A Method for Estimating Turfgrass Nutrient Requirements[1]

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Turfgrass nutrient requirements are related to the growth rate of the grass. The amount of an element necessary to apply as fertilizer can be determined based on the amount of that element in the soil and on the growth potential of the grass for a specified time period. If there is more of an element in the soil than the grass requires, then none of that element needs to be added as fertilizer. This presentation describes the procedures involved in estimating minimum fertilizer requirements based on the amount of an element harvested, the amount needed in the soil, and the amount actually present in the soil.

[1] This handout is a supplement to the presentation made on this topic at Keilir Golf Club at a meeting of the Icelandic Green and Groundskeepers Association. For more information, see `http://www.asianturfgrass.com/turf-information.html` and `http://www.blog.asianturfgrass.com/fertilizer/`.

THIS METHOD for estimating turfgrass nutrient requirements is based on five interrelated principles. These are summarized here.

The elemental content of fertilized turfgrass leaves is relatively constant

As grass grows, and leaves are cut off through mowing, mineral nutrients are removed from the plant. If the clippings are harvested (boxed off), the effect is the same as if the soil had been mined of those elements. But the concentration of elements in leaves is not a mystery. The elemental content remains relatively constant, with the normal concentrations shown in Table 1. These values are consistent with hundreds of leaf samples I've studied in my research, and with research on different species of cool-season grass[2] in England.

Element	%
Nitrogen	4
Potassium	2
Phosphorus	0.5
Calcium	0.4
Magnesium	0.2
Sulfur	0.2
Iron	0.01
Manganese	0.005

Table 1: Normal levels of mineral elements in the dry matter of turfgrass leaves

[2] David Lawson. Leaf nutrient analysis. *International Turfgrass Bulletin*, (205): 26–29, July 1999

The amount of nitrogen supplied to the grass controls growth and uptake of the other nutrients

Turfgrass managers know that adding more nitrogen will cause grass to grow more quickly. This necessarily results in more uptake of the other nutrients. In an intensive investigation[3] of nitrogen, growth, and nutrient demand, Kussow et al. found:

> N supply was the primary determinant of turfgrass growth rate, plant nutrient demand, and nutrient uptake. Nitrogen uptake accounted for over 88% of uptake of all other nutrients. Uptake of P and K were strongly related to tissue N content irrespective of soil test levels.

The full paper can be read or downloaded at `http://www.hindawi.com/isrn/agronomy/2012/359284/`.

[3] Wayne R. Kussow, Douglas J. Soldat, William C. Kreuser, and Steven M. Houlihan. Evidence, regulation, and consequences of nitrogen-driven nutrient demand by turfgrass. *International Scholarly Research Network*, 2012:1–9, 2012

A temperature-based growth potential can predict how much nitrogen the grass will use

THE GROWTH POTENTIAL (Equations 1 and 2) was developed by PACE Turf [4] to describe the relationship between turfgrass growth and temperature. Cool season (C_3) grasses have their greatest growth rate when the temperature is about 20°C, with slower growth at lower[5] or higher temperatures; warm-season grasses (C_4) have their greatest growth rate when the temperature is about 31°C, with slower growth at cooler temperatures. The growth potential equations provide a simple way to predict that growth.

[4] Wendy Gelernter and Larry Stowell. Improved overseeding programs 1. The role of weather. *Golf Course Management*, pages 108–113, March 2005

[5] It is likely that *Festuca rubra* and *Poa annua* optimum growth temperatures may be less than 20°C. I suggest making adjustments in the optimum temperature until the calculated growth potential matches the observed turfgrass response in your location.

$$GP = e^{-0.5\left(\frac{t-t_o}{var}\right)^2} \tag{1}$$

GP = growth potential, on a scale of 0 to 1
e = 2.71828, a mathematical constant
t = actual temperature
t_o = optimum temperature, 20 for C_3 grass, 31 for C_4 grass
var = adjusts the change in GP as temperature moves away from t_o; I use 5.5 for C_3 and 8.5 for C_4

This equation gives the same result.

$$GP = \frac{1}{e^{0.5\left(\frac{t-t_o}{var}\right)^2}} \tag{2}$$

We can make use of the growth potential by relating the nitrogen requirement of the grass to the growth potential. Empirical observations of turfgrass growth rates and nitrogen amounts to create the desired playing conditions for turfgrass in 2013 allow us to estimate a maximum monthly nitrogen use rate[6] of about 2 g N m^{-2} mo^{-1} for *Festuca rubra* and *Agrostis canina*, 3 g N for other *Agrostis* species, and more than 4 g N for *Poa annua*, *Poa pratensis*, and *Lolium perenne*. We can then simply calculate the estimated nitrogen requirement for a given amount of time by multiplying the growth potential times the maximum nitrogen rate.

[6] This estimate is general and only serves as a starting point. Every site will have a slightly different maximum level, based on the grass species and the desired growth rate of the grass. We can make the grass grow faster with more nitrogen, and slower with less nitrogen, and these values are based on standard conditions.

The growth potential can be calculated on a daily, weekly, or monthly basis, with a corresponding nitrogen requirement, to estimate how much nitrogen fertilizer may be required by the grass during that time period. Note that these estimates are of how much nitrogen the grass will use, so fertilizer nitrogen applications should be made in advance to supply the desired amount of nitrogen during the given time period.

The MLSN guidelines ensure that soil nutrient levels remain high enough to produce excellent turf conditions

Dr. Larry Stowell from PACE Turf (`http://www.paceturf.org/`) and I have developed the minimum levels for sustainable nutrition (MLSN) guidelines for interpreting Mehlich 3 soil test results for turfgrass.[7] The MLSN guidelines are simple, and they are based on a rigorous review of soil tests from good-performing turfgrass sites.

[7] The Mehlich 3 extracting solution is a widely-used standard method for soil tests and the solution contains 0.2 *N* acetic acid, 0.25 *N* ammonium nitrate, 0.015 *N* ammonium flouride, 0.13 *N* nitric acid, and 0.001 *M* EDTA with a pH of 2.5.

From a database of over 16,000 soil samples, we selected those that are classified as having good turf, that have a pH in the range of 5.5 to 7.5, and those with a low estimated cation exchange capacity of less than 60 $\text{mmol}_c\ \text{kg}^{-1}$. This selected about 1,500 samples, from which Dr. Stowell fit a log-logistic model to the observed soil test data. This allows us to define the soil nutrient concentration at which a certain amount of the soil tests are above or below a certain level.

For the MLSN guidelines (Table 2), we chose the 10% level to set the target guidelines, meaning that 10% of the samples in the database were below the guideline but were still performing well. The goal of the MLSN guidelines is to provide a scientific and data-based approach to interpreting soil tests for turfgrass sites, making sure that there is a high probability of good turfgrass performance, while minimizing unnecessary application of fertilizer. These guidelines are intended to simplify and replace the impossibly convoluted conventional guidelines.[8]

Element	MLSN (ppm)
Potassium	35
Phosphorus	18
Calcium	360
Magnesium	54
Sulfur	13

Table 2: The minimum levels for sustainable nutrition (MLSN) guidelines as of 1 September 2013

[8] R.N. Carrow, L. Stowell, W. Gelernter, S. Davis, R.R. Duncan, and J. Skorulski. Clarifying soil testing: III. SLAN sufficiency ranges and recommendations. *Golf Course Management*, 72(1): 194–198, January 2004

By considering the previous points, mathematically, the minimum nutrient requirement can be determined

We can estimate the nutrient harvest based on a nitrogen-controlled growth rate and the typical leaf nutrient content. We can measure the amount of each element in the soil and can compare the soil amount[9] to the MLSN guideline. Then, it is a simple matter to calculate how much of each element may be required as fertilizer. The objective is to ensure that the soil level remains at or above the MLSN guideline. If the amount of an element in the soil is above the MLSN guideline, we are confident that the turf can perform at its highest level.

[9] In making calculations about soil concentrations and amounts of a mineral element applied to the surface, it may be useful to use a conversion factor. The turfgrass rootzone is often at a depth of about 10 cm. In that case, in a sand rootzone, 1 m^2 to a depth of 10 cm has a mass of 150 kg. One gram of any element applied to 1 m^2 and distributed evenly throughout the top 10 cm is expected to increase the amount of that element in the soil by 6.7 ppm. Likewise, the harvesting of that element will decrease the amount of that element in the soil by 6.7 ppm for each gram of element harvested in 1 m^2.

The estimated N use can be calculated from Equation 1 or 2 and then multiplying the growth potential by the maximum N use. Based on an average leaf N content of 4%, we can estimate clipping yield per unit area simply by dividing the estimated N use by 0.04. Then, for any element, we can calculate its estimated harvest by multiplying the clipping yield per unit area by the average leaf content of that element, as shown in Table 1.

Once we have the necessary information, it is simple to determine how much of an element we need to apply as fertilizer. We know that at the MLSN level (Table 2), there is enough of that element in the soil to produce excellent turfgrass conditions. So we want to make sure the soil has the nutrient at or above the MLSN level. The amount A in equation 3 gives us the total amount of an element needed in the soil to keep the soil above the MLSN guideline.

$$A = MLSN\,(g\,m^{-2}) + Harvest\,(g\,m^{-2}) \tag{3}$$

To find how much of an element needs to be applied as fertilizer (F), we then subtract the actual amount on a soil test, which we can denote as $Soil_{test}$ and express in units of g m^{-2}.

$$F\,(g\,m^{-2}) = A - Soil_{test} \quad (4)$$

If F is a positive number, that is amount of the element required to keep the soil above the MLSN guideline. If F is a negative number, that element is not required as fertilizer.

Seminar questions and additional information

A question was raised regarding the relatively accuracy or practical use of leaf tissue tests vs. soil tests. Leaf tissue tests are not especially useful in determining what nutrients are required. This is because turfgrass leaves tend to have relatively constant elemental content in the leaves, even though the soil nutrient levels can be varying widely. The leaf tissue tests are accurate, but they are not useful in determining if a nutrient should be applied as fertilizer. Therefore, I find leaf tissue tests interesting from a research perspective, but of limited to no value in general turfgrass maintenance.

We discussed a series of soil tests done on football fields in Iceland. Those tests showed that P was low and based on the test it was recommended that P should be applied. However, the turfgrass performance on these fields was fine. This is not unusual or unexpected. Soil nutrient guidelines for turfgrass tend to be higher than what is actually required to produce excellent turfgrass conditions. In short, most nutrient guidelines are too high. As an example, Ebdon et al.[10] saw "no observed changes in shoot and root growth in response to K fertilization even at low soil test K levels." These type of results are well-documented, and are a strong indication that conventional guidelines are not correct. The new MLSN guidelines, shown in Table 2, are the most accurate guidelines I am aware of.

[10] J.S. Ebdon, M. DaCosta, J. Spargo, and W.M. Dest. Long-term effects of nitrogen and potassium fertilization on perennial ryegrass turf. *Crop Science*, 53:1750–1761, 2013

The MLSN guidelines and the Global Soil Survey are developed using the Mehlich 3 soil test extractant. If other soil test extractants are used, the MLSN guidelines are difficult (or in some cases, impossible) to use. For calcium, magnesium, and potassium, however, most soil tests will return a similar value. Some information on conversion equations between Mehlich 3 and other extractants, with the work done by Ketterings et al. at Cornell University, can be found here: `http://nmsp.cals.cornell.edu/publications/soilconversion.html`.

For more information about the MLSN guidelines, see `http://www.paceturf.org/journal/minimum_level_for_sustainable_nutrition`. A new project, the Global Soil Survey (`http://www.paceturf.org/journal/global_soil_survey`), allows turf managers from around the globe to participate in the development and implementation of new guidelines.