0 to 6 g/m^2 over two growing seasons in Ithaca, N.Y. Soil analyses showed a progressive decline in available K at all application rates < 2 g K/m^2 reaching low levels (< 1.25 mmol/K/kg soil). Nevertheless, K applications had no beneficial effects on turfgrass quality or performance. Turf disease incidence was not increased under lower K levels and gray snow mold actually was more prevalent each spring on the higher K turf. The authors concluded satisfactory bentgrass green performance can be achieved over a broad range of soil K levels and tissue concentrations when grown in calcareous sand root-zones. They suggested excessive K applications may be in common practice on greens management (Woods et al., 2006). We will comment on this further in the next section.

> Cell walls are a non-living continuum with which water and nutrient ions travel from roots to and throughout shoots.

In general, the availability of nutrients in the soil water influences the quantity and composition of nutrients within the cell wall space of turfgrass roots. However, moderate nutrient selection occurs within the apoplast with divalent cations becoming concentrated due to their binding with cation exchange sites and anions being partially repelled. Still, the concentration of free (non-bound) ions remains sufficiently low in cell wall water that precipitation of low solubility salts rarely occurs.

We mentioned earlier the cell walls constitute a non-living continuum through which water and nutrient ions can travel from the roots into and throughout the shoots. If that were really true, the plant would have no way to discriminate among or control which mineral ions enter and are transported throughout the plant. That clearly is not the case. Ion discrimination is achieved by bands of cells (the endodermis) that encloses the root's vascular cylinder (xylem and phloem) and has a waxy material (suberin) impregnated in its walls. These endodermis cells block the inward flow of water and minerals in their apoplast forcing them to cross a cell's plasma membrane and enter its protoplast (symplasm). To enter the xylem (part of the apoplast) and move into the shoot, water and minerals must again cross the plasma membrane of a cell in the vascular cylinder and reenter the apoplast. Any mineral ion that cannot enter the symplast at the endodermis can go no further and remains within the roots. In this way, a plant's stems and leaves are protected from potentially toxic elements.

Greatest selectivity for and potential interactions in nutrient uptake and distribution within turfgrass plants is centered at plasma membrane transport: loading into the symplast and unloading into the xylem (apoplast). That will be considered in our next article.

Richard Hull is professor emeritus of plant sciences at the University of Rhode Island and adjunct professor of horticulture at Clemson University. Haibo Liu is professor of turfgrass physiology and management at Clemson University. Liu earned his Ph.D. with Hull at the University of Rhode Island, and they continue to collaborate on research and publications in turfgrass physiology and nutrition.

REFERENCES

Astolfi, S., S. Zuchi, H-M. Hubberten, R. Pinton and R. Hoefgen. 2010. Supply of sulphur to S-deficient young barley seedlings restores their capability to cope with iron shortage. J. Environmental Botany 61:799-806.

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

Ghasemi-Fasaei, R. and A. Ronaghi. 2008. Interaction of iron with copper, zinc and manganese in wheat as affected by iron and manganese in a calcareous soil. J of Plant Nutrition, 31:839-848.

Hull, R.J. and H. Liu. 2005. Turfgrass nitrogen: physiology and environmental impacts. International Turfgrass Society Research Journal 10:962-975.

Hull, R.J. and H. Liu. 2010. Nutrient interactions in turf management I. Golfdom/Turfgrass Trends 2010:

Kobayashi, T., T. Yoshihara, T. Jiang, F. Goto, H. Nakanishi, S. Mori and N. K. Nishizawa. 2003. Combined deficiency of iron and other divalent cations mitigates the symptoms of iron deficiency on tobacco plants. Physiologia Plantarum 119: 400-408.

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

Woods, M. S., Q. M. Ketterings, F. S. Rossi and A. M. Petrovic. 2006. Potassium availability indices and turfgrass performance in a calcareous sand putting green. Crop Science 46:381-389.

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