Less Familiar Nutrients Also Deserve Spotlight

By Richard J. Hull

In this series on the mineral nutrition of turfgrasses, we have discussed all six macronutrients and the eight micronutrients. However, the subject would not be complete unless some recognition was given to the beneficial but less familiar beneficial nutrients. These beneficial elements generally are present in turfgrass tissues but they do not meet one or more of the four criteria for essentiality. The presence of these elements does have a beneficial effect on turf growth, however. Turfgrasses can grow to maturity in the absence of these elements, but growth is better when they are present.

In 1939, Daniel Arnon and Perry Stout published a set of criteria to judge a mineral element's essential role in plant nutrition. The three criteria proposed by Arnon and Stout are the following:

- In the absence of the element in question, a plant cannot complete its vegetative or reproductive life cycle.
- Deficiency symptoms of the element in question can be prevented only by supplying that element.
- The element in question must directly satisfy a nutritional requirement of the plant apart from any effects it may have in favoring the growth of a beneficial microorganism or alleviating the effects of a toxic soil chemical.

Over time, a fourth criterion was added: The element in question must be found essential for the majority of plants or at least for a significant plant group.

While these criteria for essentiality have been criticized as not strictly applying to several elements that are generally accepted as required by plants, they remain the only widely applied standards. A more significant criticism of these criteria is their exclusion of several elements that have been found to be beneficial to plants but fail one of the criteria.

Frequently, the inability to identify a specific metabolic function for an element excludes it from being classified as essential even though its beneficial properties are widely recognized. The universal criterion also excludes some elements from achieving the rank of essential.

Beneficial elements

In his book, *Mineral Nutrition of Higher Plants*, Horst Marschner (1995) discusses five elements as generally regarded as beneficial to plants and probably essential for some. These are summarized in Table 1.

Cobalt (Co), both free-living and those that grow symbiotically in plant roots, is required by bacteria, especially those capable of fixing

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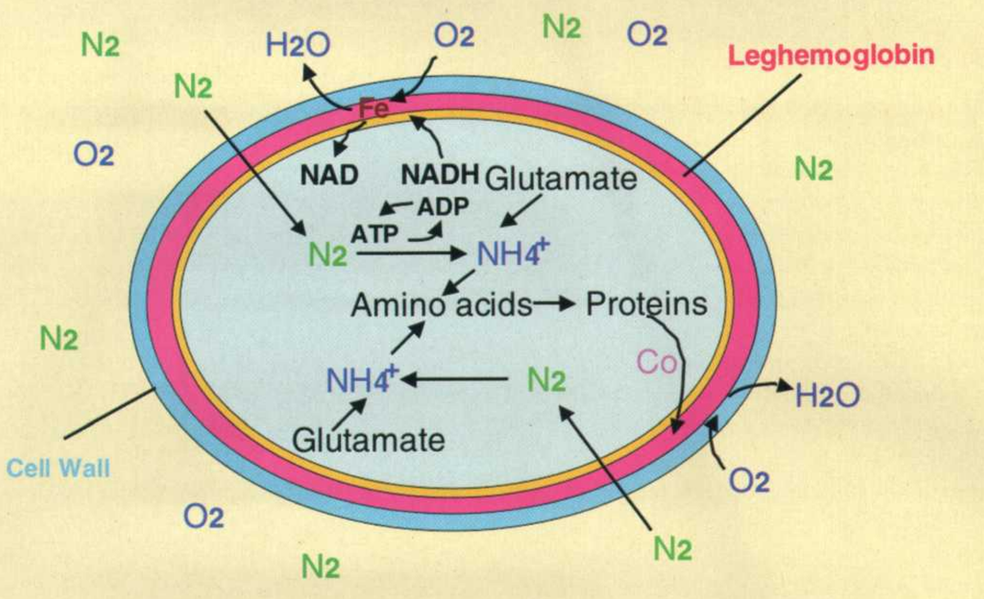
TABLE 1

Mineral elements generally thought to be beneficial to plants at some concentrations.

ELEMENT	CHEMICAL symbol	IONIC FORM absorbed by plants	CONCENTRATION* In soil sol. mg/L	In plant mg/kg
Sodium	Na	Na+	2.3-25	680
Silicon	Si	H4SiO4	7-40	16800
Cobalt	Co	Co+2	0.05-2.0	0.05-0.3
Selenium	Se	SeO4-2	2-4	<10
Aluminum	Al	Al(OH)2+	<1	153

* Elemental concentration typical of turfgrasses and slightly acid soils

How Leghemoglobin blocks O_2 entry into N_2 fixing bacterial cell



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atmospheric nitrogen (N_2). The latter include most legumes and several woody plant species. Here, the host plant maintains the bacterial cells in fleshy nodules that grow from roots much like lateral roots.

Because the enzyme that fixes N_2 (nitrogenase) is poisoned by oxygen (O_2), the bacterial cells must be maintained in an anaerobic space if they are to fix N_2. This is not easily achieved in plant-root nodules growing in well-aerated soils. However, the membranes surrounding bacterial cells contain leghemoglobin that binds O_2 as it diffuses into the cells. By removing this O_2 before it can enter a bacterial cell, nitrogenase is not inhibited and can fix N_2 even when its cell is in an environment containing O_2.

The biochemical sequence of reactions, that synthesize leghemoglobin in nodule bacteria or hemoglobin in free-living N_2-fixers, requires a B_{12} cofactor that has a Co atom at its core. Thus, the N_2 fixation process will not occur unless Co is present. For plants that depend on N_2 fixation for their N source, Co is essential.

Because turfgrasses do not obtain N through biological N_2 fixation, at least not directly, Co is not regarded as essential for them. However, when turf does obtain some of its N from free-living bacteria residing within the rhizosphere of turfgrass roots, that N depends on the presence of Co. This is most likely to be significant for warm-season grasses growing in subtropical areas.

Selenium (Se) exists in soils as divalent anions, mostly selenate (SeO_4-$_2$) but also as selenite (SeO_3-$_2$), that is generally much less abundant and less readily absorbed by roots. Selenate and sulfate (SO_4-2) are chemically similar and compete for the same protein transporter for absorption into root cells. Thus, selenate is much less readily absorbed from the soil when sulfate is abundant. Although Se is an essential element for animal and human nutrition, it is not known to be required for any biochemical function in plants.

Often, the inability to identify a specific metabolic function for an element excludes it from being classified as essential.

Plants vary greatly in their ability to accumulate Se from high Se soils. Accumulator plants can contain several thousand milligrams (mg) Se per kilogram (kg) of dry tissue, and the toxic Se concentration provides protection from insect and

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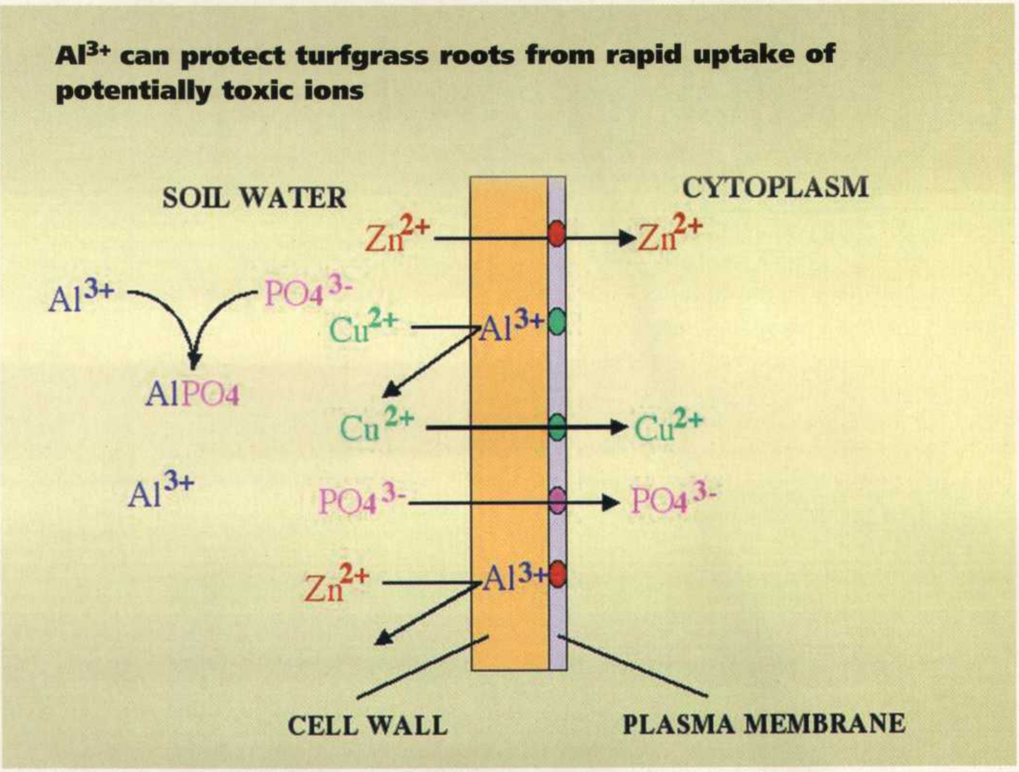

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animal grazing in those plants. Such plants can be troublesome for ranchers. Much of this Se is incorporated into amino acids and accumulated harmlessly (to the plant) in vacuoles.

In nonaccumulator plants, which includes most turfgrasses, the Se content is only 2 mg per 10 mg/kg dry weight. When accumulator plants are grown on a low Se medium, excessive phosphate absorption often occurs and can reach toxic levels. The addition of SeO_{4-2} reduces phosphate uptake and the plant exhibits no toxic symptoms. For these plants, Se does appear to be essential.

There is no doubt that that cobalt, aluminum and sellenium are beneficial to a great many plants including turfgrasses.

Aluminum (Al) is highly abundant in the lithosphere and comprises about 8 percent of the earth's crust. In mineral soils, the soil solution contains less than 1 mg Al per liter when the pH is 5.5 or higher. As soil acidity increases (pH decreases below 5.5), soluble Al levels increase sharply. This greater availability of soluble Al in acid soils contributes to the failure of many plants to grow well in such soils. In short, Al is normally regarded as a toxic element and not essential for plant growth.

Some plants can accumulate Al to tissue concentrations as high as 1 millimoles or more with no toxic effects. In such plants, much of the Al is bound to organic chelates and sequestered in vacuoles. Even in these Al accumulating plants, there is no evidence that Al is essential. However, in most plants experiencing Al toxicity, Al remains in the cell walls of root epidermal and cortical cells with little entering the symplasm (interconnected living protoplasts of plant tissues) or transported to the shoots. We will consider this in greater detail in a future article on turf responses to heavy metals.

There is abundant evidence that Al at low concentrations (20 micromoles to 40 micromoles) can be beneficial to plant growth. Here the Al appears to inhibit the rapid influx of potentially toxic concentrations of phosphorus, copper or zinc, probably by forming insoluble precipitates with phosphate or impeding the movement of metal cations through channels in the plasma membranes of root cells.

Turfgrasses generally experience inhibited root growth in acid soils because of elevated Al concentrations. However, considerable variation in sensitivity to Al has been observed among turfgrass species and among cultivars of some species (Liu et al., 1997a). Fine fescue was found to be considerably more tolerant of high Al levels than perennial ryegrass, tall fescue or Kentucky bluegrass. Among the bentgrasses, colonial bentgrasses were more Al tolerant than most creeping bentgrass cultivars, but there was considerable variation in Al tolerance among these cultivars (Liu et al., 1997b).

Other elements that have been reported to be beneficial to plant growth include iodine, vanadium, titanium, lanthanum and cerium (Marschner, 1995). Such reports are often confined to a few species or have not been confirmed in controlled experiments. Obviously, a good amount of further research on this subject can be justified. However, there is no doubt that the two common elements, sodium and silicon, are beneficial to a great many plants including turfgrasses. In future articles, we will consider these elements in greater detail.

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REFERENCES

Arnon, D.I. and P.R. Stout. 1939. "The essentiality of certain elements in minute quantity for plants with special reference to copper." *Plant Physiology* 14:371-75.

Beard, J.B. 2002. *Turf Management for Golf Courses.* 2nd Edition. Ann Arbor Press, Chelsea, Mich.

Brownell, P.F. 1965. "Sodium as an essential micronutrient element for a higher plant (Atriplex vesicaria)." *Plant Physiology* 40:460-468.

Brownell, P.F. and C.J. Crossland. 1972. "The requirement for sodium as a micronutrient by species having the C4 dicarboxylic photosynthetic pathway." *Plant Physiology* 49:794-797.

Carrow, R.N., D.V. Waddington and P.E. Rieke. 2001. *Turfgrass Soil Fertility and Chemical Problems Assessment and Management.* Ann Arbor Press, Chelsea, Mich.

Harivandi, A.H., J.D. Butler and L. Wu. 1992. "Salinity and turfgrass culture." P. 207-229. IN D.V. Waddington, R.N. Carrow and R.C. Shearman (eds.), *Turfgrass — Agronomy Monograph No. 32.* ASA-CSSA-SSSA, Madison, Wis.

Liu, H., J.R. Heckman and J.A. Murphy. 1997a. "Greenhouse screening of turfgrasses for aluminum tolerance." *Inter. Turfgrass Soc. Res. J.* 8:719-728.

Liu, H., J.R. Heckman and J.A. Murphy. 1997b. "Aluminum tolerance among genotypes of Agrostis species." *Inter. Turfgrass Soc. Res. J.* 8:729-734.

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

Marcum, K.B., G. Wess, D.T. Ray and M.C. Engelke. 2003. "Zoysiagrasses, salt glands, and salt tolerance." *USGA Turfgrass & Environmental Research Online* 2(14):1-6.

Ohnishi, J-I., U-I. Flugge, H.W. Heldt and R. Kanai. 1990. "Involvement of Na+ in active uptake of pyruvate in mesophyll chloroplasts of some C4 plants." *Plant Physiology* 94:950-959.

Turgeon, A.J. 2002. *Turfgrass Management,* 6th Edition. Prentice Hall, Upper Saddle River, N.J.

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