

Productivity and nutritional value of four forage grass cultivars compared to Rhodes grass irrigated with saline water

Ihsan Abu-Alrub^{1*}, Kenneth B. Marcum², Neamat Kabir¹, Ahmed Aran¹, Mohammed Al Hammadi¹

¹R&D Division, Abu Dhabi Food Control Authority, P.O. Box 52150, Abu Dhabi, United Arab Emirates

²Department of Arid Land Agriculture, United Arab Emirates University, P.O. Box 15551, Al Ain, Abu Dhabi, United Arab Emirates

*Corresponding author: ihsan.joma@adfca.ae

Abstract

Shortage of fresh water resources and deterioration of groundwater quantity and quality is an increasing problem globally. Effects include limitations on the number of crops that can be successfully grown. The United Arab Emirates (UAE) has one of the world's harshest environments, with scarce surface and groundwater. The present study assessed the performance of five forage cultivars under different salinity stresses to determine their salt tolerance. Two Buffel grass (*Cenchrus ciliaris*) cultivars Laredo and Pecos, two Guinea grass (*Panicum maximum*) cultivars Guinea and Green Panic, and one Rhodes grass (*Chloris gayana*) cultivar Katambora were evaluated over two successive years for their potential yield and nutritional values under four salinity levels of irrigation water viz. control (200 ppm), 6000, 12000, 18000 ppm. The highest dry yield production was observed in *Cenchrus ciliaris* cv. Pecos and Laredo, *P. maximum* cv. Green Panic, and *Chloris gayana* cv. Katambora under moderate salinity (6000 ppm). All forage grasses showed significant yield reductions at 12000 ppm ranging between 14 to 23%, compared to control. Salinity slightly improved forage quality parameters by significantly increasing crude protein (CP) and decreasing acid-detergent fibre (ADF). These results identified salt tolerant forage species that could enhance saline agriculture scheme in the UAE. *Cenchrus ciliaris* cv. Laredo and Pecos exhibited good productive potential under salinity and can be grown to enhance farm productivity in arid environment and conserve freshwater for other usages.

Keywords: Dry yield; *Cenchrus ciliaris*; *Chloris gayana*; *Panicum maximum*; salt tolerance; UAE.

Introduction

Salinity is a major constraint limiting agricultural productivity worldwide, and occurs in more than 100 countries of the world (Rengasamy, 2006). Groundwater salinization has become a global issue mainly in water-scarce areas, particularly in arid and semi-arid regions, where groundwater is the primary source of water.

The United Arab Emirates (UAE) is located within the arid region, where summer temperature can reach above 48 °C, and the annual average rainfall is less than 100 mm. Agriculture in the UAE totally depends on irrigation and consumes the majority of high quality water. For instance, it is estimated that 60% of all agricultural water is used to produce Rhodes grass (*Chloris gayana*) alone to meet the growing demand on forage grass for livestock sector (EAD, 2009). Over use of groundwater for agriculture has resulted in a sharp decline in groundwater levels leading to seawater intrusion (Peacock et al., 2003; Murad et al., 2007) and only 3% of groundwater resources remain fresh (EAD, 2006). Consequently, many farms become unproductive and were abandoned due to increase of salinity in irrigation water (Rao et al., 2017). UAE has large brackish groundwater resources and the present level of salinity in the water rises up to 15000 ppm, creating an obstacle to grow forage crops sensitive to salinity. Under such conditions, identifying salt-tolerant fodders may help to address forage

shortages arising from the scarcity of quality water and natural salinization of vast areas.

Cultivars of Buffel grass (*Cenchrus ciliaris*) and Guinea grass (*Panicum maximum*) are being used for fodder production in other regions. They were originally introduced into the UAE to replace the main fodder crops, Rhodes grass (*Chloris gayana*) and Alfalfa (*Medicago sativa*).

Cenchrus ciliaris is suitable for forage production due to its high yields and nutritional level, drought tolerance, easy to establish and high palatability (Ruiz and Taleisnik, 2013; Al-Dakheel et al., 2015a). Additionally, *Panicum* spp. are considered as a high-quality fodder grasses (Khan et al., 2009) and identified to be the most promising species under saline conditions in sandy loam soil (Tomar et al., 2003).

Chloris gayana is a salt tolerant crop (Oi et al., 2012), while *Cenchrus ciliaris* and *Panicum maximum* are moderately tolerant (Al-Dakheel et al., 2015b). Salinity stress can impact many aspects of a plant's physiology (Negrão et al., 2017) such as delay in germination, high seedling mortality, poor crop stand, stunted growth and reduce yield (Ahmad et al., 2010). The decline in plant growth subject to gradual increase in salinity is mainly related to increase in osmotic tension of soil solution which reduces absorption of water by roots and/or due to accumulation of various ions in toxic levels (Munns, 2002;

Tester and Davenport, 2003). While there are many reports confirming the observed field or greenhouse tolerance of *Cenchrus* and *Panicum* (Arshad et al., 2007; Alfaidi et al. 2017, Fraser et al., 2017), there are limited studies on their performance in harsh saline environments. This study compared a range of species in the field under controlled levels of soil salinities. This information will help making decisions about crop selection in adverse climatic conditions. Farmers will be able to alter their production systems and reduce reliance on stock feed importation.

Results

Total dry yield

Results in Figure 1 indicate significant differences in dry yield among the five grasses at each salinity level. There was a significant decrease ($p < 0.05$) in dry weight for all grasses as the salinity level of the irrigation water increased.

Dry yield was slightly increased in *C. ciliaris* cv. Pecos, *P. maximum* cv. Guinea, and *Chloris gayana* cv. Katambora under moderate salinity (6000 ppm), compared to salinity control (200 ppm). All grasses showed significant yield reductions at 12000 ppm and these reductions ranged between 14 to 23%, compared to salinity control (200 ppm). Highest yield at 12000 ppm was observed in *Chloris gayana* cv. Katambora, followed by *C. ciliaris* cvs. Laredo and Pecos and *P. maximum* cv. Guinea. However, dry matter yields were similar in these four grasses at 18000 ppm. Yield reduction at 18000 ppm was 49, 42, 37, 100, and 40% from G1 through G5 stages, respectively, compared to salinity control. The *P. maximum* cv. Green Panic had the lowest tolerance to salinity stress. It produced the lowest dry yields among all grasses at both 12000 and 18000 ppm, and was unable to survive at 18000 ppm.

Plant height

Plant height trends followed dry matter yields under increasing salinities, generally resulting in decreasing plant heights (Fig. 2). Maximum significant plant heights overall were observed in *P. maximum* cv. Guinea, followed by *P. maximum* cv. Green Panic. *C. ciliaris* cvs. Laredo and Pecos were the shortest plants overall.

Plant nutritive composition

Salinity had a significant effect on the forage quality. As the salinity level was increased, acid-detergent fiber (ADF) significantly dropped, while crude protein (CP) increased, indicating improved digestibility and quality of crop with increasing salinities across all grasses (Table 1). Across all salinities, *Chloris gayana* cv. Katambora and *P. maximum* cv. Green Panic had the lowest ADF, followed by *P. maximum* cv. Guinea, with the two *C. ciliaris* cultivars having the highest ADF. *Panicum maximum* cv. Guinea had the highest CP, with the other four grasses having similar, lower CP. There was no significant interaction between salinity level and forage grasses on average ADF and CP.

Increasing concentrations of Na⁺ in shoot tissue as a function of increasing irrigation salinity were observed (Fig. 3). Among the *Cenchrus* and *Panicum* cultivars, *P. maximum* cv. Green Panic accumulated the highest Na⁺ levels, indicating it as most salt sensitive cultivar. However, comparison of all 5 grasses showed the highest shoot Na⁺ levels in *Chloris gayana* across all

salinity levels. This was unexpected, as it was one of the most salt tolerant grasses in the study. It might be related to existence of salt glands in this species that extrude excess salt.

Of all the salinity ions, K⁺ had the highest accumulation in the shoots under saline condition. No significant differences were found in the concentration of K⁺ in the shoot tissues above 6000 ppm with higher salinity treatments. Both *Cenchrus* cultivars tended to have the highest shoot K⁺ level, while *Chloris gayana* tended to have the lowest shoot K⁺ across all salinities.

Shoot Ca²⁺ levels were declined with increasing salinity in all grasses, while shoot Mg²⁺ was increased with salinity levels in *P. maximum* cv. Green Panic and *Chloris gayana* only. *P. maximum* cv. Green Panic accumulated the highest Mg²⁺ level among all grasses.

Soil salinity

At the end of experiment, soil samples were collected from three soil layers to measure electrical conductivity (ECe) of soil paste extracts. The upper soil layers (0-20 cm) showed a higher ECe values as compared with the lower layers for all irrigation salinity treatments (Table 2). Increasing irrigation water salinity levels resulted in gradual increase in soil ECe values for each soil layers. The maximum soil salt built-up occurred under the highest irrigation water salinity treatment.

Discussion

In our study, dry yield reduction was observed with increasing salinity. This result agrees with Ruiz and Taleisnik (2013), in which they indicated that growth and yield reductions of *Cenchrus ciliaris* began to occur at 7000 ppm and continue to decrease gradually with increasing salinity. Moreover, Tomar (2002) found a decrease of 27% in forage yield of *P. maximum* grown in sandy loam soil associated with high salinity of irrigation water.

Slight growth stimulation was observed under moderate salinity (6000 ppm) for *C. ciliaris* cv. Pecos, *P. maximum* cv. Guinea and *Chloris gayana* cv. Katambora. This result concurs with a previous study by Koryo (2013), who observed same trend in *Panicum turgidum* grown at saline condition of 100 mM NaCl. Similarly, Al-Khateeb (2006) found a significant growth promotion of *Panicum turgidum* at moderate salinity levels. This growth stimulation is thought to be due to osmotic adjustment, which resulted in cell elongation in some salt tolerant grass (Flowers and Colmer, 2008).

Feeding value of forages is mainly depends on crude protein (CP) and total digestible nutrients. Irrigation salinity slightly improved forage quality by increasing CP and decreasing ADF. The present results agree with Al-Dakheel et al. (2015b), who reported that increasing the CP content of *C. ciliaris* was associated with increasing salinity levels. Moreover, our results showed that ADF was decreased with increasing salinity for all grasses, indicating that the digestibility of the forages improved with increasing salinity (Suyama et al., 2007).

Toxicity of Na⁺ was clearly noticeable on *P. maximum* cv. Green Panic, which produced the lower dry yield at high salinity irrigation treatments. The growth inhibition due to Na⁺ toxicity is the commonly observed effect of soil salinity, which is consistent with several previous studies (Saqib et al., 2008; Munns and Tester, 2008). Consequently, genotypes having low Na⁺ content in tissues such as *Ciliaris* cv. Pecos and *P. maximum* cv. Guinea, resulted in higher biomass and better salt tolerance

Table 1. Effects of salinity level and forage grasses with their interactions on average crude protein (CP) and acid-detergent fiber (ADF).

| Treatment | ADF (%) | CP (%) |
|-------------------------------------|---------|--------|
| Salinity Level (ppm) | | |
| Control | 37.6 a | 9.7 c |
| 6000 | 34.6 b | 10.3 c |
| 12000 | 32.1 c | 11.5 b |
| 18000 | 29.5 d | 12.4 a |
| LSD (P<0.05) | 0.59 | 0.66 |
| Forage Grasses | | |
| <i>C. ciliaris</i> cv. Laredo | 34.7 a | 10.5 b |
| <i>C. ciliaris</i> cv. Pecos | 34.5 a | 10.7 b |
| <i>P. maximum</i> cv. Guinea | 31.4 c | 12.2 a |
| <i>P. maximum</i> cv. Green Panic | 33.4 b | 10.9 b |
| <i>Chloris gayana</i> cv. Katambora | 33.2 b | 10.6 b |
| LSD (P<0.05) | 0.69 | 0.49 |
| G X S | ns | ns |

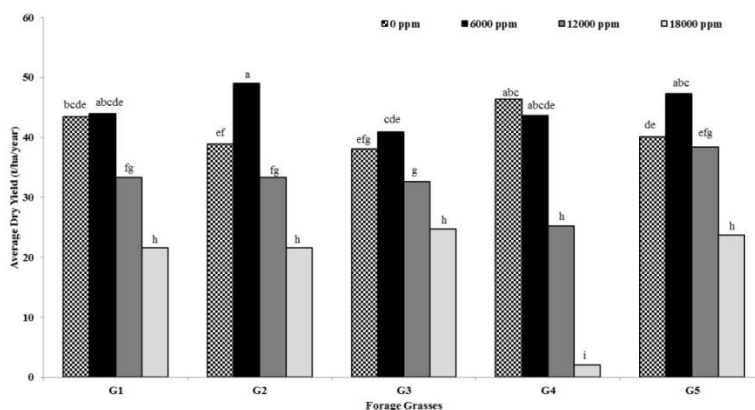


Fig 1. Average dry yield ($t\ ha^{-1}\ year^{-1}$) of 5 forage grasses at four salinity levels. G1-*C. ciliaris* cv. Laredo, G2-*C. ciliaris* cv. Pecos, G3-*P. maximum* cv. Guinea, G4-*P. maximum* cv. Green Panic, G5-*Chloris gayana* cv. Katambora. LSD at 5% G=3.2, S=4.1, GXS = **.

Table 2. Soil salinity (ECe) (ppm) for each treatment at the end of experiment.

| Salinity treatment (ppm) | Soil depth (cm) | | |
|--------------------------|-----------------|-------|-------|
| | 0-20 | 20-40 | 40-60 |
| Control | 1888 | 2105 | 1888 |
| 6000 | 5320 | 4641 | 4200 |
| 12000 | 7966 | 6692 | 6132 |
| 18000 | 17200 | 10115 | 6986 |

Table 3. Physico-chemical properties of the experimental soil before planting.

| Soil Properties | Soil depth (cm) | | |
|-----------------------|-----------------|-------|-------|
| | 0-20 | 20-40 | 40-60 |
| Clay (%) | 0.01 | 0.05 | 0.01 |
| Silt (%) | 0.6 | 0.5 | 1.7 |
| Sand (%) | 99.1 | 99.4 | 97.5 |
| pH | 8.0 | 8.1 | 8.2 |
| ECe (ppm) | 2624 | 2060 | 1640 |
| CaCO ₃ (%) | 27.8 | 27.8 | 23.5 |
| CEC (meq/100g) | 3.7 | 3.5 | 7.3 |
| Organic matter (%) | 1.9 | 1.6 | 2.2 |
| Total N (ppm) | 534 | 374 | 917 |
| Available P (ppm) | 70 | 64 | 21 |
| Extractable K (ppm) | 352 | 262 | 134 |

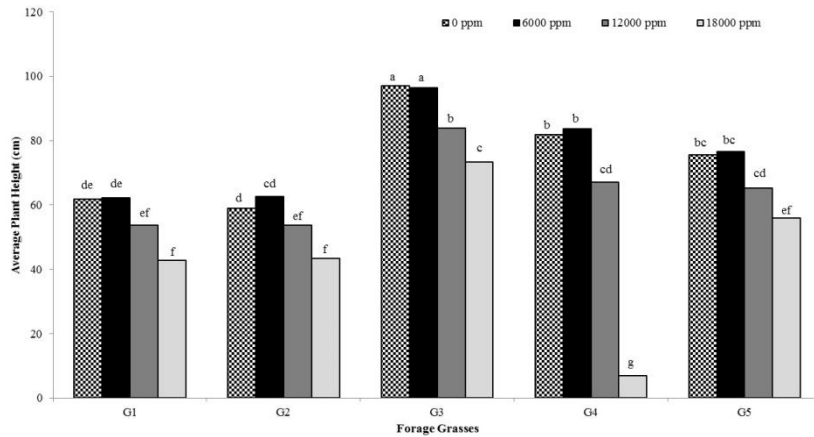


Fig 2. Average plant height (cm) of 5 forage grasses at four salinity levels. G1-*C. ciliaris* cv. Laredo, G2-*C. ciliaris* cv. Pecos, G3-*P. maximum* cv. Guinea, G4-*P. maximum* cv. Green Panic, G5-*Chloris gayana* cv. Katambora. LSD at 5% G=1.6, S=1.4, GXS = **.

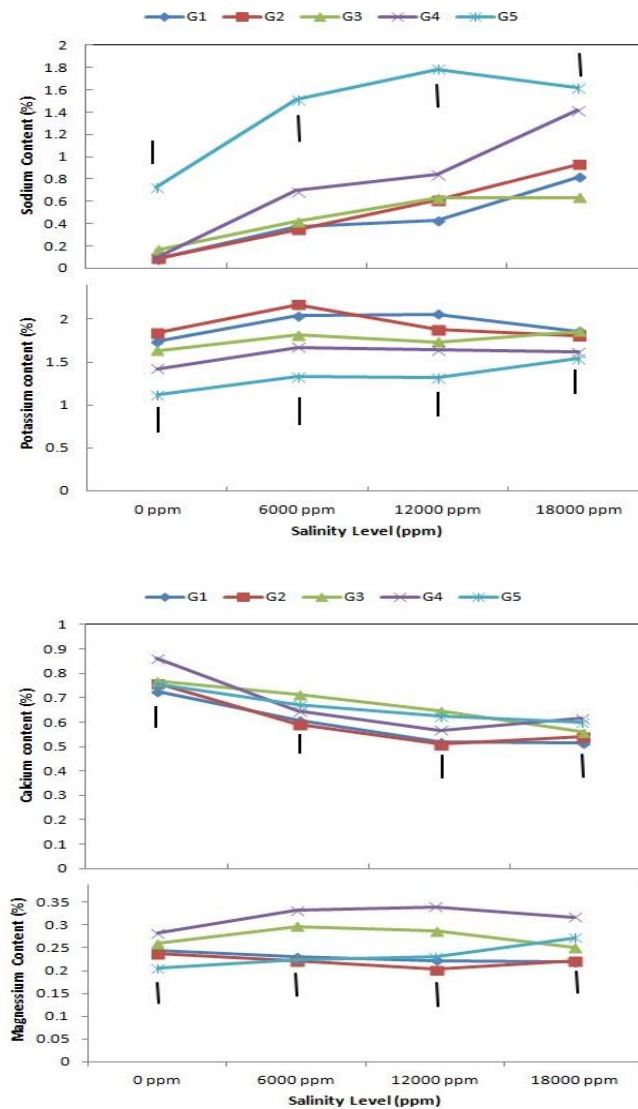


Fig 3. Effects of salinity level and forage grasses with their interactions on average mineral content. G1-*C. ciliaris* cv. Laredo, G2-*C. ciliaris* cv. Pecos, G3-*P. maximum* cv. Guinea, G4-*P. maximum* cv. Green Panic, G5-*Chloris gayana* cv. Katambora. Vertical bars indicate l.s.d. ($P = 0.05$) separating genotypes within a salinity level.

Table 4. Chemical characteristics of irrigation water treatments.

| Salinity treatment (ppm) | pH | Cations (ppm) | | | | Anions (ppm) | | |
|--------------------------|-----|------------------|------------------|-----------------|----------------|-----------------|-------------------------------|-------------------------------|
| | | Ca ²⁺ | Mg ²⁺ | Na ⁺ | K ⁺ | Cl ⁻ | HCO ₃ ⁻ | SO ₄ ⁻² |
| Control | 7.4 | 26 | 0.9 | 13.2 | 0.5 | 43 | 1.2 | 10.2 |
| 6000 | 7.7 | 160 | 106 | 1663 | 44 | 2403 | 92 | 1351 |
| 12000 | 7.6 | 318 | 231 | 3702 | 95 | 4849 | 122 | 1785 |
| 18000 | 7.7 | 486 | 363 | 5823 | 143 | 7562 | 122 | 2760 |

in saline conditions. Concentration of Na⁺ was still below the concentration of K⁺ for both *C. ciliaris* cultivars and *P. maximum* cv. Guinea, suggesting that the mechanism to tolerate salt stress is mainly related to the capacity of plants to maintain high levels of K⁺ despite Na⁺ competition (Hanin et al., 2016; Chakraborty et al., 2016). The lowest K:Na ratio was observed in *P. maximum* cv. Green Panic indicating that plants naturally possess differences in accumulating ions in response to salinity (Nadaf, 2008). *Chloris gayana* is a salt tolerance fodder particularly useful in saline areas (Ribotta et al., 2013). The salt tolerance of this grass is related to the salt gland, which is located on the leaves and secretes excess salts transported into the leaf (Oi et al., 2012). In our study, *Chloris gayana* accumulated the highest Na⁺ level in the shoot among all grasses. This is mainly related to the salt crystals secreted through the leaves, even though the Na⁺ level in internal tissues could actually be much lower. The soil salinity data in the present study showed that the maximum ECe in soil layers remained equal or less than the irrigation water salinity for all treatments. The same trend was observed by Tomar (2003) and Rao (2017) throughout their assessment the suitability of forage grasses to saline irrigation in sandy and sandy loam soils. The physical and chemical characteristics of sandy nature together with efficient irrigation management, does not allow salinity to build up beyond irrigation levels (Qadir and Oster, 2004; Mostafa et al., 2012). The soil salinity in this study was maintained by means of proper leaching and drainage at acceptable levels of crop growth.

Materials and methods

Plant Materials

Five forage grasses evaluated in this study for salinity tolerance were: two Buffel grass cultivars (*Cenchrus ciliaris* cvs. Laredo and Pecos), two Guinea grass cultivars (*Panicum maximum* cvs. Guinea and Green Panic), and one Rhodes grass cultivar (*Chloris gayana* cv. Katambora).

Site and soil description

The experiment was conducted over 3 growing seasons at Abu Dhabi Food Control Authority, Bani Yas Research Station, United Arab Emirates (24° 18' N, 54° 39' E, elevation 120 m above sea level). The site represent a hot arid climate, with a daily high temperature ranging from 24 to 47 °C, and average annual rainfall ranging from 100-150 mm. Summer (May to October) is distinctly hot, with daytime temperatures normally exceeding 42 °C. Soil is sandy, with physico-chemical characteristics listed in Table 3.

Experimental design and crop management

Field experiment was established on 7 February 2012 with subsequent data collected over three successive years.

Experimental design was a randomized complete block with split plot design with 4 replications, main plots assigned 4 irrigation salinity levels, and subplots being 5 grass forage cultivars representing 3 species. Four salinity treatment levels of irrigated water were applied: control (200 ppm), 6000, 12000 and 18000 ppm. Water from two sources were used; fresh water (EC=200 ppm) reaching the site through the municipality and brackish water (EC = 40,000 ppm) from a local saline well. Before delivery to the experimental field, the two sources were blended in a mixing unit and adjust to achieve the target treatment salinity levels and supplied to plants through drip irrigation system. Chemical analysis of irrigation water is listed in Table 4.

The field was drip irrigated using one drip line per row, each line containing drippers with a discharge rate of 8.0 h⁻¹ placed at 33 cm intervals. The field was irrigated with fresh water for the first 70 days after planting, followed by an initial harvest at 8 cm height, which was disposed of. Salinity treatments were then imposed, and gradually increased by 10% till reaching the designated level for each treatment. Irrigation amount at each application was based on daily ETo estimated from pan evaporation according to Class A Pan method. Rainfall is very low or absent in many years, but when it occurred it was subtracted from ETo estimates.

Soil salinities were monitored and appropriate leaching fractions were used to maintain soil water salinity approximately equal to irrigation water treatment levels. Therefore, salinity treatment plots (6000 and 12000 ppm) received 1.5 x ETo irrigation, salinity treatment plots (18000 ppm) received 2 x ETo volume, while control (Salinity = 0) plots received 1 x ETo. Soil samples were collected periodically at a depth of 30 cm and analyzed for root zone soil salinity as per standard procedure (USSL, 1954) to ensure steady state condition and effective salt leaching.

Individual plot size was 4 X 2.25 m, consisting of 3 rows, with distance 75 cm between rows. Seeding rate was 40 kg ha⁻¹. All plots were fertilized with the recommended dose of 1000 kg N, 400 kg P2O5 and 250 kg K ha⁻¹ yr⁻¹ in the form of urea, triple super phosphate and potassium sulphate, respectively. The N was applied as urea (N 46%), P as Monoammonium phosphate (P2O5 61%), and K as potassium nitrate (K2O 46 %). N and K fertilizers were applied weekly via fertigation, and P was top dressed once before planting. Prior to planting the field received a dressing of cow manure at 3 t ha⁻¹.

Plant measurements

Salinity treatments were initiated in April 2012. Grasses were harvested at 32-50 day intervals depending on the time of the year. The number of cuttings obtained was 7, 8, and 3 times during 2012, 2013 and 2014, respectively. Prior to cutting, the lengths of 10 randomly selected plants were measured from the ground to the tip of the shoot. Fresh yields were measured in the field in 1 m² located in the centre of each plot. The grasses were sun dried for 24 hours for dry yield determination. Dry

samples of grass from each plot were analyzed for the mineral content of Na⁺, K⁺, Ca²⁺ and Mg²⁺ using inductively coupled plasma (ICP) after digestion with di-acid (Bhargava and Raghupathi, 1993). Plant N concentration was determined by Kjeldahl digestion and P concentration determined colorimetry in a nitric acid system (Jackson, 1985). Crude protein (CP) concentration was estimated by multiplying total nitrogen content by a factor of 6.25 (AOAC, 2005). Acid-detergent fiber (ADF) was measured as described by Van Soest (1982).

Statistical analysis

Analysis of variance for balanced data with GLM model (SAS, version 9.3, 2010) was used to determine differences between treatments. Comparison among treatment differences was by Least Significant Difference (LSD) at $P \leq 0.05$.

Conclusion

Brackish ground water has the potential for enhancing the production of forage grasses. The recommended species should not only be tolerant to salinity but also well-adapted to the local agro climate and maintain productivity in hot summer temperatures. Our results showed that both cultivars of *C. ciliaris* cv. Laredo and Pecos, possess productive potential particularly under saline condition and; therefore, represent an option for farmers to replace Rhodes grass in arid environments. *P. maximum* cv. Guinea can be a second option for saline condition. Introducing such forage grasses to the bio saline agriculture will contribute to save fresh water in the short and the long term.

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