The New Soil Test Interpretations for Wisconsin Golf Turf

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The handwriting was on the wall by the year 2001. We were entering the era of regulation of fertilizer use on turfgrass based on soil tests. This has since become a reality for phosphorus use on home lawns in several communities in the state and for all of Dane County. March 10, 2008, state-wide regulations will go into effect requiring that all turf areas of 5 or more acres under single ownership be fertilized according to soil tests in abeyance with the NR 151 Technical Standards currently being developed by a DNR-appointed committee. Note that the phrase "5 or more contiguous acres" has disappeared. This has interesting implications. For example, is a 5 or more acre housing development subject to these regulations until the homes are sold? Sod farms are exempt on the premise that they are agricultural enterprises.

The specter of regulation of fertilizer use based on soil tests was disconcerting to us . Soil test interpretations for turf used by state soil testing labs prior to 1994 were developed in the 1960's. They were based primarily on forage grass research. Turfgrass research at that time was still in its infancy. These were revised in 1994 using a very meager data base derived primarily from research conducted in other states. The changes were dramatic. For example, the optimum level of soil test P was reduced from 70 to 20 ppm for established lawns. How valid was this dramatic change? We decided that it was vital to the state's turfgrass industry that our soil testing labs have interpretations whose validity and reliability had a solid scientific base and that this had to be done as quickly as possible.

Very few states, if any, have ever implemented a major research effort directed toward the development of comprehensive soil test interpretations for turfgrass. There are several reasons for this. The process is costly, time consuming, does not generate the refereed publications that junior researchers must have to get promoted, and is fraught with difficult decisions that have to be made.

The first decision that has to be made is one that is fundamental to the whole process. The starting point in soil test interpretation is determination of the relationship between soil test levels of nutrients and plant response. For field crops, selection of an appropriate plant response is obvious. It's going to be yield in bushels per acre or whatever is appropriate for a particular crop. With turf, our goal is not that of maximizing clipping production, but maintaining acceptable quality.

But there is a problem in using turf quality. Turf quality is a subjective rather than a quantitative property that is influenced by many factors other than nutrition. After giving the matter considerable thought, we decided that our plant parameter would be shoot nutrient concentration. In other words, our task was to determine, for example, how turfgrass clipping P concentrations vary with increasing levels of soil test P. This decision was the driving force behind our collection of paired samples of turfgrass clippings and soil from the area where the clippings were collected. This had to be done for all major types of turf in the state and over a broad area.

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funded W.R. Kussow Distinguished Graduate Fellowship, to a collaborative relationship with industry, and to the cooperation of many of you, over the period of 2003 to 2005, we were able to assemble a collection of 614 paired clipping and soil samples. The single largest set of samples, some 417, was collected from golf courses because this was where there were no preexisting data. The remaining 197 pairs of samples came primarily from lawns, institutional grounds and athletic fields. The clippings were analyzed for all the essential nutrients of importance to the study. The soil samples were analyzed for pH, P, K, Ca, Mg, B, Fe, Mn, Cu, and Zn by way of several different methods because at that point we didn't know which methods would yield the most reliable results. Through this effort we generated a data base with nearly 25,000 entries.

The use made of this large data base was to meet the objective of determining which of the various soil test methods used performed best for turfgrass. Soil test performance is judged according to the strength of the relationship between soil analyses and plant response. The stronger the relationship, the greater the assurance that the test extracts from soil only those forms of nutrients truly available to plants.

We found these relationships to be very weak, statistically insignificant, and of little value in deciding whether one test method performed better than another. More intensive inspection of our data revealed why this was the case. We were being confronted with one of the unique features of turfgrass as compared to field crops. Nitrogen application rates on field crops are set at non-growth limiting levels because this results in maximum economic returns for the crop. We determined through field experiments that in our climate it takes at least 16 lb N/1,000 ft²/yr⁻¹ to maximize clipping production on a Kentucky bluegrass lawn and in excess of 3.8 lb N/1,000 ft/mo⁻¹ on a bentgrass fairway (Fig. 1). Because no one fertilizes at much more than 1/4 these rates, N is almost always growth limiting. From this we surmised that it is N that drives clipping production and, in so doing, drives turfgrass uptake of all the other essential nutrients. This phenomenon is vividly illustrated in Figure 2 for P and K. What this figure indicates is that turfgrass clipping P and K concentrations are more dependent on fertilizer N rate than soil supplies of P and K. As you might imagine, this complicated subsequent attempts to establish relationships between soil test levels of nutrients and their tissue

Figure 1a. Bentgrass N Response Curve

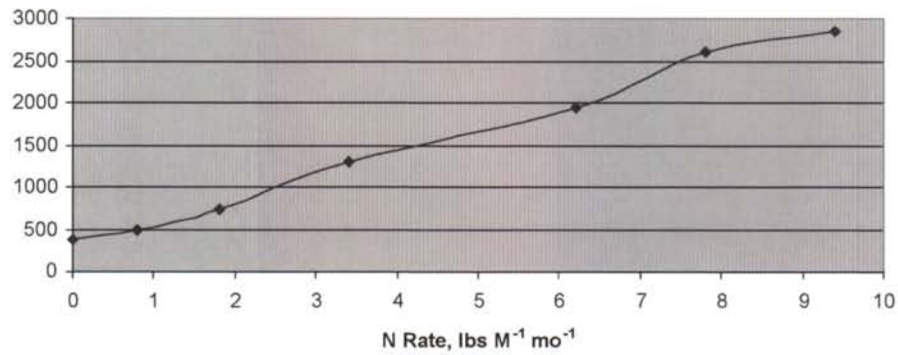


Figure 1b. Bluegrass N Response Curve

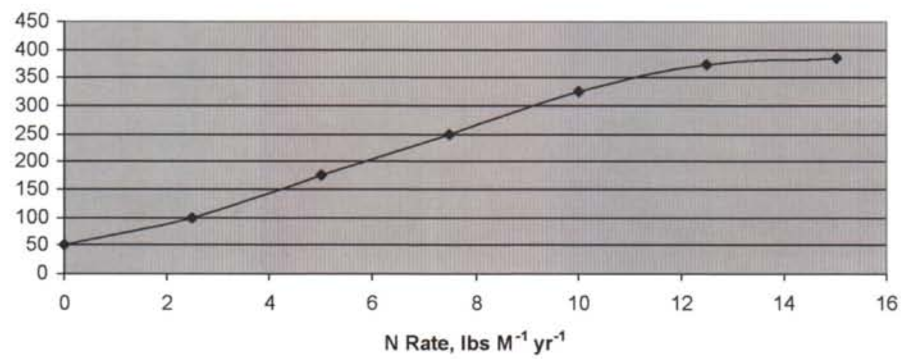
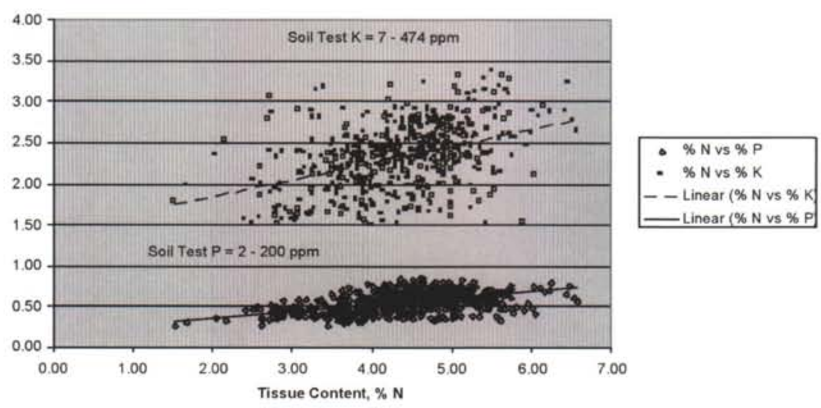


Figure 2. Clipping N vs Clipping P and K

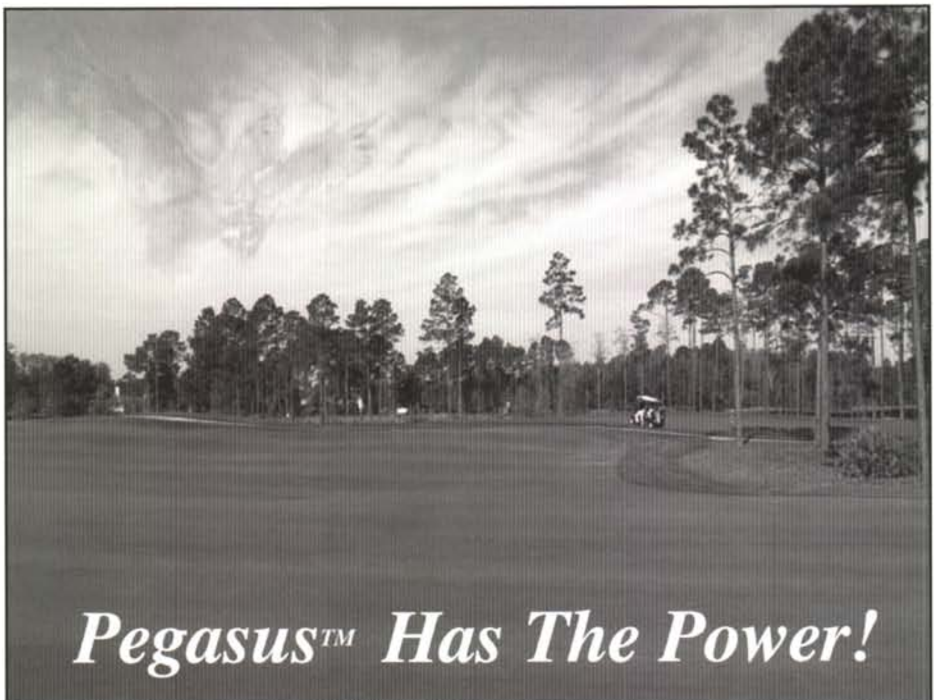


concentrations. Such relationships provide the basis for defining critical soil test levels of the nutrients, those above which plants do not respond to further increases in test levels of the nutrients.

Before attacking the task of circumventing the N influence on nutrient uptake, we addressed a concern with the so-called Bray-1 method for extracting soil P and K. This is the method currently being used by all soil testing laboratories in the state. The method was developed for use on acid soils and does not function well for soils with significant amounts of carbonates. In Wisconsin, many golf putting greens and some athletic fields have been constructed with calcareous sands and wherever turf has been irrigated for some time with ground water that has filtered through limestone, soil pH values approach and even exceed 7.6 after a few years of watering. This is the pH where we begin to find carbonates in soil. Thus, the possibility existed that the Bray-1 soil test method was not appropriate for all turf soils. To examine this potential problem, we compared the amounts of soil P and K extracted by the Bray-1 method to the amounts extracted by a method held to function effectively across a wide range in soil pH. This comparison indicated that for our 617 soil samples with pH ranging from 4.25 to 7.9 the Bray-1 procedure functioned with equal effectiveness and there is no reason not to use it for turf soils. Minnesota research has shown that failure of the Bray-1 test to adequately extract P and K from soils does not occur until soils contain 12 % or more carbonates. Chances of encountering a turf soil in Wisconsin with carbonates levels this high are close to zero.

A statement sometimes made is that UW-Madison research has shown that the P measured by soil tests in calcareous soils is unreliable because what's measured is not truly plant available. We could not find any evidence of this in our research.

When we plotted turfgrass clipping nutrient concentration against soil nutrient content to identify critical soil test values, the result was a literal mess. The data plotted in Figure 2 for golf putting greens with up 40 ppm Mehlich III phosphorus show what we're talking about. While it's obvious from the figure that above a certain soil test level of P there is no change in clipping P concentration, it's equally clear that clipping P can range from 0.34 to 0.8 % at a single level of 25 ppm soil test P. To put



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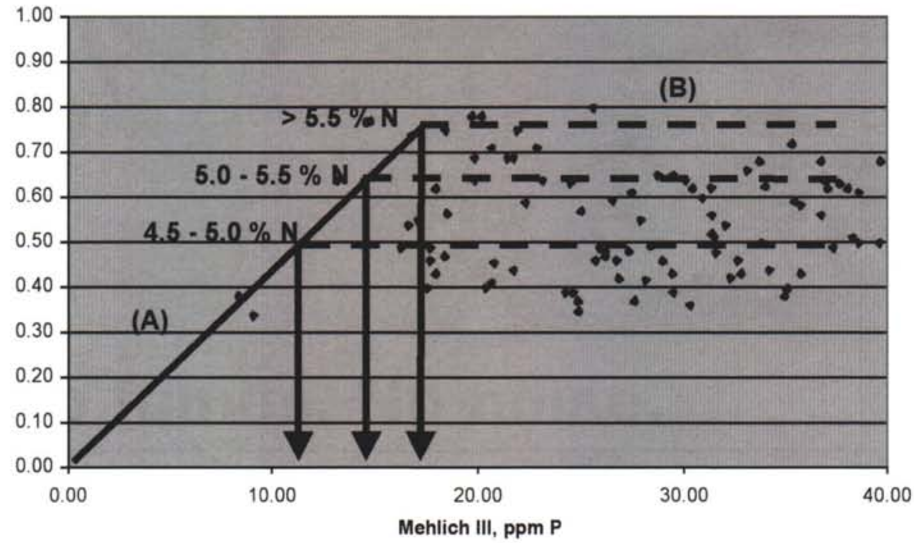
this in perspective, 0.34 % P in bentgrass clippings is considered by turfgrass researchers to be low and 0.8 % P is excessive. We surmised that this situation reflects the fact that, as shown in figure 2, N supply controls how much soil P turfgrass takes up. This prompted sorting of the samples into clipping % N ranges and computing for each range the relationship between clipping and soil P.

The result of this exercise is shown in Figure 3. By drawing in the appropriate lines, this figure tells us that what might be established as a critical soil test value actually varies with clipping N concentration; the higher the clipping N, the greater the critical soil test value. To some, this might suggest that soil tests cannot be reliably interpreted without knowledge of clipping N concentrations. We took the stance that it is unrealistic to require that turf soil samples submitted to labs for analysis be accompanied by clipping samples.

Our approach to this problem was to define critical soil test values at what we viewed as reasonable and realistic clipping nutrient concentrations. For P in putting greens, we chose 0.6 %. One reason is that this concentration is at the upper end what is considered to be the sufficiency range for P in bentgrass. What this decision did was ignore clippings whose % N was above about 5.5. In essence, we were deciding that more than 5.5 % N is excessive and arose either from inappropriate use of N or a temporary condition that might exist shortly after fertilizer N application. The other reason for selecting the 0.6 % P tissue concentration has to do with the fact that grass clipping P concentrations are considerably lower during periods when low air temperatures restrict growth. In view of the strong influence of turfgrass growth rate on nutrient uptake, this temperature effect is understandable. After consulting turfgrass literature, we became confident that if bentgrass has a midseason clipping P concentration of 0.6 %, the % P will most likely never drop below a potentially growth restricting level of 0.35 % during cold weather.

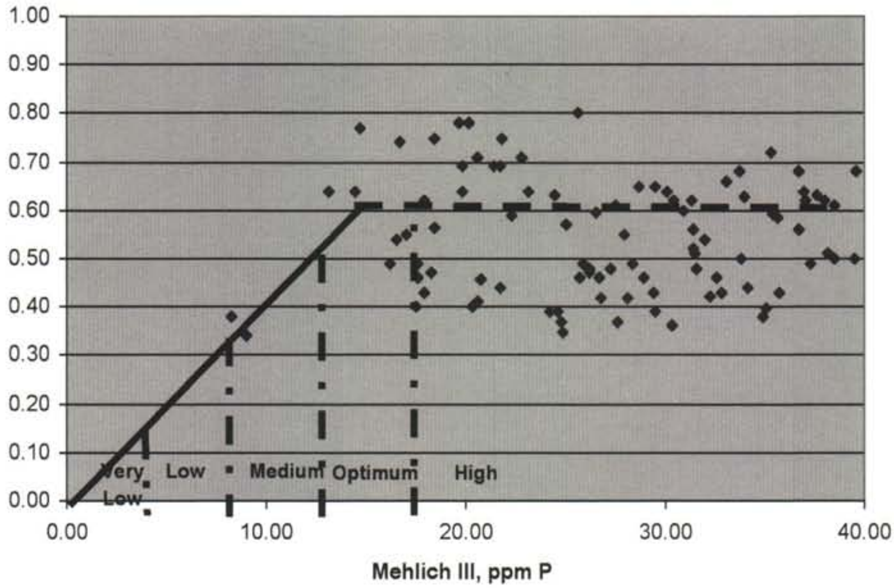
Figure 3. Critical Mehlich III P Concentrations for Different Tissue N Ranges



Yet another problem we encountered in the project was the fact that among the 417 putting greens sampled, there were only one or two instances where soil and tissue P and K concentrations were very low or low. In fact, more than 48 % of the greens had such high soil test levels of P and K that their data were of no value when it came to identifying critical soil test values. To overcome this deficiency in our data base, we had to reconstruct a putting green, deliberately creating deficiency levels of soil P and K. Having a range of increasing soil test values over which tissue nutrient concentrations increased accordingly was vital to the establishment of critical soil test values. This relationship results in the line "A" in figure 3. Where it is drawn determines the point of intersection with line "B, the critical soil test value. Therefore, having sufficient data to define line "A" has a lot to do with the reliability of the soil test calibrations.

Having worked through all of the above processes and making rational judgments regarding what we would use as "target" clipping nutrient concentrations, the next step was to establish critical soil test values. It was at this point that we focused our attention on the data for the different types of turf we were dealing with to see if there was a justifiable need to calibrate soil tests differently for each of these different turf types. What became obvious to us is that bentgrass putting greens and tees are distinctively different from fairways, lawns and athletic fields. The main reason for this separation is the consistently higher N concentrations in bentgrass than in Kentucky bluegrass and, therefore, bentgrass has higher P and K requirements. With our data base, we could not justify separate soil test calibrations for fairways, lawns or athletic fields. Collection of more data might allow for separation of bentgrass fairways from lawns, athletic fields and bluegrass or fine fescue fairways for the purpose of soil test calibration. In the

Figure 4. Mehlich III P Calibrations For Golf Greens and Tees



meantime, those of you with bluegrass or fescue fairways are being treated generously. The optimum soil test ranges are probably higher than they should be.

We attempted two different approaches for determination of critical soil test values. One was a mathematical method in which a curvilinear response curve is generated for soil test values below the critical value and a flat, straight line computed for those soil test values above which there is no change in tissue nutrient concentrations. The intersection of the two lines defines the critical soil test value. We had to abandon this approach because we simply did not have enough data points to reliably compute the curvilinear portion of the response curve. This led to use of a graphical approach that has been used extensively for field crops and has a statistical basis. We used the technique to identify critical values for the various soil test methods employed and for the two turf groups – golf tees + greens and fairways + lawns + athletic fields.

The final step in this study was to develop soil test interpretations. This is a simple process once the critical soil test values have been determined. It involves dividing the range in soil test from zero up to the critical value into several segments. The number of segments depends on the nutrient, is a matter of personal preference, and is commonly either 4 or 5 for nutrients such as P and K. Each range in soil test values is then assigned an interpretation such as *very low, low, medium*, and so on. Here again, the terms used reflect personal preference. We elected to go with 5 divisions for P and K and interpretations of *very low, low, medium, optimum*, and *high*. An example of these soil test interpretations is shown in Figure 4. Note that the critical soil test value is near the midpoint of the optimum soil test range. In the case of micronutrients, soil tests are not as reliable as for P, K, Ca, Mg, and S and the range of values tends to be very narrow. In this case, soil test values below the critical level are declared deficient or insufficient and those above the critical value are termed sufficient or adequate.

Although not a part of this study, fertilizer recommendations had to be developed as a final step for completion of what constitutes a complete soil testing program. It is this complete package that is required by soil testing laboratories. The amounts of fertilizer recommended are those deemed to be necessary to take any soil from its current soil test level to the optimum level as defined by its critical value. Ideally, these recommendations are based on research that has determined for different soils what rate of application of a particular nutrient is equivalent to a single unit increase in soil test. We are very fortunate because these relationships already exist for P and K for soils of different textures and origins in the state. These relationships are referred to as nutrient buffering capacities and are what were used to develop fertilizer recommendations for P and K based on our new soil test interpretations for turfgrass. If and when customers request fertilizer recommendations for the secondary and micronutrients, more creativity will be required to create them because buffering capacities of these nutrients have not been established.

Per our recommendation, there is a subtle but important distinction between the fertilizer recommendations for lawns and golf turf. For lawns, no fertilizer P is recommended once soil test P is in the optimum range or above. For golf turf, there are fertilizer P and K recommendations for soils testing in the optimum ranges. We have successfully argued that due to continual nutrient removal in clippings, applications of P and K have to be allowed when soil test are in the optimum range. The rates of P and K being recommended are what we estimate to be those required to maintain soil P and K in their optimum ranges.

We're pleased to report that our new interpretations for the Bray-1 tests for soil P and K and corresponding fertilizer recommendations have already been adopted by the University of Wisconsin soil testing labs in Madison and Marshfield and made available to all soil testing labs in the state that are certified by the Wisconsin Department of Agriculture and Consumer Protection. Furthermore, our soil test interpretations and fertilizer recommendations are being written into the DNR technical standards for regulations on fertilizer use on 5-acre or more turf areas under single ownership that are scheduled to go into effect in 2008. Thus, we have met the original intent of this research project, which was to develop reliable, state-based soil test interpretations for turfgrass before they became the basis for regulation of fertilizer use.

But we're not done yet. We've already begun to explore the possibility of soil testing lab adoption of the Mehlich III method of soil analysis for golf turf. The reason is that unlike the Bray-1 procedure, this method has multi-nutrient extraction capability and is soil pH insensitive. Furthermore, as part of this research effort we determined the critical soil test levels for all nutrients extracted by Mehlich III method. What this will do is provide you with soil test results and interpretations for Ca, Mg, S, Fe, Mn, Cu, Zn, and B as well as P and K. Additionally, by including Na in the analyses, good estimates of soil CEC can be provided. For the foreseeable future, this more comprehensive soil testing service will only be available through the Madison lab because this is the only lab that currently has the several thousand dollar instrument required for rapid analysis for all of these nutrients. Rest assured that you will be notified when this service becomes available. Baring unforeseen problems, that should be within a couple of months.

So this is it — probably more than you ever wanted to know about the rationale and science behind Wisconsin's new soil test interpretations and fertilizer recommendations for turfgrass. We hope it alleviates some of your concerns about being mandated to fertilize your turf according to soil test.

Wayne Kussow is Emeritus Professor of Soil Science. Steve Houlihan, the second recipient of the Wisconsin Turfgrass Association W.R. Kussow Distinguished Graduate Fellowship, is now Assistant Superintendent, Merrill Hills Country Club.

New Soil Testing Service

A new soil testing service for golf and professionally managed turf is now available through the University of Wisconsin Soil and Plant Analysis Laboratory in Madison. The new service is based on a soil test procedure known as Mehlich III. Selection of this procedure and interpretations of the test results are based on research recently completed in the UW-Madison Department of Soil Science.

The beauty of the Mehlich III procedure is that it has multi-nutrient extraction capability and is soil pH insensitive. In other words, the test results are equally reliable for acid and high pH soils, including those that contain carbonates. The nutrients extracted are P, K, Ca, Mg, S, B, Cu, Fe, Mn, and Zn. Detection of Na along with K, Ca, and Mg allows for calculation of soil CEC. In addition to soil CEC and all of the above nutrients, you'll also receive in formation on soil pH, lime requirement and organic matter content. You will not receive percent base saturations, but can calculate them based on soil CEC and the analyses for Ca, Mg, and K.

Along with all the soil test results and interpretations, you'll receive fertilizer recommendations for P and K. The recommendations are tailored to type of turf, whether golf or professionally managed lawns, athletic fields, institutional grounds and parks. Golf turf is split into greens/tees and fairways/roughs. The greens and tees are further divided according to type; sand based or push-up (native soil).

The Mehlich III based soil P and K interpretations and recommendations are being written into the DNR Technical Standards for turf in NR 151 along with newly revised interpretations and recommendations for the Bray #1 soil test procedure being used by the UW and all private state labs certified by DATCP. Thus, results from either soil test procedure will satisfy the NR 151 regulations that go into effect on March 10, 2008.

The cost of this new soil testing service is $20 per sample. Details on where and how to submit samples can be found on the UW lab web site http://uwlab.soils.wisc.edu. Go to the Services menu, then to Submission Forms and finally to Golf Course and Professionally Managed Turf. On the submission form note that you have the option of receiving your soil test results via FAX or Email.