(Continued from page 19)

TABLE 2. Essential plant nutrient contents of the natural organic fertilizers used. †

Fertilizer	N	P_2O_5	K_2O	Ca	Mg	S	B	Cu	Fe	Mn	Zn
	Nutrient content										
	%						ppm				
Milorganite	6.71	3.17	0.36	0.83	0.37	0.80	16.2	296	59,300	160	687
Hou-Actinite	6.17	4.52	0.37	1.85	0.30	0.67	14.9	258	20,700	169	687
Frororganic	5.95	4.59	0.12	3.72	0.22	1.33	16.6	558	8,580	68	849
Sustane	5.12	4.07	3.70	3.80	0.71	1.68	37.5	214	14,700	322	597
5-3-1	5.86	3.68	1.86	5.63	0.58	0.73	21.0	182	38,400	272	544
Hynite	12.60	0.09	<0.01	.066	0.10	2.06	9.1	40	1,070	11	23
Lorganic-8	7.81	<0.01	<0.01	0.58	<0.01	0.04	3.7	13	89	1	6

† Means for the various size grades.

A concern that sometimes arises with natural organic fertilizers compounded from waste materials is their heavy metal content. The fertilizers used in the present study varied considerably in this regard (Table 3). However, with exception of the 29,500 ppm chromium and 2,480 ppm selenium in Hynite, the levels of heavy metals in all the other fertilizers are so low as to meet EPA standards for application on food crops as well as turf.

TABLE 3. Heavy metal contents of the natural organic fertilizers used. †

Fertilizer	Arsenic	Cadmium	Chromium	Nickel	Lead	Selenium
	Heavy metal					
	ppm					
Milorganite	<28	16.1	656	47.5	155	24
Hou-Actinite	<28	10.7	84	25.2	66	<19
Flororganic	<28	9.0	64	26.0	102	<19
Sustane	<28	2.3	28	18.5	<11	<19
5-3-1	<28	6.9	396	<22	89	113
Hynite	35	<1	29,500	<4	11	2,480
Lorganic-8	<28	<1	43	<4	11	<19

† Means for the various size grades.

Nitrogen Mineralization

Temperature was understandably one of the most important factors affecting organic N mineralization rates. This was evidenced by the fact that organic N mineralized in 42 days averaged 23% higher at 90°F as compared to 68°F (Table 4). This 1.8-fold difference in N mineralization emphasizes the point that turfgrass response to natural organic fertilizers is typically very temperature sensitive. This generalization did not, however, hold true for Lorganic-8. The amount of inorganic N released from this product was nearly as great at 68°F as at 90°F.

Another way of characterizing the sensitivity of N mineralization from natural organic fertilizers to temperature is to examine the percent increase in N mineralization per 10° rise in temperature. As shown in Table 4, these values ranged from a low of 3.2 for Lorganic-8 to a high of 15.9 for the 5-3-1 fertilizer not inoculated with mold culture. The higher these values, the greater the sensitivity of organic N mineralization to temperature.

Composition effects on the amounts of organic N mineralized in the 42-day incubation were nearly as great as temperature effects when the fertilizers were incubated at 68°F (Table 4). Examples of this are the 23% more N released from Milorganite F as compared to Fllororganic and 36% more N released from Lorganic-8 as compared to the Frororganic. Incubation of the fertilizers at 90°F greatly diminished fertilizer composition influences on organic N mineralization.

The effects of fertilizer particle size on organic N mineralization were likewise considerably greater at 68° than at 90°F (Table 4). In fact, at 90°F particle size effects were not only small but erratic as well. This was most evident in the Milorganite treatments. At 68°F, going from the regular to fine grade of Milorganite increased organic N mineralization 16%. But at 90°F, mineralization of organic N was 5% less from the fine grade rather than the regular grade of Milorganite.

TABLE 4. Organic N mineralized during a 42-day laboratory incubation and percent increase in mineralization per 10oF temperature increase.

Fertilizer	Physical state †	Organic N mineralized 68°F	Organic N mineralized 90°F	Increase in mineralization
Milorganite	R	26.0	55.8	13.5
	G	33.1	51.7	8.4
	F	36.6	51.0	6.5
Hou-Actinite	R	29.4	53.4	10.9
	G	29.7	47.5	8.1
Frororganic	R	13.6	34.5	9.5
Sustane	R	37.8	59.8	10.0
	F	20.7	43.0	10.1
5-3-1	R	15.3	50.2	15.9
	R(1)	20.6	49.8	13.3
	R(2)	21.4	52.2	14.0
Hynite	R	31.5	58.7	12.4
Lorganic-8	L	49.9	56.9	3.2

† R = regular grade; G = greens grade; F = fine; R(1) = 1% mild culture added; R(2) = 2 % mold culture added; L = liquid.

Inoculation of the 5-3-1 fertilizer with mold culture slightly increased organic N mineralization at 68°F but not at 90°F (Table 4). The maximum increase in organic N mineralization that resulted from microbial inoculation of the fertilizer was 6.1%.

Cumulative release of the organic N from the fertilizers when incubated at 68°F is illustrated in Figure 1. Similar N release patterns were observed at 90°F. The patterns of N release are essentially the same for all but Hynite. Mineralization was rapid and essentially linear with time for the first 14 days and then leveled off. This pattern of N release is typical. It reflects that fact that natural organic fertilizers contain a wide array of compounds that vary in their susceptibility to microbial decomposition. Simpler compounds such as amino acids and proteins decompose rapidly, leaving behind N-bearing compounds whose decay rate is much lower.

The initial delay in N mineralization from Hynite (Figure 1) is believed have resulted from the physical state of the fertilizer. The fertilizer pellets are large, showed no sign of disintegration during the first 7 days of incubation, and very small quantities of N were mineralized. Once pellet disintegration began, N mineralization increased markedly to rates comparable to those for the other natural organic fertilizers. At the end of the 42 day incubation period, the N mineralization rate for Hynite was greater than for the other fertilizers.

Thus, it is possible that if the incubation time had been extended beyond 42 days, the amount of N mineralized from Hynite may have approached that of Sustane.

Non-cumulative N mineralization is an important property of natural organic N fertilizers because it shows whether or not different fertilizers release N at different time after application. As shown in Figure 2, mineralization of N from Milorganite, Hou-Actinite and Lorganic-8 peaked at 7 days. The peak in N mineralization for Sustane occurred at about 14 days and for Hynite at 28 days. These differences in N mineralization patterns suggest that turfgrass greenup would be quickest for a fertilizer such as Milorganite and slowest for Hynite. On the other hand, one might expect that turfgrass color retention times would be longer for Sustane or Hynite than for the sewage sludge fertilizers.

Among the fertilizers studied, Lorganic-8 displayed a distinctive N mineralization pattern (Figure 1). Mineralization of N was high the first 7 days, dropped somewhat between days 7 and 14, and then held steady between days 14 and 28. This suggests that the product may provide both quick greenup and better than average turfgrass color retention times.

CONCLUSIONS

The results of this study show that while temperature exerts a major influence on the rate of organic N mineralization from natural organic fertilizers, other factors may have to be considered as well. At temperatures that are not optimal for microbial activity, fertilizer composition and particle size effects can be as great as temperature effects. Different fertilizers display different temperature sensitivities and particle size effects vary with the particular fertilizer applied. Mineralization of N from Lorganic-8 was observed to be quite temperature insensitive. Particle size effects on N mineralization were evident for Milorganite, did not exist for Hou-Actinite, while reducing particle size actually seemed to adversely affect N release from Sustane.

At optimal temperatures for microbial activity, the influences of fertilizer composition, particle size and microbe inoculation on organic N mineralization rates were greatly reduced. Thus, choice of natural organic fertilizer is much less an issue when application is being made in the summer months as compared to spring and fall. The same cannot be said when good turfgrass color response is expected from early spring and late season applications of natural organic fertilizers.

•••

Jeff Barlow is a May 1995 graduate of the University of Wisconsin Turf and Grounds Management Program. Dr. Wayne R. Kussow was his advisor.

Figure 1. Cumulative organic N mineralized at 68°F from several natural organic turf fertilizers

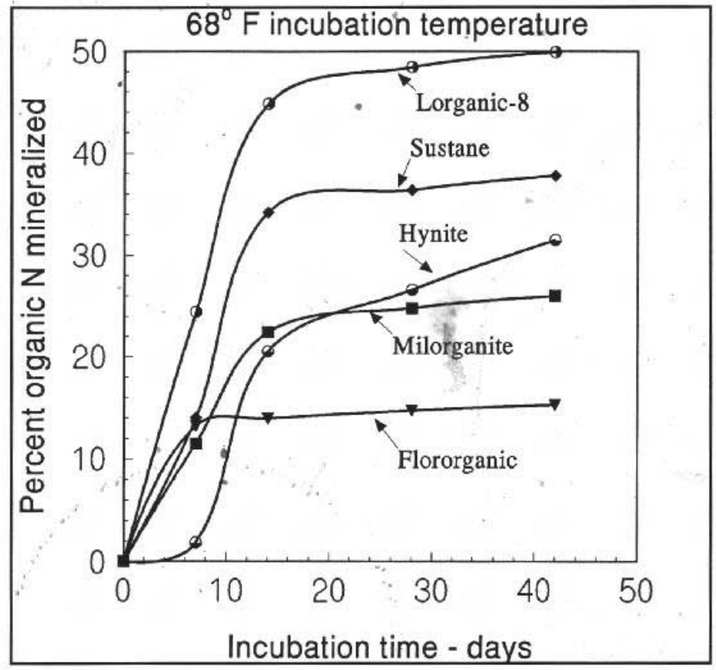
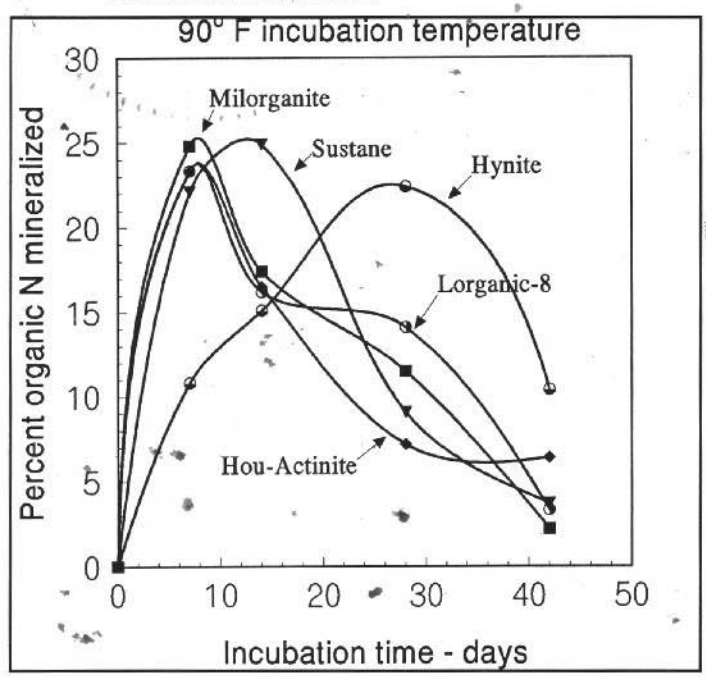


Figure 2. Organic N mineralized from several natural organic turf fertilizers incubated at 90°F



Manipulating Creeping Bentgrass Nutrition

By Dr. Wayne R. Kussow
Department of Soil Science
University of Wisconsin-Madison

Disease occurrance, severity and subsequent recovery in creeping bentgrass have long been linked to the nutrient status of the grass. Statements such as "Low N favors dollar spot" or "High N favors pythium" are common. But what is "low" N or "high " N? Are other nutrients involved in the nutrition-disease connection? What are the mechanisms involved? How can we effectively manipulate the nutrient status of creeping bentgrass ? These are some of the questions that Dr. Julie Meyer and I hope to answer in a cooperative research project being funded by the Wisconsin Turfgrass Association.

Knowing the mechanisms involved in nutrition-disease relationships can be the key to manipulating turfgrass nutrition for disease control purposes. A classic example involves take-all disease. It has been known for some time that lowering soil pH reduces the severity of the disease and increases the effectiveness of chemical control. Only recently have we come to understand that what is involved here is manganese (Mn). The take-all fungus immobilizes Mn in the root zone through oxidation of the nutrient. This reduces plant uptake of Mn and, in the process, weakens the physiologic barrier to root penetration by the fungus. Lowering soil pH favors the reduction and plant uptake of the Mn.

This is but one example of how manipulation of turfgrass nutrition through cultural practices can aid in disease control and increase the efficacy of chemical control agents. Assuming other examples will be disclosed in our research, my task is to determine how turfgrass nutrition can most effectively be manipulated.

Manipulation of turfgrass nutrition is not as simple as just applying the nutrient of interest. As an example, consider Mn. Soil application of the nutrient when soil pH is around 7.0 is often ineffective because the Mn quickly undergoes oxidation and is rendered unavailable to turfgrass. Foliar application of the nutrient is not the answer either because the Mn does not readily translocate to the roots to change the resistance to take-all fungus penetration.

Another reality one has to deal with in attempting to manipulate turfgrass nutrition is the plant itself. Turfgrass, like all other plants, does not indiscriminately accumulate nutrients. Plants exercise considerable control over the amounts of nutrients taken up. To further complicate matters, the degree of control exercised varies from one nutrient to another. Manipulation of turfgrass nutrition requires knowledge of the limits turfgrass itself places on nutrient absorption.

Our study is being conducted at the O.J. Noer Turfgrass Research and Education Facility. Last season a stand of 'Penncross' creeping bentgrass was established on silt loam soil and is being maintained under fairway conditions. The soil pH averages 5.8, contains 2.9% organic matter, and has soil tests of 61 ppm P and 180 ppm K. These P and K levels are considered to be high to very high for turfgrass. The fertilizer treatments consist of three N rates, two rates each of P and K, various NPK combinations and annual applications of lime and elemental sulfur.

Analyses of a set of clippings collected last October have already begun to shed considerable light on how the nutrition of creeping bentgrass can be manipulated. By going from 2.0 to 8.0 lb N/M/season, there was a substantial increase in shoot growth. This, in turn, altered the nutrient demand of the turfgrass and clipping concentrations of several nutrients changed accordingly. Without this change in nutrient demand, uptake of nutrients such as P and K remained unchanged even when the nutrients were applied. For example, the clipping concentration of P remained at 0.44% whether P was applied or not and applying K increased tissue K a mere 0.02%, from 2.54 to 2.56%. How many more times do I have to say that applying nutrients to turfgrass growing on soil already well supplied with the nutrients is a waste of time and money?

Examination of the relationships of clipping N (an index of nutrient demand) to other nutrients revealed how and the extent to which alteration of nutrient demand can be used to manipulate bentgrass nutrition. The types of relationships found, the strength of the relationships and the percent changes in clipping nutrient content are shown below.

Nutrient	Relationship	Strength	Nutrien change percent
P	Positive	0.998	19.0
K	Positive	0.982	22.5
Ca	Negative	0.046	4.5
Mg	Positive	0.941	7.7
S	Positive	0.904	21.1
Zn	Positive	0.972	16.5
B	Negative	0.707	18.1
Mn	Positive	0.204	3.1
Fe	Negative	0.242	12.2
Cu	Positive	0.790	10.7

Positive relationships mean that clipping nutrient concentration increased as clipping N and nutrient demand increased. The strength of the relationships between clipping N and the other nutrients can vary from 0 to 1.0. The indication is, the closer this value is to 1.0, the more strongly that bentgrass uptake of that nutrient depended on clipping N concentration; i.e., on nutrient demand.

(Continued on page 25)

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(Continued from page 23)

The above information is good evidence that bentgrass clipping concentrations of P, K, Mg, S and Zn can be manipulated by increasing plant nutrient demand through an increase in the rate of N application. Clipping Cu was also dependent on nutrient demand, but the strength of the relationship indicates other factors were involved as well. Changing nutrient demand does not appear to be a means for increasing clipping concentrations of Ca, B, Mn or Fe. Applying lime did not alter clipping Ca concentrations either.

The fact that clipping B levels decreased substantially with increasing nutrient demand likely reflects a case in which plant influence over uptake of the nutrient is minimal and increases in clipping production simply caused a dilution of the B taken up. This suggests that B is an example of a nutrient where soil application can be effective in manipulating its clipping concentration.

Iron and Mn clipping concentrations displayed little or no dependency on turfgrass nutrient demand. This becomes understandable in light of the fact that both nutrients must undergo reduction in soil before they can be absorbed by plant roots. Thus, efforts to manipulate turfgrass Fe and Mn concentrations have to focus on the creation of conditions that favor or decrease reduction of the two nutrients in soil. Reduction in soil of Fe and Mn is favored by low soil pH. Liming favors oxidation and a decrease in plant availability of the two nutrients. Our observations bear this out.

	Clipping concentrations	
Soil treatment	Fe	Mn
	ppm	
None	178	146
+ Lime	154	116
+ Sulfur	188	229

The indications from these data are that raising soil pH reduces plant availability of Fe and Mn while reducing soil pH with S has the opposite effect. The Mn concentrations were affected most. This reflects the fact that in-soil reduction of Mn is more sensitive to pH than is Fe.

One final observation here on how turfgrass cultural practices sometimes have unanticipated effects on turfgrass nutrition. In one series of treatments, lime application is in conjunction with use of three different N carriers: polymer+S coated urea; urea; and ammonium sulfate. Clipping N concentrations in October from these three treatments were as follows.

N Carrier	Clipping N
	%
Ammonium sulfate	4.27
Poly-S	4.15
Urea	3.40

What we see here is the effect of liming on volatilization loss of fertilizer N. Even though the bulk soil pH is only 5.8, liming obviously raised the soil surface pH high enough to promote volatilization of urea-N.

These initial research results provide strong indications that if we find bentgrass nutrition to be an important aspect of disease incidence and control, there are means to manipulate nutrient status. These means do, however, vary with the nutrient in question. Changing plant nutrient demand affords some control over clipping nutrient contents even when soil is well supplied with these nutrients. The nutrients subject to manipulation by way of nutrient demand are P, K, Mg, S, Zn, and, to a lesser extent, Cu. Boron uptake appears not to be under plant control and can be altered through fertilization. Iron and Mn can be regulated via soil pH adjustment.

A Perfect Day At Hartford Country Club

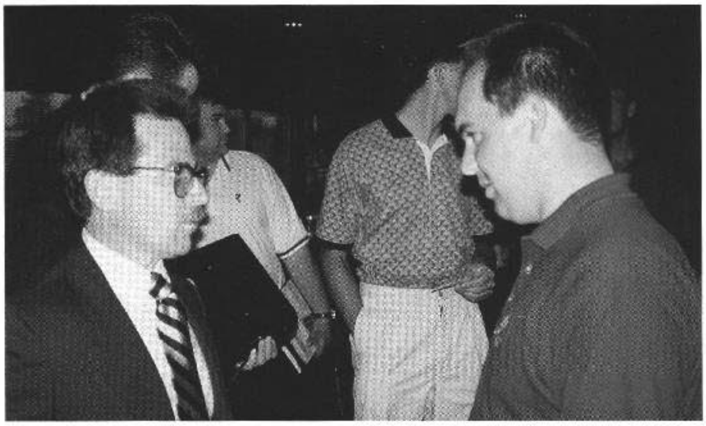
By David Brandenburg

Monday May 22 was very possibly the nicest day of the month and a great day for WGCSA to be invited to Hartford Country Club by host superintendent Joe Kuta.

Attendance was good with 72 golfers and 11 more for dinner. Joe and his staff had the golf course in great condition and we appreciate their hard work. Some of us occasional golfers have trouble with trees at the sides of the holes but Hartford's 17th hole, a par three, has two trees in front of the green. Those who handled that hole as well as the rest of the course in the 2 man scramble are as follows.

Net
1st – Andy Gruse - Dr. Jerry Ingalls
2nd – John Feiner - Skip Willms
3rd – Tom VanValin - Bill Knight

Gross
1st – Andy Gruse - Dr Jerry Ingalls
2nd – Dan Shaw - Jim Shaw
3rd – Bruce Worzella - Bruce Halfman



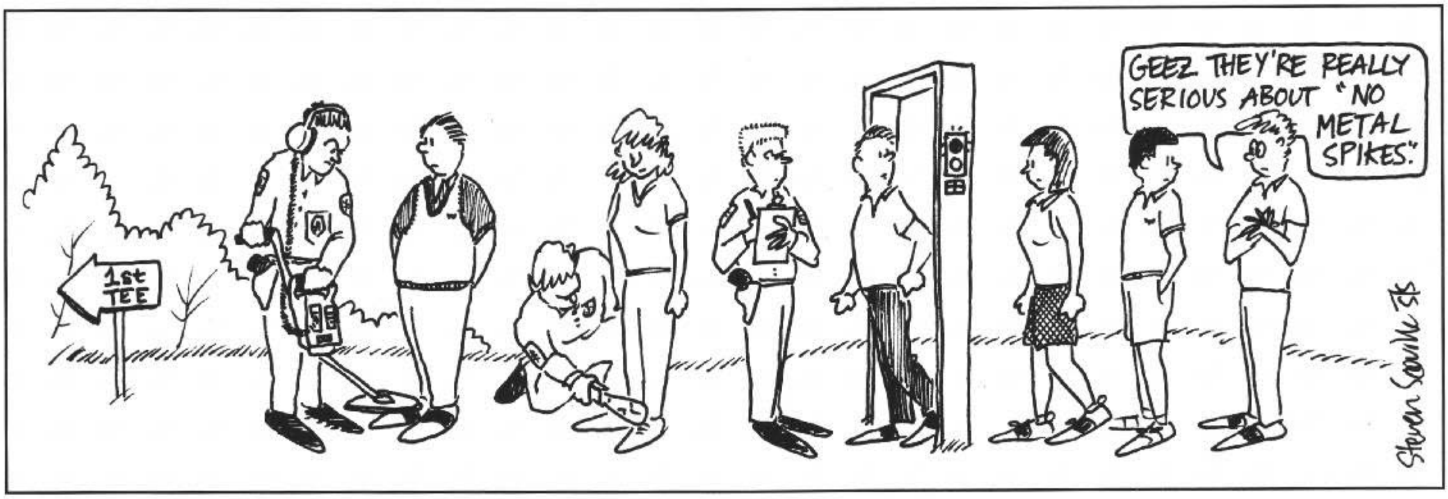
GCSAA director Tommy Witt (no relation to our great governor Tommy Thompson!) visits with Scott Schaler

My apologies to the four flag event winners as I misplaced the names, but congratulations anyway.

After a tasty tenderloin dinner our guest speaker was Mr. Tommy Witt, superintendent at Wynstone Golf Club in North Barrington, IL and a GCSAA Director. Tommy's speech "The Superintendent — How Valuable Are You?" touched on the importance of expressing to members and boards that we not only run expense centers, but that the golf course is the key to all income at the club. It was nice to have Tommy come up and speak to us and we hope to have him again.

Our thanks to superintendent Joe Kuta and professional Earl DuPont for providing an excellent day.

Finally! Don Steinmetz gets his 25 year membership plaque from President Semler



OZAUKEE WINS SUPER/PRO

By Rod Johnson

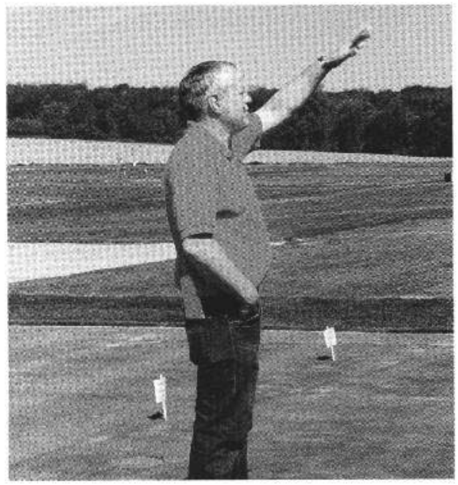
When the dust settled, the day's final tally showed the Ozaukee Country Club team of Wayne "the Old Pro" Otto and Rich Tock, golf professional, winners of the 1995 Super/Pro event at University Ridge golf course. West Bend's Bruce Worzella and Don Hill finished second and were followed by Butte des Morts' Steve Schmidt and Bill Brodell.

The real winners were the 33 teams which took advantage of a special opportunity to tour the O.J. Noer Turfgrass Research and Education Facility. It was a great chance for our business to do a little "showing off". Dr. Frank Rossi, Dr. Wayne Kussow and Dr. Julie Meyer did their usual superb job in conducting a tour designed especially for us and our PGA guests. Many thanks to them as well as Tom Schwab, Noer manager, and Audra Anderson.

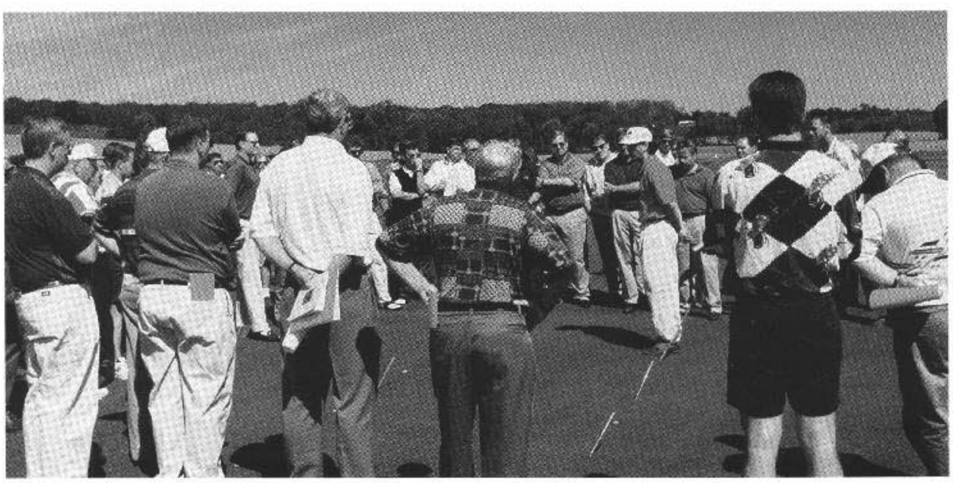
The Golf Foundation of Wisconsin and the O.J. Noer Foundation were big winners, too. These two foundations split the proceeds from the event, which will go to promote both golf in Wisconsin and turfgrass research in our state.

A very special thanks were earned by the event sponsors — Milorganite, Jacobsen and Club Car.

The renewed interest in this event, as evidenced by the excellent turnout, has inspired planners to plan a similarly exciting day for next year. Keep it in mind!



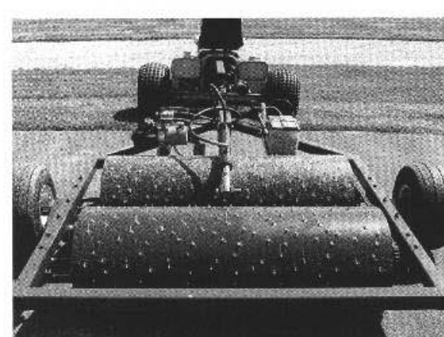
Professor Kussow—another one who cannot talk without his hands–gave details about putting green organic amendments.



Dr. Rossi held everyone's interest while explaining bentgrass variety differences.

Dr. Julie Meyer led a discussion of some alternative disease controls.

Frank Rossi welcomed participants to the Noer Research Facility before the tour started.



The golf spike traffic simulator drew the interest of many, especially with the soft spike issue getting so much attention.

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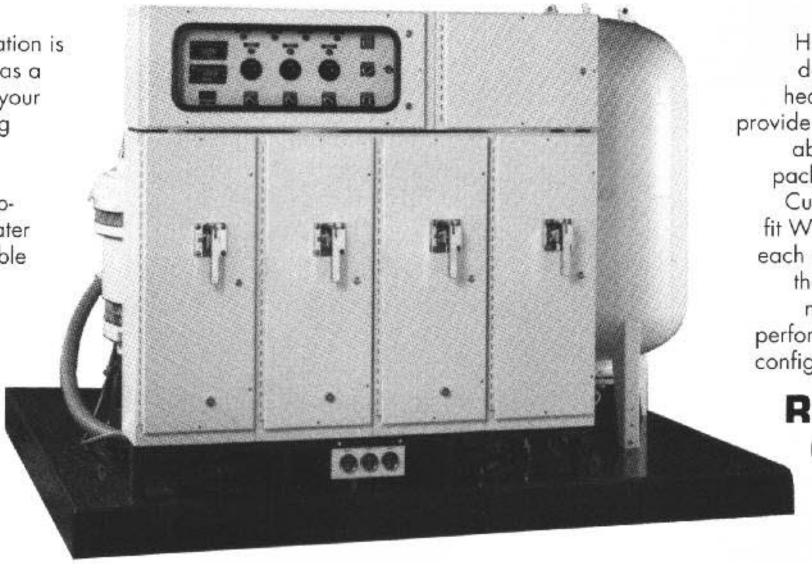

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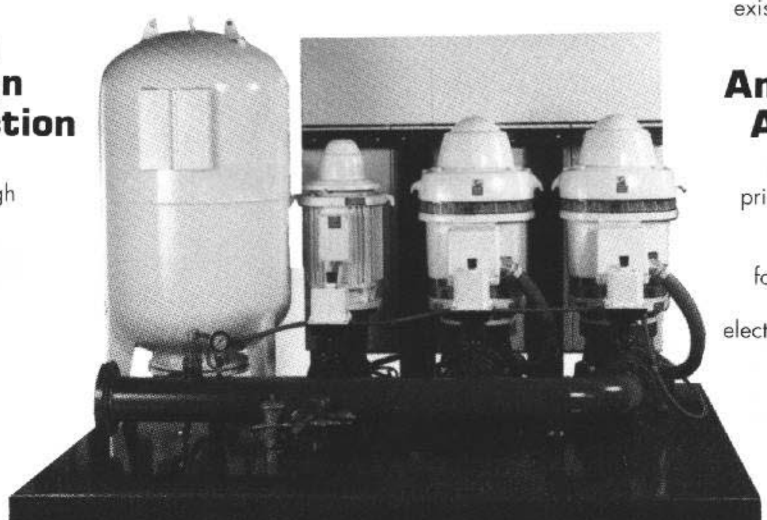

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Potential Contributions of Urban Vegetation to Phosphorus in Storm Water

By Oscar J. Peterson

Lake eutrophication becomes a hot topic in Madison every year because of highly publicized algal blooms in lakes Mendota and Monona. The media has often aired some misleading accusations as to the causes of the problem. Last fall I became interested in the issue when a classmate assaulted golf courses and lawn care companies as the root cause of lake eutrophication. This led to my examination of the problem and the conduct of some research that I saw as being needed to fill in some gaps in our knowledge of the sources of phosphorus in urban landscapes.

BACKGROUND

Lakes start out being oligotrophic, meaning that they are low in nutrients, clear, rich in oxygen and generally unproductive with regard to aquatic life. As time passes, the water becomes more and more nutrient enriched, aquatic plant life increases, oxygen levels in the water decline due to plant respiration and decay, and the lake slowly fills with sediments. As this happens, lakes become eutrophic. Oxygen becomes limiting to game fish, the water becomes murky, filled with weeds and algae and the lake is unappealing for recreation purposes. Understandably, people want to stop, or at least slow this natural process.

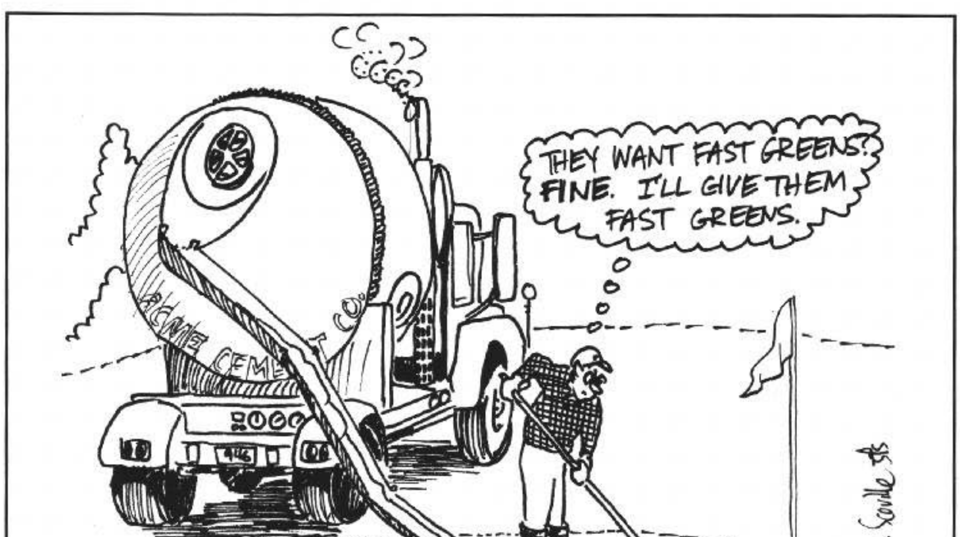
The rate at which eutrophication occurs depends on many different variables: depth and size of the lake, climate, geography, surrounding land use and vegetation and amounts of nutrients annually added to the water. Of these, nutrient supply is the one where control is most realistic. This typically leads to restrictions or regulations regarding sediment control, boundary vegetation and fertilizer use.

Nitrogen and phosphorus are the two most important nutrients. But it should be noted that the sources of these nutrients are not entirely or, perhaps even predominantly the product of human activity. When the Department of Natural Resouces rated 12 state lakes, Mendota ranked fourth as being naturally eutrophic (11). In other words, Lake Mendota would be eutrophic even if man and all of his influences were excluded.

Because of the vast amounts of nitrogen that cycles through the environment and the high mobility of the nutrient, nitrogen is seldom the limiting factor in algae and weed growth. In more than 80% of Wisconsin lakes phosphorus is the limiting factor (3). There are several reasons for this. One is the low solubility of P in water. The nutrient rarely leaches because of the formation of insoluble calcium, iron and aluminum precipitates (10). In fact, one way to inactivate P in is to add chemicals that contain aluminum (9).

The sources of P entering lakes can be split into two major categories: natural and man-induced. Natural sources can come from vegetation, precipitation, wildlife, fish and the weathering of lake sediments. The contribution from precipitation is usually small. For Lake Mendota, precipitation is thought to contribute less than 2% of the annual P input (3). On the other hand, wildlife can contribute substantial amounts of P. One study reported that ducks add almost 400 grams of P per duck per year (3). Fish, bottom feeders in particular, release and recycle P in lakes. Phosphorus stored in bottom sediments gets stirred up by fish, thereby making sediment P accessible to algae (1). Removal of bottom-feeding fish, especially carp, has been tried as an algae control measure in some small lakes, as has dredging of the sediments.

Major man-induced P sources come from multiple sources: fossil fuels; untreated sewage; fertilizers; manure; erosion; and decaying plant material. Not long ago, sewage was a main source of P in lakes. With the introduction of P-free detergents and mandatory sewage treatment, this is no longer the case. Conservation tillage and other erosion control practices have reduced agriculture's contribution of P to lakes. Turf fertilizers are now thought by many people to be a major P source and have recently received the brunt of the media's attention. These accusations ignore



the growing body of scientific literature regarding the effects of fertilization on P loss from managed turf and other sources of P in urban environments.

Runoff losses of P from fertilized lawn-type turf in the Madison area have averaged less than 0.12 lb/acre and more than one-half of the loss occurred from frozen soil (6). Even if all of this P were attributed to the fertilizer applied, it would still amount to less than 0.7% of the fertilizer P applied. Runoff loss of P from a golf course fairway receiving eight applications of P-bearing fertilizer per year was no greater than that found in the irrigation water itself (7). From these two studies it becomes evident that P losses from turf are typically very small and fertilizer may very well not be the primary source. Even if the contribution of P from turf fertilizer were notable, the total impact in urban settings is questionable. One short-term study in Madison has indicated that only about 14% of the P in storm water can be attributed to home lawns during the growing season (2).

Numerous studies have shown that there are two peaks in the P in urban runoff: at the time of snowmelt and late in fall. The fall peak in P coincides with the time of leaf fall (4). Since these are times of the year that lie outside the normal schedules for turf fertilization, one has to question the sources of the P. The most logical source of P in snowmelt is surface plant residue. One study has shown that the P in tree leaves is subject to leaching (4). The same may be true for turfgrass leaves. It is this aspect of potential lake eutrophication that interested me because it is such an obvious source of P and has received little attention.

RESEARCH

In the fall of 1994 clippings from Kentucky bluegrass and creeping bentgrass and fallen leaves from white pine, burr oak, Chinese elm, Russian mulberry and sugar maple were collected and brought into the laboratory. Amounts of water soluble P were measured in the fresh grass clippings, air-dried clippings, frozen clippings and clippings frozen and then air-dried. The same P determination was made on air-dried leaves, leaves that were frozen for 8 weeks and leaves that were allowed to decompose for 8 weeks at 90° F. The purpose of these various treatments was to simulate fall, winter thaw, and spring leaching of P. Total P content of the grass and leaf samples was measured to allow calculation of the percentage of tissue P that was leachable.

RESULTS AND DISCUSSION

Percentages of leachable P in the turfgrass clippings varied with the source of the clippings and treatment prior to extraction of the P (Table 1). More P was leached from the creeping bentgrass clippings than the Kentucky bluegrass clippings. This may be because the bentgrass clippings were much finer and had a higher percentage of cellar contents exposed for P extraction. Air-drying, freezing and freezing plus air-drying progressively increased the percentages of total P in the grass clippings that were soluble in water. This progression clearly indicates that grass residues are most prone to leaching loss of P in the spring of the year. Clippings subjected to simulated overwintering released 3 to 4.5 times more P than did the fresh clippings.

Tree specie seemed to have a big effect on the the percentages of P that leached from the air-dried leaves (Table 1). These ranged from a low of 5.5% for burr oak to 33% for Chinese elm. Freezing of the leaves prior to water extraction of P greatly reduced the percentage of P removed from the Chinese elm leaves, but had little effect on the other species. Partial decomposition of the leaves had the effect of generally reducing the percentage of P that was leachable. This surprising result may be explained by the fact that tree leaves are relatively nutrient poor as far as microbial decomposition is concerned. It is entirely possible that leaf P was immobilized as microbial P during the decay process. From these observations, the conclusion is that more P will be leached from tree leaves in the fall than in the spring.

The total concentrations of P in the grass clippings and tree leaves and the amounts of P leached are presented in Table 2. The concentrations of P in the Kentucky bluegrass and creeping bentgrass clippings differed by only 170 mg/kg, or 0.017%. Yet, the amounts of P leached differed 2- to 3-fold. This supports the earlier assumption that finess of the clippings has a much greater influence on P leachability than does total P content. This also indicates that changes in clipping P concentration as a result of fertilization will not have much effect on the amounts of P leached from grass clippings.

The amounts of P leached from the grass clippings and tree leaves provide some basis for estimating their potential contributions to urban runoff water. To do this, one has to come up with some estimates of the dry weights of tree leaves and the dry weight of tissue on the surface of a good quality turf when snowfall occurs. For 20-year old trees, the leaf dry biomass for deciduous trees is in the range of 7.5 kg (personal communication, Prof. T Gower, Forestry Department). Assuming these leaves fall to occupy an area of approximately 1,000 ft2, one can then use the figures in Table 2 for P leached from air-dried leaves to estimate potential runoff loss of P. This would be a worst-case scenario. The values one arrives at are a high of 0.024 lb P/1,000 ft2 for a Chinese elm tree to a low of 0.0003 lb P for a pine tree that produces only about 1/3 the leaf biomass of deciduous trees.

TABLE 1. Water leachable P in grass clippings and tree leaves when subjected to various treatments.

	Percent of P leached				
Grass or tree	Fresh	Air-dried	Frozen	Frozen & dried	Decomposed
Kentucky bluegrass	7.0	10.2	20.3	31.7	—
Creeping bentgrass	19.7	23.4	39.0	58.5	—
Chinese elm	—	33.0	8.8	—	25.9
White pine	—	8.5	9.2	—	4.4
Burr Oak	—	5.5	4.1	—	6.1
Russian mulberry	—	6.6	7.0	—	3.8
Sugar maple	—	20.8	25.8	—	13.6