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Effect of Potassium and Nitrogen Fertilizers on the Growth and Biomass of Some Halophytes Grown under High Levels of Salinity

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Abstract: A field experiment was carried out at Nahshala Farm, about 50 km from Al-Ain, UAE during the 2001/2002 growing seasons, using five halophyte species; *Spartina sp., Distichlis palmeri., Paspalum vaginatum, Juncus roemerianus and Batis maritima,* under six levels of N and K fertilizer combinations irrigated with salinity water of 20 g L^{-1}. The objectives of the experiment were twofold; 1) to find out the optimum rate of potassium and nitrogen under such high salinity stress and 2) to study the response (growth and biomass production) of such halophytes to different levels of K and N as an anti-salinity nutrients. The experiment was conducted in triplicate with a split-plot design arranged in randomized complete block. Results indicate that controlling soil fertility especially N and K under saline soils condition is considered one of the most important factors in order to conduct reliable study on the evaluation of tolerance of plants to salinity stress. Nitrogen and potassium proved to increase plant salt tolerance to produce high biomass. This study also supports the idea of using high saline water of about 20 g L^{-1} salt concentration in agriculture along with N and K fertilizers accompanied with increasing leaching fraction to maintain satisfactory yield production of such halophytes.

Key words: Salinity, leaching fraction, plant growth, dry matter accumulation

INTRODUCTION

Under sodic saline conditions, the mineral nutrition of most plants can be expected to be detrimentally affected. The interactions between K and Na may be emphasized under such conditions and ultimately decrease plant growth. Soil structure has also been shown to be adversely affected by high levels of Na[1]. Although Na has been shown to replace K in some of its physiological roles in sugar beets[2], other plants show much less ability to substitute Na for K[3]. The significance of K in stomatal regulation has been well established[4]. The proportion of the total K that is actively capable of fulfilling the role in stomatal regulation may be inadequate when Na is present in high amounts.

Reduction in plant growth under salt stress is usually attributed to osmotic stress due to a lowering of external water potential[5], or to specific ion effect on metabolic processes in the cell. The two effects are not mutually exclusive. Thus, ion regulation and osmo-regulation are subjects of intensive research into possible mechanisms of salt tolerance[5]. It is commonly accepted that correlation exists between Na and K leading to a reduced level of internal K^+ at high external NaCl concentrations. This phenomenon has been described in plants as well as cultured cells. Detailed studies with cotton plants showed a reduced content of K^+ in roots subjected to high NaCl concentrations and that K^+/Na^+ selectivity is an important factor in salt tolerance of plants[6]. Leigh and Wyn Jones[7] hypothesized that critical K^+ concentration is correlated with growth of plant cells.

Studies of cell cultures of tobacco[8] showed that a higher level of internal K^+ could be correlated with a higher level of salt tolerance. Fertilization assumes an important role since sodic soils are poor in fertility[9]. A higher rate of N than one utilized on non-sodic soils[10] and the application of Zn during the years of soil reclamation[11] result in increased crop yields.

Sodic soils contain high amounts up to 136 kg ha^{-1} of $NaCO_3$ extractable P, which decreases with increasing soil depth[12]. Sodic soils are dominated by Na which adversely affects K concentration of the plants[3-16]. However, information on the beneficial effect of potassium fertilizers to crops grown in sodic soils is badly lacking.

Dvorak and Noaman[17] in study of the effect of Kna1 locus transferred from *Triticum aestivum* to durum wheat found that under salt stress, the $Kna1^+$ families had higher K^+/Na^+ ratios in the flag leaves and higher yields of grain and biomass than the $Kna1^-$ families. They concluded

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that K^+/Na^+ ratio is one of the factors responsible for the higher salt tolerance in wheat.

The addition of K to the root medium of barley and rye grass was found to reduce the harmful effects of high Na concentrations[18,19].

Noaman *et al.*[20] studying the effects of potassium on barley crop under salinity stress found that on the average, overall salinity levels, the application of 57 kg K_2O ha^{-1} increased biological and grain yield significantly by about 20 and 14%, respectively over the control treatment. They also found that higher levels of K (114 kg K_2O ha^{-1}) caused some non-significant reduction in both characteristics by about 5.5 and 4%, respectively.

The main objective of this study was, therefore to study the effects of soil salinity and potassium and nitrogen application on the performance of five halophytes grown under salinity stress.

MATERIALS AND METHODS

A field experiment was carried out at Nahshala Farm, about 50 km from Al-Ain, UAE, during the 2001/2002 growing seasons, using five halophyte species; *Spartina sp., Distichlis palmeri., Paspalum vaginatum, Juncus roemerianus and Batis maritima,* under three levels of Nitrogen fertilizer (40, 100 and 160 kg N ha^{-1}) and two levels of Potassium fertilizer (48 and 96 kg K_2O ha^{-1}) in six combinations as follow:

- F1 = 40 Kg N ha^{-1} + 48 kg K_2O ha^{-1},
- F2 = 40 Kg N ha^{-1} + 96 kg K_2O ha
- F3 = 80 Kg N ha^{-1} + 48 kg K_2O ha^{-1},
- F4 = 80 Kg N ha^{-1} + 96 kg K_2O ha^{-1}
- F5 = 120 Kg N ha^{-1} + 48 kg K_2O ha^{-1} and
- F6 = 120 Kg N ha^{-1} + 96 kg K_2O ha^{-1},

irrigated with saline water of about 22 g l^{-1} (22,000 ppm) concentration. The experiment was conducted in triplicate with a split-plot design arranged in randomized complete block with the halophyte species as the main plot, nitrogen fertilizer as sub-plots and potassium fertilizer as sub-sub-plots. Plot area was 3.6 m^2 for each treatment in six rows 30 cm apart and 2 m long. The original plant materials were introduced from Arizona, USA, then seedlings were propagated by stem cuttings in January 1999. These species were chosen primarily not only because they represent a wide range of physiotypes, but also because they have already been used to some extent for beneficial purposes such as animal fodder, grain, camel feed and landscaping. *Distichlis palmeri*, a C_4 perennial salt-tolerant grass, *Batis maritima*, a C_3 perennial succulent plant, *Spartina sp.* a C_3 perennial grass, *Paspalum vaginatum and Juncus roemerianus,* are C_3 herbaceous perennials. Potassium fertilizer was added before planting during land preparation while the nitrogen fertilizers were spited into three equal doses added in weekly intervals starting 20 days after planting to avoid any nitrogen losses or leaching. The plants of different species included in the experiment were first grown from seed or from stem cuttings in greenhouse pots for about 6-8 weeks, then seedlings were transplanted into the field and were irrigated with saline water. Growth rate was measured using plant height development where individual plant heights were measured at four stages of plant growth during the course of the experiment and immediately before harvest. The time between measurements was about 15-20 days. Total biomass was determined by harvesting the entire plants of each species, weighed for fresh weight measurement and then washed, dried at 60°C for 3 days and their respective dry weight was determined. The analyses of variance were performed for the split-plot design by the procedures outlined in Steel and Torrie[21] at P-value = 0.05 and 0.01. Once the significance level of the treatment effects were established by F-tests, the significance of the observed differences among species at the different salt levels and fertilizer treatments was evaluated by the Least significant differences (LSD) test method.

RESULTS AND DISCUSSION

Effect of P and N fertilizers on plant development: The differences between fertilizer treatments for different halophyte species regarding plant height were not significant at the initial stage of growth and thereafter the differences became apparent at the third stage (55-60 days after planting and application of N and K fertilizer). Table 1 shows plant heights of the five halophytes at four growth stages including the time of harvest under six levels of N and K fertilizer treatments along with applicable statistical parameters. The data in this Table indicate that application of nitrogen and potassium did not affect plant height at the early growth stages until the second stage, but at the third stage the differences between fertilizer treatments regarding plant height started to appear with increasing N and k fertilizer up to F5 for most halophyte species, significantly ($P<0.05$). Further increase in fertilizer did not cause significant increase in plant height with some exceptions in some halophyte species such as *Spartina sp.* and *Distichlis sp.* At harvest, plant height differences among different fertilizer treatments reached the maximum except for *Juncus sp.* and *Batis sp.* where they were stable in plant height at higher fertilizer levels.

Table 1: Plant height (cm) of five halophyte species measured at four growth stages as correlated to the mean fertilizer treatments grown at Nahshala Farm, 2001/2002

	Plant species					
Fertilizer treatments	*Spartina sp*	*Distichlis palmeri*	*Paspalum vaginatum*	*Juncus roemerianus*	*Batis maritima*	Mean
1st stage						
F1	18.0	12.7	12.7	23.0	11.3	15.5
F2	20.3	12.0	14.7	20.7	11.0	15.7
F3	17.0	13.3	15.0	22.0	11.0	15.7
F4	18.7	14.0	13.0	22.7	10.6	15.8
F5	19.6	14.4	12.3	22.3	11.7	16.1
F6	23.0	15.0	14.7	24.0	12.0	18.3
Mean	19.4	13.6	13.7	22.5	11.3	
S.E. $_a$ (df = 4) 1.53						
S.E. $_b$ (df = 20) 1.39						
2nd stage						
F1	23.7	15.7	13.7	31.0	12.6	19.3
F2	23.3	13.8	15.6	30.0	13.0	19.9
F3	21.3	15.0	16.0	31.3	13.0	19.3
F4	22.7	17.2	14.3	31.5	12.8	19.7
F5	26.0	15.6	13.4	30.7	12.9	20.4
F6	25.0	16.6	15.8	31.0	14.7	20.6
Mean	23.7	17.3	14.8	32.6	13.8	
S.E. $_a$ (df = 4) 2.37						
S.E. $_b$ (df = 20) 3.48						
3rd stage						
F1	28.0	18.0	14.3	44.0	13.4	23.5
F2	28.7	17.7	17.5	43.0	15.8	24.5
F3	25.6	18.0	17.8	43.3	14.3	23.8
F4	27.4	20.3	17.0	44.8	14.4	24.8
F5	29.3	20.4	18.7	45.7	14.8	25.8
F6	33.5	23.2	19.6	45.5	14.9	27.3
Mean	28.8	19.6	17.5	44.4	14.6	
S.E. $_a$ (df = 4) 2.67						
S.E. $_b$ (df = 20) 4.27						
Harvest						
F1	38.7	35.4	26.5	60.0	26.5	37.4
F2	37.6	35.6	28.0	61.0	28.0	39.1
F3	41.3	37.0	29.7	61.6	25.6	38.0
F4	42.2	38.5	31.5	61.8	24.9	39.8
F5	45.8	38.4	30.4	61.3	24.8	40.1
F6	48.0	43.7	33.9	61.2	25.7	42.5
Mean	42.3	38.1	30.0	61.1	25.9	
S.E. $_a$ (df = 4) 1.93						
S.E. $_b$ (df = 20) 2.71						

* S.E. $_a$ (Degrees of freedom for species means) S.E. $_b$ (Degrees of freedom for species x fertilizer interaction)

Table 2: Fresh weight in (t ha^{-1}) of five halophyte species under different N and K fertilizer treatments in an experiment grown at Nahshala Farm, 2001/2002

	Fertilizers							
Plant species	F1	F2	F3	F4	F5	F6	Mean	LSD (0.05)
Spartina sp	6.687	7.060	7.550	8.110	8.210	10.033	7.942	2573
Distichlis palmeri	13.416	16.586	17.233	20.660	20.276	22.193	18.394	
Paspalum vaginatum	35.476	39.666	39.943	45.393	44.176	50.526	42.530	
Juncus roemerianus	14.116	17.593	19.500	21.293	23.616	25.166	20.214	
Batis maritima	45.000	48.543	44.333	53.710	47.250	51.166	48.334	
Mean	22.939	25.890	25.712	29.833	28.706	31.817		
LSD (0.05)	2.762							
S.E.	18.63							
CV%	11.18							

Regarding the differences among halophyte species at different fertilizer treatments, two halophytes did not response to increasing fertilizer application, they are *Juncus roemerianus* and *Batis maritime* and no significant differences were found among different fertilizer treatments. The highest significant response to fertilizer treatments of all halophytes was found in the two grasses, *Spartina sp.* and *Distichlis palmeri* ($P<0.05$) especially at the third stage and at harvest.

It was concluded from this part of study that nitrogen and potassium fertilizer are very important to the three halophyte species; *Spartina, Distichlis* and *Paspalum sp.*

Table 3: Dry matter in kg ha^{-1} of five halophyte species under different N and K fertilizer treatments in an experiment grown at Nahshala Farm, 2001/2002

Plant species	Fertilizers F1	F2	F3	F4	F5	F6	Mean	LSD (0.05)
Spartina sp	2820.00	3110	3090	3657	4520	5647	3807	1569
Distichlis palmeri	7537.00	8817	9050	11380	10546	12127	9909	
Paspalum vaginatum	14777.00	17853	18650	21120	18356	23080	18973	
Juncus roemerianus	7663.00	9086	10473	13336	14886	14033	11579	
Batis maritima	7687.00	8913	7086	8177	7190	8533	7931	
Mean	8096.00	9556	9670	11534	11099	12684		
LSD (0.05)	1894.00							
S.E.	15.39							
CV%	8.62							

Table 4: Concentration of some nutrients in plant tissues of five halophytes grown under different levels of N and K fertilizers at Nahshala Farm, 2001/2002

Plant species	Fertilizer	K Na^{-1} Ratio	% Nutrients in Plant Tissues N %	P (mg L^{-1})	K (mg L^{-1})	Na (mg L^{-1})
Spartina sp.	F1	0.31	1.25	800	6042	19651
	F2	0.34	1.11	800	5063	15035
	F3	0.25	0.95	700	5105	20683
	F4	0.32	0.98	800	5856	18514
	F5	0.33	1.00	820	8774	26777
	F6	0.29	0.97	760	6704	22749
Distichlis palmeri	F1	0.32	0.79	600	2395	7466
	F2	0.43	0.75	700	3329	7803
	F3	0.37	0.93	700	5123	13694
	F4	0.37	0.88	800	5342	14331
	F5	0.21	0.81	500	2584	12286
	F6	0.39	0.85	980	4851	12400
Paspalum vaginatum	F1	0.41	0.78	870	5250	12655
	F2	0.34	0.71	860	5931	17312
	F3	0.44	0.77	700	7229	16327
	F4	0.45	0.73	900	7318	16123
	F5	0.53	0.68	900	9024	16851
	F6	0.45	0.80	1000	8544	19184

Table 4: (Continued)

Plant species	Fertilizer	K Na^{-1} Ratio	% Nutrients in Plant Tissues N %	P (ppm)	K (ppm)	Na (ppm)
Juncus roemerianus	F1	0.61	0.71	960	5143	8457
	F2	0.60	0.70	760	5064	8381
	F3	0.83	0.71	800	5545	6643
	F4	0.59	0.69	800	6336	10725
	F5	0.52	0.76	900	4820	9171
	F6	0.54	0.73	920	4475	8295
Batis maritima	F1	0.05	0.77	670	2741	51872
	F2	0.16	0.69	1000	6068	37683
	F3	0.12	0.75	830	4657	37704
	F4	0.15	0.71	700	4424	29917
	F5	0.10	0.74	920	5146	50048
	F6	0.15	0.73	1050	4383	30077

and to less extent to the other two halophytes, *Juncus sp.* and *Batis sp.* at high salinity levels.

Effect of fertilizer application on biomass and yield production: Halophytic plants, which have evolved in saline environment, responded differently in terms of biomass and yield production to increasing N and K fertilizer. In general, their biomass and yield production significantly increased as the fertilizer increased ($P<0.05$) with no exception. The relative effects of N and K on vegetative and reproductive growth seem to vary from species to species. However, at higher fertility, biomass production of *Batis sp.* was extremely high and reached over 51,000 t ha^{-1} total fresh weight from four cuts and it was followed by *Paspalum sp.* with no significant differences between the two species. The lowest fresh and dry weight biomass production was obtained from *Spartina sp.*, which gave about 10,000 t ha^{-1} from the same number of cuttings (Table 2). We conclude from this part of study that it is important to add N and K in order to obtain high yielding halophytes especially for *Batis sp.* and *Paspalum sp.* which produce very high yields when applying high levels of N and K fertilizer.

Dry matter production obtained per each species is shown in Table 3. The story here is different due to huge differences in water content of the different halophyte species. It was found that *Batis sp.,* which gave the highest fresh weight is giving the second least dry matter production due to its high water content (succulent plant), whereas *Paspalum sp.* stayed on the top regarding dry matter production with significant differences compared to all other halophyte species ($P<0.05$) (Table 3).

It was obvious that *Spartina sp.* was the lowest in both fresh and dry matter production among all five species, significantly (Tables 2 and 3), while the highest fresh and dry matter production was *Paspalum vaginatum,* which can be used as a forage crop for animal feeding under high saline soils[22].

Plant Nutrients content as affected by fertilizer treatments: As we mentioned earlier that K is a major plant nutrient and could be useful against high soil salinity as was found by Dvorak *et al.*[17] who concluded that higher K^+/Na^+ ratios in the flag leaves is one of the factors responsible for the higher salt tolerance in wheat. It was also found that the addition of K to the root medium of barley and rye grass reduced the harmful effects of high Na concentrations[18,19]. Therefore, one of the objectives of this study was to measure K and Na content in plant tissues of these halophyte species and relate that to salt tolerance and yielding capacity under salt stress. Table 4 shows concentration of some nutrients in plant tissues of the five halophyte species under different levels of N and K fertilizers. It was obvious that K/Na ratio for each species behaved differently under different levels of N and K fertilizer. For example, the ratio was extremely low for *Batis sp.* (ranging from 0.05 to 0.16) compared to the highest valued from *Juncus sp.* (0.52 to 0.83). Sodium content in plant tissues of this was extremely high with an average of 39550 mg L^{-1} with relatively lower K content with an average of 4570 mg L^{-1} (Table 4). Regarding *Paspalum sp.*, which gave the highest fresh and dry biomass, the K Na^{-1} ration was intermedium ranging from 0.34 to 0.53), but the K content was the highest compared to the other four halophytes ranging from 5250 to 9024 mg L^{-1}. In general, the relationship between K/Na ratio and N and K in one hand and biomass production in the other hand was not evident in this study (Table 4). There was no clear trend between the values of K/Na and the biomass production and nutrient content in plant tissues. However, nitrogen and phosphorus content in plant tissue did not reflect the salinity tolerance or biomass production in different halophyte species which indicates that they are independent criteria and it can not be rely upon in the selection procedure for salt tolerance.

DISCUSSION

Controlling soil fertility especially N and K under saline soils condition is considered one of the most important factors in order to conduct reliable study on the evaluation of tolerance of plants to salinity stress. In the present study N and K were applied in an adequate rate to increase plant salt tolerance to produce high biomass, especially Paspalum sp. which produced high fresh and dry biomass for forage use. *Paspalum vaginatum* proved to be salt tolerant species under high and intermediate salt stress as was concluded by Noaman and El-Haddad[22] and can tolerate more than 20 g l^{-1} of salt concentration. Under this salt stress using N and K fertilizer, most halophyte species under study gave satisfactory biomass production with some differences in values among them. It should be recognized that soil salinity under the high salt treatments will continue to rise and plant growth may deteriorate unless the same high level of leaching fraction should be applied for a long period of time along with N and K fertilizers. The present study showed that most of the tested halophyte species can produce high yield and biomass if they are fertilized with K and N at moderate levels such as 120 kg N ha^{-1} and 48 kg K_2O ha^{-1} and can grow satisfactorily using brackish water of 20 g l^{-1} salinity. However, such a practice will cause salinity accumulation in the drainage water which may exceed that of seawater salinity. Therefore, irrigation strategies for using such seawater should involve higher levels of leaching and also more frequent water applications[22]. Our study also supports the idea of using high saline water of about 20 g L^{-1} salt concentration in agriculture along with N and K fertilizers accompanied with increasing leaching fraction to maintain satisfactory yield production of such halophytes.

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