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.

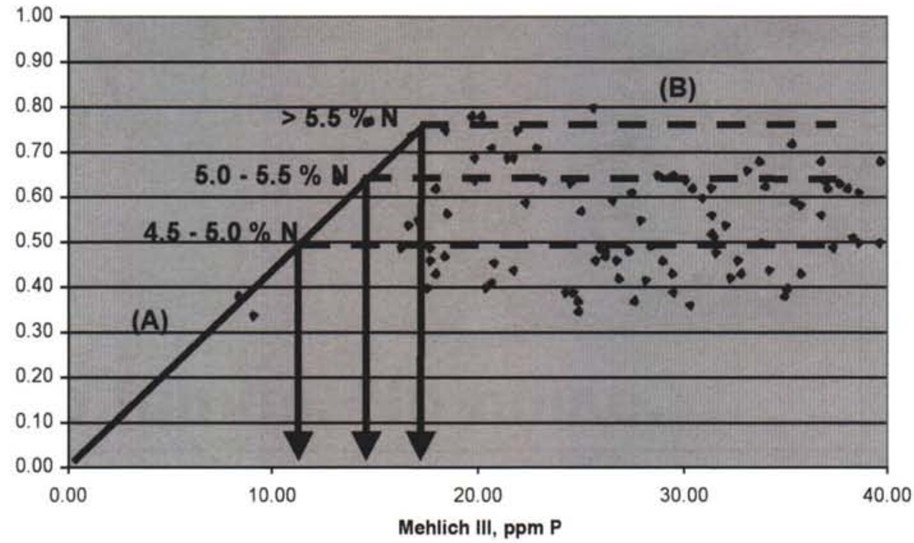
A statement sometimes made is that UW-Madison research has shown that the P measured by soil tests in calcareous soils is unreliable because what's measured is not truly plant available. We could not find any evidence of this in our research.

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 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 mid-season 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.

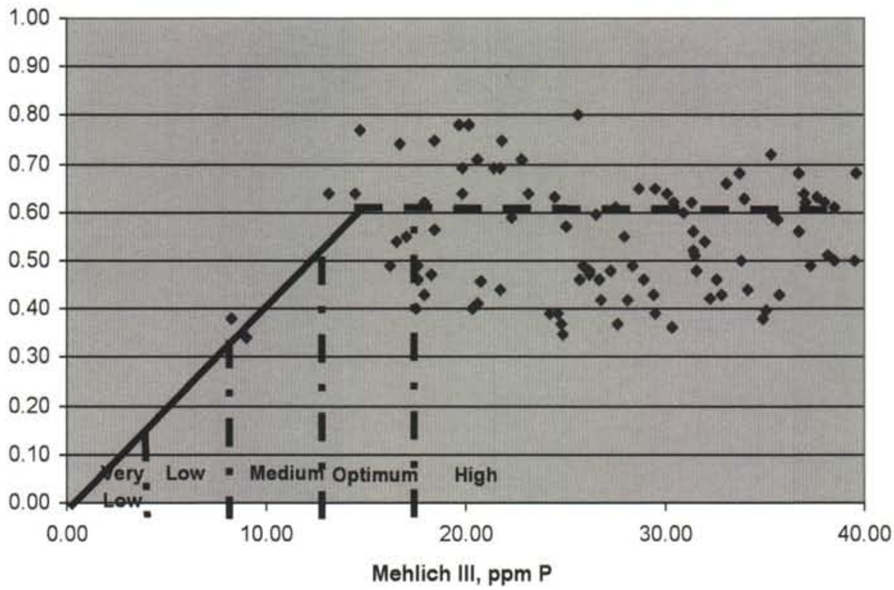
Figure 3. Critical Mehlich III P Concentrations for Different Tissue N Ranges



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

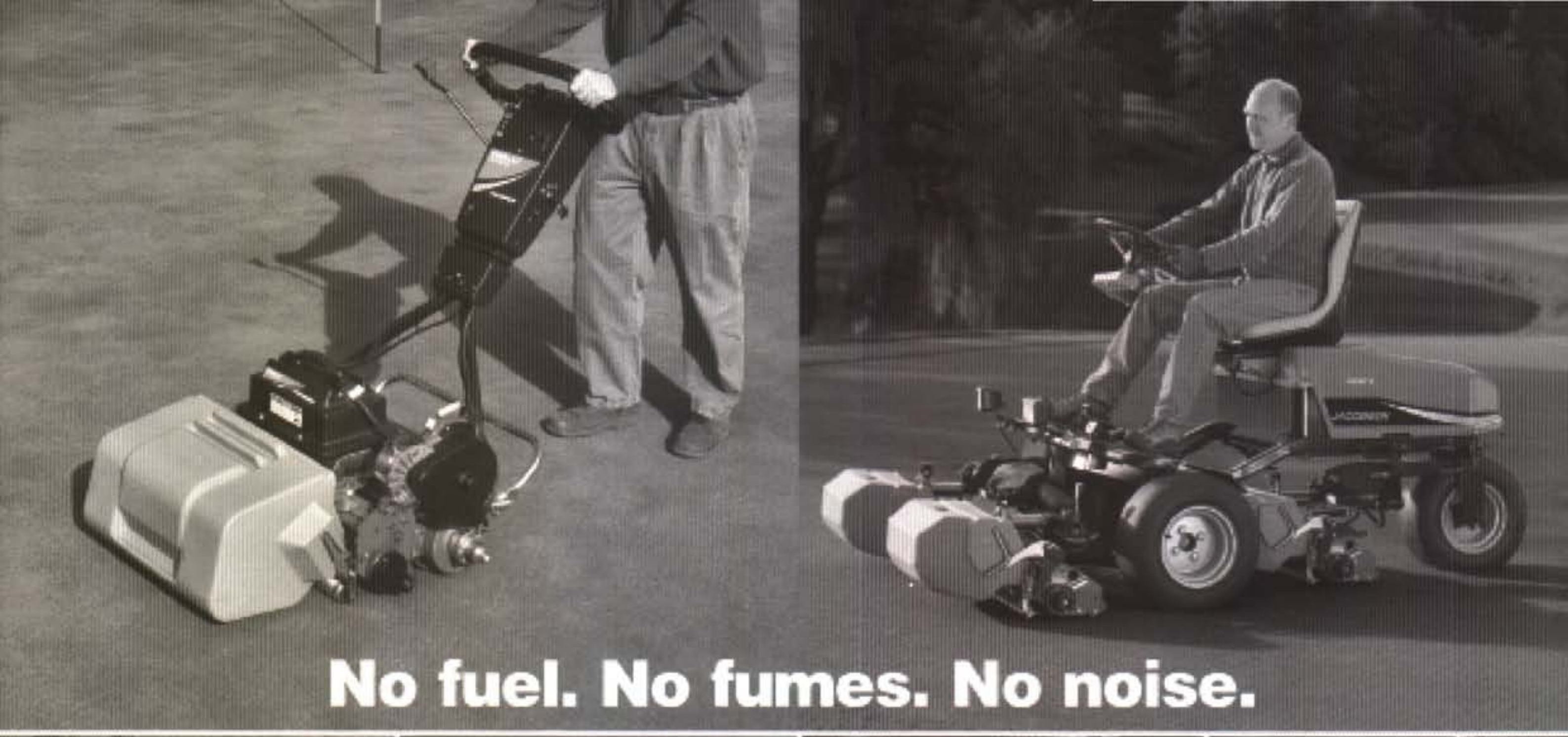
A new soil testing service for golf and professionally managed turf is now available through the University of Wisconsin Soil and Plant Analysis Laboratory in Madison. The new service is based on a soil test procedure known as Mehlich III. Selection of this procedure and interpretations of the test results 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.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Turfgrass's Cutting Edge

By Linda L. McCandless, *CALS Director of Communications, Cornell University*

Frank Rossi has never seen a blade of grass either dead or alive that he didn't like. And whether he is working from the back of a tractor, a lawnmower, or a pick-up truck, he is quick to tell you the Cornell University Turfgrass Team is committed to improving the environment one turf at a time. The associate professor of turfgrass science likes being outdoors. He also likes the kind of work where he can let grass die and not sweat it. "In fact, sometimes I encourage it," he says.

Photo by Robert Barker

The fast-talking New Yorker from the Bronx started mowing lawns when he was 11, got his first job at the Leewood Golf Course in Westchester County when he was 15, and became the superintendent of the Greenwich Country Club when he was 25. He has always spent a lot of time on golf courses, and although he has a serious tan, he says he has no golf game. Don't even bother asking him about his handicap. The fact is Rossi, who has a Ph.D. in plant science with an emphasis on weed science and plant biology from Cornell (1992), rarely frequents the front of the house or swings a nine iron. He is more likely to be found behind the clubhouse, talking with the superintendent about putting greens, fixed-head mowers, and annual bluegrass.

Rossi's work doesn't just cover golf courses - which is what most people think when they hear the word "turf." Rossi and the other members of the team also focus on major league stadiums, parks, public school grounds and playing fields, cemeteries, sod farms, public landscaping projects and home lawns.

"Because the turfgrass industry in New York is the largest in the United States, it is incredibly significant from both an economic and an environmental stewardship point of view," notes Rossi, who served on the faculty of Michigan State (1990 – 1992), and the University of Wisconsin-Madison (1992 – 1996), prior to returning to Cornell in 1996.

Turfgrass covers 3.43 million acres in New York, while farm fields and woodlots take up 7.4 million acres. In 2003, landscapers, golf courses, and other turf-related businesses employed 43,000 people and spent $5 billion on labor, equipment, and supplies. Rossi's main message is that New York's turfgrass industry is driven primarily by homeowners, scholastic athletes, and golfers. "Homeowners spend more money every years than the professionals do," he says, citing statistics from a survey conducted in 2003 that homeowners spent $88 million for fertilizer and $37 million for pesticides. "Private residents control six times the turf acreage of either golf courses or lawn care companies, and most of them are not trained to make applications and asses the lawn's needs."

The Cornell Turfgrass Team develops efficient turfgrass management systems based on sound scientific research from five academic departments in the College of Agriculture and Life Sciences. Agronomists, horticulturalists, plant pathologists, entomologists, human resource specialists, and toxicologists improve cultural management of turfgrass systems by increasing stress tolerance and providing a greater understanding of turfgrass pest ecology. The primary focus of the interdisciplinary group is to educate homeowners and professionals on the most environmentally responsible research-based information that improves resource efficiency.

In collaboration with a network of turfgrass extension field staff located around the state, the Turfgrass Team also delivers an impressive educational curriculum of newsletters, informational bulletins, diagnostic services, and workshops. The cornerstone of the extension education program is the weeklong Turfgrass Management Short Course, which has trained more than 1,500 turf professionals from around the world since its inception in 1985.

Other educational opportunities include the quarterly research newsletter CUTT, which has 2,500 subscribers, and a weekly e-newsletter – shortCUTT – which Rossi calls "just in time education." The weekly e-newsletter is the direct result of a conference call, during which Rossi chats with turf, weather, and industry specialists from around the Northeast. The conversation is then transcribed, edited, and electron-


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ically delivered to members of the New York State Turfgrass Association (NYSTA) and over 500 professionals around the country.

The Turfgrass Team is a strong advocate for the golf turf industry, but is also engaged with citizen action groups and policy makers who rely on good science for decision-making. In the past, they have worked closely with the Breast Cancer Environmental Research Fund (BCERF) on controversial issues that involve pesticide use.

CUTTING edge projects

Cornell turfgrass researchers work on a wide range of projects. They include the use of reclaimed water for irrigation on golf courses on eastern Long Island that feed into the Peconic Estuary; weed programs that rely on natural products produced by plants to control weeds; and the ecology of the annual bluegrass weevil, the most significant insect pest on golf courses in metropolitan New York.

One high-profile project involves the Bethpage State Park Green Course, in Farmingdale, N.Y., a project that is in its fifth year. There, Rossi and Jennifer Grant PhD '01, assistant director of the NYS Integrated Pest Management Program (IPM), are conducting a systems comparison of conventional, IPM, and nonchemical management of golf course greens under both standard and alternative (stress-reducing) cultural practices. The project aims to maximize playability while minimizing chemical use.

"In the first year, we managed six greens with no chemicals and all six died," Rossi says. But six years later, the research is beginning to pay off. "We aren't able to go with no chemicals," he says, "but by careful management, we have been able to cut traditional pesticide use on those greens by 70 percent."

One invention from Rossi has made a real impact on community soccer clubs, and schools and colleges with multi-use fields: a turfgrass paint that acts like invisible ink. The Remarkable Paint system of paint and paint removers can be used to mark lines on playing fields and other turf and does not damage the grass when applied or removed. This means a field can be marked for soccer, used for a game, then "erased" by the grounds crew, and remarked for a different sport, repeatedly and easily during the same playing season.