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Growth response and ion regulation of seashore paspalum accessions to increasing salinity

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ABSTRACT

Seashore paspalum (*Paspalum vaginatum* Swartz) is an important warm-season turfgrass indigenous to tropical and coastal areas worldwide. The objectives of this study were to investigate the growth response and ion regulation of Chinese seashore paspalum germplasm under salinity stress. Twenty-seven seashore paspalum accessions and one check cultivar “Sea Isle 2000” were grown in solution culture in a glasshouse, with NaCl added to achieve salinities of 0 (control), 340 and 510 mmol/L. Compared with the nonsaline controls, the salinity stressed accessions showed significantly increased leaf firing, decreased shoot growth, and an increase or decrease in root growth. Significant genetic variations in the leaf firing (LF), relative shoot weight (RSW) and relative root weight (RRW) were found among the different accessions, with coefficients of variation ranging from 19.54% to 37.84%. The P40 accession had the best salinity tolerance with little leaf firing under salinity stress, followed by Sea Isle 2000, P29 and P14. For the control, the average K^+ concentration was 1161.69 mmol/kg in the shoots and 383.73 mmol/kg in the roots. Compared to the control, the salinity treatment showed that the K^+ concentration treatment decreased in both the shoots and roots; however, the percentage of the reduction in the shoots was significantly lower (26.20%) than that in the roots (69.68%). The Na^+ concentration was very low in both the shoots and roots of the seashore paspalum, with an average of 65.90 mmol/kg and 39.50 mmol/kg, respectively, under the treatment of nonsalinity. Compared to the nonsalinity control, the Na^+ concentration greatly increased in both the shoots and roots; however, the percentage of the increase in the shoots was lower (15-fold) than in the roots (25-fold). The results indicate that taking up more of the K^+, maintaining a high K^+ concentration in the shoots and reducing the Na^+ being transferred from the roots to the shoots could be the mechanisms for Na^+ and K^+ regulation for salinity tolerance in seashore paspalum.

1. Introduction

Soil salinity is an escalating problem worldwide (Shahid, 2013). More than 20% of cultivated land worldwide is affected by salt stress, and the amount is increasing every day (Gupta and Huang, 2014). Approximately 37 million hectares of land is suffering from salinization and secondary salinization in China (Zhang et al., 2007). One strategy to address salinization and to make full use of land resources is to develop and use plants with improved salinity tolerance. However, some lands are currently too saline for conventional agriculture, and an alternative is to grow salt-tolerant grasses in those areas (Roy and Chakraborty, 2014). Some of the turfgrass species are halophytic in nature. The use of salt-tolerant turf varieties would allow landscape development in saline environments and would be ideal in such environments, where limited or no fresh water is available for irrigation, and salt water is the only option for irrigation practices (Uddin et al., 2012).

Seashore paspalum (*Paspalum vaginatum* Swartz) is a littoral, warm season perennial turfgrass indigenous to tropical and coastal areas worldwide. Seashore paspalum spreads rapidly by stolons and rhizomes to form a fine-textured, dense turf, with a deep root system (Duncan and Carrow, 2000). Seashore paspalum has demonstrated superior salt tolerance compared to other turfgrasses (Dudeck and Peacock, 1985; Marcum and Murdoch, 1994;

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Shahba, 2010; Shahba et al., 2012; Uddin et al., 2012). At the highest salinity level of 48 dS m^{-1}, high injury (80–100% leaf firing) was observed in *Digitaria didactyla, Cynodon dactylon* "Tifdwarf" and *C. dactylon* "Satiri", followed by *Z. matrella* (39%) and *Zoysia japonica* (25%); however, only 15% leaf firing was observed in seashore paspalum (Uddin et al., 2012). Under the salinity level of 54.0 dS m^{-1}, the seashore paspalum cultivar 'Salam' showed the lowest leaf firing percentage (80%), followed by 'Excalibur' (90.5%), whereas bermudagrass cultivars and seashore paspalum cultivar "Adalayd" showed 100.0% leaf firing (Shahba, 2010). Marcum and Murdoch (1994) reported that seashore paspalum (Hawaii selection) was the most salt-tolerant turfgrass compared with bermudagrass cv. Tifway or Japanese lawngrass cv. Korean common. The shoot growth of Hawaii was reduced by 50% at 400 mM salinity, however, the shoot growth of Tifway and Korean common was reduced by 50% at 270 mM and 230 mM salinity, respectively. Now, seashore paspalum is being widely used as a salt-tolerant turfgrass on golf courses, sport fields and general landscapes (Chen et al., 2005).

Even though seashore paspalum is a true halophyte, some concentration of salinity exists that has a negative effect on the plant density, texture, color and/or growth habit for each cultivar. Seashore paspalum exhibits a wide range in salinity tolerance among ecotypes, Salt-tolerant ecotypes exhibit higher relative shoot and root growth rates and lower leaf-firing percentages compared to salt-sensitive ecotypes (Lee et al., 2004a,b; Dudeck and Peacock, 1985; Marcum and Murdoch, 1994). Shoot-growth responses and root-growth responses to salinity of some seashore paspalum ecotypes were evaluated by Lee et al. (2004a,b). The results showed that the variance in the ranges of the leaf-firing, shoot growth and root growth at EC_w40 (the sea-salt amended nutrient solution with the electrical conductivity of 41.1dS m^{-1}) was from 7% to 41%, from 0.06 to 0.35 g, and from 0.52 to 1.66 g, respectively (Lee et al., 2004a,b).

Salinity stress is also considered as a hyperionic stress. Initially, soil salinity is known to repress plant growth in the form of osmotic stress, which is then followed by ion toxicity (Deinlein et al., 2014; Gupta and Huang, 2014). Ion toxicity is one of the most detrimental effects of salinity stress (James et al., 2011). Marcum and Murdoch (1990) evaluated the growth responses, ion relations and osmotic adaptations of eleven C4 turfgrasses to salinity, and the results showed that seashore paspalum can maintain higher shoot and root K^+ concentrations and can reduce the toxicity of relatively high levels of Na^+ and Cl^- concentrations by maintaining much higher tissue water levels. However, ion toxicity also occurs in seashore paspalum grown under saline stress. Increasing the salinity reduced the uptake of the K^+ and increased the Na^+ and Cl^- tissue content (Dudeck and Peacock, 1985, 1993; Lee et al., 2007). Genotypic differences in ion accumulation among the different seashore paspalum have been reported, where most salt-tolerant types exhibited the lowest shoot tissue concentrations of Na^+ and Cl^- as salinity increased (Dudeck and Peacock, 1985). Lee et al. (2007) also reported that the K^+ uptake decreased and the Na^+ uptake was enhanced with increasing salinity for nine tested seashore paspalums, and significant differences existed in the Na^+ and K^+ concentrations among the ecotypes. They also found that the shoot and root growth of seashore paspalum was positively correlated to the K^+ content of the tissue, K^+ was the primary ion for solute potential (Ψs) adjustment, and Na^+ tissue content among the seashore paspalums was small in magnitude and without an apparent relation to salinity tolerance. The studies evaluated the ion accumulation of seashore paspalum under salinity stress; however, knowledge of correlations between the growth and the ion concentrations of the shoots and roots and the ion regulation mechanisms are still insufficient.

Seashore paspalum is widely grown in China, where some introduced cultivars, such as "Adalayd," "Salam," "Seaspray," and "Sea Isle 2000" are broadly used. However, because of their poor adaptation to local environments, these cultivars can not perform to the expected levels in China. Seashore paspalum is also naturally distributed in the southern China. However, researchers seldom pay attention to this plant in China. Until now, only one research work on the genetic diversity of Chinese seashore paspalum resources has been reported. Xie et al. (2004) collected three natural populations of seashore paspalum from Guangzhou City, Guangdong Province, China, and analyzed their genetic diversity by random amplification polymorphic DNA (RAPD) marker technology, and the results showed high genetic variation among the populations. We collected 27 accessions of seashore paspalum from the seaside, natural grasslands, roadsides, and farmlands of Guangdong Province and Hainan Province in China in 2013, which cover the main natural distribution area of the seashore paspalum in China. In our preliminary observation, we identified abundant genetic variation in the morphological characteristics among the different germplasm. Therefore, this experiment was designed to determine the salt tolerance of germplasm resources of seashore paspalum, to screen the better accessions for the breeding of seashore paspalum and to examine the relations between salt tolerance and the Na^+ and K^+ concentrations in the shoots and roots, therefore gaining a better understanding of the ion regulation mechanisms of seashore paspalum under salinity stress.

2. Materials and methods

2.1. Plant materials and growth conditions

Twenty-eight accessions of seashore paspalum were used in the experiment, including 27 accessions collected from Hainan Province and Guangdong Province, China, and 1 turf-type commercial cultivar "Sea Isle2000" (Supplemental Table 1). All accessions were planted in a plot (50 cm $\times$ 60 cm) in the experimental field of the Institute of Botany, Jiangsu Province and Chinese Academy of Sciences (32°02′N, 118°28′E; elevation 30 m).

The experiment was conducted from 22 July to 22 October 2013 in solution culture in a greenhouse. Twenty uniform sprigs of each grass from the experimental field of the Institute of Botany were planted in 9-cm-diameter and 6-cm-deep plastic pots with coarse nylon screen bottoms and filled with coarse silica sand. Six pots (three for the salinity treatment and three as the control) were planted for every sample. Pots were suspended over tanks containing 45 L (66.5 $\times$ 45.5 $\times$ 17.0 cm^3) 1/2 Hoagland's solution as the nutrient medium. Grasses were clipped weekly and allowed to establish well before the salinity treatments began. During the experiment, the daily minimum and maximum air temperatures in the greenhouse were 16 °C and 38 °C, and the average air temperature was approximately 25 °C. Plants were grown under natural light, with photosynthetically active radiation ranging from 800 to 1800 μmol m^{-2} s^{-1}.

2.2. Salinity treatment and growth measurements

After 40 days of plant culture, the salinity treatments were applied. Prior to initiation of the salinity treatments, all plants were cut to a height of 4 cm, so later measurements would be made on tissue produced after the imposition of salinity stress. To avoid salinity shock, at first salinity levels were gradually increased by increments of 42.5 mmol/L every day until reaching a concentration of 340 mmol/L NaCl. Grasses were then cut to a height of 4 cm, and the clippings were washed three times with double-distilled (DD) water and dried at 70 °C for 48 h for the determination of