RE SEARCH

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Just what the grass requires: Using minimum levels for sustainable nutrition

Good turf performance can be achieved at lower nutrient levels.

In 2012, we introduced the minimum levels for sustainable nutrition (MLSN) as an alternative to conventional soil nutrient guidelines (7). Conventional guidelines are epitomized by the low, medium, high and very high classification scheme described in the third part of the "Clarifying Soil Testing" series published in *GCM* 10 years ago (1).

In light of recent trends in reduced inputs and increased sustainability, and taking newly published data into account, the conventional approach requires scrutiny and significant revision. Conventional guidelines are not only complex, they are also relatively static, without regular or systematic updates.

However, regular updates seem like a good idea, because many research projects suggest that high-quality turf can be produced at levels below the conventional guidelines (2,3,4,6,8). As an alternative to the conventional guidelines, the MLSN guidelines are an attempt to identify not the optimum levels for soil nutrients, but rather the minimum levels of soil nutrients at which we can be confident of good turf performance.

You may have seen the same thing yourself: high-quality turf with no problems, growing in a soil classified as low in one or more essential elements. The question then arises, if the soil is lacking in these elements, why is the grass performing so well? Adding a nutrient may change the soil test result to move the level up to a desired range, but if the nutrient addition has no effect on the grass performance, is it necessary?

How to use the MLSN guidelines at your facility

The MLSN guidelines (Table 1) take a new approach to soil test guidelines. Turfgrass managers will have two questions about fertilizer application, and the MLSN guidelines answer both of them. The first question is, "Does this element need to be applied as fertilizer?" As a follow-up to the first question, one also needs to ask, "If this element is required, how much should be applied?"

To answer the first question, simply compare the MLSN guideline value for an element to the soil test level for that element. If the element is below the MLSN guideline, or if the estimated use of that element will drop the soil to the MLSN guideline during the course of the growing season, then that element should be applied. If the element, as measured by the soil test, is above the MLSN guideline, and if estimated use of that element during the growing season will keep the soil above the MLSN guideline, then that element is not required as fertilizer.

In experiments with creeping bentgrass at Cornell University, a wide range of soil potassium levels were established in these research plots, but no benefit to applied potassium was observed even when the soil potassium levels were well below the conventional guidelines. **Photos by Micah Woods**

Penn A-1 creeping bentgrass grown in soils with decreasing levels of potassium from left to right; keeping soils at or above the MLSN guideline provides a level of safety that such deficiency symptoms will not occur.

This creeping bentgrass green at Takarazuka GC near Osaka, Japan, has calcium, magnesium and potassium levels not only below the conventional guidelines, but also below the MLSN guidelines, yet still has produced excellent turfgrass conditions since the soil was first tested in 2009.

To answer the second question, regarding how much of an element to apply, simply add enough of that element to keep the soil at or above the MLSN guideline at the end of the growing season. To calculate that, compare the soil test result to the MLSN guideline and to an estimate of how much of that element the grass will use.

To try the MLSN approach, you will need some recent soil test results from tests done using the Mehlich 3 extractant. You will also need an estimate of how much nitrogen will be applied to your turf in the upcoming year. Because nitrogen controls the uptake of other nutrients (5), we can use the nitrogen estimate to predict the grass's use of other elements.

Before making the calculations, we will make some assumptions about grass growth and the relationship between fertilizer applied to the two-dimensional soil surface and the soil test levels within the three-dimensional root zone. These include:

- The grass cannot use more of an element than it harvests.
- The growth and consequently the nutrient uptake are determined by the amount of nitrogen applied.
- The concentrations of macronutrients and secondary nutrients in the leaves will be estimated as in Table 2.
- One gram of an element spread over 1 square meter on the surface is equivalent to 4.4 ppm of that element in the root zone of 1 square meter to a 15-centimeter depth, and vice versa.
- One pound of an element spread over 1,000 square feet on the surface is equivalent to 22 ppm of that element in the root zone of 1,000 square feet to a 6-inch depth, and vice versa.

Minimum Levels for Sustainable Nutrition guidelines

Nutrient	Analytical test	Conventional guideline (ppm)	MLSN guideline (ppm)
Phosphorus	Mehlich 3	>50	18
Potassium	Mehlich 3	>110	35
Calcium	Mehlich 3	>750	360
Magnesium	Mehlich 3	>140	54
Sulfur	Mehlich 3	15-40	13

Table 1. Minimum Levels for Sustainable Nutrition (MLSN) soil guidelines for macronutrients and secondary nutrients. A full copy of the current MLSN guidelines is available at www.paceturf.org/PTRI/Documents/1202_ref.pdf

Example 1: Potassium

Let's say the potassium soil test level is 52 ppm, and we plan to apply 3 pounds of nitrogen/1,000 square feet in the upcoming year. How do we determine the potassium requirement to ensure we stay above the MLSN guideline for potassium of 35 ppm? As shown in Table 2, the grass is expected to use half (0.5) as much potassium as it does nitrogen. That is, we predict the grass will use 1.5 pounds of potassium/1,000 square feet, which is equivalent to a depletion of 1.5 * 22 = 33 ppm from the soil. Because we want to keep the soil at or above the MLSN guideline, the total amount of potassium required is the plant use (33 ppm or 1.5 pounds) added to the amount we want to ensure remains in the soil (35 ppm or 1.6 pounds). In our example, this is 68 ppm or 3.1 pounds. The amount of potassium in the soil

Expected leaf nutrient content

Nutrient	Expected % in leaf dry matter	Amount in proportion to nitrogen
Nitrogen	4	1
Potassium	2	0.5
Phosphorus	0.5	0.125
Calcium	0.5	0.125
Magnesium	0.2	0.05
Sulfur	0.2	0.05

Table 2. Expected leaf nutrient content and proportion relative to nitrogen. These values are suitable as a starting point for most turfgrass species. If site-specific data are available, those values can be substituted to further refine these calculations for a particular site.

From 2006 to 2009, more than 50 varieties of warm-season grasses were grown at the Asian Turfgrass Center research facility north of Bangkok in soils with nutrient levels below the conventional soil guidelines, yet the turf still met all performance goals.

test is 52 ppm (2.4 pounds). The amount required as fertilizer is the difference between the amount required (68 ppm or 3.1 pounds) and the amount actually present (52 ppm or 2.4 pounds), which comes to 16 ppm or 0.7 pound. Thus, the fertilizer requirement for potassium in this situation using the MLSN guidelines is 0.7 pound potassium/1,000 square feet.

Example 2: Magnesium

If the soil test level for magnesium is 75 ppm and we plan to apply 3 pounds of nitrogen/1,000 square feet in the upcoming year, how do we determine the magnesium requirement to ensure we stay above the MLSN guideline for magnesium of 54 ppm? As shown in Table 2, we expect the grass to use 20 times more nitrogen than magnesium. That is, we predict the grass will use 0.15 pound of magnesium/1,000 square feet (3 pounds nitrogen * 0.05 = 0.15), which is equivalent to a depletion of 0.15 * 22 = 3.3 ppm from the soil. We want to keep the soil at or above the MLSN guideline, so the total amount of magnesium required is the plant use (3.3 ppm or 0.15 pound) added to the amount we want to ensure remains in the soil (54 ppm or 2.5 pounds). In our example, this is 57.3 ppm or 2.6 pounds. The amount on the soil test is 75 ppm (3.4 pounds). The amount required as fertilizer is the difference between the amount required (57.3 ppm or 2.6 pounds) and the amount actually present (75 ppm or 3.4 pounds). Because the amount present is more than the amount required, we do not need to apply any magnesium to keep the soil above the MLSN guideline.

How the guidelines were developed

We started with soil test data from the PACE Turf database. This consisted of data from more than 17,000 individual soil samples, each drawn from a stand of turf that was performing well. Because the data in those samples were from sites where turf performance was good, we could expect that whatever the nutrient levels were at those sites, those levels would be sufficient to produce turf that performed well. Then we filtered the data, selecting only the data from sites with a cation exchange capacity (CEC) less than 6 $cmol_c$/kilogram.

This filter removed all the soils with high nutrient-holding capacity from the working data set. We wanted to look at only the soils that had a relatively low nutrient-holding capacity, yet still produced good turf conditions, to investigate and identify the individual nutrient levels in those soils. For the MLSN guidelines, we assume that if there is enough of an element to produce good turfgrass in a low-nutrient-holding soil (such as a sand root zone from a golf course putting green), then the same amount of that element will be sufficient to produce good turfgrass conditions in a more nutrient-rich soil that has a higher CEC. We think that if there is enough of an element to produce good turfgrass in a sand root zone on a golf course putting green, then the same level of that element in a soil-based green or on a golf course fairway will produce good turfgrass as well.

We added one more filter to the data. This was for pH. We selected only those samples with soil pH from 5.5 to 7.5. The purpose of this was to develop guidelines that would be accurate for a range of elements using the widely used Mehlich 3 soil test extractant. When soil pH is less than 5.5, we recommend application of liming materials to reduce soluble aluminum, to increase soil microbial activity and to reduce the risk of toxic soil-soluble ammonium levels. Because of that, there was no reason to include soils with a pH of less than 5.5 in the data set.

In soils with a pH above 7.5, there is a high probability that the Mehlich 3 extractant may dissolve some soil minerals that contain calcium or magnesium. Such dissolution would have introduced error into the guidelines, which we avoided by selecting for a pH range at which mineral dissolution is minimal, and above which magnesium and calcium would not be deficient.

After the two filters were applied, we were left with a working data set of more than 1,500 soil samples. These were from turf that performed well, had a relatively low CEC typical of golf course putting greens or relatively sandy soil, and a pH of 5.5 to 7.5. Because all of these soils were producing good turf, one could conclude that all the soils had sufficient nutrients, so anything at or above those nutrient levels would be fine. Rather than divide the data from these soils into low, medium and high classifications, we took a different approach, in which we modeled the distribution of the data for each element (7).

Nutrient concentrations in the soil are a continuous random variable with a minimum possible value of zero and a virtually unlimited maximum possible value. We analyzed the filtered data set using EasyFit distribution-fitting software from Mathwave (www.mathwave.com) and found a good fit for each element in these soil test results with a three-parameter log-logistic distribution. From this modeled distribution, based on the actual data from turfgrass sites that had good performance, we identified the MLSN guidelines. A visual representation of the cumulative distribution function is shown for the potassium data in Figure 1 and for the phosphorus data in Figure 2.

If we look at the data for potassium, for example, we see the cumulative proportion of the samples at any particular level as we go from 0 to 280 ppm. The conventional guidelines would seem to be taking a number of sites with good performance and then choosing to target the higher end of that range as a guideline.

MLSN potassium data

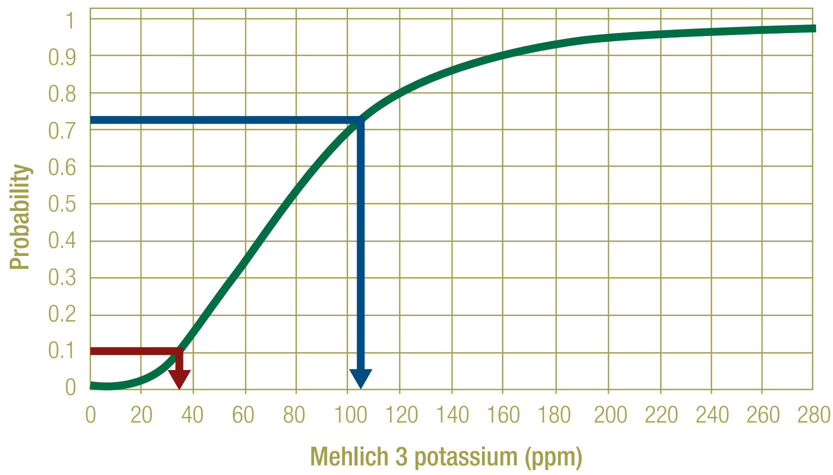

Figure 1. The cumulative distribution function for the potassium data was used to identify the MLSN guideline. At the 0.1 probability level, 10% of the samples report potassium values lower than 35 ppm (red line). This is the potassium MLSN guideline. The blue line indicates the conventional guideline of 110 ppm for potassium. Seventy-two percent (probability = 0.72 = sustainability index) of the samples report values lower than the conventional potassium guideline.

MLSN phosphorus data

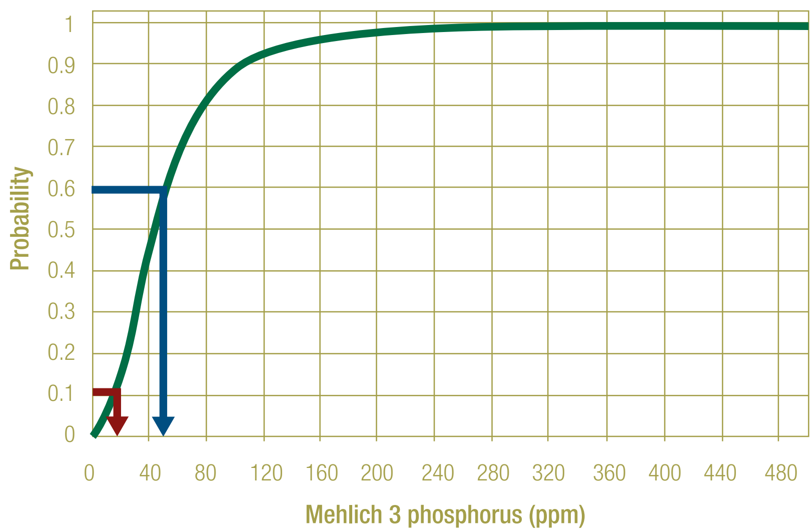

Figure 2. The cumulative distribution function for the phosphorus data was used to identify the MLSN guideline. At the 0.1 probability level, 10% of the samples report phosphorus values lower than 18 ppm (red line). This is the phosphorus MLSN guideline. The blue line indicates the conventional guideline of 50 ppm for phosphorus. Fifty-nine percent (probability = 0.59 = sustainability index) of the samples report values lower than the conventional phosphorus guideline.

High-performance turf at Keya GC near Fukuoka, Japan, is maintained in soils with sulfur and magnesium near the MLSN guideline and potassium below conventional guidelines. Adding data from sites like this helps to improve the accuracy of the guidelines as they are updated.

With MLSN, we take a different approach, taking the data from thousands of sites with good performance, assuming that there must be enough nutrients available to produce good turf because the sites are already performing well, and then selecting a conservative value at the 0.1 level at the lower end. Because we have already omitted the sites with bad performance from our data set, we can have some confidence that these apparently low levels are sufficient to meet the requirements of the grass.

Four advantages of this approach

1. The guidelines are based on real data from actual turfgrass sites. We worked only with a data set from sites with good performance, omitting soil test results from problem areas and nutrient-deficient soils. The modeled distribution is a mathematical representation of the soil nutrient levels as they are distributed on actual turfgrass sites. Because the data are carefully selected from soils that are already producing good turf, there is a layer of safety in the model. That is, any clearly deficient soils were not included in the model, so the results are not skewed lower by nutrient-deficient soils.

2. Once the model has been fit to the actual data, we can select a base level we wish to stay above. Again, this model and the associated level are based on the actual nutrient levels in the soil at sites where turfgrass performs well. We chose the nutrient level coinciding with the 10th percentile to define the MLSN guideline for each element. At this level, 10% of the samples in the data set would have a lower soil nutrient level than the selected MLSN guideline.

3. We can calculate a sustainability index for each element, based on a comparison of the concentration of that element on a soil test with the modeled MLSN distribution for that element. The sustainability index is the proportion of the modeled distribution that reports values lower than the sample soil test value. This is a metric that assists turf managers in the evaluation of soil nutrient levels over time. It also provides a guide for the development of nutrient management programs. Perhaps most important, the sustainability index identifies and rewards the restriction of nutrient inputs when they are not necessary to meet turf performance goals.

4. The MLSN guidelines are easily updated as we add new data from turfgrass sites with good performance (see the sidebar on page 138).These guidelines are self-correcting. Using this method and continuously adding to the reference data set with soil test data from turfgrass sites that perform well, we will see the guidelines move up if they are too low or down if they are too high. In short, these guidelines are designed to be updated as the core data set grows, and the MLSN guidelines will adjust based on samples added to the data set from turfgrass that performs well on various soils and across a wide geographic range.

Additional Information

For more about these guidelines, videos explaining the guidelines, and a link to the most current version of the guidelines, see: www.paceturf.org/journal/minimum_level_for_

Global Soil Survey for Sustainable Turf

PACE Turf and Asian Turfgrass Center have teamed up to administer a citizen scientist project known as the "Global Soil Survey for Sustainable Turf."

The survey hopes to enlist the participation of superintendents from around the globe in an effort to validate and expand upon the Minimum Levels for Sustainable Nutrition (MLSN) soil guidelines described in this article, and in so doing, contribute to positive changes in the way turf is fertilized.

Participants in the survey will receive a sampling kit that allows them to collect soil samples from three areas of turf that performs well at their facility. These samples will be analyzed by Brookside Labs for nutrient content, and the data will be added to the PACE Turf/Asian Turfgrass Center database and analyzed. The result will be new and improved sustainable guidelines for turf nutrition that will be publicly shared with the turf community.

If you are interested in learning more about the Global Soil Survey, read more at: www.paceturf.org/journal/global_soil_survey

The RESEARCH SAYS

- Turf soil nutrient requirements for several key elements may be much lower than previously thought.
- The Minimum Levels for Sustainable Nutrition (MLSN) guidelines are a new, more sustainable approach to turfgrass nutrition.
- Use of the MLSN guidelines can result in dramatic cost savings, and an improved environmental profile, without a loss in turf quality.
- The guidelines were developed using data collected from thousands of soil samples from turf that performed well.
- The concept of a "sustainability index" — a tool for measuring progress toward reduced inputs — is introduced.

sustainable_nutrition. To join other turfgrass managers from around the world in a discussion of these guidelines or to pose questions about the guidelines, go to the MLSN page on Facebook: www.facebook.com/mlsnturf. For even more examples of how the MLSN guidelines fit into turfgrass nutrient requirements and how these requirements can be calculated, download Understanding Turfgrass Nutrient Requirements at: http://calendar.asianturfgrass.com/understanding_turfgrass_nutrient_requirements_5june2012.pdf.

Acknowledgments

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