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EFFECT OF SALINITY ON GROWTH AND YIELD OF SUGAR BEET (*BETA VULGARIS* L.) UNDER LOWER SINDH ENVIRONMENT

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ABSTRACT

Rising demand of sugar with increasing population pressure needs to grow more sugar crops. However, the world is depriving of good quality soil and water to grow these crops. Hence it requires exploring specific germplasms to grow on salt-affected soils. A field experiment was conducted at the experimental farm of National Sugar and Tropical Horticulture Research Institute, Thatta.The aim of the experiment was to investigate the effect of varying salinity levels (0, 4, 8, 12 and 16 EC dS m^{-1}) on the growth and yield of ten sugar beet genotypes (California, Ernestina, Magnolia, Mirabella, Sandrina, SD 12970, SD PAK 03/06, SD PAK 01/07, SD PAK 07/07) and SD PAK 09/07). Planting was done in a Randomized Complete Block Design with three replications. Fifteen-day-old seedlings were stressed with salt solutions of 4, 8, 12 and 16 dS m^{-1} up to maturity. There was significant effect of salinity and genotypes on growth and yield of sugar beet crop. Salinity at lower levels did not show adverse effect on almost all recorded growth and yield traits it rather encouraged the growth and yield at lower levels. The beet yield produced by SDPAK 09/07, California and SDPAK 01/07 genotypes was encouraging as compared to other genotypes tested. In case of sugar yield, it increased up to 8 dS m^{-1} then it reduced by 36.0 and 55.0% at EC 12 dS m^{-1} and EC 16 dS m^{-1}, respectively. It was concluded that sugar beet genotypes SDPAK 09/07, California and SDPAK 01/07 displayed better performance for beet yield in salinity levels over the other genotypes. The defined genotypes SDPAK 09/07 and California displayed better performance for sugar yield in salinity levels.

Keywords: beet yield, genotypes, salinity levels, sugar beet, sugar yield

INTRODUCTION

The increasing problem of soil salinity mostly occurs in arid and semi-arid regions, where >900 million ha of agricultural lands are badly affected by salinity (Rengasamy, 2010**;** Ma *et al*., 2015). Nonetheless, the magnitude of global distribution of saltdiffers with area and place. Soil salinity hazards become most worstin those regions of world agriculture mostly depends on irrigation (Zhu,

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2001). In Pakistan, the most important cause of soil salinity is use of inadequate and uneven application of irrigation water (Chandio *et al.,* 2010). The issue becomes more serious due to the poor drainage triggered waterlogging, dubios quality groundwater, inefficient water management and use of brackish water for irrigation purpose (Ashraf *et al.,* 2011). Consequently, root zone salinity is elevated and favors sodicityand waterlogging. According to Rajpar *et al*. (2010), the major causes for the development of soil salinity in the Sindh province are: parent material, application of poor quality groundwater to field crops, low precipitation, high temperature, coastal floods and sea water intrusion. Soil salinity reduces plant growth and crop productivity (Zhang and Shi, 2013; Bhatti *et al*., 2015). Soil salinity imposes three major stresses on the plant growth: one is a high osmotic pressure in the soil solution, this results in reduced water availability; the second is high concentration of ions, especially sodium (Na^+) and chloride (Cl^-) in the soil solution that build-up high concentration of ions in leaves; the third is nutrient disorder in plants (Zhang and Shi, 2013). However, different salinity approaches have been made by various plant scientists to improve crop production on salt-affected soils by using salt-tolerant crops including economically important field crops, e.g. fiber crops (Yu *et al*., 2016), cereals (Zafar *et al*., 2015), oilseeds(Jamil *et* al., 2006). Hence, the screening, identification and promotion of salinity tolerant crop species and their genotypes appeared to be the most economical technique to deal with these problem soils.

Sugar beet (*Beta vulgaris,* L.) – known to be a cropresistant to salinity (Moreno, 2001) – is rankedsecond after sugarcane as the most important sugar crop. It produces~40% of total globally produced sugar (Hameed and Ghaffar, 2010). The salt-tolerance of sugar beet is around 9.5 dS m^{-1} (Gupta, 1985) and can be grown under moderately saline condition (Ayars and Schoneman, 2006). It is highly salt-tolerant during vegetative growth (Abbas *et al*., 2011), however, it is very sensitive at early growth stages, i.e. germination, emergence, seedling (Kaffka and Hembree, 2004; Farkhondeh *et al.,* 2012). Therefore, salt-tolerant sugar beet genotypes must be selected and recommended for adoption under salinity stress. The study envisaged the effect of varying levels of salinity on the growth and beet and sugar yield of different sugar beet genotypes.

MATERIALS AND METHODS

Experimental site

The research was executed at 'National Sugar and Tropical Horticulture Research Institute' (NSTHRI), Thatta, Sindh, Pakistan (located between 24.5^{0}N and 67.50^0 E).

Plant material and experimental design

Selected genotypes of sugar-beet, viz. California, Ernestina, Magnolia, Mirabella, Sandrina, SD-12970, SDPAK 03/06, SDPAK 01/07, SD PAK 07/07 and SDPAK 09/07 were included in the study. Pure seed of these gentoypes was obtained from National Agriculture Research Center (NARC), Islamabad. The experiment was launched following RCBD split plot design, repeated thric. There were five varying levels of salinity treatments (EC: control, 4, 8, 12 and 16 dS m^{-1}).The soil of the experimental site (0-15 and 15-30 cm) was analyzed for selected physico-chemical properties before sowing of beets (Table 1). The land was prepared to fine tilth. One meter long ridges were developed for planting seed. Distance between ridges was kept one meter. Seeds (2-3) were sown on the both sides of ridges (20 cm apart). Nitrogen (N) and phosphorus (P) were both applied at the recommended rate (120 kg N and P ha^{-1} each) as suggested elsewhere (Memon *et al*., 2004). Full dose of P through diammonium phosphate (DAP) and ½ of N in through urea was applied at sowing. The left over ½ N was applied in two equal doses, i.e. after 50 and 120 days of sowing. Potassium can alleviate the salt-stress as a consequence of K^+ to Na^+ antagonism. Therefore, K fertilizer application was avoided. Thinning was done after full emergence of seedlings. Inter-culturing was done for eradication of weeds. To avoid initial shock of salts to plants, the salt solution was applied in the pre designated plots initiated soon after establishment of seedlings (15 DAS) and continued up to the maturity of the crop.

Growth and beet yield traits

At maturity, i.e. after 160 days of sowing, the data were recorded various growth and yield traits, viz. number and area of leaves, fresh and dry beet root biomass, root length and beet and sugar yield.

Sugar yield

Sugar yield was calculated by using the standard formula, i.e. [Beet yield (t ha^{-1}) ÷ sugar recovery% × 100] as suggested by Gobarah and Mekki (2005). Sugar recovery was calculated by sub-tracting a constant value of 2.75 from the value of percent Pol (Usmanikhail, 2011).

Statistical analysis

The statistical analyses were performed by using the statistical software Statistix 8.1. The treatment means were separated through Tukey's Honestly Significant Difference (HSD) Test at alpha 0.05 (Steel, 1997).

RESULTS

The genotypes xsalinity interactionwas non-significant for most of the parameters except leaf area, root length and sugar yield. Results for number of leaves per plant given in Table 3 showed that sugar beet plants were able to produce more leaves at EC 4 dS m^{-1} then the number of leaves decreased by about 39.5% at 16 dS m^{-1} electrical conductivity (EC) as against control. In terms of genotypes, more leaves per plant were observed on SDPAK 09/07, followed by SDPAK-03/06 and SDPAK 01/07. Comparatively lower number leaves per plant were observed on Ernestina and SDPAK 07/07. Leaf area was slightly reduced at 4 and 8 dS m^{-1} EC beyond that it decreased rapidly (Table 4). More leaf areawas noted for SD-12970, followed by SDPAK 03/06 and California. Lower leaf area was shown by Sandrina. In case of salinity × genotypes interaction, larger leaf area was observed in SDPAK 01/07 at EC 8 dS m^{-1}, followed by SD-12970 and SDPAK 03/06 at control and EC 4 dS m^{-1}, respectively. Lower leaf area was recorded in Sandrina at EC 16 dS m^{-1}. Root length was also significantly (P<0.05) influenced by salinity (Table 5). Maximum root length was observed under control and minimum at EC 16 dS m^{-1}.

In terms of genotypes, well developed and lengthy root system was noted in SDPAK 09/07, followed by California (24.44 cm) and SD-12970 (21.11cm), while less developed and shortest root system was displayed SDPAK 07/07 and Ernestina. The SDPAK 09/07 and California exhibited better performance in terms of root length under EC 8 dS m^{-1}. Fresh beet root biomass (Table 6) indicated that maximum fresh beet root weight was recorded at EC 4 dS m^{-1} and minimum at EC 16 dS m^{-1}. In case of genotypes, maximum fresh beet root biomass was obtained from SDPAK 09/07, followed by California and SDPAK 01/07. Minimum fresh beet root obtained from was SDPAK 07/07 genotype. Similarly dry root biomass was also significantly decreased by increase in salinity. Higher dry root reduction was noted in SDPAK 07/07 genotype than other genotypes (Table 7). Regarding beet yield, it can be observed from Table 8 that beet yield increased from 41.0 to 45.0 t ha^{-1} as EC elevated from to 4 dS m^{-1} and decreased after wards. In case of genotypes, higher beet yield was given by SDPAK 09/07 genotype, followed by California and SDPAK 01/07 while, lowest was given by SDPAK 07/07 (29.0 t ha^{-1}) and Mirabella. Sugar yield enhanced from 5.5 to 6.5 and 6.3 t ha^{-1} with the increase in salinity level from control to 8 dS m^{-1}, respectively (Table 9). However, it was reduced beyond that. Moreover, maximum sugar yield was noted in case of SDPAK 09/07, followed by California and SDPAK 01/07. Minimum sugar yield was obtained for SDPAK 07/07. At varying levels of salinity, highest sugar yield was noted in case of SDPAK 09/07 as against other genotypes at EC level of 8 dS m^{-1}. Where, SDPAK 07/07 produced lowest sugar yield (1.2 t ha^{-1}) at EC 16 dS m^{-1}.

DISCUSSION

It is observeable from the data that leaf number and area, biomass production (fresh /dry root weight) and beet and sugar yields enhanced under salinity levels of EC 4 and 8 dS m^{-1}, beyond that salinity showed negative impact on all traits. This is was possibly because of reduction in new leaf formation, decrease in leaf and beet size and photosynthetic activities in plants due to combined effect of osmotic and specific ions Na^{+} and Cl^{-1} (Munns and Tester, 2008; Farkhondeh *et al.,* 2012). Similar results were also reported by Munns and Tester (2008) and Rozema and Schat (2013). Number of leaves in all genotypes significantly decreased with increasing salinity levels. The genotype SDPAK 09/07 and California showed well performance under all salinity levels due to better growth and development under salt-stress environment. It is well documented that various genotypes (sugar beet and cabbage) respond differently to salt-stress (Jamil *et al.,* 2006; Mostafavi, 2012). Salinity encouraged the leaf area up to EC 8 dS m^{-1} and then decreased it by about 28.6 and 48.3% at EC 12 and 16 dS m^{-1}. This result is in harmony with Dadkhah (2011) who reported that leaf area increased under low salinity level (50 m*M*).

However, the leaf area of plant decreased under higher salt concentration. The reduction in leaf area might be related to inhibition of leaf expansion due to closing of stomata (Manivannan *et al*., 2007), and reduced photosynthetic activities and respiration rate in plants under salinity (Mundree *et al*., 2009; Shahid *et al.,* 2011). The genotypes, SD-12970, SDPAK 03/06, and California produced significantly greater leaf area than the others. The result suggested that the genotypes of a crop species may have different behavior towards salt-tolerance (Farkhondeh *et al.,* 2012). The beet yield increased from control to EC 4 dS m^{-1} with production of 41.0 to 45.0 t ha^{-1}. However, it decreased at higher salinity level with about 32.61% at EC 16 dS m^{-1}. The reduction in beet yield was possibly due to reduced water and nutrient uptake under high salinity environment. This may change mineral balance of plants causing reduction in photosynthetic activity and carbohydrates metabolisms (Mundree *et al*., 2009). The result is supported by findings of Mustafavi (2012) who reported that beet yield declined under high salinity levels (16 dS m^{-1}). The SDPAK 09/07, California and SDPAK 01/07, genotype showed better performance in terms of high beet yield over the other genotypes. It indicates that different sugar beet genotypes show different behavior in terms of beet yield under different salinity levels.

The negative impact of high (12 and 16 dS m^{-1}) salinity on sugar yield can be the result of accumulation of Na^{+} ions by plants. These findings are in line with the previous findings of Zaki *et al*. (2014) who repoted that sugar yield is reduced due to absorbed Na^{+} ions. The genotypes SDPAK 09/07, California and SDPAK 03/06 performed well and produced higher sugar yield under salt-stress environment. Zaki *et al*. (2014) also reported that maximum sugar yields was given by top variety and less by Ghazile variety under salt-stress environment. The result is also in agreement with Kaloi *et al.* (2014).

Table 1. Physico-chemical properties of experimental field before sowing

Parameter	**Unit**	**Soil depth(cm)**	
		0-15	**15-30**
Sand	%	14.78	13.53
Silt	%	48.82	49.72
Clay	%	36.4	36.72
Textural class (USDA)		Silty clay loam	Silty clay loam
$EC_{1:5}$	(dS m^{-1})	1.25	1.60
$pH_{1:5}$		7.60	7.21
Organic matter	%	0.88	0.71
Lime content	%	6.14	7.42
SAR		4.33	3.84
ESP		4.49	4.30

Table 2. Mean square from analysis of variance of data for quantitative and qualitative data of sugar beet genotypes under salt stress environment

Source of variance	**df**	**Number of leaves plant^{-1}**	**Leaf Area plant^{-1}**	**RL**	**FRW**	**DRW**	**Beet yield (t ha^{-1})**	**Sugar yield (t ha^{-1})**
Salinity (S)	9	540.15**	31293.3**	652.79**	1260948**	181453**	1714.84**	93.656**
Genotype (G)	4	199.95**	9353.2**	148.30**	355292**	16886**	1177.21**	37.937**
SXG	36	NS	2106.7**	18.99**	NS	NS	NS	2.375**
Error	100	10.681	665.7	9.169	74304	3759	131.20	2.5403

*, **. =significant at 0.05%, respectively, NS=non-significant., df=degrees of freedom. RL=root length (cm), FRW and DRW= fresh and dry root weight plant$^{-1.}$

Table 3. Effect of different salinity levels on number of leaves plant^{-1} of sugar beet genotypes

Genotype	Salinity (EC dS m^{-1})					Mean
	Control	4	8	12	16	
California	24.5	33.0	27.6	21.1	17.4	24.8 A
Ernestina	21.2	21.6	17.8	16.9	11.5	17. 9 B
Magnolia	22.6	21.8	19.0	17.0	11.3	18.3 B
Mirabella	21.8	21.1	17.9	15.6	15.3	18.3 B
Sandrina	22.1	22.2	19.2	17.9	11.6	18.6 B
SD-12970	23.1	23.5	21.6	18.5	13.9	20.1 B
SDPAK 03/06	28.22	29.3	28.9	24.6	16.0	25.4 A
SDPAK 01/07	26.3	27.4	27.4	25.6	18.6	25.1 A
SDPAK 07/07	21.4	18.3	20.0	16.8	10.3	17.3 B
SDPAK 09/07	27.1	32.3	28.1	25.0	18.1	26.1 A
Mean	23. 9 A	25.0 A	22.8 A	19.9 B	14.4 C	-

Means followed by the same letters in column and row did not differ significantly at $P<0.05$

Table 4. Effect of different salinity levels on leaf area (cm^2) of sugar beet genotypes

Genotype	Salinity (EC dS m^{-1})					Mean
	Control	4	8	12	16	
California	136.63b-j	163.22a-g	193.59a-d	117.46c-k	98.49e-k	141.88A
Ernestina	137.89b-j	156.29a-h	100.37e-k	84.42f-k	56.92j-k	107.18CD
Magnolia	156.98a-h	117.66c-k	104.92e-k	102.6e-k	67.16i-k	109.86BCD
Mirabella	111.05d-k	113.3c-k	99.97e-k	97.72e-k	77.03g-k	99.81D
Sandrina	148.64a-i	100.42e-k	89.15f-k	62.87i-k	40.46k	88.31D
SD-12970	214.16ab	192.33a-d	181.82a-e	121.16c-k	82.11f-k	158.32A
SDPAK 03/06	146.7a-i	199.71a-c	199.00a-c	146.65a-i	96.77e-k	157.77A
SDPAK 01/07	119.65c-k	129.09b-j	233.68a	121.82c-k	93.81f-k	139.61AB
SDPAK 07/07	167.82a-f	143.85b-j	94.16f-k	69.65g-k	57.28j-k	106.55CD
SDPAK 09/07	134.32b-j	148.7a-i	163.15a-g	128.29b-j	91.74f-k	133.23ABC
Mean	148.0 A	147.0 A	146.0 A	105.0 B	76.0 C	-

Means followed by the same letters in column and row did not differ significantly at $P<0.05$

Table 5. Effect of different salinity levels on root length (cm) of sugar beet genotypes

Genotype	Salinity (EC dS m^{-1})					Mean
	Control	4	8	12	16	
California	27.22a-e	29.44a-d	30.77abc	18.88e-o	15.88f-o	24.44AB
Ernestina	24.22a-h	19.11e-o	19.22e-o	13.44i-o	10.55n-o	17.31DE
Magnolia	27.11a-e	18.88e-o	19.88d-o	15.22g-o	11.11m-o	18.44CDE
Mirabella	21.44b-l	22.33a-l	22.77a-j	13.00j-o	13.11j-o	18.53CDE
Sandrina	23.00a-j	19.22e-o	20.77c-m	19.22e-o	15.22g-o	19.48CDE
SD-12970	27.44a-e	22.00a-l	25.22a-g	18.44e-o	12.44k-o	21.11CDE
SDPAK 03/06	20.22d-n	23.33a-i	24.55a-h	20.44d-n	14.44h-o	20.60CD
SDPAK 01/07	19.22e-o	22.44a-k	21.88a-l	18.77e-o	14.66h-o	19.40CDE
SDPAK 07/07	25.44a-f	18.44e-o	16.22 f-o	12.22l-o	9.88 o	16.44E
SDPAK 09/07	29.55a-d	31.11ab	32.00 a	21.27b-m	18.88 e-o	26.56A
Mean	24.48 A	22.63 A	23.33 A	17.9 B	13.62 C	-

Means followed by the same letters in column and row did not differ significantly at $P<0.05$

Table 6. Effect of different salinity levels on fresh beet root weight (g) of sugar beet genotypes

Genotype	Salinity (EC dS m^{-1})					Mean
	Control	**4**	**8**	**12**	**16**	
California	1027.8	1129.6	1469.9	1242.1	855.6	1145.0 AB
Ernestina	958.3	1029.1	912.4	797.6	627.8	865.0 BC
Magnolia	923.8	1052.9	937.5	681.5	496.3	818.4 C
Mirabella	883.3	1119	855.2	715.3	513	817.2 C
Sandrina	1326.4	1222.2	1127.8	692.6	591.7	992.1 ABC
SD-12970	1472.2	1284.2	831.0	812.5	694.4	1018.9 ABC
SDPAK 03/06	1069.9	1152.8	1111.1	813.5	731.5	975.8 ABC
SDPAK 01/07	1131.5	1208.3	1244.4	955.1	739.6	1055.8 ABC
SDPAK 07/07	1066.7	929.6	769.9	655.6	475.5	779.4 C
SDPAK 09/07	1157.4	1410.7	1522.2	1242.9	919.0	1250.4 A
Mean	1101.7A	1153.9A	1078.1A	860.9B	664.4B	-

Means followed by the same letters in column and row did not differ significantly at $P<0.05$

Table 7. Effect of different salinity levels on dry root weight (g) of sugar beet genotypes

Genotype	Salinity (EC dS m^{-1})					Mean
	Control	**4**	**8**	**12**	**16**	
California	328.0	346.3	331.0	264.3	184.6	290.8 AB
Ernestina	273.6	325.6	218.0	200.3	158.6	235.2 BC
Magnolia	287.3	318.6	219.6	179.0	134.6	227.8 BC
Mirabella	227.3	323.00	207.6	176.6	127.3	212.4 C
Sandrina	338.3	331.3	273.0	174.6	144.0	252.2 ABC
SD-12970	394.6	385.0	192.6	200.3	157.0	265.9 ABC
SDPAK 03/06	376.0	364.6	248.6	179.6	165.3	266.8 ABC
SDPAK 01/07	356.0	374.6	274.3	216.3	172.6	278.8 ABC
SDPAK 07/07	300.3	253.6	192.0	171.3	126.3	208.7 C
SDPAK 09/07	357.6	379.0	333.3	269.0	206.6	309.1A
Mean	323.9 A	340.1A	249.1 A	203.1 A	157.7 A	-

Means followed by the same letters in column and row did not differ significantly at $P<0.05$

Table 8. Effect of different salinity levels on beet yield (t ha^{-1}) of sugar beet genotypes

Genotype	Salinity (EC dS m^{-1})					Mean
	Control	**4**	**8**	**12**	**16**	
California	39.5	44.8	61.9	50.0	35.4	46.3AB
Ernestina	33.3	39.1	36.2	30.8	28.0	33.4 BC
Magnolia	40.9	40.1	35.8	26.7	21.5	33.0 BC
Mirabella	31.1	38.0	34.1	21.3	20.2	29.0 C
Sandrina	39.7	47.4	31.6	18.6	14.7	30.4 C
SD-12970	48.9	52.6	34.4	35.0	28.8	39.9 BC
SDPAK 03/06	38.7	43.6	46.1	27.2	34.1	38.0 BC
SDPAK 01/07	44.8	48.1	57.6	42.2	29.70	44.4 AB
SDPAK 07/07	40.5	32.3	30.9	22.9	19.2	29.0 C
SDPAK 09/07	49.7	65.5	68.5	54.3	42.7	56.0 A
Mean	41.0 AB	45.0 A	44.0 A	33.0 BC	27.0 C	-

Means followed by the same letters in column and row did not differ significantly at $P<0.05$

Table 9. Effect of different salinity levels on sugar yield (t ha^{-1}) of sugar beet genotypes

Genotype	Salinity (EC dS m^{-1})					Mean
	Control	4	8	12	16	
California	5.9	7.2	9.6	5.8	3.3	6.3B
Ernestina	4.4	5.9	5.3	2.9	2.0	4.1 DE
Magnolia	5.9	5.8	4.4	2.4	1.8	4.0 DE
Mirabella	4.4	5.0	4.5	2.2	1.4	3.5 DE
Sandrina	5.0	6.0	4.2	1.5	1.3	3.6 DE
SD-12970	5.5	6.5	4.7	2.9	2.4	4.4 CDE
SDPAK 03/06	5.4	6.7	7.2	3.3	3.9	5.3 BCD
SDPAK 01/07	6.5	7.3	8.6	4.8	3.2	6.1 BC
SDPAK 07/07	5.3	4.4	3.2	2.0	1.2	3.2 E
SDPAK 09/07	7.5	10.1	11.3	7.6	4.7	8.2 A
Mean	5.5 A	6.5 A	6.3 A	3.5 B	2.5 B	-

Means followed by the same letters in column and row did not differ significantly at $P<0.05$

CONCLUSION

Salinity stress with electrical conductivity levels of 4 and 8dS m^{-1} encouraged the growth and beet and sugar yield of all genotypes. The sugar beet genotypes California, SDPAK 09/07, SDPAK 03/06, and SDPAK 01/07, performed well in terms of beet and sugar yields under all salt treatments. Hence, these genotypes may be considered and encouraged for cultivation on salt-affected soils, using saline water and can be included in further breeding program.

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