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Response of Pomegranate (Punica granatum L.) to Saline Water Irrigation under Arid Conditions

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ABSTRACT

Pomegranate is an economically important fruit crop of arid and semiarid regions owing to its immense medicinal, therapeutic values and high remuneration. A study was conducted to note down response of pomegranate (*Punicagranatum* L.) to saline water irrigation under arid conditions. A survey in pomegranate growing belt in Barmer district of Rajasthan revealed perceptible changes in soil conditions and irrigation water quality within 10km of radius. Per say EC and RAC of irrigation water ranged from 1.5 to 12.0 dsm^{-1} and 0.0 to 6.8meq L^{-1},respectively, however soil pH ranged from 7.35 to 9.9. The present study aimed to give supplemental knowledge about response of pomegranate to normal, moderate and high salinity of irrigation water under arid conditions. It was observed that there was not much negative effect of salinity up to 8 dS/m. However, trees irrigated with higher saline water (>8 ds/m) showed drastic reduction in plant height and canopy spread compared to low and moderate saline water. Even with moderate saline irrigation water plant height and canopy spread was slightly higher compared to low level of saline irrigation water but fruit weight, yield and juice yield decreased.

Key Words: Saline water, Pomegranate, Irrigation

INTRODUCTION

Pomegranate is an economically important fruit crop of arid and semiarid regions of the world. There has been enormous increase in area, production and export of pomegranate worldwide over the past decades owing to its immense medicinal, therapeutic values and high remuneration. Recent growth trend have shown a rapid increase in area under pomegranate in arid part of India due to its versatile adaptability, low water requirement and low maintenance cost. These ambiances provide opportunities to widen area of pomegranate from its traditional belt *viz.,*Maharashtra, Karnataka and Tamil Nadu to non-traditional areas like Gujarat and Rajasthan. However, salinity is one of the major environmental stresses and often associated to high temperature, low atmospheric humidity, high wind velocity, intense radiation and high evaporation. The combined effects of high evaporative demand and salinity under these conditions have more deleterious impacts on plant growth, development and survival (Abdel Latef and Chaoxing, 2014).The deleterious effects of salinity on plant growth are associated with, low osmotic potential of soil solution,nutritional imbalance or deficiencies or toxicity symptoms (Chartzoulakis*et al*, 2002, Fernandez-Ballester*et al*, 2003),specific ion effect(Munns R, 2002),fruit yield and quality reduction (Allen *et al*, 1998). However, the cumulative effect of salt stress on plants depends on the concentration and time of exposure of salt, plant genotypes and environmental factors.

The increase in water salinity level decreased the plant height, stem girth and yield (34%) in ECiw 12 dS/ m compared to normal irrigation water (Chauhan, 2013).Mojtaba*et al*(2014) observed that pomegranate is salinity tolerant plant because salinity stress did not reduce pomegranate fruit

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yield up to 8.5 $dS.m^{-1}$. The mechanisms responsible for pomegranate tolerance to saline water are not yet fully understood however, it is well documented that pomegranate tissues accumulated sodium, chlorine and potassium in response to irrigation with saline water (Naeini*et al,* 2004).

One of the most important issues concerning in successful pomegranate production in arid regions is the ability to use saline irrigation water in water scarce zone which changes at micro level. Under these conditions making production sustainable and profitable, vis-à-vis further systematic area expansion, more information about tree crop behavior in the field within and throughout seasons using different saline irrigation water was needed. The present study aimed to give supplemental knowledge about response of pomegranate to normal, moderate and high salinity of irrigation water under arid field conditions.

MATERIALS AND METHODS

This study was conducted during fruiting season of 2015-16 and 2016-17. The commercial pomegranate growing area in village Budiwara of Balotra block in Barmer district of Western Rajasthan was selected as study site (25.83^{0}N, 72.24^{0}E, altitude of 119 m above sea level). I t typically represents weather conditions of arid region with very high temperature during the summer touching a maximum of 49ºC, short (December to mid- February) cool and dry winters (temperature varies from 0^{0}C to 14ºC), high evaporation and generally low humidity (20-50%). Annual average rainfall is 270 mm, mostly confined between July to September. The experimental soil belongs to family coarse loamy Typichaplocambids.

Barmer is the leading district and orchards are developed with Bhagwa variety under ferti-drip system with 4 drippers of 8l/h/tree. Rectangular planting system at spacing of 4m x 3.5m (4 x 3m) accommodating 7,15,833 plants/ ha on multi stem training with 3-4 main stem is common practice. All growers regulatecrop for *Mrigbahar*(flowering in July-August and fruit harvesting from December to March) by withholding water in June followed by spraying of ethephon (2.0ml/L) in July.

An extensive survey was conducted comprising 72 pomegranate producingfarm in three different villages. Seventy two composite soil and irrigation water samples were collected and brought to the laboratory for its analysis. There was perceptible variation in soil conditions and irrigation water quality within the collected samples. Per say EC and RAC of irrigation water ranged from 1.5 to 12.0 dsm^{-1} and 0.0 to 6.8meq L^{-1} , respectively, however soil pH ranged from 7.35 to 9.9 (1:2).To ascertain the impact of these irrigation water on pomegranate response with respect to growth, yield, biochemical quality and plant nutrient status, these farms were grouped in to three categories on the basis of EC of irrigation water i.e. <4.0dS/m, 4-8dS/m and > 8dS/m. Nine farms as three farms per replication having one hectare area in each category were selected for further data collection.These selected farms were followed similar cultural operations and inputs during study period.Physico-chemical properties of water in different categories used for irrigation were represented in table 1.

Soil chemical properties

The soil characteristics of the experimental orchard were deter-mined at the beginning of experimentations. The pH and electricalconductivity (EC) of the soil solution were measured on mixtureof soil water (1:2.5 and 1:5). Total nitrogen (N) wasdetermined by the Kjeldhal method. Phosphorus (P) content by Olsen and Sommers methods (1982). The Exchange-able bases (Na and K) were determined by atomic absorptionspectrophotometry (HITACHI Model Z-6100). Walkley-Black method was usedfor the soil organic matter analysis (Nelson and Sommersm, 1996).The soil chemical properties of different categories were presented in table 2.

Table 1.Physico-chemical properties of irrigation water used.

Properties	Low saline (<4ds/m)	Moderately saline (4-8ds/m)	Highly saline (>8 ds/m)
pH	7.93	7.64	8.13
$CO_3^{=}$	0	0	0
HCO_3^{-}	7.73	8.93	8.33
Cl^{-}	17.6	47.46	80.8
$SO_4^{=}$	0.54	1.08	0.933
K	0.07	0.1	0.19
Na	24.56	48.24	76.24
Ca + Mg	4.33	9.53	11.46
SAR	16.75	22.06	34.65
RSC	3.4	0.13	2.26

Plant growth and fruit yield

The observations on tree height and tree spread (E x W, N x S) were recorded from five randomly selected trees per replication in each category at flower bud initiation stage every year. Tree height was measured with expandable ruler between the base of the tree and the tip of the highest branch on the tree and expressed in meter. Tree spread in east-west direction and north –south direction was recorded by measuring the longest branch in both directions.

At each picking, fruit yield wasmeasured and the average cumulative yield per tree was calculated as kg/tree for each category. Twenty randomly selected fruits from the all side of tree during each picking were harvested and weight was taken using top pan digital balance and average fruit weight was expressed as g/fruit. The fruits from different treatment categories were weighedcut in to two halves and then juice was extracted by manual hydraulic juice extractor. The juice obtained after straining underaseptic condition was measured and the juice per cent was determined from thevolume of the juice divided by fruit weight andmultiplied by 100.

Biochemical analysis of fruits

Twenty randomly selected fruits from the all side of tree during each picking were harvested and used for biochemical analysis. A drop of pomegranate juice was placed on digital hand held refractometer (Model: Brix 54, Bellingham + Stanley Ltd., UK) and total soluble solid (^{0}B) was noted at room temperature. The titerable acidity was determined by method as suggested in A.O.A.C. (1990). 5 ml juice was titrated against N/10 NaOH solution using phenolphthalein as an indicator and acidity was express in per cent. The sugar contents was determined by volumetric method using Fehling

Table 2.Soil nutrient status of experimental study site.

Properties	Low saline (<4dS/m)	Moderately saline (4-8dS/m)	Highly saline (>8 dS/m)
pH	8.32	8.86	9.38
EC (dS/m)	0.527	0.644	0.595
OC (%)	0.122	0.127	0.182
Avail N (kg/ha)	64.2	64.6	67.2
Avail. P (kg/ha)	6.36	5.30	6.28
Avail. K (kg/ha)	212.4	223.8	202.2

Table 3.Effects of irrigation water salinity on plant growth, fruit yield and juice content of pomegranate cv. Bhagwa.

Salinity level (ds/m)	Plant height	Canopy spread		Fruit weight (g)	Yield (kg/ tree)	Juice yield (%)
		E-W	N-S			
<4	204.6	222.0	243.3	241.9	18.46	31.52
4-8	228.0	249.3	260.6	229.6	16.52	30.66
>8	165.3	182.6	177.0	200.7	11.70	29.19
CD (0.05)	23.6	28.8	28.6	18.9	3.5	3.9

solution based on the principle that sucrose content of fruit is quantitatively hydrolyzed to glucose and fructose in the presence of HCL as per the method suggested by A.O.A.C. (1990).

Leaf Mineral analyses

Leaf mineral analyses were carried out on dry material. Samples of five leaves per tree were collected from the mid-section of current year shoots. Leaflets were separated from leaves and rinsed with distilled water and dried at 65◦C during at least72 h until weight stabilization. After dry combustion at 400°Cfor 2 h, leaf samples were mineralized through a digestion process in 1N nitric acid solution (HNO3−). The sodium (Na+) and potassium (K+) contents were measured by flame emission photometry (Jenway PFP7, Bibby Scientific limited, Staffordshire, UK).Chlorides (Cl−) content was determined by titration with 0.1Nsilver nitrate (AgNO3) in the presence of potassium bichromate according to a modified colorimetric method of Mohr (Mathieu C andPieltain F 2003). Calcium (Ca2+) content was analyzed using an atomic absorption spectrophotometer (Analyst 300, Perkin Elmer,Inc.,Waltham, MA, USA). The total nitrogen (N) content was deter-mined following Kjeldahl technique (1883).

RESULTS AND DISCUSSION

Plant growth and fruit yield

Plant growth has consequent effect on fruit yield and quality. Saline water irrigation induced a significant effect on plant growth in terms of plant height and canopy spread (East-West x North-South). The plant height and canopy spread pomegranate trees were significantly affected by level of salinity in irrigation water. Results of plant growth showed that there was not much negative effect of salinity up to 8 dS/m. However, trees irrigated with higher saline water (>8 ds/m) showed drastic reduction in plant height and canopy spread compared to low and moderate saline water (Table 3). Even with moderate saline irrigation water plant height and canopy spread was slightly higher compared to low level of saline irrigation water.

The data (Table 3)showed that fruit yield decreased significantly with increasing salinity of irrigation water. Decrease being less up to moderate salinity but there was drastic reduction (36.6%) in trees irrigated with water having Ec more than 8ds/m.Decrease in yield was supported by the lower mean weight of fruits with corresponding treatment while number of fruits per tree was maintained more or less same in each treatment as cultural practice. Small but non-significant decrease in fruit juice content was noticed with increasing salinity of irrigation water.

Quality characteristics of juice

An inverse relationship was noticed for pH of juice as it was found decreased with increasing salinity level of irrigation water. Electrical conductivity of fruit juice did not exhibit any definite trend and it increased up to moderate salinity (up to 8 ds/m) and then decreased with highest level of saline irrigation water though the difference was non-significant.

The total soluble solids increased with increasing

Table 4. Effects of irrigation water salinity on quality characteristics of pomegranate fruit juice.

Salinity level (ds/m)	Juice (%)	Juice Ph	Juice EC	TSS	Acidity	TS
<4	31.52	3.21	3.44	16.3	0.40	11.65
4-8	30.66	3.15	3.54	16.6	0.50	12.67
>8	29.19	3.19	3.53	17.13	0.44	13.07
CD (0.05)	1.2	NS	NS	0.12	NS	0.88

salinity of irrigation waterbut the difference in TSS up to moderate salinity was meager while perceptible change observed with higher salinity (>8 ds/m). Fruit juice acidity was found highest with moderate salinity of irrigation water however, differences were not significant. Likewise TSS, total sugars was also showed increasing trend with increasing salinity of irrigation water but difference between moderate and higher salinity of irrigation water was non-significant (Table 4).

Leaf mineral content

Nutrients available in soil are transported from roots to the leaves via xylem vessels. These nutrients have subsequent effects on growth, yield and fruit quality. Therefore, leaf mineral content was analyses and presented in Figures (1a to 1f). Plants irrigated with saline water showed a continual increase in leaf P content as salinity of irrigation water increased. This salinity induced increase was significantly higher (17.5%) with highest level of salinity though this difference was not significant with moderate level of saline irrigation water.

Bar diagram of Figure 1 b representing leaf K content showed a decreasing trend from low to moderate salinity but with highest level of salinity it was recorded highest concentration of K in leaf. Figure representing leaf Ca content followed roughly similar pattern of K content in leaf. It was recorded lowest with moderate salinity level of irrigation water while either low or high salinity of irrigation water had equal concentrations of leaf Ca. leaf Mg content followed similar pattern as leaf K and Ca and was recorded highest in plants irrigated with low saline water. It was noticed that saline irrigation water induced a significant increase in leaf Na content as salinity level increased from low to high it was roughly 30.6% higher. The K/Na and Ca/Na ,ratios data presented in Fig.1e and Fig 1f respectively, revealed that higher salinity (ECw 4-8 or > 8 ds/m) irrigation water provoked a significant decrease of these ratios. Trees irrigated with moderate saline water or high saline water exhibited more or less equal K/Na and Ca/Na ratios.

Results of plant growth showed that there was not much negative effect of salinity up to 8 dS/m. However, trees irrigated with higher saline water (>8 ds/m) showed drastic reduction in plant height and canopy spread compared to low and moderate saline water. It is well documented that high salinity affects plants in two main ways: high concentrations of salts in the soil disturb the capacity of roots to extract water, and high concentrations of salts within the plant itself can be toxic, resulting in an inhibition of many physiological and biochemical processes such as water stress, nutrient uptake and assimilation (Hasegawa *et al*,2000, MunnsR, 2002). Together, these effects reduce plant growth, development and survival. Reduction in shoot growth due to salinity is commonly expressed by a reduced leaf area and stunted shoot growth. Similar results were also observed in present study as plant height and canopy spread was drastically reduced in plants irrigated with water having EC >8dS/m. Chauhan (2013) also observed decreased in plant height, stem girth and yield reduction (34%) in pomegranate irrigated with water containing EC 12 dS/m compared to normal irrigation water. Khayyat*et al,*(2014) reported that plant height, number of leaves, and stem diameter of pomegranate plants decreased significantly with increasing soil salinity.

Similar findings were reported on other species (Carr, 2014, Benhassaini*et al*, 2012,Hajiboland*et al*, 2014,Karimi and Hasanpour, 2014 &BenHamed and Lefi, 2015). In present study, decrease in fruit yield recorded less up to moderate salinity but there was drastic reduction (36.6%) in trees irrigated with water having Ec more than 8ds/m and this decrease in yield was supported by the lower mean weight of fruits rather than number of fruits. Considering stress effects due to osmotic mechanism under high salinity (Bhantana and Lazarovitch,2010), low water availability in plant system subsequently causes more dry matter accumulation which might be responsible for higher total soluble solutes and more sugar accumulation with low acid content in fruit. Both reduced and non-reduced sugars with nitrogen compounds accumulate in cells under stress conditions and play a role as osmotic regulators(Suyigma*et al,* 1991). It has been stated that, in stress conditions, the most increasing type of sugar is sucrose and the second is fructose. Especially sucrose has an important role in adapting to stress conditions.

Mineral content in leaves

Phosphorus (P), potassium (K) and calcium (Ca) as well as K/Na and Ca/Na ratios decreased withincreasing salt concentration in the irrigation water.Statistical analysis of summer data revealed a significant decrease of P leaf content as salinity of irrigation waterincreased.Irrigation with moderate saline water(ECw = 5 dSm−1) did not affect and even induced an increase in leafCa^{2+}content. At an ECw = 12 dSm−1, Ca2+content in the leaveswas significantly reduced during all the duration of the study.Salinity may reduce nutrient availability and uptake in growingplants. The mechanisms responsible for pomegranate tolerance to saline water up to certain level are not yet fully understood. However, it is well documented that pomegranate tissues accumulated sodium, chlorine and potassium in response to irrigation with saline water (Naeini*et al*, 2004).

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