Pak. J. Agri. Sci., Vol. 54(3), 645-652; 2017
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
DOI: 10.21162/PAKJAS/17.6192
http://www.pakjas.com.pk

BER (*Zizyphus mauritiana* L.) PRODUCTION AND QUALITY AS INFLUENCED BY DIFFERENT SALINITY LEVELS IN WATER

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About 70-75% of the pumped ground water of Pakistan is brackish in nature and Ber cultivation is considered as a good option for such conditions. Objective of the present study was to evaluate whether brackish water is suitable for Ber production without affecting its quality. The research was conducted at Experimental Garden, Ghazi University and Horticultural Research Station, Dera Ghazi Khan. Statistical inferences showed significant variation for all studied traits (growth, physical and biochemical characteristics) and ber varieties against brackish water treatment. Significant interaction among varieties and treatments was found for MBL, Ca, K, PRO, SS, VC and TS during 2013 and 2014. On contrary, FLSR, TY, Na and TA were consecutively found non-significant in both years. While CD, SB and TNF, FLW, SW, FW, CHL, TSS and pH were significant in 2013 but non-significant in 2014 against brackish water treatment. Normal water improved all the studied traits in both years. Brackish water least affected Ber production without affecting its quality as compared to Brackish + normal water treatment. Among the varieties, Delhi White performed better than Suffan , Karela and Mehmud Wali in both experimental years. Brackish water can be used to grow Ber and Delhi White variety is recommended for cultivation on marginal lands in Pakistan.
Keywords: *Zizyphus mauritiana*, physical attributes, biochemical analysis, salt stress, marginal lands, fruit yield.

INTRODUCTION

Ber (*Zizyphus mauritiana* L.) is a member of family *Rhamnaceae*. The genus *Zizyphus* contains 135 to 170 species (Islam and Simmons, 2006). *Zizyphus mauritiana* is a spiny, evergreen shrub or small tree up to 15 m height. It is a fast-growing tree, with an average bearing life of 25 years. It is well adapted to arid and semi-arid conditions with adequate rain during the vegetative period. The fruit's skin is smooth, glossy, and thin but tight. The flesh is white and crispy. When semi-ripened, it is bit juicy and possesses a pleasant aroma (Pareek, 2013). The fruit is a good source of vitamin C, carotene, phosphorus and calcium. Leaves contain 6% digestible crude protein which is an excellent source of ascorbic acid and carotenoids (Abbass *et al.*, 2012; Ismail, 2013; Boora and Bel, 2008). Average fruit yield per tree ranges from 50-250 kg tree^{-1} and is relatively easy and cheap to cultivate. The worldwide annual production of ber fruit is 0.90 million tons and cultivated on an area of 88, 000 hectares. Ber trade has expanded over the last decade and is expected to continue in future. India, Thailand and Pakistan export ber to the Middle East, Malaysia and Far East but only Thailand exports on a year-round-basis (Szabolcs, 1994).

Soil and water salinity is major bottleneck for sustainable production in arid and semi-arid areas of Pakistan. It is also increasing steadily in many part of the country. According to conservative estimate, about 7% of total land area of the world is saline to varying degrees (Szabolcs, 1994). Moreover, it is estimated that 70-75% of the pumped ground water of Pakistan is brackish in nature.

Agricultural crops exhibit various responses to salt stress. It decreases the agricultural production, physicochemical properties of soil and ecological balance as well. General output of salinity is significant decrease in the agricultural productivity and soil erosion. Hence, they cause low economic returns (Hu and Schmidhalter, 2002). Salinity effects the morphological, physiological, and biochemical processes in plants including germination, development and nutrient uptake (Akbarimoghaddam *et al.*, 2011). Salt stress also imposes osmotic stress, oxidative stress, ion toxicity thus limits water uptake from soil. Excessive accumulation of Na ion in cell walls rapidly leads to osmotic stress and cell death (Munns, 2002). Higher salt concentrations also affect photosynthesis by reduction in stomatal conductance, leaf area and chlorophyll content through a decrease in photosystem II efficiency (Netondo *et al.*, 2004). It adversely affects the reproductive development by enhancing senescence of fertilized embryos, programed cell death, ovule abortion. Recent reports also show that salinity adversely affects enzyme activity (Seckin *et al.*, 2009), DNA, RNA, protein synthesis and mitosis (Tabur and Demir, 2010; Javid *et al.*, 2011).

For overcoming the salt stress, two primary lines of action are emphasized, reclamation or by growing salt tolerant plants

(Shannon and Grieve, 1999; Iqbal *et al*., 2015). During the past few decades' scientists have emphasized the latter strategy, formally called the biotic approach considering it economical, feasible and efficient (Ashraf and McNeilly, 2004). For this purpose, use of salt-tolerant plants has been suggested (Cha-um and Kirdmanee, 2008).

Ber fruit is considered a very good option for such marginal lands. It can be grown with moderately saline irrigation water. However, growth and greenery effect was adversely affected when the irrigation water salinity was greater than 10 dSm^{-1} (Singh and Singh, 1994). Maximum root density in ber fruit tree is found at deeper soil layer (Ismail and Almarshadi, 2013). Though, research information regarding improvement in ber production and its post-harvest studies is very limited. Therefore, present research was conducted to evaluate the effect of brackish water on ber production and its quality.

MATERIALS AND METHODS

The present study was conducted at Experimental Garden, Ghazi University and Horticultural Research Station, Dera Ghazi Khan. Experiments were organized in such a way that initial field trials were led to evaluate different strategies to improve ber production under arid and semi-arid conditions. Detailed analysis of the soil fertility and the applied water was carried out before the start of the experiment. Commercial ber cultivars viz. Delhi White , Suffan , Karela and Mehmud Wali were selected randomly in ber orchard of the College. There were three treatments of water (normal water fit for irrigation; brackish water 11 dsm^{-1} and 50% brackish water + 50% normal water) and each treatment was replicated thrice. Cultural practices were followed throughout the study as per requirement. Growth (main branch length=MBL, collar diameter from the main branch=CD, number of secondary branches=SB, total number of fruit on randomly selected tag branch=TNF); physical (flesh weight=FLW, stone weight=SW, flesh stone ratio=FLSR, fruit weight=FW, total yield/plant=TY) and biochemical (leaves: Calcium=Ca, Sodium=Na, potassium=K, proline=PRO, chlorophyll contents=CHL, soluble sugars=SS. Fruits: vitamin C=VC, total soluble solids=TSS, titratable acidity=TA, total sugars reducing and non-reducing=TS, pH) characters were determined.

The branch length of the ber was measured with help of measuring tape. Five plants were tagged and average tree length was calculated in cm. The branches of ber were calculated manually. Five tagged plant were selected and the total number of fruits present on the branches were counted manually. Flesh weight was also taken with the help of electric balance. The fruit weight from five tagged plant was measured with the help of electric balance. The yield of five tagged tree plants was measured in gram and converted into kg. Mineral contents (Ca, Na and K) were determined by using Inductive Coupled Argon Plasma (Jones, 1977). The proline was determined according to the Bates *et al.* (1973) method. Total soluble sugars were determined according to the method of Yemm and Willis (1954).

***Statistical analysis*:** Field studies were arranged in randomized complete block design while laboratory experiments in a completely randomized design with factorial arrangements. Data collected was analyzed statistically using standard procedures (Steel *et al.*, 1997).

RESULTS

***Growth characteristics*:** The analysis of variance for the data regarding MBL, CD, SB and TNF showed highly significant difference among genotypes and treatments in both years 2013 and 2014. The Interaction among varieties and treatments was significant for MBL in both years and significant in 2013 and non-significant in 2014 for CD and SB (Table 1).

Normal water performed better than others treatments in both years 2013 & 2014. It provided maximum values of MBL (315.50 cm); CD (16.83 cm); SB (11.50) and TNF (31.41 g branch-1) during 2014, while brackish water

Table 1. Analysis of variance of growth characteristics of Ber in 2013 (light faced values) and 2014 (bold faced values).

SOV	DF	MBL (cm)	CD (cm)	SB	TNF
Replication	2	58.7	0.0833	0.5278	9.361
		86.3	**2.1111**	**0.1111**	**0.861**
Treatments	2	25154.1***	21.5833***	12.4444***	34.694***
		23760.8* **	**17.6944*** **	**3.0278** **	**1.861** **
Varieties	3	9640.3***	16.0741***	19.3704***	186.000***
		9783.4* **	**11.1389*** **	**19.8796*** **	**56.222*** **
Treatments × Varieties	6	772.6***	0.5463NS	1.2593**	14.139**
		881.9* **	**2.6944** **	**0.7685NS**	**21.306*** **
Error	22	72.9	1.0530	0.3157	2.997
		99.6	**0.6869**	**0.5354**	**3.770**

*, P≤0.05, **, P≤0.01, ***, P≤0.001, NS=Non-significant, SOV=sources of variation, DF=degree of freedom, MBL=main branch length, CD =collar diameter of main branch, SB=number of secondary branches, TNF=total number of fruits on randomly tag branch.

resulted into the minimum values of MBL (227.33cm) and CD (14.16 cm) during 2013. However, least values of SB (9.50) and TNF (28.08 g branch-1) were recorded in Normal+Brackish water in 2013(Table 5).

Delhi white performed better than all other varieties. Highest values of MBL (296.00 cm) and CD (16.77 cm) was recorded during 2014 while TNF (35.00 g branch-1) was higher in 2013. Moreover, the SB (12.33) remained same for the both years. On contrary, the lower values of MBL (217.44 cm); CD (13.55 cm) and TNF (23.88 g branch-1) were recorded in Mehmud Wali during 2013, keeping the SB (8.77) same for the both years (Table 9).

Table 2. Analysis of variance of physical characteristics of Ber in 2013 (light faced values) and 2014 (bold faced values).

SOV	DF	FLW (g)	SW (g)	FLSR	FW (g)	TY (Kg/plant)
Replication	2	8.982	0.12437	11.100	8.201	14.58
		0.690	**0.03377**	**8.738**	**2.626**	**8.53**
Treatments (T)	2	40.534**	0.42519***	61.786**	39.452***	114.33**
		41.020**	**0.41734*****	**45.504****	**24.124NS**	**258.86*****
Varieties	3	464.625***	1.65948***	115.717***	654.564***	1162.92***
		458.773***	**2.00219*****	**128.117*****	**649.800*****	**1232.77*****
T × Varieties	6	15.805*	0.08985NS	7.842NS	22.225***	18.56NS
		4.67NS	**0.0265NS**	**6.489NS**	**5.816NS**	**11.05NS**
Error	22	5.107	0.04292	7.631	4.291	14.58
		6.929	**0.04674**	**8.046**	**8.724**	**15.01**

*, P≤0.05, **, P≤0.01, ***, P≤0.001, NS=Non-significant, SOV=sources of variation, DF=degree of freedom, FLW=flesh weight, SW=stone weight, FLSR=flesh stone ratio, FW=fruit weight, TY=total yield kg/plant.

Table 3. Analysis of variance of biochemical characteristics of Ber leaves in 2013 (light faced values) and 2014 (bold faced values).

SOV	DF	Ca (%)	Na (%)	K (%)	PRO (mmole g^{-1} fresh weight)	CHL (mg/g fresh weight)	SS (%)
Replication	2	1.064	0.348	0.5278	17.2	0.00441	0.00071
		0.965	**0.234**	**1.1944**	**538.5**	**2.89867**	**0.09250**
Treatments (T)	2	189.888***	124.762***	44.5278***	21429.4***	0.51882***	4.28065***
		168.424***	**143.788*****	**53.8611*****	**22737.2*****	**2.39331***	**1.51083***
Varieties	3	0.771*	0.077NS	2.3981**	10981.3***	0.10468***	2.19769***
		1.396**	**0.237NS**	**2.6204*****	**8691.4*****	**3.55268NS**	**1.64991****
T × Varieties	6	0.594NS	0.060NS	3.8981***	829.5***	0.09060***	0.52480NS
		1.924*	**0.182NS**	**1.8981*****	**985.1***	**2.73950NS**	**1.64713*****
Error	22	0.263	0.186	0.4066	68.4	0.00477	0.24272
		0.480	**0.193**	**0.3157**	**318.7**	**2.78789**	**0.24947**

*, P≤0.05, **, P≤0.01, ***, P≤0.001, NS=Non-significant, SOV=sources of variation, DF=degree of freedom, Ca=calcium ion, Na=sodium ion, K=potassium ion, PRO=Proline, CHL=chlorophyll contents, SS=soluble sugars.

Table 4. Analysis of variance of biochemical characteristics of Ber fruits in 2013 (light faced values) and 2014 (bold faced values).

SOV	DF	VC (mg $100g^{-1}$)	TSS (°Brix)	TA (%)	TS (%)	pH
Replication	2	0.333	1.2295	0.00130	0.37279	0.04141
		2.333	**0.5965**	**0.00064**	**0.30773**	**0.04694**
Treatments (T)	2	15.750***	17.5209**	0.00634***	5.68751***	0.35361**
		11.083***	**34.7574*****	**0.01271***	**2.35686****	**0.59694*****
Varieties	3	214.296***	14.8870**	0.00215*	2.60739**	1.60825***
		188.028***	**6.7157*****	**0.00721NS**	**3.06390*****	**1.34176*****
T × Varieties	6	11.046***	3.3389NS	0.00078NS	2.84850***	0.05847NS
		7.528***	**6.7912*****	**0.00122NS**	**1.97362*****	**0.09731***
Error	22	0.939	2.7048	0.00051	0.39128	0.05088
		0.667	**0.6651**	**0.00269**	**0.30850**	**0.03785**

*, P≤0.05, **, P≤0.01, ***, P≤0.001, NS=Non-significant, SOV=sources of variation, DF=degree of freedom, VC=vitamin C, TSS=total

Table 5. Effect of brackish water on growth characteristics of Ber during 2013 (light faced values) and 2014 (bold faced values).

Treatments	MBL (cm)	CD (cm)	SB	TNF (g/ branch)
Normal water	313.08 a	16.50 a	11.50 a	31.41 a
	315.50 a	**16.83 a**	**10.83 a**	**31.00 a**
Brackish water	227.33 c	14.16 b	10.16 b	29.16 b
	227.67 c	**14.25 b**	**10.41 ab**	**30.41 a**
Normal+Brackish water	249.17 b	14.75 b	9.50 c	28.08 b
	249.58 b	**14.91 b**	**9.83 b**	**30.25 a**

MBL=main branch length, CD=collar diameter of main branch, SB=number of secondary branches, TNF=total number of fruits on randomly tag branch.

Table 6. Effect of brackish water on physical characteristics of Ber during 2013 (light faced values) and 2014 (bold faced values).

Treatments	FLW (g)	SW (g)	FLSR	FW (g)	TY (kg plant^{-1})
Normal water	19.025 a	1.35 a	16.74 a	21.25 a	108.58 a
	18.980 a	**1.38 a**	**16.47 a**	**20.47 a**	**108.00 a**
Brackish water	16.940 b	1.31 a	14.13 b	19.12 b	107.42 a
	16.297 b	**1.25 a**	**14.03 b**	**18.36 ab**	**107.75 a**
Normal+Brackish water	15.361 b	1.01 b	12.22 b	17.65 b	102.75 b
	15.435 b	**1.02 b**	**12.62 b**	**17.78 b**	**99.83 b**

FLW=flesh weight, SW=stone weight, FLSR=flesh stone ratio, FW=fruit weight, TY=total yield.

Table 7. Effect of brackish water on biochemical traits of Ber leaves during 2013 (light faced values) and 2014 (bold faced values).

Treatments	Ca (%)	Na (%)	K (%)	PRO (mmole g^{-1} fresh weight)	CHL (mg/g fresh weight)	SS (%)
Normal water	16.00 a	10.77 a	10.91 a	349.83 a	1.25 a	5.41 a
	16.00 a	**11.00 a**	**11.08 a**	**351.17 a**	**1.76 a**	**5.08 a**
Brackish water	10.41 b	6.25 b	7.66 b	315.92 b	0.94 b	4.58 b
	11.16 b	**5.75 b**	**7.50 b**	**312.00 b**	**1.27 a**	**4.50 b**
Normal+Brackish water	8.30 c	4.53 c	7.50 b	265.83 c	0.85 c	4.25 b
	8.62 c	**4.46 c**	**7.33 b**	**264.25 c**	**0.87 b**	**4.44 b**

Ca=calcium ion, Na=sodium ion, K=potassium ion, PRO=Proline, CHL=chlorophyll contents, SS=soluble sugars.

Table 8. Effect of brackish water on biochemical traits of Ber fruits during 2013 (light faced values) and 2014 (bold faced values).

Treatments	VC (mg 100g^{-1})	TSS (°Brix)	TA (%)	TS (%)	pH
Normal water	16.25 a	16.167 a	0.3242 a	8.54 a	5.53 a
	15.50 a	**14.750 a**	**0.3267 a**	**8.21 a**	**5.55 a**
Brackish water	14.75 b	14.954 ab	0.2892 b	7.83 b	5.33 b
	14.66 b	**13.680 b**	**0.2900 ab**	**7.75 ab**	**5.24 b**
Normal+Brackish water	14.00 b	13.750 b	0.2808 b	7.16 c	5.19 b
	13.58 c	**11.417 c**	**0.2600 b**	**7.33 b**	**5.12 b**

VC=vitamin C, TSS=total soluble solids, TA=titratable acidity, TS=total sugars (Reducing + Non-reducing).

***Physical characteristics*:** Ber plants exhibited significant ($P \leq 0.001$) effects under different treatments and varieties. The analysis of variance for the data regarding FLW, SW, FLSR, FW and TY showed highly significant difference among genotypes and treatments in both years (2013 and 2014). The Interaction among varieties and treatments was significant in 2013 but non- significant in 2014 for FLW, SW and FW, while it remained non-significant for FLSR and TY in both years (Table 2). The different treatments performed better in all varieties of ber. The maximum values of FLW (19.025 g); FLSR (16.74); FW (21.25 g) and TY (108.58 kg/plant) were observed in Normal water during 2013 and increased SW (1.38 g) in 2014. while the minimum values of FLW (15.345 g); SW (1.01 g); FLSR (12.22)and FW (17.65 g) were recorded in Normal+ Brackish water in

Table 9. Effect of varieties on growth traits of Ber during 2013 (light faced values) and 2014 (bold faced values).

Varieties	MBL (cm)	CD (cm)	SB	TNF (g/branch)
Delhi white	292.11 a	16.66 a	12.33 a	35.00 a
	296.00 a	**16.77 a**	**12.33 a**	**33.55 a**
Suffan	279.67 b	15.00 b	10.33 b	29.33 b
	276.67 b	**15.66 b**	**10.44 b**	**29.66 b**
Karela	262.22 c	14.88 b	10.11 b	30.00 b
	267.22 c	**15.33 b**	**9.88 b**	**31.33 b**
Mehmud wali	217.44 d	13.55 c	8.77 c	23.88 c
	218.44 d	**14.00 c**	**8.77 c**	**27.66 c**

MBL=main branch length, CD=collar diameter of main branch, SB=number of secondary branches, TNF=total number of fruits on randomly tag branch.

Table 10. Effect of varieties on physical traits of Ber during 2013 (light faced values) and 2014 (bold faced values).

Varieties	FLW (g)	SW (g)	FLSR	FW (g)	TY (Kg/plant)
Delhi white	24.811 a	1.74 a	18.77 a	29.35 a	115.33 a
	24.811 a	**1.76 a**	**19.07 a**	**27.89 a**	**115.44 a**
Suffan	17.254 b	0.95 c	14.59 b	18.33 c	109.00 b
	17.254 b	**0.84 c**	**13.67 b**	**16.01 c**	**105.33 c**
Karela	18.873 b	1.40 b	14.08 b	21.03 b	111.00 b
	18.873 b	**1.46 b**	**14.84 b**	**23.14 b**	**111.22 b**
Mehmud wali	7.496 c	0.80 c	10.00 c	8.65 d	89.67 c
	7.496 c	**0.80 c**	**9.91 c**	**8.44 d**	**88.78 c**

FLW=flesh weight, SW=stone weight, FLSR=flesh stone ratio, FW=fruit weight, TY=total yield kg/plant.

Table 11. Effect of varieties on biochemical traits of Ber leaves during 2013 (light faced values) and 2014 (bold faced values).

Varieties	Ca (%)	Na (%)	K (%)	PRO (mmole g^{-1} fresh weight)	CHL (mg/g fresh weight)	SS (%)
Delhi white	11.96 a	7.28 a	9.33 a	351.67 a	1.10 a	5.22 a
	12.27 a	**7.30 a**	**9.33 a**	**349.22 a**	**2.23 a**	**5.22 a**
Suffan	11.61 ab	7.17 a	8.88 ab	312.22 b	1.10 a	5.05 ab
	12.22 a	**7.07 a**	**8.77 b**	**308.78 b**	**1.14 a**	**4.74 ab**
Karela	11.41 b	7.21 a	8.33 bc	312.00 b	0.95 b	4.61 b
	11.77 ab	**6.95 a**	**8.33 bc**	**305.11 b**	**0.96 b**	**4.53 bc**
Mehmud wali	11.30 b	7.06 a	8.22 c	266.22 c	0.86 b	4.11 c
	11.44 b	**6.95 a**	**8.11 c**	**273.44 c**	**0.87 b**	**4.20 c**

Ca=calcium ion, Na=sodium ion, K=potassium ion, PRO=Proline, CHL=chlorophyll contents, SS=soluble sugars.

2013 but decrease in TY (99.83 kg/plant) during 2014 (Table 6).

The Delhi White performed better than others. It exhibited highest values of SW (1.76 g); FLSR (19.07); and TY (115.44 kg/plant) in 2014 while keeping FLW (24.811 g) same during both years. However, FW (29.35 g) was comparatively higher in 2013. Lowest values of FLSR (9.91); FW (8.44) and TY (88.78 kg/plant) were recorded in Mehmud wali during 2014 while FLW (7.496 g) and SW (0.80 g) remained minimum during both years (Table 10).

Biochemical characteristics

***Leaves*:** Ber plants exhibited significant ($P \leq 0.001$) effects under different treatments and varieties. The analysis of variance for the data regarding Ca, Na, K, PRO, CHL and SS showed highly significant difference among genotypes and treatments in both years 2013 and 2014. The Interaction among varieties and treatments was significant for Ca and K ions, PRO and in both years; significant in 2013 and non-significant in 2014 for CHL content. However, it remained non-significant in case of Na ions in both years (Table 3).

Normal water performed better than all others treatments in both years (2013 & 2014). The maximum value of Na (11.00); K(11.08); PRO (351.17) and CHL content (1.76) were observed in normal water during 2014. However, this treatment exhibited similar Ca levels (16.00) in both years but SS (5.41) was higher in 2013 only. Minimum value of Ca (8.30); CHL (0.85) and SS (4.25) were recorded in Normal+Brackish water treatment in 2013. While, least

Table 12. Effect of varieties on biochemical traits of Ber fruits during 2013 (light faced values) and 2014 (bold faced values).

Varieties	VC (mg $100g^{-1}$)	TSS (°Brix)	TA (%)	TS (%)	pH
Delhi white	19.11 a	16.593 a	0.3200 a	8.63 a	5.65 a
	18.55 a	**14.512 a**	**0.3300 a**	**8.56 a**	**5.58 a**
Suffan	18.55 a	15.357 ab	0.2911 b	7.75 b	5.50 a
	17.66 b	**13.219 b**	**0.2900 ab**	**7.32 b**	**5.42 a**
Karela	13.66 b	13.778 b	0.2967 b	7.56 b	5.52 a
	13.55 c	**12.842 b**	**0.2956 ab**	**7.84 b**	**5.46 a**
Mehmud wali	8.66 c	14.100 b	0.2844 b	7.44 b	4.72 b
	8.55 d	**12.556 b**	**0.2610 b**	**7.33 b**	**4.73 b**

VC=vitamin C, TSS=total soluble solids, TA=titratable acidity, TS=total sugars (Reducing + Non-reducing).

values of Na (4.46); K (7.33); PRO content (264.25) were recorded in Normal+Brackish water treatment in 2014 (Table 7).

Delhi white performed better than all other varieties. It exhibited highest values of Ca (12.27); Na (7.30) and CHL content (2.23) during 2014. While K (9.33) and SS (5.22) remained similar for the both years. PRO contents (351.67) were comparatively raised during 2013 in Delhi white. Mehmud wali resulted into lowest level of Na (6.95) and K (8.11) in 2014 but Ca (11.30); PRO (266.22); CHL content (0.86) and SS (4.11) were recorded at minimum in 2013 for the same variety (Table 11).

***Fruits*:** Ber plants exhibited significant ($P \leq 0.001$) effects under different treatments and varieties. The analysis of variance for the data regarding VC, TSS, TA, TS and pH showed highly significant difference among genotypes and treatments in both years 2013 and 2014. The Interaction among varieties and treatments was significant for VC and TS in both years 2013 and 2014; non-significant in 2013 but significant in 2014 for TSS and pH. But it was non-significant for TA in both years (Table 4).

Different treatments imposed varying response in all varieties but Normal water performed better than all during both years (2013 & 2014). Maximum value of VC (16.25); TSS (16.16) and TS (8.54%) were recorded in 2013 while TA (0.32%) and pH (5.55) were comparatively higher in 2014 under normal water application. Minimum value of VC (13.58); TSS (11.41); TA (0.26%) and pH (5.11) were recorded in 2014 in Normal+brackish water but TS (7.16%) was higher in 2013 under the same treatment (Table 8).

Delhi white performed better than all other varieties. Highest values of VC (20.67); TSS (16.59); TS (8.63%) and pH (5.65) were observed in Delhi white during 2013, while TA (0.33%) was higher during 2014 only. Mehmud wali exhibited lower VC (8.55); TSS (12.55); TA (0.26%) and TS (7.33%) in 2014 but lower pH (4.72) in 2013 (Table 12).

DISCUSSION

The present study showed that the growth, physical and biochemical characteristics of all ber cultivars were significantly affected by brackish water. However, only a few plants grow well under saline conditions. Among those, one of the most important horticultural trees such as ber can be cultivated successfully under such conditions (Bhatt *et al.*, 2008). However, long term irrigation of saline water affects yield, total soluble solids, number and size of the fruit (Boman *et al.*, 2005).

In the present study, growth and physical characteristics of ber were reduced by the application of brackish water. Earlier experiment by Hooda *et al*. (1990) were conducted on salt tolerance in ber; artificially salinized with NaCl, $CaCl_2$, $MgCl_2$ and $MgSO_2$. Results indicated that no plant was survived the highest salinity of 20 dSm^{-1} electrical conductivity (EC). Similar results were observed in wheat (*Triticum aestivum* L.) where growth and yield was reduced by the application of brackish water particularly under higher value of EC (Electrical conductivity), SAR (Sodium absorption ratio) and RSC (Residual sodium carbonate) (Chaudhry *et al.*, 2001). Bajwa *et al.* (1992) used sodic and saline-sodic water for cotton and wheat (*Triticum aestivum* L.) crops in a field study showing higher buildup of SAR/ESP under saline-sodic treatments and decrease in crop yield. Decline in wheat (*Triticum aestivum* L.) yield under sodic water treatment (EC 1.16 dS m^{-1}; SAR 10.1; RSC 10.0 m mol L^{-1}) was 154 to 26% as compared to fit water treatment.

In the present study, physical characteristics were also affected by brackish water application. These characters included collar diameter, branch length, number of secondary branches and number of fruits. Earlier research on stem diameter of ber was conducted during 1990-92 in stoneware pots, with artificially built-up sodicity and salinity levels, indicating that stem diameter decreased at more than 38.8% exchangeable sodium and 14.8 dS m^{-1} salinity level (Awasthi *et al.*, 1995). Our conclusion about fruit set was supported by an investigation on 175 Chinese jujube cultivars showed that 87.9-99.9% flowers and 68.5% young fruits dropped off during development and finally the fruit set was only 1.1% on the basis of flower averagely. The fruit number per 100 bearing branches varied from 4.26 to 175 among cultivars.

Only 8.5% of the cultivars could set more than one fruits per bearing branch. It has been further justified that genetic variation and salt stress adversely affect the fruit set and fruit size of ber (Liu *et al.*, 2009; Hooda *et al.*, 1990). It was concluded that branch length was influenced by brackish water treatment in both years. However, this character predominantly could be associated with genetic variations (Ismail and Almarshadi, 2013).

In the present study, various biochemical alterations were recorded in ber while treated with brackish water. Most significant interaction was found in Ca, K, PRO, SS, VC and TS in both years. Overall it was noticed that brackish water treatment in ber has significantly reduced the uptake of ions. Our conclusion was sustained by *Ziziphus* response to the salt stress where high EC significantly reduced the uptake of calcium as compared to the healthy control (Bhat *et al.*, 2008). It has been observed that ber plant exhibited higher amount of Na and K ions. Similar results were found in the present study where Na and K were found in sufficient quantity. These conclusions are supported by Pareek (2013) concluding that ber plant exhibit higher amount of Na and K ions.

In the present study, pigments were also affected by brackish water treatment, similarly reported by Sohail *et al.* (2009). Proline content were also reduced in salt stress as seen in the results. Earlier research about proline have justified that activity of proline anabolic enzymes; -Pyrrolline-5-carboxylate reductase, -Pyrrolline-5-carboxylate synthetase and Ornithine- -aminotransferase were recorded higher in salt affected ber plants with significant decrease in proline dehydrogenase (Bagdi and Bagri, 2016). Bhat *et al.* (2008) have reported a significant decrease in the TSS in terms of dry matter in ber, when subjected to the brackish water treated with sodium chloride; also supports our conclusion. It was determined that vitamin C has shown minor decline in its conc. Previously, it has been known that vitamin C ranges vary due to availability of nutrients and salts in the soil (Rani, 2012). In the present study pH of ber varieties was significantly reduced in both years. This interaction was significant with all varieties. Our conclusions are supported by the results of Abdel-Hameed and Sahar (2015), concluding that brackish water reduce the pH in ber at different levels of salinity.

***Conclusion*:** The results have shown that significant variations exist for all studied traits *i.e.* growth, physical and biochemical characteristics of ber against brackish water treatment as well as among the varieties. Although normal water was found best for ber cultivation, but it can be successfully grown under brackish/saline conditions within economic threshold level. Delhi White variety of ber is recommended for marginal lands in Pakistan. Future studies could be conducted by studying the effect of various soil amendments on ber varieties under brackish water application. Moreover, a routine collection and characterization of indigenous ber germplasm may also be conducted.

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