A PRACTICAL RESEARCH DIGEST FOR TURF MANAGERS

TURFGRASS TRENDS

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SEED SELECTION

How Predictable is NTEP Data for Your Particular Site?

By Doug Brede, Ph.D.

Last fall I worked with a client in Edmonton, Alberta, Canada, who was planting a golf course to Kentucky bluegrass. I asked if he had consulted data from the National Turfgrass Evaluation Program (NTEP) to aid in his decision, and he said he had. The client explained that he had chosen a handful of varieties from the top of the Grand Mean column and wanted to construct a blend.

Sound familiar? This same scenario plays out in locations across the continent all the time. Contractors, landscape architects, and turf managers consult the NTEP listings as a routine part of their planting plans. But the question remains: Is this the best way to pick varieties for your site?

In this article I'm going to examine some of the relationships buried inside the NTEP data. Most people who use NTEP data look at just the single column of Grand Mean averages for recommendations. But is this the right thing to do? Or are there idiosyncrasies hidden within the statistics that may paint a misleading picture? I will show you what some of these rating values really mean by examining underlying interrelations among the variables.

First, I'm going to explain some of the more confusing concepts within NTEP, such as the differences and similarities between such things as density and texture. (Does anyone really know the difference between those two?) By doing so, I'll provide insights into the thought-processes of the raters and the meaning of their results.

Next, I'll show you why you may be making a giant mistake by following the Grand Mean Quality results for your variety recommendation needs – as my Edmonton client later discovered.

Hidden interrelationships in NTEP data

Whenever I tell one of my non-turf colleagues about the NTEP trials – our "yardstick" of turf breeding – the question invariably comes up: What kind of meters do you use to take the readings? Most scientists are accustomed to carrying gadgets and gizmos with them to measure things. My non-turf colleagues are always surprised to learn that there are no such gadgets with turf. Every measurement in the NTEP trial is based on eyeball estimates.

To those of you familiar with the process, this comes as no surprise. But it may surprise you to learn that some of these visual estimates are strongly interrelated. Many are highly correlated: Factor A influences the rater's judgment on Factor B.

To explore these interrelationships, I downloaded tables from the 2000 results of the 1995 Kentucky bluegrass trial from NTEP's web site (www.ntep.org). I used a software package called Statistica to analyze the data. However you can do many of the same manipulations with Microsoft Excel on your desktop.

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Are raters color-blind?

One of the classic relationships in NTEP is between color and quality. Raters I've spoken with take pride in the fact that they don't let the color of a grass taint their judgment when rating turfgrass quality. Most assert that a dense, pest free, light green grass would be rated just as highly as a good dark one. Or are they swayed? When I plotted the genetic color versus the Grand Quality Mean, a strong relationship appeared (Fig. 2a).

The graphs in Figure 2 display data points of all 103 varieties in the 1995-2000 trial. I labeled a handful of landmark varieties to establish mileposts in the sea of dots: KenBlue (a common-type variety), Classic and Baron (two older, intermediate types), Eclipse and Glade (top varieties from the 1980's), Limousine (a high density variety), and Award and Midnight (varieties presently at the top of the quality charts).

The computer did not draw a straight line for the relationship of color versus quality but one with a bowed center (Fig. 2a). Nonetheless, darker color does appear to influence higher quality scores. KenBlue, one of the lightest colored varieties in the trial, also had the lowest turf quality. Award and Midnight both had high quality and dark color.

Certainly there are other explanations for this connection of color and quality. An argument can be made that dark color has a physiological benefit to the plant. A darker plant, it's been shown, contains more chlorophyll – the energy compound in plants. With more energy, darker green varieties are able to grow faster, produce a denser turf, and regrow foliage lost to mowing, disease, and wear. Therefore two associations are at play: A preference by the raters for darker color, and a physiological advantage to the plant from more chlorophyll.

Are raters dense?

Turf density and texture are among the most misunderstood ratings in NTEP. In theory, density reflects the number of plants per square inch. But no one actually gets down on their hands and knees to count. We stand and judge. And by doing so, we get confounding results. For example, how do you tell if a plot has more plants per square inch, or whether it has more leaves per plant? You can't.

Leaf texture is an evaluation of the width of individual blades. In leaf texture ratings, finer-bladed varieties are scored higher. Again, no one gets out a ruler to measure leaf width (which would be the logical but time-consuming way to approach the problem). Instead, we stand and judge.

One misleading assumption in leaf texture ratings is that finer texture is more desirable. After all, why would finer texture ratings have a higher number if it didn't mean narrower is better? Personally, I prefer a variety with a leaf texture rating of about a "7" (on a 1 to 9 ratings scale). I think it is entirely possible for a variety to be too finely bladed, possibly sacrificing toughness, wear tolerance, or mixability with others. Other evaluators may feel differently.

In Figure 2b you can observe the tight clustering of leaf texture with turf density about the slope line. As the example in Figure 1 shows, a tighter adherence to the slope line indicates a stronger relationship and better predictability. The main difference between texture and density is in point spread: Leaf texture has a 3-point ratings spread (from 5 to 8) from best to worst, while density has only a 1-point spread. Could it be that the raters are more comfortable with the concept of texture than density? It's hard to say for sure, but that's a possibility.

Turf density has two other interesting associations, those being with ground coverage and disease. The skin-tight clustering of the points about the slope line (Fig. 2d) indicates that density and ground coverage are virtually synonymous. Over the years I've questioned whether the "ground coverage" rating was even necessary. These results suggest that either the raters can't distinguish between the two, or that density so affects ground coverage as to make it superfluous.

I must admit, at first sight, the relationship between turf density and disease resistance (Fig. 2c) caught me by surprise. Classical plant pathology says that stands with higher plant densities tend to get more disease. That's because typically, denser stands have smaller, frailer plants, easily prone to fungal attack and spread. While there is a fairly good association between density and leafspot resistance (as evidenced by the clustering), the surprise was that slope of the line was positive, not negative. If a denser stand was truly more disease prone, the line would slope downward not up.

ASSIGNING A NUMBER TO PREDICTABILITY

The science of statistics is all about assigning numbers to things that happen in nature. Like anything else, predictability can be quantified and assigned a meaningful value. Take, for example, my golf scores. Based on my past research, my success rate for driving straight down the fairway tends to increase with the hole number. I nearly always flub the first tee shot. But the longer I play, the better I get and the greater my success of hitting a straight drive.

This relationship can be graphed, showing a fairly straight line between my tee-off success rate and the hole number. Of course, not every data point falls on a straight line. Towards the end of the match, my drives again tend to stray, as fatigue and Miller Genuine Draft takes effect.

Back in high school, I remember my math teacher demonstrating a way to take a straightedge, estimate the best fit through a clump of data points, and draw a pencil line through the middle. The straight line represents the relationship between the hole number and the score. Statisticians have an even classier way of doing this, called the Least-Squares Method. Using a computer program, the computer digests the data points and constructs the straight-line relationship using a mathematical method of Best Fit. You find Least-Squares programs running behind the scenes in popular software programs such as Microsoft Excel's graphing routine.

Software can even estimate the Goodness of Fit or predictability of that line. If my 18 golf data points all fell exactly on a straight line, the percent fit would be 100% (see graph below). Of course, 100% predictability rarely happens in nature. More often, you have no relationship, or something in between. Where no relationship exists, the data points form a "glob" on the X-Y scatterplot. Better fits are illustrated by a tighter clustering to the slope line. The degree of fit can be expressed as a number value, or r2 value, expressing the percent predictability.

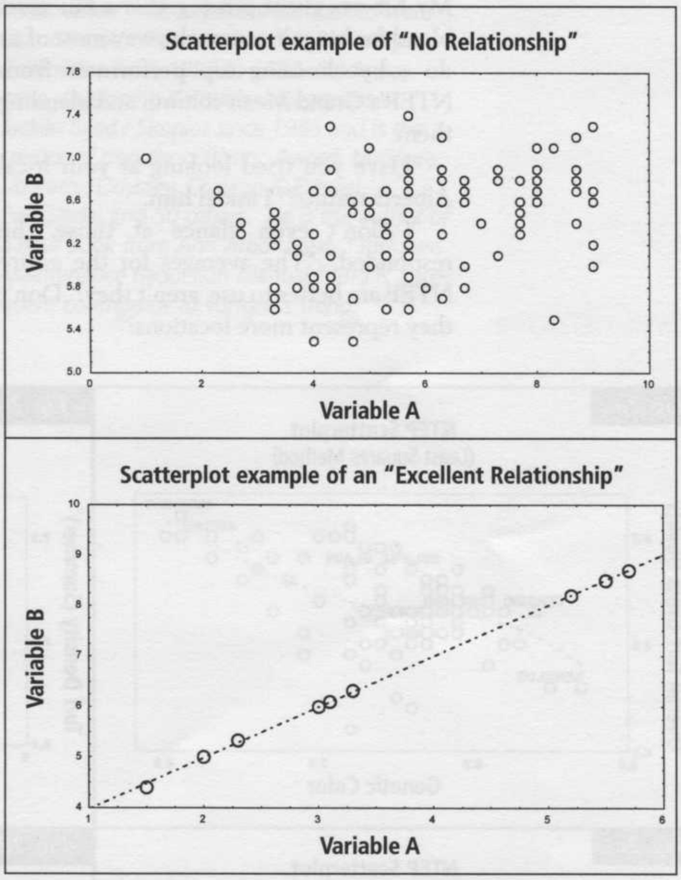


***Figure 1.** Scatterplots are handy ways for examining relationships between two sets of numbers. Let's say you survey 100 people, measuring their height and their cholesterol level. By plotting each point, with their height on one axis and their cholesterol reading on the other, you might get a graph like the one below (top chart). This scatterplot illustrates a classic "no relationship" response. In other words, taller people do not have a tendency toward higher cholesterol. Now let's say you surveyed the same people, recording the height at the top of their head versus the height of their shoulders. These two variables are obviously interrelated and illustrate a nice, straight-line relationship, as shown in the lower graph.*

Here's what I believe is occurring: Disease-resistant cultivars are simply able to produce more shoots than susceptible ones. Varieties like Award and Midnight, which are nearly immune to leafspot, are not encumbered by the thinning of disease attack. These varieties help illustrate the real reason behind the positive relationship of density and disease resistance.

How useful is "grand quality mean?"

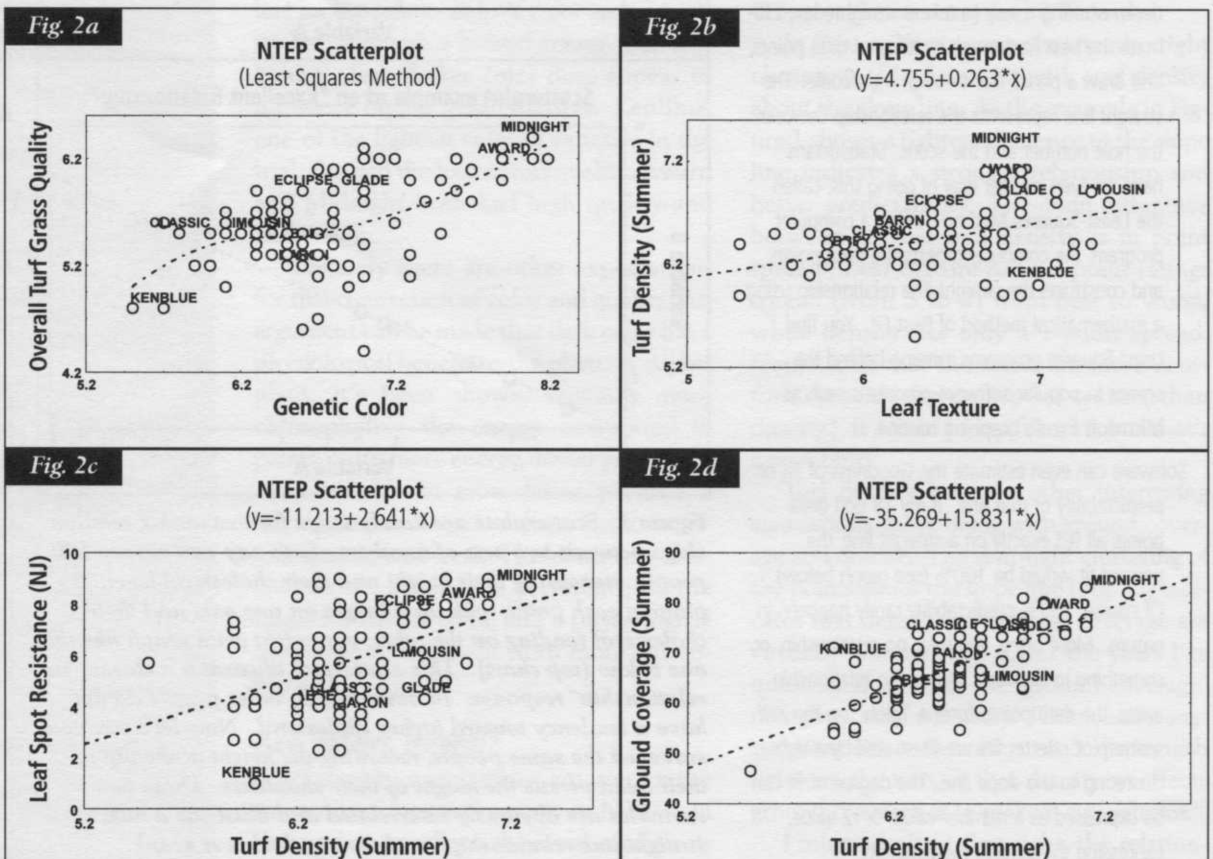
My Alberta client put together a bluegrass blend for his golf course the way most of us do – by choosing top performers from NTEP's Grand Mean column and blending them.

"Have you tried looking at your local Alberta results?" I asked him.

"I don't even glance at those," he responded. "The averages for the entire NTEP are better to use, aren't they? Don't they represent more locations?"

After that conversation, I did some thinking about whether his approach was right or wrong. Unable to reach a conclusion, I decided to let statistics help me find an answer. Using the same data mentioned above, I compared the individual State/Province averages of the 103 bluegrass varieties versus the Grand Quality Mean. I used Statistica to calculate the "predictability" of each State/Province versus the Grand Mean. A predictability value of 100% would indicate that the particular State's mean was exactly shadowing the Grand Mean and the user could consult either result with equal certainty.

Among the 26 sites in the trial, the NJ1 site (New Brunswick, NJ) gave the best correlation with the Grand Mean, with 68% predictability. Turf managers in New Jersey can probably utilize either their State results or the Grand Mean with fairly equal implications. (It makes you wonder why we don't just have Drs. Bill Meyer and Reed



Funk at Rutgers do the whole NTEP there themselves!) Curiously, a second site in New Jersey (Adelphia) gave just 34% predictability. Minnesota also had a strong positive correlation. Years ago when I ran a similar analysis on the 1985-1990 trial, there was a negative correlation between the Minnesota site and the Grand Mean. In other words, varieties that did well in the Minnesota trial, tended to do poorly nationally. Strange but true.

But getting back to my Edmonton client, I found there was absolutely zero predictability between his local Alberta site and the NTEP Grand Mean. Yet, this fellow was taking the Grand Mean as gospel, downplaying the need to even glance at his local site results.

Examples like that force me to conclude that the Grand Mean may be more of an albatross than a benefit – especially when it misleads people more than it helps. Clearly half of NTEP's sites predict one-third or less of the variability in the Grand Mean. My Edmonton colleague would have been far better served to consult his local site data and not even glance at the national results.

Does that mean that certain State data are wrong or even bad? Not at all. It means the results are State specific. Data from New England and some Midwestern states correlated closely with the Grand Mean, showing high levels of association. Canada, the Mid-Atlantic region, Iowa, and the West correlated poorly with National averages. Turf managers in those areas should preferentially take the State readings over the Grand Mean.

NTEP is presently grappling over dispensing with the Grand Mean column and emphasizing individual State/Province results. My advice to you: If your state has a predictability of less than 50% (Fig. 3), I'd stick with your State results and forget about the Grand Quality Mean.

Doug Brede has had a long association with NTEP, dating back to 1979 when he attended a planning meeting at Rutgers University to establish the initial protocols for NTEP. Even before that time, he was an evaluator for Penn State University's plots of Project NE-57, which was the precursor of the modern NTEP trial. Brede was an evaluator and host site for NTEP trials from 1980 (NTEP's inception) until 1994, when trials at private companies were discontinued. He served on NTEP's Policy Committee from 1997 to 1999. Brede has been developing Kentucky bluegrasses at Jacklin Seed / Simplot since 1986 and is the creator of popular cultivars, Award, NuGlade, Liberator, Odyssey, Chicago II, Everest, EverGlade, and 50 others. He is the author of a new book from Ann Arbor Press, "Turfgrass Maintenance Reduction Manual," and is a frequent contributor to Turfgrass Trends

Manganese Usage by Turfgrasses

By Richard J. Hull
University of Rhode Island

Any consideration of micronutrient use in turfgrass management is limited by a general lack of specific research aimed at defining turf needs for these essential elements. The age of turfgrass fertility research has long passed, leaving the present turf manager with little more than hype from fertilizer salesmen and anecdotal accounts of product effectiveness.

Unless a plant nutrient is viewed as a threat to surface or ground water quality and thereby a risk to human health, it is virtually impossible for a serious turf researcher to obtain grant funds to study its role in turf physiology or management. This is unfortunate because turf is increasingly being grown on artificial substrates that often have little inherent nutrient content. If all mineral nutrients, including micronutrients, must be supplied as part of a management program, the questions of how much, in what form and when become critical. Research generated 30 or 40 years ago is poorly suited to address these questions because nutrient sources, turfgrass genotypes and end user expectations all have changed dramatically. This is a problem especially for less appreciated micronutrients such as manganese (Mn).

This is the third in our series on

Many soil fungi that normally would not be pathogenic or only weakly so will cause disease in Mn deficient plants.

Table 1. Manganese content in leaf tissues of several turfgrasses.

Turfgrass	Manganese content* Waddington & Zimmerman (1972)	Butler & Hodges (1967)
	ppm (mg/kg)	
Annual bluegrass	250	
Kentucky bluegrass	154	33
Colonial bentgrass	414	83
Creeping bentgrass	339	
Tall fescue	434	71
Creeping red fescue	185	54
Perennial ryegrass	304	73
Bermudagrass	—	57
Zoysiagrass	—	29

* AS REPORTED IN TURNER & HUMMEL (1992)

micronutrient use by turf with iron (Hull 1999a) and zinc (Hull 2001) having been discussed earlier in this journal. As was the case with Zn, the literature on Mn use by turf is not extensive. Turner and Hummel (1992) summarized the few reports on Mn content in several turfgrasses and found that the values varied widely among grass species and between laboratories (Table 1). The Mn content of dried clippings reported by Waddington and Zimmerman (1972) for seven turfgrasses averaged 297 mg/kg (ppm) while that reported for another seven turfgrasses by Butler and Hodges (1967) averaged only 46 mg/kg. Waddington and Zimmerman (1972) were concerned about these differences and compared the Mn content of creeping bentgrass leaves on several dates throughout a growing season. They found the Mn content ranged from 163 to 391 mg/kg. These differences could reflect the fact that Mn is not readily redistributed in plants so it pretty much remains in those leaves into which it is delivered by xylem transport from the roots.

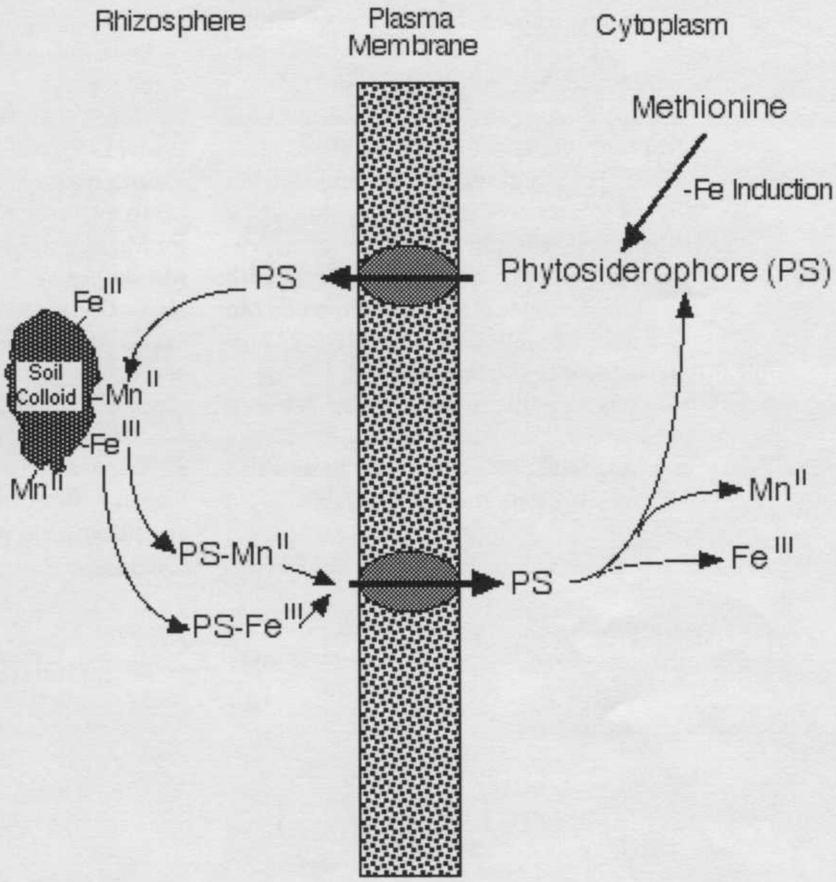


Fig. 1. Mechanism employed by grasses to recover Fe and Mn form soils having these ions in nonavailable form.

During times of slow shoot growth, Mn would have more time to accumulate in leaves before they were sampled for analysis. Variation between analytical laboratories could reflect differences in methods utilized or differences in the amount of Mn available to the turf (sand vs. soil based greens). Jones (1980) concluded that a Mn sufficiency range for turfgrasses was between 25 and 50 mg Mn/kg dry leaf tissue. The critical Mn concentration (plant tissue concentration that will support 90% of maximum growth rate) generally ranges from 10 to 20 mg Mn/kg dry weight (Marschner 1995). This makes the turfgrass requirement for Mn about the same as that for zinc.

Soil manganese

Manganese is a reasonably abundant element with an average concentration in the earth's crust of 1000 ppm and a soil range of 20 to 3000 ppm averaging about 600 ppm.

Manganese is present in most Fe-Mg containing igneous rocks and when solubilized by weathering, forms several secondary minerals mostly pyrolusite (MnO_2) and manganite (MnOOH). Thus, most soil Mn is insoluble and not available to plant roots. The plant-available form of free Mn in soil solution is the divalent cation Mn^{2+}. Manganese solubility is very much dependent on soil pH, decreasing 100 fold with each unit increase in pH. Consequently Mn is much more soluble and available to plants in acid soils (pH < 5.5).

However, for free Mn^{2+} to be released into the soil solution and occupy cation exchange sites, reducing power in the form of organic matter must be available.

$$MnO_2 + 4H^+ + 2e^- \longleftrightarrow Mn^{2+} + 2H_2O$$

Here, minerals containing Mn in oxidized form (Mn^{3+} or Mn^{4+}) will be reduced to Mn^{2+} by acquiring electrons (e^-) through the microbial oxidation of organic carbon.

To meet the nutritional needs of plants for Mn, the soil solution and exchangeable Mn should be 2-3 ppm and 0.2-5.0 ppm, respectively. In acid soils, soluble Mn may exceed these levels by substantial amounts and become toxic to plants. This is likely in situations where soil minerals contain Mn, the organic matter content is high, the pH is low and the soil is periodically waterlogged (low in free oxygen). Under such conditions, acid inhibition of plant growth

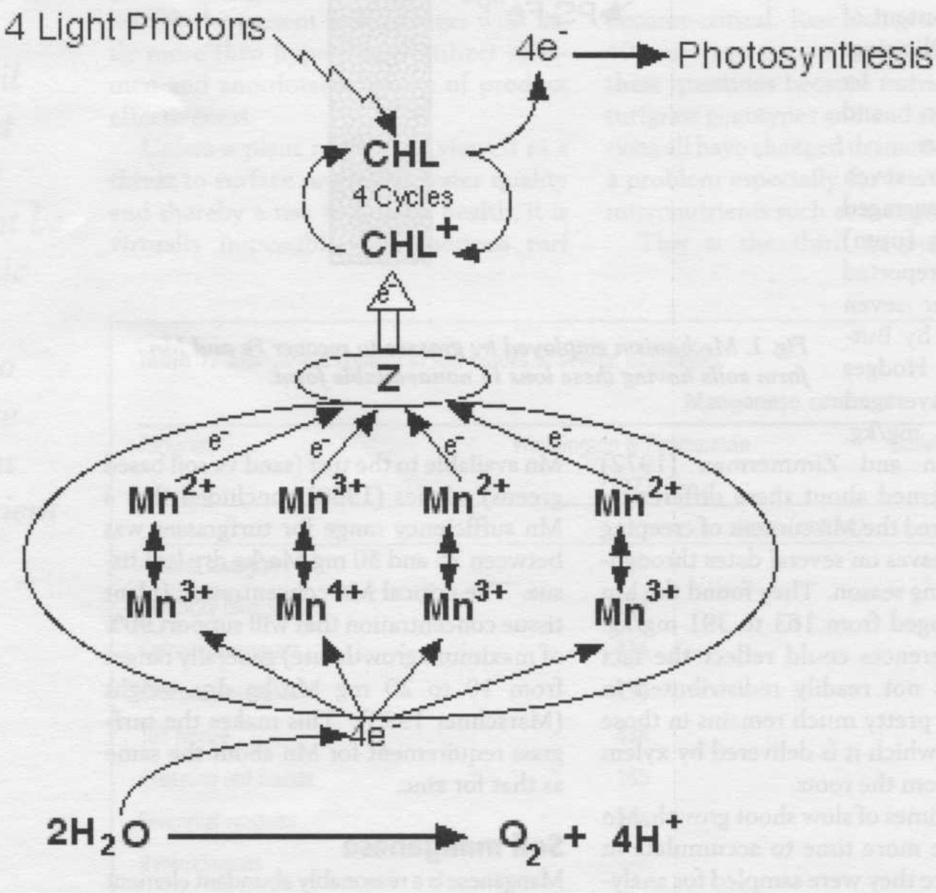


Fig. 2. Oxygen evolving mechanism of plant photosynthesis in which water repaces electrons driven by light from chlorophyll through the re-dox action of Mn.

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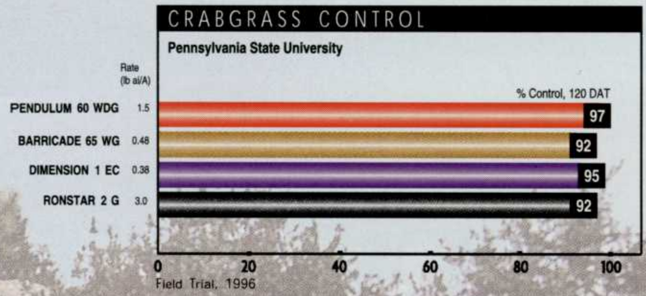

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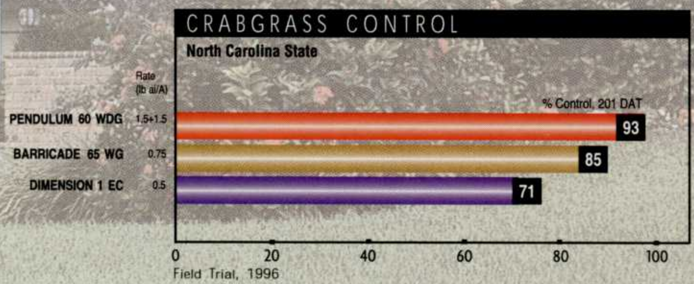

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may be due primarily to toxic levels of available Mn.

Under opposite conditions (parent minerals low in Mn, alkaline pH, low organic matter and good drainage) inadequate supplies of available Mn are likely. Some 13 million acres in 30 states of the US exhibit chronically inadequate levels of Mn (Tisdale et al. 1993). For the turf manager, Mn insufficiency is a more likely problem than its toxicity.

Soluble soil Mn is also present in the form of Mn-chelates. These organic chelates are excreted from plant roots or produced during the metabolism of organic residues. They will bind with Mn^{2+} but remain in solution as uncharged molecules. Much of the soluble Mn in organic soils will be present in a chelated form. Being soluble, Mn chelates are mobile in the soil and can be drawn to roots via mass flow when plants are removing water from the soil through transpiration. This process can assist in Mn uptake as we will see below.

Manganese uptake

Plant roots can absorb Mn primarily as the divalent cation (Mn^{2+}). It enters root cells by crossing their plasma membrane via a specific transporter protein following an electrical gradient (cell interior is more negative than the cell wall). Other divalent micronutrient cations, such as Copper (Cu^{2+}) and Zinc (Zn^{2+}), do not compete with Mn^{2+} for membrane transport sites although they do compete with each other (Bowen 1969).

Most soil Mn is insoluble and not available to plant roots.

However, the abundance of several macronutrients on cation exchange sites within the cell walls of root cells (the apoplasm) can influence Mn absorption by roots. Manganese is much less available from soils of high pH. This is in large part due to the high concentrations of Calcium and Magnesium ions (Ca^{2+} & Mg^{2+}) in such soils. When Ca^{2+} and Mg^{2+} dominate cation exchange sites in root cell walls, there are few places for less abundant ions like Mn^{2+} to be retained.

Since cations absorbed by roots are drawn mostly from those present within the cell wall matrix, any less abundant ions (including most micronutrients) will have a difficult time reaching the plasma membrane when they are vastly outnumbered by basic divalent cations. This is the reason why most micronutrient metals are less available in soils of neutral or alkaline pH.

In acid soils, the principle competing cation is Hydrogen (H^+) and it is not held on exchange sites as tightly as most divalent cations. However, if other cations such as aluminum (Al^{3+}), potassium (K^+) or other micronutrients greatly outnumber Mn^{2+} even in acid soils, Mn may become deficient. Even so, the most common method for increasing Mn availability to plants is to apply acid fertilizers such as $(NH_4)_2SO_4$ or urea.

The availability and absorption of Mn from soils is more influenced by microbial activity than is any other

TABLE 2.
MANGANESE FUNCTIONS IN HIGHER PLANTS INCLUDING TURFGRASSES

Essential component of two enzymes:

- O_2 evolving component of photosynthesis (PS II)
- Mn-containing superoxide dismutase (MnSOD)

Activating cofactor for ~35 enzymes required for:

- Respiratory metabolism of organic acids (TCA cycle)
- RNA synthesis in chloroplasts (RNA polymerase)
- Shikimic acid pathway (aromatic amino acid synthesis)
- Lignin synthesis in roots (cell wall peroxidases)
- Lipid synthesis including chlorophyll and carotenoids
- Regulating auxin levels and isoprenoid synthesis (GA)

Required for root elongation and lateral root formation

micronutrient. To be absorbed by plants, Mn must be reduced to the divalent Mn^{2+} ion and this requires the action of microbial metabolism (Marschner 1995). Under acid conditions, Mn-containing minerals will slowly be solubilized and several ionic forms of free Mn and $Mn(OH)_n$ will be released to the soil solution. Under such conditions, most plant roots will discharge low molecular weight exudates (organic acids, sugars, amino acids and phenolics) to the soil immediately adjacent to the roots (rhizosphere). These exudates along with dead root cells (root cap cells, root hairs, epidermal and cortical cells) fuel microbial activity and, especially when the soil is waterlogged, supply electrons to reduce Mn ions to the plant-available Mn^{2+} form.

To meet the nutritional needs of plants for Mn, the soil solution and exchangeable Mn should be 2-3 ppm and 0.2-5.0 ppm, respectively.

This ion can then be absorbed by root cells as described above.

In grasses, there is a cooperative mechanism for acquiring Mn by plants experiencing an Iron (Fe) deficiency. Because of its low solubility and the inability of membrane transporters to accommodate trivalent ions, Fe^{3+} poses some special problems in its availability to plants.

Grasses have a unique strategy for making Fe^{3+} ions available for root uptake (Marschner 1995; Hull 1999a). In response to low Fe stress, grass roots are induced to release special amino acids called phytosiderophores that chelate free Fe^{3+} allowing it to move to root surfaces and be absorbed (Fig. 1). While phytosiderophores have a very high affinity for Fe^{3+} and root cells have enhanced transporter capacity for the Fe-phytosiderophore complex, other micronutrient cations can also be chelated by phytosiderophores and become mobilized within the rhizosphere.

Thus when Fe is deficient, Mn^{2+} can be chelated by phytosiderophores and diffuse to the root surface where it is absorbed into the root. The Mn-phytosiderophore complex is not absorbed as readily as is that formed with Fe^{3+}. However, this Fe deficiency induced mechanism for capturing micronutrient ions can make nutrients other than Fe more available to grasses.

Functions of manganese

Manganese serves a number of functions in plants (Table 2). Its most important roles are as an essential component of the oxygen (O_2) evolving complex in photosynthesis and as an activator cofactor of several major enzymes involved in numerous metabolic sequences. Manganese also plays a role in root elongation and lateral root initiation possibly by regulating the auxin levels along the root axis. Some of these functions that are most significant for turfgrass performance will be discussed in this section.

Oxygen evolution in photosynthesis

Because of the central role played by photosynthesis in the life of all green plants, the requirement for Mn in the oxygen evolving complex of Photosystem II in the photosynthetic electron transport chain assumes primary importance. Virtually all oxygen in the atmosphere is derived from photosynthesis and its Mn requiring oxygen evolving complex. Thus, all aerobic life including human life is absolutely dependent on this Mn facilitated biochemical process.

The electrons used in photosynthesis to reduce carbon dioxide (CO_2) to carbohydrates [$(CH_2O)n$] ultimately are taken from the oxygen in water (H_2O). When two molecules of water are so

$$CO_2 + 2H_2O \xrightarrow{\text{light}} (CH_2O)_n + O_2 + H_2O$$

oxidized (lose 4e-), one molecule of oxygen gas (O_2) is produced as a byproduct and the $4e^-$ reduce an electron carrier that eventually will reduce the C of one CO_2 to one carbohydrate C. The oxygen of water does not easily surrender its electrons and it will only do so in the presence of a very strong oxidant (substance having a powerful affinity for electrons). This strong oxidant forms when a special chlorophyll molecule receives a quantum of light energy that drives off an electron from the excited chlorophyll to a nearby electron acceptor (Fig. 2). This begins the photosynthetic electron transport pathway.

The chlorophyll that has lost an electron must obtain another or it will become further oxidized and destroyed. Electrons are provided from a near by protein that contains a cluster of four Mn atoms each capable of donating an electron to the oxidized chlorophyll. When each Mn atom has donated an electron (become oxidized from Mn^{2+} to Mn^{3+} or Mn^{4+}), these four oxidized Mn atoms together represent an oxidant so strong that they can strip electrons from the oxygen of water.

To reduce the four Mn atoms, four electrons are needed and that requires the oxidation of two water molecules.

$$2H^2O + 4Mn^{3+} \longrightarrow 4Mn^{2+} + O_2 + 4H^+$$

The Mn cluster is now ready again to deliver electrons to chlorophyll when it becomes oxidized through photoactivation. Thus, the Mn-containing oxygen evolving complex allows the flow of electrons to continue as light drives electrons from chlorophyll ultimately to reduce CO_2.

Manganese-containing superoxide dismutase (Mn-SOD)

Like Fe and Zn (Hull 1999a & 2001), Mn is the core atom (prosthetic group) in an enzyme that catalyzes the destruction of a potentially damaging oxygen free radical, superoxide (O_2). Wherever O_2 is involved in biochemical reactions and a source of electrons is present (reducing agents), the probability of $O_2\cdot$ being formed is great. To eliminate this toxic radical, a family of SOD enzymes has evolved each employing a different metal as its prosthetic group.

The Fe-SOD and CuZn-SOD are most active in chloroplasts with the latter also found in mitochondria. The Mn-SOD is not so widely distributed among plant families and is most active in mitochondria and in peroxisomes that are involved in photorespiration (Hull 1999b). The Mn-SOD enzyme is the major SOD in several groups of rhizosphere bacteria. Plants transformed to over-produce Mn-SOD experienced less chlorophyll degradation and mitochondrial leakage when grown in high light. These enzymes permit most grasses to grow in full sunlight without experiencing photo-oxidative damage.

Mn and phenol biosynthesis leading to lignin

Lignin is a complex polymer of unsaturated six-sided ring structures that are produced in cell walls and give plant tissues great strength. The highly lignified vascular cells and fibers of trees enable them to reach great heights and withstand considerable mechanical stress.

Lignin also contributes to the strength of grass stems and leaves and its presence in root cell walls helps resist pathogen attack. Manganese serves as activator for several enzymes of the shikimic acid pathway that leads to the synthesis of aromatic (phenolic) amino acids (phenylalanine and tyrosine). These are the starting products for the synthesis of phenolic acids and alcohols that are produced in response to attack by pathogenic fungi and constitute a major disease defense mechanism.

These substances are also the building blocks of lignin molecules that are assembled in cell walls through the action of Mn-containing peroxidases. Manganese plays a central role in several reactions required for the synthesis of phenolic compounds and its function cannot be substituted by any other element.

TABLE 3.
SOURCES OF FERTILIZER MANGANESE

Source	Formula	% Mn content
Manganese chloride	$MnCl_2$	17
Manganese oxide	MnO	41-68
Manganese sulfate	$MnSO_4 \cdot 4H_2O$	26-28
Manganese chelates	MnEDTA	5-12

ADAPTED FROM TISDALE ET AL. 1993 PAGE 337.

Manganese deficiency and toxicity

As is the case for most micronutrients, deficiency symptoms of Mn are subtle and not easily recognized. For turfgrasses, physical deficiency symptoms are almost useless for diagnosing problems. Such symptoms are poorly defined and their presence invariably indicates that substantial damage has already occurred. Consequently I will not attempt to describe the appearance of Mn deficient turf but rather concentrate on the impact insufficient Mn can have on turfgrass growth and performance.

Manganese insufficiency results in dull chlorotic leaves that do not grow rapidly.

The most common turf response to inadequate Mn is a markedly reduced growth rate of both shoots and roots. This occurs because the oxygen evolving complex of photosynthesis is highly sensitive to low Mn levels and when it malfunctions, photosynthetic rates decline sharply. This results in a reduced supply of carbohydrates that in turn depress amino acid and protein synthesis and the growth of cells. As a result, nitrate, phosphate and other nutrients may accumulate because they cannot be utilized in plant growth. Root growth is also inhibited because photosynthetic energy from shoots (sugars) is not available to support root growth. Thus, even though roots are the first to receive whatever Mn might be available from the soil, resources from the shoots are not sufficient to support much growth.

Increased disease incidence is another symptom of Mn deficiency. Because Mn plays many critical roles in the biosynthesis of phenolics and lignin, grasses deficient in Mn are unable to respond to pathogen attack by producing phytoalexins that would inhibit spore germination and block fungal invasion. As a result, disease outbreaks are more frequent and difficult to control.

Many soil fungi that normally would not be pathogenic or only weakly so will cause disease in Mn deficient plants. This makes disease identification more difficult and reduces the effectiveness of fungicides. In short, the grass is unable to do its part in resisting infection and has no chance of growing out of an infection.

You might suspect that Mn supplies are low when turf receiving acid generating fertilizers exhibits less disease. Fertilizer materials such as $(NH_4)_2SO_4$, NH_4NO_3 and urea tend to acidify the rhizosphere making Mn more soluble and available to grass roots. If liming promotes an increase in disease incidence, again you might suspect that Mn supplies are marginal.

Because Mn is not readily mobilized within a plant (it does not translocate well in the phloem), new leaf growth is most likely to become chlorotic when Mn is deficient. This symptom can easily be confused with that resulting from an Fe deficiency. Iron deficiency causes emerging new leaves to be bright yellow and continue growing at a reasonable rate.

Manganese insufficiency results in dull chlorotic leaves that do not grow rapidly. Soil conditions that would promote Mn deficiency (elevated pH, high organic matter and carbonate enrichment) would also tend to reduce the availability of Fe. However, deficiencies of Mn are less common in turf than are those of Fe.

Turf grown on soil may experience Mn toxicity. Any program that would acidify soils (NH_4-fertilizers, sulfur sources) could make Mn increasingly available and reach toxic levels. As mentioned above, Mn toxicity is part of the acid soil toxicity syndrome but this can usually be avoided by maintaining the soil at pH 5.5 or higher.

Turf grown on artificial media (sand based greens) is prone to suffer from inadequate Mn unless it is applied in fertilizer or top dressing. The materials from which artificial greens are constructed will contain very little Mn and sufficient amounts will not likely be provided as contaminants in fertilizers or most other soil amendments. Thus, Mn should be considered as part of a micronutrient management program.

Sources of manganese

When a Mn insufficiency is suspected, it should by confirmed by a tissue test to determine if it is approaching the critical concentration of 25 ppm. If an addition of Mn is indicated, there are several sources available (Table 3). The material most widely used for the correction of Mn deficiency is $MnSO_4 \cdot 4H_2O$. It can be applied through the soil or as a foliar spray. MnO is largely insoluble but it can be used effectively as a Mn source if ground finely and incorporated throughout the root zone. There are a number of natural organic Mn complexes and synthetic Mn chelates that are effective sources of Mn when applied as a foliar spray. Manganese application rates generally range from 1 to 25 lbs/acre with the lower rates used as foliar treatments. When soils have a high capacity for binding and immobilizing soluble Mn, foliar applications are strongly recommended.

Because Mn will not translocate from leaves to perennial plant organs, several foliar applications may be needed to provide season-long benefits. Frequent mowing and clipping removal will reduce the effectiveness of foliar applications to greens or other intensively managed turf. For such areas, Mn and other micronutrients should be incorporated into a comprehensive turf management program. This could involve an application of Mn with selected pesticide treatments, top dressings, syringings or other appropriate opportunities throughout the season.

On sand-based greens, Mn immobilization within the root zone should not be a problem and less expensive granular Mn sources can be applied during aerification or when the turf is being established.

Broadcast topical applications can be made to established turf and incorporated via irrigation.

As turf is managed ever more intensely, the chances of micronutrients becoming deficient increase sharply. For elements such as Mn, deficiencies are not easily detected and the turf manager can spend much time and effort trying to identify the cause of problems that are indirectly related to a nutrient deficit. To avoid such problems, a preventive approach might be best.

Micronutrient treatments are not costly and if applied properly rarely can cause injury. Thus, the management of Mn in turf might best be guided by the saying: an ounce of prevention is worth a pound of cure.

— The author is on the Editorial Review Board.

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Red Thread and Rust Control

Q: What is the best way to control red thread and rust mold? I'm seeing a lot of these diseases in lawns I service and want to know what to tell the homeowners.

ON-LINE RESOURCES

You might put into your web browser (I use google.com) the key words "turf rust control" or "red thread control" and see the dozens of fact sheets that pop up!

A: *Our answer comes from Dr. Dave Shetlar, landscape entomologist at Ohio State University:*

Even though I'm an entomologist, this question is asked all the time and I'm very familiar with what our plant pathologists have said. For both the diseases that you mention - redthread and rust - most plant pathologists agree that these are associated with turf under stress, usually minimum fertilization and improper watering.

Rust is also becoming much more of a problem as many lawns are now mainly perennial ryegrass cultivars that are highly susceptible to rust. When these lawns were mainly Kentucky bluegrass, we had much less problem with rust throughout the cool-season turf areas.

For both diseases, most pathologists are recommending a minimum of three pounds of Nitrogen per year and more like four pounds N. During the heat of the summer, slow release is desired in order to keep the nutrients coming as the turf grows.

Irrigation timing is also extremely important. Many folks have been told to water at night to save water, but this can be a turf disease disaster if the watering is done in the evening or in the middle of the night. If night watering is demanded, it should be done within an hour or two of daybreak in order to get the turf dried off as soon as possible.

If irrigation restrictions are not a factor, many suggest watering in mid-morning so that the turf dries in mid-day and stays dry. Light and frequent watering (i.e., daily) is also poor management in this case. Try to irrigate only once or twice a week and water deeply (until the top two to three inches of soil is moist).

If these diseases show up, some also recommend dropping the mowing height by a half inch - this is assuming that the homeowner is mowing at the recommended three inches. If the lawn is already being mowed at two inches or less, then a light fertilization (no more than one-half pound of N) and deep but infrequent watering is the best remedy.

There are fungicides registered for both diseases, but these generally are considered too costly for normal lawn maintenance - especially when adjustments to fertility, irrigation and mowing height practices often can solve the problem.

The Need for Training

By Curt Harler/Managing Editor

While waiting in line for parts at the local tractor shop, the fellow behind me tagged me as a kindred spirit and struck up a conversation. "What's with kids today?" he asked. His shirt read Joe's Lawn Service, so I grunted in agreement and asked Joe what he meant.

"Look at this," he said, holding up a contorted blade mount. "Can you believe how stupid kids are today?"

It's a situation we all encounter and, of course, we all believe we were so much smarter when we were 15 or 17 years old. But Joe's story got worse while leading to the crux of the matter.

"He's not a bad kid at all," Joe continued. "He just does not know how to do work."

Joe's story was bizarre, but common. He hired a 16-year-old to mow lawns for his small company. The first day (about four days earlier) he took the kid out on the truck, dropped him off and told him to mow two neighboring properties. "What do I do?" the kid asked. "Mow the lawns," Joe said. "How?" the kid asked.

Joe must be more patient than I am. He talked to the kid and discovered the fellow had never started a lawnmower (let alone run a 48-in. walk-behind). "My parents have a lawn service do that for them," the kid explained.

By this time, Joe had a rapt audience of several other landscape professionals, each sharing their own versions of similar stories.

The simple fact is that many homes do not give kids the practical education and skills they require to deal with the everyday facets of life. It underscores the need for people in our industry to support local vo-tech programs, offer work-study opportunities, and otherwise help the next generation obtain the skills they need.

As for Joe, he forgot to tell his new kid that you can't drive lawnmowers over tree stumps, and that cost Joe a trip to the shop. To his credit, Joe hadn't given up on the boy. In his own way, Joe's doing his bit to train the next generation of turfgrass professionals. He also bought himself an expensive course in how to train workers. But some day that kid may buy Joe's route or become the super at a local golf course. We can only hope he'll afford some other neophytes the same opportunity Joe gave him.

Curt Harler
Managing Editor

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