Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 4 [1] December 2014: 146-151

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.533
Universal Impact Factor 0.9804

ORIGINAL ARTICLE

Integrated Impact of salinity and drought stress on Quantity and Quality of Pomegranate (*Punica granatum* L.)

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ABSTRACT
Approximately half of the irrigated land is affected by salinity, sodium or over irrigation. Both salinity and drought stress induce water limitation for plants and will reduce growth rapidly along with metabolic changes. Pomegranate (Punica granatum L.) which is native to Iran is mainly cultured in arid and semi-arid regions, but suitable irrigation regime and accurate water requirements are not identified. Therefore a factorial experiment with irrigation at 5 levels (well water, 10, 20, 30 and 40% well water) and salinity at 3 levels (1.5, 5 and 8 $dS.m^{-1}$) based on a completely randomized design with 4 replicates was conducted on 4 year old trees in Ferdows town of Iran during 2011-2013. Total yield and other qualitative traits were measured at the end of second year. Results showed a significant decrease in total yield and some other qualitative traits from integrated deficit irrigation and salinity stress. Deficit irrigation decreased fruit yield compared to control treatment. Antioxidant activity increased in response to deficit irrigation, however, it is not considered very important regarding marketability. In addition, fruit yield was observed none-significant among salinity treatments. Hence it generally seems that pomegranate could be classified as a drought sensitive and salinity tolerant plant.
Keywords: *Drought stress; salinity stress; deficit irrigation; pomegranate*

Received 23.08.2014 **Revised 11.11.2014** **Accepted 03.12.2014**

INTRODUCTION

Environmental stresses are among the most important factors determining plant distribution across the world. In Iran due to severe scarcity of water resources in many parts, drought stress as well is considered to be the most influencing stress on plants. Annually yield reduction due to drought stress is known to be 17% which can rise up to 70% [1]. Plant responses to drought stress depends on species, cultivar, stress duration, plant age and phonological stage, cell type and plant organ as also sub-cell organelles [2]. Salinity is a major environmental stress and is a substantial constraint to crop production. It is defined as the presence of additional mineral compounds or salt deposition in land which can interfere with plant growth. Agriculture development in arid and semi-arid regions along with high irrigation demands has led to soil salinity due to soil hydrology imbalance. Plant responses to salinity and drought stress are very similar. Just like drought, osmotic mechanisms are also involved in salinity which limits water availability and subsequently reduces growth along with metabolic changes similar to drought stress [3]. Salinity will not influence all plants naturally grown in saline soil in a same manner [4]. Regulated deficit irrigation (RDI) is a useful method for producing yields in a water limiting condition, which allows a bearing plant to reduce its yield wisely due to a lower water demand. In this way it actually is very important to determine the maximum reduced evapotranspiration economic benefit which is equal or even greater than full irrigation [5]. Kozlowski [6] stated the negative effect of drought on flower initiation, fruit set, growth and fruit quality. Benefits of deficit water irrigation are shown in peach [7], cherry [8] and apricot [5]. Deficit irrigation by 50% of control water use in apple trees for the last growth stage and also full water in the whole production period did not show any negative effect on total yield, but regulated deficit irrigation in production period reduced fruit size [7]. Bhantana and Lazarovitch [9], studied irrigation with saline water on evapotranspiration, Kc and growth of pomegranate cuttings and observed a significant decrease in daily and total evapotranspiration.

According to this, pomegranate tree can be considered as a sensitive rather than a resistant plant. Khattab et al [10] studied the effect of different irrigation levels on vegetative growth and fruiting of 20 years old pomegranate trees of Manfalouty cultivar. They found out that, fruit yield was significantly influenced by water and it decreased by water limitation linearly. Pomegranate is native to Iran and 82000 hectare is under production with great quality. High marketability performance and visual appearance along with bright color makes this fruit a good export candidate. Finding a good watering regime is of great importance.

MATERIAL AND METHODS

Climatic characteristics

In order to evaluate the effects of integrated salinity and drought stress on quality and quantity of pomegranate fruit, a factorial experiment with irrigation at 5 levels (0 well water, 10, 20, 30 and 40% well water) and salinity at 3 levels (1.5, 5 and 8 $dS.m^{-1}$) based on a completely randomized design with 4 replicates was conducted on 4 year old trees in Islamic Azad University, Ferdows branch during 2011-2013. Total water quantity and different overall quality of irrigation water in both years was kept similar. Total yield and other qualitative traits were measured and evaluated at the end of second year.

Ferdows city is a close neighbor to the central desert of Iran. The climate of Ferdows according to Ambridge classification is considered as dry and cold. Mean climate characteristics are shown in table 1:

Table 1- Climatic conditions of Ferdows city

Annual rainfall (mm)	Annual sunny hours	RH(%)	Mean temperature (^0C)	Climate
140	2900	37	25	Dry and cold

The soil texture is sandy-clay with Field capacity (FC) of 20.7% and Permanent wilting point (PWP) of 10.3% w/w.

Experimental planning and design

A factorial experiment with irrigation at 5 levels (0 well water, 10, 20, 30 and 40% well water) and salinity at 3 levels (1.5, 5 and 8 $dS.m^{-1}$) from different water sources, based on a completely randomized design with 4 replicates was conducted on 4 year old pomegranate trees in Islamic Azad University, Ferdows branch during 2011-2013. Root depth was first determined for water requirement calculations. Then considering field capacity (FC) and permanent wilting point (PWP) of the local soil, irrigation treatments were planned using FC method. Irrigation depth was determined using formula 1.

$$I_n = (F_C - PWP) MAD \times Dr_z \quad \textbf{(1)}$$

Which I_n, specific irrigation depth (mm), FC, field capacity, PWP, permanent wilting point, MAD, allowed soil watering use (%), Dr_z, root distribution depth (mm). Soil moisture sensitive sensors (Davis instruments 6440) were used for determining the time of different irrigation treatments.

Table 2- Total water used in different irrigation treatments during growth period

Irrigation treatments	Well water	40% well water	30% well water	20% well water	10% well water
Water volume (Litre)	5400	3240	3780	4320	4860

Pomegranate fruits were harvested and weighted after ripening. 4 fruits were selected for evaluation and trait measurements. Visual traits were observed at first and then samples were taken to the laboratory for measuring other qualitative properties.

RESULT AND DISCUSSION

Collected results of different traits measured are shown in table 3. Results showed irrigation treatments had a significant effect on total fruit yield, vitamin C and antioxidant activity, but other traits were not affected. Salinity also affected vitamin C and antioxidant activity only and did not change other indexes in this manner (table 3).

Table 3- Mean comparison of different traits measured in this experiment

	Tree yield	Size	Fresh weight (10 aril)	Dry weight (10) aril	Antioxidant activity	Vitamin C	Weight ration
Irrigation (%well water)							
1	10.71a	1.55a	4.25a	1.59a	44.66b	8.83a	2.79a
2	9.66a	1.55a	3.47a	1.62a	47.21b	4.85b	2.3a
3	7.65b	1.53a	3.55a	1.89a	52.34ab	7.33ab	1.99a
4	6.82b	1.6a	4.09a	2.28a	58.02a	7.29a	1.8a
5	5.23c	1.52a	3.77a	2.25a	61.02 a	6.76ab	1.72a
Salinity (dSm^{-1})							
1.5	7.87a	1.53a	3.46a	1.99a	41.35b	7.74a	1.98a
5	8.00a	1.59a	3.97a	2.02a	56.87a	5.95b	2.06a
8	7.18a	1.53a	3.89a	1.77a	60.05a	7.64a	2.34a

Table 4- Interaction effects of salinity and drought stress on mean total yield

	I1	I2	I3	I4	I5
S1	12.78	10.61	8.20	7.31	5.47
S2	10.23	9.76	7.80	6.90	5.27
S3	9.14	8.61	6.95	6.27	4.95

Interaction effect of drought and salinity stress on yield components

Total yield, vitamin C and antioxidant activity were significantly affected by the interaction of salinity and drought ($P \leq 0.05$ and $P \leq 0.01$ respectively) while others were not. Interaction effect on total yield is shown in Fig. 1. Salinity levels in different watering regimes do not show a regular pattern. Considering stress effects individually revealed that, low water availability lays the main role in yield reduction. By the way salinity can also limit water uptake by the plant which makes water scarcity more sever [11].

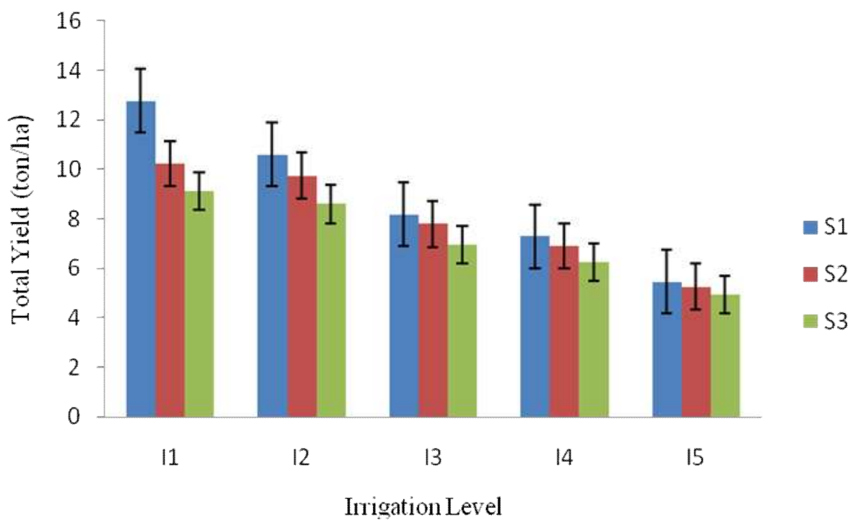


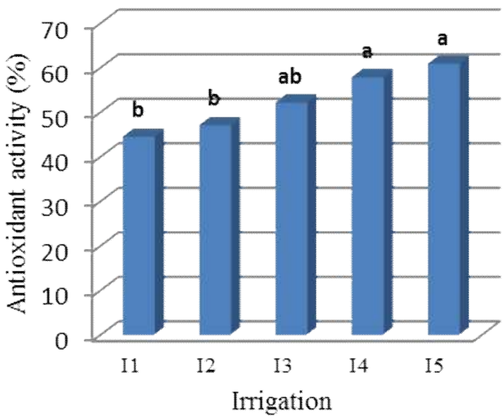
Figure 1. Interaction effects of salinity and drought stress on total yield

Effect of drought stress on yield

Total yield reduces along with drought stress (Fig. 2). According to the yield in different irrigation treatments, it is observed that yield reduction is greater than a specific watering reduction. In other words, if irrigation efficiency is 100% and the amount of water in each treatment was equal to evapotranspiration, it can be definitely mentioned that pomegranate is a drought sensitive plant according to the equation below:

$$\frac{Y_a}{Y_t} = K_y \left(1 - \frac{ET_a}{ET_p}\right) \quad \textbf{(2)}$$

Which Yt is maximum yield, Ya real yield, ETp, potential evapotranspiration, Eta, real evapotranspiration and Ky is the yield reduction related to evapotranspiration reduction. Ky is higher than 1 for sensitive plants. Khattab et al [10] also mentioned fruit yield was significantly influenced by water and it decreased by water limitation linearly. Other researches on dry region trees have revealed different results. Hence according to results it is obvious that pomegranate is not sensitive to low and mild drought stress during the growth period and sever stress caused a significant yield reduction. Therefore pomegranate is considered a drought sensitive plant.



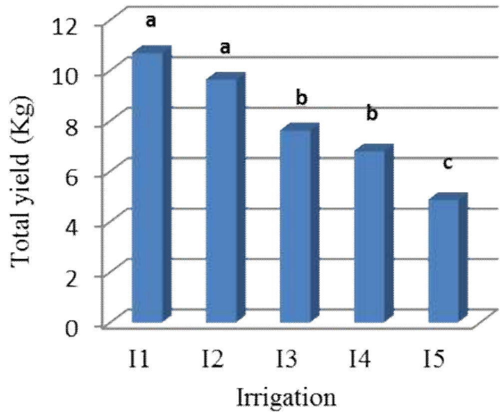


Figure 2- Total yield in irrigation levels

Figure 3- Antioxidant activity in irrigation levels

Effect of drought stress on antioxidant activity

Results indicate that antioxidant activity increased with drought stress severity and this increase is significant (Fig. 3). Antioxidants are divided into osmo-protectants and enzymes which are both increased under stress conditions.

Effect of drought stress on fresh to dry weight of 10 arils ratio

Fresh to dry weight ratio which is an indicator of aril turgidity and quality, improves the marketability and visual quality as well as organoleptic taste. Highest ratio is observed in well water treatment and in decreases along with water limitation in other irrigation treatments (Fig. 4). Water scarcity has not reduced fresh to dry weight ratio significantly and it is just noticed as a market index which may negatively influence export.

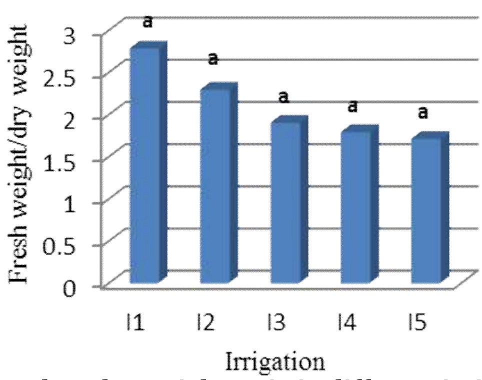


Figure 4- Fresh to dry weight ratio in different irrigation levels

Effect of salinity stress on yield components

Plant responses to drought and salinity stress is mainly very similar, however some specific salinity effects are known which may bear subsequent impacts on plant growth [11].

Effect of salinity stress on total fruit yield

Saline water effect on total pomegranate yield was not significant, although control treatment showed the highest yield (Fig. 5).

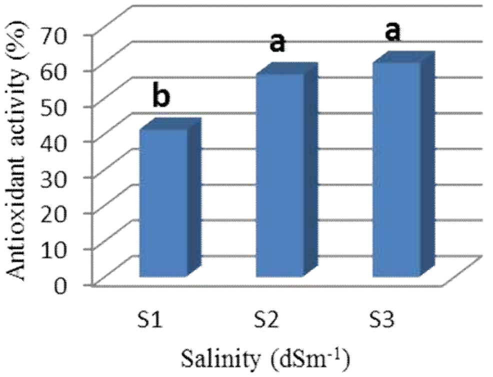


Figure 5- Total yield within salinity stress Stress

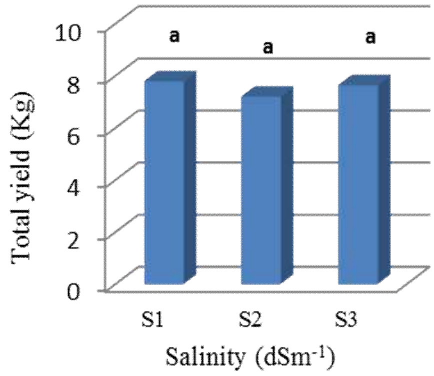


Figure 6- Antioxidant activity within salinity

Bhantana and Lazarovitch [9] investigated saline water irrigation on evapotranspiration and pomegranate cutting growth and evaluated pomegranate as a salinity sensitive plant due to reduced evapotranspiration in response to saline water irrigation. They however did not evaluate tree yield and is only related to cuttings. The main parameter in fruiting trees is total yield and the results of this study showed that salinity had no significant effect on this trait.

Effect of salinity stress on antioxidant activity

Similar to drought, salinity stress by inducing osmotic stress subsequently performed the same responses on antioxidant activity. In other words, antioxidant activity rose along with stress severity. 5 and 8 dS.m-1 treatments did not show noticeable changes (Fig. 6).

Effect of salinity stress on fresh to dry weight of 10 arils ratio

Results recorded show no significant difference on this trait but a slight increase is observed (Fig. 6). Fresh to dry weight ratio shows a little increase with saline water irrigation severity. In other words, with saline stress severity arils come fleshier and thus improved fruit quality. Sanchez et al [12] stated that salinity caused a significant decrease in fruit juice of lime. Lime is classified in salt sensitive group plants and little amounts of salinity will impose noticeable effects on yield and fruit quality.

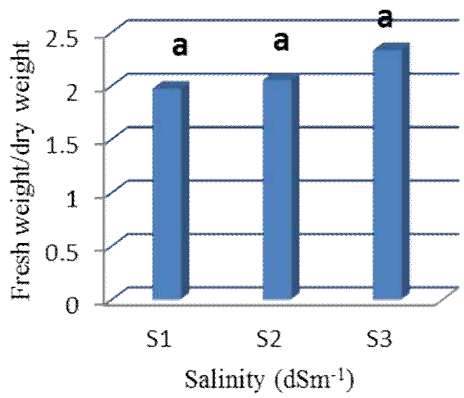


Figure 7- Fresh to dry weight ratio of 10 arils in salinity stress

CONCLUSION

Results generally indicated that pomegranate fruit yield is significantly affected by both drought (deficit irrigation) and salinity stress and the integration of them. Salinity stress alone did not reduce fruit yield up to 8.5 $dS.m^{-1}$ sever stress in this experiment and the reduction was considered to be related to drought stress. In addition, qualitative traits related to marketability, were not significantly affected by neither drought nor salinity. Hence it seems that pomegranate could be classified as a drought sensitive and salinity tolerant plant.

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ITATION OF THIS ARTICLE

Mojtaba T, Freidoon K, Amin A, Hossein B, Ali T. Integrated Impact of salinity and drought stress on Quantity and Quality of Pomegranate (*Punica granatum* L.).Bull. Env. Pharmacol. Life Sci., Vol 4[1] December 2014: 146-151