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Evaluation of a crop water stress index for irrigation scheduling of bermudagrass

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ABSTRACT

This study was conducted to assess crop water stress index (CWSI) of bermudagrass used widely on the recreational sites of the Mediterranean Region and to study the possibilities of utilization of infrared thermometry to schedule irrigation of bermudagrass. Four different irrigation treatments were examined: 100% (I_1), 75% (I_2), 50% (I_3), and 25% (I_4) of the evaporation measured in a Class A pan. In addition, a non-irrigated treatment was set up to determine CWSI values. The status of soil water content and pressure was monitored using a neutron probe and tensiometers. Meanwhile the canopy temperature of bermudagrass was measured with the infrared thermometry. The empirical method was used to compute the CWSI values. In this study, the visual quality of bermudagrass was monitored seasonally using a color scale. The best visual quality was obtained from I_1 and I_2 treatments. Average seasonal CWSI values were determined as 0.086, 0.102, 0.165, and 0.394 for I_1, I_2, I_3, and I_4 irrigation treatments, respectively, and 0.899 for non-irrigated plot. An empirical non-linear equation, $Q_{ave} = 1 + \lfloor 6[1 + (4.853\ \mathrm{CWSI}_{ave})^{2.27}]^{-0.559} \rfloor$, was deduced by fitting to measured data to find a relation between quality and average seasonal CWSI values. It was concluded that the CWSI could be used as a criterion for irrigation timing of bermudagrass. An acceptable color quality could be sustained seasonally if the CWSI value can be kept about 0.10.

1. Introduction

Efficient use of water in the Mediterranean Region is becoming an important issue due to increasing irrigation water requirements as well as environmental sustainability. Decision-makers and turfgrass managers in the province of Antalya at the Southern Turkey are particularly interested in studies concerning the conservation and management of water because a large amount of water is required to irrigate the recreational and sporting facilities covered with grass in the recently build hotels and residential neighborhood.

Irrigation on grass-covered areas is aimed essentially to sustain turf quality and performance by maintaining a favorable soil water level (Kneebone et al., 1992). This aim can be achieved with well-scheduled irrigation together with other appropriate inputs, such as fertilizer. Generally, irrigation scheduling methods fall into three categories: (1) soil based, (2) plant based, and (3) meteorologically based. The plant essentially integrates its soil and atmospheric environments and reflects the prevailing conditions in growth processes. Therefore, irrigation scheduling based on plant monitoring is increasingly used (Grimes et al., 1987).

As plants close their stomata because of water stress, stomatal conductivity, heat flux, transpiration and the cooling effects of evaporation decrease and the canopy temperature increases, compared to non-stressed plants. This is the basis for the use of canopy temperature to determine plant water status (Stokcle and Dugas, 1992). The energy balance on the

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plant surface should be understood well to explain the canopy-air temperature difference (Jackson, 1982; Guyot, 1998; Alves et al., 1998; Al-Faraj et al., 2001). An infrared thermometer measures the surface temperature of a crop canopy without making direct physical contact (Jackson and Idso, 1969). Many references regarding the use of infrared thermometry can be found in the literature (Pinter and Reginato, 1982; Hatfield, 1990; Jones, 1999; Baker et al., 2001).

Different indexes, such as stress degree day (SDD), crop temperature variability (CTV), temperature stress day (TSD) and crop water stress index (CWSI) have been developed utilizing canopy-air temperature difference to quantify the crop water stress. However, the ability to employ such indexes depends on local conditions (Alves and Pereira, 2000). Among the aforementioned indexes, the CWSI is the most often used and offers quite reliable results (Reginato and Howe, 1985). Moreover, the CWSI could be used as an indication to obtain the target yield and quality and also to conserve more water (Irmak et al., 2000; Alderfasi and Neilsen, 2001; Orta et al., 2003; Cremona et al., 2004). There are three methodologies to quantify crop water stress by calculating CWSI: the energy balance method developed by Jackson et al. (1981), an empirical approach developed by Idso et al. (1981), and a wet-bulb temperature method developed by Alves and Pereira (2000). All of these methods have their own advantages and disadvantages.

Comparing the irrigation scheduling indices based on canopy temperatures, Throssell et al. (1987) reported that canopy-air temperature difference was a good water stress indicator for Kentucky bluegrass (*Poa Pretensis* L.) and CWSI could be used for irrigation scheduling. Jalali-Farahani et al. (1993) compared the calculated CWSI values with three different methods to assess water stress and irrigation timing of bermudagrass. They concluded that the changes in CWSI values depended on the applied irrigation level. Furthermore, Al-Faraj et al. (2001) determined that the canopy-air temperature differential ($T_c - T_a$) increased with a decrease in soil water content in tall fescue (*Festuca arundinacea* Schreb.) turfgrass and inferred that CWSI could also be used in turfgrass for irrigation timing. Nevertheless, the lack of studies regarding the irrigation scheduling of bermudagrass as turfgrass based on determination of CWSI in the Mediterranean Region encouraged us to conduct this study for assessing its potential as an indicator. The objectives of this current study were to: (1) assess the use of a CWSI of bermudagrass in the Mediterranean Region, (2) determine the irrigation level sustaining the best color quality, and (3) study the possibilities of utilization of infrared thermometry for irrigation scheduling of bermudagrass.

2. Materials and method

The study was conducted between June and September 2004 at the Agricultural Research Station of Akdeniz University, Antalya, Turkey. The research station was located at a latitude of 36°54′N, a longitude of 30°38′E, and an altitude of 54 m. The research area has a typical Mediterranean climate: hot and dry summers and mild and rainy winters. The soils of research area are classified as Entisols formed on a massive travertine having shallow soil depth in the profile and a clay-loam in texture (Sari et al., 1993). Some physical properties of the soils are given in Table 1.

To accomplish proposed research goals, the research area was established and covered with grass in May 2003 by planting bermudagrass (*Cynodon dactylon* L. Pers.) seeds, a widely used turfgrass in Antalya Region (Arslan and Cakmakci, 2004). The bermudagrass was mowed at a level of 5 cm above ground when it was 10–12 cm tall (Ritchie et al., 2002). The mowing intervals ranged between 9 and 16 days depending on climatic conditions and growth phase. The treatments were fertilized on 27 May 2004 with the $N_{15}P_{15}K_{15}$ type of fertilizer as 5 g m^{-2} and on 29 June, on 31 July and on 30 August with 5 g m^{-2} N (Martin et al., 1994). As a nitrogen source, the fertilizers of ammonium sulfate on 29 June and ammonium nitrate on 31 July and 30 August were applied to the plots.

The experimental plots were designed according to randomized blocks and each treatment was replicated three times at randomized locations within the blocks. The size of the assigned plots was 4 m × 5 m and each plot was surrounded with a 20 cm high earth berm, with a 1 m wide buffer space between the plots. Irrigation treatments were based on the evaporation data (Epan, mm) obtained from a Class A pan located next to the plots. The pan was placed on a wooden support at a height of 15 cm above soil surface and readings were recorded daily. Four different irrigation treatments were selected to examine the effectiveness of irrigation scheduling, i.e. I_1 = 1.00 Epan, I_2 = 0.75 Epan, I_3 = 0.50 Epan and I_4 = 0.25 Epan (Bastug and Buyuktas, 2003). Irrigation interval was 2 days for all treatments. Also, a non-irrigated plot was included to determine the upper baseline required to compute CWSI.

The soil water content was monitored daily in each plot by using a neutron probe (a Neutron Scattering Moisture Gauge, Model 4300, Troxler Electronic Lab., Inc., Raleigh, NC) at 15 cm intervals down to 60 cm. One aluminum access tube was installed in the middle of each plot. The soil water tension at upper 10 cm depth was also monitored using tensiometers installed nearby the neutron access tubes in the plots. The

Table 1 – Physical properties of the soil

Depth (cm)	Textural analysis				FC[a] (%, w/w)	PWP[b] (%, w/w)	Bulk density (g/cm^3)
	Sand (%)	Silt (%)	Clay (%)	Texture class			
0–30	29.3	40.00	30.7	CL	20.9	13.2	1.37
30–60	59.3	24.00	16.7	SL	13.2	6.4	1.46

[a] FC: field capacity.
[b] PWP: permanently wilting point.