Pak. J. Bot., 40(4): 1521-1531, 2008.

EFFECT OF DIFFERENT SOURCES AND RATES OF NITROGEN AND SUPRA OPTIMAL LEVEL OF POTASSIUM FERTILIZATION ON GROWTH, YIELD AND NUTRIENT UPTAKE BY SUGARCANE GROWN UNDER SALINE CONDITIONS

M. YASIN ASHRAF[1*], FAQIR HUSSAIN[1], JAVED[1] AKHTER[1], ATTIYA GUL[1], MARCUSS ROSS[2] AND GEORG EBERT[2]

[1]*Soil Science Division, Nuclear Institute for Agriculture and Biology (NIAB), P.O. Box 128, Jhang Road, Faisalabad, Pakistan.*
[2] *Agricultural Advisory Departments, K+S KALI, GmbH, Kessel, Germany.*

Abstract

The results of our pervious studies indicated that application of potassium @150 kg K_2O ha^{-1} is effective in achieving economical sugarcane yield and optimum nutrient uptake under saline conditions. Keeping in view these findings, experiments were conducted on salt-affected soils at three sites of Punjab, Pakistan to select a suitable source and rate of N for obtaining optimum sugarcane yield and nutrient uptake from salt-affected soils. The experiments were conducted with two sugarcane varieties, salt tolerant (SPSG-26) and sensitive (CP-77400) using supra optimal level of K (150 kg K_2O ha^{-1}) as sulphate of potash SOP, P @ 100 kg P_2O_5 ha^{-1} as DAP (diammonium phosphate) and N @100 and 200 kg N ha^{-1} as urea or calcium ammonium nitrate (CAN). The results showed that cane length and diameter, number of tillers per plant, cane yield and sugar recovery increased with the application of N in both the sugarcane varieties under normal or saline conditions. Sugarcane growth and yield increased with increasing N rate from 100 to 200 kg N ha^{-1} in case of both urea and CAN. However, CAN as N source was more effective in enhancing sugarcane growth and yield than urea. The concentration of Na^+ increased in both the sugarcane varieties due to salinity, however, application of K and N decreased its concentration. The combined application of NPK also significantly reduced Na^+ uptake in leaves, however, the best combination observed was DAP+SOP+CAN. It was also observed that salt tolerant variety (SPSG-26) had lesser accumulation of Na^+ than that of sensitive one (CP-77400). Application of N fertilizers significantly enhanced the nutrient (K, P, and N) uptake in both the varieties at both N rates (100 and 200 kg N ha^{-1}) under normal as well as saline conditions. However, maximum uptake of nutrients was recorded at the highest dose (200 kg N ha^{-1}) but CAN treated plants performed better than that of urea. On the basis of above results, the application of K as SOP and N as CAN was recommended for salt-affected soils to enhance the sugarcane yield. The salt tolerant variety for higher yield in salt-affected soil is also necessary for improving the cost benefit ratio. The results revealed that if salinity level of soil would exceed 10 dS m^{-1}, considerable reduction in sugarcane yield could occur.

Introduction

Sugarcane is an important industrial and cash crop in Pakistan and in many countries of the world. It is grown in tropical and sub-tropical regions of the world in a range of climates from hot dry environment near sea level to cool and moist environment at high elevations (Plaut *et al*., 2000). Besides sugar production, sugarcane produces numerous

[*] Correspondence Author: niabmyashraf@hotmail.com ; myashrafsp@yahoo.com

valuable byproducts like, alcohol used by pharmaceutical industry, ethanol used as a fuel, bagasse used for paper and chip board manufacturing and press mud used as a rich source of organic matter and nutrients for crop production (Kumar *et al.*, 1996; Lingle *et al.*, 2000). Sugarcane is grown on an area of about one million hectares in Pakistan (on 62 % of the total area in Punjab, 26 % in Sindh and 16 % of total area in North West Frontier Province). National average cane yield is 47.5 t ha^{-1}, which is far below the existing potential. Decrease in the yield potential is due to biotic and abiotic stresses. Among abiotic stresses, salinity is a major stress that is increasing day by day due to lack of proper drainage system and proper management of soil (Idrees *et al*., 2004).

Pakistan has a geographical area of 80.5 Mha out of which 20.36 Mha is cultivated. An area of 16.23 Mha is irrigated through canals and tube wells, and the remaining 4.13 Mha is dependent on rain. Salt-affected area is about 6.3 Mha, which is confined mostly to the irrigated parts of the Indus Plain (Ayub *et al*., 1999). The yield losses of sugarcane in moderately salt-affected areas were calculated to be 62%. Different approaches are being used to utilize or to reclaim the salt-affected soils. Presently it is planned to utilize the moderately salt- affected soils for sugarcane production by the management of Na/K ratio (Alam, 1994).

Management of soil fertility especially for N and K in salt–affected soils is essential because these nutrients are required in high amounts for good crop growth and high production (Noaman, 2004). Nitrogen is an essential element of bio-molecules such as amino acids, proteins, nucleic acids, phytohormones and a number of enzymes and coenzymes (Khan *et al.,* 1990; Ashraf & Khan*.,* 1993). Nitrogen is mainly involved in the initial growth processes, such as replication of chromosomes, synthesis of deoxyribonucleic acids and nuclear protein. Similarly, K^+ is also involved in numerous physiological processes and both N and K^+ influence plant growth in a synergistic way (Helal *et al.,* 1975). The continuous supply of K^+ to meristematic tissues stimulates the growth processes and the plant treated with K^+ showed better growth. Phytohormones and K^+ are involved in a synergistic way in the growth process (Shirazi *et al.,* 2005). Meristematic growth is the prerequisite of crop production. Therefore, a balanced K^+ and N supply may be useful to enhance the yield. The present study was conducted to select the appropriate source and rate of N application with the supra optimal supply of K for obtaining economical sugarcane yield and nutrient uptake under saline conditions.

Materials and Methods

Three field and one pot-culture experiments were conducted at three selected sites i.e. NIAB, Faisalabad, Pindi Bhattian and Jhang, Pakistan to select the suitable source and rate of N for obtaining economical cane yield and optimum nutrient uptake under saline conditions. Two sites i.e. Jhang and Pinidi Bhattian were saline while site at Faisalabad was normal, whose soil characteristics are summarized in table 1. Seven treatments of NPK and their combinations were maintained with three replications, and in pot experiment same fertilizer treatments were created under normal and saline conditions (10 dS m^{-1}). Fertilizer treatments were applied using two N sources i.e. urea and calcium ammonium nitrate (CAN) and three N levels i.e. 0, 100 and 200 kg N ha^{-1} along with 100 kg P_2O_5 ha^{-1} as DAP and 150 kg K_2O ha^{-1} as SOP (Table 3). Experiments at all sites were conducted with salt tolerant (SPSG-26) and salt sensitive (CP-77400)

Table 1: Soil characteristics of four selected sites

Soil Characteristics	Selected Sites			
	Pot culture experiment	NIAB	Rashida (Pindi Bhattian)	Jhang
Physical				
Soil Texture	Clay loam	Clay loam	Clay	Clay loam
EC_e (dS m^{-1})	1.11-1.25	1.03-1.732	4.5- 7.2	5.2-10.05
pH	7.78-8.12	7.4-7.9	7.8-8.29	7.71-7.91
SAR	0.51-0.58	0.45-0.62	6.29-15.86	11.01-19.30
Na^+ (meq L^{-1})	0.85-1.22	0.9-1.2	10.23-25.78	16.70-29.28
Ca^{2+}+Mg^{2+} (meq L^{-1})	6.98-8.70	7.5-10.0	10.56-18.46	9.21-14.37
K^+ (meq L^{-1})	0.87-1.15	1-1.25	2.23-2.30	1.79-2.44
CO_3^{2-}(meq L^{-1})	-	-	-	-
HCO_3^- (meq L^{-1})	-	-	2.87-3.27	3.33-3.66

Table 2: Characteristics of tube well waters used for irrigation at four selected sites

Tube well water Characteristics	Selected sites			
	NIAB	Pot-Expt.	Rashida (Pindi Bhattian)	Jhang
EC (dS m^{-1})	0.77	0.77	1.02	1.50
pH	7.90	7.90	7.50	7.80
SAR	8.08	8.08	6.20	18.36
Na^+ (meq L^{-1})	7.00	7.00	5.78	9.35
Ca^{2+}+Mg^{2+} (meq L^{-1})	3.00	3.00	2.50	1.04
K^+ (meq L^{-1})	0.70	0.70	1.05	0.33
CO_3^{2-}(meq L^{-1})	-	-	-	-
HCO_3^- (meq L^{-1})	2.00	2.00	5.09	10.78

Table 3: Treatment details

Treatment	Description	Source	Rate
T_0	Control	Without fertilizer	
T_1	P	DAP*	100 kg P_2O_5 ha^{-1}
T_2	P+ K	DAP +SOP**	150 kg K_2O ha^{-1} +100 kg P_2O_5 ha^{-1}
T_3	N+P+K	Urea+ DAP +SOP	100 kg N ha^{-1} +150 kg K_2O ha^{-1} +100 kg P_2O_5 ha^{-1}
T_6	N+P+K	CAN***+ DAP +SOP	100 kg N ha^{-1} +150 kg K_2O ha^{-1} +100 kg P_2O_5 ha^{-1}
T_5	N+P+K	Urea+ DAP +SOP	200 kg N ha^{-1} +150 kg K_2O ha^{-1} +100 kg P_2O_5 ha^{-1}
T_6	N+P+K	CAN+ DAP +SOP	200 kg N ha^{-1} +150 kg K_2O ha^{-1} +100 kg P_2O_5 ha^{-1}

* DAP = Diammonium phosphate, SOP** = Sulphate of Potash
***CAN= Calcium ammonium nitrate

sugarcane varieties and salinity levels in pots were maintained by NaCl (1.02 and 10 dS m^{-1}) while at other sites salt- affected lands were used for the present study.

Under ground brackish water was used to irrigate the crop at all sites except NIAB (Faisalabad) where crop was irrigated with canal water. The soil and irrigation water samples of all sites were analyzed for physical and chemical properties using the analytical procedures given in US- salinity staff book (USDA, 1962). Soil and water characteristics are summarized in table 1 and 2. The growth and yield parameters i.e. plant height, cane diameter, number of tillers per plant and cane yield were determined at maturity.

The leaf samples before maturity were collected for Na, K, P, and N analyses from all sites. Leaf samples were washed with tap and distilled water and dried at $65\pm5^{o}C$ in an oven for 72 h. Dried ground material was digested as described by Wolf, (1982) in H_2SO_4 –H_2O_2. The aliquot was used for the determination of Na, K, P and N. Sodium and K were determined by Flame Photometer, P by using Barton's reagent (Jackson, 1962) and total N by Kjeldahl method (Bremner, 1965). The data were analyzed statistically to compare the means (Steel & Torrie, 1997).

Results

Soil and water characteristics: The soils at Rashida and Jhang sites were salt-affected with EC_e ranging from 7.2 to 10.05 and pH 7 to 8, respectively. All the selected soils are suitable for the cultivation of sugarcane. The irrigation water EC ranged from 0.77 to 1.5 dS m^{-1} with pH 7.5 to 7.9 and other water characteristics are summarized in table 2. The irrigation water of NIAB was better than all other sites in all respects (Table 2).

Growth and yield: Increase in plant height was recorded due to the application of different levels of N in sugarcane varieties under normal and saline conditions. DAP alone had increased the plant height but it was much pronounced when it was applied along with supra optimal level of SOP and N under normal as well as under saline conditions. Plant height increased more with the amendment of N from 100 to 200 kg ha^{-1} in the form of urea and CAN sources. The comparison of N sources indicated that CAN was better than urea. The prominent differences in tolerant and sensitive varieties regarding plant height were noted under saline conditions. The plant growth was also influenced by texture and chemical properties of soil of different sites.

Cane diameter was significantly increased by the application of N fertilizers under normal and saline conditions. The cane diameter was more in the plants treated with K and N under saline conditions. Cane diameter was increased with the increase in N rate from 100 to 200 kg ha^{-1}. The N source CAN was more effective for increasing the cane diameter than urea, especially under saline conditions. Varietal differences regarding cane diameter were also clear in experiment conducted on salt-affected soils. However, under normal conditions, the cane diameter was non-significantly influenced.

DAP alone did not influence the number of tillers but it non-significantly enhanced tiller number when applied in combination with SOP under normal as well as under saline condition. However, the combination of DAP+Potash+N was more effective in providing the desired results regarding number of tillers per plant than others. Number of tillers per plant increased with the increase in N rate from 100 to 200 kg N ha^{-1} in case of both urea and CAN. However, the N source CAN was much better than urea. Sugarcane

Table 4: Effect of NPK on plant height, cane diameter and number of tillers per plant of sugarcane under saline and normal conditions.

	Pot-Culture Expt				NIAB		Rashida		Jhang		
	Non-saline soil (1.2 dS m^{-1})		Saline soil (10 dS m^{-1})		(Field Experiment)		(Pindi Bhattian)				
Treatments	V_1	V_2	V_1	V_2	*V_1	**V_2	V_1	V_2	V_1	V_2	**Means**
					Plant height (cm)						
Without fertilizer	226	238	178	143	225	235	217	213	215	210	210 f
DAP	235	246	188	152	267	245	250	240	252	238	231e
DAP+SOP	259	266	216	162	285	255	260	245	262	262	247 d
DAP+SOP +$Urea_{100}$	281	288	246	206	296	270	280	260	282	270	268 c
DAP+SOP +CAN_{100}	291	290	259	220	328	298	288	265	285	270	279 b
DAP+SOP +$Urea_{200}$	303	310	273	240	346	306	296	270	301	280	293 a
DAP+SOP +CAN_{200}	315	312	278	236	361	316	297	275	307	285	298 a
					Cane diameter (cm)						
Without fertilizer	2.6	2.5	2.2	2.0	2.5	2.4	2.4	2.5	2.5	2.4	2.4 c
DAP	2.7	2.5	2.4	2.4	2.7	2.7	2.6	2.5	2.6	2.6	2.6 ab
DAP+SOP	2.8	2.7	2.5	2.5	2.8	2.8	2.7	2.6	2.8	2.6	2.7 ab
DAP+SOP +$Urea_{100}$	3.0	2.9	2.5	2.4	3.0	2.9	2.9	2.8	2.9	2.8	2.8 ab
DAP+SOP +CAN_{100}	3.0	2.9	2.7	2.5	3.0	2.9	3.1	2.8	3.1	2.9	2.9 a
DAP+SOP +$Urea_{200}$	3.1	3.0	2.8	2.6	3.0	2.9	3.1	2.8	3.1	3	2.9 a
DAP+SOP +CAN_{200}	3.2	3.0	2.9	2.7	3.2	3.1	3.0	2.8	3.1	2.9	3.0 a
					Number of tillers per plant						
Without fertilizer	1.78	2.42	1.58	1.51	2.11	2.54	1.61	2.05	1.50	1.78	1.88 d
DAP	1.77	2.39	1.61	1.46	2.12	2.57	1.60	1.98	1.60	1.74	1.88 d
DAP+SOP	1.81	2.47	1.72	1.56	2.08	2.61	1.63	2.22	1.70	1.78	1.95 c
DAP+SOP +$Urea_{100}$	2.85	3.05	2.05	2.15	2.45	2.68	2.45	2.58	2.40	2.45	2.51 b
DAP+SOP +CAN_{100}	2.98	3.28	2.35	2.38	2.48	2.70	2.48	2.64	2.40	2.45	2.61 a
DAP+SOP +$Urea_{200}$	2.88	3.22	2.42	2.34	2.51	2.72	2.52	2.40	2.41	2.41	2.58 a
DAP+SOP +CAN_{200}	2.90	3.24	2.51	2.30	2.61	2.70	2.57	2.42	2.50	2.44	2.62 a

*cv. SPSG-26, **cv. CP-77400

Means sharing same letters do not differ significantly at the 5 % level of significance

Table 5. Effect of NPK on sugar recovery and cane yield of sugarcane grown under normal and saline conditions.

	Pot-Culture Expt				NIAB		Rashida		Jhang		
	Non-saline soil ($1.2\ dS\ m^{-1}$)		Saline soil ($10\ dS\ m^{-1}$)		(Field Experiment)		(Pindi Bhattian)				
Treatments	V_1	V_2	V_1	V_2	*V_1	**V_2	V_1	V_2	V_1	V_2	Means
Sugar Recovery (%)											
Without fertilizer	9.9	10.9	8.5	8.2	11.2	13.3	11.8	10.7	12.0	10.2	10.6 d
DAP	9.7	11.0	8.8	8.3	12.0	13.5	12.0	10.8	12.0	9.9	10.8 d
DAP+SOP	11.7	12.2	9.8	8.6	13.3	14.1	12.7	11.4	12.0	10.2	11.6 c
DAP+SOP +$Urea_{100}$	13.4	14.7	12.7	10.9	14.2	14.7	13.3	11.6	13.0	11.2	12.9 ab
DAP+SOP +CAN_{100}	14.3	14.9	13.2	11.2	14.8	15.1	13.0	11.9	13.0	12.98	13.3 ab
DAP+SOP +$Urea_{200}$	14.4	14.9	13.2	11.2	14.9	15	13.2	11.9	13.0	11.5	13.3 ab
DAP+SOP +CAN_{200}	14.6	15.1	13.4	11.5	14.9	15.0	13.5	12.2	13.0	11.5	13.5 a
Cane yield ($ton\ ha^{-1}$)											
Without fertilizer	40.8	42.8	36.7	20.8	42.9	48.0	36.56	26.8	35.0	24.5	35.4 d
DAP	46.9	52.9	40.2	26.5	44.6	48.1	38.2	27.0	35.0	25.0	38.6 d
DAP+SOP	60.5	64.9	51.3	31.8	52.8	57.7	51.6	35.9	49.0	31.8	48.7 c
DAP+SOP +$Urea_{100}$	86.4	94.4	60.5	40.7	70.6	74.6	68.4	40.7	66.0	38.9	64.1 b
DAP+SOP +CAN_{100}	93.9	97.8	64.6	41.7	74.8	76.9	70.4	42.7	68.0	38.8	66.9 b
DAP+SOP +$Urea_{200}$	98.2	105.0	70.6	42.4	76.8	80.7	73.7	45.8	71.0	42.8	70.7 a
DAP+SOP +CAN_{200}	102.8	107.0	77.4	43.7	78.8	83.0	76.3	46.8	72.0	43.7	73.2 a

*cv. SPSG-26, **cv. CP-77400

Means sharing same letters do not differ significantly at the 5 % level of significance

variety CP-77400 performed better than SPSG-26 only under normal conditions on the other hand SPSG-26 was successful in producing more number of tillers under saline conditions.

Increase in sugar recovery was recorded due to different levels of N in sugarcane varieties under normal and under saline conditions. DAP alone had no effect on sugar recovery, but it was much pronounced when it was applied in combination with SOP and N. Sugar recovery was not significantly influenced by enhancing N rate. Nitrogen source CAN was more effective in increasing sugar recovery than urea. Varietal differences were more prominent in sugar recovery under normal and saline conditions. It was observed that CP-77400 had higher sugar recovery under normal condition while reverse was the case under saline conditions where SPSG-26 competed CP-77400.

Cane yield was increased with DAP alone but increased more with K and N in the order of $P<P+K<N+P+K$. The amendment with N at the rate of 100 and 200 kg N ha^{-1} also enhanced cane yield. The N source CAN was effective for increasing cane yield, especially in salt-affected soils. Sugarcane variety CP-77400 produced more cane yield under normal condition but it failed to produce economical yield under saline conditions

Table 6: Interactive effect of different rates of N on Na^+ and K^+ contents in leaves of two sugarcane varieties grown under normal and saline conditions

	Pot-Culture Expt				NIAB		Rashida		Jhang		
	Non-saline soil (1.2 dS m^{-1})		Saline soil (10 dS m^{-1})		(Field Experiment)		(Pindi Bhattian)				
Treatments	V_1	V_2	V_1	V_2	*V_1	**V_2	V_1	V_2	V_1	V_2	Means
Na^+ concentration (μ mole g^{-1})											
Without fertilizer	25.2	27.4	177.8	271.7	55.8	58.7	185.8	246.0	206.0	263.8	151.8 a
DAP	30.2	29.8	172.2	250.8	48.8	55.7	180.6	241.0	195.0	256.8	146.1 b
DAP+SOP	22.4	26.5	142.3	187.5	34.6	45.7	130.2	163.0	172.0	223.3	114.7 c
DAP+SOP +$Urea_{100}$	25.8	23.8	140.8	178.2	40.6	45.6	125.6	155.0	165.0	214.2	111.5 c
DAP+SOP +CAN_{100}	25.4	22.7	134.7	168.8	46.8	57.5	120.6	146.0	158.0	188.0	106.8 d
DAP+SOP +$Urea_{200}$	22.6	20.7	139.5	162.4	56.5	68	124.7	144.0	173.0	231.5	114.2 c
DAP+SOP +CAN_{200}	24.5	26.8	124.7	158.2	56.5	65.8	122.7	139.0	155.0	202.4	107.5 d
K^+ concentration (μ mole g^{-1})											
Without fertilizer	234	241	166	125	370	366	212	235	185	144	228 f
DAP	254	246	187	135	391	405	244	235	205	180	248 e
DAP+SOP	478	485	245	207	480	493	279	247	249	209	337 d
DAP+SOP +$Urea_{100}$	511	514	275	241	512	510	306	286	275	231	366 c
DAP+SOP +CAN_{100}	514	521	296	216	528	525	322	306	295	259	378 b
DAP+SOP +$Urea_{200}$	535	531	307	260	513	502	328	279	315	276	385 b
DAP+SOP +CAN_{200}	541	539	335	281	535	528	357	302	332	281	403 a

*cv. SPSG-26, **cv. CP-77400

Means sharing same letters do not differ significantly at the 5 % level of significance

while SPSG-26 was effective in producing economical cane yield under saline conditions.

Nutrient uptake: The concentration of Na^+ increased in both the sugarcane varieties under saline conditions, however, application of K along with N was effective in reducing the Na^+ uptake. The higher dose of N (200 kg N ha^{-1}) reduced the Na^+ uptake more. The most effective combination was 150 kg K_2O, 100 kg P_2O_5 and 200 kg N ha^{-1} (SOP+DAP+CAN) in reducing significant uptake of Na^+. The site-to-site variation in the concentration of Na^+ was noted. The N fertilizer CAN caused more reduction in the uptake of Na^+ under saline conditions than urea.

The concentration of K was increased by applying SOP under normal as well as under saline conditions in both sugarcane varieties. The K^+ concentrations were much higher under normal conditions while salinity significantly reduced the K^+ concentration at all selected sites. The salinity effect regarding K^+ concentration was more pronounced in pot experiment. Application of N fertilizers i-e urea or CAN, significantly enhanced K^+ concentrations at both doses of N (100 and 200 kg ha^{-1}) in both the varieties under normal as well as saline conditions. However, maximum K^+ concentration was recorded at the highest dose (200 kg N ha^{-1}) but CAN treated plants had more K^+ than that of urea. Salt tolerant variety maintained higher K^+ under saline conditions. The data indicated that soils of different sites did not influence K^+ uptake, only salinity and fertilizers significantly affected K^+ uptake.

The uptake of phosphorus is also significantly influenced by application of N and K fertilizers. It was significantly enhanced with DAP and even more when it was applied in combination with N and K. However, the effect of CAN under saline conditions was more pronounced than urea. Reduction in P uptake was more pronounced in plants grown in pots under saline conditions. Under normal conditions, the behavior of both the varieties was similar, however, under saline conditions, the salt tolerant variety proved better. Both the varieties positively responded to fertilizer amendments.

The concentration of N was increased by applying N as urea or CAN under normal as well as under saline conditions in both sugarcane varieties. The N concentrations were much higher under normal conditions while salinity significantly reduced the N concentration at all selected sites. Application of N fertilizers, urea or CAN, significantly enhanced N concentrations at both rates i.e., 100 and 200 kg N ha^{-1} under normal as well

Table 7: Effect of different rates of N on P and N content in the leaves of two sugarcane varieties grown under normal and saline conditions

	Pot-Culture Expt				NIAB		Rashida		Jhang		
	Non-saline soil (1.2 dS m^{-1})		Saline soil (10 dS m^{-1})		(Field Experiment)		(Pindi Bhattian)				
Treatments	V_1	V_2	V_1	V_2	$^*V_1$	$^{**}V_2$	V_1	V_2	V_1	V_2	**Means**
P concentration (µ mole g^{-1})											
Without fertilizer	49.5	50.7	40.6	35.7	67.8	65.8.0	51.6	38.9	48.9	37.6	48.7 d
DAP	102.4	99.9	65.8	55.4	112.5	116.0	75.5	61.3	67.8	58.2	81.4 c
DAP+SOP	120.4	123.0	70.5	58.9	136.6	135.0	80.6	67.5	72.7	61.9	92.6 b
DAP+SOP +$Urea_{100}$	125.4	128.0	78.7	62.6	145.8	147.0	87.6	70.6	80.4	63.8	98.9 a
DAP+SOP +CAN_{100}	120.3	126.0	80.6	61.9	142.8	149.0	88.9	75.8	78.9	61.8	98.6 a
DAP+SOP +$Urea_{200}$	126.5	131.0	82.4	63.2	149.5	144.1	90.5	76.6	76.9	63.7	100.4 a
DAP+SOP +CAN_{200}	129.9	128.0	84.7	62.5	132.5	131.0	92.1	77.3	81.3	61.2	98.0 a
N concentration (µ mole g^{-1})											
Without fertilizer	1287	1366	745	561	1233	1269	766	691	667	603	919 f
DAP	1414	1494	766	614	1476	1494	889	748	741	674	1031 e
DAP+SOP	1607	1643	864	689	1548	1621	956	784	893	718	1132 d
DAP+SOP +$Urea_{100}$	1693	1776	949	712	1713	1704	1048	993	953	765	1231 c
DAP+SOP +CAN_{100}	1705	1799	989	789	1789	1763	1136	1044	1034	798	1285 b
DAP+SOP +$Urea_{200}$	1735	1816	997	795	1798	1773	1177	1086	1067	845	1309 a
DAP+SOP +CAN_{200}	1825	1857	1124	812	1825	1889	1206	1124	1145	866	1316 a

*cv. SPSG-26, **cv. CP-77400

Means sharing same letters do not differ significantly at the 5 % level of significance as saline conditions. However, maximum N was recorded at the highest rate (200 kg N ha^{-1}) but CAN treated plants had more N than that of urea. Salt tolerant variety (SPSG-26) maintained higher N under saline conditions than sensitive one (CP-77400).

Discussion

Increase in plant height was recorded due to different levels of N and supra optimal level of K in sugarcane varieties under normal and under saline conditions (Table 4). P alone had increased the plant height but it was more pronounced when it was applied in combination of K and N. It was observed by many workers that sugarcane plant height and cane diameter increased with the application of proper rates of NPK (Ahmed *et al.,* 1990; Sarwar *et al.*, 1996; Ayub *et al.,* 1999). As the application of potassium at supra optimal level was very effective in reducing lodging due to wind or greater plant height and consequently increased in number of milling cane and yield up to 30 %. These results are very similar to that of Shirazi *et al.* (2005) obtained for wheat. The comparison of N sources indicated that calcium ammonium nitrate was better than urea because the tallest plants were in the plots treated with CAN in saline as well as normal conditions.

Cane diameter and number of tillers per plant were significantly increased by the application of N and supra optimal level of K fertilizers under normal and saline conditions. Idress *et al.* (2004) also reported that application of potash along with N is beneficial to improve sugarcane growth and cane yield. The N source CAN perform better than urea and salt tolerant variety (SPSG-26) maintained more plant height, cane diameter and number of tillers per plant. It is obvious that the plants with more diameter, number of tillers and plant height certainly had more cane yield. Varietal differences were also reported by Nasir *et al.* (2000) and Lingle *et al.* (2000) in sugarcane. They indicated that salt tolerant variety is necessary to get more yield from saline lands. The results of the present study support their findings and suggest that without proper soil nutrient management even with salt tolerant variety, economical yield cannot be achieved.

Increase in sugar recovery was recorded due to different levels of N and supra optimal level of K in sugarcane under normal and under saline conditions (Table 5). But increase in N rate did not significantly improve the sugar recovery. There is direct relation of sugar and K in enhancing gas exchange during photosynthesis, which increase photosynthetic activity and enhanced yield and sugar contents (Qasim *et al.,* 2003; Shirazi *et al.*, 2005).

The results clearly indicated that if optimum N is applied to plants in the presence of suitable K level, plant productivity increases which could be due to increase in N use efficiency of the plants. Helal *et al.* (1975) indicated that application of potassium increased the uptake of N and improved its metabolism in barley as a result of which yield and yield parameters increased. Cheeseman (1988) also indicated that plants with higher K and N content are more salt tolerant and produced higher yield under saline conditions. Similarly, Lingle *et al.* (2000) reported that sugarcane varieties which maintained higher K^+ levels, had higher K/Na ratio are salt tolerant and had higher yield and better juice quality.

It is well documented (Khan & Ashraf, 1988; Ashraf *et al.*, 2002; Shirazi *et al.*, 2005; Hamid *et al.*, 2008) fact that salinity increased Na^+, although results of the present studies confirmed their findings but application of N along with K decreased its concentration (Table 6). The combination of NK significantly reduced Na^+ uptake in leaves, however, the best combination observed was SOP+CAN and the increase in plant height, and cane diameter and cane yield was also observed under this combination

(Table 5). The higher dose of N (200 kg N ha^{-1}) reduced the Na^+ uptake, which may be due to higher availability of N. It is also well documented (Khan & Ashraf, 1988; Ashraf *et al.*, 1999; 2002) that salt tolerant varieties had less accumulation of Na^+ than the sensitive one. However, it is also found that application of N and K improved the ability of plant to avoid or resist to uptake of Na^+. The N fertilizer, CAN was more active in reducing the uptake of Na^+ under saline conditions.

The K^+ concentrations were generally higher in those plants treated with SOP. Application of N fertilizers, urea or CAN, significantly enhanced K^+ concentrations at both rates of N (100 and 200 kg N ha^{-1}) under normal as well as saline conditions (Table 6). However, maximum K^+ was recorded at the highest dose (200 kg N ha^{-1}) but CAN treated plants had more K^+ than that of urea. As there is an interaction among K^+, Ca^{2+}, Mg^{2+}, and NH_4^+ plays an important role in favour of K^+ uptake (Ashraf *et al.*, 2005) that may be the reason of high concentration of K^+ in plants applied with CAN fertilizer. The tolerant plants develop such mechanism where they take up minimum Na^+ to reduce its toxicity (Alam, 1994). The sugarcane crop requires more K and N to enhance its vegetative growth because the sugar content and other raw materials depend on its vegetative growth (Nisar *et al.*, 2000; Idrees *et al.*, 2004). Under saline conditions, the balanced NPK supply may accelerate growth and produce more benefit than cost (Table 6 and 7).

The uptake of P was also significantly influenced by application of N and K fertilizers (Table 7). However, the effect of urea and CAN was similar in enhancing P uptake. Application of K as SOP reduces pH of the soil and increases the availability of P and other micronutrients thus resulting in enhanced growth (Idrees *et al.*, 2004). Nitrogen concentration reduced with salinity (Table 7). It is well documented that salinity reduces the uptake of N (Khan *et al*., 1990; Ashraf & Khan, 1993), however, application of K enhances N in plants. Salinity may reduce the synthesis of certain enzymes involved in the N metabolism such as nitrate reductase or may reduce the substrate due to the presence of high salts in the root medium (Khan *et al.*, 1990, Ahmad *et al.*, 2007). The salt tolerant variety was successful in maintaining the higher concentration of N, P and K than sensitive.

From the results it can be concluded that application of N as CAN along with supra optimal level of K as SOP is useful to manage higher yield and adequate nutrients in sugarcane under saline conditions. However, the rate of application should be based on soil analysis. Present study also confirmed that the salt tolerant variety is necessary to obtain economical sugarcane cane yield from saline lands.

References

Ahmed, R., M. I. Qureshi, M.B. Gill, S.A. Cheema and M.M. Bajwa. 1990. Studies on comparative yield performance of some varieties of sugarcane planted in autumn. *Pak. J. Agri. Sci*., 7:381-385.

Alam, S.M.,1994. Nutrient uptake by plants under stress conditions. In: *Handbook of Plant and Crop Stress (Pessarakli, M., ed.),. Marcel Dekker, New York, pp. 227-246.*

Ashraf M.Y., R.A. Wahed, A.S. Bhatti, G. Sarwar and Z. Aslam. 1999. Salt tolerance potential in different Brassica species, Growth studies. In: *Halophytes Uses in Different Climates* - II (Hamdy H., H. Lieth, M. Todorovic and M. Moschenko eds.), Backhuys Publishers, Leiden, The Netherland. pp.119-125.

Ashraf, M.Y. and A.H. Khan. 1993. Effect of NaCl on nitrogen status of sorghum. In: *Current Development in Salinity and Drought Tolerance of Plants*. (Naqvi, S.S.M., R. Ansari, T.J. Flower, A. R. Azmi, eds) pp. 84-88.

Ashraf, M.Y., A.K. Alvi, G. Sarwar, M.S. Qureshi, M.Ashraf and M. Hussain. 2005. Effect of ammonium chloride on the growth and nutrient uptake by cotton grown in alkaline soils. *Agrochimica*, XLIX:154-163.

Ashraf, M.Y., G. Sarwar, M. Ashraf, R. Afaf and A. Sattar. 2002. Salinity induced changes in α-amylase activity during germination and early cotton seedling growth. *Biol. Plant.,* 45:589-591.

Ayub, M.R., R. Ahmad, A. Tanveer, H.Z. Ahmad and M.S. Sharar. 1999. Growth, yield and quality of sugarcane (*Saccharum officinarum* L.) as affected by different levels of NPK application. *Pak. J. Biol. Sci*., 2:80-82.

Bremner, J M. 1965. Total nitrogen and inorganic forms of nitrogen. In: *Methods of Soil Analysis*. Ed. C. A. Black. Vol. 2. Amer. Soc. Agron. Madison. Wisconsin, 1149-1237.

Cheeseman, J. M. 1988. Mechanisms of salinity tolerance in plants*. Plant Physiol*., 87: 547-550.

Hamid, M. M.Y. Ashraf, K.U. Rehman and M. Arshad. 2008. Influence of salicylic acid seed priming on growth and some biochemical attributes on wheat growth under saline condition. *Pak. J. Bot.*, 40: 361-367.

Helal, M., K. Koch and K. Mengel, 1975. Effect of salinity and potassium on the uptake of nitrogen and on nitrogen metabolism in young barley plants. *Agron. J*., 351: 310-313.

Idrees, S., M.S. Qureshi, M. Y. Ashraf, M. Hussain. 2004. Influence of sulphate of potash (SOP) and farmyard manure (FYM) on sugarcane (*Saccharum officinarum* L.) grown under salt stress. *Pak. J. Life Soc. Sci*., 2:65-69.

Jackson, M.L. 1962. *Soil Chemical Analysis*. Constable and Company, London, UK.

Khan, A.H. and M.Y. Ashraf. 1988. Effect of sodium chloride on growth and mineral composition of sorghum. *Acta Physiol. Plant*., 10: 259-264

Khan, A.H., M.Y. Ashraf and A.R. Azmi. 1990. Effect of NaCl on growth and nitrogen metabolism of sorghum. *Acta Physiol. Plant.*, 12: 233-238.

Kumar, M.D., K. S. Channabasappa and S.G. Patil. 1996. Effect of integrated application of pressmud and paddy husk with fertilizer on yield and quality of sugarcane (*Saccharum officinarum* L.). *Ind. J. Agron*., 41:301-305.

Lingle, S.E., R.P. Wiedenfeld and J.E. Irvine. 2000. Sugarcane response to saline irrigation water. *J. Plant Nutrition*, 23:469-486.

Nasir, M.N., R. H. Qureshi, M. Aslam and J. Akhtar. 2000. Comparative studies on two selected sugarcane lines for differences in physiological traits. *Pak. Sugar*, 6: 52-61.

Noaman, M. N. 2004. Effect of potassium and nitrogen fertilizers on the growth and biomass of some halophytes grown under high levels of salinity. *J. Agron*., 3 : 25-30.

Plaut, Z., F.C. Meinzer and E. Federman. 2000. Leaf development, transpiration and ion uptake and distribution in sugarcane cultivars grown under salinity. *Plant Soil*, 218:59-69.

Qasim, M., M. Ashraf, M. A. Jamil, M.Y. Ashraf, S. R. Rehman and E. S. Rha. 2003. Water relations and leaf gas exchange properties in some elite canola (*Brassica napus*) lines under salt stress. *Ann. Appl. Biol*., 142:307-316.

Sarwar, M., M.S. Gill and K.B. Malik. 1996. Comparison of pit and trench planting of sugarcane at different fertilizer levels*. Pak. Sugar J*., 10:11-16.

Shirazi, M.U., M.Y. Ashraf, M.A. Khan and M.H. Naqvi. 2005. Potassium induced salinity tolerance in wheat (*Triticum aestivum* L.). *Int. J. Environ. Sci. Tech*., 2:233-236.

Steel, R.G.D., J.H. Torrie and D. Dickey. 1997. *Principles and Procedures of Statistics*. McGraw Hill Book Co. Inc., New York.

USDA. 1962. US Salinity Laboratory Staff: Diagnosis and improvement of saline and alkaline soil. Agriculture Handbook No. 60. USDA, Washington DC.

Waraich, E.A. R. Ahmad, A. Ali and S. Ullah. 2007. Irrigation and nitrogen effects on development and yield of wheat (*Triticum aestivum* L.). *Pak. J. Bot.*, 39: 1663-1672.

Wolf, B., 1982 . A comprehensive system of leaf analysis and its use for diagnosing crop nutrient status. *Comm. Soil Sci. Plant Anal*., 13, 1035-1059.

(Received for publication 21 April, 2008)