Nutrient Requirements of Tropical Turfgrass[1]

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[1] This handout is a supplement to the presentation given on this topic at the Sustainable Turfgrass Management in Asia 2013 conference at Pattaya, Thailand.

High performance turf requires enough nutrients, and an important question turfgrass managers must answer is "what amount of each mineral nutrient should I supply to the grass?" By looking at what is in the grass and estimating how much is harvested when leaves are removed from the plant, we can estimate how much of each element is used. Another, more general approach, is to use the temperature-based growth potential (GP) to predict the growth and the nutrient use of the grass. Once we have that estimate of nutrient use, we can compare the amount used to the amount available in the soil, and that information forms the basis for the development of a science-based and efficient fertilizer program.

The logical place to start is to look at what is in the grass leaves. There are 14 essential mineral elements for plants (Table 1) and 3 essential nonmineral elements. The nonmineral elements, carbon, hydrogen, and oxygen, are taken up by plants as carbon dioxide from the atmosphere and as water from the soil. Mineral elements are taken up by the roots and a portion of them can also be absorbed through the foliage.

Nonmineral	Mineral
Hydrogen	Nitrogen
Oxygen	Phosphorus
Carbon	Potassium
	Calcium
	Magnesium
	Sulfur
	Boron
	Chlorine
	Iron
	Manganese
	Zinc
	Copper
	Molybdenum
	Nickel

Table 1: The 17 essential elements for plants, divided into nonmineral and mineral

Leaf nutrient content and the controlling role of nitrogen

If we were to analyze the grass leaves for mineral nutrient content, we would find nitrogen in the largest amount, usually at about 4%, then potassium, usually at about 1.5% to 2%, and then phosphorus and calcium, which are found in similar amounts, usually just under 0.5%. Table 2 shows the relative amounts of the eight mineral elements found in the highest concentration in leaves.

Element	Percent %
Nitrogen	4
Potassium	2
Phosphorus	0.5
Calcium	0.5
Magnesium	0.2
Sulfur	0.1
Iron	0.01
Manganese	0.005

Table 2: Approximate percentage of the most abundant mineral elements in the leaves of many turfgrass species

Grass will grow faster when more nitrogen is applied. But turfgrass managers apply less nitrogen than the grass can use. It is important to recognize that turfgrass managers use this technique to produce the desired growth rate and the desired turfgrass conditions. For both cool-season[2] and warm-season grasses[3], the actual amounts of nitrogen applied to the turf are considerably less than what the grass can use.

Because nitrogen is the mineral element required in the largest amount by the grass, and because nitrogen supply is always less than the grass can use, it becomes apparent that nitrogen controls clipping production and thus nitrogen also controls the turfgrass uptake of the other essential elements.

[2] Wayne Kussow and Steven Houlihan. The new soil test interpretations for Wisconsin golf turf. *The Grass Roots*, pages 19–25, May-June 2006

[3] E.A. Guertal and D.L. Evans. Nitrogen rate and mowing height effects on TifEagle bermudagrass establishment. *Crop Sci.*, 46:1772–1778, 2006; and L.E. Trenholm, A.E. Dudeck, J.B. Sartain, and J.L. Cisar. Bermudagrass growth, total nonstructural carbohydrate concentration, and quality as influenced by nitrogen and potassium. *Crop Sci.*, 38:168–174, 1998

How much is removed by mowing

MOWING REMOVES NUTRIENTS from the grass by cutting the leaves. In the situation where clippings are returned to the turf, most of the nutrients are recycled by the turf. When clippings are harvested, as is the common practice on golf course putting greens and other high maintenance turfgrass areas, the nutrients in the leaves are removed with the clippings.

During periods of active growth, when maintained using standard management techniques and nitrogen rates, I estimate that maximum clipping removal from turfgrass[4] may be about 100 to 125 grams of dry matter per m^2 per month.

One of the ways we can determine the nutrient requirement is simply to replace the nutrients that are removed by mowing. However, we cannot measure the exact amount of leaf clippings that are harvested. Also, the growth rate of the grass changes throughout the year in response to temperature, soil moisture, and light intensity. Because we are not able to measure the exact nutrient loss by mowing, a general model of growth can help us to predict nutrient requirements.

[4] Tim L. Springer. Biomass yield from an urban landscape. *Biomass and Bioenergy*, 37, 82-87 2012

Temperature-based growth potential

THE GROWTH POTENTIAL (Equations 1 and 2) was developed by PACE Turf [5] 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 or higher temperatures; warm-season grasses (C_4) have their greatest growth rate when the temperature is 31°C or above, with slower growth at cooler temperatures. The growth potential provides a simple way to predict that growth.[6]

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

GP = growth potential, on a scale of 0 to 1
e = 2.71828, a mathematical constant
t = average temperature for a location, in °C
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.

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

Figure 1 shows the growth potential as calculated by equation 1 across the range of temperatures from 0 to 31°C. For warm-season grasses, the growth potential rises above 0.1 at 13°C. We can interpret a growth potential of 0.1 as being 10%, and at that tempera-

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

[6] A more complex growth model would require information that is not readily available, namely the maximum potential growth rate of a specific grass variety combined with, at a minimum, knowledge of the effect of temperature, plant water status, leaf nitrogen content, and photosynthetic irradiance on the growth of the grass. The temperature-based growth potential is a simplification but it is easy to use and effective as a planning and management tool.

For the equations using the Fahrenheit temperature scale, see Gelernter & Stowell (2005). Use a variance of 7 for C_4 grasses if you want to match almost exactly the results of Gelernter & Stowell. Variance of 8.5 predicts slightly more growth away from the optimum temperature than does the original equation.

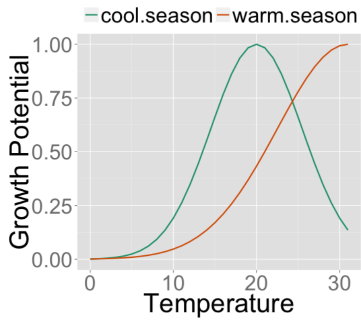

Figure 1: The predicted growth potential for cool-season (C_3) and warm-season (C_4) grasses

ture, all other things being equal, the grass would have the potential to grow at about 10% of its maximum rate. At a temperature of 17°C the growth potential for warm-season grass reaches 0.25, and this model predicts that 21°C is an average temperature at which growth potential will be 0.5.

Above an average temperature of 25°C, this model predicts warm-season grass will have a growth potential more than 0.75. For cool-season grass, the growth potential declines quickly[7] above a temperature of 25°C. At a location such as Bangkok or Singapore, the average temperature is always above 25°C, and thus the warm-season growth potential is always above 0.75 in those locations. In looking at Hong Kong, Shanghai, and Sydney (Figure 2) we can see the seasonal changes that occur in growth potential.

[7] The reason for this rapid decline is **photorespiration**, which increases more rapidly than photosynthesis as temperatures rise above 20°C. **Photorespiration**, which occurs in C_3 grasses but not in C_4 grasses, essentially undoes the reactions of photosynthesis.

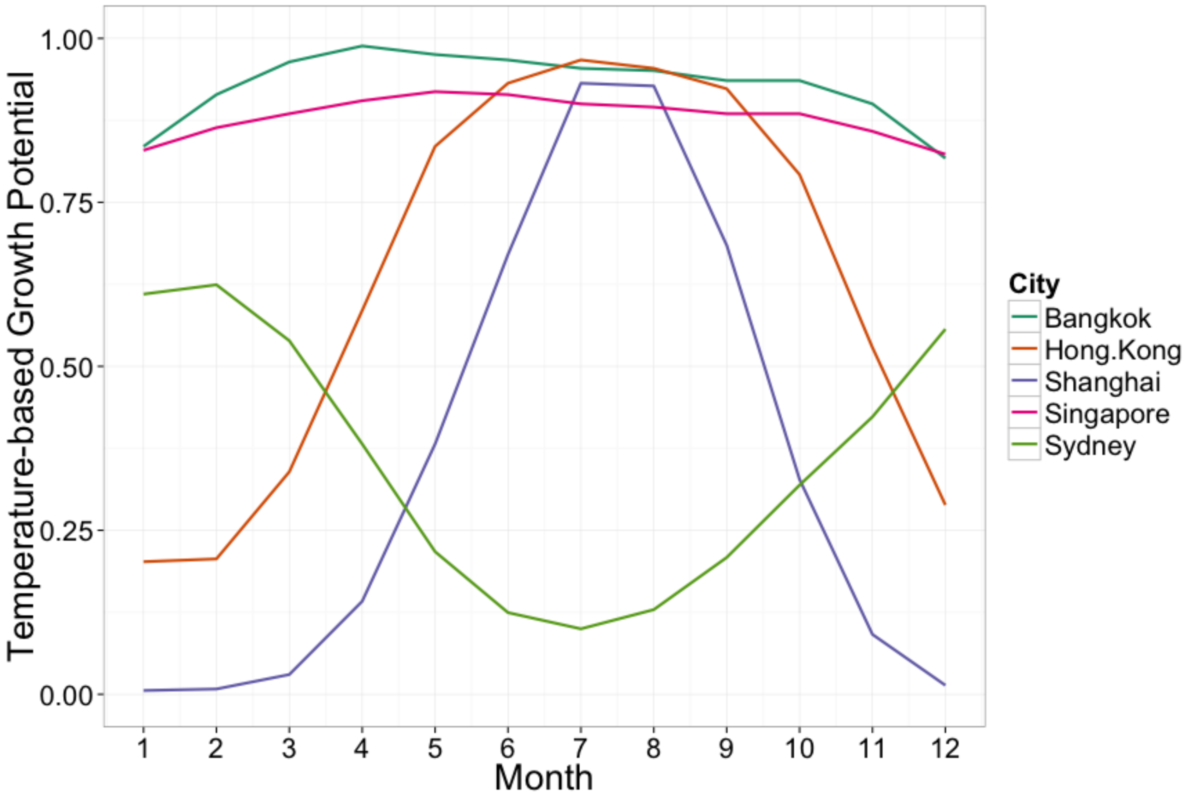

Figure 2: Growth potential calculated using equation 1 based on average monthly temperatures for these cities

Hong Kong is slightly warmer, on average, than Shanghai, so we can see that the growth potential for warm-season grasses is slightly higher at Hong Kong than at Shanghai. And we also can see that average temperatures at Sydney are more moderate, with cooler summers than both Hong Kong and Shanghai, but with a warmer winter than Shanghai and only a slightly cooler winter than Hong Kong. The growth rate and consequently the nutrient requirements of the grass are strongly influenced by temperature, and we can use the growth potential to predict the nutrient requirements of the turf.

Linking the leaf nutrient content with growth potential to predict nutrient requirements

Nitrogen

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 golf course turf in 2013 give us a maximum monthly nitrogen use rate[8] of about 4 g N m^{-2} for bermudagrass (*Cynodon*) and 3 g N m^{-2} for seashore paspalum (*Paspalum vaginatum*) and manilagrass (*Zoysia matrella*).

[8] These estimates are general and only serve as a starting point. Every golf course will have a slightly different maximum level, based on 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.

When the growth potential is 1, the grass can grow at its maximum rate, the clipping harvest of nutrients will be at a maximum, and that is when the estimated nitrogen use rate will be at a maximum. When the growth potential is less than 1, the clipping harvest will be less than the maximum, and thus the nitrogen use of the grass will be correspondingly less. And when the growth potential is 0, the grass will not grow at all, the clipping harvest of nutrients will also be 0, and the nitrogen use rate will be 0.

We can then simply calculate the estimated nitrogen requirement for a given amount of time by multiplying the growth potential times the maximum monthly nitrogen rate.

Potassium

As shown in Table 2, the average potassium content of turfgrass leaves is usually about half that of nitrogen. The potassium requirement of the grass, then, is about half that of nitrogen. If the maximum nitrogen rate were 4 g m^{-2} mo^{-1}, then the maximum potassium rate would be 2 g m^{-2} mo^{-1}. Adding more potassium than the grass can use[9] will not provide any benefit to the grass.

[9] Grady Miller. Potassium application reduces calcium and magnesium levels in bermudagrass leaf tissue and soil. *HortScience*, 34(2):265–268, 1999; George H. Snyder and John L. Cisar. Nitrogen/Potassium fertilization ratios for bermudagrass turf. *Crop Sci.*, 40:1719–1723, 2000; and Micah S. Woods, Quirine M. Ketterings, and Frank S. Rossi. Measuring the effects of potassium application on calcium and magnesium availability in a calcareous sand. *International Turfgrass Society Research Journal*, 10(2):1015–1020, 2005

Even in situations when the soil contains as much or more sodium than potassium, it is not necessary to apply extra potassium, at least for bermudagrass turf.[10]

[10] George H. Snyder and John L. Cisar. Potassium fertilization responses as affected by sodium. *International Turfgrass Society Research Journal*, 10: 428–435, 2005

Other elements, with calcium as an example

The same approach as used for potassium can be applied to the other elements. We can use the growth potential to predict how much the grass may grow, and consequently how much of an element it may use at any time, recognizing that nitrogen controls the uptake of the other mineral elements.

Let's take calcium as an example, for a bermudagrass green at Bangkok in the month of March. The growth potential at Bangkok in March is 0.96. For simplicity let's just round that up to 1. And let's assume that we have decided that our desired growth rate for bermudagrass is achieved at a maximum monthly nitrogen use of 4 g m^{-2}. The ratio of nitrogen to calcium in bermudagrass leaves is about 8:1, with there being close to 4% nitrogen in leaves compared to about 0.5% calcium. So if we estimate that the grass is using 4 g N m^{-2} in March, then it can only use $1/8^{th}$ as much calcium, or 0.5 g m^{-2}.

Using a spreadsheet or other software program, it is a matter of just a few minutes to estimate nutrient use rates of the grass at your location given your desired maximum growth rate.[11]

[11] The growth potential can be applied on a daily, weekly, or monthly basis, as can the associated nutrient use estimates. To get annual estimates of nutrient requirements, as shown in Table 3, we can sum the daily, weekly, or monthly estimates.

But simply knowing how much the grass is using is not enough. If there is already enough of an element in the soil, adding more as fertilizer will have no effect on the grass.

How much is harvested relative to how much is in the soil

THE PREVIOUS SECTIONS have described how to estimate the nutrients that are used by the grass. In that sense we may say they are required by the grass. But are they required as fertilizer? They are if there is not enough of the element available in the soil to meet the plant requirements. But for most elements other than nitrogen, phosphorus, and potassium, the amounts in the soil are usually sufficient to meet the needs of the grass.

The minimum levels for sustainable nutrition (MLSN) guidelines have been developed[12] to provide guidance to turfgrass managers in soil test interpretation and especially in determining whether the amount of an element in the soil is adequate to meet the plant requirements. The latest version of the MLSN guidelines can be downloaded at `http://www.paceturf.org/PTRI/Documents/1202_ref.pdf`.

[12] Micah S. Woods and Larry Stowell. Minimum levels for sustainable nutrition soil guidelines. Technical report, Asian Turfgrass Center and PACE Turf, 2012

Taking the location of Bangkok as an example, using the growth potential model, and setting a maximum nitrogen rate for bermudagrass of 4 g N m^{-2}, we have an estimated annual harvest of elements as shown in Table 3. The MLSN guidelines are shown for reference, and it is clear in comparing the estimated use of elements by the grass with the amount in the soil at the MLSN guideline that only nitrogen, potassium, and phosphorus tend to have an estimated harvest greater than the amount in the soil. Calcium, magnesium, and sulfur, however, even at the low MLSN guideline, are present in the soil at greater amounts than the grass is estimated to use in one year, and thus they are rarely required as fertilizer.

Element	Estimated harvest $g\ m^{-2}\ yr^{-1}$	MLSN ppm	MLSN $g\ m^{-2}$	Deficit $g\ m^{-2}$
N	44.6	na	na	-44.6
K	22.3	35	5.2	-17.1
P	5.6	18	2.7	-2.9
Ca	5.6	360	53.7	none
Mg	2.2	54	8.1	none
S	1.1	13	1.9	none

Table 3: Estimated annual harvest of N, K, P, Ca, Mg, and S from bermudagrass at Bangkok assuming maximum N rate of 4 g N m^{-2} mo^{-1} when growth potential is 1. The current MLSN guidelines are shown in both ppm and equivalent g m^{-2} units. Deficit shows the amount the estimated harvest will exceed the MLSN guideline.