

Does Research Offer Answer to Problem of Summer Decline?

By Richard J. Hull and John T. Bushoven

To the average turf manager, research on the physiology of turfgrasses addressing some challenging problem such as summer decline of cool-season grasses often appears to be abstract and frankly rather irrelevant to the problems confronted in turf management.

Even a turfgrass physiologist, when asked to name a problem in turfgrass culture that has been solved by his/her research, will probably have to think for a while before giving a less than convincing response. To be sure, basic research in any branch of horticulture is rarely directed to the resolution of a specific practical problem. However, every now and then, basic scientific understanding that is slowly being advanced by such research reaches a point where a major management problem suddenly appears capable of being solved. This article will describe the convergence of two research lines in turfgrass physiology that soon just may solve the problem of summer decline in cool-season turf.

In recent articles published in *TurfGrass Trends*, we discussed a basic research program on the impact of nitrate-nitrogen ($\text{NO}_3\text{-N}$) absorbed by roots of cool-season turfgrasses on the subsequent growth of their leaves and roots. Like many before us, we observed that high NO_3 levels stimulated leaf growth but at the expense of root growth, causing a dramatic reduction in the plant's root:shoot ratio and its eventual decline. This response was restricted to $\text{NO}_3\text{-N}$ because when ammonium-nitrogen ($\text{NO}_4\text{-N}$) was absorbed in elevated amounts, shoot growth was again preferentially stimulated but root growth was not depressed (Hull & Bushoven, 2007b) and the turf remained healthy.

During several years of experimentation, we observed that most NO_3 was transported from roots to leaves in cool-season turfgrasses. There it was reduced to NH_4 and assimilated into amino acids that, in turn, serve as building blocks for proteins, nucleic acids and many enzymes, hormones, mineral chelates, stress-responsive metabolites and secondary metabolites.

The capacity of roots to metabolize NO_3 proved to be decidedly limited, becoming

saturated when soil-solution concentrations exceeded 0.035 millimeter (mm) (0.5 parts per million) $\text{NO}_3\text{-N}$. Considering that turfgrass soils often contain five times that much NO_3 , it is not surprising that more than 95 percent of absorbed NO_3 passes through the roots and into the leaves, where it is reduced and assimilated by means of photosynthetic energy. When NO_3 is metabolized in the leaves, the amino acids produced stimulate growth of the nearest growing points: namely, shoot apical and intercalary meristems. This metabolic activity in the shoots consumes a substantial amount of energy generated by photosynthesis, leaving little available for transport to the roots. There is also good evidence that NO_3 itself acts as a signal molecule in leaves, diverting photosynthetically fixed carbon toward amino acids and shoot growth and away from sugars that could be translocated to and support the growth of roots (Champigny & Foyer, 1992). This pretty much explains the NO_3 -stimulated shift from root growth to shoot growth.

There are turf-management practices that can capitalize on this information to lessen NO_3 -induced suppression of root growth. The trick is to maximize photosynthesis so sufficient energy (sugar) is available to assimilate NO_3 and support root growth. Raising the mowing height, insuring adequate light conditions, irrigating so as to minimize drought injury to roots,

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Mid-summer heat injury on turf composed of cool-season grasses is often a combination effect of drought and heat stresses.



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Before long, it will be time to think about cleaning up weeds on dormant bermudagrass turf. Don't forget about an old standby for taking care of tough weeds – Sencor® herbicide. This product offers highly effective, broad-spectrum weed control on both dormant and actively growing bermudagrass turf. In addition, Sencor can be tank mixed with MSMA to control crabgrass, nutsedge, barnyardgrass, common yellow woodsorrel, sandbur and dallisgrass.



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Many factors play into the development of better root systems. Adequate water and mineral absorption is dependent on extensive networks of primary and lateral root axis along with root hairs that provide increased surface area. The more extensive the root systems are, the greater the capacity for absorption. Continuous root growth may take place throughout the year, but only when the rhizosphere, or microenvironment surrounding the root, is abundant in water and minerals. However, even when water and mineral availability are at optimal levels, the roots may not be able to keep pace with shoot growth. Providing the best soil conditions for increased root growth can help support the shoots and the stresses they are subjected to in modern turfgrass management.

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and employing foliar applications of urea and $\text{NO}_4\text{-N}$ sources for summer fertilization should help maintain root health and turf quality. In the long run, genetic modification of turfgrasses to increase the root's capacity for NO_3 metabolism and at least partially to inhibit NO_3 loading into and transport through the root's xylem and into the leaves will be necessary to maintain a favorable root:shoot ratio of 1:1 for intensively managed cool-season turfgrasses.

There remains another major problem with maintaining turf quality under summer conditions. The roots of cool-season grasses cannot tolerate high soil temperatures. Turfgrasses could metabolize nitrogen ideally, as described above, but if their roots are exposed to temperatures greater than 25 degrees Celsius (77 Fahrenheit), they will sustain serious injury. If these high temperatures persist for several days, heat-caused death will likely follow. The summer decline often observed in cool-season turfgrasses is primarily the result of high-temperature stress.

However, research reported from Rutgers University by Bingru Huang, her colleagues and her students has shed considerable light on the nature of heat injury in cool-season turfgrasses. Over the past decade, Huang's studies have demonstrated that high-temperature stress results in the production of highly reactive oxygen free radicals that readily oxidize lipids and proteins in cell membranes, causing leakage of electrolytes (ions) and disrupting numerous cellular functions, such as water and nutrient uptake, photosynthetic electron transport and hormone synthesis. Roots were shown to be most sensitive to heat stress, resulting in a failure to deliver adequate nutrients and water to the shoots as well as cytokinins, the plant hormones that are essential for normal shoot growth (Huang et al., 2001; Wang et al., 2004). Fundamental to these physiological disturbances was a failure of the antioxidant enzyme system within roots and shoots to keep heat-induced oxygen-free radicals below injurious concentrations.

The classical approach to identifying those plant responses to stress conditions that may contribute to greater stress tolerance has involved comparing stress responses of plants that are susceptible with those that are at least

partially resistant to the stress. Huang employed this approach; comparing creeping bentgrass cultivars (*Agrostis stolonifera*) that were somewhat tolerant to heat (PennA-4, Independence and L-93) with those that showed less tolerance (Kingpin, Century and Putter). A few years ago, her efforts were assisted tremendously by the discovery of a genuinely heat-tolerant bentgrass (*Agrostis scabra*) growing in geothermal areas of Yellowstone National Park, where soil temperatures are as high as 50 degrees C (122 degrees F). When this thermal bentgrass was compared with creeping bentgrass cultivars, it proved to be vastly more tolerant to elevated soil temperatures by maintaining much greater respiratory control and more efficient energy utilization (Rachmilevitch et al., 2006; Huang, 2007). When grown for 28 days in soils at 99 degrees F compared with 68 degrees F, root respiration rates of thermal bentgrass increased by 50 percent while those of creeping bentgrass cultivars showed a 100 percent increase. The thermal bentgrass generally showed a lesser high temperature-induced decline in root growth, cell membrane stability and NO_3 uptake. At elevated temperatures, NO_3 allocation to shoots was also greater. In this case, NO_3 metabolism in leaves might be an advantage since it would make less of a demand on energy in the roots.

Using tools from molecular biology, Huang identified several genes that were more actively expressed under high temperatures and several that were less expressed. While both bentgrass species exhibited such genes, the thermal bentgrass responded to temperature stress by altering the expression of more genes, especially those that were stimulated. Two-dimensional protein displays were also prepared from heat-stressed and unstressed plants. Again, several proteins become more abundant under heat stress while others remained unchanged or declined. Of course, a number of heat shock proteins (common response proteins to stress conditions) were observed to become more abundant but a few others were as well. One protein in particular, that was the product of a heat-enhanced gene in tissues of both bentgrasses, was especially abundant in roots and shoots of heat-stressed thermal bentgrass. This protein was identified as an α -expansin enzyme (alpha-expansin).

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Expansins are cell wall proteins that play a critical role in cell expansion and tissue growth. They've been identified in many plants and are most abundant in growing organs where cell divisions and enlargement occur. Expansins have also been found to increase in abundance during stress conditions in plants that exhibit some tolerance to the stress. So it was that Dr. Huang found an α -expansin protein present in thermal bentgrass leaves, increased dramatically within four hours of exposure to heat (40°C to 104°F). The same protein also increased in leaves and roots of creeping bentgrass cultivars following exposure to heat but the response was not as great. A significant positive correlation was observed between α -expansin increase and greater heat tolerance of bentgrasses, with thermal bentgrass having the most expansin and being most heat tolerant while some creeping bentgrasses (Pennlinks, Backspin, Kingpin and Putter) had very little expansin and were highly heat sensitive. Creeping bentgrasses: Declaration, Penn-A4, Shark, L93, Century and Independence all produced intermediate levels of expansin and ranged from heat tolerant to moderately so. Roots of thermal bentgrasses contained high levels of α -expansin even when grown at low temperatures.

Heat tolerance in cool-season turfgrasses undoubtedly depends on more than a single, or even family of, expansin proteins. But the close correlation between heat tolerance and induction of an α -expansin in bentgrasses certainly is highly suggestive of a functional relationship. The presence of toxic oxygen radicals is most likely to occur when metabolism is being stimulated by high temperature, but growth is suppressed by some failure in the energy-growth coupling system.

When chemically reactive metabolites are not utilized efficiently, they produce free radicals often with oxygen. These radicals can oxidize membrane lipids and enzymatic proteins causing irreparable damage resulting in cell and eventually tissue death. If expansins are not induced sufficiently to meet cell needs during heat stress, growth will be inhibited, toxic radicals will be formed and accumulate with the result being death. Thus, failure of a single critical step in a complex plant response

to stress may be the cause of metabolic disruption and plant injury.

Only further research and time can tell if Huang's discovery of a heat responsive α -expansin will provide an explanation of heat tolerance in all cool-season turfgrasses. Nevertheless, the convergence of her findings with those of nitrogen partitioning and metabolism on grass growth clearly offer hope for developing heat tolerant cool-season turfgrasses and effective strategies for managing them as fine turf.

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