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Saltgrass, a High Salt and Drought Tolerant Species for Sustainable Agriculture in Desert Regions

Mohammad Pessarakli

School of Plant Sciences, the University of Arizona Tucson, AZ 85721, USA

Abstract: Continuous desertification of arable lands due to urbanization, global warming and low rainfall mandates use of low quality/saline water for irrigation, especially in regions experiencing water shortage. Using low quality/saline water for irrigation imposes more stress on plants which are already under stress in these regions. Thus, there is an urgent need for finding salt/drought tolerant plant species to survive/sustain under such stressful conditions. Since the native plants are already growing under such conditions and are adapted to these stresses, they are the most suitable candidates to be manipulated under the minimum cultural practices/inputs (i.e., water and fertilizer) for use under these harsh arid conditions. If stress tolerant species/genotypes of these native plants are identified, there would be a substantial savings in inputs in using them under these stressful conditions. My studies on various native grasses indicated that saltgrass (*Distichlis spicata* L.) which has three major usages, including animal feed, soil conservation/reclamation and use for lawns/recreation areas has a great potential to be used under harsh environmental desert conditions and combat desertification, yet perform satisfactory growth. The objectives of the following salinity and drought stress studies were to find the most salinity or drought tolerant of various saltgrass genotypes and to recommend them as the potential species for use under arid, semi-arid and areas with saline soils and limited water supplies or drought conditions for sustainable agriculture and combating desertification. Various saltgrass genotypes were studied in a greenhouse to evaluate their growth responses in terms of shoot and root lengths, DM and quality under salinity or drought stress. Grasses were grown vegetatively either hydroponically in culture solution for salt tolerance or in galvanized cans contained fritted clay for drought tolerance. For the salt stress tolerance, grasses were grown for 60 days prior to exposure to salinity. Then, they were grown for 10 additional weeks under 4 treatments [EC of 6 (control), 20, 34 and 48 dSm•^{1} salinity stress] with 3 replications in a RCB design experiment. During this period, shoots were clipped bi-weekly, clippings were oven dried at 65°C and DM recorded. At the last harvest, roots were also harvested, oven dried at 65°C and DM determined. Grass quality was weekly evaluated. For the drought stress tolerance, the growth responses of the grasses were evaluated under progressive drought condition in a split plot design experiment with 3 replications at two (2.5 and 5 cm) mowing heights. Plants were grown under normal (daily watering and weekly fertilization) for 6 months for complete establishment, then, deprived from water for 4 months. Shoots were harvested bi-weekly and oven dried at 65°C for DM determination. Grass quality was weekly evaluated. Although growth responses reduced at high salinity levels or as drought period progressed, all the grasses showed a high degree of salinity or drought tolerance. However, there was a wide range of variations observed in salinity or drought tolerance among the genotypes. The superior salinity and drought tolerant genotypes were identified which could be recommended for sustainable production under arid regions and combating desertification.

Key words: Saltgrass, sustainable agriculture, combating desertification.

INTRODUCTION

The inland desert saltgrass (*Distichlis spicata* L.) Greene var. stricta (Gray Beetle), indigenous to the Southwest, a potential animal feed plant, saline soil reclamation, soil establishment/erosion control and use as a turfgrass species for lawns/recreation areas, grows 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, 2]. Its dominant and most common habitats are arid and semi-arid regions [3]. The plant is abundantly found in areas of the western

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Corresponding Author: Mohammad Pessarakli, School of Plant Sciences, the University of Arizona Tucson, AZ 85721, USA

parts of the United States as well as on the sea-shores of Saudi Arabia, the United Arab Emirates and several other Middle-Eastern countries, Africa, South and Central American countries [4].

The species can be manipulated to modify its performance and increase its yield and productivity. This plant has multi-purpose usages. It can be substituted for animal feeds like alfalfa, used for biological reclamation of saline soils, soil conservation and erosion control for covering road sides and soil surfaces in lands with high risks of erosion and use as a turfgrass species.

Recently, the United States Golf Association (USGA) and the US Bureau of Land Management (BLM) have shown a great deal of interest in financing research work on this plant to use it as a turfgrass or for soil erosion control and saline soil reclamation. Most of these research works have been conducted at the University of Arizona and Colorado State University. Consequently, the USGA and the BLM funds for the investigations on this grass species have been allocated to these institutions. Positive and promising results have already been obtained from these studies [3, 5-10, 11-25].

Most of the published reports on saltgrass, including those of Sigua and Hudnall [26], Sowa and Towill [27], Enberg and Wu [28], Miyamoto *et al.* [29], Rossi *et al.* [30] and Miller *et al.* [31] are concerned only with the growth of this species, usually concentrated only on one grass genotype or the species of a specific location.

The objectives of the following two studies were to find the most salinity or drought tolerant of various saltgrass genotypes and to recommend them as the potential species for use under arid, semi-arid and areas with saline soils and limited water supplies or drought conditions for sustainable agriculture and combating desertification.

Experiment 1: Salt Stress Tolerance

MATERIALS AND METHODS

Plant Materials: Twelve inland saltgrass (*Distichlis spicata* L.) clones (A37, A49, A50, A60, 72, A86, A107, A126, A136, A138, 239 and 240), collected from different locations in several western states of the United States (Arizona, California, Nevada and Colorado) were used in a greenhouse experiment to evaluate their growth responses in terms of shoot and root lengths as well as shoot and root dry weights and visual grass quality under different levels of salinity stress conditions, using a hydroponics technique.

Plant Establishment: The plants were grown as vegetative propagules in cups, 9 cm diameter and cut to 7 cm height. Silica sand was used as the plant anchor medium. The cups were fitted in plywood lid holes and the lids were placed on 42 cm X 34 cm X 12 cm Carb-X polyethelene tubs containing half strength Hoagland nutrient solution [32]. Three replications of each treatment were used in a randomized complete block (RCB) design in this investigation. The plants were allowed to grow in this nutrient solution for 8 weeks. During this period, the plant shoots were harvested weekly in order to reach full maturity and develop uniform and equal size plants. The harvested plant materials were discarded. The culture solutions were changed biweekly to ensure adequate amount of plant essential nutrient elements for normal growth and development. At the last harvest, 10th week, the roots were also cut to 2.5 cm length to have plants with uniform roots and shoots for the stress phase of the experiment.

Salt Treatments: The salt treatments were initiated by gradually raising the EC (electrical conductivity) of the culture medium to 6, 20, 34 and 48 dS m•^{1} by adding Instant Ocean salt to the nutrient solutions, followed procedures used by Pessarakli and Kopec [24, 15]. The EC of the culture solutions were raised by increments of 6 (first day) and 7 every other day until the desired EC levels were reached. Four treatments were used, including control (EC = 6 dS m•^{1}, several of my salinity stress experiments showed that saltgrass at relatively low level of salinity for this high salinity tolerant halophytic grass performs better than growing in normal condition, therefore, for the control, usually, I use EC = 6 dS m•^{1}), 20, 34 and 48 dS dS m•^{1} (EC = 48 dS dS m•^{1} is a good representative of the EC of sea water which is normally between 30 and 60 dS m•^{1}). The culture solution levels in the tubs were marked at the 10 liter volume and the solution conductivities were monitored/adjusted to maintain the prescribed treatment salinity levels. After the final salinity levels were reached, the shoots and the roots were harvested and the harvested plant materials were discarded prior to the beginning of the data collection of the salinity stress phase of the experiment.

Then, plant shoots were harvested bi-weekly for 10 weeks for the evaluation of the dry matter (DM) production. At each harvest, both shoot and root lengths were measured and recorded. The harvested plant materials were oven dried at 65°C and DM weights were measured and recorded. The recorded data were considered the bi-weekly plant DM production. At the termination of the experiment, the last harvest, plant roots were also harvested, oven dried at 65°C and dry weights were determined and recorded. Weekly visual evaluation of the grass quality was also performed and recorded.

The data were subjected to Analysis of Variance, using SAS statistical package [33]. The means were compared using Duncan Multiple Range test [34].

RESULTS AND DISCUSSION

Shoot Dry Matter (DM) Weight: The shoot dry matter (DM) weights of all the saltgrass clones decreased with increased salinity stress level. A marked reduction in shoot dry weights occurred at the higher salinity levels (EC 34 and 48 dS m•^{1}) across all the clones (Table 1). For the dry weights of the shoots, the gap between the means of the stressed plants and the control (EC = 6 dS m•^{1}) was wider as the exposure time to salinity stress progressed.

Root Dry Matter (DM) Weight: The effect of salinity on root dry weight was less severe compared to that of shoot dry mass (Table 2). Sagi *et al.* [35] and Pessarakli and Tucker [36, 37] also found that the adverse effect of salinity stress was more pronounced on plant shoots than the roots. This is a common phenomenon in halophytic plant species that usually under salinity stress conditions, their shoots are more severely affected than their roots.

Clone 240 had excellent root growth at EC 6 dS m•^{1} and the second highest root production at EC 48 dS m•^{1} (Table 2), but had poor quality under high salinity level. The same was true for clone 239. Clone A138 had twice the root mass of most other clones at EC 48 dS m•^{1}, but essentially had no green foliage at EC 48 dS m•^{1} at the close of the test.

At EC 6 dS m•^{1}, clone A128 produced twice the test mean average for roots (3.46 g) with fairly good absolute root production afterwards, but showing a significant change in root production as EC levels increased (Table 2).

Although the root dry weight was enhanced at the lower level of salinity for most of the clones, there was not statistically significant difference detected between the means of the different treatments (Table 2).

Grass Visual Quality: Any level of salinity stress had a significant adverse effect on the grass visual quality (Table 3 and Fig. 1). Quality scores for various clones ranged from 9.7 to 2.6 at different salinity stress levels. At EC 20 dS m•^{1}, quality scores ranged from 5.1 to 9.7 (Table 3) throughout the entire test. As shown in Table 3, all clonal entries had good quality and full maintenance of green tissue retention at EC 6 dS m•^{1} at the end of the trial.

The grass (clone) x EC interaction effect was significant for the visual quality, showing that some clones quality decreased at different rates for overall quality as salinity stress level increased (Table 3, Fig. 1).

Table 1: Saltgrass shoot dry weight (DM) under salt stress

	Shoot	DM (g)*	at EC	dS m•^{1}
Grass ID	6	20	34	48
A37	1.10cde**	0.57bcde	0.27cde	0.15c
A49	1.26bcd	0.77ab	0.32bcde	0.13c
A50	1.65ab	0.60bcd	0.21de	0.17bc
A60	1.03cde	0.38e	0.17e	0.13c
72	1.38bc	0.82a	0.38abc	0.19bc
A86	1.66ab	0.86a	0.26cde	0.14c
A107	0.95de	0.52cde	0.30bcde	0.20bc
A126	0.83e	0.41de	0.18e	0.15c
A128	1.37bc	0.73abc	0.52a	0.30a
A138	1.09cde	0.46de	0.36abcd	0.25ab
239	1.67ab	0.88a	0.44ab	0.15c
240	1.94a	0.91a	0.49a	0.24ab

*The values are the means of 3 replications of each treatment

**The values followed by the same letters in each column are not statistically significant at the 0.05 probability level

Table 2: Saltgrass root dry weight (DM) (cum. values) under salt stress

	Root	DM (g)*	at EC	dS m•^{1}
Grass ID	6	20	34	48
A37	0.74cde**	0.99def	1.10cdef	0.78cd
A49	1.61b	1.11cdef	1.56bcd	1.03bcd
A50	1.83b	1.65a	1.94abc	0.74cd
A60	1.46bc	1.71a	1.31bcde	0.84bcd
72	0.77cde	0.93def	0.72def	0.50d
A86	1.06bcde	1.18bcde	0.76def	0.81bcd
A107	0.68de	0.84ef	0.53ef	0.68cd
A126	0.50e	0.68f	0.26f	0.48d
A128	3.46a	1.50abc	2.05ab	1.18bc
A138	1.17bcde	0.88def	0.43ef	2.28a
239	1.31bcd	1.30abcd	2.82a	1.21bc
240	3.36a	1.63ab	1.25bcde	1.42b

*The values are the means of 3 replications of each treatment

**The values followed by the same letters in each column are not statistically significant at the 0.05 probability level

Fig. 1: Saltgrass visual quality under control (EC = 6 dS m•^{1}) and various levels (20, 34 and 48 dS m•^{1}) of salinity stress. Tubs in each row from left to right, EC = 6, 20, 34 and 48 dS m•^{1}, respectively.

Table 3: Saltgrass visual quality under salinity stress

	General	Quality[*]	at	EC
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Grass ID	6	20	34	48
A37	8.0cde[**]	5.1f	3.3g	2.6e
A49	7.7def	6.4d	4.3ef	2.8e
A50	8.6abc	7.2bc	5.0cd	4.0bc
A60	8.2bcd	5.5ef	3.9fg	3.5cd
72	9.0a	7.4bc	5.9b	4.8a
A86	8.5abc	6.7cd	5.7b	3.9bc
A107	7.5def	5.9def	5.4bc	4.4ab
A126	6.7g	5.3f	4.6de	3.9bc
A128	7.1fg	6.2de	5.0cd	3.0de
A138	8.6abc	7.9b	5.4bc	4.2ab
239	8.9ab	9.3a	6.6a	4.2ab
240	9.2a	9.7a	7.1a	2.8e

[*] The quality values are the means of 3 replications of each treatment and 10 weekly evaluations

[**] The values followed by the same letters in each column are not statistically significant at the 0.05 probability level

Table 4: Salt tolerance ranking of Saltgrass based on shoot weight, root weight, or grass visual quality

	Salt	Tolerance	Based	On
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Tolerance	Shoot wt.	Root wt.	Quality	Overall
High	240a[*]	A128a	240a	240a
	A128ab	240ab	239a	239a
	239ab	239ab	72ab	A128ab
	72ab	A50ab	A138ab	72ab
	A86ab	A60abc	A50abc	A138ab
	A138abc	A138abc	A86bc	A50b
	A50bc	A49bc	A60bcd	A86b
	A49bc	A86bc	A49cde	A49bc
	A107cd	A37cd	A128de	A60cd
	A37cd	72cd	A107de	A107cd
	A126d	A107cd	A37de	A37cd
Low	A60d	A126d	A126e	A126d

[*] The clones followed by the same letters in each column are not statistically significant at the 0.05 probability level

After 10 weeks growth at EC 34 dS m•^{1} (salinity level equal to that of sea level salinity), entries 239 and 240 were the only clones to have quality ratings of 6 (acceptable quality, on the scale of 1 - 10) or greater (Table 3). These two clones represented the best quality clones at EC 34 dS m•^{1} at the end of the test.

At EC 48 dS m•^{1}, no entries produced an acceptable plant quality (scores of 6 or higher). Most clones decreased in (final) quality as EC increased from EC 6 to 48 dS m•^{1}, but the entries 239 and 240 showed a more of typical halophytic response, having an increase in quality at EC 20 dS m•^{1} over that observed at EC 6 dS m•^{1} (Table 3).

Salt Tolerance Ranking of the Various Clones of Saltgrass: Salinity tolerance ranking of the various saltgrass clones used in this study based on shoot DM weight, root DM weight, grass visual quality, or overall ranking considering all the study parameters together, are presented in Table 4.

Although there are some minor differences in salt tolerance ranking of the clones when compared based on shoot DM weight, root DM weight, or grass visual quality, the overall ranking is the best representation of the salinity tolerance of the various tested clones.

Considering all the study parameters together, there was a wide range of salinity tolerance found among the 12 saltgrass clones. The 240 and 239 clones were the most salt tolerant clones (especially, up to EC of 34 dS m•^{1}) followed by A128, 72, A138. These were closely followed by A50, A86 and A49 in salinity tolerance. A49 clone laid between this and the last group in regards to salinity tolerance. A60, A107, A37 and A126 were among the lowest salinity tolerant grasses which the A126 was the least tolerant clone.

CONCLUSIONS

The results of the shoot and the root dry mass and the visual grass quality showed that the maintenance of green foliage and tolerance under saline hydroponic conditions are under physiological conditions/ adjustments that are not totally related to dry matter (DM) production in shoots and roots. This was corroborated by the results that clones which maintained the highest quality under EC 34 dS m•^{1} exhibited either a large increase in root mass (i.e., clone 239), or only a small increase of the root mass (i.e., clone 240) produced at EC 6 dS m•^{1}. Likewise, clone A138 produced a large increase of its EC 6 dS m•^{1} root mass at the highest EC level of 48 dS m•^{1}. However, it could not maintain green foliage at 10 weeks of exposure to this high EC. The same was true for shoot DM production that occurred in a more narrow range of values than did root DM production.

In terms of salinity tolerance (quality), green foliage retention was empirically the best assessment of the clonal response to increased salinity. For large scale screening of saltgrass germplasm, the maintenance of green tissue at a specific EC level would seem to be adequate as a simple selection method for salinity tolerance.

Shoot and root lengths and dry weights decreased with increased salinity stress. However, shoots were more severely affected by salinity stress than the roots. Grass visual quality was significantly affected (lower quality) as the salinity levels of the culture solutions increased.

In short, saltgrass shoot DM weight decreased linearly with increased salinity levels for all clones. For most clones, there was no difference among the root DM of the grass at different salinity levels. Visual quality of the grass followed the same pattern as the shoot DM weight. It decreased linearly with increased salinity levels for all clones. Clones differed greatly in their maintenance of green color retention (quality) as EC levels (salinity) increased. Two clones which produced acceptable quality at the EC level of 34 dS m•^{1} were clones 239 and 240. No clones could maintain adequate quality color at EC level of 48 dS m•^{1} after 10 weeks of exposure at this EC level. The difference in salinity tolerance level among the clones was significant.

The grasses were separated in several groups with different degrees of salt tolerance. Considering all the study parameters together, there was a wide range of salinity tolerance found among the 12 saltgrass clones. The 240 and 239 clones were the most salt tolerant clones (especially, up to EC of 34 dS m•^{1}) followed by A128, 72 and A138. These were closely followed by A50, A86 and A49 in salinity tolerance. A49 clone laid between this and the last group in regards to salinity tolerance. A60, A107, A37 and A126 were among the lowest salinity tolerant grasses which the A126 was the least tolerant clone.

Overall, the results of this investigation indicate that saltgrass is a very high salinity tolerant species and the results further suggest that this grass growing even under poor soil conditions (salt-affected desert soils) can be a suitable and beneficial plant species for growth and production in arid regions and still show a favorable growth.

Experiment 2: Drought Stress Tolerance

MATERIALS AND METHODS

Plant Materials: Various clones [A37, A49, A50, A60, 72, A86, A107, A126, A128, A138, 239 and 240] of inland saltgrass collected from several southwestern states of the USA that were used in Experiment 1 (Salt Stress Tolerance) were used in this study too.

Plant Establishment: The grasses were grown as vegetative propagules in cups, 9 cm diameter and cut to 7 cm height. Cups were placed in stainless steel galvanized cans (45.7 cm diameter, 55.9 cm height), filled with 150 kg fritted clay as plant anchor medium (Fig. 2).

Fig. 2: Galvanized can (1 replication of the plants) containing fritted clay and the cups planted with saltgrass at the beginning of the plant establishment stage

Fig. 3: Galvanized cans (3 replications of the plants for each of the 2 mowing heights for later stage of the drought phase of the study) containing fritted clay and the cups planted with saltgrass at the beginning of the establishment stage.

Two mowing heights (2.5 and 5 cm) and 3 replications of each mowing height were used in a split plot design (Fig. 3), where drought stress was tested as whole plots, with mowing height and grass selection combinations appearing as sub-plots, in this investigation.

The grasses were grown under normal condition [daily irrigation, weekly fertilization and weekly clipping (clippings discarded)] for 6 months to produce equal size and uniform plants before the initiation of the drought stress phase of the experiment.

Fig. 4: Plants are either dead or in dormancy stage at the termination of the drought experiment

Drought Stress: A dry-down fritted clay system which mimics progressive drought [38] was used in this investigation. This procedure has been used successfully in our previous drought stress studies [20, 21]. The system imposes a gradually prolonged drought stress to plants (i.e., various saltgrass clones) planted in separate cups (experimental units).

The drought stress started by completely saturating the cans containing 150 kg fritted clay and the cups containing the grasses, then depriving the grasses from water and fertilizer for a period of 4 months. During the stress period, while there was measurable growth (14 weeks, 7 bi-weekly harvests), shoots were clipped bi-weekly for the evaluation of growth and dry matter (DM) production. The harvested plant materials were oven dried at 65°C and DM weights were measured and recorded. The recorded data were considered the bi-weekly plant DM production. The grass visual quality was weekly evaluated and recorded.

Two months 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 4-month drought stress period, the majority of the plants were either dead or gone to dormancy stage (Fig. 4). Then, all the grasses were re-watered for the recovery rate determination.

Statistical Analysis: Data were subjected to the analysis of variance technique [33]. The means were compared using Duncan Multiple Range test [34].

RESULTS AND DISCUSSION

Shoot Length: For most of the clones, shoot length was decreased more by drought stress at the 2.5 than at the 5 cm mowing height (Table 5).

There was a wide range of differences found in shoot lengths among the clones at either 2.5 or 5 cm mowing height. The shoot length of A128 clone was the highest at either mowing height. The shoot lengths of clones 239 and 240 which are turf type grasses were the lowest at either 2.5 or 5 cm mowing height. There was not a significant difference detected between the shoot lengths of either one of these clones at the 2.5 compared with the 5 cm mowing heights (Table 5).

Shoot Dry Matter (DM) Weight: The shoot DM weight generally followed the same pattern as the shoot length, it decreased under drought stress at either 2.5 or 5 cm mowing height. However, in contrast to the shoot length, for most of the clones, shoot DM weight was higher at the 2.5 compared with the 5 cm mowing height (Table 5).

At both 2.5 and 5 cm mowing heights, clones 72 and 239 produced numerically the highest DM weights. However, there was not statistically a significant difference between the shoot DM weights of these two clones and A49, A50, A128, A138 and 240 at either mowing height (Table 5). Among all the clones, clone A60 produced the lowest DM weight at either 2.5 or 5 cm mowing height.

Table 5: Saltgrass shoot length and DM weight (average of 3 replications and 7 bi-weekly harvests) under drought stress condition at 2 mowing heights

	Shoot length* at		Shoot DM (g)* at	
Grass ID	5cm cut	2.5cm cut	5cm cut	2.5cm cut
A37	3.8ab**	2.6ab	0.15bc	0.12bc
A49	3.1bc	2.5abc	0.20ab	0.23a
A50	2.0de	2.1bcd	0.18ab	0.24a
A60	2.0de	2.1bcd	0.05d	0.07c
72	2.6cd	2.8a	0.23a	0.26a
A86	2.7cd	1.8de	0.12c	0.15b
A107	2.3cde	2.0cd	0.10cd	0.12bc
A126	2.7cd	1.7de	0.12c	0.13b
A128	4.4a	2.9a	0.18ab	0.23a
A138	1.9de	1.9d	0.19ab	0.26a
239	1.7de	1.7de	0.23a	0.26a
240	1.4e	1.3e	0.20ab	0.23a

*The values are the means of 3 replications of each treatment at 7 bi-weekly harvests

**The values followed by the same letters in each column are not statistically different at the 0.05 probability level

Table 6: Saltgrass quality [average of 3 replications and 14 weekly (7 bi-weekly) evaluations] under drought stress at 2 mowing heights

	Visual quality* at 2 mowing hts	
Grass ID	5cm	2.5cm
A37	6.5bcd**	6.5bcd
A49	5.9cd	7.6a
A50	5.8d	5.4ef
A60	5.9cd	4.8f
72	7.5a	7.9a
A86	6.5bcd	5.9de
A107	6.4bcd	6.5bcd
A126	5.8d	6.2cde
A128	5.9cd	6.2cde
A138	7.1ab	7.0abc
239	7.1ab	7.2ab
240	6.6bc	7.2ab

*The quality values are the means of 3 replications of each treatment at 14 weekly (7 bi-weekly) evaluations

**The values followed by the same letters in each column are not statistically different at the 0.05 probability level

Grass Visual Quality: The grass visual quality followed the same pattern as the shoot DM weight, it decreased by drought stress at either 2.5 or 5 cm mowing height (Table 6). For most of the clones, grass visual quality was affected more by drought stress at the 5 than at the 2.5 cm mowing height. There was a wide range of differences found in grass visual quality among the clones at either 2.5 or 5 cm mowing height. Clone 72 had the best visual quality scores at either mowing height. At the 5 cm mowing height, statistically there was no difference between this clone and clones A138 and 239. At the 2.5 cm mowing height, clones A49, A138, 239 and 240 were statistically the same as clone 72. Under drought stress, clones A49, A50, A60, A126 and A128 scored the lowest at the 5 cm mowing height (Table 6). At the 2.5 cm mowing height, clone A60 scored the lowest under drought stress. The scores of clone A50 was slightly higher (statistically not significant) than that of clone A60 at the 2.5 cm mowing height under drought stress (Table 6).

CONCLUSIONS

At either mowing height, saltgrass shoot length and shoot dry matter (DM) weight decreased linearly as drought period progressed. However, there were significant differences among the shoot lengths and DM weights of different clones at any mowing height and at each harvest. There was no difference among the shoot lengths or shoot DM weights of most clones between the two mowing heights. Visual quality of most clones followed the same pattern as the shoot DM weight. It decreased linearly as drought period progressed. However, visual qualities of various clones were significantly different than each other at either mowing height and at any weekly evaluation. Most of the clones at the 2.5 cm mowing height maintained their green color for longer period compared with those mowed at 5 cm. Considering all the study parameters together, there was a wide range of drought and mowing tolerance found among the various clones. Among all the studied clones, clone 72 was superior and the most tolerant to combined effects of drought and mowing stress, while clone A60 was the least tolerant one.

Overall, considering the results of both of these experiments, the following general conclusions can be drawn. Saltgrass is a true halophytic plant, very high tolerant to both salinity and drought stresses. Growing even under poor soil conditions (salt-affected desert soils) and drought (characteristics of the arid regions), saltgrass is a suitable and beneficial plant species for cultivation under arid and semi-arid regions and shows a favorable growth and development with satisfactory soil surface coverage and yield under harsh desert environmental conditions. Consequently, saltgrass can be one of the most suitable plant species to be used for cultivation under arid, semi-arid regions and areas with saline soils and limited water supplies or drought conditions. Therefore, this species can be successfully used for restoration of the arid lands and for sustainable agriculture in arid regions and combating desertification.

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