

Understanding the Soil Test Report

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UNDERSTANDING THE SOIL TEST REPORT

WHAT IS A SOIL TEST?

A soil test chemically extracts and measures most of the elements essential to plant nutrition. It also measures soil acidity and pH. These factors are indicators of lime requirement, nutrient availability, and the potential of the soil to produce crops. This information enables growers to apply nutrients with environmental stewardship and profitability in mind.

The NCDA&CS Agronomic Division conducts two types of soil tests: predictive and diagnostic. The predictive is the standard soil test that provides the lime and fertilizer recommendations necessary to optimize yields. In contrast, the diagnostic soil test is used when samples are collected because of an observed problem situation. The purpose of a diagnostic test is to identify specific nutrient deficiencies or excesses that may be preventing optimal plant growth.

Predictive Soil Testing

NCDA&CS lime and fertilizer recommendations are based on field experiments conducted in North Carolina across a variety of soil types and cropping sequences. The rates suggested are designed to eliminate fertility constraints that may limit optimal crop production.

Other factors that have a strong impact on yield include environmental conditions during the growing season (rainfall, temperature, etc.), soil productivity, water-holding capacity, planting date, variety, pest and disease pressure, and soil compaction. If any of these factors are less than optimal, reduced yield results. Optimum production requires reasonable management of all factors involved in the overall crop production scheme.

Continuous field calibration research is essential to determine fertility requirements dictated

by changes in farming practices and cropping sequences. These studies are conducted by N.C. State University researchers in conjunction with NCDA&CS agronomists.

The NCDA&CS soil test uses Mehlich-3 extractant for determining levels of phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), manganese (Mn), copper (Cu), zinc (Zn) and sodium (Na). Results may or may not agree with those of other laboratories depending on method of extraction and other procedural variables. Growers are encouraged to use a laboratory whose recommendations are validated by field research within their own state.

Diagnostic Soil Testing

Problem soil samples are handled separately from routine predictive samples because, in these cases, results are needed for immediate management of a current crop-production issue. Samples for problem diagnosis must be submitted with a fully completed *Diagnostic Soil Sample Information* form that accurately describes crop history, symptoms and other relevant factors. In addition to the routine analyses, levels of soluble salts (**SS-I**) may also be determined. Test results for problem soil samples are reviewed by an agronomist, who provides appropriate comments regarding the cause of the problem and recommended treatment.

Plant tissue analysis, in conjunction with a diagnostic soil test, is the best way to troubleshoot a nutrient problem. Soil samples for nematode assay may also be warranted depending on the crop, soil type and pattern of poor growth. If you want to collect enough soil for both tests (soil test and nematode assay) at one time, be sure to collect samples from the crop root zone.

Collect soil and plant samples from both “good” and “bad” areas for comparison purposes.

When submitting matching samples, assign the same sample ID to both the soil sample and its corresponding plant sample: for example, GOOD1 could be the sample ID for both samples from the "good" area and BAD1 could be the ID for those from the "bad" area. This labeling system makes it easy to compare results.

ASSISTANCE AVAILABLE

The NCDA&CS Agronomic Division tries to present soil-test results and recommendations in a way that is easy to understand. Reports contain explanatory information, hyperlinks to relevant publications and, often, specific comments from an agronomist. If additional guidance is required, regional agronomists and county Cooperative Extension personnel are available to help clients interpret results and implement recommendations.

In essence, lime and fertilizer recommendations on a soil report are like a prescription to be filled. Without it, fertilizer suppliers are somewhat handicapped in their ability to advise farmers. If they make general fertilizer recommendations without a soil test, undue criticism may be levied toward their product if crop response is poor.

THE REPORT

The header contains the report number (e.g., FY13SL00001), relevant dates and the client's name and address. An advisor may be listed, if the client specified one. **Agronomist's Comments**, an advisory section, may or may not appear just below the header. Descriptive information for each sample includes **Sample ID** and **Lime History**. Report results for each sample include two types of information: **Recommendations** on the upper row and **Test Results** on the lower row. The last page of each soil report contains explanatory information and useful hyperlinks.

Lime History

This section contains any recent lime application information provided by the client on the sample

information form. If lime was applied within 12 months prior to sampling, this information is used to determine the residual lime credit (RC). For an explanation of the residual credit calculation and its impact on lime recommendations, refer to the section titled **Lime** later in this document.

Recommendations

Details supplied by clients affect the quality of recommendations received. The codes selected to specify **FIRST CROP** and **SECOND CROP** on the sample information form determine the recommendations for **Crop 1** and **Crop 2** that appear on the soil report. Recommendations for **Crop 2** do not take into account fertilizer recommendations for **Crop 1**.

When recommendations for two crops with different target pHs are requested, the lime recommendation given will be for the crop that is least acid tolerant. This lime recommendation will be listed for **Crop 1**. Therefore, the higher of two possible lime recommendations will be given.

Soil-test calibration for the micronutrients Mn, Zn and Cu is not as well defined as it is for the macronutrients P, K, Ca, Mg and S. However, with the increased concern about maximizing yields through better management practices, research efforts to refine the calibration for micronutrient soil tests in relation to yields have increased. In addition, advances in laboratory instrumentation have led to more accurate determination of the critical soil-test levels at which a crop response can be expected.

Lime

Lime rates for crops grown on a large scale are expressed in units of tons/acre; recommendations for small areas, such as lawns and gardens, are given in units of lb/1000 ft². Rate calculation involves soil pH, exchangeable acidity (*Ac*), target pH and residual lime credit (*RC*). The lowest recommended rates are 0.3 ton/acre and 15 lb/1,000 ft². If the lime recommendation is 0, no lime should be applied. The formula is

$$\text{tons lime / acre} = \text{Ac} \left[\frac{\text{target pH} - \text{current pH}}{6.6 - \text{current pH}} \right] - \text{RC}$$

RC is the amount of lime applied in the last 12 months that has not reacted with soil acidity; it is reported in units of tons/acre. The *RC* calculation uses a reactivity rate that varies with soil type. The equation for determining *RC* is as follows:

$$RC = rate - (rate \times months \times reaction\ rate)$$

where

- *rate* is amount of lime applied in tons/acre,
- *months* is the number of months between lime application and the current soil test and
- *reaction rate* is 0.08 (8%) for mineral soils or 0.16 (16%) for mineral-organic and organic soils.

If *rate* = 1.2 tons/acre, *months* = 8, and *reaction rate* = 0.08, then $RC = 1.2 - (1.2 \times 8 \times 0.08) = 1.2 - 0.8 = 0.4$ ton/acre. If this lime application is not recorded on the *Soil Sample Information* form and the resulting soil-report lime recommendation is 0.9 ton/acre, then the adjusted recommendation after taking into account *RC* would be 0.5 ton/acre.

To convert ton/acre to lb/1000 ft², multiply by 46.

Example: 0.8 ton/acre \times 46 = 36.8 lb/1000 ft².

To convert lb/1000 ft² to ton/acre, multiply by 0.0218.

Example: 20 lb/1,000 ft² \times 0.0218 = 0.4 ton/acre

Nitrogen (N)

In most cases, soil tests do not measure nitrogen because N does not persist long in soil. Soil reports provide a **N** recommendation based on the known requirements of the crop(s) specified on the sample information form. Suggested application rates (lb/acre) are based on field research studies, but higher N rates may be justified under intensive management systems.

N applications must be timely to maximize yield and minimize potential environmental impact. Therefore, the total suggested N rate may not be applied all at once. Nitrogen is often put out in several applications: e.g., at or near planting followed later, as needed, by sidedress or topdress applications.

Supplemental N applications (more than the total suggested on a soil report) may be required under certain soil and climatic conditions, e.g., heavy rainfall with leaching. Soil reports for field crops contain a hyperlink to *Note 3*, which explains the conditions under which supplemental N may be needed. Use of plant tissue testing is also encouraged to justify supplemental N.

Phosphate (P₂O₅)

The application rate of P₂O₅ suggested on the soil report is based on **P-I** value, soil type and crop to be grown. Crop need for phosphorus is determined by rate studies on a number of different soils and cropping situations. Equations have been established to meet the majority of soil and crop conditions.

Potash (K₂O)

The suggested rate for potash is established in the same manner as for phosphate. Split applications may be beneficial on sandy soils with low cation exchange capacity that are prone to leaching.

Magnesium (Mg)

If the amount of magnesium in a soil sample is found to be below a pre-established critical level, then an application of 25 lb/acre will be recommended. If a rate is recommended for **Crop 1**, then a \$ will appear on the line for **Crop 2** to remind the grower that **Crop 2** may need Mg if it is not applied to **Crop 1**. Clients should review the \$ *Note* via a hyperlink, located on the last page of the soil report. The note discusses options for applying Mg and micronutrients. Whenever lime is recommended, use of dolomitic lime will provide adequate Mg.

Sulfur (S)

When needed, as suggested by a sulfur index (**S-I**) of 25 or less, sulfur is recommended at rates of 15–20 or 20–25 lb/acre. Since sulfur leaches readily from sandy soils, split application as with N or K may be beneficial. Sulfur often helps optimize N use by the crop.

Manganese (Mn)

The Mn-availability index (**Mn-AI**) is calculated based on the soil-test Mn-index (**Mn-I**), crop sensitivity and soil pH. Of all the micronutrients, Mn is most closely correlated with soil pH: as pH increases, Mn availability decreases. The critical **Mn-AI** value is 25.

A zero (**0**) will appear in the **Mn** column if the soil level is considered adequate. When **Mn-AI** is 25 or below, an application rate of 10 lb/acre will be suggested for nearly all field crops because they are known to respond well to Mn. If a rate is recommended for **Crop 1**, then a **\$** will appear on the line for **Crop 2** to remind the grower that **Crop 2** may need Mn if it is not applied to **Crop 1**.

When soil levels of Mn are low for crops without established response data (pastures, vegetables, etc.), a **\$** appears on the soil report. This symbol refers to the *\$ Note*, which provides further information on rates of application.

If soil pH is high enough to affect Mn availability, the **pH\$** or **\$pH** notations will appear in the **Mn** recommendations column. Refer to the *\$ Note* provided via hyperlink for specific recommendations.

Zinc (Zn)

Zinc application is suggested for specific crops if the Zn-availability index (**Zn-AI**) is 25 or below and, the crop is known to respond to Zn. The **Zn-AI** is calculated based on soil levels of Zn and other factors affected by soil class. The current recommendation for Zn is 6.0 lb/acre broadcast or 3.0 lb/acre banded, regardless of soil type.

If a rate is recommended for **Crop 1**, a **\$** symbol appears on the line for **Crop 2**. The **\$** draws attention to this nutrient as a reminder that **Crop 2** may need Zn if it was not applied to **Crop 1**. Whenever insufficient data regarding crop response are available, the **\$** symbol will appear when **Zn-AI** is 25 or below. The *\$ Note* provides further information on rates of application.

Potential zinc toxicity is indicated whenever **Z** appears in the **Zn** column of the **Recommendations** section of a report. For most

crops, the **Z** designation indicates that **Zn-AI** is greater than 2000 (the critical toxic level being 3000). However, in the case of peanut, which has a critical toxic level of 500, the **Z** notation indicates a **Zn-AI** value of 300 or more. Zn toxicity has occasionally been reported in peanut at a **Zn-AI** value as low as 250, especially under low pH situations. Management of pH is critical to reduce potential toxicity. Whenever **Z** appears on a soil report, check the **Agronomist's Comments** section for further information.

Copper (Cu)

An application rate for copper is provided if the **Cu-I** value is 25 or below for specific crops that have been shown to respond to fertilization. Uniform broadcasting and thorough incorporation contribute to optimum Cu response. If a rate is recommended for **Crop 1**, a **\$** will appear on the line for **Crop 2**. The **\$** draws attention to this nutrient as a reminder that **Crop 2** may need Cu if it was not applied to **Crop 1**. The **\$** will appear when **Cu-I** is 25 or below and when Cu response data are limited or unavailable. The *\$ Note* provides further information on rates of application.

A potential Cu toxicity is indicated whenever a **C** appears in the **Cu** column of the **Recommendations** section of a report. The **C** indicates that the **Cu-I** is greater than 2000. The critical toxic level is 3000. Whenever this notation appears on a soil report, check the **Agronomist's Comments** section for further information.

Boron (B)

Boron recommendations are made for crops that are known to respond to this micronutrient. Recommendations are based on field studies for specific crops. Actual levels of boron in soil are not measured due to the nutrient's high mobility in sandy soils, where many of the crops that require B are grown.

Test Results

The abbreviated headings that appear in the **Test Results** section of the soil report are explained briefly in Figure 1. Detailed explanations follow under the appropriate headings.

Many of the nutrients are reported as indices, which provide a relative scale of actual soil-test nutrient levels. Table 1 relates these index values to general nutrient availability and indicates the

Table 1. Crop Response to Fertilization as Related to Soil Test Levels

Index	Nutrient Status	Response* to Applied					
		P	K	Mn	Zn	Cu	S
0–10	Very Low	VH	VH	VH	VH	VH	VH
11–25	Low	H	H	H	H	H	H
26–50	Medium	M**	M**	N	N	N	M
51–100	High	N	L/N	N	N	N	L/N
100+	Very High	N	N	N	N	N	N

* Crop response to fertilizer is expected to be very high (VH), high (H), medium (M), low (L) or none (N).

** Response decreases as soil test index increases.

Table 2. Recommended Micronutrient Rates*

Soil Class	Banded		Broadcast			Foliar Spray		
	Mn	Zn	Mn	Zn	Cu	Mn	Zn	Cu
MIN	3	3	10	6	2	1/2	1/2	1/4
M-O	3	3	10	6	4	1/2	1/2	1/4
ORG	3	3	10	6	6	1/2	1/2	1/4

* Rates = lb element per acre.

Table 3. Soil Class Determinations as Based on Humic Matter and Weight per Volume

Soil Class	Humic Matter (HM%)	Weight/Volume (W/V) g/cc
Mineral	0–3.37	> 0.5
Mineral-Organic	3.4–5.2	> 0.5
Mineral-Organic	0–3.37	< 0.5
Organic	> 5.3	> 0.5
Organic	3.4–5.2	< 0.5

likelihood of crop response to fertilization. Table 2 shows micronutrient application rates by soil type, nutrient, and application method.

Soil Class

Each soil sample is classified as mineral, mineral organic or organic. These classifications are based primarily on humic matter percent (**HM%**), but in some cases, weight/volume ratio (**W/V**) is involved in class determination (Table 3). Each soil class has a different target pH: 6.0–6.5 for mineral soils, 5.5 for mineral-organic soils and 5.0 for organic soils. There are very few crops that have a target pH below 6.0 for mineral soils.

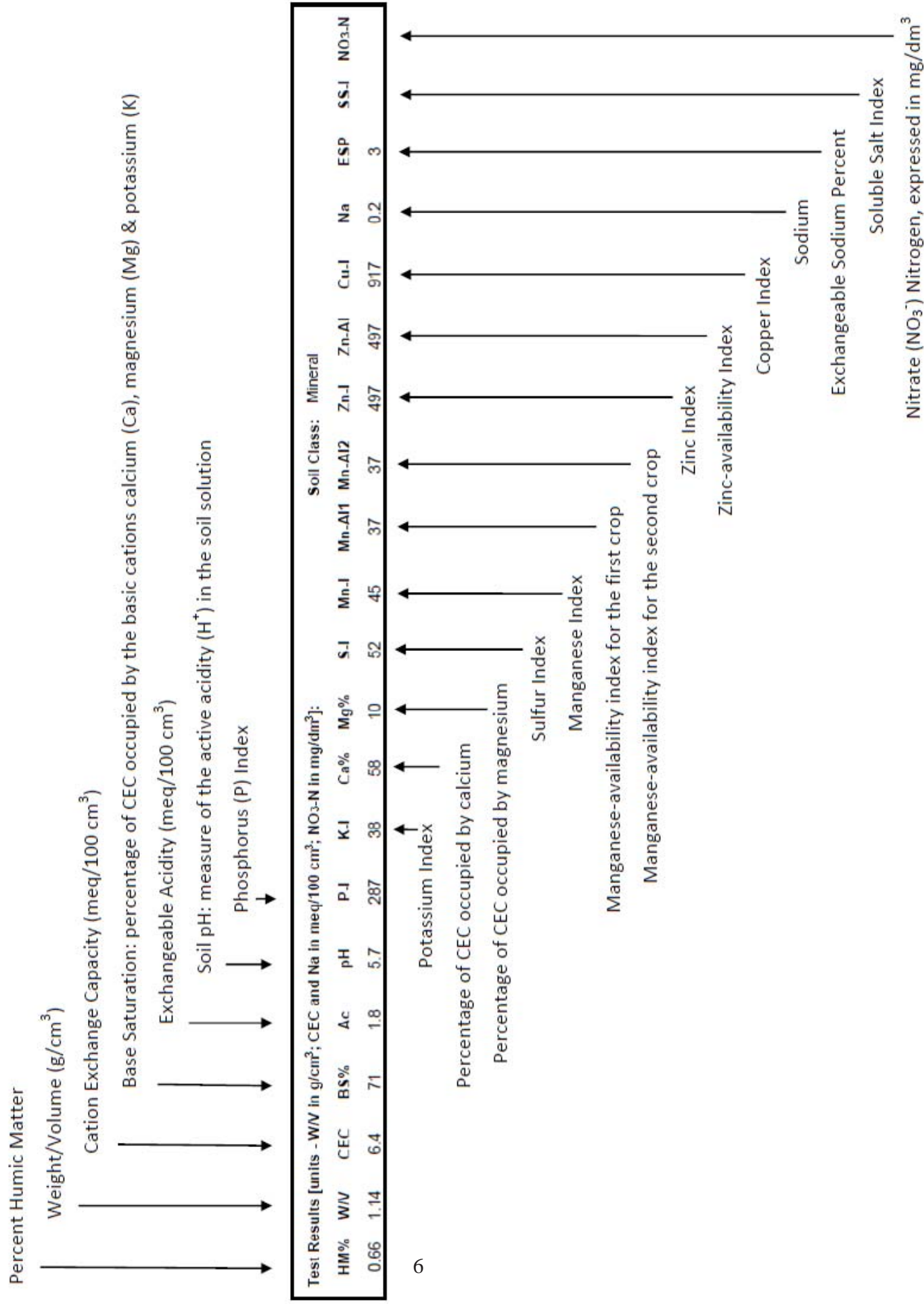
Mineral soils require a higher pH to neutralize exchangeable aluminum so that plant growth is not affected. Since mineral-organic and organic soils contain less exchangeable aluminum due to their lower mineral content or due to complexation with organic matter, a lower pH can be maintained without any detrimental effects to crop production. In addition, since mineral-organic and organic soils have much higher buffering capacity (resistance to change in pH in this case), it is not economically feasible or agronomically practical to apply lime at rates sufficient to raise the soil pH to 6.0.

Humic Matter (HM%)

Humic matter percent is a measurement of humic and fulvic acid components of soil organic matter, expressed on a volume basis. It represents the percentage of soil organic matter that is soluble in a dilute alkaline solution (NaOH). This portion represents the chemically active organic fraction used in determining lime rates.

Humic matter percent may or may not correlate with percent organic matter. For example, sandy soils have very low organic matter content and a correspondingly low **HM%**. In contrast, an organic soil could have in excess of 50% organic matter with a **HM%** of less than 0.10. In this case, such readings would imply that most of the organic matter has not yet decomposed to the humic and fulvic acid fractions. In general, as **W/V** increases, **HM%** usually decreases.

Figure 1. Explanation of Soil Test Results



Weight/Volume Ratio (W/V)

Weight/volume ratio, expressed in g/cm^3 , is used to classify the soil type of a sample. For example, a very sandy soil may have a **W/V** of 1.5 g/cm^3 , whereas the **W/V** of an organic soil may be as low as 0.5 g/cm^3 . Soils high in clay fall within these two extremes. **W/V** is generally inversely related to the cation exchange capacity (**CEC**) of the soil: that is, soils with a high **W/V** generally have a low **CEC**.

Cation Exchange Capacity (CEC)

CEC is a relative measure of the nutrient-holding capacity of a soil. It is expressed in units of meq/100 cm^3 and is determined by summation of extractable calcium, magnesium, potassium and exchangeable acidity (**Ac**). The **CEC** of North Carolina soils ranges from low ($< 2.0 \text{ meq/100 cm}^3$) for sandy soils to as high as 25 meq/100 cm^3 for clay and organic soils.

A high **CEC** is desirable because nutrients are less subject to leaching and adequate quantities of nutrient reserves can be maintained. However, sandy soils, by nature, have low **CEC**, and little can be done to change it. The **CEC** will vary with changes in soil pH, organic matter and clay content.

Base Saturation (BS%)

Base saturation is expressed as a percentage of the **CEC** that is occupied by basic cations, principally calcium, magnesium and potassium. Base saturation and pH are directly correlated: as pH increases, so does **BS%**. A higher **BS%** also corresponds to a lower level of soil acidity.

Exchangeable Acidity (Ac)

Exchangeable acidity represents that portion of the **CEC** that is occupied by hydrogen (H^+) and aluminum (Al^{+++}) and is expressed as meq/100 cm^3 . **Ac** is one of the measurements used in calculating the lime recommendation.

Current pH

The **pH** is a measure of the active acidity or the hydrogen ion (H^+) activity in the soil solution.

The **pH** value alone does not determine how much lime is required but is used in conjunction with exchangeable acidity (**Ac**) in determining lime rates. The **pH** determination is useful for indicating when too much lime has been applied and for evaluating micronutrient availability, particularly manganese.

Phosphorus (P-I) & Potassium (K-I) Indices

Levels of phosphorus and potassium are reported as indices. The index ranges are as follows: 0–10, very low; 11–25, low; 26–50, medium; 51–100, high; and 100+, very high.

When levels are low, plants will respond to addition of these nutrients. At medium levels, response will depend on particular crop needs. With high soil nutrient levels, crop response to fertilization is not generally expected. When soil-test indices are above 100, no fertilization is recommended, except for especially high-value crops. Crop responses can occur when not expected if other stresses such as cold, wet soil conditions are factors.

The fertilizer recommendation is based on soil-test results and varies with the crop to be grown. Refer to Table 1 for P and K ratings and expected crop response to fertilizer at given soil-test levels.

Calcium (Ca%) & Magnesium (Mg%) Percents

Levels of calcium and magnesium are reported as percentages of the **CEC**. For example, if **Ca%** is 62, then 62% of the soil's capacity to hold nutrients (**CEC**) is occupied by Ca. Ca determination is essential to calculate **CEC** and to evaluate relationship among Ca, Mg and K. However, no specific **Ca%** or **Mg%** values have been associated with ideal fertility.

In general, Ca is the predominant cation in most soils. It is seldom low enough in soil to cause crop deficiency. Peanuts are an exception, and for this crop, landplaster (CaSO_4) is a good source of supplemental Ca.

The **Mg%** value determines whether Mg should be added to the soil. Dolomitic lime or a

Mg fertilizer are both good sources. Multiplying **Mg%** by **CEC** gives the amount of Mg present in units of meq/100 cm³.

In general, Mg application is not necessary if

- **Mg%×CEC** is at least 0.5 meq/100 cm³ *or*
- **Mg%×CEC** is between 0.25 and 0.5 meq/100 cm³ and **Mg%** is greater than 10.

Mg application is necessary if

- **Mg%×CEC** is less than 0.5 meq/100 cm³ and **Mg%** is less than 10 *or*
- **Mg%×CEC** is no more than 0.25 meq/100 cm³.

When Mg is needed, the recommended rate is usually 25–30 lb/acre. The cheapest source is dolomitic lime since it contains 120 lb/ton. Additional information regarding Mg is provided in \$ *Note*.

Sulfur Index (S-I)

Sulfur is a mobile element. Therefore, it is most likely to be low in sandy soils, which have low organic matter and are prone to leaching. Sulfur is more abundant and usually adequate in piedmont and mountain soils due to their high clay content.

Recommendations are made when the **S-I** is 25 or less, depending on soil class. These recommendations are based on N.C. field studies conducted in corn and small grains in the mid-2000s.

In sandy topsoils that have clay within 16 inches of the surface, there can be appreciable amounts of S. This factor should be considered when evaluating S status and crop needs even when topsoil S levels are low. Under normal growing conditions, S is usually sufficient in organic soils.

Manganese Index (Mn-I)

Mn-I is an indicator of Mn levels in the soil. Since Mn availability is closely associated with soil pH, a Mn-availability index (**Mn-AI**) is calculated, depending on crop sensitivity to this element.

Manganese-availability Index (Mn-AI)

Two manganese indices are given on a soil report when two crops are specified on the sample information form. **Mn-AI1** is the manganese-availability index for **Crop 1**; **Mn-AI2** applies to **Crop 2**. **Mn-AI** values decrease as soil pH increases. Values above 25 are considered sufficient for most crops if the pH is 6.0 or below.

If **Mn-AI** is 25 or below, the report provides a hyperlink to \$ *Note* for fertilization suggestions.

Zinc Index (Zn-I)

Although **Zn-I** indicates the amount of Zn present in the soil, the actual availability of Zn is indirectly influenced by soil pH. It is the target pH of the soil class that dictates availability.

Zinc-availability Index (Zn-AI)

The **Zn-AI** is based on soil class as follows: 1.0×**Zn-I** for mineral soils, 1.25×**Zn-I** for mineral-organic soils, and 1.66×**Zn-I** for organic soils. The critical **Zn-AI** value is 25. When **Zn-AI** is above 25, zinc is considered sufficient for most crops.

Copper Index (Cu-I)

The **Cu-I** is a measure of plant-available copper in the soil. Adjustments in its availability are not made as they are for Mn and Zn. The **Cu-I** critical value is 25.

Sodium (Na)

Sodium is evaluated for all samples. Values less than 0.4 meq/100 cm³ are inconsequential to plant nutrition. However, on sandy soils, values of 0.4 to 0.5 meq/100 cm³ or greater may indicate that sodium accounts for 15 to 20% of the **CEC** as calculated by the exchangeable sodium percentage. Such levels could interfere with plant uptake of calcium, magnesium and potassium and also adversely affect soil structure. When **Na** is excessive, soluble salt levels may be high enough to cause root injury.

Exchangeable Sodium Percent (ESP)

Sodium (**Na**) levels may become too high in soils amended with industrial by-products, irrigation water high in sodium, or overspray of coastal waters during hurricanes. The acceptable limit for **Na** saturation of the **CEC**, also called exchangeable sodium percent (**ESP**), is generally 15%. **Na** levels higher than 15% of the **CEC** could result in soil dispersion, poor water infiltration and possible toxicity to plants. Note that the **CEC** value on the NCDA&CS soil report does not include **Na** in its calculation since **Na** levels are typically very low in N.C. soils.

Soluble Salt Index (SS-I)

SS-I indicates relative content of fertilizer salts within a soil after equilibrating for 4 hours in distilled/deionized water. Results are expressed in 10^{-5} mho/cm, which is a measure of electrical conductivity. Units can be converted to ds/m by dividing by 100.

This measurement is provided on all diagnostic soil reports and on routine reports whenever a

greenhouse crop code is specified. The explanatory Notes hyperlinked within the report explain the effect of soluble salts within specific greenhouse media. **Agronomist's Comments** are provided on diagnostic reports.

The submission of potting media (pine bark, perlite, vermiculite, etc.) as a soil sample is discouraged. The properties of such media are better evaluated through soilless media analysis, which uses saturated media extract (SME). This test is available from the NCDA&CS Agronomic Division for a fee of \$4 per sample.

Nitrate Nitrogen ($\text{NO}_3\text{-N}$)

This test indicates the level of $\text{NO}_3\text{-N}$ available at the time of sampling. Nitrate is a plant-available, water-soluble form of nitrogen. This test is conducted on a special-needs basis only. Since $\text{NO}_3\text{-N}$ leaches very readily and fluctuates considerably with rainfall and soil texture, $\text{NO}_3\text{-N}$ measurements have little predictive value. $\text{NO}_3\text{-N}$ is reported in mg/dm^3 , which is equivalent to parts/million on a volume basis.