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Clarifying soil testing: III. SLAN sufficiency ranges and recommendations

Given correct soil test results and the knowledge to interpret them, superintendents can determine proper amounts of nutrients to add to soils for healthy turf.

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EDITOR'S note:

This article and the one that precedes it are part of a continuing series on soil testing that began with "Clarifying soil testing: I. Saturated paste and dilute extracts" in the September 2003 issue of *GCM*.

Do accurate soil test data ensure that the recommendations from the data are accurate? Not necessarily. Sound interpretation of the data is also important. In the preceding article about the SLAN (sufficiency level of available nutrients) approach for soil testing, we discussed the importance of using an extractant appropriate to the soil conditions to ensure reliable soil test results (3). Once the data are available, they must be interpreted. In this article we discuss acceptable sufficiency levels for macronutrients, differences between test results from different labs and year-to-year variations.

Review of SLAN approach

Chemical extractants used in the SLAN approach to soil testing do not remove the total quantity of a particular nutrient. Rather, the fraction that is potentially available to the plant over the growing season is removed for analysis; it extracts a "quantity" of plant-available nutrient. For example, on a soil sample from a sand green, the lab used Mehlich III extractant and found that extractable potassium was 20 parts per million (ppm) (= 20 milligrams/kilogram). The total potassium contained in all soil minerals and organic matter would be much higher than the



Figure 1. If two different labs used two different extractants on two halves of a soil sample, both tests should produce approximately the same ranking if the extractants are reliable — even if the numbers differed.

amount that is extractable and available to the plant. Various soil fractions that contribute to

plant-available nutrients are noted in the companion paper (3).

Superintendents often ask what this value (quantity of potassium) means. Is the plant-available potassium level in the soil low, medium or high? For the Mehlich III extractant, this level of potassium (20 ppm) on a high-sand green would be ranked "low" based on the rankings in Table 1 (4,5,6,7).

- **Low range:** a high probability (80-100%) that applying the nutrient will elicit a growth response
- **Medium range:** approximately a 50% chance of getting a plant growth response from application of the nutrient; if supplemental fertilizer is not applied, growth will probably be limited, especially as the

KEY points

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Sound interpretation of data from soil test reports is important.

Superintendents must know the extractant used for each nutrient, the medium SLAN ranges and the numerical value for each nutrient.

Given the correct soil test results, a superintendent can estimate the amount of each nutrient needed by the soil.

season progresses

- *High range:* little or no crop response is expected from applying the particular nutrient
- *Very high range:* additional application of the nutrient may cause a nutrient imbalance or reduced growth in some cases.

Some soil test reports contain another range

called "very low." For turfgrasses, the medium range usually provides sufficient information to interpret the soil test data. Many laboratories report only the medium range or use the low, medium and high designations.

The ranges are based on *expected* growth responses. Sometimes superintendents fertilize turfgrass to increase stress tolerance (potassium) or to prevent a calcium defi-

ciency in the root system caused by high sodium or aluminum (often referred to as sodium or aluminum toxicities).

SLAN ranges and labs

Traditionally, ranges for various nutrients are based on the past 60 years of fertility studies, particularly on forages, agronomic and horticultural crops, with adjustments

SLAN RANGES

Nutrient	Soil	Medium sufficiency range (ppm)	Extractant
Phosphorus	all	15-30	Mehlich I
	all	26-54	Mehlich II
	all	15-30	Bray P1
	all	12-28	Olsen
	all	10-20	Morgan
Potassium	sands	75-175	NH ₄ OAc (pH 7.0)
	others	100-235	NH ₄ OAc (pH 7.0)
	sands	50-116	Mehlich III
	others	75-176	Mehlich III
	sands	50-100	Mehlich I
	others	90-200	Mehlich I
	all	155-312	Olsen
	all	120-174	Morgan
Calcium	all	200-350 [†]	Mehlich I
	all	500-750 [†]	Mehlich III
	all	500-750 [†]	NH ₄ OAc (pH 7.0)
	all	500-750 [†]	Morgan
Magnesium	sands	30-60	Mehlich I
	others	50-100	Mehlich I
	sands	60-120	Mehlich III
	others	70-140	Mehlich III
	sands	100-200	NH ₄ OAc (pH 7.0)
	others	140-250	NH ₄ OAc (pH 7.0)
	all	>100	Morgan
Sulfur	all	10-20	Ca(H ₂ PO ₄) ₂
	all	30-60	NH ₄ OAc (pH 7.0)
	all	15-40	Mehlich III

Note. The values in this table are from many sources and are typical. A particular laboratory may vary from these rankings for local soil conditions.

[†]Soils that have high CEC (>15 cmol/kg) may exhibit a higher "medium" sufficiency range. The "medium" sufficiency range in this table is based on sands or other soils with CEC <15 cmol/kg.

[‡]On sites receiving irrigation water high in sodium, the upper level of the sufficiency range should be used as a guideline (for example, for Mehlich III, this would be 750 ppm calcium or higher).

Table 1. Typical soil test SLAN sufficiency ranges for macronutrients using common extractants.

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made to fit perennial turfgrasses based on studies and the judgment of experienced university turfgrass scientists (1,4,5,6,7). Soil fertility research in most states has resulted in the development of extractants well adapted to the state or regional soils, and the soil test ranges have been correlated to plant growth within these locations. Since many individuals involved in agronomic or horticultural crop production use state or university lab results, recommendations have been developed to reflect fertility needs accurately. Thus, the ranges are often broken out for certain soil types.

Until about 10 or 15 years ago, using local state or university labs was the most common means of soil testing for golf courses, and many superintendents still use

this approach. Superintendents can contact the soil-test lab at their state or land grant university and request information on the extractants used and the soil test ranges related to turfgrasses. (Not all states have such publicly supported labs.) Online publications are available for several states (4,5).

More commercial laboratories have offered turfgrass soil testing, and these labs may test soils from many states or other countries. Sufficiency ranges may or may not be adjusted for the specific soil type or local conditions, which would be typical of state and university labs. Table 1 lists common sufficiency ranges for different extractants used for the various macronutrients based on a review of numerous sources, especially state and university labs, and the authors' experi-

ences. A specific laboratory may use somewhat different ranges, but these provide a general guideline. The authors have seen cases in which a fertilizer company will offer free soil testing to its customers, but the laboratory running the sample will use fertilizer ranges that are consistently higher than the guidelines in Table 1. This practice results in many samples showing low fertility levels when, in fact, the fertility status is medium or higher.

Using the guidelines

The ranges shown in Table 1 are for general comparisons and may differ for a specific soil. However, if a laboratory is using ranges that differ greatly from those in Table 1, superintendents may have cause for concern.

Comparisons of ranges of one extractant

AVERAGE SOIL TEST VALUES

Mehlich III Extractable

Location*	Phosphorus (ppm)	Potassium (ppm)	Calcium (ppm)	Magnesium (ppm)	Sulfur (ppm)	Sodium (ppm)	Soil CEC (cmol/kg)	Soil pH
Greens								
Desired†	26-54	50-116	500-750	60-120	15-40	<67	>3	6.0-7.5
California (39)	99	156	1346	174	139	174	9.9	7.1
Minnesota (12)	24	146	1660	160	13	10	7.8	7.0
Illinois (24)	105	170	2726	343	63	41	7.8	7.0
Louisiana/ Mississippi (18)	28	37	225	53	4	1	1.6	6.9
Florida (21)	85	88	544	91	20	48	2.1	6.5
Fairways								
Desired	26-54	75-176	500-750	70-140	15-40	<67	>3	6.0-7.5
Minnesota (12)	52	210	2,419	372	34	13.9	16.8	7.1
Illinois (24)	126	316	3,770	910	215	109	29.0	7.1
Louisiana/ Mississippi (18)	41	109	774	226	16	1	6.3	6.2

*Numbers in parentheses are the number of golf courses participating; two greens and two fairways were tested at each course.
†Based on data in Table 1.

Table 2. Average soil test values from different locations in the United States based on Mehlich III extractant (2).

versus another are general in nature and may vary for different soil types.

The values shown in Table 1 are for "all" soils or, in the case of potassium and magnesium, for "sands." However, the "all" category only applies to soils with a cation exchange capacity (CEC) less than 15 centimoles/kilogram. Soils with higher CEC values may have "medium" sufficiency ranges somewhat higher than those listed in the table.

Superintendents often attempt to maintain soil nutrient status in the "medium" range and then supplement with fertilization rather than trying to maintain high soil test values over time. Because turfgrasses are perennial and, therefore, have a longer growing season than most production crops, applying high rates of fertilizer for season-long use to achieve a high range can result in leaching or excessive fixing of some nutrients in the soil. Targeting a medium range and then spoon-feeding nutrients as needed results in efficient fertilizer use. In some cases, however, the target may be at the upper end of the medium range or even somewhat higher, as illustrated by the case of calcium (below).

Calcium sufficiency range

The calcium sufficiency range is of special interest. True calcium deficiencies, as evidenced by symptoms of calcium deficiency in shoots, are extremely rare. Of all the nutrients, calcium is most abundant in plant-available form, and the plant's nutritional needs for adequate growth are easily met. However, when high levels of either aluminum (pH < 4.8) or sodium (sodic soil or irrigation water high in sodium) are present in the root zone, these ions can displace calcium from root tissues and cause aluminum and sodium toxicities. Sodium also may cause sodic soil conditions. High aluminum levels are corrected by routine liming to pH > 5.0. In high sodium sites, gypsum is often applied to provide higher calcium levels in the soil. When high sodium is likely to be an ongoing problem, targeting somewhat near the top of the medium soil test range for calcium is suggested.

Thus, soil test results for calcium may be used for different purposes such as nutrition, preventing or alleviating root toxicities from aluminum or sodium, and preventing sodic conditions. The rate of calcium for each of these purposes may differ substantially. (For sodic conditions, other soil chemical parameters besides calcium level are taken into account to determine the rate of gypsum application.)

Soil test results: Golf courses vs. SLAN ranges

To find out how typical golf courses aligned with the SLAN ranges, Steve Davis coordinated a series of studies in which soil samples from greens and fairways from different regions within the United States were analyzed using Mehlich III extractant (Table 2). The Louisiana/Mississippi and Florida courses were all located on the coast from the panhandle of Florida to Louisiana. The soil from these courses had a very low CEC because the greens, in particular, have very small amounts of clay or organic matter.

Except for sulfur and phosphorus in Minnesota, all macronutrients were well within the sufficiency ranges for the California, Minnesota and Illinois greens. This is not surprising because the greens all exhibited ample CEC.

Higher CEC levels result in higher extractable levels of most macronutrients. A comparison of the values for greens and fairways within a region illustrates this point. For many of these courses, phosphorus fertilization, especially, could be reduced. In Minnesota, however, the average phosphorus test on greens showed results in the low range, indicating careful attention to minimizing phosphorus fertilization. The inherent sulfur levels appear to be low in Minnesota, and some sulfur may be required if it is not provided in another source such as potassium sulfate.

For the Louisiana-Mississippi greens, the average low SLAN levels for phosphorus, potassium, calcium, magnesium and sulfur reflect the combination of low CEC, very pure irrigation water (this was determined as part of the study) and high rainfall. Because of environmental conditions, applying high rates of nutrients on these soils will not build up the SLAN extractable levels.

Incorporating a good zeolite may raise CEC in these situations. Based on the average 1.6 CEC of these greens and assuming a zeolite with a CEC of 160 centimoles/kilogram, about 195 pounds of zeolite per 1,000 square feet (9,520.7 kilograms/hectare) would be required to raise the CEC to 2.6 centimoles/kilogram to a 4-inch (10-centimeter) depth (2). Other sand substitute materials have CEC levels less than 31 centimoles/kilogram and would require substantially higher rates. Spoon-feeding all macronutrients on a relatively frequent basis is the most effective means of maintaining adequate nutrients without, in most cases,

increasing SLAN levels.

Data such as those presented in Table 2 are valuable for "benchmarking" purposes, allowing superintendents to observe how their soil nutrient levels compare to others within their region's soil and climatic conditions.

Using SLAN information

Figuring supplement amounts

Information from the soil test report can be used to determine how much supplemental nutrient should be applied to turfgrass. At the beginning of the paper, we used the example of 20 ppm extractable potassium, which was ranked low, indicating that supplemental potassium would be necessary. It is possible to estimate *approximately* how much potassium to apply by using the difference from the low reading to the medium range.

$$\begin{aligned} &\text{Desired ppm (from Table 1)} - \\ &\text{Reported ppm} = \text{Deficit ppm} \end{aligned}$$

If the answer is negative, no fertilizer is needed.

To convert parts per million to pounds per acre, multiply parts per million by 2.

To convert pounds/acre to pounds/1,000 square feet, divide pounds/acre by 43.56.

The soil report shows that potassium is present in your sandy soil at 20 ppm using the Mehlich III extraction. To calculate the deficit:

$$\begin{aligned} &51 \text{ ppm} - 20 \text{ ppm} \\ &= 31 \text{ ppm deficit for potassium} \end{aligned}$$

$$31 \text{ ppm} \times 2 = 61 \text{ pounds/acre potassium required to correct the deficit}$$

To find the approximate potassium requirement:

$$\begin{aligned} &61 \text{ pounds/acre} \div 43.56 = 1.4 \text{ pounds} \\ &\text{potassium/1,000 square feet} \\ &\text{to correct deficit} \end{aligned}$$

Other considerations

However, regardless of the extractant used, the approximate quantity of supplemental potassium fertilizer is influenced by many factors in addition to the soil test. This is also true when considering fertilizer rates for other nutrients based on SLAN data. Important factors to consider are (2):

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- soil type: sandy soils vs. more fine-textured soils, which encompasses differences in CEC and leaching potential
- grass type
- climatic conditions
- length of growing seasons
- clippings removed or returned
- quality expectations
- traffic on the turf
- irrigation or no irrigation
- irrigation water quality, effluent and other nonpotable water
- balance of other cations

Typically, additional potassium above the estimated amount may be required on high-use turf to increase stress tolerance because the low end of the medium range may not be enough potassium to meet needs caused by stress from wear, drought and high temperatures. Additional potassium is also necessary when leaching is anticipated. Less leaching is expected in the arid Southwest than in subtropical Florida, even with similar sand media and CEC levels. Finally, supplemental potassium above the estimated amount is usually necessary when appreciable levels of other cations (especially calcium and sodium) are in the irrigation water or added as a result of management practices.

The necessity of integrating all of these factors, in addition to soil test results, has several implications. First, two soil samples may have identical extractable levels of a nutrient but the recommendation for total quantity of fertilizer to apply over the growing season may differ if the samples came from different sites that vary in the above conditions. Second, consideration of all of these factors demonstrates that development of a soil fertility program is site-specific (2). It is not unusual for a superintendent to use a consultant in the soil testing process, but as the on-site turfgrass professional, the superintendent is the best person to integrate all factors affecting annual fertilization needs, rates per application and times of application. An understanding of soil tests and their interpretation is a part of this process.

Nutrient imbalances

Initially, it appears that each nutrient is viewed separately under the SLAN approach. Could this result in imbalances? As noted above, SLAN soil test values are only the first approximation of the nutrient levels in the

soil. Once the soil test values have been established, superintendents must consider other important factors, including unusually high levels of competing cations either already present or expected to be added via irrigation, fertilization, liming or gypsum. For example, applying high rates of gypsum often results in higher rates of potassium and magnesium fertilization. In normal situations, without large additions of competing cations or materials that may tie up phosphorus, fertilizing at appropriate levels based on SLAN and the other factors outlined above will produce proper nutrient balances.

Other considerations for SLAN extractants

Two labs, two values

How do two laboratories analyze two halves of a single soil sample and arrive at different numerical values? Each specific chemical extractant will extract different absolute quantities of nutrients from the soil based on the strength of the extractant (a stronger acid would extract more nutrients than a weak acid). But, each extractant is correlated to plant growth responses so that a particular concentration of an extracted nutrient can be ranked as low, medium or high relative to the ability of the soil to supply the nutrient. If two different labs used two different extractants on two halves of a soil sample, both tests should produce approximately the same ranking if the extractants are reliable—even if the numbers differed. Therefore, superintendents should ask for the name of the extractant used for each nutrient and, at least, the medium sufficiency level range, as in Table 1.

Annual changes

Why do soil test levels change from year to year when the same lab and extractant are used? Extractable nutrient levels are somewhat dynamic and change seasonally and over longer time periods. Soil test values may change because of nutrient additions by fertilization, lime or irrigation water over the year; leaching or clipping removal of nutrients and, in some cases, conversion of the nutrient to forms that are less available to the plant and therefore are not extracted; or change in soil sample depth (for example, changing from 3 inches to 4 inches would dilute nutrient levels).

Key application points

- Request from the laboratory or consultant

the names of the extractants used for each nutrient (SLAN approach), the medium ranges for all SLAN extracted nutrients, and the numerical values for the extracted nutrients (for example, ppm phosphorus).

- Make sure that the SLAN ranges the laboratory uses are in general agreement with those widely used and adapted over time for turfgrasses.
- Use the SLAN information to determine the approximate annual fertilization need for the nutrient of interest. Adjust this approximate value based on the other factors that influence fertilization requirements. This will result in site-specific fertilization.

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