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RESEARCH ARTICLE

Performance of *Aeluropus lagopoides* (mangrove grass) ecotypes, a potential turfgrass, under high saline conditions

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Abstract

Climate change has become a real threat, and its impacts are being felt throughout the world. Temperature is considered one of the significant elements by the recent consequences of climate change and global warming, specially the salinity which is increased at higher temperature. Turfgrasses are adversely affected due to an increasing trend in salinity. The main aim of this investigation was to find out salt-tolerant ecotypes from native species of UAE to mitigate the salinity problem. Performance of a native grass, *Aeluropus lagopoides*, was investigated under high saline conditions during the year 2014 under the UAE climatic conditions. The experiment was planned under randomised complete block design (RCBD) with two factors and four replications. During the experiment, 50 ecotypes of *Aeluropus lagopoides*, alongside *Paspalum vaginatum* (as control), were tested at different salt levels, i.e. 0, 15, 30, 45, 60 and 75 dSm^{-1}. Significant differences were found among various ecotypes as well as salinity levels for different agronomic traits including green cover, canopy stiffness, leaf colour and salinity of leaf rinseates. Most of the ecotypes tolerated salinity up to 30 dSm^{-1}, maintaining the quality, but beyond this level the quality declined. However, some of the ecotypes survived under high salinity, even beyond sea level (75 dSm^{-1}). All the ecotypes, except RUA2, RUA3 and RUA1, showed better performance than *P. vaginatum*, the prevailing commercial turfgrass in the UAE. Based on their performance, the ecotypes RUDA7, FA5, RA3, RUDA2 and RA2 could be used for turf purposes under saline conditions.

Keywords Halophytes · Indigenous grass · Sustainable landscaping · Climate change

Introduction

The world population is increasing at the rate of 34%, and by 2050, it is expected to reach around 9.1 billion, which will demand for 70% more food production (FAO 2009) and other living requirements from the agriculture sector. Fulfilling these requirements of the growing population remains a challenging task as climate changes have endangered the sustainability and productivity of the agricultural production systems (Asad et al. 2017; Aziz et al. 2017a; Fahad and Bano 2012; Fahad et al. 2013; Fahad et al., 2014a, b, 2015a, b. 2016a, b, c, d, n.d.). Middle East is considered one of the most susceptible regions to climate change impacts, due to its water scarcity (the highest in the world) where an increase in temperature of up to 2 °C in the next 15–20 years and over 4 °C for the end of the century is estimated (Elasha 2010). Giorgi (2006) recognised the Mediterranean among the most physically vulnerable regions to climate change. Climate models are projecting hotter, drier and less predictable climates in most of the Middle East by 2050 (Milly et al. 2005). Plants are

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suffering from various abiotic stresses while they are growing under field conditions (Fahad et al. 2014a, 2014b, 2015a, 2015b, 2016a, 2016b, 2016c, 2016d, n.d.). Modern agriculture is also exposed to several abiotic stresses, such as higher intensities of salinity, drought, chilling and heat as a major constriction affecting crop yields (Tardieu and Tuberosa 2010; Saud et al. 2013; Fahad et al. 2014a, 2015a, 2015b, 2016a, 2016b, 2016c, 2016d, n.d.; Hafiz et al. 2016; Awais et al. 2017; Muhammad Hafiz et al. 2017; Naeem et al. 2017; Noman et al. 2017; Saud et al. 2013; Saud et al. 2014; Saud et al. 2016; Saud et al. 2017; Shah et al. 2013). More than 50% reduction in average yield of major crops has been attributed to the abiotic stresses (Fahad et al. 2014a, 2015a, 2015b, 2016a, 2016b, 2016c, 2016d, n.d.; Qamar-uz et al. 2017; Zahida et al. 2017). Globally soil salinity has badly affected approximately 30% of the irrigated area and 6% of the total land area (Chaves et al. 2009) causing financial loss of US$12 billion in the agricultural production system (Shabala 2013). Soil salinization is one of key stresses causing more than 831 million hectares of the agricultural lands in the world (FAO 2005). Owing to the increasing trend of salinity on agricultural lands, it is necessary to study the plant tolerance mechanisms and explore the salt-tolerant plants in order to sustain crop productivity (Parida and Das 2005; Tuteja 2007).

The United Arab Emirates (UAE) has vast brackish (highly saline) groundwater resources, which, though too saline for conventional crops, could be used for biosaline agriculture and urban landscape. *Aeluropus lagopoides* is typically found in coastal *sabhkas*, with soil salinities up to 100 dS m^{-1} (twice that of seawater); therefore, direct seawater can be used for its irrigation (Murad et al. 2007; Environment Agency Abu Dhabi 2009). Halophytes (salt-loving plants) have been proposed as a new remedy for salt water irrigation culture, which will save a huge amount of freshwater for domestic use (Khan and Weber 2006).

Although plant species used for food do not have considerable salt tolerance, some halophyte species have potential for use in urban landscaping particularly as turfgrass. However, to date there has been no success in developing and releasing a halophytic turfgrass cultivar to the commercial landscape market. *Paspalum vaginatum* is the most salt-tolerant turfgrass currently available, with several cultivars having been recently developed (Duncan and Carrow 2002). However, it has a high water use requirement (Kim et al. 1988), and is not a true halophyte, as it cannot tolerate highly saline conditions, such as seawater (Marcum and Murdoch 1994). Nevertheless, there are many wild halophytic grass species, which are closely related to the conventional turfgrasses used in landscaping, such as Bermuda grass (*Cynodon dactylon*) and Zoysia grass (*Zoysia* spp.), belonging to the grass subfamily Chloridoideae (Gould and Shaw 1983).

Halophytes have salt-secreting structures called salt glands, which move ions from the symplast out to the leaf surface. Salt glands are dumping sites for excessive salts absorbed by plants along with water from soil and thus help plants to manage the internal salt load, and adopt to live in the saline environment. These salts are periodically washed off by rain, irrigation or tides in coastal marshes (Rumman 2012). The main feature of the study consisted of the measurement of salt concentration taken from washed leaves (rinseates) which indicates salt gland activity. The sequential increase in salt levels of irrigation water applied to same ecotypes is the unique procedure.

The UAE is in a prime location to become the world leader in developing a biosaline agricultural industry. So far, there has been no release of native halophytic grass cultivars for use as turfgrass in urban landscapes. Therefore, this study was carried out (1) to explore and select ecotypes of *Aeluropus lagopoides*, a potential turfgrass from native Arabian flora, under high saline conditions and (2) to introduce the best ecotypes in the local landscaping. For this purpose, 50 ecotypes of *Aeluropus lagopoides* collected from various parts of UAE were studied for their salt tolerance during this experiment.

Materials and methods

Aeluropus lagopoides, a native Arabian Gulf grass, exhibits turf-type growth characteristics in their natural habitat as shown in Figs. 1 and 2. Various ecotypes of the grass were collected from different areas of UAE and grown in pots. The salinity tests were conducted in the year 2014 in Al Khatim, located along the Abu Dhabi-Al Ain highway, approximately 70 km away from Abu Dhabi City (Google coordinates 24° 12′ 2.19″ N, 55° 1′ 32.69″ E) under the supervision of the Department of Arid land Agriculture, UAE University. The experiment was laid out in RCBD with two factors and four replications.

Fig. 1 Pictures of *Aeluropus lagopoides* taken from research collection sites

Fig. 2 *Aeluropus lagopoides* growing in the natural habitat

Two factors were studied:

Factor 1: salinity levels (five levels, i.e. 15, 30, 45 60 and 75 dSm^{-1} + tap water as control)
Factor 2: *Aeluropus lagopoides* ecotypes (50 + *Paspalum vaginatum* as control)

Five salinity levels (NaCl) along with control (tap water) were applied to all the ecotypes using the drip irrigation system in the same way used by Uddin et al. (2009) during their salinity tests on various grasses. Similarly, Marcum and Pessarakli (2006) also used the same sequence of salinity levels (0, 15, 30, 45 and 60 dSm^{-1}) for screening 35 Bermuda turf cultivars.

Irrigation system

The drip irrigation system with a single emitter per pot was designed, which was connected to a 500-L water tank via non-corroded, salt-resistant manually operated pumps. Daily 200-mL irrigation water was applied per pot. The pots were flushed with freshwater once a week to avoid salt accumulation. The water requirement of pot was calculated from Abu Dhabi Municipality irrigation specifications and actual site requirement. The irrigation system was operated manually on a daily basis, and the pots were irrigated in the morning.

Preparation of salt solution

The water tank was filled with water. Then, salt (99%NaCl) was added gradually and checked with a EC meter until the required electrical conductivity (EC) level was achieved. The fertilizer application was also integrated with saline water application before reaching the final value of treatment once a month.

Procedure

Fifty ecotypes of *Aeluropus lagopoides* were grown in 10-cm plastic pots using the standard planting medium, a mixture of sand and compost (9:1) using the same concept of Uddin et al. (2009). Once fully covered with grass, the pots were shifted to a shade house with 30% shade material. The pots were kept there during summer months i.e. May to August with 38 °C average day temperature and variable relative humidity (44 to 49%). The shade was provided to reduce water requirement and to keep the grass from harsh wind and other environmental impacts.

Acclimatization

After the freshwater application for 2 weeks and data taken, salt (NaCl) was added to the water tank with an increment of 5 dSm^{-1} after each 3 days till reaching the first treatment (15 dSm^{-1}), following the procedure of Marcum and Murdoch (1994). First, data was taken after completion of the first treatment of irrigation water for 2 weeks. Then, the solution concentration was increased to second level (30 dSm^{-1}) and so on. Data was taken after 2 weeks of salt solution of second treatment till the final treatment (75 dSm^{-1}) was achieved by progressively advancing the salinity levels with a gap of the acclimatization period as mentioned above. For each treatment, after the completion of the acclimatization period, grasses were clipped at 3 cm on a weekly basis and discarded (Mintenko and Smith 2001). Data were taken for the following parameters.

Parameters studied

The following variables were studied during the course of experiment to observe responses of different ecotypes to the varying salinity levels.

1) Green cover (1–10)
2) Canopy stiffness (1–10 how the grass feels softness)
3) Leaf colour (1–10)
4) Salinity of leaf rinseates (mg L^{-1})

Green cover is one of the most important turfgrass characteristics, which cannot be ignored while selecting any turfgrass variety. Green cover data were taken by a visual method considering the pot coverage by green biomass. The data were taken after the final mowing of grass. The scale was from 1 to 10, where 1 means least green cover and 10 fully covered, while 0 means dead (Toler et al. 2007).

Canopy stiffness is the second most important feature of turfgrasses, which shows how soft or hard the grass feels while using it. Canopy stiffness was rated on a scale of 1–10, where 1 stands for minimum stiffness (the softest) by touching and 10 for maximum stiffness (the hardest). In other words, lower-stiffness grass provides better performance due to its soft feel, while higher stiffness, being harder, is not liked. The data were the average of the judgment of the panel consisting of five members, as the touch feel would be different for different individuals (Toler et al. 2007).

Leaf colour rating of the ecotypes was assessed using a visual score based on the 1 to 10 scale with 1 being very poor and 10 being excellent. Lawn colour quality assessment was carried out by a minimum of five individuals on each evaluation date. Specific instructions on lawn quality rating were provided to raters to reduce error. Ratings were not calibrated to any standard form; however, during lawn quality ratings, the raters based their scoring on individual judgments (Alumai et al. 2009).

Leaf rinseate salinity indicates the salt gland activity and is equal to the concentration of salt in the leaf rinseate. Randomly, five leaves were collected from each pot by forceps to avoid salt crystal drop page and placed in 30-mL glass vials. The vials were filled with water and kept for 2 h till all the salts dissolved. Then, the leaf rinseates were transferred to a beaker, making a final volume of 80 mL, and then the salinity (mg L^{-1}) was measured by a total dissolved solids (TDS) meter (Model AD8000, Sony Ltd., Japan). The leaf area was measured with a leaf area meter, and thus, TDS per unit leaf area were calculated for each ecotype at each specific salinity level. The concentration of solution shows salt gland activities. Actually, halophytes (including halophytic grasses) excrete salts via glands on their leaves when grown in high-salinity conditions. Gland activity is the major characteristic of halophytes. Glands are present on both sides of the leaf in longitudinal rows parallel to veins consisting of two cells. These cells collect the salts from leaves and excrete to the outside to combat the high salt concentration in the soil or water medium (Barhoumi et al. 2008).

Statistical analysis

The response of different ecotypes was studied. The data were analysed via Statistix 8.1 software applying the analysis of variance (ANOVA) technique (Steel et al. 1980) to see the variance among the means. In case the differences were significant, the means were further subjected to Tukey's test to observe the differences between individual means (Abdi and Williams 2010). Due to the large number of ecotypes, it was difficult to explain the data using the ANOVA technique, so cluster analysis (CA) was applied using Statistica version 7 (Dell Inc., USA). Based on the recorded data, the grass ecotypes having high salt tolerance were selected and recommended for further multiplication.

Results

Cluster analysis

According to cluster analysis (Fig. 3), at a linkage distance of 5.2, four clusters were extracted. Cluster 1 included only control grass (ADPV1) while cluster 2 had 9 ecotypes namely FA2, DASA1, RUDA7, FA5, DADA1, ZUDA2, JD1, RA3 and MADA1. Cluster 3 consisted of 17 ecotypes, including SAADA2, BAAD2, RUDA5, BADA5, SAADA1, ZUDA4, NSDA1, TADA1, RUADA1, RUA3, BAADA3, RUA1, MADA2, RUA2, BAADA4, RUDA6 and FA4. Cluster 4 included 24 ecotypes i.e. RUDA3, RUDA2, GD1, TADA2, RA4, ZUDA6, NSDA2, JADA2, ZUDA1, ZUDA5, ASA1, JADA1, FA3, RA1, RUDA4, ZUDA3, NSDA3, RUDA1, RA2, RUADA2, UA1, FA1, BAADA1 and DADA1.

As indicated in Table 1, cluster 2 gave higher mean values for green cover (6.28), canopy stiffness (3.56), leaf colour (6.99) and leaf rinseate salinity (0.74 mg L^{-1}), while the remaining three clusters had no higher means for any parameter. In case of canopy stiffness, cluster 2 had the lowest mean value showing the best performance as the lowest canopy stiffness (softness) is recommended.

Green cover (1–10)

Different salinity levels had a significant ($P \leq 0.001$) effect on the green cover of *Aeluropus lagopoides* ecotypes. The mean data of salinity (Table 2) show that a maximum (9.49) green cover was observed in grasses supplied with tap water (control) while the green cover of 8.36 was recorded at 15 dSm^{-1} followed by 8.11 spread at 30 dSm^{-1}. Salinity at 45 dSm^{-1} reduced the green cover to 6.65; thus, the lowest

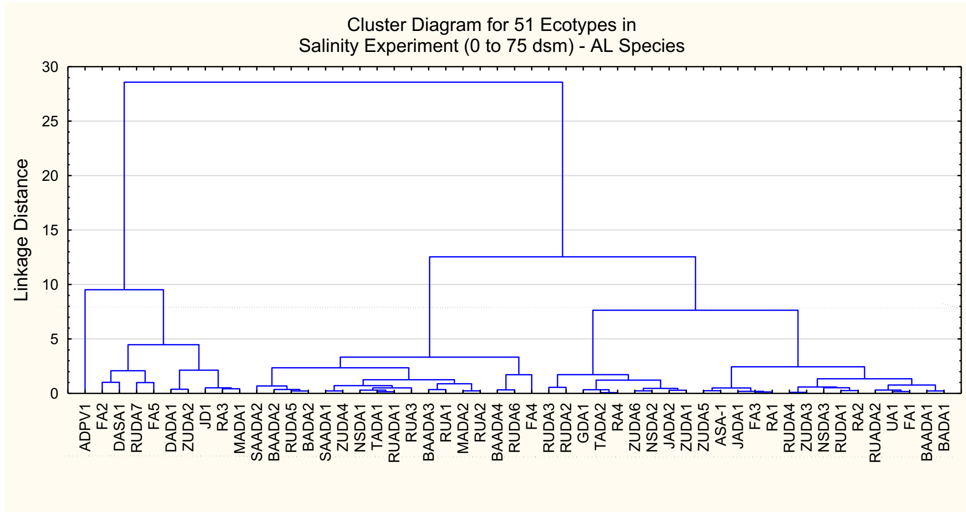

Fig. 3 Dendrogram for 50 *Aeluropus lagopoides* ecotypes and *Paspalum* (ADPV1; control) based on various agronomic characters

green cover was given at 75 dSm^{-1} (0.23). Varying performance of different ecotypes was observed for ground cover as shown in Table 2 (main effect). To further evaluate the comparison of the ecotypes, the data were subjected to cluster analysis. According to the dendrogram (Fig. 3), four main clusters were produced. Among these, cluster 1 had only the control grass (ADPV1), while the remaining ecotypes were divided into other three clusters as shown in Fig. 3. Cluster 2 gave the best performance in terms of green cover (6.28) followed by cluster 4 (5.49), while a minimum green cover was recorded in cluster 1 providing spread of 4.95 followed by cluster 3 (5.40). The best-performing ecotypes in cluster 2 were RUDA7 (7.69) followed by FA5 (6.92) and RA3 (6.44). As indicated in Table 2, at higher salinity levels, most of the ecotypes were adversely affected except a few as mentioned above which could survive but which acquired a very low green cover. The control grass (ADPV1) did not survive at 75 dSm^{-1}.

Canopy stiffness (1–10)

The data regarding canopy stiffness (Table 2) shows that the canopy stiffness of *Aeluropus lagopoides* ecotypes was significantly ($P \leq 0.001$) affected by different salinity levels. According to the mean data of salinity levels (Table 2), it is clear that the highest (5.01) canopy stiffness was provided at 45 dSm^{-1} followed by 4.5 at 30 dSm^{-1} while the lowest (1.41) canopy stiffness was recorded for tap water. A varying performance of different ecotypes was observed (Table 2) at different salinity levels. For further details, cluster analysis was carried out as explained above. According to Fig. 3, four main clusters were produced. Cluster 2 had a maximum (3.56) mean value for canopy stiffness followed by cluster 1 (3.54) while the remaining clusters 3 and 4 had the lowest canopy stiffness of 2.52 and 2.56 respectively. The best-performing (lowest canopy stiffness) ecotypes were included in cluster 3 i.e. RUDA2 (1.63) followed by FA3 and RA2 (1.92).

Leaf colour (1–10)

As indicated in Table 3, the leaf colour of different ecotypes was significantly ($P \leq 0.001$) affected by salinity levels. The best (9.64) performance was observed in grasses with supplying tap water followed by those grown at 15 dSm^{-1} (7.75) salinity level. The leaf colour decreased with the increase in salinity, such as minimum (0.87) leaf colour which was recorded in grasses that survived at 75 dSm^{-1}. At 30 and 45 dSm^{-1}, also a satisfactory performance in terms of leaf colour (6.58 and 6.12 respectively) was achieved. To further elaborate the comparison of ecotypes, the data were subjected to cluster analysis and four clusters were

Table 1 Cluster means and standard deviations for various parameters for *different Aeluropus lagopoides* ecotypes (50) and *Paspalum* (ADPV1; control)

Parameter	Cluster I (1 ecotype)	Cluster II (9 ecotypes)	Cluster III (17 ecotypes)	Cluster IV(24 ecotypes)
Green cover	4.95	6.28 ± 0.67*	5.40 ± 0.37	5.49 ± 0.34
Canopy stiffness	3.54	3.56 ± 0.54	2.52 ± 0.57	2.56 ± 0.56
Leaf colour	5.58	6.99 ± 0.67	4.86 ± 0.46	5.25 ± 0.52
Salinity of leaf rinseates	0.15	0.74 ± 0.19	0.24 ± 0.02	0.28 ± 0.13

* Standard deviation

Table 2 Effect of different salinity levels (0–75 dSm^{-1}) on green cover (1–10) and canopy stiffness (1–10) of 50 *Aeluropus lagopoides* ecotypes and *Paspalum* (ADPV1; as control)

Ecotypes	Green cover (1–10)							Canopy stiffness (1–10)						
	Salinity levels (dSm^{-1})							Salinity levels (dSm^{-1})						
	0	15	30	45	60	75	Means	0	15	30	45	60	75	Means
BADA1	8.75	8.75	8.13	5.25	0.00	0.00	5.15	1.75	2.00	2.75	5.25	0.00	0.00	1.96
MADA1	9.25	8.00	9.25	5.00	3.25	1.13	5.98	1.50	2.00	2.63	5.00	5.00	6.00	3.69
JD1	10.00	9.00	10.00	6.00	1.75	0.75	6.25	1.50	1.50	4.50	5.00	5.38	4.63	3.75
FA1	9.75	8.25	9.50	4.13	0.00	0.00	5.27	1.50	3.00	3.75	6.00	0.00	0.00	2.38
FA5	9.50	8.25	8.25	7.00	4.75	3.75	6.92	1.25	2.50	3.25	4.50	4.00	4.00	3.25
DASA1	8.75	8.00	8.00	7.50	1.08	0.00	5.55	1.75	3.00	4.25	4.50	5.88	0.00	3.23
FA2	10.00	7.50	9.00	5.75	3.43	1.13	6.13	1.00	2.50	3.25	5.00	3.75	4.13	3.27
ZUDA1	10.00	8.75	8.25	5.50	0.00	0.00	5.42	1.00	2.50	4.25	6.00	0.00	0.00	2.29
RA3	10.00	9.25	9.00	6.25	3.13	1.00	6.44	1.00	2.00	3.25	5.88	5.00	5.88	3.83
RA1	10.00	9.00	8.25	5.38	0.00	0.00	5.44	1.25	2.25	4.75	3.50	0.00	0.00	1.96
RA2	9.25	8.75	7.50	5.75	0.00	0.00	5.21	1.25	2.00	4.50	3.75	0.00	0.00	1.92
ZUDA2	9.00	8.75	8.50	6.25	1.88	0.63	5.83	2.00	3.00	5.00	4.88	5.25	6.00	4.35
ZUDA3	9.25	8.50	8.50	7.13	0.00	0.00	5.56	1.50	2.50	4.50	4.25	0.00	0.00	2.13
ASA-1	10.00	8.75	8.50	7.50	0.00	0.00	5.79	1.25	3.00	5.00	4.50	0.00	0.00	2.29
FA3	9.75	8.50	7.25	7.25	0.00	0.00	5.46	1.25	2.00	5.00	3.25	0.00	0.00	1.92
FA4	8.50	8.25	7.50	6.13	1.50	1.13	5.50	1.75	2.00	4.50	4.50	5.25	5.50	3.92
RUA2	8.25	6.00	6.50	5.63	0.00	0.00	4.40	2.50	3.50	6.50	6.25	0.00	0.00	3.13
RUDA1	9.50	8.75	8.00	7.00	0.00	0.00	5.54	1.00	2.50	3.50	5.00	0.00	0.00	2.00
RUDA2	10.00	9.50	9.00	7.00	0.00	0.00	5.92	1.00	1.75	3.25	3.75	0.00	0.00	1.63
RUDA3	9.50	9.50	8.75	6.63	0.00	0.00	5.73	1.50	2.00	3.75	4.50	0.00	0.00	1.96
RUDA4	10.00	8.25	9.00	6.63	0.00	0.00	5.65	1.25	4.75	3.75	5.00	0.00	0.00	2.46
UA1	9.75	8.00	8.50	6.88	0.00	0.00	5.52	1.25	3.50	4.50	4.38	0.00	0.00	2.27
RUA3	9.25	7.00	7.50	5.50	0.00	0.00	4.88	1.25	3.75	5.00	5.00	0.00	0.00	2.50
RUADA1	8.50	8.00	7.75	6.38	0.00	0.00	5.10	2.00	4.75	4.50	6.25	0.00	0.00	2.92
MADA2	9.25	8.00	7.00	6.75	0.00	0.00	5.17	1.50	6.25	4.75	6.88	0.00	0.00	3.23
BADA2	9.25	8.75	6.75	6.63	0.00	0.00	5.23	2.00	6.00	5.50	6.75	0.00	0.00	3.38
RUDA5	9.50	8.75	8.00	6.75	0.00	0.00	5.50	1.50	6.75	4.50	7.25	0.00	0.00	3.33
RUDA6	9.25	9.00	7.75	6.75	1.13	0.00	5.65	1.25	2.75	5.25	5.25	4.63	0.00	3.19
RUDA7	10.00	9.50	9.75	7.75	7.38	1.75	7.69	1.00	1.75	2.50	3.38	3.13	3.50	2.54
RUA1	8.25	8.50	6.75	6.00	0.00	0.00	4.92	2.00	2.25	4.50	4.50	0.00	0.00	2.21
RA4	10.00	8.25	7.00	6.88	0.00	0.00	5.35	1.00	3.25	4.25	5.25	0.00	0.00	2.29
NSDA1	10.00	7.25	7.50	5.63	0.00	0.00	5.06	1.00	6.00	4.25	6.88	0.00	0.00	3.02
NSDA2	10.00	8.75	8.50	7.00	0.00	0.00	5.71	1.00	3.00	4.50	5.38	0.00	0.00	2.31
NSDA3	9.75	9.50	9.25	8.13	0.00	0.00	6.10	1.25	2.25	3.75	5.38	0.00	0.00	2.10
BAADA1	9.50	7.75	8.50	7.75	0.00	0.00	5.58	1.00	3.25	4.50	3.25	0.00	0.00	2.00
BAADA2	9.00	7.50	8.75	6.25	0.00	0.00	5.25	1.00	6.75	6.00	7.50	0.00	0.00	3.54
BAADA3	8.50	7.75	7.75	5.88	0.00	0.00	4.98	2.00	2.50	6.25	6.25	0.00	0.00	2.83
BAADA4	10.00	9.00	8.50	8.13	1.00	0.00	6.10	1.00	2.25	5.75	4.50	6.25	0.00	3.29
ZUDA4	10.00	8.75	9.25	7.88	0.00	0.00	5.98	1.00	4.75	6.50	5.50	0.00	0.00	2.96
ZUDA5	9.50	8.25	8.25	7.88	0.00	0.00	5.65	1.75	2.75	5.25	4.50	0.00	0.00	2.38
ZUDA6	10.00	8.50	7.50	7.00	0.00	0.00	5.50	1.00	2.00	6.50	3.50	0.00	0.00	2.17
RUADA2	9.25	8.00	7.00	7.00	0.00	0.00	5.21	1.25	3.50	4.75	4.25	0.00	0.00	2.29
JADA1	9.50	8.75	9.00	7.50	0.00	0.00	5.79	1.75	3.00	3.75	3.75	0.00	0.00	2.04
JADA2	10.00	8.25	8.50	7.63	0.00	0.00	5.73	1.00	3.00	5.25	3.63	0.00	0.00	2.15
GDA1	9.50	9.33	8.50	7.88	0.00	0.00	5.87	1.75	3.00	4.75	4.00	0.00	0.00	2.25

Table 2 (continued)

Ecotypes	Green cover (1–10)							Canopy stiffness (1–10)						
	Salinity levels (dSm^{-1})							Salinity levels (dSm^{-1})						
	0	15	30	45	60	75	Means	0	15	30	45	60	75	Means
SAADA2	9.25	6.50	8.25	5.75	0.00	0.00	4.96	2.25	6.25	4.50	7.00	0.00	0.00	3.33
SAADA1	10.00	8.50	7.75	7.38	0.00	0.00	5.60	1.00	6.00	3.75	6.38	0.00	0.00	2.85
DADA1	10.00	7.50	8.25	6.75	1.18	0.63	5.72	1.00	3.75	4.00	4.75	4.25	6.75	4.08
TADA1	9.25	7.75	7.50	6.88	0.00	0.00	5.23	1.75	5.00	4.75	5.75	0.00	0.00	2.88
TADA2	9.00	8.50	7.75	7.63	0.00	0.00	5.48	2.00	3.25	4.75	4.00	0.00	0.00	2.33
ADPV1	9.75	8.50	3.75	6.50	1.18	0.00	4.95	1.50	4.00	5.00	4.25	6.50	0.00	3.54
Means	9.49	8.36	8.11	6.65	0.64	0.23	5.58	1.41	3.32	4.50	5.01	1.26	0.91	2.74
Tukey's values	Salinity levels at $P \leq 0.001 = 0.1965$							Salinity levels at $P \leq 0.001 = 0.2119$						
	Ecotypes at $P \leq 0.001 = 0.7377$							Ecotypes at $P \leq 0.001 = 0.7958$						

obtained (Fig. 3). Among these, cluster 1 had only control grass (ADPV1), while the remaining ecotypes were divided into three clusters. According to Table 1, cluster 2 gave the best performance in terms of leaf colour (6.99) followed by cluster 1 (5.58) and cluster 4 (5.25), while a minimum (4.83) leaf colour quality was recorded in cluster 3. The best-performing ecotypes in cluster 2 included RUDA7 (8.10) followed by RA3 (7.44) and FA5 (7.38).

Salinity of leaf rinseates (mg L^{-1})

The salinity of leaf rinseates of *Aeluropus lagopoides* ecotypes was significantly ($P \leq 0.001$) affected by various salinity levels. This is because different salinity levels significantly affected the leaf rinseates so the increase in salinity caused the grass leaves to excrete more salts. Maximum salinity was found in the leaf rinseates at 45 dSm^{-1} (0.64 mg L^{-1}) followed by 30 (0.53 mg L^{-1}), 75 (0.42 mg L^{-1}) and 15 dSm^{-1} (0.23 mg L^{-1}) while minimum salinity was recorded in the leaves at 60 dSm^{-1} (0.21 mg L^{-1}). To further elaborate the mean comparison of ecotypes, the data were subjected to cluster analysis. According to cluster analysis, cluster 2 had the highest mean value of leaf rinseate salinity (0.74 mg L^{-1}) followed by cluster 4 (0.28 mg L^{-1}) and 3 (0.24 mg L^{-1}) while the lowest salinity was observed in cluster 1 which included only control grass (ADPV1) with the lowest (0.15 mg L^{-1}) leaf rinseate salinity value. The best-performing ecotypes in cluster 2 included ZUDA2 (1.03 mg L^{-1}) followed by DADA1 (0.97 mg L^{-1}) and RA3 (0.77 mg L^{-1}).

Discussions

Climate changes have multidimensional effects on consequences of abiotic stress, which endanger the sustainability and productivity of agricultural systems. The modern agricultural system is also not safe from the adverse effect of abiotic stresses such as salinity which is considered the major factor affecting the productivity (Fahad and Bano 2012; Fahad et al. 2014a, 2015a, 2015b, 2016a, 2016b, 2016c, 2016d, n.d.; Adnan et al. 2018; Arif et al. 2017; Aziz et al. 2017b; Ghulam et al. 2017; Bakhat et al. 2018; Kamarn et al. 2017; Wajid et al. 2017; Yang et al. 2017; Turan et al. 2017; Turan et al. 2018; Akcura et al. 2019; Shahbaz et al. 2019; Sönmez et al. 2016). Soil salinity is an escalating problem worldwide, with nearly 10% of the earth's total land surface (954 Mha) covered with salt-affected soils, and up to 100 Mha salinity due to irrigation. Between 10 and 20 Mha of irrigated lands deteriorate to zero productivity each year due to salinity (Marcum and Pessarakli 2006). According to the Environment Agency Abu Dhabi (2009), 55% area of total UAE is recorded as increase in salinity between 2002 and 2008. The quality characters of grasses such as green cover, leaf colour and canopy stiffness are adversely affected by salinity. Halophytic grasses have adjustment techniques to combat these challenges as indicated by the excretion of salts via their leaves in terms of concentration of salts in leaf rinseates.

Green cover (1–10)

Most of the ecotypes showed resistance to salinity at 45 dSm^{-1} which is close to the salinity (54 dSm^{-1}) of seawater (Lee et al., 2002). The main feature of any turfgrass is the green cover or density. Thus, the higher the grass density, the higher will be the quality and aesthetic value. Since most of the ecotypes survived at a salinity of seawater level, they have the advantage over exotic cultivars of turfgrasses. The present results are in line with the findings of Shahba (2010) who carried out similar experiments on Bermuda grass cultivars for various salinity levels. Naz et al. (2010) also found

Table 3 Effect of different salinity levels (0–75 dSm^{-1}) on leaf colour (1–10) and leaf rinseate salinity (mg L^{-1}) of 50 *Aeluropus lagopoides* ecotypes and *Paspalum* (ADPV1; as control)

Ecotypes	Leaf colour (1–10) Salinity levels (dSm^{-1})							Leaf rinseate salinity (mg L^{-1}) Salinity levels (dSm^{-1})						
	0	15	30	45	60	75	Means	0	15	30	45	60	75	Means
BADA1	9.25	8.50	8.00	6.00	0.00	0.00	5.29	0.00	0.16	0.64	0.24	0.00	0.00	0.17
MADA1	9.75	9.00	9.00	5.00	6.13	4.25	7.19	0.00	0.19	0.56	0.69	0.90	2.21	0.76
JD1	9.50	9.50	6.50	6.00	5.25	3.25	6.67	0.00	0.19	0.62	0.75	0.86	1.62	0.67
FA1	9.75	8.75	6.75	6.38	0.00	0.00	5.27	0.00	0.19	0.62	0.65	0.00	0.00	0.24
FA5	10.00	8.50	7.00	6.00	6.75	6.00	7.38	0.00	0.16	0.51	0.61	0.86	2.25	0.73
DASA1	9.25	8.00	6.75	6.50	5.38	0.00	5.98	0.00	0.16	0.51	0.69	0.77	0.00	0.36
FA2	10.00	8.50	7.50	6.00	6.63	5.13	7.29	0.00	0.25	0.63	0.65	0.74	1.77	0.67
ZUDA1	10.00	8.50	6.50	6.25	0.00	0.00	5.21	0.00	0.26	0.51	0.67	0.00	0.00	0.24
RA3	10.00	9.00	8.00	6.25	5.88	5.50	7.44	0.00	0.17	0.64	0.72	0.88	2.22	0.77
RA1	9.75	8.75	6.25	7.00	0.00	0.00	5.29	0.00	0.24	0.46	0.66	0.00	0.00	0.23
RA2	9.75	9.00	6.75	6.75	0.00	0.00	5.38	0.00	0.24	0.64	0.72	0.00	0.00	0.27
ZUDA2	9.25	8.00	6.00	6.50	5.25	4.88	6.65	0.00	0.25	0.67	0.72	0.90	3.66	1.03
ZUDA3	9.50	8.50	7.00	6.75	0.00	0.00	5.29	0.00	0.21	0.67	0.76	0.00	0.00	0.27
ASA-1	9.75	8.00	6.00	6.00	0.00	0.00	4.96	0.00	0.27	0.65	0.73	0.00	0.00	0.28
FA3	9.75	8.25	6.00	7.13	0.00	0.00	5.19	0.00	0.25	0.62	0.72	0.00	0.00	0.27
FA4	9.25	8.50	7.25	6.13	5.50	5.00	6.94	0.00	0.27	0.49	0.67	0.90	2.24	0.76
RUA2	9.00	6.75	4.50	6.00	0.00	0.00	4.38	0.00	0.25	0.68	0.54	0.00	0.00	0.24
RUDA1	10.00	7.75	6.75	6.00	0.00	0.00	5.08	0.00	0.26	0.42	0.67	0.00	0.00	0.23
RUDA2	10.00	9.25	8.00	6.13	0.00	0.00	5.56	0.00	0.22	0.44	0.64	0.00	0.00	0.22
RUDA3	10.00	9.00	7.50	7.00	0.00	0.00	5.58	0.00	0.26	0.39	0.64	0.00	0.00	0.22
RUDA4	9.75	7.00	7.50	5.50	0.00	0.00	4.96	0.00	0.18	0.50	0.64	0.00	0.00	0.22
UA1	9.75	6.75	7.50	5.75	0.00	0.00	4.96	0.00	0.25	0.52	0.66	0.00	0.00	0.24
RUA3	9.75	6.75	6.00	5.75	0.00	0.00	4.71	0.00	0.27	0.54	0.64	0.00	0.00	0.24
RUADA1	9.00	7.25	7.25	6.00	0.00	0.00	4.92	0.00	0.25	0.41	0.65	0.00	0.00	0.22
MADA2	9.50	3.75	6.25	3.38	0.00	0.00	3.81	0.00	0.24	0.29	0.62	0.00	0.00	0.19
BADA2	9.00	6.50	5.50	5.75	0.00	0.00	4.46	0.00	0.27	0.60	0.69	0.00	0.00	0.26
RUDA5	9.50	7.00	7.00	5.50	0.00	0.00	4.83	0.00	0.24	0.56	0.65	0.00	0.00	0.24
RUDA6	9.75	8.25	6.25	6.13	5.38	0.00	5.96	0.00	0.21	0.49	0.61	0.89	0.00	0.37
RUDA7	10.00	9.50	8.75	6.00	7.38	7.00	8.10	0.00	0.16	0.44	0.58	0.96	1.97	0.69
RUA1	9.00	8.25	5.75	6.63	0.00	0.00	4.94	0.00	0.21	0.44	0.57	0.00	0.00	0.20
RA4	10.00	8.00	6.25	6.00	0.00	0.00	5.04	0.00	0.26	0.40	0.65	0.00	0.00	0.22
NSDA1	10.00	6.75	6.50	5.13	0.00	0.00	4.73	0.00	0.24	0.50	0.63	0.00	0.00	0.23
NSDA2	10.00	8.00	7.50	5.25	0.00	0.00	5.13	0.00	0.20	0.60	0.65	0.00	0.00	0.24
NSDA3	9.75	9.00	7.50	7.88	0.00	0.00	5.69	0.00	0.24	0.57	0.74	0.00	0.00	0.26
BAADA1	10.00	7.25	6.00	7.25	0.00	0.00	5.08	0.00	0.25	0.67	0.71	0.00	0.00	0.27
BAADA2	10.00	4.75	5.00	4.00	0.00	0.00	3.96	0.00	0.26	0.42	0.64	0.00	0.00	0.22
BAADA3	9.00	7.00	4.00	5.13	0.00	0.00	4.19	0.00	0.26	0.47	0.59	0.00	0.00	0.22
BAADA4	10.00	8.00	5.00	7.13	1.25	0.00	5.23	0.00	0.19	0.47	0.60	0.84	0.00	0.35
ZUDA4	10.00	8.25	4.75	6.63	0.00	0.00	4.94	0.00	0.26	0.45	0.63	0.00	0.00	0.22
ZUDA5	9.25	7.50	5.25	6.63	0.00	0.00	4.77	0.00	0.26	0.47	0.66	0.00	0.00	0.23
ZUDA6	10.00	8.50	6.50	6.75	0.00	0.00	5.29	0.00	0.22	0.66	0.67	0.00	0.00	0.26
RUADA2	9.75	7.25	6.25	6.38	0.00	0.00	4.94	0.00	0.26	0.64	0.66	0.00	0.00	0.26
JADA1	9.25	7.00	7.50	6.50	0.00	0.00	5.04	0.00	0.27	0.66	0.70	0.00	0.00	0.27
JADA2	10.00	7.75	6.00	6.63	0.00	0.00	5.06	0.00	0.27	0.66	0.46	0.00	0.00	0.23
GDA1	9.25	7.25	7.00	6.38	0.00	0.00	4.98	0.00	0.22	0.64	0.71	0.00	0.00	0.26
SAADA2	9.00	7.00	6.75	5.63	0.00	0.00	4.73	0.00	0.19	0.54	0.64	0.00	0.00	0.23

Table 3 (continued)

SAADA1	10.00	6.75	7.25	6.50	0.00	0.00	5.08	0.00	0.24	0.50	0.61	0.00	0.00	0.23
DADA1	10.00	5.75	7.25	5.38	5.38	3.50	6.21	0.00	0.24	0.50	0.61	0.89	3.57	0.97
TADA1	9.25	7.00	6.25	6.25	0.00	0.00	4.79	0.00	0.24	0.41	0.65	0.00	0.00	0.22
TADA2	9.00	7.00	6.25	6.13	0.00	0.00	4.73	0.00	0.24	0.64	0.63	0.00	0.00	0.25
ADPV1	9.75	8.50	5.00	6.50	3.75	0.00	5.58	0.00	0.05	0.14	0.27	0.45	0.00	0.15
Means	9.64	7.75	6.58	6.12	1.37	0.87	5.39	0.00	0.23	0.53	0.64	0.21	0.42	0.34
Tukey's values	Salinity levels at $P \leq 0.001 = 0.2078$							Salinity levels at $P \leq 0.001 = 0.0209$						
	Ecotypes at $P \leq 0.001 = 0.7801$							Ecotypes at $P \leq 0.001 = 0.0783$						

similar salinity effects on native grasses. Chen et al. (2009) found that increasing the salinity levels adversely affected the green cover of four salt-tolerant grasses which also support these findings.

Canopy stiffness (1–10)

Most of the ecotypes did not survive when the salinity was increased to 60 or 75 dSm^{-1}. However, some of them did survive and gave less than 5 for canopy stiffness (Table 2), which is the acceptable range as mentioned by Mintenko and Smith (2001). The canopy stiffness/softness is the main quality character of a turfgrass, which was achieved by most of the ecotypes even better than control grass (*Paspalum vaginatum*). Most of the ecotypes, though adversely affected, survived up to 45 dSm^{-1} levels but ceased to grow above that level. It may be due to the adaptation strategy of ecotypes at this stage. Hu et al. (2012) also found a similar trend of decreasing grass quality by increasing salt stress. The results are in line with the findings of Tuttolomondo et al. (2007) who also found significant variations in the response of various native ecotypes. The variations and diversity found in ecotypes in terms of canopy stiffness could be used in future breeding programs as stated by Dilaver (2013). Romani et al. (2002) identified similar better performing ecotypes for future breeding.

Leaf colour (1–10)

The performance of ecotypes reduced significantly with the increase in salinity, such that beyond the 45-dSm^{-1} salinity level, most of the ecotypes ceased to survive, and those which did survive had stunted growth. However, those had better performance than the control grass (ADPV1) in terms of salt tolerance. The control grass survived up to 60 dSm^{-1} salinity with unacceptable (3.75) leaf quality but did not withstand a higher salinity of 75 dSm^{-1}. Leaf colour was negatively affected by increasing salinity levels as shown in the means (Table 3). Pooya et al. (2013) found a significantly different response from various native grasses, which comply with these results. Similarly, Romani et al. (2002) also found significant effects while evaluating 226 native ecotypes.

Salinity of leaf rinseates (mg L^{-1})

Comparing the effect of salinity levels on ecotypes (Table 3), it is indicated that the highest value of salts in leaf rinseates was observed at the salinity level of 45 dSm^{-1} then 30, 75 and 15 dSm^{-1} which is not regular while 60 dSm^{-1} of leaf rinseates was minimum which shows that at high salinity level the ecotypes may lose the ability to combat and they are in the transition stage to get higher salts in the next stages as described by Hu et al. (2012). The concentration of salts in leaf rinseates indicates the salt gland activity available at the leaves of halophytes such as *Aeluropus lagopoides* and exclusion of salts from leaves is one of the adaptation strategies in these grasses as described by Barhoumi et al. (2008) who found that no serious damages occurred at higher salt concentrations in irrigation water because of using this phenomenon. The same mechanism has been defined by Rumman (2012) as well. These results are confirmed by Gulzar et al. (2003) who worked on the *Aeluropus lagopoides* grass and found that increasing salinity treatment leads to increased salt concentration in leaves.

Conclusions

Conclusively, the native grasses of UAE have potential to be used for turf purposes. *Aeluropus lagopoides* species have ecotypes with significant variations and variabilities, which show that they have the adaptive capacity towards climate change. Salinity issues of UAE could be managed by utilization of the local grasses in public landscapes; even seawater could be used in worse conditions. *Aeluropus lagopoides* needs further genetic improvement and research work so that it can be released as the first turf variety in the Middle East. Further research work is recommended on native ecotypes of the grass to find out their potential as donors of salt-tolerant characteristic for improving other crops in breeding programs.

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