9. Nutrient Management for Small Grains

Carl Crozier, Ron Heiniger, and Randy Weisz

Routine Soil Testing to Prevent and Manage Nutrient Deficiencies

Soil testing before planting is an essential component of a small grain fertility management program. Different fields can vary so widely in pH and nutrient levels that it is impossible to predict optimum application rates without soil test results. It is much more economical to prevent yield losses associated with nutrient deficiencies than to try to correct them once visible symptoms appear. Producers should sample each field once every two to three years at the same time of the year, preferably in the early fall. Often this is done before a corn or cotton crop, which tends to be more sensitive to applied nutrients than small grains. However, if you suspect a nutrient problem, then sample more frequently before a small grain crop and use that information to adjust nutrient applications. Sample boxes, information sheets, test results, and recommendations are provided free of charge by the Agronomic Division of the NCDA&CS, and guidelines for soil testing procedures can be found in another Extension publication: SoilFacts: Careful Soil Sampling, The Key To Reliable Soil Test Information (www.soil.ncsu.edu/publications/Soilfacts/AG-439-30).

Diagnostic Soil Sampling and Plant Tissue Analysis

When abnormal growth or plant color is observed, it is often useful to obtain diagnostic samples to determine if there is a nutrient deficiency. If samples are collected to diagnose an observed problem rather than for routine purposes, then separate samples should be submitted to represent the surface soil (0 to 4 inches) and the subsoil (4 to 8 inches). Tissue analysis can determine whether an adequate amount of fertilizer has been applied or if a particular nutrient is limiting crop growth. Plant tissue analysis is particularly useful in determining a crop’s need for mobile nutrients, such as nitrogen, sulfur, and boron; and for diagnosis of deficiency symptoms for manganese, copper, or zinc. To take a tissue test, clip a handful of plants above the ground with 8 to 10 samples collected from both the problem area and a corresponding area of normal growth. When taking diagnostic samples, both soil samples and plant tissues from the affected "bad" area and a nearby unaffected "good" area should be submitted for analysis to the NCDA&CS diagnostic laboratory.

Soil pH and Lime Recommendations

Proper pH is critical in obtaining good crop growth and yield. Small grains grow best when the pH is near the target level for each soil class. If pH is too low, soluble aluminum and acidity can limit root growth and nutrient uptake. If pH is too high, micronutrients such as manganese, iron, copper, and zinc can become unavailable. Stunted growth, nutrient deficiency symptoms, and low yield are the most common problems associated with soil pH levels that are not maintained in the proper range. Often nutrient deficiencies are the result of low or high pH rather than a lack of adequate nutrient amounts of the nutrient in the soil. Ideal soil pH levels vary based on soil type. Target levels are 6.0 for mineral soils, 5.5 for mineral organic soils, and 5.0 for organic soils. When the soil pH is below these targets, apply lime as early as possible in the production year to allow time for neutralizing soil acidity. Liming rates and the type of lime applied cannot be determined based on soil pH alone; they also depend on residual soil acidity, residual credit for recently applied lime, and measurement of available magnesium. For more information see SoilFacts: Soil Acidity and Liming for Agricultural Soils (www.soil.ncsu.edu/publications/Soilfacts/...
Phosphorus Recommendations
Phosphorus (P) plays a key role in germination and early plant growth, promotes winter hardiness, stimulates the growth of the wheat kernel, and has a role in determining when the plant reaches maturity.

Phosphorus Deficiency Symptoms
Purpling of the leaf margins and bottom leaf surfaces of the lower plant leaves and purpling of the leaf sheaths at the stem’s base are symptoms of P deficiency. Slow growth or stunting is another sign of P deficiency. Phosphorus-deficient plants are slow to mature, and green heads are often found in spots in the field at harvest. Deficiency symptoms are often found on waterlogged, cool soils in late winter or early spring.

Phosphorus Fertilizer Rates
As noted previously, a good soil test is the best way to determine fertilizer requirements. The following P recommendations are made only as guidelines and should not replace soil testing as the primary means of determining crop nutrient needs.

A wheat crop yielding 40 bushels per acre typically requires 40 pounds of $P_2O_5$ (25 pounds in the seed and 15 pounds in the straw). Mineral soils, such as those found in the NC coastal plain and piedmont, bind P and prevent it from leaching. Heavy organic soils do not bind P, resulting in a movement of P to the lower soil horizons or to drainage waters. Soils high in clay content, such as those found in the piedmont, bind P very tightly making it unavailable to the crop. Consequently, both heavy organic soils and soils high in clay content often test low in available P even though high amounts of P fertilizer are applied every year. Care must be taken on these soils to apply P in a way that limits the interaction between the P fertilizer and the soil. Because animal wastes are high in P, soils where heavy applications of animal waste have been applied will have high levels of available P. Table 9-1 shows the recommended rates for P fertilizer in the different regions and major soil types of the state.

Phosphorus Placement and Timing
Phosphorus should be broadcast on the soil just before planting. Growers farming heavy organic or clay soils should limit the amount of soil-fertilizer contact (and thus reduce nutrient binding), which means little to no tillage should occur after a P application.

Potassium Recommendations
Potassium (K) influences grain quality (including test-weight) and oil content, prevents lodging, and plays an important role in drought and disease tolerance.

Potassium Deficiency Symptoms
The most common deficiency symptom for K in small grains is stunted growth and early lodging. Plants with a K deficiency will have low vigor, poor drought or disease tolerance, and reduced kernel size. Under severe K deficiency, the leaf tip and margins on the lower leaves will bronze and eventually turn yellow and die. Deficiency symptoms are more likely on deep sandy soils or soils that are waterlogged and compacted.

Potassium Fertilizer Rate
A wheat crop yielding 40 bushels per acre typically requires 64 pounds of $K_2O$ (16 pounds in the seed and 48 pounds in the straw). Because so much of the K in the plant is in the straw, most of it will be recycled in the soil. Most of the agricultural soils in NC have adequate to high levels of available K. In particular, soils where animal waste has been applied will be high in available K. The exception to this rule is that available K is low on sandy soils in the NC coastal plain and tidewater. Sandy soils do not bind K, so the K leaches below the root zone.
Table 9-1. Critical macronutrients for small grain production.

<table>
<thead>
<tr>
<th>Element</th>
<th>Common deficiency symptoms</th>
<th>Common fertilizer forms 1</th>
<th>Basis for fertilizer rate</th>
<th>Suggested rates per acre if soil test data are not available 2</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus (P)</td>
<td>Stunting, purpling on margins of lower leaves or on leaf sheaths, delayed maturity</td>
<td>Granular monoammonium phosphate (MAP, 11-52-0)</td>
<td>Soil test</td>
<td>Coastal plain mineral soils: 0 to 30 lbs P₂O₅</td>
<td>Limit the amount of soil-fertilizer contact on heavy organic or clay soils.</td>
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<tr>
<td></td>
<td></td>
<td>Granular diammonium phosphate (DAP, 18-46-0)</td>
<td></td>
<td>Tidewater organic soils low P index: 30 to 50 lbs P₂O₅</td>
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<td></td>
<td></td>
<td>Liquid ammonium phosphate (10-34-0)</td>
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<td>Piedmont clay soils, shallow topsoil: 30 to 40 lbs P₂O₅</td>
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<tr>
<td>Potassium (K)</td>
<td>Lower leaf tip and margin burn, weak stalks, lodging at harvest, small ears, slow growth</td>
<td>Potassium [plus chloride (muriate 0-0-60), sulfate, nitrate, hydroxide, or magnesium sulfate]</td>
<td>Soil test</td>
<td>Sandy or very sandy soils: 50 to 60 lbs K₂O</td>
<td>On deep sand, apply just before planting or split apply at planting and at growth stage 30.</td>
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<td></td>
<td>Organic soils (only if K is deficient): 50 to 60 lbs K₂O</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Mineral or clay soils: (only if K is deficient): 50 to 60 lbs K₂O</td>
<td></td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>Terminal and root tip damage, dark green, weakened stems, ear disorders</td>
<td>Lime, calcium sulfate (gypsum)</td>
<td>Soil test</td>
<td>Apply lime at recommended rate.</td>
<td>Generally ok if limed to target pH.</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>Intervereinal chlorosis in older leaves, leaf curling, margin yellowing</td>
<td>Dolomitic lime, magnesium sulfate (epsom salt), potassium magnesium sulfate, magnesium oxide</td>
<td>Soil test, tissue analysis</td>
<td>If needed: 20-30 lb Mg</td>
<td>Generally ok if dolomitic lime used.</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>Yellowing of young leaves, small spindly plants, slower growth and maturation</td>
<td>Elemental sulfur; sulfate [plus ammonium, calcium (gypsum), magnesium (epsom salt), potassium, potassium magnesium]; Ammonium thiosulfate; Sulfur-coated urea</td>
<td>Tissue analysis or soil criteria</td>
<td>Sandy soils low in S: 15 to 25 lb S</td>
<td>Deficiency likely if sandy surface is 18+ inches deep.</td>
</tr>
</tbody>
</table>

1 This table does not list all available chemical forms of fertilizers or recommend use of any specific form. Percent chemical analyses included are examples only, and may not reflect the composition of any specific commercial source.

2 Soil samples should be taken to avoid underestimating or overestimating actual needs.

**Potassium Placement and Timing**

Potassium should be broadcast just prior to planting. On sandy or very sandy soils with a high leaching potential, K should be applied in two applications, half at planting and the other half just prior to growth stage 30 when N is applied. There is no benefit to applying K to a growing crop after growth stage 31.
**Sulfur Recommendations**

Sulfur (S) increases kernel weight, kernel size, grain protein, yield, and test-weight. Sulfur is required for the production of chlorophyll and many enzymes involved in the utilization of N. Consequently, a small grain crop must have adequate amounts of S to use N fertilizer property.

**Sulfur Deficiency Symptoms**

Symptoms of S deficiency include yellowing of young leaves, small spindly plants, slowed growth, and delayed maturation. Sulfur deficiency looks very much like N deficiency except that with S deficiency the young leaves at the top of the plant are the first to turn yellow. Sulfur deficiency symptoms usually occur in patchy spots across the field. Generally, S deficiencies are only found on deep sandy soils. However, in recent years, S deficiency symptoms have occurred in clay and organic soils during cool, wet weather when the plant is small. Periodic checks in the late winter and early spring can help identify fields with S deficiency.

**Sulfur Fertilizer Rate**

A wheat crop yielding 40 bushels per acre typically requires 10 pounds of elemental S (4 pounds in the seed and 6 pounds in the straw). While most of the agricultural soils in NC will have adequate to high levels of available S, sandy soils with low levels of organic matter usually are deficient in S because S is water soluble and easily leached. On sandy, S deficient soils, 15 to 25 pounds S per acre can be applied at planting or with the N sidedress. Sulfur should be applied before jointing to avoid crop damage and increase the likelihood of an economic response.

**Calcium and Magnesium Recommendations**

Calcium (Ca) deficiency symptoms include terminal and root tip damage, dark green stems, weakened stems, and poor ear formation. Magnesium (Mg) deficiency symptoms include interveinal chlorosis in older leaves, leaf curling, and yellowing of the leaf margins. Generally, Ca and Mg levels are maintained through dolomitic lime applications. If deficiencies occur and no pH change is desired, then sulfate forms such as gypsum (calcium sulfate) or epsom salts (magnesium sulfate) can be applied at the rates recommended in Table 9-1.

**Micronutrient Management**

Due to expense and the potential for toxicity, applications of micronutrients (including copper, manganese, and zinc) are generally not made to small grains unless they are specifically recommended by a soil test or if specific deficiencies are identified. Common problems often found in wheat in NC include manganese deficiencies on overlimed soils and copper deficiencies on organic soils.

**Copper Recommendations**

Proper levels of copper (Cu) in the plant enhance protein content of the kernel and grain yield.

**Copper Deficiency Symptoms**

Common Cu deficiency symptoms include stunting, leaf tip or shoot die-back, and poor upper leaf pigmentation. Perhaps the best way to diagnose a Cu deficiency is by observing the leaf tip. "Pigtailing" or "corkscrewing" of the leaf tip is a sign of Cu deficiency. Organic soils are naturally low in Cu, and often deficiency symptoms can be found in plants grown in these soils, particularly when the plant and root system are small. Wheat is very sensitive to Cu deficiency and will be one of the first crops to show symptoms.

**Copper Fertilizer Rate**

A wheat crop yielding 40 bushels per acre typically requires 0.04 pounds of elemental Cu per acre (0.03 pounds in the seed and 0.01 pounds in the straw). Table 9-2 shows the rate of Cu to use when a soil test detects a low level or when deficiency symptoms are noted. Growers should take care to avoid the over-application of Cu fertilizers since...
### Table 9-2. Critical micronutrients for small grain production.

<table>
<thead>
<tr>
<th>Element</th>
<th>Common deficiency symptoms</th>
<th>Common fertilizer forms ¹</th>
<th>Basis for fertilizer rate</th>
<th>Suggested rates per acre if soil test data are not available²</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper (Cu)</td>
<td>Stunting, leaf tip/shoot dieback, poor upper leaf pigmentation</td>
<td>Copper sulfate, copper oxide, copper chelates</td>
<td>Soil test, tissue analysis</td>
<td>If deficient: apply 0.25 lb Cu to foliage with 0.50 lb of hydrated lime, or 2.8 lb³ Cu to soil.</td>
<td></td>
</tr>
<tr>
<td>Boron (B)</td>
<td>Leaf thickening, curling, wilting; reduced flowering/ pollination</td>
<td>Boric acid, borax, solubor, borates</td>
<td>Tissue analysis</td>
<td>Avoid toxicity, apply only as needed.</td>
<td></td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>Interverinal chlorosis of young leaves</td>
<td>Ferrous sulfate, ferric sulfate, ferrous ammonium sulfate, iron chelates</td>
<td>Tissue analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>Upper leaves pale green or streaked</td>
<td>Manganese sulfate, manganese oxide, manganese chelate, manganese chloride</td>
<td>Soil test, tissue analysis</td>
<td>Coastal plain, sandy soil or any soil with Mn index less than 25: 10 lb Mn. If deficient: apply 0.5 lb Mn to foliage, or 10 lb Mn to soil.</td>
<td>Overliming decreases availability.</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>Decreased stem length (rosetting), mottling, stippling, interveinal chlorosis</td>
<td>Zinc sulfate, zinc oxide, zinc chelates, zinc chloride</td>
<td>Soil test, tissue analysis</td>
<td>If deficient: apply 0.5 lb Zn to foliage, or 6 lb Zn to soil.</td>
<td></td>
</tr>
</tbody>
</table>

¹ This table does not list all available chemical forms of fertilizers or recommend use of any specific form. Percent chemical analyses included are examples only, and may not reflect the composition of any specific commercial source.

² Soil samples should be taken to avoid underestimating or overestimating actual needs.

³ NCDA guidelines are 2 lb Cu/ac or 6 lb CuSO₄/ac for mineral soils, 4 lb Cu/ac or 12 lb CuSO₄/ac for mineral-organic soils, and 8 lb Cu/ac or 24 lb CuSO₄/ac for organic soils.

High concentrations of Cu can be toxic to the plant.

**Timing a Copper Application**

The recommended time to apply Cu is preplant. This avoids the high cost of Cu chelates, eliminates the chance of leaf burn, and allows a much longer residual effect. However, if deficiency symptoms occur, a foliar spray can be applied at much lower rates than are recommended for soil applications. Usually, Cu chelates or organic dusts are recommended for foliar application. Do not apply Cu after jointing.

**Manganese Recommendations**

Proper levels of manganese (Mn) in the plant enhance plant growth and the production of chlorophyll.
**Manganese Deficiency Symptoms**

Manganese deficiency symptoms include stunting, gray specks in the leaf, and pale to almost whitish upper leaves or streaked yellowing (interveinal chlorosis) of the upper leaves. Manganese deficiency can be distinguished from a Mg deficiency in that Mn effects the upper leaves while Mg effects the lower leaves. Manganese deficiencies commonly occur in overlimed soils (pH greater than 6.5 on mineral soils or greater than 6.1 on mineral-organic or organic soils) with low cation exchange capacity. A common situation where Mn deficiencies are noted is the over-limed areas at the ends of the field where the spreader truck turned or where lime was stockpiled.

**Manganese Fertilizer Rate**

A wheat crop yielding 40 bushels per acre typically requires 0.25 pounds of elemental Mn (0.09 pounds in the seed and 0.16 pounds in the straw). Sandy soils in the NC coastal plain are typically low in available Mn. Table 9-2 shows the rate of Mn to use when soil test levels are low or when deficiency symptoms are noted.

**Timing of Manganese Fertilizer Application**

The best time to apply Mn on soils with low test levels is preplant. However, to correct a deficiency if the soil pH is high, use a foliar application. Manganese is commonly supplied as manganese sulfate, manganese oxide, and manganese chelates or organic complexes. Manganese chelates and organic complexes are recommended only for foliar application due to soil reactions that tend to convert the Mn to unavailable forms. Application of foliar fertilizers may have to be repeated several times to correct severe deficiency symptoms on fields that have been overlimed. Once wheat is jointing, consider whether response to fertilizer is likely to outweigh crop damage due to traffic.

**Zinc Recommendations**

Zinc (Zn) deficiency symptoms include decreased stem length (rosetting), mottling, and interveinal chlorosis. Zinc deficiencies are most common if the soil pH is greater than 6.5 and the soil phosphorus index is greater than 75. As with other micronutrients, recommended rates (Table 9-2) are lower for foliar applications, but residual effects are greater with soil applications.

**Special Consideration for No-Till Production**

Before a field is placed in 100 percent no-till production, it should be soil tested and brought to target pH and optimum nutrient levels. Once adequate fertility levels are achieved throughout the root zone, no-till production can begin. Long-term no-till studies suggest that yields and soil fertility can be maintained even though lime and fertilizer are applied to the soil surface without incorporation. Routine soil samples in established no-till fields should be collected to a depth of 4 inches. Use of starter fertilizers containing N and P are more important in no-till production because plant development is delayed.

**Special Consideration for Precision Agriculture**

Currently, precision agriculture is being used for three primary reasons: (1) to identify areas in fields with different pH or soil test indexes, and vary lime and fertilizer rates accordingly; (2) to monitor and map crop yield and moisture content; and (3) to document material applications, including fertilizers and pesticides. The cost of collecting grid soil samples or using a yield monitor must be returned by decreasing the amounts of lime or fertilizer applied, increasing crop yield, reducing negative environmental impacts, or by some combination of these benefits. Growers are more likely to increase profits by using precision farming practices in situations where pH or fertility levels are limiting wheat yields. An examination of the variability in soil pH or fertility within a field should indicate the potential for increasing crop yield through variable-rate lime or fertilizer applications. If at least a fourth of the field area has soil nutrient indexes
below 25, or pH levels below the target value for that crop and soil class, then it is likely that precision farming practices will increase wheat yields and profits.

**Special Consideration for Animal Wastes and Sewage Sludge**

Animal waste and sewage sludge can be excellent sources of nutrients and organic matter for a wheat crop. Organic forms of P can move deeper in soils than do inorganic fertilizer sources. Consequently, they can be advantageous in no-till or conservation tillage systems. When applying animal waste as a fertilizer material for wheat, all amendments should be tested *before* application to determine optimum application rates. Soils that are being fertilized with waste materials should be tested to determine nutrient levels. The amount of waste material applied should be based on the need for desirable nutrients, such as P or K, and the requirement that levels of P, Zn, Cu, cadmium, lead, and mercury should not exceed prescribed limits. Producers should rotate applications as much as possible to obtain nutrient benefits while minimizing excess nutrient and toxic metal accumulation. If you use lime-stabilized sludge or poultry litter, monitor the soil pH carefully to prevent overliming and possible Mn deficiency.

Applications of animal waste are most effective when made prior to planting a small grain crop. However, topdress applications of poultry or swine manure can be done in January or early February with good results. Several good publications on application of animal waste and/or sludge can be found online: [www.soil.ncsu.edu/about/publications.php#WasteManagement](http://www.soil.ncsu.edu/about/publications.php#WasteManagement).