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Performance evaluation of pomegranate (*Punica granatum*) genotypes under saline conditions

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ABSTRACT

Pomegranate (*Punica granatum* L., family: Lytheraceae) is widely grown in arid and semi-arid areas across the globe, where moderate or relatively high salt concentration in the soil negatively affect the plant growth properties. However, there is scarce information on the response of pomegranate cultivars under saline field conditions. Therefore, this experiment was conducted in a saline field (soil EC_e 6-8 dS/m, EC_{iw} 3.9-4.2 dS/m) during two consecutive years (2017-18) at Nain Experimental Farm, Panipat, India to study the effects of salinity on vegetative growth and fruit quality traits in 15 genotypes of pomegranate. The experiment was laid out in Randomized Block Design with four replications. Analysis of Variance revealed highly significant differences among the genotypes for fruit growth and quality traits. Results showed considerable variation in the plant growth and fruit quality traits of the pomegranate genotypes. Our findings indicated that fruit quality traits like fruit weight, juice percentage, number of arils, and aril colour could be used as criteria for selecting promising pomegranate genotypes for salt-affected soils. Overall, genotypes Udaipur 2, Udaipur 3, Rajasmand 4 and Jaipur 1 seem to be more tolerant of salinity stress than other genotypes and thus have potential for cultivation in saline soils.

Key words: Fruit quality, Pomegranate, Salinity, Variability

Pomegranate (*Punica granatum* L.) is widely grown throughout the world for its nutritious fruits (Chandra *et al*. 2010) and consumption of pomegranate products has steadily increased in the last few years, giving impetus to its commercial cultivation (Fawole and Opara 2013). Better adaptability to varying agro-climatic conditions is one of the main reasons for wide distribution and cultivation of pomegranate (Levin 2006a, Rajkumar 2016). In India, pomegranate is grown over about 209.0 thousand ha area with total fruit production of 2442.0 thousand tonnes. Maharashtra followed by Karnataka, Gujarat, Andhra Pradesh and Madhya Pradesh are the major pomegranate producing states of India. Although Maharashtra accounts for nearly 65.0% of total pomegranate area and production in the country, it lags behind other states in average productivity (MAFW 2017). Insect-pests, diseases and environmental stresses are the major factors responsible for poor fruit yields in the leading pomegranate producing states of India (NIPHM 2014). Although, pomegranate is considered to be moderately salt tolerant fruit crop, but environmental stresses particularly high salinity in soils and irrigation waters and associated problems like drought or water-logging are the major obstacles to profitable pomegranate cultivation in India (Rajkumar 2017), Iran (Naeini *et al.* 2006), Israel (Bhantana and Lazarovitch 2010) and Spain (Costa and Melgarejo 2000). Most of the research work to evaluate the pomegranate genotypes for selection and breeding programs is based on fruit characteristics (Dafny-Yalin *et al.* 2010, Wetzstein *et al.* 2011). Still, very little information is available on genotypic variability in fruit quality attributes in salt-affected soils. Such information could be useful to the breeders in selecting the desirable traits for the genetic improvement (Leon *et al.* 2004). In light of these facts, this experiment was carried out to evaluate 15 different pomegranate genotypes on the basis of fruit quality attributes for identifying the promising pomegranate genotypes for cultivation in salt-affected soils.

MATERIALS AND METHODS

Present experiment was conducted during two consecutive years (2017-18) to study the effects of salinity on vegetative growth and fruit quality parameters of 15 pomegranate genotypes. Pomegranate genotypes collected from the farmers' fields and research institutions in Rajasthan state of India were used in this study. Genotypes were code named after the respective places of collection including one each from Pali (Pali-1), Jodhpur (Jodhpur-1) and Nagaur (Nagaur-1), three each from Jaipur (Jaipur-1, Jaipur-2 and Jaipur-3) and Udaipur (Udaipur-1, Udaipur-2 and Udaipur-3), four each from Rajasamand (Rajasmand-1,

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Rajasmand-2, Rajasmand-3 and Rajasmand-4) and Ajmer (Ajmer-1, Ajmer-2, Ajmer-3, Ajmer-4) and two commercial cultivars Ganesh and Bhagwa. Cuttings were initially raised in polybags containing garden soil, sand and farmyard manure (2:1:1) for root induction. Subsequently, sufficiently developed six months old plants were transplanted in saline soils at ICAR-CSSRI Nain Experimental Farm, Panipat (29°19'08.88" N, 76°47'38.47" E). Planting was done in pits at row-to-row and plant-to-plant spacing of 4 m each. Experimental soil was sandy loam in texture. Mean soil EC_e was 6.9 dS/m and 8.2 dS/m at 0-30 cm and 0-60 cm soil depths. Standard cultural practices recommended for pomegranate cultivation were followed. The experiment was laid out in Randomized Block Design with four replications. Plant height and spread were recorded using a measuring tape and stem diameter by a digital Vernier Caliper (Mitutoyo, Japan). Mature fruits were harvested in the month of July during both the years for determining various fruit quality parameters, viz. fruit length (cm), width (cm), weight (g), volume (ml^3), density (g/cm^3), juice percentage (%), number of arils, weight of arils/fruit, weight of 100 arils, aril colour and softness, rind thickness, rind colour and TSS (°B). Pooled data analysis of two years following standard statistical methods was carried out using SAS 9.2 software (SAS institute, Cary, NC, 2011). Correlations between fruit characteristics were also determined.

RESULTS AND DISCUSSION

Data revealed significant genotypic differences only for plant height; stem girth and canopy spread did not differ significantly after two years of planting (Table 1). Genotype Jaipur-1 attained the maximum plant height (207.10 cm), while the minimum height (154.47 cm) was recorded in Bhagwa. Only four genotypes (Udaipur-2, Udaipur-3, Jaipur-1 and Rajasmand-4) showed average stem diameter of around 5.0 cm, while it mostly ranged between 4.0-4.5 cm in others. The maximum canopy spread (N-S) of 185.83 cm was recorded in Rajasmand-3 followed by Jaipur-2 (162.93 cm) and Jaipur-1 (160.70 cm). Similarly, the maximum canopy spread (E-W) of 188.43 cm was noted in Jaipur-1 followed by Rajasmand-3 (180.13 cm) and Udaipur-3 (175.77 cm). Earlier study also reported considerable reductions in stem length and marginally decline in stem diameter with increasing salinity of irrigation water (Khayyat *et al*. 2014). Pomegranate cultivars vary widely in salinity tolerance, i.e. some cultivars do not show or show only nominal decreases in growth up to a threshold salinity, others are adversely affected (Naeini *et al.* 2006, Okhovatian *et al.* 2010, Amri *et al.* 2011, Karimi and Hasanpour 2014). Another study conducted at ICAR-CSSRI, Karnal revealed that salinity had a more repressive effect on branching and leaf emergence in guava and bael while plant height and stem girth were relatively less affected (Singh *et al.* 2018). Despite relatively high soil EC_e (~8.0 dS/m), use of saline waters with low electrolyte concentration (EC_{iw} ~4.0 dS/m) could have enhanced salt leaching to the lower depths, resulting in better plant growth. It has been shown that application of moderately saline waters (EC_{iw} ~5.0) reduces salt load in highly saline soils (Arora *et al.* 2012). Further, salts accumulated during previous irrigation events also tend to leach below the rootzone in semi-arid areas receiving moderate rainfall of 500-600 mm (Sharma *et al.* 2005).

Fully ripe fruits were picked during both the years of the experiment. Because there were only slight differences in various parameters between the years, data were pooled for analysis. Results indicated significant differences in various fruit quality attributes (Table 1 and 2; Fig 1) among the pomegranate genotypes studied. Fruit length, width, volume and weight ranged from 6.04 to 7.55 cm, 5.90 to 7.76 cm, 113.50 to 253.25 cm^3 and 133.25 to 238.88 g, respectively, with corresponding mean values of 6.86 cm, 7.09 cm, 188.01 cm^3 and 194.37 g, respectively.

Previous studies have shown that weight and shape are the major fruit traits determining genotypic differences in pomegranate. Furthermore, a close positive correlation has been reported between fruit size, and number and weight of arils plus seeds (Blasco *et al.* 2009). Okhovatian *et al.* (2010) found that while low salinity (4 dS/m) stimulated growth in some pomegranate cultivars; moderate and high salinities (7 and 10 dS/m) led to considerable reductions in the biomass yield. Grieve *et al.* (2007) reported that salt treatments (0.44 dS/m to 2.50 dS/m) decreased average fruit weight by 4%, reduced average fruit size and decreased juice content in Valencia orange trees. Nieves *et al.* (1991) reported that total soluble solids, density and peel thickness increased while juice content remained unaffected in citrus fruits with increasing salinity.

The juice percentage ranged from 37.09 to 54.74, with the minimum in genotype Nagaur 1 and the maximum in

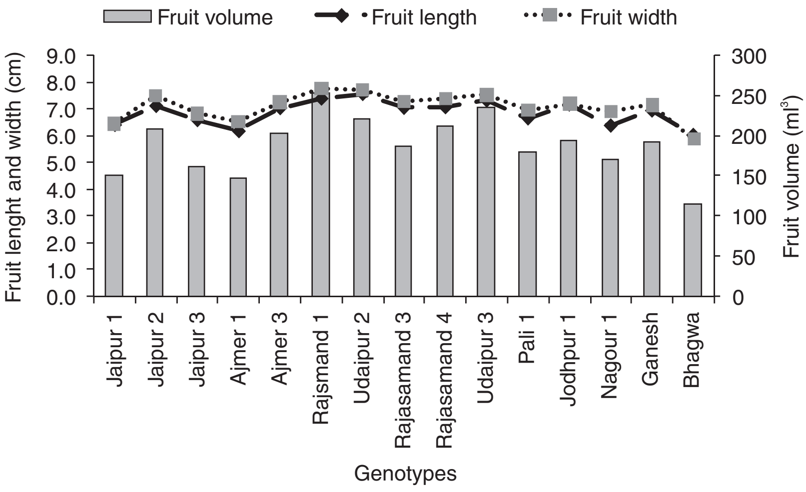

Fig 1 Fruit volume, fruit length and fruit width in different genotypes of pomegranate.

Table 1 Plant growth analysis, fruit weight, juice percentage, number of arils, rind thickness, weight of 100 arils, TSS (°B) and weight of arils per fruit and fruit density in different genotypes of pomegranate

Genotype	Plant height (cm)	Stem diameter	Plant spread		Fruit weight (g)	Juice (%)	Number of arils	Rind thickness	Weight of 100 arils	TSS (°B)	Weight of arils/fruit	Fruit density (g/cm^3)
			N-S	E-W								
Jaipur 1	207.10^{a}	4.93	160.70	188.43	168.13^{def}	52.56^{ab}	481.75^{def}	0.36^{bcd}	22.05^{abcd}	13.91^{e}	101.93^{efg}	1.14^{ab}
Jaipur 2	196.20^{ab}	4.50	162.93	173.03	216.38^{abc}	45.28^{bcdefg}	669.50^{abc}	0.42^{abc}	21.02^{bcd}	13.78^{e}	133.02^{abc}	1.05^{bcdef}
Jaipur 3	180.97^{abcd}	4.47	150.77	150.77	169.38^{def}	42.68^{defg}	556.88^{cde}	0.46^{ab}	20.71^{bcd}	15.14^{ab}	105.01^{defg}	1.05^{bcde}
Ajmer 1	189.70^{abc}	3.97	144.03	149.40	163.88^{ef}	46.77^{abcdef}	423.13^{ef}	0.36^{bcd}	22.56^{abc}	14.00^{e}	90.92^{fg}	1.14^{abc}
Ajmer 3	197.30^{ab}	4.00	145.07	160.37	203.75^{abcde}	51.32^{abc}	602.00^{bcd}	0.36^{bcd}	22.83^{abc}	13.83^{e}	124.88^{abcde}	1.04^{def}
Rajasmand 1	178.90^{bcd}	4.30	157.80	165.27	238.88^{a}	47.06^{abcdef}	779.00^{a}	0.36^{bcd}	20.75^{bcd}	15.61^{a}	152.3^{a}	0.96^{f}
Udaipur 2	180.37^{abcd}	5.27	160.07	165.67	236.63^{ab}	43.27^{cdefg}	706.87^{ab}	0.40^{abc}	23.29^{ab}	13.86^{e}	152.06^{a}	1.08^{bcde}
Rajasmand 3	193.57^{abc}	4.63	185.83	180.13	206.63^{abcde}	54.74^{a}	556.63^{cde}	0.43^{abc}	24.56^{a}	14.23^{de}	119.66^{bcde}	1.12^{abcd}
Rajasmand 4	176.70^{bcd}	4.93	151.07	150.10	210.63^{abcd}	47.34^{abcdef}	633.50^{bc}	0.35^{bcd}	24.40^{a}	15.05^{ab}	130.33^{abcd}	1.00^{ef}
Udaipur 3	170.37^{bcd}	5.02	158.50	175.77	231.75^{ab}	41.22^{efg}	617.88^{bcd}	0.40^{abc}	23.79^{ab}	14.88^{bcd}	142.53^{ab}	1.00^{ef}
Pali 1	159.70^{d}	4.10	146.40	148.27	176.38^{cdef}	41.16^{efg}	575.50^{bcd}	0.27^{d}	22.96^{ab}	15.01^{abc}	108.49^{cdef}	0.99^{ef}
Jodhpur 1	157.80^{d}	4.87	122.83	123.63	199.00^{abcde}	49.43^{abcde}	563.50^{cd}	0.36^{bcd}	23.30^{ab}	14.29^{cde}	135.06^{abc}	1.05^{cdef}
Nagour 1	168.53^{cd}	4.23	150.37	146.70	167.37^{def}	37.09^{g}	537.88^{cdef}	0.49^{a}	19.67^{cd}	14.86^{bcd}	100.11^{efg}	0.99^{ef}
Ganesh	162.07^{d}	4.37	145.63	160.53	193.50^{bcde}	50.33^{abcd}	599.50^{bcd}	0.32^{cd}	22.37^{abc}	14.09^{e}	114.63^{cdef}	1.03^{ef}
Bhagwa	154.47^{d}	4.70	134.20	143.97	133.25^{f}	40.70^{fg}	410.38^{f}	0.31^{cd}	19.12^{d}	13.64^{e}	79.50^{g}	1.19^{a}
LSD (P=0.05)	27.144	NS	NS	NS	44.528	8.5719	140.36	0.1132	3.2476	0.7277	27.452	0.0917

Note: Means (n=4) with at least one letter common are not statistically significant using Duncan's Multiple Range Test at 5% level of significance. NS: non-significant.

Rajasmand-3, respectively. In pomegranate, juice recovery varies between 42-55% (Chobe 1999). The number of arils ranged from 410.38 (Rajasamand 1) to 779 (Bhagwa), respectively. Lal *et al.* (2013) found that number of arils rather than aril size determines the fruit size: fruits with more arils tend to be relatively large sized compared to those having fewer alleles. The rind thickness varied from 0.27 cm in genotype Pali 1 to 0.49 cm in the genotype Nagaur 1 and was found to be non-significant among various genotypes. Lal *et al.* (2013) also observed that rind thickness ranged from 1.27-4.46 mm in pomegranate cv. Dholka. The weight of 100 arils ranged from 19.12 to 24.56 g with the minimum in Bhagwa and the maximum in the Rajasmand 3. However, the weight of 100 arils did not vary significantly between different genotypes. Caliskan and Bayazit (2013) reported that weight of 100 arils ranged between 17.5 to 66.7g in pomegranate accessions grown in a Mediterranean climate. The maximum weight of arils per fruit (152.31 g) was recorded in the genotype Udaipur 2 which was statistically at par with Udaipur 2 (152.06 g). Fruit total soluble solids were the highest (15.61 ˚B) in the genotype Rajasmand 1 and the lowest (13.64 ˚B) in genotype Bhagwa. The concentration of total soluble solids is the most significant factor in determining fruit quality. Akbarpour *et al.* (2009) found that TSS ranged from 15.17 to 22.03% among twelve pomegranate cultivars studied for different chemical characters. Sinha (2014) reported that TSS content was maximum (15.87°B) in Purple Heart and minimum in (9.93°B) in Ovadan cultivars of pomegranate. Generally, saline conditions tend to increased TSS concentrations in the fruit juice. Garcia-Sanchez *et al.* (2000) observed significant decrease in juice content in fruits of salt stressed lime trees. Saito *et al.* (2006) reported that tomato fruit Brix increased from 6.1 to 9.9% when nutrient solution EC was increased up to 8.0 dS/m. Fruit density varies significantly from 0.96 to 1.19 g/cm^3 in Rajasmand 1 and Bhagwa, respectively. One of the reasons for the non-significant differences in some fruit quality traits could be ascribed to more or less similar agro-climatic conditions in the growing areas from where the pomegranate genotypes were collected.

It was observed that genotypes having yellowish fruit peel mostly had white colored arils (Table 2). On the basis of seed mellowness, an important fruit quality parameter, genotypes Jaipur 1, Ajmer 1, Ajmer 3, Udaipur 2, Rajasmand 3, Rajasmand 4, Udaipur 3, Jodhpur 1, Ganesh and Bhagwa were characterized as soft seeded. In general, genotypes with light pink coloured arils were sweet sour in taste and hard seeded. The variations in fruit peel characteristics in salt treated plants seem to be caused by the loss of water in albedo due to osmotic stress (Sinclair 1984). Salinity also affects the anthocyanins and non-pigment phenolics, and thus influences the fruit colour intensity (Borochov-Neori *et al.* 2014). It is known that seed hardness and red and pink aril colour are the dominant traits over seed softness and white aril colour in pomegranate (Jalikop 2003, Jalikop *et al.* 2005).

Table 2 Fruit traits for different pomegranate genotypes grown under saline conditions

Genotype	Peel color	Aril color	Taste	Seed hardiness
Jaipur 1	Yellowish	White	Sweet	Soft
Jaipur 2	Greenish Red	Pink	Sweet-Sour	Hard
Jaipur 3	Yellowish	White	Sweet-Sour	Hard
Ajmer 1	Yellowish	White	Sweet	Soft
Ajmer 3	Yellowish	White	Sweet	Soft
Rajasmand 1	Yellowish	Light Pink	Sweet-Sour	Hard
Udaipur 2	Yellowish	White	Sweet	Soft
Rajasmand 3	Yellowish	Light Pink	Sweet-Sour	Soft
Rajasmand 4	Yellowish	White	Sweet	Soft
Udaipur 3	Reddish Yellow	White	Sweet	Soft
Pali 1	Greenish Red	Pink	Sweet-Sour	Hard
Jodhpur 1	Reddish Yellow	White	Sweet	Soft
Nagour 1	Reddish Yellow	Light Pink	Sweet-Sour	Hard
Ganesh	Reddish Yellow	White	Sweet	Soft
Bhagwa	Reddish	Red	Sweet	Soft

Pearson's correlation was used to investigate the relationship among all these fruit parameters. It was found that fruit length, volume, width, weight and weight of arils had significant positive correlation with r^2 value > 0.85. Fruit length had a significant positive correlation with fruit width (r^2 = 0.882) and weight (r^2 = 0.897); fruit volume with fruit width (r^2 = 0.899), weight (r^2 = 0.960) and weight of arils per fruit (r^2 = 0.885); fruit width with fruit weight (r^2 = 0.930); fruit weight with weight of arils per fruit (r^2 = 0.923) and number of arils with weight of arils per fruit (r^2 = 0.862). In contrast, significant negative correlation was observed between density of fruits and fruit volume (r^2 =- 0.633*) for all the genotypes.

Based on these findings, it is concluded that fruit quality traits, viz. fruit length, width, weight, volume, density, juice percentage, number of arils, weight of arils, weight of 100 arils, rind thickness, TSS (˚B), color of fruit, color of aril and softness of aril could be used as criteria for selecting promising pomegranate genotypes for salt affected soils and may also be useful for the genetic characterization of pomegranate germplasm. Results showed considerable variation in the plant growth and fruit quality traits of the pomegranate genotypes. Overall, genotypes Udaipur 2, Udaipur 3, Rajasmand 4 and Jaipur 1 have more capacity to sustain the injurious effects of salinity than other genotypes and thus have potential for cultivation in saline soils

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