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Productivity of Saltbush (*Atriplex*) Species Under Saline Soil and Water Conditions in Oman

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إنتاج شجيرات الرغل المتحملة للملوحة تحت ظروف التربة والمياه المالحة في عمان

الملخص: أجريت تجربة ملاحظة لنوعين من الشجيرات المتحملة للملوحة وهما نوع كوالي (*Atriplex lentifornis* L.) وفورونيق (*Atriplex canescens* L.) - وكلاهما من الأشجار المعمرة من أمريكا الشمالية- وذلك بهدف تقييم الإنتاجيه وجودة العلف، وذلك ابتداء من مايو ١٩٩٥م وحتى مايو ١٩٩٧م. وقد تم ذلك في المديرية العامة للبحوث الزراعية بسلطنة عمان تحت نظام الري بالتنقيط وبماء ري تزيد ملوحته عن ١٠ ديسيسمين/م وبأدنى معاملات فلاحية. أظهرت النتائج تفوقا معنويا لنوع كوالي على النوع فورونيق في كل من الجزات الخمس حتى ديسمبر ١٩٩٦م، ولكل صفة تم أخذها في التقييم، بينما كان النوع فورونيق متفوقا على النوع كوالي في الجزة السادسة فقط بالنسبة لوزن العلف. أنتج النوع كوالي ٥٣,٢٩ كجم/للنبات من مجموع العلف الأخضر أي ما يعادل ٥٩,٢١ طن/هكتار بالمقارنة مع ٣١,٢٧ كجم/للنبات (٣٤,٧٥ طن/هكتار) من مجموع العلف الأخضر للنوع و فوروينق خلال سنتين تقريبا (٧٤٧يوما). كان هناك فرقا معنويا بين إنتاجية الجزة وبين تأثير التداخل (الأنواع والجزات) بالنسبة لجميع الصفات. أشارت الدراسات حول التركيب الكيميائي للنوعين أن النوع كوالي يملك تركيزا أعلى للصوديوم والبوتاسيوم والكلور والكالسيوم بالمقارنة مع النوع فوروينق. كما أظهرت دراسات القيمة الغذائية للنوعين أن المادة الخضراء تحتوي على ٣٤,٣٠% من المادة الجافة مقارنة مع ١٩,٨% لحشيشة الرودس والتي تعتبر الأكثر انتشارا في السلطنة. وعلى أساس المادة الجافة فإن الرغل يحتوي على ٩,٤% من البروتين الخام و ٢٤% من الألياف و ١,٥% من مستخلص الإيثر و ١٩,٦% من الرماد و ٤٥,٥% من مستخلص النيتروجين الحر. يمكن اعتبار الرغل مصدرا مغذيا ورخيصا لإضافة النيتروجين إلى العليقة ولكن نسبة الرماد كانت عالية. يعتبر الرغل جيدا لإنتاج العلف في سلطنة عمان كما هو الحال في الدول الأخرى وبالتالي يمكن زراعته في المناطق الغير صالحة للزراعة والأراضي المتأثرة جزئيا بالملوحة أو في حالة تملح مياه الري.

ABSTRACT: A field observation trial was carried out at Agricultural Research Center, Rumais, Sultanate of Oman to evaluate the productivity and forage quality of two species of Saltbush viz. Quali saltbush (*Atriplex lentiformis* L.) And Fourwing saltbush (*Atriplex canescens* L.), both are perennial and of North American origin. Plants were irrigated with brackish water (EC>10.00 dS/m) under drip irrigation and grown with minimum tillage and sub-optimum management conditions. Biomass production was evaluated in terms of five characters i.e. plant height, plant width, plant volume, green fodder yield/plant and green fodder yield/ha over the experimental period (747 d). *Atriplex lenformis* produced a total green fodder yield of 53.29 kg/plant equivalent to 59.21 t/ha as compared to that of 31.27 kg/plant (34.75 t/ha) produced by *Atriplex canescens*. The cut yields and interaction effects (between the species and cuts) were also significantly different with respect to all the characters. Chemical composition of the *Atriplex* species indicated that *A. lentiformis* had higher levels of Na, K, Cl and Ca as compared to *A. canescens*. The studies of nutrient composition of bulk samples of the *Atriplex* species revealed that the fresh material contained 34.30% dry matter. On dry matter basis, the *Atriplex* material had 9.40% crude protein (CP), 24.00% crude fiber (CF), 1.5% extract (EE), 19.60% ash and 45.50% nitrogen free extract (NFE). Despite its high ash content, *Atriplex* material appeared to be a nutritious and cheap source of nitrogen complementation.

The Sultanate of Oman, being the second largest country in the Arabian Peninsula, has 2.3 million hectares of land suitable for agriculture (Anonymous, 1990) while 101346 hectares have been considered as agricultural land of which 61530 ha is currently under cultivation with fodders, fruits, vegetables and field crops (Anonymous, 1995). Of late, the farms near the coast of Batinah have developed both water and soil salinity owing to prolonged drought over the years, over pumping of ground water and sea water intrusion. Where as in Interior areas/deserts like Nejd and Adam, gypsiorthids, calciorthids, salorthids or saline basins in common. As soil and ground water resources are becoming extremely saline, adequate resources of good quality irrigation water have become limited. Rainfall is scanty to support crop production. Natural vegetation is very scarce while grazing is widespread in the range lands. Increasing need for the production of food, fodder and fuel from plants and decreasing availability of fresh water for agriculture use would render the use of low quality saline water and soil for crop production. The Sultanate has now abundant sources of such water that could be used for irrigating crops. However, the salinity of such water and soil has exceeded the limit tolerable by the economic field or food crops. The normal approach to tackle this problem is to breed genotypes tolerant to desired level of salinity in important crop species of the country. Another approach could be to make use of the halophytic plant species growing under naturally saline conditions as they are tolerant to high salinity (Flowers *et al.,* 1986). The Sultanate has fortunately few of such halophytic species like *Atriplex* (*A. farinosum* and *A. coriacea*) and *Salsola* (*S. forskalli*, *S. rubescens*, *S. spinescens*, *S. barysoma* and *S. bottae*) sporadically distributed in different agro-ecological regions (Sankari, 1983; Miller and Morris, 1987). While halophytes can be used in grazing by camels, sheep, goats, cattle etc. as supplementary feed during unfavorable conditions (Koocheki, 1993), their economic uses in reclamation and rehabilitation have also been described (Le Houerou, 1993). Within this decade, substantial progress has been made in evaluating halophytes for their potential as crop plants in many countries like USA, Australia, Pakistan, Israel, Iraq, Iran, Morocco, Libya, Egypt, Saudi Arabia, Algeria, Syria, Jordan, Tunisia, Yemen, Spain, South Africa, Chile, etc. through experimental demonstrations and large scale development operations (Aronson, 1985; Malcolm, 1986; O'Leary, 1988; Choukr-Allah, 1993). Ibrahim (1998) reported that Quali saltbush (*Atriplex lentiformis* L.) and Fourwing saltbush (*Atriplex canescens* L.) could be succesfully grown under high salt conditions. The present investigation was carried out in the observation nursery of these two *Atriplex* species established in Farm No. 3 of Agriculture Research Center, Rumais, Sultanate of Oman, to know the potential of biomass production of these two species and their forage quality under drip irrigation with minimum tillage and sub-optimum management conditions.

Materials and Methods

The seedlings of two saltbush received from ACSAD, Syria viz. Quali saltbush (*Atriplex lentiformis* L.) and Fourwing saltbush (*Atriplex canescens* L.) were transplanted on 15.05.94 in pits of 30 cm diameter and 60 cm depth in an unreplicated Observation Nursery that comprised three rows for each species with 3m spacing between rows and plants. Each species had 24 plants with 8 plants in each row that received irrigation through a drip system with water of EC ranging from 10.00 to 15.00 dS/m for a duration of two hours, twice a week in the winter and thrice a week in the summer. The crop was subjected to minimum tillage in the beginning with just ½ kg organic manure per pit and had sub-optimum management with no inorganic fertilizer application. All the shrubs were pruned uniformly to 60 cm height on 15.05.95 for recording the observations on growth and yield attributes to initiate studies. The values of some physical and chemical characteristics of the experimental soil and chemical characteristics of irrigation water are respectively presented in Tables 1 and 2.

The first cut harvest was done during December 1995 after about seven months when the shrubs began to bloom and fruit, by clip cutting the twigs of pencil thickness along with the leaves; the fresh weight of the green fodder was recorded in kg for each plant. Subsequent cuts were taken at a time that indicated fairly good regrowth of fresh twigs and leaves. At the fourth cut, each plant was subjected to heavy pruning retaining its height to about 60 to 70 cm which ensured uniform canopy growth in all plants.

TABLE 1

Values of some physical and chemical characteristics of the experimental soil.

Physical Characteristics	
Course sand (%)	20.80
Fine sand (%)	67.30
Silt (%)	2.40
Clay (%)	9.70
Texture	Sand
Chemical Characteristic(S)	
EC_e (dSm^{-1})	11.54
pH	7.70
Soluble Cations (meq/100g)	
Ca	0.50
Mg	0.80
Na	1.37
K	0.04
SAR	1.70
Soluble Anions (meq/100g)	
HCO_3	0.50
Cl	1.00
SO_4	4.21
Av.P (ppm)	traces
N %	0.02

TABLE 2

Values of some chemical characteristics of irrigaton water.

EC (dSm^{-1})	14.63
pH	7.00
Cations (meq/1)	
Ca	17.80
Mg	52.10
Na	42.00
K	2.50
SAR	7.10
Anions (meq/1)	
HCO_3	1.70
CO_3	0.40
Cl	100.50
SO_4	11.80

The observations on plant height (cm) and diameters (cm) (North-South and East-West) were recorded at the time of harvest. Plant width (cm) was estimated by taking an average of the two diameters and plant volume (m^3) was computed by multiplying plant height (cm) with diameters (cm) (North-South and East-West). Samples of the first and last harvest were taken to the laboratory for proximate (nutritive value) (AOAC, 1984) and chemical (minerals) (Chapman and Pratt, 1961) analyses, respectively. The data on agronomic attributes was subjected to statistical analyses as two factor-CRD with two *Atriplex* species as factor A, cuts (harvests) as factor B and plants as repetitions, according to the methods of Gomez and Gomez (1984) using MSTAT computer program.

Results and Discussion

The cut-wise mean data on five characters viz. plant height (cm), plant width (cm), plant volume (m^3), green fodder yield/plant (kg) and per hectare yield estimate (t/ha) of *Atriplex lentiformis* and *Atriplex canescens* along with required statistical parameters are given in Table 3.

The results revealed that *Atriplex lentiformis* was significantly superior to *Atriplex canescens* in each of five cuts till December, 1996 for each character considered for evaluation ($p<0.01$), while in the sixth cut *Atriplex canescens* was superior to *Atriplex lentiformis* only with respect to forage yield ($p<0.01$). *Atriplex lentiformis* produced a total green fodder yield of 53.29 kg/plant equivalent to 59.21 t/ha as compared to that of 31.27 kg/plant (34.75 t/ha) produced by *Atriplex canescens* in about two years (747 d). The cut yields and interaction effects (between the species and cuts) were also significantly different with respect to all the characters ($p<0.01$). The total yield in both species was contributed most by the first cut in 211 d, fourth cut in 119 d and sixth cut in 172 d. In the case of *Atriplex lentiformis*, the first two cut periods that spanned from May 1995 to March 1996 (307 d) had a lower contribution of green fodder (20.16 t/ha) as compared to those of latter two cuts between April 1996 and September 1996 (23.11 t/ha in 176 d). This was because seasonal differences existed between the two growth periods. The former two cut yields were the outcome of crop performance mostly in the winter season (low temperature) while the latter were obtained during summer season (high temperature). In general, *Atriplex* species are known to have higher rate of growth and development in the summer than in the winter (Choukr-Allah, 1991; Qureshi *et al.,* 1993). Similar trends were also evident for the green fodder yields of 1 & 2 cuts (11.17 t/ha in 307 d) and 3 & 4 cuts (8.16 t/ha in 176 d) in the case of *Atriplex canescens*. In *Atriplex lentiformis*, high green fodder production in the summer season was attributed to higher plant volume (10.14 to 16. 71 m^3), plant height (203.54 to 238.54 cm) and plant width (217.92 to 257.42 cm) as compared to their values in the winter: plant volume - 10.73 to 12.84 m^3; plant height - 161.83 to 225. 83 cm and plant width 223.87 to -232.50 cm. However, in the case of *Atriplex canescens*, these characters had not been affected due to seasonal differences but they had developed a greater number of branches (secondary, tertiary, etc.) with narrow leaves during the summer thereby resulting in comparatively higher biomass as compared to that in winter. *Atriplex lentiformis* was taller (161.83 to 238.54 cm) with greater plant width (217.92 to 295.37 cm) and volume (10.14 to 19.81 m^3). This species was also found superior with respect to plant volume and fresh weight to other species under irrigated (Choukr-Allah, 1991) and rainfed (Choukr-Allah 1991; Qureshi *et al.,* 1993) conditions. The fresh weight per plant and per hectare dry matter yield estimates for the *Atriplex* species in the study under both saline soil and water conditions were comparable with dry matter yields reported by earlier workers (Le Houreou, 1993; Qureshi *et al.,* 1993). In the native plant stands under good management, *Atriplex* species are known to produce 3 to 5 t/ha/year while under less optimum conditions the yields would be reduced by half (Franclet and Le Houerou, 1971, and Le Houerou *et al.,* 1982). However, under irrigation, dry matter yields vary between 5 to 20 t/ha/year depending upon the species, soil and management (Le Houreou, 1991).

The studies on chemical composition of the *Atriplex* species indicated that *A. lentiformis* had

TABLE 3

Cut-wise means of five characters of Atriplex lentiformis and Atriplex canescens (recorded since 15.05.95).

			Atriplex lentiformis					Atriplex canescens				
Cut No.	Date of Cut	Period of Growth	Plant Height (cm)	Plant Width (cm)	Plant Volume (m^3)	Green Fodder yield/plant (kg)	Green Fodder Yield t/ha (estimate)	Plant Height (cm)	Plant Width (cm)	Plant Volume (m^3)	Green Fodder yield/plant (kg)	Green Fodder Yield t/ha (estimate)
1	12.12.95	211	161.83	223.87	10.73	15.61	17.34	138.12	185.42	5.08	8.77	9.75
2	18.03.96	96	225.83	232.50	12.84	2.53	2.82	112.08	139.79	2.46	1.27	1.42
3	14.05.96	57	235.54	257.42	16.71	4.57	5.07	123.54	148.12	3.04	1.59	1.76
4	10.09.96	119	203.54	217.92	10.14	16.23	18.04	112.21	144.58	2.64	5.76	6.40
5	11.12.96	92	226.46	243.21	13.71	3.72	4.13	122.75	147.17	2.88	1.48	1.64
6	31.05.97	172	214.83	295.37	19.81	10.63	11.81	161.71	243.34	10.75	12.40	13.78
Total Green Fodder Yield (747 days)			—	—	—	53.29	59.21	—	—	—	31.27	34.75
Green Fodder Yield/ Year (365 days)			—	—	—	—	28.93	—	—	—	—	16.97
Dry MatterYield/ Year (On the basis of 34.30% DM)			—	—	—	—	9.92	—	—	—	—	5.82

Statistical Parameters

Characters	LSD (5%) for Species	LSD (5%) for Cuts	LSD (5% for Interaction)
Plant Height	7.56	13.10	18.53
Plant Width	11.58	20.05	28.36
Plant Volume	1.33	2.33	3.27
Green Fodder Yield/Plant (kg)	0.99	1.74	2.46
Green Fodder Yield (t/ha) (estimate)	1.11	1.93	2.73

TABLE 4

Chemical composition of A. lentiformis and A. canescens.

Species	K%	Na%	Cl%	Ca%	K/Na
A lentiformis	2.01	2.77	11.60	1.80	0.72
A. canescens	1.57	1.40	3.60	1.18	1.12

accumulated higher levels of Na, K, Cl and Ca as compared to *A. canescens* (Table 4) which is contrary to the findings of Ibrahim (1998) who studied salt tolerance of *Atriplex* species during germination and early growth. However, *A. canescens* could be considered to be comparatively more tolerant to salinity based on the higher K/Na level (Feigin, 1985). The studies on nutrient composition of bulk samples of the *Atriplex* species revealed that the fresh material contained 34.30% dry matter as compared to 19.80% in case of Rhodes grass (*Chloris gayana* L.) (Anonymous, 1993), which is a popular perennial forage in the Sultanate (Table 5). On dry matter basis, the *Atriplex* material had 9.40% crude protein (CP), 24.00% crude fiber (CF), 1.50% ether extract (EE), 19.60% ash and 45.50% nitrogen free extract (NFE). *Atriplex* species could be considered similar in the nutritive value to Rhode grass due to its low CF content and could be a cheap source of nitrogen complementation but plant material contained more ash. Studies on feeding values of *Atriplex* fodder elsewhere have redealed that it contained relatively low energy and high ash content (Le Houreou, 1992). Nevertheless, along with high ash and fiber contents, relatively high CP has also been found (Warren and Casson, 1993). Various studies on the feeding value with *Atriplex* as forage or as feed for animals such as sheep or goats, indicated that *Atriplex* species are valuable forages that provide a cheap source of nitrogen complementation and can be best utilized as a supplement to those feeds high in energy such as cereal grains or conventional green fodders (Choukr-Allah, 1993; Nawaz and Hanjra, 1993; Warren and Casson, 1993).

Thus, Atriplex species have been found to be productive in providing forage yields comparable to those in other countries like USA, Australia, Spain, Pakistan, Iran, Morocco, Syria, Libya etc. that are well engaged in the utilization of the halophytes and hence these could be grown in environments which are unsuitable for agriculture crops, particularly in the salt affected lands or with saline irrigation water.

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TABLE 5

Nutrient composition of Atriplex species (bulk sample) in comparison with Rhodes grass.

Plant Species	Contents (% DM-basis)					
	Dry Matter (%)	Crude Protein (%)	Crude Fiber (%)	Ether Extract (%)	Ash (%)	Nitrogen Free Extract (%)
Atriplex Species	34.30	9.40	24.00	1.50	19.60	45.50
Rhode grass (Anonymous, 1993)	19.80	8.80	34.00	1.80	12.60	42.80

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