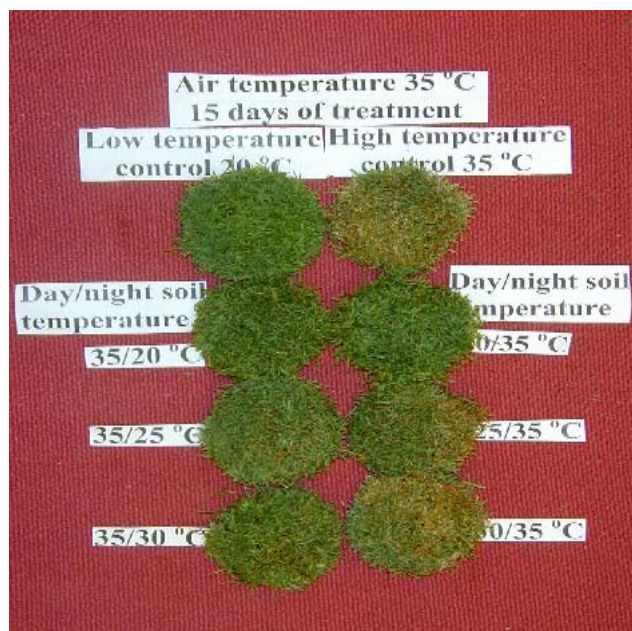


Turfgrass and Environmental Research Online

...Using Science to Benefit Golf



In a series of growth chamber experiments, Rutgers University researchers were able to show that lower soil temperatures significantly enhanced the quality of 'Penncross' creeping bentgrass. Soil cooling at night was more effective than cooling at daytime for maintaining quality creeping bentgrass exposed to high air temperature.

PURPOSE

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Soil Temperatures Controlling Creeping Bentgrass Growth

Bingru Huang, John Pote, and Qingzhang Xu

SUMMARY

Three experiments were conducted under controlled environment conditions at Rutgers University to investigate critical soil temperatures influencing creeping bentgrass growth. The results include:

- Growth and physiological activities of both roots and shoots of creeping bentgrass declined when plants were exposed to elevated rootzone temperatures at or above 23°C for extended periods of time. The rootzone temperature that caused the decline varied with plant parameters and stress duration. The decline in net photosynthesis, root production and activities occurred at lower rootzone temperatures and earlier during the treatment compared to turf quality. Therefore, effective management practices, such as syringing and inserting fans, should be taken when physiological signs of heat injury occur and when soil temperature reaches the minimum detrimental levels to prevent declines in visual turf quality during summer months.
- Lowering soil temperature by 3°C from 35°C was effective in improving shoot and root growth of creeping bentgrass when air temperature was maintained at high level (35°C). The effectiveness of soil cooling for turf growth increased with the duration of cooling and the amount that the soil temperature was reduced.
- Soil cooling at night was more effective than soil cooling during daytime for maintaining quality of creeping bentgrass exposed to high air temperature.

Creeping bentgrass, a widely used cool-season turfgrass on golf courses, grows most actively in spring and fall, but often has the poorest turf quality during summer months in warm climatic areas. Loss of turf has been observed on bentgrass greens in many courses each summer. The problem worsens as the use of bentgrass is extended farther south.

Soil temperature is a critical factor controlling plant growth (4, 8, 9, 10). High soil tem-

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perature is more detrimental than high air temperature in causing growth and physiological inhibition of shoots and roots in creeping bentgrass (2, 8, 9, 10). The inhibitory effects of high soil temperature on turf growth are largely due to limited root growth, nutrient and water uptake, and hormone (i.e. cytokinins) synthesis (3, 5). Research has shown that application of nutrients and cytokinins to creeping bentgrass under high soil temperatures improves shoot and root growth, but cannot reverse the adverse effects of high temperature (1, 5, 6). This suggests resumption of growth by external treatments would be difficult once high soil temperature causes damage to the roots.

When soil temperature was lowered to 20°C, 'Penncross' and 'L-93' creeping bentgrass grown at high air temperature (35°C) maintained the same turf quality as those cultivars grown

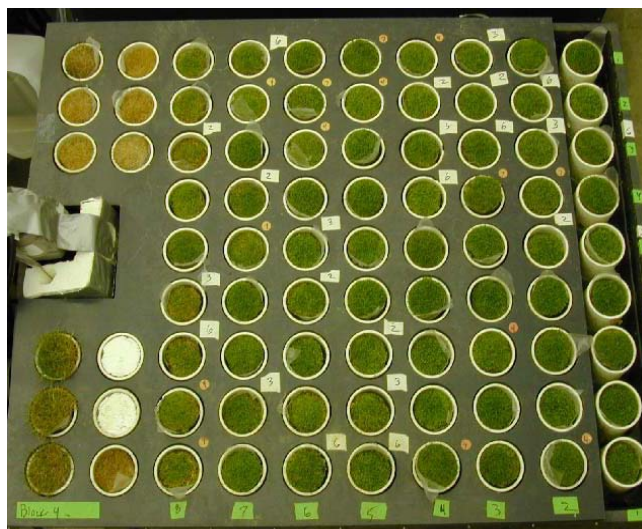


Figure 1. Nine creeping bentgrass cultivars ('Penn A-4', 'Viper', 'Penn G-6', 'L-93', 'Century', 'Crenshaw', 'SR1020', 'Putter', 'Penncross') were grown in clear polyethylene tubes (5 cm in diameter and 50 cm long) filled with sand. The tubes were placed in a gradient soil-temperature chamber (100 cm wide x 200 cm long x 50 cm deep) to expose roots to a range of soil temperatures (shown above).

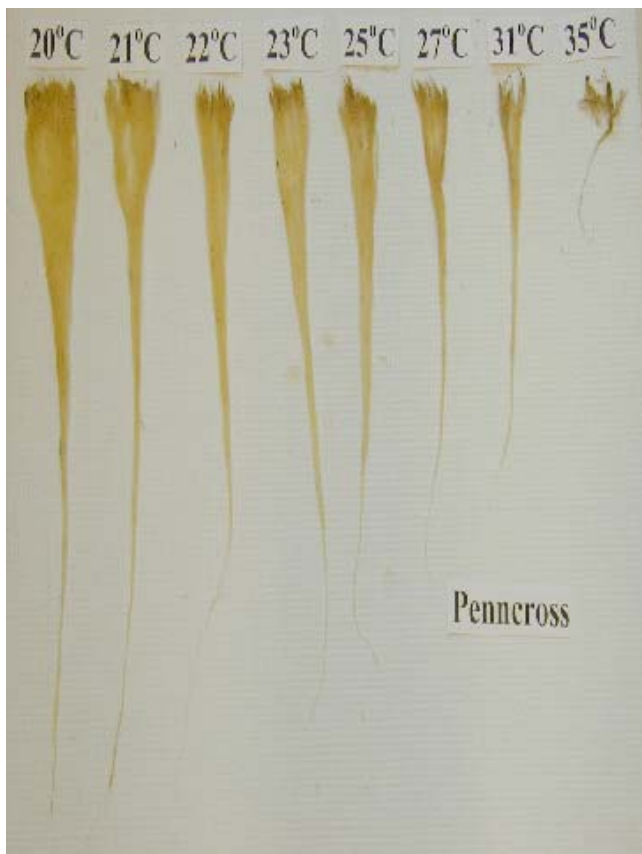


Figure 2. When air temperature was held at 20 C and soil temperatures were increased up to 35 C, root number, root dry weight, root depth, and active root biomass of 'Penncross' creeping bentgrass declined as shown above.

under optimum air and soil temperature conditions (8, 9). These results clearly demonstrate that reducing soil temperature is an effective means to prevent summer bentgrass decline. Cultural practices that can reduce soil temperatures would help improve turf quality during summer. However, reducing soil temperature to the optimum level (20 C) from supraoptimal levels (35 C) is difficult to achieve by routine cultural practices.

Several questions need to be addressed before effective management practices can be developed to manipulate soil temperatures in order to prevent summer decline. First, the critical high temperature in the rootzone that induces decline in growth and physiological activities is not clear and needs to be quantified. Second, the highest soil temperatures that rootzone soils can be lowered to so that turf quality can be maintained under high air temperatures needs to be determined. Finally, it is not clear when the best

time is (daytime vs. nighttime) for soil temperature manipulation for improving shoot and root growth under high air temperatures. This article summarizes results of three independent studies to address these three questions, respectively.

Detrimental Superoptimal Soil Temperatures

A study was designed to determine the critical soil temperature that is high enough to cause decline in shoot and root growth (7). Nine creeping bentgrass cultivars ('Penn A-4', 'Viper', 'Penn G-6', 'L-93', 'Century', 'Crenshaw', 'SR1020', 'Putter', 'Penncross') were grown in clear polyethylene tubes (5 cm in diameter and 50 cm long) filled with sand. The tubes were placed in a gradient soil-temperature chamber (100 cm wide x 200 cm long x 50 cm deep) to expose roots to a range of soil temperatures (Figure 1). Soil temperatures were increased from 20 to 35 C (20, 21, 22, 23, 25, 27, 31, 35 C) while air temperature was controlled at 20 C.

Root number, root dry weight, root depth, active root biomass, turf quality, leaf cytokinin content, and canopy net photosynthetic rate (Pn), decreased in all nine cultivars as rootzone temperature increased from 20 to 35 C, but the time and temperature at which the decline occurred varied with the physiological parameter measured. At the same temperature, 'Penn A-4', 'L-93', and 'Century' generally performed best, while 'Putter' and 'Penncross' had the lowest performance, and other cultivars were intermediate. Net photosynthesis, cytokinin content, root number, and turf quality declined at 23, 27, 27, and 35 C, respectively, after four weeks of exposure. Active root biomass, root number, root dry weight, turf quality, and rooting depth declined at 23, 25, 25, 25, and 35 C, respectively, at 54 days of treatment.

Our results in this study suggest that rootzone temperature of 23 C was the critical level for root activities, Pn, and overall turf growth. When soil temperature was higher than 23 C, all growth and physiological parameters were negatively affected, even if shoots were kept at optimum temperature (20 C).

Lowering Soil Temperatures to Improve Turf Performance

This study was initiated to determine the soil temperature that rootzones could be lowered to in order to maintain high quality turf and active root growth of creeping bentgrass when air temperature is high (10). Two creeping bentgrass cultivars, 'L-93' and 'Penncross', were exposed to the following air/soil temperature regimes in growth chamber and soil-temperature chambers:

- optimal air and soil temperature (20/20 C, control),
- lowering soil temperature by 3, 6, and 11 C from 35 C (35/32, 35/29, 35/24 C), and
- high air and soil temperature (35/35 C).

Soil temperature was reduced from 35 C by circulating chilled tap water in water baths surrounding soil. Turf quality, leaf chlorophyll content, shoot growth rate, and root-to-shoot ratio increased as soil temperature was reduced from 35 to 32 C. This increase was greater for 'Penncross' than for 'L-93'. Significant increases in tiller density, clipping yield, root number and fresh weight were not observed until temperature was reduced to 29 C. When soil temperature was reduced to 24 C, turf quality, shoot growth rate, and root-to-shoot ratio were maintained at the same level as the control (20/20 C).

These results suggested that reducing soil temperature by 3 C or more effectively improved shoot and root growth for creeping bentgrass under high air temperature conditions. Lowering soil temperature was an effective means of improving turf quality, leaf chlorophyll content, shoot extension rate, and root number when air temperature was high. The effectiveness increased as soil temperature was reduced to a lower level.

Effectiveness of Reducing Daytime versus Nighttime Soil Temperatures for Improving Turf Performance

The objective of this study was to investi-

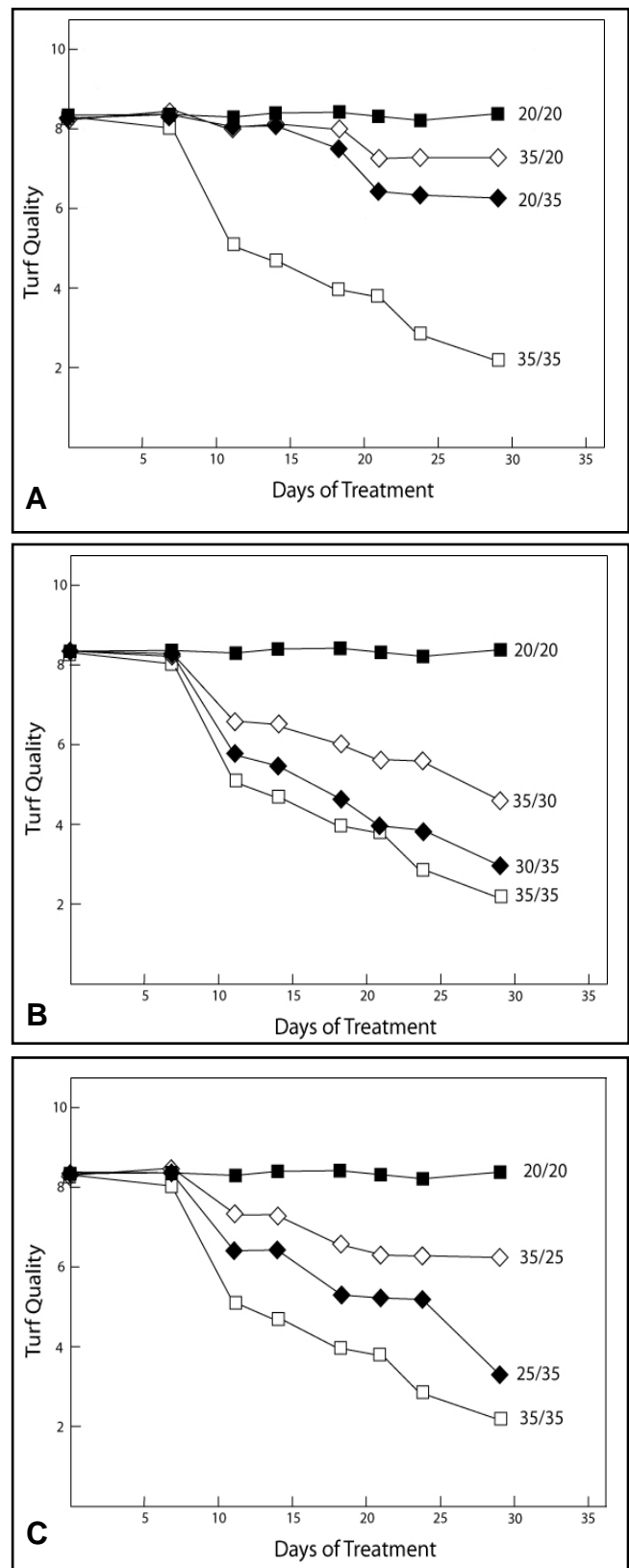


Figure 3. As air temperatures were maintained at supraoptimal levels (35 C), creeping bentgrass was subject to various daytime/nighttime rootzone temperature regimes shown above. In each case, it was shown that lowering nighttime rootzone temperatures was more effective at maintaining turf quality than lowering daytime rootzone temperatures.



Figure 4. Root number, length, and root weight were increased by reducing daytime or nighttime soil temperature from 35 C. However, the rooting increases were more pronounced when nighttime rootzone temperatures were lowered compared to lowering daytime rootzone temperatures

gate whether reducing soil temperature during the night is more effective than reducing soil temperature during the day for improving shoot and root growth of creeping bentgrass when air temperature is supraoptimal (11). Plants were exposed to the following temperature treatments:

- optimal air and soil temperature during the day and night (20/20C, day/night, control);
- high air and soil temperature during the day and night (35/35 C, day/night);
- lowering soil temperatures during the day (20/35, 25/35, and 30/35 C, day/night) while air temperature was maintained at 35 C during the day and night; and
- lowering soil temperature during the night while air temperature was maintained at 35 C during the day and night (35/20, 35/25, and 35/30 C).

Turf quality (on 1-9 scale) increased to 6.5, 3.0, and 2.5 by reducing daytime soil temperature to 20, 25, and 30 C, respectively, at 28 days of treatment, compared to the quality of 2.0 at 35/35 C (Figure 3 A-C). Turf quality increased from 2.0 at 35/35 C to 7.0, 6.0, and 4.5, respectively, by 28 days of exposure to nighttime temperatures of 20, 25, and 30 C (Figure 3 A-C). Root number, length, and root weight also were increased by reducing daytime or nighttime soil temperature, and the increases were more pronounced for reducing nighttime temperatures than daytime temperatures (Figure 4).

The results in this study demonstrated that reducing nighttime soil temperature was more effective than reducing daytime soil temperature in improving shoot and root growth in creeping bentgrass under high air temperature conditions. Soil cooling management should be practiced at nighttime to efficiently lower soil temperature.

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