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Impact of irrigation water salinity on agronomical and quality attributes of *Cenchrus ciliaris* L. accessions

Abdullah J. Al-Dakheel, M. Iftikhar Hussain*, Abdul Qader M. Abdul Rahman

Crop Diversification and Genetic Improvement Section: International Center for Biosaline Agriculture (ICBA), P.O. Box 14660, Dubai, United Arab Emirates

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ABSTRACT

Cultivation of salt tolerant perennial grasses using saline water irrigation is potentially an important strategy to save fresh water resources and maximize the forage yield of small-scale farms in the marginal environment. Field evaluation of 40 Buffel grass (*Cenchrus ciliaris* L.) genotypes was conducted at ICBA, Dubai, UAE over eight years (2006–2013) under three irrigation water salinities (EC: 5, 10 and 15 dS m^{-1}) to identify salinity tolerance potential based on plant growth, biomass yield and quality attributes. Total annual and average fresh (FW) and dry biomass (DW) varied significantly among genotypes under all salinity levels. Lower DW producing accessions were higher in nutritive value while higher DW producing accessions had lower nutritive value in terms of crude protein (CP) and neutral detergent fiber (NDF). From multivariate analysis, accessions 37, 2, 3, 12, and 15 were salt tolerant, high biomass and stable genotypes with adequate nutritive value at different salinities. In contrast, genotypes 21, 23, 24, 25, and 40 were salt sensitive and low yielding. Genotype 37 (Grif 1619) was the most stable and high yielder at all salinity levels. The local accession 38 (MAF 74) had higher yield comparable to 37 but declined sharply at the highest salinity that made it suitable for medium level salinity. It is concluded that wide genotypic diversity exists among a diverse collection of *C. ciliaris* accessions for salinity tolerance biomass production and multivariate analysis facilitate the grouping of stable and high yield accessions into different clusters. These salt-tolerant accessions can be grown to maximize forage production and desertification combat in the arid environment.

1. Introduction

Salinity problems in crop production will become worse in areas with rapidly growing human population and limited water resources, which force growers to use poor quality water for irrigation. Soil salinity is a serious threat limiting crop production (Munns, 2002) as it adversely reduces the overall productivity of ecosystem. The plants face numerous abnormal, physio- morphological and biochemical changes under salinity stress and cause delayed germination, high seedling mortality, poor crop stand, stunted growth and reduce yields (Ahmad et al., 2010). The identification and development of salt tolerant fodder crops may help to address the scarcity of good quality water in many arid regions of the world where vast reserves of saline and brackish water exist. Many grasses and salt tolerant crops are able to produce high biomass under saline conditions. Buffel grass (*Cenchrus ciliaris* L.) is an important C_4 forage grass (family: Poaceae) being perennial, sometimes produces rhizomes and is native to the Arabian Peninsula. It is drought tolerant plant that can be grown under the marginal soils and water scare conditions. It is very good pasture grass for hot and dry regions in the tropics and sub tropics and mainly cultivated for permanent pastures in Africa, Australia and Asia (Franklin et al., 2006; Arshadullah et al., 2011). Buffel grass has proved useful for pasture and soil retention in a wide range of environment due to its drought tolerance, deep roots, rapid response to summer rains, relative palatability and resistance to overgrazing. It produces viable seed so that stands can be self-replacing and pastures may not need to be reseeded. Buffel grass seed may survive for up to an estimated 4 years in the soil, but plants can live for many years (Winkworth, 1971). *C. ciliaris* plants are constantly confronted with various biotic and abiotic stress factors like high temperature, salt, drought, flooding, heat, oxidative stress and heavy metal toxicity (Ibarra-Flores et al., 1995; Ward et al., 2006).

Improved salinity tolerance permits the conservation of fresh water and its use for high value purposes, providing both ecological and economic benefits essential for sustainable agriculture in dry lands (Keating et al., 2010). The initial step in the development of salt-tolerant cultivars is to identify sources of salinity tolerance

* Corresponding author. Fax: +971 43361155.
E-mail address: m.iftikhar@biosaline.org.ae (M. Iftikhar Hussain).

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Table 1
Buffel grass (*Cenchrus ciliaris* L.) germplasm collection with genebank entry numbers and country of origin during 2004–2005.

S.No.	Accessions	Entry numbers	Country of origin	S.No.	Accessions	Entry numbers	Country of origin
1	PI 153,671	2	Kenya	21	PI 409,267	393	South Africa
2	PI 161,633	6	South Africa	22	PI 409,295	417	South Africa
3	PI 161,637	9	South Africa	23	PI 409,429	507	South Africa
4	PI 185,564	18	South Africa	24	PI 409,556	565	South Africa
5	PI 225,012	48	Ghana	25	PI 409,585	576	South Africa
6	PI 225,583	49	South Africa	26	PI 409,669	600	South Africa
7	PI 271,206	88	India	27	PI 409,689	619	South Africa
8	PI 271,208	90	India	28	PI 409,704	632	South Africa
9	PI 271,209	91	India	29	PI 414,447	653	South Africa
10	PI 271,214	96	India	30	PI 414,452	658	South Africa
11	PI 271,219	101	India	31	PI 414,499	702	South Africa
12	PI 279,596	111	Philippines	32	PI 414,513	714	South Africa
13	PI 294,595	124	Australia	33	PI 442,096	750	Japan
14	PI 295,659	130	Zimbabwe	34	PI 443,507	754	Mexico
15	PI 365,650	220	Tanzania	35	PI 516,516	760	Morocco
16	PI 365,651	221	Tanzania	36	Grif 1619	764	Australia
17	PI 365,720	252	Tanzania	37	Grif 1639	784	Pakistan
18	PI 385,321	287	Tanzania	38	MAF 74		UAE
19	PI 409,174	315	South Africa	39	MAK 7		UAE
20	PI 409,216	349	South Africa	40	MAK 9		UAE

within the crop and, when available, within its wild relatives. These accessions should be characterized by high productivity under saline conditions, thereby extends agriculture to more marginal environments. Previously, no systematic effort has been undertaken to evaluate salinity tolerance in a wide range of *C. ciliaris* genotypes. Therefore, the present work was undertaken to evaluate and identify the salt-tolerant *C. ciliaris* from a large collection stored at ICBA's gene bank. The specific objectives of this study were to (a) identify genetic diversity among *C. ciliaris* genotypes for salt tolerance (b) evaluate genotypes for relative salt tolerance potential in terms of fresh biomass and dry matter yield under agro-ecological conditions of Dubai (U.A.E.) using multivariate analysis.

2. Materials and methods

2.1. Plant material

The organization of core collection of particular plant population and selection of top performing accessions under field offers better opportunities for specie screening and evaluating genetic diversity (Turi et al., 2012). We evaluated 40 *C. ciliaris* L. genotypes (selected from initial screening trial in germination bioassays out of 800 accessions from a global collection supplied by USDA) for salt tolerance potential under field condition (Table 1).

2.2. Field trial and experimental design

The experiments were conducted between 2006 and 2013 at International Center for Biosaline Agriculture (ICBA), Dubai, United Arab Emirates (25°13″N and 55°17″E). The experimental station is located in an arid desert climate where temperature is high and rainfall is negligible from April to November (Karim and Al-Dakheel, 2006). The soil is a carbonatic, hyperthermic typic torripsamment with a negligible level of inherent soil salinity (0.2 d Sm^{-1}). Prior to planting, the site was harrowed to ensure an even seedbed. Organic compost from cow manure (41% organic matter, 1.64% moisture, pH 7.7, C/N = 16.5, 1.5% N, 1.65% K and 1.22% Na, Al Bayadir®, Jabel Ali, Dubai, UAE) was spread and incorporated at the rate of 30 t ha^{-1}. Plots measuring 0.5 m × 4 m, (for a plot area of 2 m^2) were established and planted manually with a row spacing of 0.5 m to enable manual weeding. An equal number of 16 plants per entry were used since the germination rate from prior tests did not differ between entries. The plots were sown in mid October to avoid high temperatures and desicating winds. N–P–K fertilizer (20–20–20%) was applied at a rate of 100 kg ha^{-1} (Growfert Solub™), corresponding to the recommended rate for the region.

2.3. Salinity treatments and agronomic measurements

Three salinity treatments were established, corresponding to irrigation water salinities of 5, 10 and 15 dS m^{-1}, denoted as S1, S2 and S3, respectively. The S1 level corresponds to the lowest salinity in irrigation water, while S2 is the prevailing level in the farmer's fields of the region and S3 is the maximum salinity level recommended by the extension services. The target saline irrigation water (5, 10, 15 dS m^{-1}) were accomplished by mixing highly saline groundwater (with ECw up to 25 dS m^{-1}, SAR > 26 mmol/L with Na and Cl concentrations higher than 190 meq/L and pH 7.6) with the 2 dS m^{-1} water, which was the lowest saline water available (SAR = 4 mmol/L with Na and Cl concentrations lower than 11 meq/L and pH 8.5). A control treatment with lowest salinity, therefore, could not be established. The three salinity levels were maintained constantly throughout the cropping season during all the years. Each salinity level was monitored twice a week using a portable EC meter (TetraCon® 325Cond 197i, WTW, USA). Irrigation was applied at rates equivalent to ET_0 plus 10% for leaching requirements. After harvest, all plots were irrigated at ET_0 plus 25% for additional leaching. The plant samples were collected at heading stage from the middle 1 m of the two central rows to avoid edge effects and weighed to measure fresh biomass (t ha^{-1}), dried at 70 °C for three days and re-weighted to determine dry matter yield (t ha^{-1}). Every year, average five harvests were achieved and 120 samples of 0.5 m^2 were collected at each harvest.

2.4. Irrigation management system

The experimental field plots were supplied with high and low salinity water from two large reservoirs. Before delivery to the field, the water was mixed in a mixing unit inside a chamber and adjusted to achieve the target salinity and supplied to plants through drip irrigation system in the field plot area. The plots were laid out in strips where each genotype was grown on 1 row 4 m long with a planting density of 4 plants per linear meter. The field experiment was equipped with a drip system (4 L hr^{-1} flow rate) 0.5 m distance between rows and 0.25 m between drippers.