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Growth responses of sacaton grass (*Sporobolus airoides* Torr.) and seashore paspalum (*Paspalum vaginatum* Swartz) under prolonged drought stress condition

Abstract

Climate change and global warming has resulted in a substantial increase in temperature and decrease in precipitation in various regions, especially in the arid and semi-arid regions throughout the world. This has caused a severe shortage of water and drought condition, particularly in desert areas that have already been encountered water shortage, thus has mandated use of low quality waters for irrigation and cultivation of plant species with high degrees of drought tolerance. Therefore, there is an urgent need for finding drought tolerant plant species to survive under such stressful conditions. My preliminary investigations indicated that Alkali sacaton grass (*Sporobolus airoides* Torr.) and Seashore paspalum (*Paspalum vaginatum* Swartz), halophytic grass species, have a great potential to be used under harsh and stressful arid regions' conditions. Therefore, these grasses were studied in a greenhouse to evaluate their growth responses under a prolonged drought stress condition. Four replications of each grass species were used in a complete randomized block design trial. Plant shoots were harvested weekly, oven dried at 70°C, and dry weights recorded. At each harvest, shoot height was also measured and recorded and the grasses' general qualities were estimated. The results showed at all weekly measurements, shoot height of the Alkali sacaton grass was substantially higher than that of Seashore paspalum under drought stress condition. In contrast, compared with the Alkali sacaton grass, at all weekly harvests both shoot fresh and dry weights of Seashore paspalum were significantly higher than that of Alkali sacaton grass. The shoot fresh and dry weights of both grasses decreased as drought stress progressed. The reductions in shoot fresh and dry weights were more pronounced at later harvests and the effect of drought stress was more severe on both grasses and significantly reduced them. Shoot succulence of the grasses followed the same pattern as the shoot fresh and dry weights. The shoot succulence of Seashore paspalum was substantially higher than that of Alkali sacaton grass at all weekly harvests. At all weekly harvests, the general quality of Seashore paspalum was substantially better than that of Alkali sacaton grass. Although the quality of both grasses decreased as drought stress period progressed, at later harvests, the grass quality was acceptable for Seashore paspalum. However, the quality of Alkali sacaton grass was significantly lower at the later harvests and was unacceptable (quality scores of<6) for Alkali sacaton grass, starting at the 4th week of drought stress. These halophytic plant species had a satisfactory growth (Seashore paspalum was more tolerant than Alkali sacaton grass) under drought stress condition. This indicates that these halophytic grasses can successfully and effectively be used as cover plant species to prevent soil erosion and combat desertification under dry arid regions with limited water resources and drought conditions.

Keywords: halophytic plant species, alkali sacaton grass, seashore paspalum, drought stress, combating desertification

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Introduction

Halophytic plant species are the dominant vegetation cover found under harsh arid regions characterized by high temperatures and shortage of water, drought conditions. They are multi-purpose usage plants, can be used as potential animal feed plant, for saline soil biological reclamation or soil establishment/erosion control, and as a desert landscaping species for recreation areas. These species grow in very poor to fair condition soils, in both salt-affected soils and soils under poor fertility as well as drought and harsh environmental conditions.[1–3] Their dominant and most common habitats are arid and semi-arid regions.[2,4] These plants are abundantly found in areas of the western parts of the United States as well as on the Seashores of Saudi Arabia, the United Arab Emirates, and several other Middle-Eastern countries, Africa, South and Central American countries.[2,4,5–9,10–12] These plant species can be manipulated to modify their performance and increase their yield and productivity. Water shortage and its quality and quantity are major problems worldwide, especially in arid regions and areas with limited water resources and drought conditions.[2,5,8,10,13–15] Water shortage and drought conditions are widespread and persistent environmental problems in many regions, especially in desert areas and water-limited systems, and can lead to substantial reductions in soil productivity and fertility,[2,16,17] water quality and quantity, and the timing and supply of ecosystem services such as soil formation, hydrologic partitioning, and stream flow generation.[5] An effective strategy to enhance plant survival and recovery from drought stress is to use cultivars with superior drought tolerance.[6,7,9,14,19–23] However, development of drought-tolerant cultivars is not simple because the trait is controlled by many physiological mechanisms and genes.[24–26] Therefore, reliable selection criteria are fundamental for developing drought-tolerant cultivars.

Perennial vegetation coverage in arid regions must maintain adequate growth and persistence under variable growth conditions and factors limiting growth such as water shortage and drought conditions over several years. Successful assessment of drought tolerance of perennial, halophytic plant species, therefore, should be based on growth at normal (no-drought), moderate, and severe drought conditions.[5,16,19,21,24,27,28] Therefore, halophytic plant species such as bermudagrass (*Cynodon dactylon* L.), Seashore paspalum (*Paspalum vaginatum* Swartz), Salt grass (*Distichlis spicata* L., Greene), and Alkali sacaton grass (*Sporobolus airoides* Torr.) need to be evaluated under these various drought stress conditions to select the best cultivars/accessions/genotypes. Water shortage and drought conditions are major problems in many agricultural sites and the problem is becoming more severe, especially in arid and semi-arid regions and areas where water resources are limited. Conversion of arable lands to unusable agricultural lands and desertification processes caused by climate change, global warming, industrialization, and improper management practices is one of the greatest current environmental challenges. In arid regions, the rate of desertification and severity of drought is high and crop production is at risk.[5–9,11,14] In such circumstances, a mixture of initiatives and strategies may be required to prevent further desertification processes. Among these, proper water management, use of low quality water, use of drought tolerant plant species, and revegetation of the desert regions are effective initiatives and strategies for mitigating or slowing down desertification processes.[10,16,22,26,27,29] Revegetation of saline soils and dry lands with limited water resources and drought conditions via usage of plant species that are better adapted and tolerant to the harsh and stressful conditions of the environments is likely the most effective practice owing to its affordability and feasibility for widespread implementation. Re-establishment and maintaining vegetation cover, particularly under arid and semi-arid regions and areas characterized by drought conditions and limited water resources is a critical factor in addressing desertification problems.[5–8,12,16,19,27,30,31] Halophytes are particularly effective in this regard by reducing salinity level of the soil via removing the salts or by utilizing saline and low quality waters for their growth and by their nature of low water requirements that are tolerant plant species and well adapted to drought and harsh desert conditions with limited water resources. Bermudagrass (*Cynodon dactylon* L.), Seashore paspalum (*Paspalum vaginatum* Swartz), Alkali sacaton grass (*Sporobolus airoides* Torr.), and Salt grass (*Distichlis spicata* L., Greene), true halophytes, are among the most effective halophytic plant species to be established under arid regions with highly saline soils, limited water, and drought conditions. These plant species have multiple usages, including animal feed, soil conservation and reclamation, and use for recreation areas, and especially xeriscape landscaping associated with limited water resources and drought conditions. They have great potential to maintain growth and combat desertification processes. Although some cultivars of some halophytic grass species have been evaluated for drought tolerance,[10,22] a wider range of tested cultivars are needed to increase management options. Based on work to date,[5–8,10,22,29] an additional cultivars of two halophytic grass species have been identified suitable drought tolerance candidates for cultivation under limited water and drought conditions and combating desertification. These cultivars of the halophytic plant species have already been tested by the author and his co-workers[9] for salinity stress and proved to be highly salt tolerance and suitable for cultivation under arid regions with high soil salinity and saline water conditions. Therefore, the objectives of this study were to evaluate establishment and growth responses of these two halophytic plant species, Seashore paspalum (*Paspalum vaginatum* Swartz), cv. Sea spray and Alkali sacaton grass (*Sporobolus airoides* Torr.) as candidate grass species for use in dry lands with high soil salinity, limited water resources, arid and drought conditions with the high risk of desertification. For this purpose, shoot length, shoot fresh and dry weights, and the grasses' general qualities were evaluated under prolonged drought stress conditions. Also, responses of these two species were compared to identify the one likely to be more effective for establishment and survival under arid regions, limited water resources or drought conditions, and for combating desertification processes. Finally, the study was aimed to recommend the most drought tolerant cultivar as the potential species for use under arid, semi-arid, and areas with harsh desert conditions and limited water supplies or drought conditions for sustainable agriculture and combating desertification processes.

Materials and methods

Alkali Sacaton grass (*Sporobolus airoides* Torr.) and Seashore paspalum (*Paspalum vaginatum* Swartz), cv. Sea Spray were studied in a greenhouse at the University of Arizona to evaluate their growth responses to prolonged drought period and their survival and establishment under desert conditions. Four replications of each grass cultivar were used in a randomized complete block design trial.

Grass Establishment

The grasses were grown either from seeds (Alkali sacaton grass) or by vegetative propagules (Seashore paspalum) in cups, 9cm diameter and 7cm height. Cups were placed in large stainless steel galvanized cans (45.7cm diameter, 55.9cm height), filled with 150kg fritted clay as plant anchor medium (Figure 1) (Figure 2). The grasses were grown under normal condition [daily irrigation, weekly fertilization, and weekly clipping (clippings discarded)] for 3months to produce equal size and uniform plants before the initiation of the drought stress phase of the experiment. During this period, the plant shoots were harvested weekly in order to develop uniform and equal-size plants. The harvested plant materials were discarded.

Drought stress

A dry-down fritted clay system which mimics progressive drought that was designed by White et al.,[32] was used in this investigation. This procedure has been used successfully in our previous drought stress studies.[5,10,19,22,23,29] The system imposes a gradually prolonged drought stress to the various grass cultivars planted in separate cups (experimental units). The drought stress started by completely saturating the cans containing 150kg fritted clay and the cups containing the grasses, then depriving the grasses of water and fertilizer for a period of 8weeks. Figures 3-5 show the grasses after 2, 4, and 6weeks, respectively, under drought stress conditions. During the stress period, shoots were clipped weekly for the evaluation of growth and dry matter (DM) production. The harvested plant materials were oven dried at 70°C and DM weights were measured and recorded. The recorded data were considered the weekly plant DM production. The grass general quality was also weekly evaluated and recorded. Two weeks after the initiation of the drought period, the first sign of stress (leaf curling) was shown. Grasses gradually showed more signs of wilting (finally, permanent wilting, and eventually death or dormancy). At the end of the 8-week drought stress period, the majority of the plants were either dead or gone to dormancy stage (Figure 6). Although some grasses still survived, no measurable growth could be done at this stage. Then, all the grasses were re-watered for the recovery rate determination. Figures 7 & 8 show the grasses 4months after re-watering and recovery.

Figure 1 One replication of the 3 months old grasses during the establishment period.

Figure 2 All replications of the 3 months old grasses during the establishment period.

Figure 3 All replications of the grasses 2 weeks after being under drought stress.

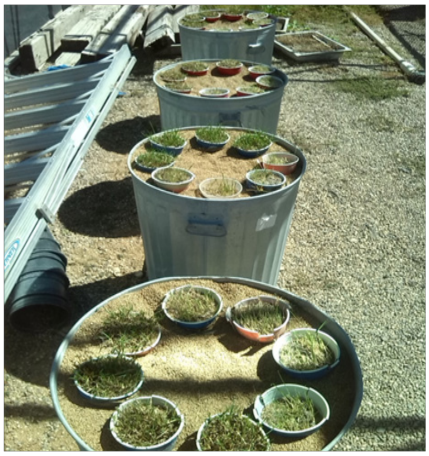

Figure 4 All replications of the grasses 4 weeks after being under drought stress.

Figure 5 All replications of the grasses 6 weeks after being under drought stress.

Figure 6 One replication of the grasses 8 weeks after being under drought stress.

Figure 7 One replication of the grasses 4 month after re-watering and recovery.

Figure 8 All replications of the grasses 4 month after re-watering and recovery.

Statistical Analysis

The data were subjected to the Analysis of Variance, using SAS statistical package.[33] The means were separated, using Duncan Multiple Range test.

Results and discussion

The results of the shoot length, shoot fresh and dry weights, shoot succulence and general qualities of Alkali sacaton grass and Seashore paspalum under a prolonged (8weeks) drought stress are presented in Tables 1 & 2. The grasses grown at different weeks under drought periods are shown in Figures 3-6.

Shoot height

As shown in Table 1, across all weekly harvests (weekly drought periods), shoot height of Alkali sacaton grass was substantially higher than that of Seashore paspalum. For both grass cultivars, shoot heights were decreased more as drought stress progressed (Table 1).

Shoot fresh weight

In contrast to the shoot height, the shoot biomasses of Seashore paspalum was substantially higher than that of Alkali sacaton grass at all weekly harvests (weekly drought periods) (Table 1). For both grass cultivars, these values significantly decreased as the drought period progressed. Reduction in biomass production with progress in drought period was more pronounced in Alkali sacaton grass than in Seashore paspalum and this reduction was more in biomass productions than that in shoot heights in both Alkali sacaton grass and Seashore paspalum. After the 8 weeks of the drought period, the grasses still maintained their green colors, but there was no measurable growth in shoot heights or weights for either grass.

Shoot Dry Matter (DM) weight

The shoot DM weight responses of both grasses followed a similar pattern as the shoot fresh weights. The shoot DM of Seashore paspalum was substantially higher than that of Alkali sacaton grass at all weekly harvests (weekly drought periods) (Table 1). For both grass cultivars, these values significantly decreased as the drought period progressed. Reduction in DM production with progress in drought period was more in Alkali sacaton grass than in Seashore paspalum and this reduction was more in DM productions than that in shoot heights in both Alkali sacaton grass and Seashore paspalum. Similar to the shoot fresh weights of the grasses, shoot DM weight of Alkali sacaton grass was more severely affected by drought stress than that of Seashore paspalum DM weight (Table 1).

Table 1 Alkali sacaton grass and Seashore paspalum shoot height, shoot fresh and dry weights, and shoot succulence under prolonged drought stress

Weekly harvest	Grass ID	Shoot height	Shoot FW	Shoot DW	shoot succulence
			cm	-------------(g)--------------	
1	Paspalum	5.62b	6.72a	2.55a	2.64a
	Sacaton	7.59a	3.38b	1.68b	2.01b
2	Paspalum	4.86b	5.86a	1.98a	2.96a
	Sacaton	6.91a	3.02b	1.25b	2.42b
3	Paspalum	3.57b	4.48a	1.22a	3.67a
	Sacaton	5.38a	2.23b	0.75b	2.97b
4	Paspalum	2.48b	2.92a	0.98a	2.98a
	Sacaton	3.97a	1.78b	0.63b	2.83a
5	Paspalum	1.54b	1.81a	0.74a	2.45a
	Sacaton	2.87a	1.07b	0.55b	1.95b

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Table Continued..

Weekly harvest	Grass ID	Shoot height	Shoot FW	Shoot DW	shoot succulence
			cm	-------------(g)-------------	
6	Paspalum	1.08b	1.15a	0.52a	2.21a
	Sacaton	2.13a	0.76b	0.37b	2.05a
7	Paspalum	0.57b	0.63a	0.30a	2.10a
	Sacaton	1.38a	0.35b	0.16b	0.16b
8	Paspalum	0.23b	0.41a	0.19a	2.16a
	Sacaton	0.64a	0.17b	0.08b	2.13a

Table 2 Alkali sacaton grass and Seashore paspalum general qualities under prolonged drought stress

Weekly evaluation	Grass ID	Quality scores
1	Paspalum	8a
	Sacaton	7.5ab
2	Paspalum	7.5ab
	Sacaton	6.5cd
3	Paspalum	7bc
	Sacaton	5.5ef
4	Paspalum	6.5cd
	Sacaton	5fg
5	Paspalum	6de
	Sacaton	4.5gh
6	Paspalum	5.5ef
	Sacaton	4hi
7	Paspalum	4.5gh
	Sacaton	3j
8	Paspalum	3.5ij
	Sacaton	2k

Shoot succulence

Shoot succulence for each cultivar was calculated by dividing the shoot fresh weights by the shoot dry weights after each weekly harvest. Shoot succulence of Seashore paspalum was significantly higher than that of Alkali sacaton grass at the first 4 weeks of the drought period. However, at the later periods of the drought stress, there was no difference among the shoot succulence of the two grasses (Table 1).

Grass general quality

Before each harvest, the grasses' general qualities were evaluated using the NTEP (National Turfgrass Evaluation Program) procedures using scales of 1-10, 1= the lowest quality, 10= the highest/best quality, scores of 6 and higher, acceptable qualities). The general qualities of both grasses followed the same pattern as the shoot fresh and DM weights, it decreased by drought stress as the stress period progressed (Table 2). At all weekly harvests (weekly drought periods), the general quality of Seashore paspalum was substantially better than that of Alkali sacaton grass (Figures 3-6). At each weekly harvest, the values for each grass species are the means of 4 replications. At each weekly harvest, the means in each column followed by the same letters are not statistically different at the 0.05 probability level. Although the quality of both grasses decreased as drought stress period progressed, at later harvests (weekly drought periods), the quality was acceptable for Seashore paspalum.

However, the quality of Alkali sacaton grass was significantly lower than that of Seashore paspalum at the later harvests and was unacceptable (quality scores of<6) for Alkali sacaton grass starting at the 3rd week of drought stress (Table 2). The unacceptable quality scores (quality scores of<6) for Seashore paspalum started at the 6th week of drought stress (Table 2). According to NTEP (National Turf Evaluation Program), acceptable quality values are 6 or greater on the scale of 1-10. The means for the grass qualities followed by the same letters are not statistically different at the 0.05 probability level.

Conclusion

For both grasses, shoot height and shoot fresh and dry matter (DM) weights decreased linearly as drought period progressed. At all weekly measurements, shoot height of Alkali sacaton grass was substantially higher than that of Seashore paspalum under drought stress condition. In contrast, compared with the Alkali sacaton grass, at all weekly harvests both shoot fresh and dry weights of Seashore paspalum were significantly higher than that of Alkali sacaton grass. The reductions in shoot fresh and dry weights were more pronounced at later harvests and the effect of drought stress was more severe on both grasses and significantly reduced them. Shoot succulence of the grasses followed the same pattern as the shoot fresh and DM weights. The shoot succulence of Seashore paspalum was substantially higher than that of Alkali sacaton grass at all weekly harvests. At all weekly harvests, the general quality of Seashore paspalum was substantially better than that of Alkali sacaton grass. Although the qualities of both grasses decreased as drought stress period progressed, at later harvests, the quality scores were acceptable for Seashore paspalum. However, quality of Alkali sacaton grass was significantly lower at the later harvests and was unacceptable (quality scores of<6) for Alkali sacaton grass starting at the 3rd week of drought stress. The unacceptable quality scores of Seashore paspalum started at the 6th weekly harvest (weekly drought stress period). Overall, considering the results of this study, the following general conclusions can be drawn. Both Seashore paspalum and Alkali sacaton grass are true halophytic plant species, very high tolerance to drought stress. Growing even under poor soil conditions (desert soils) and limited water resources (drought conditions), characteristics of the arid regions, Seashore paspalum and Alkali sacaton grass are suitable and beneficial plant species for cultivation under arid and semi-arid regions, and show a favorable growth and development with satisfactory soil surface coverage and yield under harsh desert environmental conditions. Consequently, these halophytic plant species can be among the suitable plant species to be used for cultivation under arid, semi-arid, and areas with saline soils and limited water supplies or drought conditions. Therefore, they can be successfully used for restoration of the arid and dry lands and for sustainable agriculture in desert regions and combating desertification processes.

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Conflict of interest

The author declares no conflict of interest.

References

1. Gould FW. *Grasses of the Southwestern United States*. 6th ed. Tucson, AZ, USA: The University of Arizona Press; 1993.
2. Kopec DM, Marcum K, Pessarakli M. *Collection and Evaluation of Diverse Geographical Accessions of Distichlis for Turf–Type Growth Habit, Salinity and Drought Tolerance, Cooperative Extension Agriculture Experiment Station Service*. USA: The University of Arizona; 2000. 11 p.
3. O'Leary JW, Glenn EP. Global distribution and potential for halophytes. In: *Halophytes as a Resource for Livestock and for Rehabilitation of Degraded Lands*. VR Squires, et al. editors. USA: Kluwer Academic Publishers; 1994. p. 7–19.
4. Marcum KB, Pessarakli M, Kopec DM. Relative salinity tolerance of 21 turf–type desert saltgrasses compared to bermudagrass. *Hort Science*. 2005;40(3):827–829.
5. Pessarakli, M. Salt grass, a High salt and drought tolerant species for sustainable agriculture in desert regions. *International Journal of Water Resources and Arid Environments*. 2011;1(1):55–64.
6. Pessarakli, Mohammad. Using Bermudagrass (Cynodon dactylon L.) In Urban desert landscaping and as a forage crop for sustainable agriculture in arid regions and combating desertification. *International Journal of Water Resources and Arid Environments*. 2015;4(1):8–14.
7. Pessarakli Mohammad. Screening Various Cultivars of Seashore Paspalum (Paspalum vagenitum Swartz) for Salt Tolerance for Potential Use as a Cover Plant in Combating Desertification. Proceedings of the 7th International Conference on Water Resources and Arid Environments (ICWRAE 7), Saudi Arabia; 2016. p. 509–516.
8. Pessarakli, Mohammad. Salt grass, a Minimum water and nutrient requirement halophytic plant species for sustainable agriculture in desert regions. *Journal of Earth, Environment and Health Sciences*. 2016;2(1):21–27.
9. Pessarakli M, David D Breshears, James Walworth, et al. Candidate halophytic grasses for addressing land degradation:Shoot responses of Sporobolus airoides and Paspalum vagenitum to weekly increasing NaCl concentration. *Arid Land Research & Management Journal*. 2017;31(2):169–181.
10. Pessarakli M, Marcum KB. Distichlis spicata– a salt and drought tolerant plant species with minimum water requirements for sustainable agriculture in desert regions and biological reclamation of desert saline soils. In: *Developments in Soil Salinity Assessment and Reclamation:Innovative Thinking and Use of Marginal Soil and Water Resources in Irrigated Agriculture*. [(FK Taha, et al. editors.], Springer Science & Business Media Dordrecht 2013. UAE: International Center for Bio–saline Agriculture; 2013. p. 383–396.
11. Pessarakli, Mohammad, Dennis E McMillan. Seashore paspalum, a high salinity stress tolerant halophytic plant species for sustainable agriculture in desert regions and combating desertification. *International Journal of Water Resources and Arid Environments*. 2014;3(1):35–42.
12. Pessarakli M, Touchane H. Biological technique in combating desertification processes using a true halophytic plant. *International Journal of Water Resources and Arid Environments*. 2011;1(5):360–365.
13. Kopec DM, Stephen Nolan PW, Brown, et al. Water and Turfgrass in the Arid Southwest:Water Use Rates of Tifway 419 Bermudagrass, Sea Isle 1, Seashore Paspalum, and Inland Salt grass. United States Golf Association (USGA) Green Section Record. *A Publication of Turfgrass Management*. 2006;(6):12–14.
14. Pessarakli M, Haghighi, Maryam, et al. Plant Responses under Environmental Stress Conditions. *Advances in Plants & Agriculture Research Journal*. 2015;2(6):00073.
15. West cot DW. Reuse and disposal of higher salinity subsurface drainage water: a review. *Agricultural Water Management*. 1988;14:483–511.
16. D'Odorico P, Bhattachan A, Davis KF, et al. Global desertification:drivers and feedbacks. *Advances in Water Resources*. 2013;51:326–344.
17. Miyamoto S, Glenn EP, Olsen MW. Growth, water use and salt uptake of four halophytes irrigated with highly saline water. *Journal of Arid Environment*. 1996;32(2):141–159.
18. Field JP, Breshears DD, Law DJ, et al. Critical zone services: expanding context, constraints, and currency beyond ecosystem services. *Vadose Zone Journal*. 2015;14(1):1–7.
19. Pessarakli M. *Super grass: Drought–tolerant turf might be adaptable for golf course use*. Golf week's Super News Magazine, USA; 2005. p. 1–21.
20. Pessarakli M. *Gardener's delight: Low–maintenance grass*. Tucson Citizen, Arizona, USA: Newspaper Article; 2005.
21. Pessarakli M. *Handbook of Plant and Crop Stress*. 3rd ed. Revised and Expanded, CRC Press, USA: Taylor Francis Publishing Company; 2010. p. 1–1215.
22. Pessarakli M, DM Kopec. Growth response of various salt grass (Distichlis spicata) clones to combined effects of drought and mowing heights. *United States Golf Association (USGA) Turfgrass and Environmental Research Online*. 2008;7(1):1–4.
23. Pessarakli M, Marcum KB, Kopec DM. *Drought Tolerance of Twenty one Salt grass (Distichlis) Accessions Compared to Bermudagrass*. Turfgrass Landscape and Urban IPM Research Summary 2001, Cooperative Extension, Agricultural Experiment Station, The University of Arizona, Tucson, AZ, USA, Publication AZ1246 Series P–126, USA: United States Department of Agriculture (USDA); 2001. p. 65–69.
24. Cushman JC, Bohnert HJ. Genomic approaches to plant stress tolerance. *Current Opinion in Plant Biology*. 2000;3(2):117–124.
25. Grover A, Sahi C, Sanan N. Taming abiotic stresses in plants through genetic engineering:current strategies and perspective. *Plant Science*. 1999;143:101–111.
26. Holmberg N, Bulow L. Improving stress tolerance in plants by gene transfer. *Trends in Plant Science*. 1998;3(2):61–66.
27. Bainbridge D A. *A guide for desert and dryland restoration: new hope for arid lands*. USA: Island Press; 2012.
28. Duncan RR, Carrow RN. Turfgrass molecular genetics improvement for biotic/edaphic stress resistance. *Advances in Agronomy*. 1999;67:233–305.
29. Pessarakli M, Kopec DM. Responses of Various salt grass (Distichlis spicata) clones to drought stress at different mowing heights. *Journal of Food, Agriculture, and Environment (JFAE)*. 2011;9(3–4):665–668.

30. Li J, Okin GS, Alvarez L, et al. Quantitative effects of vegetation cover on wind erosion and soil nutrient loss in a desert grassland of southern New Mexico, USA. *Biogeochemistry*. 2007;85(3):317–332.
31. Ludwig JA, Wilcox BP, Breshears DD, et al. Vegetation patches and runoff–erosion as interacting ecohydrological processes in semiarid landscapes. *Ecology*. 2005;86(2):288–297.
32. White RH, Engelke MC, Morton SJ, et al. Competitive turgor maintenance in tall fescue. *Crop Science Journal*. 1992;32(1):251–256.
33. SAS Institute, SAS/STAT User's guide, Cary, USA; 1991.