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Some Potential Plants of Coastal and Inland Salt Affected Soils and Their Relation to Soil Properties

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Abstract: The main objective of this study was to survey and collect range plants species capable of growing in severe salt affected lands and under saline irrigation to save fresh groundwater for other beneficial purposes. To achieve this objective, nine plants were collected in the coastal (Arabian Gulf, Red Sea) and inland (Al-Qaseem region) salt affected soils of Saudi Arabia to obtain information for the rehabilitation of degraded lands as sustainable rangelands for range animals. Soil samples were collected from 0-30 and 30-60 cm depth and analyzed for physical and chemical composition. Plant samples were also analyzed for N, P, Na, K, Ca and Mg. Plant species found in abundance were identified as *Aeluroapus lagopoides*, *Avicennia marina*, *Juncus rigidus*, *Nitraria retusa*, *Panicum turgidum*, *Salsola* sp., *Suaeda vermiculata*, *Salicornia europaea* and *Tamarix amplexicaulis.* Statistically evaluation of results using ANOVA and regression techniques showed negative correlation between soil salinity and N, P and K (r = -0.09 to -0.67) and positive (r = 0.11- 0.73) for Ca, Mg and Na. Similarly, the correlation was negative between soil mineral contents (-0.18 to -0.31) and the plant composition for K, Ca, Mg and positive for Na ion (r = 0.54) only. Nutrient value of some plants of forage importance were significantly affected by high soil salinity. Plants such as *Juncus rigidus*, *Nitraria retusa*, *Panicum turgidum*, *Suaeda vermiculata*, *Salicornia europaea* and *Tamarix amplexicaulis* seems to have an excellent potential for the rehabilitation of degraded salt affected lands in Saudi Arabia.

Key words: Coastal vegetation, plant communities, arid environment, soil salinity, rehabilitation, ecology

INTRODUCTION

The Kingdom of Saudi Arabia is a large country with a total land area of around 2.2×10^6 km^2. It is located at 16° N and 32° E. Its climate is characterized by long, hot, dry summer and mild, cool and short winter with a mean annual rainfall of 70 mm. The agricultural lands of Saudi Arabia, which are coarse textured containing salts to varying degrees and mostly irrigated with saline groundwater, are not considered suitable for some of the commonly grown crops. Besides, the soils have low organic matter, high percolation rate, high salinity, low water holding capacity and poor fertility due to arid climate. This situation is further aggravated due to encroachment by wind blown sand over potential agricultural lands, roads, pipe lines and other important infrastructures (Abdulwahid, 1979; Aziz and Abdulwahid, 1977; El-Khatib, 1974; Abolkhair, 1981). Establishment of windbreaks and re-vegetation of sandy desert offers sustainable approach for the rehabilitation of degraded lands (Arnest, 1942; El-Khatib, 1974; Fagotto, 1987). Al-Homaid and Khan (1994) observed in a field study that the production and growth of *Prosopis juliflora* under moderate watering was similar to that produced by low watering with manure treatment on the upwind slope of a parabolic dune area. The deleterious effects of groundwater salinity were noticed in the form of reduction in survival rates during dry period without irrigation. They also concluded that *P. juliflora* can be successfully grown with moderate irrigation in an open sandy desert. Many studies have been conducted on the nutrition evaluation (Al-Jaloud *et al*., 1994), chemical composition (Al-Noaim *et al*., 1991) of some range plants and their relation to soil properties (Al-Jaloud *et al*., 2001) in Saudi Arabia. Boer (1996) investigated the soil indicator plants along the Saudi Gulf coast of the Arabian Gulf. He found that the soils of different vegetation types of the Saudi Arabian Gulf were dominated by mangrove, salt marsh and desert plant communities (*Avicennia marina*, *Arthrocnemum macrostachyum*, *Salicornia europea*, *Halocnemum strobilaceum.* Marcar *et al.* (2003) studied the survival and growth of the tree species and provenances in response to salinity on a discharge site. They found significance differences between species with *E. occidentalis* and *A. stenophylla* showing no growth decline upto EC_e of 10 dS m^{-1}, while most other species showed varying rates of decline with increasing salinity. Similarly, Marcar *et al.* (2000) evaluated tree establishment treatments on saline seeps near Wellington and Young in New South wales. They found that the treatments generally increased basal stem diameter or stem diameter at breast height and crown volume, but the differences were usually no significant. Simpfendorfer and Harden (2000) stated that the addition of calcium as either $CaCO_3$ or $CaCl_2$ to 3 artificial media increased *in vitro* growth of 15 isolates from 20-135%. Calcium was also shown to increase the severity of root disease caused by 6 isolates of P. clandestine by up to 100% in a glasshouse experiment. Noaman and El-Haddad (2000) studied the response (growth and biomass production) of some halophytes to different levels of salinity. They stated that these halophytes species can be grown productively at a leaching fraction between 0.25 and 0.50 when salinity of irrigation water is less than 20 g L^{-1}. Mensah *et al.* (2006) evaluated the effect of salinity on germination, growth and yield of five groundnut genotypes. They revealed that salinity significantly delayed germination and also reduced the final percentages at electrical conductivities greater than 2.60 dS m^{-1}. Seedling emergence, radicle elongation, plant height and dry weight also tended to decrease with increasing salinity. Khan *et al.* (2000) conducted an experiment on the effects of salinity on growth, water relations and ion accumulation of the sub-tropical perennial halophyte, *Atriplex griffithii* var. stocksii. They concluded that plant total dry weight was significantly inhibited at 360 m M NaCl in sand culture in plant growth chamber. The Na and Cl content in both shoots and roots increased with increases in salinity. Increased treatment levels of NaCl induced decreases in Ca, K and Mg in Plants.

Major factors limiting the sustainable rehabilitation of degraded lands in an arid environment are shortage of fresh water for irrigation, low organic matter, high salinity/sodicity, low fertility, poor drainage and high salinity of groundwater. Besides, there are highly salt affected inland and coastal areas which are defined as sabkhas (land with high watertable and high salt concentration or flat salty marsh). There are few plant communities which grow successfully in these salt affected lands and sandy deserts. Knowledge about the survival of these plants may provide an opportunity for successful rehabilitation of degraded lands as range lands or pastures for the survival of range animals. Information on the ecology and physiology of these plants and their interaction with soil environment is very limited. The main objective of this study is to gather some information about plants of coastal and inland salt affected areas and their relation to the soil environment for the development of sustainable range lands in an arid environment.

Table 1: Soil temperature (°C) at 5 cm depth in Jubail area

Month	Minimum	Maximum	Mean
January	12.7	19.3	16.0
February	13.3	22.0	17.7
March	18.6	26.7	22.3
April	24.3	34.3	28.9
May	30.0	39.3	34.0
June	31.7	40.6	35.3
July	33.0	40.6	36.7
August	32.0	39.0	35.7
September	29.3	35.3	32.0
October	22.7	30.0	26.0
November	19.3	22.3	20.0
December	11.7	18.0	14.7

Amertech (1984)

MATERIALS AND METHODS

A field survey was carried out during 2005 of inland sabkha (Al-Qaseem region) and salt affected soils of the coastal areas in the Eastern (Qatif. Al-Oquir, Ras Tanura, Safwa) and the Western (Jeddah. Al-Madinah Al-Munawarah) Provinces, Kingdom of Saudi Arabia. Plants were collected, identified and classified according to the nomenclature procedure of Mandaville, (1990). The soil samples were collected from 0-30 and 30-60 cm depth of soil in the vicinity of different plants for soil salinity, mineral contents and textural class to develop relation between plants mineral composition and the soil characteristics.

The climatic data of the various regions was also collected from different meteorological stations of Ministry of Agriculture and Water (MAW, 2004). Mean annual rainfall in the study area ranges between 70-130 mm and is sporadic. Normally, rainy season extends from November to April during winter while during summer the rainfall is nil. The study areas are underlain by hard limestone varying from 0.5 m to more than 3 m deep, soil coarse to medium texture mostly covered with sand and have shallow groundwater table (Depth ranges between 1-10 m in different areas. The maximum mean soil temperature was more than 35°C in July with minimum as 16°C in the month of January. However, the maximum air-temperature in summer exceeds 50°C and reaches close to 70°C on the soil surface. The soil temperature measured at 5 cm depth by Amertech (1984) is presented in Table 1.

RESULTS AND DISCUSSION

Description of plants: The plants collected during investigation belong to the families Poaceae, Avicenniaceae, Juncaceae, Zygophyllaceae, Gramineae, Chenopodiaceae and Tamaricaceae. Description of each plant species in given in Table 2.

Table 2: Description of various plants collected from different regions

Plant species	Location	Family	Description
Aeluroapus lagopoides	Al-Oquer	Poaceae	Halophyte, can tolerate salinity upto 56 dS m^{-1}, occurs in wet area and sabkhas with a limited use as fodder.
Avicennia marina	Al-Qatif	Avicennaceae	Halophyte, dominant mangrove swamps may extend into streams and fresh water rivers, salinity tolerance upto sea water level (25-35 thousand mg L^{-1}), used as fuel, planks and boat ribs.
Juncus rigidus	Al-Qatif	Juncaceae	Perennial herb with round stem mostly found in poorly drained and salt marshes and near coastal areas.
Nitraria retusa	Ras-Tanura	Zygophyllaceae	Xerophyte shrub, arid land plant, salinity tolerance upto 90 dS m^{-1}, forage plant for range animals, also be used as edible fruit, fuel wood and as an ornamental plant.
Panicum turgidum	Al-Qatif	Gramineae	Perennial grass, plant height 1 m and above, thick root system, effective sand binder, found on medium saline soils and suitable fodder for grazing animals.
Salsola sp.	Ras Tanura	Chenopodiaceae	Shrublet, 15-60 cm high. Salinity tolerant up to 60 dS m^{-1} Shallow sand or silty soil on rocky ground along wadi banks. grazing plant for camels and used for fire wood.
Suaeda vermiculata	Ras Tanura	Chenopodiaceae	Xerophyte shrub, found in wetlands, salinity tolerance upto 56 dS m^{-1}, used as fodder and ornamental plant.
Salicornia europaea	Al-Qaseem	Chenopodiaceae	Annual herb, found in disturbed areas and marsh lands. Fresh growing tips are harvested and used sparingly in salad or as a garnish in sea food. Succulent stems are used to prepare pickle. Seed oil is used as protein in animal feed.
Tamarix amplexicaulis	Obhr	Tamariceae	Hydro-halophyte: Mostly found in wet saline lands, salinity tolerance upto 90 dS m^{-1}. Used as firewood and as an ornamental plant.

Table 3: Mean mineral composition of selected plants

Plant	Location	N	P	K	Ca	Mg	Na
Aeluroapus lagopoides	Aloquer	0.75	0.19	0.51	0.45	0.33	2.47
Avicennia marina	Al-Qatif	2.33	0.18	0.99	0.79	0.62	3.89
Juncus rigidus	Al-Qatif	0.96	0.15	1.12	0.33	0.30	0.82
Nitraria retusa	Ras-Tanura	2.05	0.11	0.82	1.61	0.59	2.43
Panicum turgidem	Al-Qatif	1.44	0.15	1.10	0.45	0.26	0.95
Salsola sp.	Ras Tanura	1.13	0.05	2.88	1.66	1.05	6.75
Suaeda vermiculata	Ras Tanura	1.19	0.07	1.66	0.86	1.25	8.25
Salicornia europaea	Al-Qaseem	1.14	0.09	1.71	1.15	0.99	10.18
Tamarix amplexicaulis	Al-Qatif	0.74	0.07	0.95	1.35	2.15	10.53

The plant composition is a mean of three replications

Chemical composition of plants

Nitrogen: Nitrogen concentration ranged between 0.74-2.33% and varied upto 4-fold in different plants (Table 3). This could be attributed to the arid environment in the region. Chapman (1966) reported the critical limits of nitrogen in the grasses as less than 1.6%, while in some species the deficiency could appear even at the 2.2% level. All the plants showed nitrogen level below the critical limits except *Avicennia marina* and *Nitraria retusa*.

Phosphorus: Phosphorus concentration ranged between 0.05-0.19%, showing a variation upto 4-fold among different plants (Table 3). Phosphorus below 0.15% is considered a deficiency level, over 55% of the plants were deficient in phosphorus. Soil phosphorus plays an important role on the plant phosphorus level. The total phosphorus concentration in the soils of Saudi Arabia ranges from 182 to 1088 mg L^{-1} and the available phosphorus from 0-90 mg L^{-1} (Bashour *et al*., 1985). These concentrations are much lower than those reported by Smeck and Runge (1971). Plant phosphorus variation indicates a fairly uniform phosphorus distribution in the soils of different regions.

Potassium: The Potassium concentration in the plants ranged between 0.51-2.88%, showing a variation up to 6-fold, indicating that there was a significant unbalanced distribution pattern of potassium in plants (Table 3). A potassium level below 1.5% is considered as a deficient level. As a general observation in the NPK group, the potassium concentration was often several fold higher than for the other two nutrients (NP). For example, Singh and Mishra (1987) reported potassium concentration of up to 18-fold from a humid temperate grassland region in the Himalayas compared with nitrogen and phosphorus concentrations of 2 and 8-fold, respectively. It was observed that all the plants fell in the deficient range (66%) except *Salsola* sp., *Suaeda vermiculata* and *Salicornia europaea* which were above deficient level.

Calcium: The calcium concentration ranged between 0.45-1.66% indicating a 4-fold variation in different plants (Table 3). Since 0-35% calcium level is associated with plant deficiency (Haarenen, 1963), so none of the plants were in the deficient range. A suitable ration between calcium and phosphorus is considered a better index for utilization as footage by animals as compare to their absolute concentration (Singh and Mishra, 1987).

Table 4: Mean composition of soil samples collected for the selected plants

Plant	Location	SP	pH	EC_e	Na	K	Ca	Mg	Cl	HCO_3	SAR	Class
A. lagopoides	Aloquer	20	7.7	85.5	15158	1803	2275	2225	30250	225	67.5	Sandy
A. marina	Al-Qatif	22	7.5	48.5	8645	498	1052	1328	1325	68	41.8	Sandy
J. rigidus	Al-Qatif	27	7.8	70.5	15158	1803	2850	1252	24249	142	59.5	Sandy
N. retusa	Ras-Tanura	20	7.9	50.2	7238	316	1449	626	15241	97	40.0	Loamy-Sand
P. turgidum	Al-Qatif	25	7.1	87.1	9356	123	4615	1725	31311	48	29.8	Sandy-Loam
Salsola sp.	Ras Tanura	18	7.5	75.4	11875	606	1780	1493	24820	69	50.2	Sandy
S. vermiculata	Ras Tanura	22	7.6	76.8	12900	546	1020	1836	24200	83	55.8	Sandy
Salicornia europaea	Al-Qaseem	22	7.6	76.8	12900	546	1020	1836	24200	83	55.8	Sandy-Loam
T. amplexicaulis	Al-Qatif	73	7.3	161	35383	948	490	1132	51894	98	200	Silty-Clay

Note: The soil analysis is a mean of three replications

Table 5: Some mean climate parameters of Al-Qaseem region (1995-2003)

	Air temperature (°C)		Relative humidity (%)			
Month	Maximum	Minimum	Maximum	Minimum	PE (Total) (mm month^{-1})	Rainfall (mm month^{-1})
January	21.5	8.2	48.3	22.3	146	2.0
February	20.0	10.7	53.4	23.9	80	50.0
March	26.3	13.5	45.7	23.8	165	34.3
April	28.6	17.2	48.8	18.3	281	19.8
May	33.7	23.5	33.1	16.4	229	1.4
June	35.1	23.7	25.6	14.4	420	0.0
July	35.6	23.8	26.7	16.5	440	0.0
August	36.7	24.2	27.3	16.5	436	0.0
September	32.4	20.0	30.6	18.5	367	0.0
October	30.4	18.1	34.3	22.6	329	0.0
November	24.9	13.0	40.6	26.8	211	2.6
December	18.8	9.7	57.0	39.3	14	118.4

The study showed plant calcium-phosphorus ratio as (2.4-33.2):1 for most of the plants.

Magnesium: The magnesium concentration ranged between 0.26 -2.15% indicating a 7-fold variation in different plants (Table 3). Magnesium concentration of 0.2% in plants is commonly regarded as the minimum dietary concentration for adequate animal health (Kemp, 1960). Only 33% of the investigated plants could be considered deficient in the magnesium dietary requirement.

Sodium: The range of sodium concentration in plants was very high with a minimum and maximum of 0.82 and 10.53%, respectively with overall variation of up to 11-fold (Table 3). The dietary concentration of Na in dry matter required for animals ranges between 0.09-0.21% (Commonwealth Agricultural Bureau, 1980). In the present case, none of the plants was in the deficient range.

Among the various cations, Na is the most toxic ion and plays an important role in the survival of plants under severe soil salinity conditions. The data show that all the plants investigated can survive high soil salinity growing conditions except *Juncus rigidus* and *Panicum turgidum* which may grow better under moderate soil and water salinity. The variability in chemical constituents of plants may be attributed to the difference of soil salinity at different places.

Soil analysis: The ranges of different chemical parameters are: SP (18-73%), pH (7.1-7.9), ECe (50.2-161 dS m^{-1}), Na (0.73-3.54%), K (0.012-0.18%), Ca (0.10-0.49%), Mg (0.06-0.22%), Cl (0.13-5.19%), SAR (41.8-200) and the soil texture sandy to silt-loam (Table 4). The analysis reveals that soil salinity is very high in all the places and may be attributed to arid climate conditions associated with low and sporadic rainfall.

Relationship between soil and plant composition: The data in Table 2 and 3 were analyzed statistically using correlation and regression analysis to determine the effect of soil salinity and composition on plant mineral constituents. A negative value of correlation coefficient (r) was observed for N (-0.67), P (-0.35) and K (-0.09) (Table 5). This suggests that the concentration of these elements decreased in plants with increasing soil salinity which may be due to lower concentration of these elements in soil as compared to other nutrient elements. The positive values of (r) for Ca (0.11), Mg (0.73) and Na (0.48) indicate that these elements increased with increasing soil salinity which may be attributed to the high concentration of these elements in soil solution (Table 6). The order of decrease for nutrient elements of forage value was N > P > K while ascending order for other elements was Mg > Na > Ca. The correlation was very poor except N, Mg and Na between soil salinity, soil composition and plant composition. The soil samples

Table 6: Correlation coefficient (r) between plant composition and soil salinity

Elements	Soil salinity (EC_e dS m^{-1})	Soil mineral composition (%)
Nitrogen (N)	-0.67	----
Phosphorus (P)	-0.35	----
Potassium (K)	-0.09	-0.31
Calcium (Ca)	0.11	-0.22
Magnesium (Mg)	0.73	-0.18
Sodium (Na)	0.48	0.54

were not analyzed for N and P, hence no correlation was calculated between soil and plants. The water-extractable concentrations of soil nutrients may not be a good indicator of plant uptake (CSTPA, 1974; Doll and Lucas, 1973). Moreover, there is no available information on the nutrient index especially for the desert plants growing in coastal and inland salt affected lands where rainfall is low and sporadic. The plants mainly depend for their water needs on the groundwater. The results of poor correlation between soil parameters and plant composition agree with those of Al-Homaid *et al.* (1990a and b) who also reported similarly poor correlation between soil and plant chemical; constituents.

The mean minimum and mean maximum air-temperature ranged between 8.2-24.2°C and 18.8-36.7°C, respectively (Table 4). The mean minimum and mean maximum relative humidity (%) ranged between 14.4-39.3 and 25.6-57.0, respectively. The man potential pan-Evaporation (mm day^{-1}) ranged between 14 and 440. The mean rainfall ranged between 0.0-118.4 mm $month^{-1}$ during 1995-2003.

CONCLUSIONS

The study highlighted some of the potential plant species such as *Aeluroapus lagopoides*, *Avicennia marina*, *Juncus rigidus*, *Nitraria retusa*, *Panicum turgidum*, *Salsola* sp., *Suaeda vermiculata*, *Salicornia europaea* and *Tamarix amplexicaulis* which can grow under severe salt affected lands and saline irrigation for the development and rehabilitation of inland saline lands and for desert greenification to improve the micro-climate under arid environments.

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