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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 290 projects at a cost of $25 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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The Importance of Carbon Balance and Root Activity in Creeping Bentgrass Tolerance to Summer Stress

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SUMMARY

Scientists at Rutgers University continue their research to identify factors affecting summer bentgrass decline. The goal is to use the results of these physiological studies to develop cultural management strategies to limit the quality decline of this important putting green species. Results to date include:

- Decreases in root growth and activities may lead to turf quality decline with increasing temperatures. Promoting extensive, healthy root systems is important for preventing or controlling summer turf quality decline in creeping bentgrass.
- Promoting carbohydrate production and reducing carbohydrate consumption may lead to increases in carbohydrate accumulation, which would help plants to survive hot summers.
- Low mowing height causes reduction in carbohydrate production, which contributes to a decline in turf quality and root growth during summer months.

Turf quality of creeping bentgrass often declines on golf courses in warm climatic regions during summer months which is typically accompanied, or preceded, by root shortening or death. This problem has been broadly defined as summer bentgrass decline (1, 2).

Many cultural and environmental factors may be associated with summer decline in turf quality and root growth. Dernoeden (2) suggested that summer bentgrass decline may be more a physiological rather than a pathological problem. Indirect high temperature is one of the major factors causing loss of turf for creeping bentgrass. Mowing turf too short, such as the ultra-low mowing of today's putting greens, imposes additional stress on the turf by removing large amounts of leaf area that would otherwise be available for photosynthesis and carbohydrate production. Nonstructural carbohydrates in plants serve as energy reserves to be used under stressful conditions (5). Closely-mowed turf may suffer from heat stress injury by depleting carbohydrate reserves due to the increased demand for carbohydrates (i.e. increased respiration) and decreased production of carbohydrates (i.e. decreased net photosynthesis).

This report summarizes results of our controlled-environment and field studies with the aim to better understand how carbohydrate metabolism is related to summer decline in turf quality and root activities of creeping bentgrass. Such information is important for developing effective management strategies to prevent or control summer bentgrass decline.

Research investigating the causes for summer bentgrass decline included the use of mini-rhizotrons (shown above) to monitor root growth during the growing season. Results indicate dramatic losses in root production and increased root death during the hottest summer months, especially in very low-cut putting green turf.

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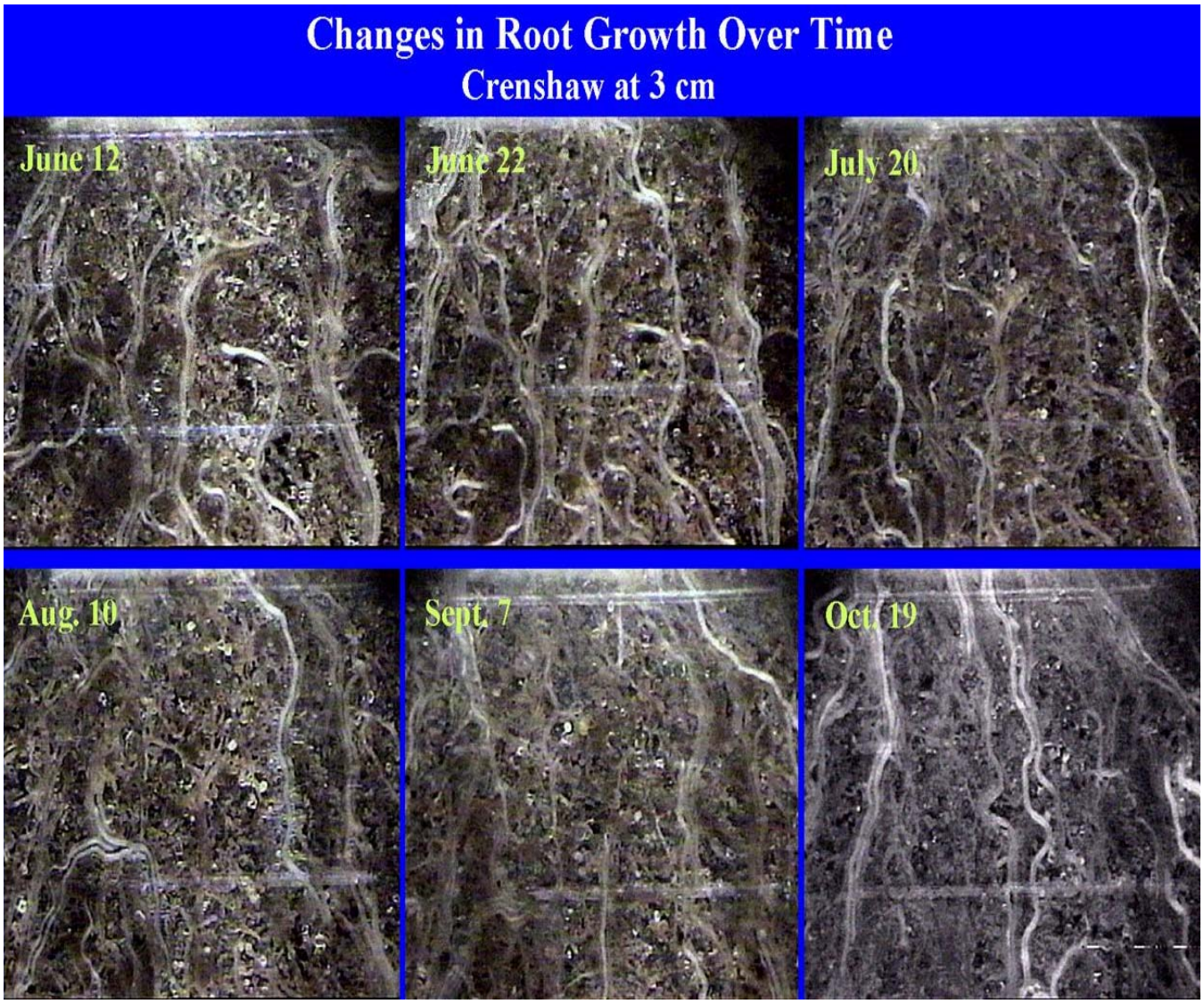

Figure 1. Root growth of field-grown 'Crenshaw' creeping bentgrass as shown using the mini-rhizotron technique in Manhattan, KS. Photos show root growth observed on June 12, June 22, July 20, August 10, September 7, and October 19, 1998. Root length and number of newly produced roots decreased while dead roots increased from July to September.

Decline in Turf Quality and Root Growth under Heat Stress

Decline in turf quality and root growth for creeping bentgrass has been observed under high temperatures (above 80º F) in controlled-environment studies and during summer months in field plots (3, 6, 7, 9, 10). Creeping bentgrass cultivars vary in heat tolerance as demonstrated by differences in severity of turf quality decline with increasing temperatures. Our studies have identified 'L-93' to be more heat-tolerant than 'Penncross', with less severe decline in turf quality and physiological activities under high temperature conditions in controlled environment studies and during summer months in the field.

Root production and mortality of three creeping bentgrass cultivars, 'Crenshaw', 'Penncross, and 'L-93', were monitored using the minirhizotron imaging technique in a USGA-specification putting green mowed at 1/8 and 5/32 inches in Manhattan, Kansas during 1997 and 1998 (4). For all cultivars, the length and number of newly produced roots decreased while those of dead roots increased from July to September in both years (Figure 1; new, active roots were white

Parameter	Days of Heat Stress
Root death	5 days
Cytokinin decline	5 - 10 days
Water deficit	15 days
N, P, K content decline	15 - 20 days
Turf quality decline	20 days

Table 1. Sequence of changes in different physiological parameters of creeping bentgrass in response to heat stress (95^{o} F soil temperature).

and dead or inactive roots were brown). Root mortality rate exceeded root production rate, resulting in decline in total root length and number. 'L-93' maintained higher production of new roots and lower root mortality than 'Penncross' during summer months, suggesting that cultivar difference in root production and mortality was associated with the differences in summer turf performance between heat-tolerant and heat-sensitive cultivars.

One of our recent studies found that root death and decreases in root metabolic activity, such as hormone synthesis (i.e. cytokinin production) and nutrientand water uptake, precede turf quality decline under heat stress in controlled-environment conditions (8). Root death occurred at 5 days of exposure to 95º F, followed by decline in cytokinin sysnthesis, nutrient and water content, and at last with turf quality declining at 20 days of heat stress (Table 1). These results suggested that decreases in root activity and increased in root mortality contribute to loss of turf quality in creeping bentgrass exposed to high temperatures. Improving heat tolerance of the root system is important for maintaining high quality turf during summer months in warm climatic regions.

Carbohydrate Metabolism and Summer Bentgrass Decline

A field study was conducted in 1999 and 2000 in Manhattan, Kansas to investigate whether summer decline in turf quality and root dieback is related to carbohydrate availability during summer months. 'Penncross' and 'L-93' were examined in the study. Grasses were managed under USGA-specification putting green conditions with daily irrigation and were mowed at 4-mm (0.157 inches).

Turf quality and the content of total non-structural carbohydrate (TNC) and soluble sugars in shoots and roots, as well as carbon allocation to roots, exhibited seasonal variations as temperature changed across the seasons (12). Turf quality of both cultivars was highest in May, declined to the lowest level in August and September, and returned to a high level in October. Corresponding to seasonal variations in turf quality, the content of total non-structural carbohydrates, sucrose, and fructans in both shoots and roots for both cultivars was highest in spring and fall and lowest during summer months in both years. Summer decline in carbohydrate content was more pronounced in roots than in shoots.

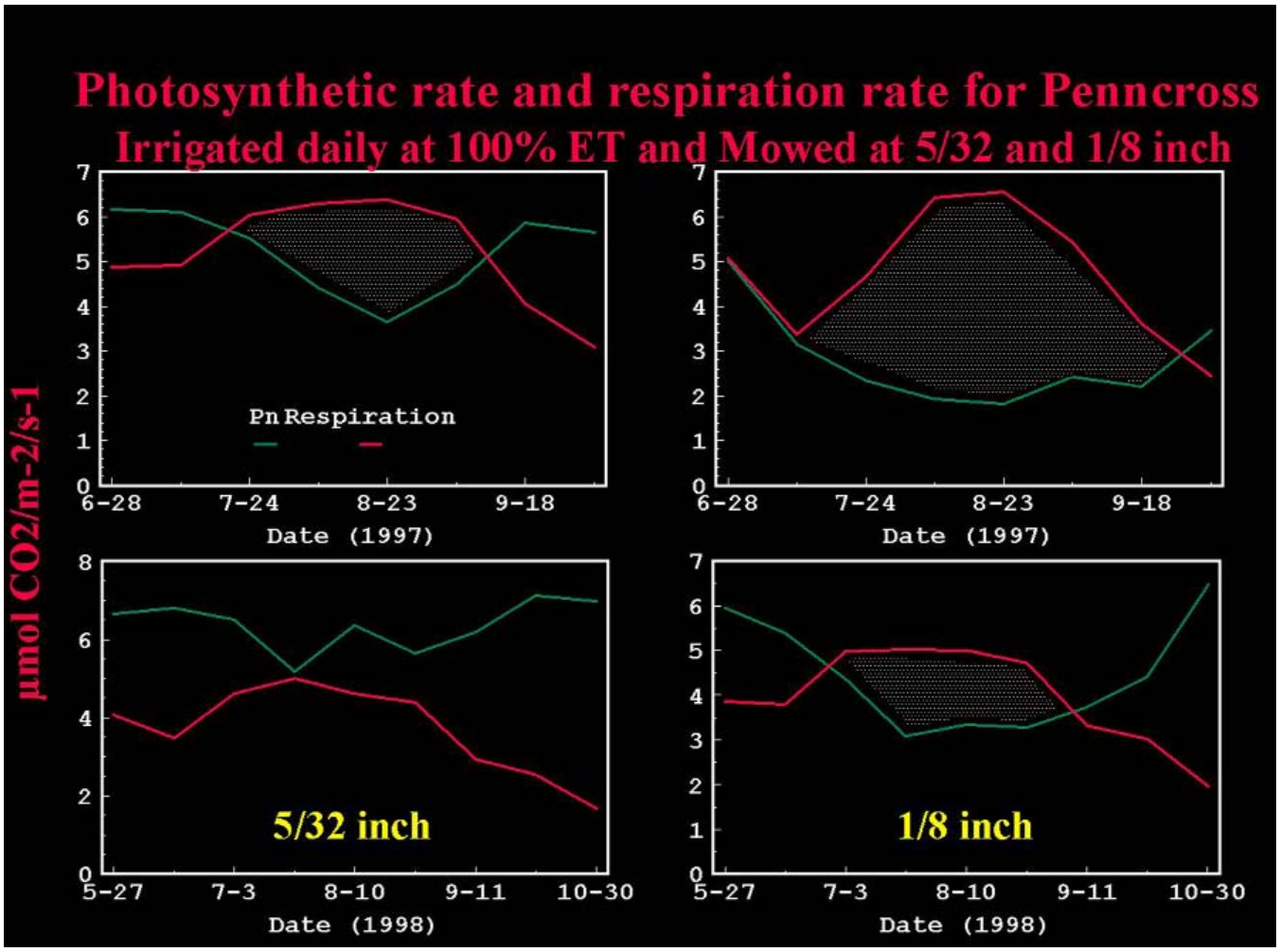

Figure 2. Photosynthetic and respiration rates of 'Penncross' creeping bentgrass mowed at 5/32 and 1/8 inches during 1997 and 1998. Green lines indicate carbohydrate-producing photosynthetic rates while red lines indicate carbohydrate-consuming respiration rates. Data show that as photosynthesis decreases during summer months, especially at the lowing mowing height, respiration increases. The result is a net loss of available carbohydrates (shaded area) closely associated with the decline of turfgrass quality.

In addition, the amount of carbon allocated to roots also decreased during summer months, particularly for heat-sensitive 'Penncross'. Our studies conducted in controlled-environment growth chambers found that carbohydrate availability in shoots and roots decreased with increasing temperatures along with the decline in turf quality (3, 6, 7, 9, 10). Our results demonstrated that the decline in carbohydrate availability in shoots and roots, particularly in roots, and limited carbon allocation to roots during summer months contributed to the decline in turf quality and root dieback of creeping bentgrass under high temperature conditions.

The decline in carbohydrate content in both shoots and roots during the summer may have resulted from an imbalance between carbon production (photosynthesis) and consumption (respiration) (3, 7, 10). Our study also measured seasonal changes in turf quality, carbohydrate production through photosynthesis, and carbohydrate consumption through respiration using an infrared gas analyzer for creeping bentgrass mowed at 5/32 inch and 1/8 inch height (Figure 2).

Turf quality declined more rapidly at the lower mowing height which was attributed mainly to reduced leaf area limiting photosynthesis. We found that canopy net carbon fixation rate decreased whereas respiration or carbon consumption rate increased for both 'L-93' and

'Penncross' during summer months. Carbon consumption rate exceeded carbon fixation rate in August and September when temperature was highest, particularly for grasses mowed at 1/8-inch height where photosynthetic capability was most limited (Figure 2). The imbalanced carbon fixation and consumption, particularly for low-mowed turf, may lead to carbohydrate depletion and a decline in turf and root growth during summer months.

Acknowledgements

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