma. Obviously winter wheat is very effective in utilizing small amounts of soil zinc. Zinc deficiencies in corn are most common where fields have been leveled or for some other reason the topsoil has been removed and the surface soil has very little organic matter. Deficiencies are easily corrected by broadcast application of about 4 to 6 lb/acre of zinc preplant. An application of this rate should remove the deficiency for 3 to 4 years. The most sensitive plant to zinc deficiency in Oklahoma is pecans. Deficiencies may occur whenever DTPA soil test values are less than 2.0 ppm. Foliar sprays are very effective in preventing and/or correcting the deficiency, a single application usually lasting the entire growing season.

Iron deficiency is most common in sorghum and sorghum-sudan crops in Oklahoma. The occurrence is limited to the western half of the state in soils that are slightly alkaline (pH above 7.5). All soils in Oklahoma contain large amounts of iron, usually in excess of 50,000 lb/acre. However, almost all of this iron is in a form (like rust) that is not available to crops. Iron availability is increased greatly in acid soils, consequently the deficiency is seldom observed in any crops in eastern and central Oklahoma, where soil pH is usually less than 7.0. Iron deficiency cannot be corrected by soil application of iron containing fertilizers because the iron from the fertilizer is quickly converted to unavailable iron just like that already present in the soil. The exception to this general rule is the use of chelated iron. However, these fertilizer materials are cost prohibitive for field scale use. Foliar application of iron sulfate solutions is effective for supplying iron to deficient plants. Unfortunately, iron is not translocated in the plant and subsequent new leaves will again exhibit the interveinal chlorosis (yellow between the veins) so characteristic of iron deficiency. Repeated spraying will provide iron for normal growth but will often be cost prohibitive. The most effective long-term corrective measure for dealing with iron chlorosis is to increase soil organic matter since iron deficiency is usually limited to small areas of a field. Organic matter can be effectively increased by annual additions of feed lot manure or rotted hay. This results in additional chelating of iron and also has a tendency to acidify the soil. Broadleaf plants have what is called an "adaptive response mechanism" that allows them to make iron more available if they experience iron stress. The strength of this mechanism is a genetic trait and some varieties, such as ‘Forest’ soybeans, do not possess this ability and will often become chlorotic if grown in neutral or alkaline soils.

**DEFICIENCY SYMPTOMS**

**Zinc**

Zinc deficiency symptoms are usually seen during the plant seedling stage. It is characterized by a broad band of bleached tissue on each side of the midrib beginning at the base of the leaf. The midribs and leaf edges remain green. On broad-leaf plants a general bronzing may occur with a pronounced interveinal chlorosis. The leaves become thick and brittle and their margins are cupped upward. In grain sorghum, heads from severely zinc deficient plants are blasted. Most crops fail to develop normal internode length resulting in severe stunting and an appearance of all leaves coming from the same node.

**Iron**

Iron deficiency can be detected by yellowing between the veins with the veins remaining green. This gives a striping appearance. In contrast to zinc deficiency, the stripes are much narrower and extend the full length of the leaf.

Iron is not mobile within the plant, therefore, a deficiency is first observed on the younger (top) leaves with the older part of the plant remaining green. In severe cases the terminal portion of the plant turns white and eventually dies.

**Boron**

Boron deficiencies develop first on the youngest growth. The upper internodes are shortened and plants develop a rosette appearance. Upper leaves near the growing point turn yellow and in some legumes are reddened. The lower leaves remain green and healthy. In severe cases the terminal leaves become white.

In cotton, boron deficiency is described as having thick and leathery older leaves. Leaf petioles are often twisted with small ruptures appearing over their surfaces. A constriction near the base of the petiole may occur giving a "ringed" condition. Severe boron deficiency in cotton results in half opened bolls and plants which are hard to defoliate.

Boron deficient peanut plants possess the typical yellowing and rosetting, but even before the symptoms are noted on the vines, the nuts may have internal damage. The center of the nut will be somewhat hollow and discolored. Nuts with "hollow-heart" are severely downgraded upon marketing.

Sometimes knowledge of the environmental conditions is useful in diagnosing the nutrient problem. These conditions should be checked. The availability of some plant nutrients is greatly affected by soil pH. Molybdenum availability is reduced by acid soil conditions, while iron, manganese, boron, copper, and zinc availabilities are increased by soil acidity.

**SOIL TEST PROCEDURES**

Fe and Zn. Extract with DTPA solutions and analyzed on ICP.

Boron (B). Extracted with hot calcium chloride solutions and analyzed on ICP

**Plant Analysis**

The term plant analysis means the chemical analysis of plant tissue to determine the concentration of essential plant nutrients, excluding carbon, hydrogen and oxygen. The level of nutrients in the plant tissue is compared to established sufficiency levels to determine possible deficiencies and hidden hunger. In some cases, poor-growth plant tissue may be compared to adjacent good-growth plant tissue to draw conclusions about the problem area.

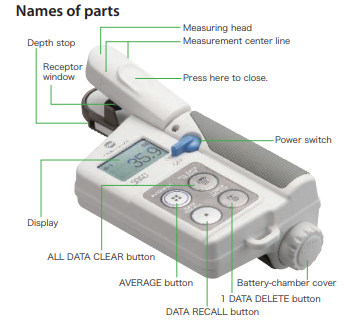
Plant analysis can be used to measure the level of plant nutrients that are difficult to test by soil testing procedures, such as molybdenum. A tool frequently used within research is known as the soil plant analysis spectrometer more commonly known as the SPAD 502-meter Figure 1. This lightweight meter easily measures the content of the chlorophyll by determining the spectral absorbance withing two wavelength regions RGB (blue 400-500nm, red 600-700nm) and near-infrared. Using the two absorbances, the meter then calculates a numerical SPAD value which is directly proportional to the amount of chlorophyll present in the leaf. It is a good tool for researchers to use when evaluating fertilizer sources or fertilizer placement and when confirming nutrient deficiency symptoms. Plant analysis cannot be used to make fertilizer recommendations because the soil pH and soil nutrient level must be known. It can be used to adjust the fertilizer recommendation once the soil level is known. The same factors that interfere with identifying nutrient deficiency symptoms must be considered when interpreting plant analysis.

A proper plant sample must be taken for plant analysis to be reliably interpreted. Sufficiency levels have been established for certain plant parts as shown in Table 1.

**Table 1. Sufficiency levels of plant nutrients for several crops at recommended stages of growth shown in Table 2.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Element** | **Sufficiency Levels** | | | | | |
| **Corn** | **Grain Sorghum** | **Soybeans** | **Small Grains** | **Peanuts** | **Alfalfa** |
| **B, ppm** | 4-25 | 1-10 | 21-55 | 5-10 | 20-50 | 30-80 |
| **Cu, ppm** | 2-6 | 2-7 | 10-30 | 5-25 | 10-50 | 7-30  - |
| **Fe, ppm** | 21-25 | 65-100 | 51-350 | 50-150 | 100-350 | - |
| **Mg, ppm** | 20-150 | 8-190 | 21-100 | 25-100 | 100-350 | 31-100 |
| **Zn, ppm** | 20-70 | 15-30 | 21-50 | 15-70 | 20-50 | 21-70 |

**Figure 1. Soil Analysis Development Meter**



Select plant tissue so it represents the field as much as possible. Take the composite sample by sampling the number of plants shown in Table 2. The same procedure should be used when sampling abnormal growth areas in a field (i.e. take the required number of plants throughout the trouble spot and select an equal-size area of normal plants to sample for comparative purposes).

Keep in mind that disease- or insect-infected plants, drought-stricken plants, and frost-damaged plants should not be sampled.

Allow samples to partially dry before mailing. Send samples in paper bags or envelopes, not in plastic bags. Damp or wet plant tissue will deteriorate if mailed in plastic or air-tight

**Table 2. Guide to plant sampling for tissue analysis.**

|  |  |  |  |
| --- | --- | --- | --- |
| Crop | Plant part  to sample | Stage of growth | Number of plants |
| Corn or Grain  sorghum | All above-ground | Seedling stage  (less than 12') | 20-30 |
| Corn or Grain  sorghum | Top fully developed  leaf | Prior to tasseling | 15-25 |
| Corn | Leaf at ear node | Tasseling to early silk\* | 15-25 |
| Grain sorghum | Second leaf from top | At heading | 15-25 |
| Soybeans | All above-ground | Seedling stage  (less than 12") | 20-30 |
| Soybeans | Top fully developed  trifoliate leaves | Prior to or during  initial flowering\* | 20-30 |
| Small grain | All above-ground | Seedling stage  (prior to tillering) | 50-100 |
| Small grain | All above-ground | As head emerges from boot\* | 15-25 |
| Peanuts | All above-ground | Seedling stage | 20-30 |
| Peanuts | Upper stems and leaves | Early pegging\* | 15-25 |
| Alfalfa | All above-ground | Prior to bloom | 30-40 |
| Alfalfa | Top 1/3 of plant | At bloom\* | 15-25 |
| Bermudagrass | Whole plant top | 4 to 5 weeks  after clipping\* | 15-25 |
| Cotton | Whole plants | Early growth | 20-30 |
| Cotton | Petioles of youngest fully expanded leaves | During bloom\* | 20-30 |

\*Recommended sampling period for fertilizer evaluation.

containers. Do not send soil or roots in the same container. Soil contaminates the plant tissue and makes it difficult to clean at the laboratory.

It is a good idea to take a soil sample in the same vicinity as the plant sample. Soil tests may help interpret the plant analysis results. Plant tissue sufficiency levels for several crops are presented in Table 1. Whenever nutrient levels in the plants fall below the sufficiency range, a deficiency is expected. The lower the concentration is below the sufficiency range, the greater the nutrient deficiency.

Some laboratories and researchers have tried to use ratios between 2 or more elements for interpretation. At the present time, the N/S ratio appears to be a good method for diagnosing sulfur deficiency. Sulfur is sufficient when the ratio is 15:1 or less and deficient when the ratio is greater than 20:1. Other combinations or ratios have not shown any benefit over the sufficiency levels shown in Table 1.

Remember to use plant analysis along with other data, including soil tests. Interpretation must be logical. Be suspicious of far-fetched diagnosis. Growers have frequently been disappointed by applying some otherwise illogical nutrient to their soil and obtaining no benefit. The OSU Soil, Water, and Forage Analytical Laboratory does not currently offer plant analysis because there is low grower benefit and interest.

**MICRONUTRIENT INTERPRETATIONS**

Zinc

The soil test interpretation for zinc is presented in Table 3. Zinc soil test values less than 0.30 ppm are considered deficient for all crops except small grains, cool season grasses (fescue, orchardgrass, and ryegrass) and new seedings of introduced grasses. The recommended rates are enough to correct a deficiency for several years. Fertilizer applications should not be repeated until a new soil test is taken. Some producers may wish to apply 2 pounds of zinc per year until the total recommended amount is applied.

**Table 3. Zinc soil test interpretation.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| SOIL TEST  INDEX  ppm Zn | |  | | INTERPRETATION |  | RECOMM-ENDED  ZINC RATE  lb Zn/A | |
| 0-0.30 |  | | Deficient for all crops except small grains, cool season grasses (fescue, orchard, and rye) and new seedings of introduced grasses. | | |  | 6-10 |
| 0.30-0.80 |  | | Deficient for corn and pecans only | | |  | 2-5 |
| 0.80-2.00 |  | | Deficient for pecans only. | | |  | Foliar only |
| 2.00+ |  | | Adequate for all crops | | |  | None |

**Iron**

Iron soil test values less than 2.0 ppm are considered low and may cause iron chlorosis in crops which are moderately sensitive such as wheat, soybeans and peanuts. Soil test values in the medium range, 2.0-4.5 ppm, may cause chlorosis in sensitive crops such as sorghum and sudan. Levels above 4.5 ppm are usually adequate for all crops. Crop sensitivity is increased when soil pH increases above 8.2 and soil test manganese levels are high (above 50 ppm). Foliar application of a 3% ferrous sulfate (or ammonium ferrous sulfate) solution is effective for correction. Severe chlorosis may require several applications. Effective control can be obtained by applying 2 lbs of iron per acre in chelated form or 8 lbs of ferrous sulfate per acre with ammonium polyphosphate solution in a band near the seed. It is important to apply the polyphosphate and ferrous sulfate solutions in the same band.

Boron

Boron deficiency in Oklahoma is of concern only in legumes, particularly alfalfa and peanuts. The soil test interpretation for boron is presented in Table 4.

**Table 4. Boron soil test interpretation.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SOIL TEST | |  | BORON RATE (lb/A) | | |
| ppm B | |  | PEANUTS | ALFALFA | |
| 0.00-0.25 |  | 1 | 2 | |
| 0.25-0.50 |  | ½ | 1 | |
| 0.50 |  | 0 | 0 | |
|  | |  |  | |  |

**MICRONUTRIENT FERTILIZERS**

**Boron (B).** A sodium borate (solubor) containing about 20 percent B is the source of boron most commonly used in liquids. Boric acid and other soluble forms containing between 14 to 20 percent B are also suitable for liquid mixes.

Borax 11.3% B

**Zinc (Zn), Iron (Fe), Copper (Cu), and Manganese (Mn)**

The micronutrient elements, zinc (Zn), iron (Fe), copper (Cu) and manganese (Mn) can be discussed as a group since their sources are somewhat similar. Industry separates the compounds into two general categories: inorganic and organic. Inorganic include sulfates, oxides, carbonates and chlorides. The term organic applies primarily to chelated products and some sequestered materials. Most chelates, and particularly liquid products, can be mixed with liquid without difficulty.

**Zinc.**

Zinc Sulfate 25-36% Zn

Zinc Oxide 50-80% Zn

Zinc Chloride 48% Zn

Zinc Chelate 9-14.5% Zn

**Iron.**

Ferrous Sulfate 20.1% Fe

Ferric Sulfate 19.9% Fe

Ferrous Ammonium Sulfate 14.2% Fe

Ferric Chloride 34.4% Fe

Iron Chelate 10% Fe

**Copper.**

Copper Sulfate 25% Cu

**Manganese.**

Manganese Sulfate 23-28% Mn

**Molybdenum (Mo).** Ammonium molybdate is satisfactory for liquids. Sodium molybdate can also be used although it is less soluble than ammonium molybdate. Since molybdenum is applied in ounces per acre, liquids are ideal for getting even distribution.

Sodium Molybdate 39.7% Mo

Ammonium Molybdate 54.3% Mo

**Chlorine.** Chlorine has only recently been found deficient in Oklahoma soils. The deficiency in wheat on deep sandy soils near Perkins, OK can be corrected using muriate of potash (0-0-60). This is the common source of potassium, which is usually also deficient in these sandy soils.

**SOIL 4234 Laboratory #9**

**Micronutrient Deficiency Data Sheet (15 points)**

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**Questions**

1. (3 pts.) A producer contacts you because they are concerned they may have a chlorine deficiency in their growing wheat crop. In discussions with the producer they tell you they soil sampled their field prior to planting and applied phosphorus and potassium fertilizer to meet soil test sufficiency requirements. Based on this given information and without ever stepping foot out into the field, why could you confidently tell the producer you don’t think they are dealing with a chlorine deficiency? **BE SPECIFIC!!!**
2. (3 pt.) List the main considerations when collecting plant tissue for analysis for making micronutrient fertilizer recommendations.
3. (3 pts.) Why would foliar applications of nutrients that are immobile in the plant not be beneficial if applied mid-season?
4. (3 pt.) List the two pathways that mobile nutrients can move through in the plant.
5. (3 point) List two disadvantages of using plant tissue testing for making micronutrient fertilizer recommendations.