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AGRONOMY

Soil Organisms
And Their Role In Healthy Turf

By Elaine R. Ingham, Ph.D.

What are the basic assumptions about growing plants by which we've been operating? We have assumed that plant nutrition is a relatively easy process and if we add chemicals at the right time, in the right place, and the right amounts, we can supply all the nutrients plants require and at the rates plants require. We thought we understood plant nutrition well enough to supply these needs. In fact, we now know that plants are much more complex than we thought.

Plant growth requirements have not been met by placing just enough nitrogen, phosphorus, and potassium for the whole of a plant's growth in the soil at one or a few times. We seem to have forgotten that plants require a host of nutrients, from boron to zinc, in small amounts that vary through the course of their active growth cycle, and for some perennial plants, even through dormant periods.

Plant roots colonized internally by beneficial symbiotic fungi called Vessicular-Arbuscular Mycorrhizae or "VAM" fungus. Parts of the VAM fungus reach out into the soil to collect phosphorus, other nutrients and water, which are transported back for use by the host plant. Where VAM is present the plant is protected from root rot disease and parasitic nematodes.

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How do plants obtain nutrients without human intervention?

Over millions of years, plants have flowered, produced seeds and fruit, and generally gotten along just fine without man's "help". Over thousands of those years, humans have selected and bred plants to have unusually large fruits, more abundant grains, darker colored foliage, bigger and more abundant flowers, etc., to meet their own nutritional and aesthetic needs. However, as advanced as these selected plants have become, their basic physiology and how they obtain their required nutrition have not changed.

Plants obtain nearly all their nutrients through the help of a complex set of beneficial organisms working in the soil around the plant's roots, called the soilfood web. From the above-ground portion of their biomass, they obtain carbon dioxide and light energy - the only other resources that plants need.

The soil foodweb is made up of beneficial organisms located in soil surrounding plant roots. These organisms provide the following benefits for plants:

- they supply nutrients in plant-available forms,
- retain nutrients in the soil instead of allowing them to leach into ground water,
- compete with, inhibit and consume disease-causing and plant parasitic organisms,
- decompose plant residue, toxic materials and pollutants that kill plant roots,
- form soil aggregates that improve water infiltration, root penetration and the water-holding capacity of soil,
- improve plant quality and increase the nutritional and aesthetic value of plants by providing the above benefits.

What are these beneficial organisms and what do they do?

The soil foodweb is composed of plants, nutrient fixing organisms, and an additional group of organisms that prey on these nutrient fixing organisms. "Fixing" organisms convert excess plant material into their own biomass, metabolites, and respiratory by-products. They include certain bacteria, fungi, root-feeding nematodes, and arthropod herbivores.

Fixing bacteria and fungi immobilize nitrogen, potassium, sulphur, calcium,magnesium and other soil nutrients in their biomass. Once nutrients are immobilized in either bacteria or fungi, they must be transformed into plant-available forms in a process called mineralization, so that the nutrients are available to plants at the time and in the places they are needed.

Along with nutrient cycling, the soil foodweb keeps organisms that cause plant disease in check. This occurs as the diversity and number of functional groups of beneficial organisms in the soil increases. Beneficial organisms compete with disease causing organisms for food. This competition lessens the potential for plant injury caused by diseases.

The soil foodweb greatly influences soil structure. It facilitates greater root penetration and water infiltration through the production of soil aggregates, soil pores and soil channels. It also increases decomposition of a greater variety of plant materials and anthropogenic compounds.

Soil compaction and the food web

The soil foodweb plays an important role in soil compaction. Mechanical soil compaction is caused by major or repeated disturbance of soil aggregation. When heavy machinery or prolonged traffic moves across soil, the pores and channels within the soil collapse. As the spaces in the soil are reduced, the organisms living in those spaces are killed. Thus, the force applied and the strength of the aggregates in the soil determine the extent of damage.

Pesticides and the soil foodweb

The direct benefits that soil organisms provide to plants, and thereby to humans, are not obtained if the vital soil organisms that make up the majority of the soil foodweb have been killed. Pesticides, herbicides, and fertilizers (mostly through a salt effect), can have both direct and indirect negative impacts on all these beneficial organisms.

Clearly, the targeted plant diseases or pests are also negatively impacted. Unfortunately, these pests and diseases can develop resistance to the chemicals, whereas the beneficial organisms do not.

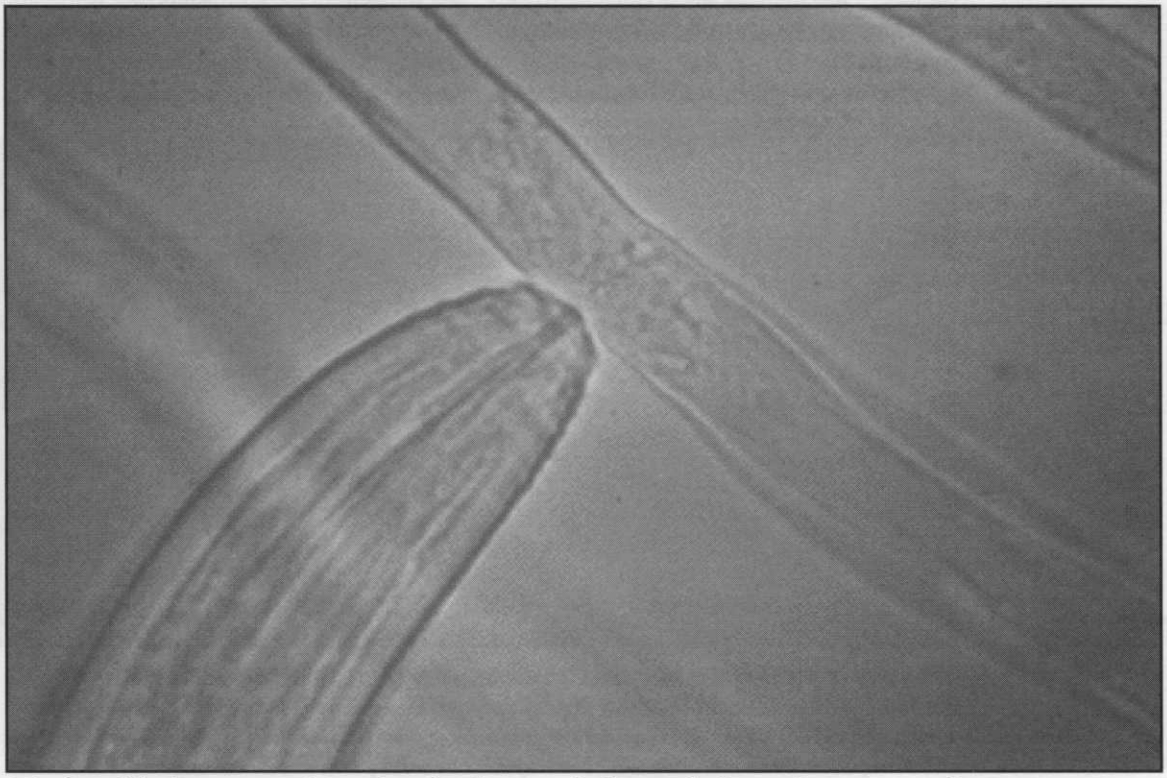
Why? Because plant pests and pathogens have naturally developed life styles that can respond rapidly to changing adverse environments. Pathogens have short life cycles (usually because they kill their hosts), produce many offspring (so at least one finds another host), and have reasonably wide genetic variability (so a response to a change in a plant's natural chemical defenses can be overcome).

Beneficial organisms don't operate the same way. They have long, complex life cycles, they don't produce huge numbers of offspring because their food resources are limited, and as time goes on, the habitats that they prefer become divided among other competing organisms. Thus, beneficials are very good at competing with other organisms, but they are not selected for the boom-and-bust conditions that typify the world of plant pests. Plants have been employing this long-term competitive approach for several hundreds of thousands of years.

Pesticides, herbicides, and fertilizers, when used in small amounts and used only once a year or less, are not all that detrimental. If the beneficials have months or years to recover, they will return and control the pathogens. It is rare in a healthy soil system to be able to document limits on plant distribution by disease, because the complex foodweb in the soil out-competes, inhibits, and consumes the disease-causing, parasitic and pest species.

Understanding the effect of cultivation on soil can be instructive for turf managers. Each time soil is disturbed during cultivation, some of the soil aggregates are broken open allowing soil organic matter to mix with the aggregates. Both processes allow bacteria to predominate, as compared to fungi. This tends to drive soil pH more alkaline (depending on the parent material, the pH may never become alkaline, but the soil will shift toward more alkaline). As bacteria dominate the soil, the major form of N will be nitrate because nitrifying bacteria are favored by soil conditions.

Meanwhile, nutrients are being taken



The fungal feeding nematode is a beneficial nematode. Here it feeds on plant parasitic fungi.

from the soil by the turf and not being replaced. This begins to reduce bacterial populations.

Reduced fungi and bacteria lower the N, P, S, or other micronutrients being cycled to the plants. These lost nutrients are traditionally replaced through the addition of manures, organic residues, and compost. But the microbial life in compost, manure, or organic matter isn't well-understood.

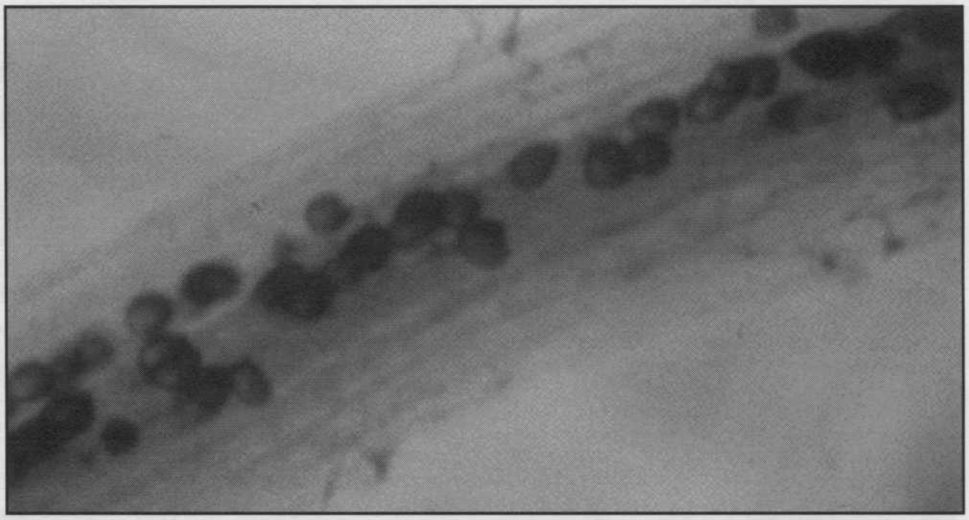
When synthetic fertilizers became available, they were easier to spreadand contained a much more concentrated form of N than compost, manures, or organic matter. The response was more reliable, since there was no question about disease-presence with fertilizer as there was with compost or organic matter. Plants grew taller, and left more residue in the fields. Thus, the micro-organisms in the soil benefitted, at least at first.

But, in many cases, too much fertilizer was applied - the classic, "if a little is good, more is better" syndrome. Fertilizer in high concentrations has about the same effect on soil organisms as dropping a human into a vat of salt - instant water removal and death. Thus, beneficials organisms within the foodweb began to be killed in increasing numbers. When the concentration of the fertilizer is lower, the effect is not nearly as dramatic. Synthetic fertilizers and the reduced use of natural fertilizers, started a downward spiral in soil health.

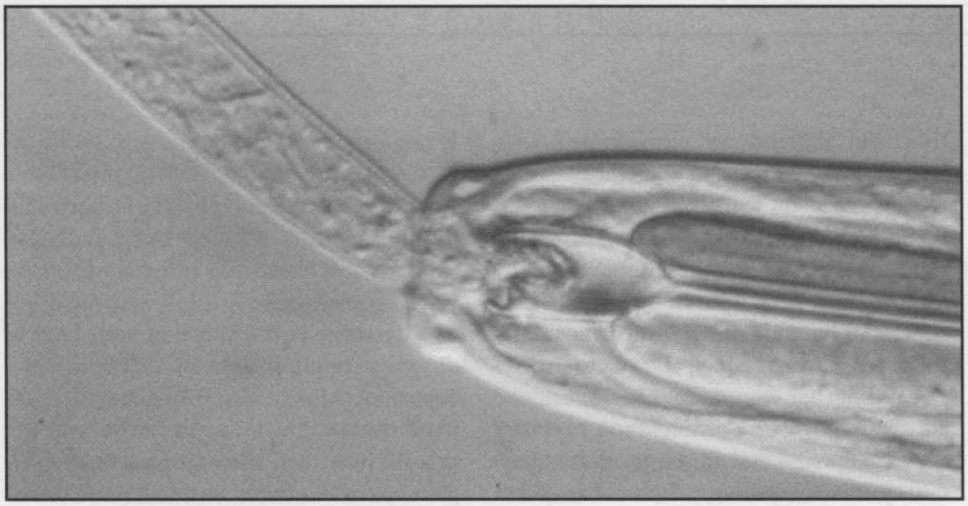
With the loss of organic matter and the negative fertilizer effect, populations of nutrient-cycling organisms (protozoa, nematodes, microarthropods) started to decline. Consequently, this increased the need for and dependency on synthetic fertilizers. As more fertilizer was used, more beneficial, pest-suppressive organisms died and damage to plants increased.

"Quick-fix" petroleum-based pesticides were observed to have noticeable detrimental effects on insect pests, fungal diseases, and weeds. Unfortunately, most pesticides were not tested for their long-term effect on non-target organisms - most of them still have not been tested even today. We still have little idea about the long-term effects of these materials.

Of those pesticides that have been tested, each has had negative effects on non-target organisms. Since these pesticides only reduce the targeted disease-causing organisms and cannot rid the soil of them completely, pesticide resistance has developed. As the beneficials were killed off, fewer and fewer competitors, inhibitors and predators of the disease-causing organisms remained in the soil. Natural biological control was



A section of plant feeder root heavily conlonized by a desirable fungus called Endomycorrhizae. Another name for endomycorrhizae is vesicular-arbuscular mycorrhize, or "VAM". Where VAM is colonizing a root, that portion will be protected from root rot and parasitic nematodes. VAM are symbiotic with plant roots.



Clarkus is the genus name of a beneficial species of nematode that hunts and eats other nematodes in the soil. Predatory nematodes help balance the populations of all other kinds of nematodes. Body waste products recycle nitrogen and other nutrients back into the soil. Predatory nematodes should be present in a balanced soil foodweb. They are very large nematodes and easily killed by physical disturbance of soils.

lost, through pesticide application, fertilizer application, and decreased use of organic sources of nutrients.

In the mid-50's, the problems of disease pressure became increasingly severe in areas where cultivation was intensive and the use of organic soil amendments declined. So, the University of California tested methyl bromide, and found it knocked down the fungal-disease causing organisms quite well.

At first, several years between applications were possible. But today, as continued application of methyl bromide has killed all but the resistant fungal diseases, nematodes, and insects, even application of methyl bromide before every crop - which can be every four months - does not prevent severe disease problems.

Pulling ourselves back from the "chemical" addiction

The chemical approach seemed to work and it would have continued to work if a healthy, complex soil foodweb had been maintained. But it wasn't and we need to move away from intensive chemical usage, and let the organisms do the work for us. The chemicals should be used *only if* there is extreme need. Defining exactly what extreme need is requires a great deal more thought.

The question is, how do we pull ourselves back from this degradation of the soil? Remember that beneficial bacteria and fungi retain the majority of nutrients in the soil, either as their own biomass or as metabolic by-products (organic matter). If you kill them off, there will be no new "absorber" for the excess nutrients that are applied to the turf each year in the form of fertilizer. With fewer nutrient absorbers, the excess fertilizer cannot be retained?. Without absorption and retention by soil, excess N added this year has a greater chance of percolating through the soil to groundwater aquifers. There is no way a soil with too few microbes can hold onto the N the plants require. If they did, the plant wouldn't require fertilizer.

Get soil foodweb in working order

Can we get the soil foodweb back in working order to grow quality turf without the addition of inorganic fertilizer N? Yes. It's being done all over the country!

Can you grow turf without any pesticides applications? Yes, it is theoretically possible, but you must define the time period you are asking about. Forever? Maybe not forever, but certainly for long periods. Given additional understanding of the soil, it might not only be possible, it may even come to pass. However a complete reduction will depend on climate, soil, site hydrology, grass species, and the tolerance of the players on your course.

So, how do we get started back along the right track? Easy, just get a complex, healthy soil foodweb back into the soil. Get all the species of bacteria, fungi, protozoa, nematodes, mycorrhizal fungi, and micro-arthropods back that compete with, inhibit, and consume the disease-problems on your turf. If you make sure that all the necessary nutrient-cyclers are present, then fewer pesticides and fertilizers would be needed.

Where to find these organisms

Where do you find these organisms needed for your particular soil, plant, climate, hydrology, and player load? How do you get them back and keep them working for you?

This isn't always easy. In fact, we don't know the species identity of most of the bacteria and fungi. What is needed is maximum diversity of beneficial organisms.

Consider these two examples. Think about a town with lots of restaurants, grocery stores -- fast-food, slow-food, every kind of food imaginable. Everyone would have the food they prefer. Lots of diversity of food resources leads to lots of diversity of beneficial organisms.

Consider if the only source of food in a town was one fast food vendor's sandwiches. The town would clear out rapidly. No diversity, just those that can make it on the vendor's sandwiches.

The story is the same in soil. Lots of diversity requires lots of different food resources. Monocultures of plant types are hard on soil health, so how do you get around it in turf? Grow mixtures of turfgrass species or, better yet, find some different food sources and apply them. Finely screened compost, compost tea, products with wide varieties of foods for beneficial organisms, or a mixture (depending on what organism needs to be encouraged) like molasses, algal extracts, and humic acids.

We need to pay more attention to beneficial organisms in the soil and reduce our dependence on synthetic, short-lived solutions to turf health. When the foodweb is in balance, plants can fully utilize nutrients available in the soil.

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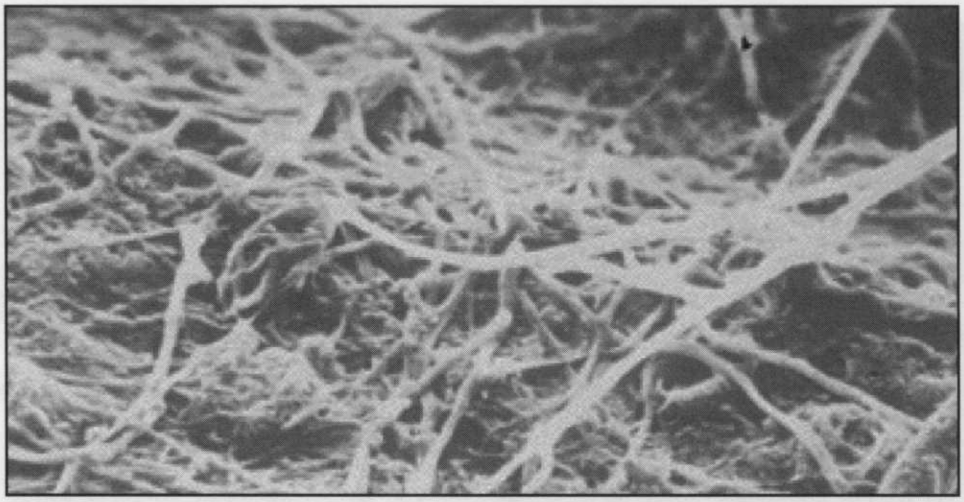

Ectomycorrhizae on tree roots. This is a highly desirable colonization of roots, usually trees and shrubs, that causes the shape of the root branching pattern to change. Roots in this condition are very efficient at absorbing phosphorus, other nutrients and water. Also, where this symbiotic colonization is present, roots are protected from root rot and parasitic nematodes.

Magnesium Usage

By turfgrasses

By Richard J. Hull, University of Rhode Island

Turf is maintained for its uniform presentation of green relaxing hues. Whether intended for athletic competition, recreation or aesthetics, the rich green color of turfgrasses is a prominent feature of its appeal and impact on the landscape. The green color of grass leaves is imparted by the presence in them of a fat-soluble pigment, chlorophyll. This green pigment brings us to the subject of the role of magnesium in turf management. Each chlorophyll molecule is constructed around a magnesium atom. Also, several steps in the biosynthesis of chlorophyll are catalyzed by magnesium requiring ions. In addition, the genetic material, which chlorophyll synthesizing enzymes depend on for expression, is held together by magnesium. In short, magnesium is an essential macronutrient upon which not only chlorophyll synthesis but all plant life depends.

The essential roles played by magnesium in plant growth and function are well recognized. Nevertheless, little research has been reported on its importance for turfgrass culture or on how best to make it available to turf. In their review of turfgrass nutrition, Turner and Hummel (1992) cite

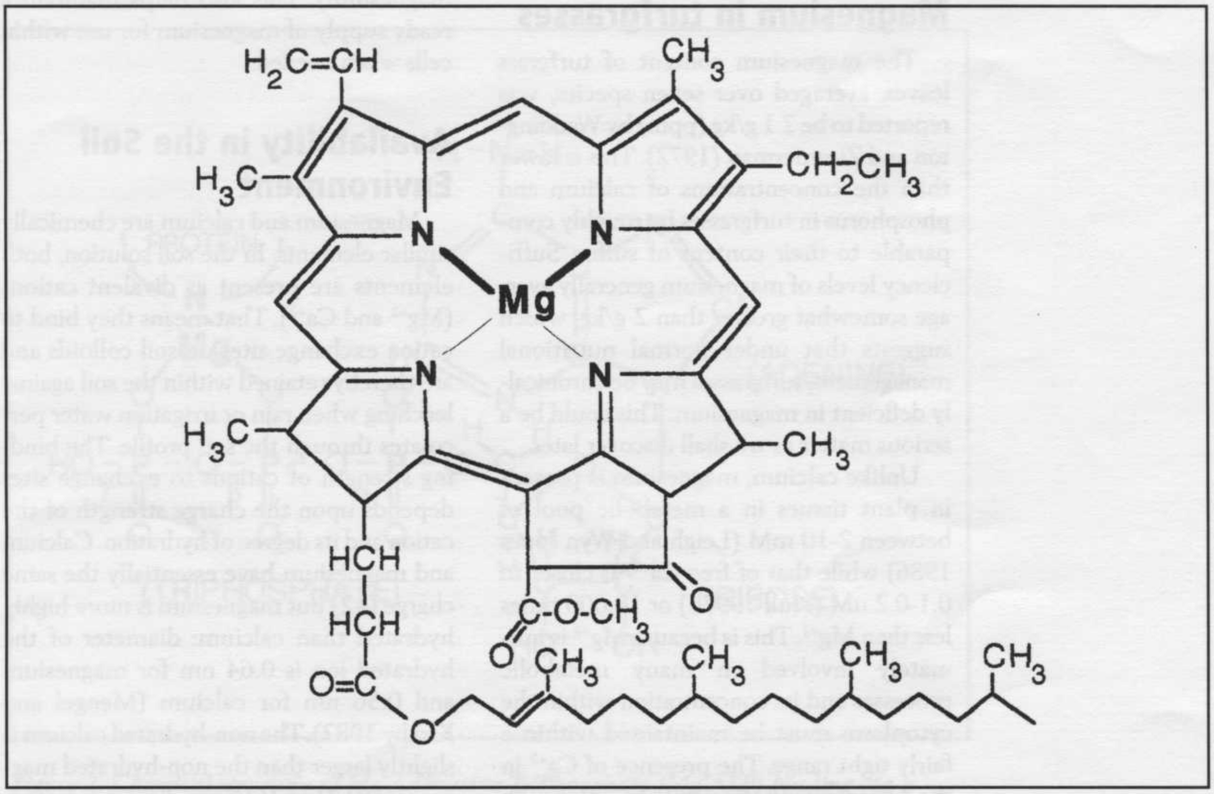

Figure 1. Structure of chlorophyll a showing the bonds formed between four nitrogens covalently binding with a single magnesium atom.

only seven reports on magnesium in turfgrass culture since the middle 1960s. Even the professional turf journals rarely consider the requirements for and management of magnesium in turf. One exception to this trend is an article in Golf Course Management by Rodney Garrett (1996) which described the contributions made by magnesium toward solving some long-standing problems on two golf courses. He mentions several important considerations in managing magnesium on turf, but not in any depth. I will try to provide an overview of magnesium's essential functions and discuss its contributions in the context of turf management for TurfGrass TRENDS readers.

Magnesium and calcium are chemically similar. Both bind to cation exchange sites on soil colloids and are retained within the soil against leaching when rain or irrigation water percolates through the soil profile.

Magnesium in turfgrasses

The magnesium content of turfgrass leaves, averaged over seven species, was reported to be 2.1 g/kg (ppm) by Waddington and Zimmerman (1972). This is lower than the concentrations of calcium and phosphorus in turfgrasses by roughly comparable to their content of sulfur. Sufficiency levels of magnesium generally average somewhat greater than 2 g/kg, which suggests that under normal nutritional management, turfgrasses may be chronically deficient in magnesium. This could be a serious matter as we shall discover later.

Unlike calcium, magnesium is present in plant tissues in a metabolic pool of between 2-10 mM (Leigh and Wyn Jones 1986) while that of free Ca^{+2} is closer to 0.1-0.2 uM (Hull 1997b) or 10,000 times less than Mg^{+2}. This is because Mg^{+2} is intimately involved in many metabolic processes and its concentration within the cytoplasm must be maintained within a fairly tight range. The presence of Ca^{+2} in the cytosol would effectively compete with Mg^{+2} for enzyme binding sites and this would be disastrous to metabolic function. This cytosolic magnesium concentration is stabilized by a large pool of reserve Mg^{+2} maintained within the vacuole where it can reach concentrations of over 100 uM. Considering that the vacuole can constitute 85% of the volume of a mature cell, this represents an enormous reserve supply of magnesium for the cell. This probably explains why magnesium deficiencies do not occur immediately following the withdrawal of available Mg^{+2} from the roots. This also indicates that Mg^{+2} plays an important role in balancing the ionic charge between vacuole and cytosol and in maintaining favorable water relations between the root and soil.

Magnesium shares with calcium the cation exchange sites within the cell walls provided by pectate chains (Hull 1997b). Again because of its stronger ionic bonding, Ca^{+2} dominates the exchange sites within cell walls but Mg^{+2} is present to a significant extent (5-10 percent of the total cell magnesium). This also helps maintain a ready supply of magnesium for use within cells when needed.

Availability in the Soil Environment

Magnesium and calcium are chemically similar elements. In the soil solution, both elements are present as divalent cations (Mg^{+2} and Ca^{+2}). That means they bind to cation exchange sites on soil colloids and are thereby retained within the soil against leaching when rain or irrigation water percolates through the soil profile. The binding strength of cations to exchange sites depends upon the charge strength of the cation and its degree of hydration. Calcium and magnesium have essentially the same charge (+2) but magnesium is more highly hydrated than calcium: diameter of the hydrated ion is 0.64 nm for magnesium and 0.56 nm for calcium (Mengel and Kirkby 1982). The non-hydrated calcium is slightly larger than the non-hydrated magnesium (0.21 vs. 0.16 nm diameter respectively). This larger amount of water surrounding the magnesium ion tends to insulate its charge making it less effective in binding to cation exchange sites. Consequently, Mg^{+2} tends to be displaced from exchange sites by Ca^{+2} when the two ions are present in equivalent amounts.

If pH adjustment is achieved by using ground limestone (calcium carbonate = $CaCO_3$), Mg^{+2} will be displaced from exchange sites and lost during clipping removal if the Mg^{+2} is absorbed by the turf or leached from the root zone if it is not absorbed by roots. In any event, the amount of Mg^{+2} available to turf may become compromised if large quantities of calcium are applied with little regard for the magnesium supply.

A favorable magnesium status in turf is even more at risk because of the unfavorable competition between Mg^{+2} absorption by grass roots and other commonly applied cations. The rate of Mg^{+2} uptake can be strongly depressed by soil cations such as potassium (K+), ammonium (NH_4+), Ca^{+2} and low pH (H+). Consequently, magnesium deficiency induced by competing cations is a fairly common occurrence (Marschner 1995).

In turf management, there is a long tradition of applying adequate potassium to improve the texture of grass blades and increase disease resistance. Because most turfgrasses grow best at a soil pH range of 6.5-7.0, liming materials rich in calcium are often applied in the more humid regions. In areas where rainfall is limited, the soil pH is often near neutral because the soils are naturally enriched with calcium and potassium. In either case, the soil's ionic environment may not favor the uptake of adequate magnesium by turf even when its presence in the soil is reasonably high. This is an important consideration in turf management which will be discussed later.

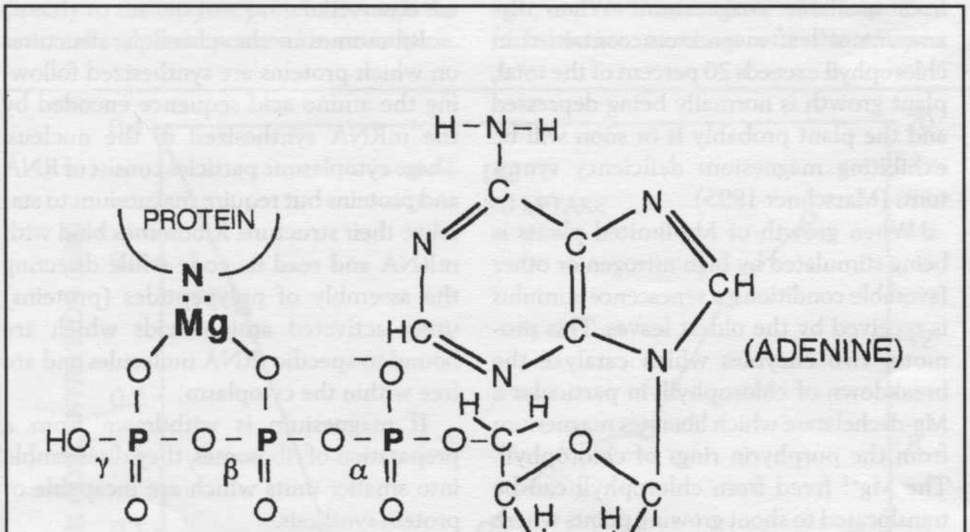

Figure 2. Chemical structure of Mg-Adenosine TriPhosphate (Mg-ATP) binding via a magnesium ion to an enzyme protein in the process of transferring the terminal phosphate of ATP to a metabolite.

Magnesium Functions

Magnesium performs at least four major functions in plant metabolism which will be considered briefly.

Component of chlorophyll. The chlorophyll molecule is coordinated around a magnesium atom to which it is covalently (nonionically) bound (Figure 1). Depending on the nutritional level, between 6 and 25 percent of plant magnesium is bound to chlorophyll (Marshner 1995). Because the incorporation of Mg^{+2} into Mg-protoporphyrin IX (the step in which Mg^{+2} is introduced into chlorophyll synthesis and is catalyzed by magnesium chelatase) has a strong affinity for free Mg^{+2}, it enjoys a high priority in the use of this nutrient (Held 1997). Consequently, other metabolic functions which depend on Mg^{+2} may suffer while chlorophyll synthesis utilizes available magnesium. When the amount of leaf magnesium contained in chlorophyll exceeds 20 percent of the total, plant growth is normally being depressed and the plant probably is or soon will be exhibiting magnesium deficiency symptoms (Marschner 1995).

When growth of Mg-limited plants is stimulated by high nitrogen or favorable conditions, a senescence stimulus is received by the oldest leaves.

When growth of Mg-limited plants is being stimulated by high nitrogen or other favorable conditions, a senescence stimulus is received by the oldest leaves. This promotes two enzymes which catalyze the breakdown of chlorophyll, in particular a Mg-dechelatase which liberates magnesium from the porphyrin rings of chlorophyll. The Mg^{+2} freed from chlorophyll can be translocated to shoot growing points where it will be utilized to synthesize chlorophyll in new leaves.

This accelerated senescence of mature leaves by low magnesium not only produces the classical symptoms of magnesium deficiency (interveinal chlorosis) of the lower leaves but also reduces the photosynthetically active leaf surface thereby limiting plant growth.

Protein synthesis. One of the most devastating effects of low magnesium on plant growth is its inhibition of protein synthesis. Inability to synthesize new proteins (enzymes) limits the plant's capacity to respond to environmental stresses such as drought, heat and attack by disease organisms. While a connection between low magnesium and increased disease or stress injury has not been reported on turfgrasses, I am not aware that anyone has conductd research in this area.

Two essential processes in protein synthesis depend on the availability of Mg^{+2}. The nuclear enzyme RNA polymerase, which catalyses the synthesis of RNA from DNA that comprises the genes on which all plant genetic information is encoded, requires free Mg^{+2}. Upon withholding magnesium from a culture of plant cells, the synthesis of RNA immediately stops but resumes as soon as magnesium is restored. This is one of the most rapid plant responses to magnesium deficiency and may initiate many of the subsequent symptoms that are observed.

Ribosomes are the subcellular structures on which proteins are synthesized following the amino acid sequence encoded by the mRNA synthesized in the nucleus. These cytoplasmic particles consist of RNA and proteins but require magnesium to stabilize their structure. Ribosomes bind with mRNA and read its code while directing the assembly of polypeptides (proteins) using activated amino acids which are bound to specific tRNA molecules and are free within the cytoplasm.

If magnesium is withdrawn from a preparation of ribosomes, they disassemble into smaller units which are incapable of protein synthesis.

Only when ribosome structure is stabilized via Mg^{+2}, which bridges negative charges on the ribosome subunits, does proteins synthesis occur. Thus Mg^{+2} is required both for the synthesis of messenger RNA (mRNA) transcribed from genetic DNA in the nucleus and for stabilizing the protein synthesizing units (ribosomes) on which the genetic code is translated into proteins.

Phosphorylation. In plant and animal metabolism, one of magnesium's most critical functions is its capacity to bind ATP (adenosine triphosphate) to the enzyme proteins which catalyze the formation of phosthate esters (Figure 2). These phosphorylated metabolites are much more reactive and will enter into chemical reactions much more readily than their non-phosphorylated form (Hull 1997a). The phosphorylation of enzyme proteins also is now recognized as an important way by which the activity of such enzymes can be regulated; either activated or inhibited. In most cases, the source of phosphorus utilized in forming phosphate esters is ATP, more specifically Mg-ATP where a Mg^{+2} is ionically bound to the ATP's terminal two phosphates. It is through this Mg-bridge that Mg-ATP binds with the enzyme protein before a phosphate ester is formed (Figure 2). Thus, wherever a phosphorylated metabolite enters a biochemical reaction, its synthesis probably required the binding of Mg^{+2} with an ATP molecule.

Enzyme activation. As mentioned above, Mg-ATP can sometimes activate an enzyme by binding a phosphate from the ATP directly to the enzyme protein through the action of a separate protein kinase enzyme. Sometimes, however, an enzyme can be activated by ionically binding directly with a Mg^{+2}. A good example of Mg^{+2} activation of an enzyme is RubisCo (ribulose bisphosphate carboxylase/oxygenase). This enzyme catalyzes the primary reaction whereby atmospheric CO_2 is photosynthetically fixed into an organic molecule. Pretty much all carbon enters the biosphere via the action of this one enzyme.

However, before this enzyme can function to assimilate CO_2, it must be activated by binding with a Mg^{+2}. This Mg-RubisCo complex requires a couple additional activation steps but only when fully activated can it catalyze the fixation of CO_2.

The binding of a Mg^{+2} to the enzyme increases its affinity (ability to bind) for CO_2 and also increases the rate of its catalytic action. Because the action of this enzyme is so important to all of biology, the involvement of magnesium in its activation stands out as an important chemical role of this nutrient. There are other enzymes, some even involved in photosynthesis, that also require activation by Mg^{+2} binding before they can function at high efficiency.

Root:shoot partitioning. For the turf manager, one of magnesium's most important functions is its involvement in the transport

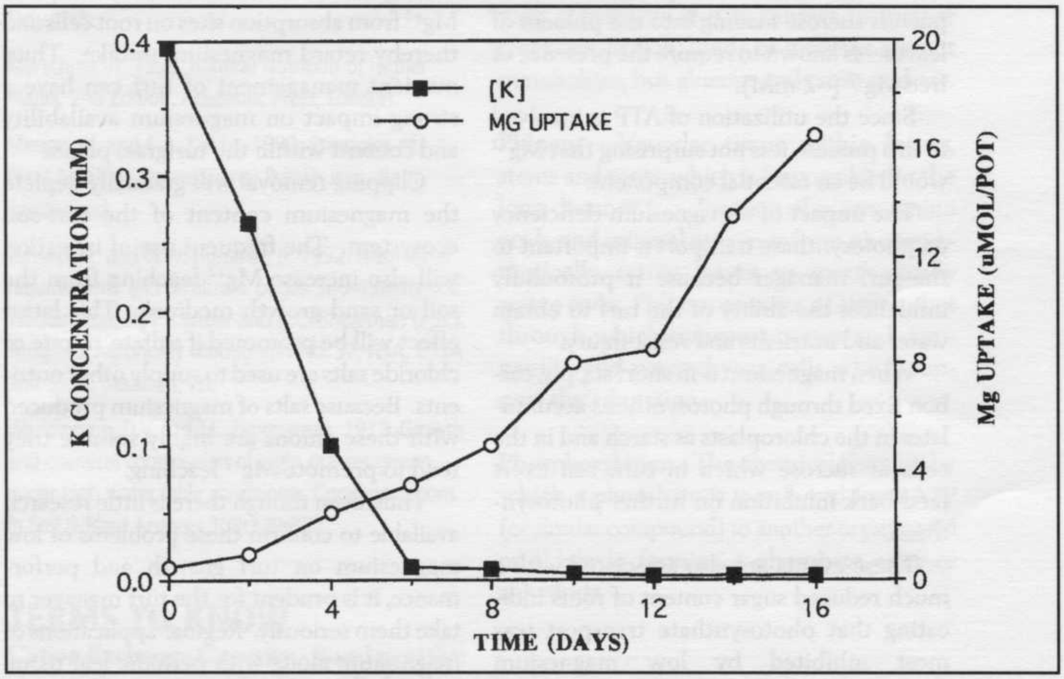

Figure 3. Magnesium uptake by ryegrass as affected by soil pH and potassium concentration (Based on Marschner 1995).

of soluble carbohydrates from leaves to sites of utilization in roots, rhizomes and growing points. One common observation associated with a magnesium deficiency is a sharp decline in the root:shoot ratio (weight of roots/weight of shoots).

When magnesium is in short supply, carbon fixed through photosynthesis accumulates in the chloroplasts as starch and in the cells as sucrose, which in turn can exert feed-back inhibition on further photosynthesis.

When magnesium is inadequate, the root:shoot ratio will often decline to less than half that of a magnesium sufficient plant.

This means that when turfgrasses are experiencing inadequate magnesium, they will produce less than half the root mass and depth that normally would be present.

It is not known at exactly what step in the transport of photosynthetic products out of leaves that magnesium is required, but the H+ pumping ATPase responsible for phloem loading is a likely candidate (Marshner 1995).

This enzyme—which creates the transmembrane pH gradient that powers sucrose loading into the phloem of leaves—is known to require the presence of free Mg^{+2} (~2 mM).

Since the utilization of ATP is involved in this process, it is not surprising that Mg^{+2} would be an essential component.

The impact of a magnesium deficiency on photosynthate transport is important to the turf manager because it profoundly influences the ability of the turf to obtain water and nutrients and resist injury.

When magnesium is in short supply, carbon fixed through photosynthesis accumulates in the chloroplasts as starch and in the cells as sucrose which in turn can exert feed-back inhibition on further photosynthesis.

These events are also associated with a much reduced sugar content of roots indicating that photosynthate transport was most inhibited by low magnesium (Marschner 1995).

Magnesium and turfgrass management

In an earlier article, I argued that promoting root growth was among the most important tasks confronting the turf manager (Hull 1996). A strong root system will make a turfgrass stand better able to mine the soil for water and mineral nutrients, stabilize the plants against wear, tolerate insect feeding and be more resistant to disease. Thus any condition that does not favor root growth is not working with the turf manager. Inadequate magnesium may be just such a condition.

The likelihood of low magnesium having a depressing effect on turf root growth can be increased by turf management practices. If soil pH adjustment is achieved through the application of lime, the increased Ca^{+2} in the soil solution along with K+ displaced from cation exchange sites by Ca^{+2} may inhibit root absorption of Mg^{+2}. Magnesium uptake might be even further reduced if additional potassium fertilizer is applied (Figure 3) and an ammonium source of nitrogen is used. In acid soils, the high H+ concentration can also displace Mg^{+2} from absorption sites on root cells and thereby retard magnesium uptake. Thus, nutrient management of turf can have a strong impact on magnesium availability and content within the turfgrass plants.

Clipping removal will gradually deplete the magnesium content of the turf-soil ecosystem. The frequent use of irrigation will also increase Mg^{+2} leaching from the soil or sand growth medium. This latter effect will be promoted if sulfate, nitrate or chloride salts are used to supply other nutrients. Because salts of magnesium produced with these anions are highly soluble they tend to promote Mg^{+2} leaching.

Thus, even though there is little research available to confirm these problems of low magnesium on turf growth and performance, it is prudent for the turf manager to take them seriously. Regular applications of magnesium along with periodic leaf tissue analyses will help the manager keep on top of a turf's magnesium status. Such diligence might very well offset problems of turf decline and help turf to tolerate environmental stresses including disease infections.

Dr. Richard J. Hull is professor of Plant Science and Chairman of the Plant Sciences Department at the University of Rhode Island. His research has concentrated on nutrient use efficiency and photosynthate partitioning in turf.

References

Garrett, R. 1996. Elementary: Turfgrass management case studies. Golf Course Management 64(8):81, 84 & 86.

Held, H-W. 1997. Plant Biochemistry and Molecular Biology. Oxford University Press, Oxford.

Hull, R.J. 1996. Managing turf for maximum root growth. TurfGrass Trends 5(2):1-9.

Hull, R.J. 1997a. Phosphorus usage by turfgrasses: The energy nutrient often neglected by turf managers. TurfGrass Trends 6(5):1-12.

Hull, R.J. 1997b. Calcium usage by turfgrasses: The nutrient forgotten by turf managers. TurfGrass Trends 6(10):6-13.

Leigh, R.A. and R.G. Wyn Jones. 1986. Cellular compartmentation in plant nutrition: the selective cytoplasm and the promiscuous vacuole. pages 249-279. IN B. Tinker and A. Lauchli (eds.). Advances in Plant Nutrition 2. Praeger Scientific, New York.

Marschner, H. 1995. Mineral Nutrition of Higher Plants, 2nd Edition. Academic Press, London.

Mengel, K. and E.A. Kirkby. 1982. Principles of Plant Nutrition. International Potash Inst., Bern, Switzerland.

Turner, T.R. and N.W. Hummel, Jr. 1992. Nutritional requirements and fertilizers. pages 385-439. IN D.V. Waddington, R.N. Carrow and R.C. Shearman (eds.). Turfgrass. Agronomy Monograph No. 32, ASA, CSSA and SSSA, Madison, WI.

Waddington, D.V. and T.L. Zimmerman. 1972. Growth and chemical composition of eight grasses grown under high water table conditions. Communications in Soil & Plant Analysis 3(4):329-337.

TERMS TO KNOW

Cation Exchange Capacity - Fixed negative charges that are capable of ionically binding positively charged cations. In soils, clay minerals and organic matter contain numerous cation exchange sites. In plant tissues, pectice substances in cell walls, proteins and nucleic acids all contain exchange sites.

Covalent bond - A chemical bond in which two atoms share one or more pairs of electrons. Sometimes referred to as an organic bond, it can occur between an organic molecule and a mineral element. Magnesium bonding within a chlorophyll molecule is covalent. Should not be confused with ionic or hydrogen bonding.

Cytoplasm - That portion of a cell protoplast exclusive of the vacuole. The part of the cell in which most metabolic reactions take place. The fluid matrix in which all cytoplasmic inclusions (chloroplasts, mitochondria, ribosomes, etc.) are suspended is called the cytosol.

Enzyme - A protein catalyst that alters the rate of a chemical reaction without being consumed in the process. An enzyme normally speeds a biochemical reaction rate but its effectiveness depends upon its degree of activation.

Metabolite - A biochemical that is part of a metabolic pathway or the end-product of such a pathway if it is subject to further reactions. Starch, lipids or proteins are not metabolites, but glucose and citric acid are.

Phloem - Vascular tissue within leaves, stems and roots, which is responsible for the long-distance translocation of sugars, amino acids, and mineral nutrients from photosynthetically active leaves to metabolically active sinks. Phloem consists of sieve tubes through which transport occurs and companion and parenchyma cells which support their function.

Phosphorylation - The chemical reaction by which a phosphate is transferred from ATP (or similar compound) to another organic acid or aldehyde forming a phosphate ester or anhydride.

Managing Magnesium in Turf

While specific research on magnesium use in turf management is very limited, we can make some general recommendations based on information derived from plant nutritional and biochemical studies. What follows are a few such ideas which may be of value and which may prompt some badly needed research on the subject.

Clipping removal depletes magnesium more rapidly than other nutrients because it is translocated to young leaves where it is built into chlorophyll molecules. Remove clippings and your remove magnesium.

1. Include magnesium in your fertilizer program. If applying lime for pH adjustment, use dolomitic limestone which contains form 5-20 percent MgO equivalent. This may cost a little more but it will do much to offset any negative impact adding calcium might have on magnesium uptake.

2. If you are on a turf tissue analysis program, have magnesium includes in your analysis and be warned if the magnesium content is consistently less than 2.5 ppm. Such values are not uncommon but may indicate an incipient deficiency especially during periods of rapid turf growth. Remember that most nutrient deficiencies retard growth and plant metabolism before any visual symptoms can be seen. In the case of magnesium deficiency, this may result in secondary effects (weak rooting, drought injury, excessive disease incidence) which are not obviously linked with insufficient magnesium.

3. If magnesium is called for and pH adjustment is not required, consider using Epsom salt ($MgSO_4 \times 7H_2O$ = 16% MgO). An annual application of 2-3 lbs Mg per 1000 sq-ft should correct any incipient magnesium deficiency problems.

4. On sand based putting greens, magnesium leaching may be a problem because of the limited cation exchange capacity. Here a slower release magnesium source would be preferred such as those suggested by Garrett (1996). More frequent lower application rates would be best with a total annual application of about 4 lbs Mg/1000 sq-ft.

5. Excessive magnesium can be a problem because of the fairly critical content required within cells. Also, it is important to retain a proper balance between magnesium and calcium. The trick is to maintain a ratio of Ca:Mg close to 5:1. If tissue analysis calls for magnesium additions, consider the calcium level and try not to deviate from the 5:1 ratio.

6. Organic composts or top dressings will contain some magnesium and these may be sufficient to maintain proper levels once they have been established. Such materials are also not likely to create an improper ratio of magnesium to other nutrients.

7. Clipping removal will deplete the site of magnesium more rapidly than it will other nutrients. Because much magnesium is translocated to young leaves where it is built into chlorophyll molecules, it is lost when these leaves are cut and transported off site. By comparison, calcium is less mobile and comparatively less is present in new leaves and lost in clippings. Retain clippings on the turf and where this is not practical (putting greens and tees) compost them and return as top dressing.

8. When turf is grown on soil with a reasonable cation exchange capacity, magnesium is not likely to become limiting especially if a Mg-containing lime is used. On sandy sites or sand-based greens, the cation exchange capacity will be low and cation retention within the soil profile will not be great. Cation leaching is likely to occur and retaining sufficient basic nutrients in the proper balance becomes more of a problem. Under these conditions, the suggestions offered above are most likely to be useful.

Morris named new NTEP director

Kevin Morris has been named the new executive director for the National Turfgrass Evaluation Program. Robert Shearman, past executive director, has been named special projects coordinator.

Morris has been with NTEP since late 1982, first as technical coordinator, then as national director, and most recently as national program coordinator. He is the first and longest tenured employee of the program, which evaluates turfgrass performance under a wide variety of environmental conditions. Characteristics studied in the tests include color, density, texture, pest resistance and stress tolerance. NTEP is a cooperative effort between the USDA and the National Turfgrass Federation.

Taylor leads Tift 94 association

T. Don Taylor is the new executive director of the Tift 94 Growers Association. Dr. Taylor was formerly Southeast regional research and development manager for Novartis Specialty Products.

The group is the exclusive producer of TifSport Certified Bermudagrass, the newest bermudagrass to be released by the University of Georgia, Tifton.

Tift 94 is used for golf course fairways and tees, sports fields and landscape turf.

States may have wetlands control

Legislation is being drafted in the US Congress to provide delegation of wetlands regulation to states. The plan is to separate wetlands from the Clean WAter Act to increase the amount of coordination of about 20 agencies with wetlands oversight.

Other goals include streamlining the permit process, rewriting rules for draining wetlands and changes in regulations for wetlands mitigation.

In Future Issues

- Endophytes in turfgrass
- Summer patch control
- The basics of botany

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