Comparing Growth Responses of Selected Cool-Season Turfgrasses under Salinity and Drought Stresses

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Abstract

This study was conducted in a greenhouse, using hydroponics system, to compare growth responses of three cool-season turfgrass species, Creeping bentgrass (Agrostis stolonifera), Rough bluegrass (Poa trivialis), and Perennial ryegrass (Lolium sperenne) in terms of shoot and root lengths and dry matter (DM), and percent canopy green cover (%CGC) under salinity and drought stresses. Grasses were grown in Hoagland solution for 90 days prior to initiation of salinity or drought stresses. Then, 24 meq NaCl/L culture solution/day were added for each -0.1 MPa OP of salinity stress, or 75 and 119 g of PEG/L were added for -0.2 and -0.4 MPa OP of drought stress treatments, respectively. The treatments included control, -0.2 and -0.4 MPa OP salinity, -0.2 and -0.4 MPa OP drought stress. Four replications of each treatment were used in a RCB design experiment. During the stress period, grass shoots were clipped weekly for DM production, shoot and root lengths were measured, and %CGC was evaluated. The weekly clippings and the roots at the last harvest were oven dried at 60^o C and DM weights were recorded. All 3 grass species were more severely affected by drought than salinity. Bluegrass was the most and bentgrass the least severely affected by either drought or salinity stress.

Introduction

Kentucky bluegrass (*Poa pratensis* L.), bentgrass (*Agrostis stolonifera*) and ryegrass (*Lolium perenne*) are used as common cool-season turfgrasses worldwide and used for overseeding on warm-season grasses in warm climatic regions. For the latter use, often the regions are under either or both drought and salinity stresses. Researchers have used some growth regulators (inhibitors) to reduce growth of turfgrasses, in turn, to reduce water use of the grasses under drought stress conditions. It has been shown that Primo-Max may improve stress (i.e., salinity and drought) tolerance of turfgrasses, although this has not been well documented. Pessarakli et al. (2006) found Primo-Max improved salt tolerance of bluegrass under salinity stress conditions.

Turf breeders are searching worldwide to develop plant species and turfgrass cultivars that can grow and perform satisfactory growth in a wide range of climates, soils, and environmental conditions. These grasses can be manipulated to produce dwarf varieties which require less mowing as well as more stress (i.e., salinity and drought) tolerant cultivars/genotypes which require less maintenance and grow in poor soil conditions (Duncan and Carrow, 1999; Lee et al., 2004). These characteristics can be substantially beneficial for plant and turfgrass growth in arid and semi-arid regions where the soils are usually saline/sodic and water is limited for irrigation and other agricultural uses. Preliminary tests of any new species/cultivars for growth under stressful conditions would prevent the unexpected results of their use under similar conditions in the real world situation.

Objectives

The objectives of this investigation were to compare growth responses of three major cool-season turfgrasses (Bent, Bluegrass, and Rye) in terms of shoot and root lengths and dry weights (shoot clippings weight) under sodium chloride (NaCl) salinity and polyethylene glycol (PEG) drought stress conditions in the culture medium.

Materials and Methods

Three major cool-season turfgrasses, Creeping bentgrass (*Agrostis stolonifera*), Rough bluegrass ("*Poa triv*", *Poa trivialis*), and Perennial ryegrass (*Lolium sperenne*) were studied in a greenhouse at the University of Arizona, using hydroponics system, to compare their growth responses in terms of shoot and root lengths and dry matter (DM) weights (shoot clippings weight), and percent canopy green cover (%CGC) under NaCl-salinity and PEG-drought stress conditions.

The grasses were grown from seeds in cups, 9 cm diameter and 7 cm height. Silica sand was used as the plant anchor medium. Each cup was fitted into one of the 9 cm diameter holes cut in a rectangular plywood sheet 46 cm (length) X 37 cm (width) X 2 cm (thickness). The plywood sheets served as lids for the hydroponics tubs and supported the cups above the solution to allow for root growth. The lids were placed on 42 cm (length) X 34 cm (width) X 12 cm (depth) Carb-X polyethylene tubs, containing half strength Hoagland solution No. 1 (Hoagland and Arnon, 1950; Marcum et al., 2005; Pessarakli and Kopec, 2004; Pessarakli et al., 2005, 2006).

The grasses were allowed to grow in this nutrient solution for 90 days. During this period, the grass shoots (clippings) were clipped weekly in order to allow the grass to reach full maturity and develop uniform and equal size plants. The clippings were discarded. The culture solutions were changed biweekly to ensure adequate amount of essential plant nutrient elements for normal growth and development.

After 90 days growing in this nutrient solution, the salinity and drought treatments were started by adding 24 meq NaCl/L culture solution/day for each -0.1 MPa OP of salinity stress (Pessarakli and Tucker; 1985), or 75 and 119 g of PEG/L for -0.2 and -0.4 MPa OP of drought stress treatments (Frota and Tucker, 1978), respectively. The combination of control, salinity, and drought resulted in five treatments (control, -0.2 and -0.4 MPa OP NaCl-salinity and -0.2 and -0.4 MPa OP PEG-drought stresses). Four replications of each treatment were used in a randomized complete block (RCB) design trial. The culture solution levels in the tubs were marked at the 10 liter volume level and maintained at this level by adding distilled water as needed. Culture solutions were changed bi-weekly to maintain the desired plant nutrient levels. The grass shoots (clippings) were harvested weekly for six weeks for the evaluation of the dry matter (DM) yield. At each harvest, shoot and root lengths were measured and recorded. The percent of the visual canopy green cover (%CGC) was also estimated and recorded.

The harvested plant materials were oven-dried at 60^{o} C and DM weights were measured and recorded. The recorded data were considered the weekly plant DM yield. At the last harvest, plant roots were also harvested, oven dried at 60^{o} C, and DM weights were determined and recorded.

Statistical Analysis

The data were subjected to Analysis of Variance, using SAS statistical package (SAS Institute, 1991). The means were separated, using Duncan Multiple Range test.

Results and Discussion

The results for the average of six weekly evaluated response parameters are presented in Tables 1-5.

Shoot Length

For all three grass species, shoot lengths significantly decreased under any level of either salinity or drought stresses (Table 1). Reduction in shoot lengths of all three grass species were more pronounced under drought compared to salinity stress. The adverse effect of drought on the grasses was significant at both -0.2 and -0.4 MPa Osmotic Potential (OP) stresses imposed by PEG. However, salinity was more detrimental at the -0.4 compared to -0.2 MPa OP stress imposed by NaCl (Table 1). The effect of PEG (drought stress) showed immediately after its application. Among the three grasses, bluegrass was the most severely affected by either salinity or drought stresses.

Root Length

Although the root lengths data were taken weekly at each harvest, the cumulative values of the root lengths data are reported here. Root lengths were also severely affected under either salinity or drought stresses (Table 2). As was observed for the shoot lengths, the effects of drought stress on root lengths were more pronounced compared to that of salinity stress. The effects of both salinity and drought stresses were more sever on the root lengths than on the shoots lengths. This is in contrast to the findings reported on the effects of stress on warm-season or more stress tolerant grasses/halophytes (Marcum et al., 2005; Pessarakli and Kopec, 2004; Pessarakli et al., 2005; Sagi et al., 1997). All these investigators found that under stress conditions, plant/grass roots of halophytes and more tolerant species were less affected than shoots.

Shoot Dry Weight

Shoot DM weights responses followed the same pattern as shoot lengths for all three grasses. It significantly decreased under either salinity or drought stresses (Table 3). Again, all three grass species were more severely affected under drought stress compared to salinity, and among the three grass species, bluegrass was the most severely affected under either stress conditions.

Root Dry Weight

Roots DM weights of all three grass species substantially decreased under either salinity or drought stresses (Table 4) at any level of stress. As was reported for the root lengths, this is in contrast with the findings reported by several investigators on the warm-season halophytic plants/grasses (Marcum et al., 2005; Pessarakli and Kopec, 2004; Pessarakli et al., 2005; Sagi et al., 1997). Among the three grass species, bluegrass was the most severely affected under either salinity or drought stress conditions. For all three grass species, the effects of drought stress were more pronounced than that of salinity.

Percent Canopy Green Cover (%CGC)

The percent canopy green cover of all three grass species substantially decreased under drought stress. For all three grasses, %CGC was less under drought stress compared to salinity stressed and control plants. Among the three grass species, bluegrass was the most and bentgrass the least severely affected species under either salinity or drought stress conditions (Table 5). There was not a significant difference in the percent canopy green cover of the bentgrass under salinity or drought stresses compared with the control plants. The %CGC of bentgrass under -0.2 and -0.4 MPa OP of PEG-drought stress were 91 and 88, respectively, compared to the control (non stressed plants). The corresponding values were 97 and 93 for the same grass under -0.2 and -0.4 MPa OP of NaCl-salinity stress conditions. These values were 73 and 64 for drought stress and 92 and 80 for the salinity stressed ryegrasses, respectively. The corresponding values were only 54 and 40 for the drought and 56 and 52 for the salinity stressed bluegrasses.

Conclusions

For all the study parameters (shoot and root lengths, DM weights, and percent canopy green cover), all three grass species were more severely affected by PEG-drought compared to NaCl-salinity stress. The adverse effect of drought on the grasses was significant at both -0.2 and -0.4 MPa OP stresses imposed by PEG. However, the adverse effect of salinity was more pronounced at the -0.4 MPa compared to -0.2 MPa OP stress imposed by NaCl stress. Among the three grass species, bluegrass was the most and bentgrass the least severely affected by either drought or salinity stress. Reductions in the canopy green cover due to drought and salinity stresses ranged between 3 to 12, 8 to 36, and 44 to 60% for bentgrass, ryegrass, and bluegrass, respectively. For each species, the lower value is due to salinity stress and the higher one resulted from the drought stress.

The values of any study parameter for the control grasses of all three species were always significantly higher than the corresponding values under either salinity or drought stress condition.

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Table 1. Bent, bluegrass, and ryegrass shoot growth responses under salinity and drought stresses.

Osmotic Pot. (MPa)	Shoot length (cm) Bentgrass	Bluegrass	Ryegrass
Control (0)	6.0abc	7.0a	7.1a
-0.2 PEG	3.4e	3.6e	3.5e
-0.4 PEG	3.3e	2.8e	3.0e
-0.2 NaCl	5.5bcd	5.2bcd	6.7a
-0.4 NaCl	5.0cd	4.8d	6.3ab

The values are means of 4 replications and 6 harvests.
All the values followed by the same letter in each column for each grass are not statistically different at the 0.05 probability level.

Table 2. Bent, bluegrass, and ryegrass root growth responses (cum. values) under salinity and drought stresses.

Osmotic Pot. (MPa)	Root length (cm) Bentgrass	Bluegrass	Ryegrass
Control (0)	17.6a	11.9ab	19.1a
-0.2 PEG	6.3bc	5.0bc	4.9bc
-0.4 PEG	5.1bc	4.0c	4.7bc
-0.2 NaCl	11.1b	7.0bc	14.7a
-0.4 NaCl	9.5b	5.6bc	14.4ab

The values are means of 4 replications.
All the values followed by the same letter in each column for each grass are not statistically different at the 0.05 probability level.

Table 3. Bent, bluegrass, and ryegrass shoot dry wt. under salinity and drought stress conditions.

Osmotic Pot. (MPa)	Shoot dry wt. (g) Bentgrass	Bluegrass	Ryegrass
Control (0)	0.45a	0.37a	0.46a
-0.2 PEG	0.26b	0.21b	0.24b
-0.4 PEG	0.24b	0.18b	0.20b
-0.2 NaCl	0.36a	0.22b	0.29ab
-0.4 NaCl	0.30ab	0.19b	0.24b

The values are means of 4 replications and 6 harvests.
All the values followed by the same letter in each column for each grass are not statistically different at the 0.05 probability level.

Table 4. Bent, bluegrass, and ryegrass root dry wt. (cum. values) under salinity and drought stresses.

Osmotic Pot. (MPa)	Root dry wt. (g)		
	Bentgrass	Bluegrass	Ryegrass
Control (0)	0.11a	0.05cd	0.07bc
-0.2 PEG	0.04de	0.02ef	0.03def
-0.4 PEG	0.03de	0.01f	0.02ef
-0.2 NaCl	0.09ab	0.03def	0.05cd
-0.4 NaCl	0.07bc	0.02ef	0.04de

The values are means of 4 replications.
All the values followed by the same letter in each column for each grass are not statistically different at the 0.05 probability level.

Table 5. Bent, bluegrass, and rye % canopy green cover under salinity and drought stresses.

Osmotic Pot. (MPa)	Canopy green cover (%)		
	Bentgrass	Bluegrass	Ryegrass
Control (0)	100	100	100
-0.2 PEG	91	54	73
-0.4 PEG	88	40	64
-0.2 NaCl	97	56	92
-0.4 NaCl	93	52	80

The values are means of 4 replications and 6 weekly ratings.
All the values followed by the same letter in each column for each grass are not statistically different at the 0.05 probability level.