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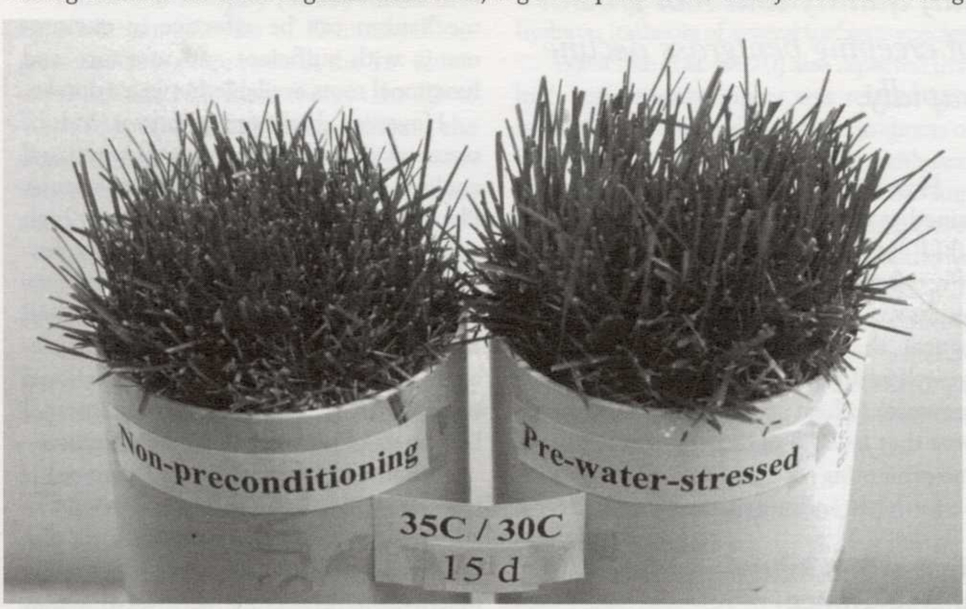
Summer Decline of Cool-season Turfgrasses:
Heat Stress and Cultural Management

Highly stressed turfgrass needs special consideration in managing irrigation and mowing, as well as a realization that the plants' mechanism for dealing with high temperatures can be rather complex

By Bingru Huang

Turf quality decline of cool-season grasses during summer is a major problem in turfgrass management in the transitional and warm climatic regions. The optimum temperatures for cool-season grasses are 60 to 75 F for shoot growth and 50 to 65 F for root growth (Beard, 1973). However, air temperature often approaches 95 F or higher during summer in those regions. Therefore, high temperature is a major stress-causing



Drought preconditioning facilitates water uptake during heat stress, as is evidenced by the Kentucky bluegrass on the right that has outgrown the grass on the left.

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summer quality decline.

It is important to understand the mechanisms by which cool-season grasses naturally tolerate high temperatures and how cultural practices affect grass tolerance to heat stress. This information can lead to efficient development of new grasses by breeding or genetic engineering for specific adaptive traits, as well as development of effective management practices to facilitate grass performance during summer.

Critical temperatures influencing turfgrass summer performance

Mid-day soil temperature is often as high as air temperature, and night soil temperature can be higher than air temperature, particularly in wet soils. Our work shows that soil temperature plays an important role in turf performance regardless of air temperature. If soil temperature is 100 F, and air temperature is 68 F, turf quality and root growth of creeping bentgrass decline rapidly. High soil temperature first causes injury to roots and then to shoots.

If soil temperature is 100 F, and air temperature is 68 F, turf quality and root growth of creeping bentgrass decline rapidly.

However, if soil temperature is maintained at 68 F, and shoots are exposed to 100 F, turf quality and root growth are not affected (Xu and Huang, 2000). Our results suggest that soil temperature is more critical than air temperature for plant growth and that roots may mediate shoot responses to heat stress. Any cultural practices that favor lowering soil temperatures and promoting root growth would help turf perform better during summer months.

Heat stress injury and tolerance

Heat injury in plants resulting from either high air temperature or soil temperature involves many physiological and morphological changes. The adverse effects of high temperatures on turf quality probably are due to direct inhibition of root growth and activity and, therefore, limitation of water and nutrient supplies to the shoot and disruption of carbohydrate metabolism.

Leaf water status of plants is controlled by three processes:

- transpiration,
- water transport and
- water uptake.

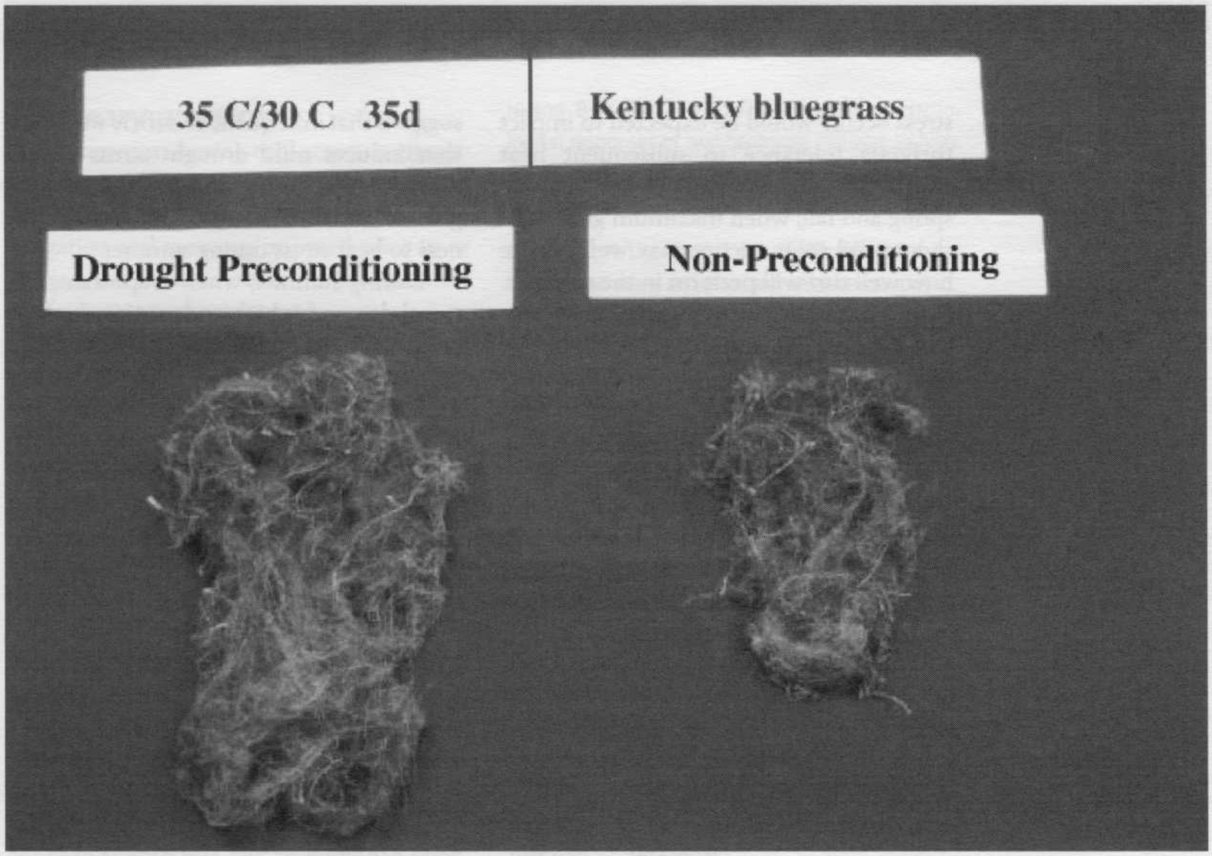
High temperature interrupts the water balance between shoots and roots by enhancing transpirational demand of leaves and inhibiting water uptake of roots. The results are leaf water deficits and a substantial increase in leaf temperature to potentially lethal levels. Jiang and Huang (2000) reported severe leaf water deficit in heat-stressed Kentucky bluegrass.

Lehman and Engelke (1993) found that turf quality of creeping bentgrass was correlated significantly with shoot water content under elevated soil temperatures ranging from 29 to 34°C. Various studies suggest that maintaining a favorable water status plays an important role in plant tolerance to heat stress.

One of the main mechanisms plants can utilize to cope with high temperatures is heat dissipation through transpiration. This mechanism can be effective in environments with sufficient soil moisture and functional roots available for water uptake.

However, high temperatures induce stomatal closure, reducing transpirational cooling and increasing leaf temperature. Plants that can survive at a relatively high temperature have significantly higher stomatal conductance and transpiration rates than plants that fail to survive (Kolb and Robberecht, 1996). Therefore, maintenance of water uptake and transpirational cooling can protect plants from internal heat stress at relatively high temperatures.

When evapotranspirational demand is high under high temperatures, water uptake and transport place a constraint on the potential use of transpiration as a cooling mechanism. Therefore, any factors that affect water uptake capacity of the root system could influence plant performance



The Kentucky bluegrass roots on the left were preconditioned for drought conditions and therefore grew more extensively than the non-preconditioned roots on the right.

under high temperature conditions. An extensive, deep, root system contributes positively to water uptake and maintenance of favorable leaf water status, which has been identified as an important characteristic of heat-resistant plants.

Bonos and Murphy (1999) found that heat-tolerant cultivars of Kentucky bluegrass had 19% more roots at the 15- to 30-cm depth and 65% more roots at the 30- to 40-cm depth than intolerant cultivars; the extensive root system of the tolerant cultivars resulted in lower stomatal resistance and a cooler canopy.

Lehman and Engelke (1987) indicated that selection for heat tolerance indirectly selected a population with increased rooting area.

Indirect heat stress may be related largely to levels of carbohydrate accumulation, because carbohydrates serve as energy reserves and provide structural materials for maintaining cell functions.

High temperature reduces photosynthesis (food production) but increases respiration (food consumption), leading to an imbalance between the two processes (Carrow, 1996; Huang and Gao, 1999; Huang et al., 1998a). Youngner and Nudge (1976) reported a negative relationship between temperature and total nonstructural carbohydrates in shoots of several turfgrass species.

Watschke et al. (1970) also reported that high temperature injury was related to a reduction in sugar concentration in shoots of Kentucky bluegrass. Our research with several cultivars of creeping bentgrass has suggested that heat stress injury is related closely to declines in carbohydrate availability in shoots and roots (Liu and Huang, 2000).

Any factors that enhance carbohydrate production or limit carbohydrate consumption would be beneficial for carbohydrate accumulation and, thus, could facilitate plant tolerance to heat stress.

Irrigation management and heat tolerance

Given the close association of water and heat stress, exposure of grasses to periodic drought stress by infrequent or deficit irrigation (drought preconditioing) before heat stress occurs would be expected to impact turfgrass tolerance to subsequent heat stress. Irrigation practices performed in the spring and fall, when maximum growth of shoots and roots occurs, may well dictate how well turf will perform in the summer.

Several studies have reported that prior exposure of plants to water deficit at low temperatures (drought preconditioning) increases their resistance to subsequent heat stress (Wehner and Watschke, 1981; Martin and Wehner, 1987; Jiang and Huang, 2000).

In our studies with Kentucky bluegrass, enhancement of turf quality (Fig. 1) during subsequent heat stress by drought preconditioning was associated with improved root growth and water relations.

Drought-preconditioned plants developed more extensive root systems deeper in the soil profile than non-preconditioned plants (Fig. 2), which facilitateed water uptake under heat stress. Drought-preconditioned plants had higher leaf water content, stomatal conductance, and transpiration rate than non-preconditioned plants under heat stress, which could lead to greater cooling ability.

Several studies have reported that prior exposure of plants to water deficit at low temperatures (drought preconditioning) increases their resistance to subsequent heat stress.

Our results also have demonstrated that leaves of drought-preconditioned grasses were more turgid than those of non-preconditioned plants during subsequent heat stress (Fig. 1). This response was related to the accumulation of solutes in leaves during drought, particularly potassium and soluble sugars.

However, Becwar et al. (1983) found that drought preconditioning did not increase heat tolerance in four turfgrass species tested in a laboratory. Nevertheless, in cases where turf managers irrigate to excess during spring, reducing irrigation frequency prior to periods of anticipated high temperature stress may well have practical appreciation for improving heat tolerance. Improved heat tolerance of cool-season grasses by drought preconditioning suggests that infrequent or deficit irrigation that induces mild drought stress during spring could be used to encourage root growth and enhance physiological hardiness to heat stress during summer.

During summer, when evapotranspirational demand is high and rooting depth is reduced, frequent, light irrigation should be applied as needed. However, it is very important to avoid over-irrigation, especially on poorly drained soils. Excessive irrigation under high temperatures can cause more damage to turf than high temperature alone, because wet soils retain heat for long periods and are associated with lack of oxygen (Huang et al., 1998a, b).

Mowing and heat tolerance

For sustaining growth and heat tolerance, it is essential that plants maintain a level of photosynthesis that is equal to or greater than the level of respiration. When food consumption exceeds production, carbohydrate depletion occurs, and decline of shoot and root growth is inevitable.

In our field studies with creeping bentgrass, mowing at 1/8 inch reduced the canopy photosynthesis rate by removing a larger amount of leaf surface area compared to grasses mowed at 5/32 inch (Huang et al., 2000).

However, low mowing caused an increase in the whole-plant respiration rate, and, thus, resulted in an imbalance between photosynthesis and respiration. The increase in respiration rate may have been related to increases in soil temperature at low mowing. The temperature within the top 2 inches of soil is 2 to 3 C higher at 1/8 inch mowing than that at 5/32 inch mowing.

Creeping bentgrass mowed at 5/32 inch maintain a higher rate of photosynthesis than respiration, even during the hottest periods. This could result in production of additional carbohydrates, which would prevent grass starvation and allow maintenance of shoot and root growth. Our research shows that raising the mowing height by only 1/32 inch during summer can have a significant, positive effect on bentgrass quality by altering physiological activities and soil temperatures.

Summary practices

In summary, managing cool-season turfgrasses during summer remains a challenge to turfgrass managers. Cultural practices, including irrigation and mowing, imposed prior to or during the summer stress period influence turf summer performance.

Infrequent irrigation during spring and fall promotes deep rooting and physiologically prepares plants to go through the summer by maintaining transpirational cooling. Light, frequent irrigation, however, is necessary when evapotranspirational demand is high and roots are shortening during summer. But over-irrigation should be avoided as much as possible.

Mowing at the highest acceptable height in midsummer will maintain the needed balance between food production and consumption and, thus, promote healthy, vigorous turf.

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REFERENCES

Beard, J.B. 1973. Temperature, p. 209-260. In: J.B. Beard (ed). Turfgrass:Science and Culture. Prentice-Hall, Englewood Cliffs, NJ.

Becwar, M.R., S.J. Wallner, and J.D. Butler. 1983. Effect of water stress on in vitro heat tolerance of turfgrass leaves. HortScience 18:93-95.

Bonos, S.A., and G.A Murphy. 1999. Growth responses and performance of Kentucky bluegrass under stress. Crop Sci. 39: 770-774.

Carrow, R.N. 1996. Summer decline of bentgrass greens. Golf Course Manage. 64: 51-56.

Huang, B. and H. Gao. 2000. Growth and carbohydrate metabolism of creeping bentgrass cultivars in response to increasing temperatures. Crop Sci. 40 (July/August).

Huang, B., X. Liu, and J.D. Fry. 1998a. Shoot physiological responses of two bentgrass cultivars to high temperature and poor soil aeration. Crop Sci. 38:1219-1224.

Huang, B., X. Liu, and J.D. Fry. 1998b. Effects of high temperature and poor soil aeration on root growth and viability of creeping bentgrass. Crop Sci. 38:1618-1622.

Huang, B., X. Liu, and J.D. Fry. 2000. Hard summer mowing weakens bentgrass turf. Golf Course Manage. 68:60-62.

Jiang, Y. and B. Huang. 2000. Effects of drought or heat stress alone and in combination on Kentucky bluegrass. Crop Sci. 40 (September/October).

Kolb, P.F., and R. Robberecht. 1996. High temperature and drought stress effects on survival of Pinus ponderosa seedlings. Tree Physiol. 16:665-672.

Lehman, V.G., and M.C. Engelke. 1993. Heritability of creeping bentgrass water content under soil hydration and elevated temperatures. Crop Sci. 33:1063-1066.

Lehman, V.G., and M.C. Engelke. 1987. Root characteristics of 'Seaside' bentgrass compared with seaside plants which survived high soil temperatures. Texas Turf Res. 9.

Liu, X., and B. Huang. 2000. Carbohydrate accumulation in relation to heat stress tolerance in two creeping bentgrass cultivars. Am. J. Hort. Sci. (in press).

Martin, D.L., and D.J. Wehner. 1987. Influence of prestress environment on annual bluegrass heat tolerance. Crop Sci. 27:579-585.

Watschke T.L., R.E. Schmidt, and R.E. Blaser. 1970. Responses of some Kentucky bluegrasses to high temperature and nitrogen fertility. Crop Sci. 10:372-376.

Wehner, D.J., and T.L. Watschke. 1981. Heat tolerance of Kentucky bluegrass, perennial ryegrass, and annual bluegrass. Agron. J. 73:79-84.

Xu, Q. and B. Huang. 2000. Growth and physiological responses of creeping bentgrass to changes in air and soil temperatures. Crop Sci. 40 (September/October).

Youngner, V.B. and F.J. Nudge. 1976. Soil temperature, air temperature, and defoliation effects on growth and nonstructural carbohydrates of Kentucky bluegrass. Agron. J. 68:257-260.