Scientia Horticulturae 122 (2009) 620–625

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Growth responses and ion regulation of four warm season turfgrasses to long-term salinity stress

Jingbo Chen [a], Jun Yan [a], Yaling Qian [b], Yanqin Jiang [a], Tingting Zhang [a], Hailin Guo [a], Aigui Guo [a], Jianxiu Liu [a,*]

[a] Institute of Botany, Jiangsu Province and Chinese Academy of Sciences, Qian Hu Hou Cun, Nanjing 210014, PR China
[b] Department of Horticulture and Landscape Architecture, Colorado State University, Fort Collins, CO 80523-1173, USA

ARTICLE INFO

Article history:
Received 29 April 2009
Received in revised form 1 July 2009
Accepted 7 July 2009

Keywords:
Salinity stress
Warm season turfgrass
Top growth
Water content
Ion regulation

ABSTRACT

Increased need for salinity tolerant turfgrasses continues due to increased use of saline water for lawn irrigation and turfgrass establishment on highly saline soil in arid and seashore regions. Turfgrasses growing on saline soil suffer from long-term salinity stress, so this experiment was conducted to study the salinity tolerance, growth, and physiological responses of four warm season turfgrasses [including 'Diamond' zoysiagrass (*Zoysia matrella* (L.) Merr.), 'Z080' zoysiagrass (*Z. japonica* Steud.), 'C291' bermudagrass (*Cynodon dactylon* (L.) Pers), and 'Adalayd' seashore paspalum (*Paspalum vaginatum* Sw.)] to 9 months of salinity stress. Seven salinity levels of irrigation water (0, 90, 180, 360, 540, 720, and 900 mM NaCl) were applied to turfgrasses grown in plastic tubes in a glass room. The salinity tolerance decreased in the following order according to percent green leaf canopy area after 9 months of salinity treatments: 'Diamond' > 'Adalayd' > 'C291' > 'Z080'. Leaf weight, leaf length, canopy height, shoot density were significantly affected by salinity treatments for all turfgrasses. However, leaf width and/or leaf number per shoot were not affected by salinity in all turfgrasses except 'Diamond'. Leaf and/or root water contents were also little affected. As salinity increased, leaf and root Na^+ concentrations and Na^+/K^+ rates increased significantly and K^+ concentrations decreased significantly except that of 'Adalayd' leaf. 'Diamond' and 'Z080' could reduce Na^+ accumulation in the leaves by salt secretion from salt glands, while 'Adalayd' could exclude Na^+ from the leaves and accumulate K^+ in the leaves. 'C291' exhibited both ion regulation mechanisms, but to much less extent. Different growth responses and ion regulation means of four turfgrasses reflected different salinity tolerance mechanisms.

1. Introduction

Salinity is a major factor reducing plant growth and productivity worldwide (Baghalian et al., 2008; Grattan and Grieve, 1999; Kaya et al., 2009; Storey and Walker, 1999; Zribi et al., 2009). In the turfgrass industry, the increased use of saline and non-potable water for water shortage, the development of turfgrass landscapes in arid and seashore regions where saline soil is common, and the use of salt for deicing roadways have increased the need for salinity tolerant turfgrasses (Bryson and Barker, 2002; Jalali et al., 2008; Marcum, 2006; Qian and Mecham, 2005). Many warm season turfgrasses are salinity tolerant (Ackerson and Youngner, 1975; Lee et al., 2005a; Marcum, 1999; Marcum and Murdoch, 1990, 1994; Qian et al., 2007) and some of them are ranked as halophytes, such as *Zoysia matrella* (L.) Merr., *Z. japonica* Steud., *Paspalum vaginatum* Sw. (Zhao et al., 2002). These turfgrasses are recognized as the preferred plants to use on saline soil. But considerable variability in salinity tolerance exists among warm season turfgrasses species, cultivars or genotypes (Lee et al., 2005b; Marcum et al., 1998; Marcum and Pessarakli, 2006; Qian et al., 2000).

Much research has been conducted on the growth and physiological responses to salinity stress in warm season turfgrasses. Shoot biomass is often reduced under salinity stress. Root growth is enhanced in some halophytic turfgrasses under low salinity stress. As salinity stress level increases further, root growth is decreased (Adavi et al., 2006; Alshammary et al., 2004; Marcum and Murdoch, 1994; Marcum, 1999). However, little has been reported regarding leaf growth and shoot density. With respect to physiological responses, tissue water contents, K^+ concentrations, and osmotic potentials are reduced under salinity stress, while Na^+ and Cl^- concentrations, Na/K rate, compatible solutes such as proline, glycinebetaine, and trigonelline, and salt secretion from salt glands are increased (Marcum, 1999; Marcum et al., 1998; Marcum and Murdoch, 1990, 1994; Marcum and Pessarakli, 2006; Qian et al. 2000).

* Corresponding author.
E-mail address: turfunit@yahoo.com.cn (J. Liu).

0304-4238/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.scienta.2009.07.004

Lee et al. (2005b) suggested that a salinity level greater than 30 dS m^{-1} is necessary for successful assessments of salinity tolerance for halophytic seashore paspalum genotypes. It was reported that no difference was found among eight bermudagrass cultivars in salinity tolerance under ECw < 9.93 dS m^{-1} (electrical conductivity of irrigation water, ECw) (Dudeck et al., 1983). Adavi et al. (2006) conducted salinity tolerance experiment for 10 bermudagrass cultivars for 1 year at 17.8 dS m^{-1} but they found that leaf firing percentage was not significantly different under this salinity. Marcum et al. (2005) found no difference in mortality of 21 turf-type desert saltgrasses under 1 M salinity for 1 week. *Z. matrella* was still alive under 6% NaCl stress for 3 weeks (Weng, 2001). Therefore, moderate levels of salinity treatments or short duration exposure could not distinguish salinity tolerance of these halophytic turfgrasses.

Therefore, information on turfgrasses's response to long-term salinity exposure is needed for better understanding their salinity tolerance. The major objective of this study was to determine the salinity tolerance based on growth and physiological response of four warm season turfgrasses to 9-months salinity treatment with irrigation water ranging from 0 to 900 mM NaCl.

2. Materials and methods

2.1. Plant materials and growth conditions

Four turfgrasses were used in this study including 'Diamond' zoysiagrass [*Z. matrella* (L.) Merr.], 'Z080' zoysiagrass (*Z. japonica* Steud.), 'C291' bermudagrass (*Cynodon dactylon* (L.) Pers), and 'Adalayd' seashore paspalum (*P. vaginatum* Sw.). 'Z080' and 'C291' were selected for their excellent turf quality by the Institute of Botany, Jiangsu Province & Chinese Academy of Sciences, China.

The experiment was carried out from 23 August 2006 to 13 June 2007 in a glass room under natural conditions. Daily maximum and minimum room temperatures are presented in Fig. 1. The maximum photosynthetically active radiation ranged from 800 to 1800 μmol m^{-2} s^{-1}. Sod pieces (10 cm in diameter) for each turfgrass were collected from the experiment field at the Institute of Botany, Jiangsu Province & Chinese Academy of Sciences, China (north latitude 32°02′, east longitude 118°28′). After removing soil by hand washing, sod pieces were transplanted to PVC tubes (40 cm long and 10 cm in diameter) filled with river sand to a uniform bulk density. Turfgrasses were grown in the PVC tubes for 3 weeks before salinity treatments were initiated. During this period, turfgrasses were irrigated with 200 ml tap water per tube every 4 d, clipped weekly to 2 cm for 'Diamond', and 3 cm for 'Adalayd', 'C291', and 'Z080'. Turfgrasses were fertilized at 6 kg N ha^{-1} using compound fertilizer (9N–9P–7K) every 8 d throughout the experiment except in winter (from 1 November 2006 to 15 March 2007).

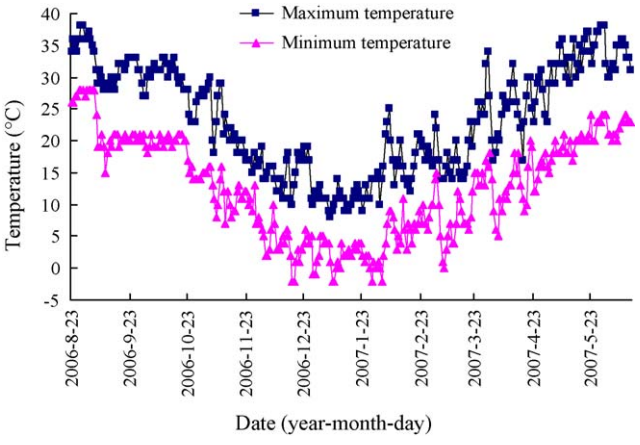

Fig. 1. Daily maximum and minimum temperatures in the glass room.

2.2. Salinity treatment and data collection

Salinity treatments began on 15 September 2006. Irrigation waters of different salinities were prepared by addition of NaCl to tap water to obtain desired salinities of 90, 180, 360, 540, 720, and 900 mM. The saline waters of different NaCl concentrations along with tap water as the control were applied to all turfgrasses with 200 ml per tube every 2 d. Excess water was freely drained from tube bottom to reduce salt accumulation in sand. To avoid salinity shock, salinity levels were gradually increased by the increments of 90 mM NaCl every 2 d.

After 6 weeks of salinity stress, shoots were clipped and discarded. From then to 15 March 2007, turfgrasses almost stopped growth under low temperature, although plants were not completely dormant in the glass room. During this period plants were not clipped or fertilized, yet were irrigated with saline water or tap water every 1 week. After 15 March, regular fertilization was resumed, yet no clipping was made until the termination of the study on 13 June 2007.

Percent green leaf canopy area (GLCA) of each tube was visually estimated on 13 June 2007. Canopy height (five random observations per tube) and density based on shoot number per square centimeter were recorded. Green leaf number per plant, leaf weight, leaf length, and leaf width were determined with 10 replications per tube.

To determine salt secretion capacity, plants were thoroughly rinsed with distilled water to remove all external salt. After 3 d, leaves were carefully excised, and immediately washed with 10 ml distilled water according to the method of Marcum et al. (1998), then removed, blotted dry, and weighed. The conductivity of the water that the leaves were washed in was measured using a conductivity meter (Model DDS-11A, Shanghai Leici Instrument Inc., Shanghai, China). Salt secretion capacity is expressed as μS cm^{-1} per gram leaf fresh weight per three days. To determine tissue water content, leaves and roots were thoroughly rinsed with distilled water, quickly blotted dry, and weighed (fresh weight, FW), then dried at 80 °C for 24 h and weighed (dry weight, DW). Tissue water content (WC) was calculated by the formula: WC (%) = (FW − DW)/FW × 100. The dried leaves and roots were powdered, and then 0.5 g samples were completely digested with HNO_3–$HClO_4$ (Zhao et al., 1994). The Na^+ and K^+ concentrations were determined by flame photometry (Model FP640, Shanghai Precise Instrument Inc., Shanghai, China). All leaves used above were the third fully expanded leaves.

2.3. Statistical analysis

The experiment was performed in a completely randomized design with three replications. All data were subjected to analysis of variance and means were compared using Duncan's Multiple Range Test by a SPSS 13.0 software (SPSS Institute, Cary, NC, USA).

3. Results and discussion

3.1. Growth responses

3.1.1. Percent green leaf canopy area (GLCA)

Percent green leaf canopy area was significantly different under different salinity levels in four turfgrasses (Table 1). 'Diamond' and 'Adalayd' maintained 100% GLCA up to 360 mM salinity treatments and died at 900 and 720 mM salinity treatments, respectively. 'C291' maintained 100% GLCA up to 180 mM salinity treatment and