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# Effects of Superabsorbents on Growth and Physiological Responses of Date Palm Seedling under Water Deficit Conditions

**Abdulhamid Mohebi***

*Assistant professor at Date Palm and Tropical Fruits Research Center, Horticultural Sciences Research Institute, Agricultural Research, Education and Extension Organization (AREEO), Ahwaz, Iran*

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**Abstract**

Irrigation is an inevitable part of agriculture which determines crop yield and thus food security. In modern era of agriculture, crop yield is determined on the basis of crop production per unit of water-use instead of crop production per land unit area. Deficit irrigation is introduced as a strategy for controlling water resources that leads to water resource preservation. Date palm requires regular irrigation after plantation at the primary growth stages. In the present study, the effect of applying superabsorbent polymers on required water for irrigation of date palm seedlings has been evaluated during 2011-2012. Treatments were 60%, 80% and 100% ETc irrigation and 0, 40, 80 and 120 g superabsorbents for each seedling. The experiment was conducted in RCBD and split-split plot experimental designs. Water requirement was calculated based on FAO pan method. Results showed that, percentage of establishment reduced significantly in all irrigation regimes including normal irrigation, mid stress, and severe stress. Moreover, using superabsorbents resulted in an increase in SOD activity under 80% irrigation deficit in comparison to full irrigation. Furthermore, it was demonstrated that superabsorbents significantly affected uptake of mineral nutrients and consequently resulted in a raise in seedling establishment.

**Keywords:** Date palm seedling, Superabsorbent, Superoxide dismutase, Water use.

## Introduction

In recent years, using low-input agricultural systems and modern strategies of resource management is attracting the attention of crop producers. Applying superabsorbent has been introduced as a successful strategy for water preservation and increasing crop yield in dry zones (Kazemian, 2005). Drought stress renders plants from meeting their genetic potential and consequence in reduction of crop yield (Abolhasani and Saiedi, 2006). In addition, drought is known as the most common factor that limits crop production in 25% of the land all over the world (Fahad et al., 2017) in such a way that, most of plants experience water stress at least once during their whole life cycle. Plants response to stress based on the growth stage, and their physiological potential. Drought stress restricts water availability for plants which limits plant growth and performance. The growth limitation caused by drought is exacerbated by other environmental stresses such as high temperature, low relative humidity, light stress and high-speed winds (Kafi and Mahdavi Damghani, 2000). It was shown that using zeolite as a superabsorbent, can reduce water stress by preserving water and gradual release of

* Corresponding Author, Email: hamidmohebi@hotmail.com

preserved water to the root zone (Zamanian, 2008). Moreover, application of zeolite ameliorated the adverse effect of drought stress and caused reduction in the rate of abnormal seedlings, enhanced seed germination and increased dry matter of rapeseed (Armand Pisheh, 2009).

Providing a condition that makes it possible to grow plants in dry lands can be a successful strategy to make use of dry lands. In this regard, for opting strategies to increase water use efficiency in plants, it is of essential importance to understand the mechanism by which plants cope with drought stress (Reddy et al., 2004).

Using hydro gel may improve plant growth and performance by retention of irrigation water and thus increasing available water in plant root zone, which can efficiently rescue plants from drought stress (Francesco et al., 2015). Due to high variation in rate of rainfall, most parts of Iran face water scarcity. The impact of drought stress imposed on plants, varies based on the magnitude, duration and the time of water deficiency (Pandey et al., 2001). Identification of the critical time for irrigation and providing crop-specific schedule for irrigation is a key step for water conservation and further sustainability of irrigated agriculture (Ngouajio et al., 2007).

Drought stress significantly limits plant growth and crop productivity. However, in drought-tolerant plants such as rapeseed, morphological and metabolic changes occur in response to drought, which are contributing to adaptation to stress (Sinha et al., 1982; Blum, 1996).

Considering water scarcity, efficient management of soil moisture is an important strategy for crop production. Any factor that retains soil water content, weather natural or synthetic, contribute significantly in increasing water availability in root zone. Polymeric organic materials and hydro gels, not only improving the soil physical properties, but also act as buffer during temporary drought stress, which led to a reduction in the risk of plant failure, during establishment (De Boodt, 1990, Johnson and Leah, 1990). Water preservation caused by using polymeric materials is achieved through reduction of evaporation by restricting water movement from the sub-surface to the surface layer (Ouchiet al., 1990).

Plants response to water stress differs significantly, depending on intensity and duration of stress, plant species and its stage of development (Chaves et al., 2003). Different types of hydrogels, can preserve at least 95% of soil water content and make the preserved water available for plant uptake (Johnson and Veltkamp, 1985). Therefore, using hydro gels is regarded as a valuable method for being applied in agriculture in this era of water scarcity.

Plants response to drought stress is a complex phenomenon that involves the synthesis of polyamines and a new set of proteins with unknown function. Oxidative stress, results from the deleterious effects of reactive oxygen species, is a common phenomenon in many stress-exposed biological systems. In plants, the role of superoxide dismutase (SOD) during environmental stresses attracted the attention of many scientists since it contributes in production of ROSs. In this regard, the possibilities for generating stress-tolerant plants by the genetic engineering of SOD have been previously discussed (Bowler, et al., 1992).

This study conducted to evaluate the effect of superabsorbent applications on performance of date palm offshoot under drought stress condition. The primary objective of this study was to examine the effect of deficit irrigation and superabsorbent on the SOD activity and water availability for date palm seedling under field conditions. The second objective of this study was to assess the possibility of introducing superabsorbent polymers as a proper method for coping with drought stress.

## Materials and Methods

This experiment was conducted in Ahvaz,

Iran (48° 32′E, 31° 15′N; 70 m a.s.l) in a randomized complete block design and factorial split-plot design with four replications during the 2011- 2012 growing season. Irrigation was carried out in three levels including irrigation based on 100%, 80% and 60% evaporation from the class A pan (normal irrigation, mild stress and severe stress, respectively) as the main plots. Superabsorbent was applied in four levels including 0, 40, 80 and 120 g per offshoot of date palm as the subplots. Ahvaz is a semi-arid region and receives an average annual rainfall of 220 mm. The taxonomic traits of soil, where experiment took place, was a *Fine, Carbonatic, Hyperthermic typic Torrifluvent* and the soil texture categorized as clay loam (Table 1).

A hydrophilic polymer, Superabsorbent A200, produced by Rahab Resin Co. Ltd., under the license of Iran Polymer and Petrochemical Institute was used in this experiment. The maximum durability of this matter is 7 years and the water uptake capacity (g/g) is equal to 220 g of distilled water.

The polymer was applied to soil meanwhile of planting offshoots of date palm (cv Deiri) to the depth of active root growth. After offshoots were planted, irrigation and drought stress treatments were applied (Table 2). All the agronomical operations were carried out uniformly for all experimental units. Measurement of crop evapotranspiration and ETc, calculated based on multiplying the reference crop evapotranspiration, ETo, by a crop coefficient, Kc:

$$ETc = Kc\ ETo \qquad (1)$$

where

ETc =crop evapotranspiration [mm $d^{-1}$],

Kc =crop coefficient [dimensionless],

ETo =reference crop evapotranspiration [mm $d^{-1}$].

The initial stage runs from the planting date to reaching approximately 10% ground cover. The length of the initial period depends on the crop, crop variety, the planting date, and the climate. The end of the initial period determined based on the time when approximately 10% of the ground surface is covered by green vegetation (Allenet al., 1998). Therefore, it is expected that, the $K_c$ during the initial period ($K_{c\ ini}$) is large when the soil is wet from irrigation and rainfall and is low when the soil surface is dry. The procedure for estimating $K_c$ in the mid and an end season is:

$$K_{c\ (mid)} = K_{c\ (mid\text{-}table)} + [0.04\ (U_2 - 2) - 0.004(RH_{min} - 45)]\ (h/3)^{0.3} \qquad (2)$$

$$K_{c\ (end)} = K_{c\ (end\text{-}table)} + [0.04\ (U_2 - 2) - 0.004(RH_{min} - 45)]\ (h/3)^{0.3} \qquad (3)$$

where

$K_{c\ (mid\text{-}table)}$ = value for Kc in mid-season taken from FAO Table (Allen et al., 1998)

$K_{c\ (end\text{-}table)}$ = value for Kc in end season taken from FAO Table (Allen et al., 1998)

$U_2$ = mean value for daily wind speed at 2 m height over grass during the mid-season growth stage [$ms^{-1}$], for 1 $ms^{-1} \leq U_2 \leq 6\ ms^{-1}$,

$RH_{min}$ =mean value for the daily minimum relative humidity during the mid-season growth stage [%], for $20\% \leq RH_{min} \leq 80\%$,

h =mean plant height during the mid-season stage [m] for 0.1 m < h < 10 m.

$K_{c\ (mid)}$ and$K_{c\ (end)}$ =values determined are average adjustments for the mid-season and late season periods.

$$T_d = (ET_c - R_e)\ (0.1\sqrt{P_d})$$

$$I_g = T_d / E$$

where

$T_d$ = estimated ET crop

$ET_c$ = crop evapotranspiration

$R_e$ = effective rainfall in mm.

$P_d$= fraction of soil surface covered or shaded by vegetation

E = irrigation efficiency

$I_g$ = Gross irrigation requirement mm$day^{-1}$

The number of leaves was determined by counting the total number of leaves in each seedling. To determine the leaf length

**Table 1. Physiochemical characteristics of soil**

| Soil depth (cm) | Texture | EC (dS/m) | pH | SAR | %OC | P (ppm) | K (ppm) | cation (meq/lit) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | $Na^+$ | $Ca^{+2}$ | $Mg^{+2}$ |
| 0-30 | Clay Loam | 4.9 | 7.8 | 3.5 | 0.59 | 12 | 170.0 | 12.5 | 7.2 | 16.5 |
| 30-60 | Clay Loam | 4.9 | 7.8 | 2.4 | 0.43 | 10 | 252.1 | 9.1 | 4.8 | 24.4 |

**Table 2. chemical characteristics of irrigation water**

| EC (dS/m) | pH | SAR | Anion (meq/lit) | | | Cation (meq/lit) | | |
|---|---|---|---|---|---|---|---|---|
| | | | $SO_4^{-2}$ | $CO_3^{-2}$ | $Cl^-$ | $Na^+$ | $Ca^{+2}$ | $Mg^{+2}$ |
| 2.3 | 8.0 | 3.5 | 3.0 | --- | --- | 4.0 | 12.0 | 9.9 |

and width, four leaves was selected which was marked in four directions. The length of each marked direction was used as an index for comparing the variance of leaf area in various treatments.

***Number, length, and width of the leaflet***

The number of leaflets was calculated by counting the total number of leaflets. Eight of closest leaflets to the middle of the flap of four marked leaves were selected for measuring the leaflets width and length.

The leaf length was determined by measuring the distance between the point where leaf attach to the leaf axis and the leaflet tip. The width of the leaf was measured from its middle part. The average of the measured values was recorded for each seedling. The trunk perimeter measured from 1cm height from soil base (Sadeghian Motahar et al., 2008). Date palm leaflets were sampled from each seedling. The frozen homogenized plant sample was used for preparing the crude extract in a buffer medium. The date palm leaflet was stored at −20°C and used for the enzyme extraction. The sample was washed twice with distilled water. Leaflet sample (10 g) was cut quickly into thin slices and homogenized in 50 mL of 100 mM sodium phosphate buffer (pH 7.0) containing 1 mM ascorbic acid and 0.5% (w/v) polyvinylpyrrolidone for 5 min at 4°C. The homogenized samples were filtered through three layers of cheesecloth and then the filtered samples were centrifuged at 5,000xg for 15 min, and the supernatant were collected. SOD activity was determined by measuring its capacity to inhibit the photochemical reduction of the chloride of nitrobluetretrazolium (NBT) (Giannopolitis and Ries, 1977). The absorbance spectra were measured at 560 nm; for evaluation of one unit of SOD activity (U as the quantity required inhibiting 50% of a photo reduction rate of NBT). Leaflets samples were collected in April. The concentration of nitrogen was measured using wet oxidation digestion developed by Kjeldahl. Phosphorous (by spectrometry) and potassium content were also measured (AOAC, 1984). The statistical analysis and Duncan test for mean comparison of data was performed using SPSS 16 software.

## Results

***Establishment percentage and vegetative growth***

The analysis of variance showed that superabsorbent significantly affected seedling establishment percentage. Based on results obtained in this study, there was no significant difference between the effect of 100% and 80% Etc on seedling establishment. But the percentage of seedling establishment was significantly different under 60% Etc (Table 3). Results demonstrated that, increase in superabsorbent contents, resulted in increase in seedling establishment. In such a way that percentage of seedling establishment increased from 62.50% (in $S_0$) to 91.67% (in $S_2$); however, no significant difference observed between applying 80 and 120 g of superabsorbent (Table 3). Application of 40, 80 and 120 g superabsorbent resulted in 20.0, 46.7 and 33.33% establishment in date palm seedling, respectively (Table 4). In water deficit scenarios seedling establishment reduced with an increase in water deficiency (Table 5). It was revealed that the highest establishment percentage (100%) obtained at 100% ETc irrigation and 80 g superabsorbent application (Table 5).

### *Trunk perimeter*

The analysis of variance showed that superabsorbent has a significant effect on seedling trunk perimeter. Results revealed that there was significant difference between 100% Etc in comparison with 80% and 60% ETc. A parallel increase in trunk perimeter with increase in superabsorbent content was observed in such a way that a 17% increase in trunk diameter was observed in S3.

However, no significant difference observed between application of 60, 80 and 120 g superabsorbent (Table 4).

The highest (75.33 cm) and the lowest (50.33 cm) offshoot trunk perimeter was observed at 100% ETc irrigation together with 80 g polymer and 60% ETc irrigation without superabsorbent polymer, respectively (Table 5).

**Table 3. Mean comparison of physiological traits of date palm under different deficit irrigation**

| Irrigation | Establishment percent | Leaflet number | Height offshoot (cm) | Trunk perimeter (cm) | Leaflet length (cm) | Leaflet width (cm) | Leaflet N (ppm) | Leaflet P (ppm) | LeafletK (ppm) | SOD(U mg$^{-1}$ protein) |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 87.50$^{A}$ | 81.75$^{A}$ | 141.21$^{A}$ | 67.25$^{A}$ | 29.53$^{A}$ | 1.98$^{A}$ | 0.22$^{A}$ | 0.072$^{A}$ | 0.054$^{A}$ | 25.37$^{C}$ |
| 80 | 78.13$^{A}$ | 78.17$^{A}$ | 127.92$^{A}$ | 57.25$^{B}$ | 29.97$^{A}$ | 1.83$^{A}$ | 0.22$^{A}$ | 0.067$^{A}$ | 0.052$^{A}$ | 41.24$^{A}$ |
| 60 | 68.75$^{B}$ | 77.92$^{A}$ | 136.75$^{A}$ | 56.00$^{B}$ | 25.80$^{A}$ | 1.89$^{A}$ | 0.20$^{A}$ | 0.071$^{A}$ | 0.053$^{A}$ | 30.34$^{B}$ |

**Table 4. Mean comparison of effect of applying superabsorbent on physiological traits of date palm**

| Superabsorbent | Establishment percent | Leaflet number | Height offshoot (cm) | Trunk perimeter (cm) | Leaflet length (cm) | Leaflet width (cm) | Leaflet N (ppm) | Leaflet P (ppm) | Leaflet K (ppm) | SOD(U mg$^{-1}$ protein) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 62.5$^{B}$ | 72.11$^{B}$ | 110.61$^{B}$ | 54.00$^{B}$ | 25.23$^{A}$ | 1.69$^{A}$ | 0.21$^{A}$ | 0.068$^{B}$ | 0.050$^{A}$ | 31.44$^{B}$ |
| 40 | 75.0$^{AB}$ | 76.89$^{AB}$ | 135.67$^{A}$ | 62.22$^{A}$ | 22.36$^{A}$ | 1.87$^{A}$ | 0.23$^{A}$ | 0.073$^{A}$ | 0.055$^{A}$ | 33.36$^{A}$ |
| 80 | 91.7$^{A}$ | 85.45$^{A}$ | 148.11$^{A}$ | 61.44$^{A}$ | 29.87$^{A}$ | 2.02$^{A}$ | 0.24$^{A}$ | 0.074$^{A}$ | 0.053$^{A}$ | 35.32$^{A}$ |
| 120 | 83.3$^{AB}$ | 82.67$^{A}$ | 146.78$^{A}$ | 63.00$^{A}$ | 32.10$^{A}$ | 2.02$^{A}$ | 0.23$^{A}$ | 0.065$^{B}$ | 0.052$^{A}$ | 29.14$^{C}$ |

**Table 5. Mean comparison of physiological and biochemical traits under application of different superabsorbent and deficit irrigation in date palm**

| Irrigation | superabsorbent | Establishment percent | Leaflet number | Height offshoot (cm) | Trunk perimeter (cm) | Leaflet length (cm) | Leaflet width (cm) | Leaflet N (ppm) | Leaflet P (ppm) | Leaflet K (ppm) | SOD(U mg$^{-1}$ protein) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $I_1$ | $S_0$ | 75.0$^{AB}$ | 75.67$^{A}$ | 56.67$^{B}$ | 119.67$^{B}$ | 27.16$^{B}$ | 1.77$^{A}$ | 0.18$^{B}$ | 0.067$^{BC}$ | 0.54$^{A}$ | 25.50$^{C}$ |
| | $S_1$ | 87.5$^{A}$ | 78.67$^{A}$ | 69.00$^{AB}$ | 137.33$^{AB}$ | 27.07$^{AB}$ | 1.96$^{A}$ | 0.20$^{B}$ | 0.066$^{BC}$ | 0.55$^{A}$ | 25.64$^{C}$ |
| | $S_2$ | 100$^{A}$ | 82.00$^{A}$ | 75.33$^{A}$ | 148.00$^{AB}$ | 33.90$^{AB}$ | 2.03$^{A}$ | 0.18$^{B}$ | 0.081$^{A}$ | 0.50 | 26.46$^{C}$ |
| | $S_3$ | 87.5$^{A}$ | 90.67$^{A}$ | 68.00$^{AB}$ | 142.00$^{AB}$ | 29.97$^{AB}$ | 2.13$^{A}$ | 0.25$^{A}$ | 0.067$^{BC}$ | 0.54$^{A}$ | 23.90$^{C}$ |
| $I_2$ | $S_0$ | 62.5$^{B}$ | 74.00$^{A}$ | 55.00$^{B}$ | 107.67$^{B}$ | 25.77$^{AB}$ | 1.77$^{A}$ | 0.24$^{A}$ | 0.070$^{B}$ | 0.50 | 37.79$^{B}$ |
| | $S_1$ | 75.0$^{AB}$ | 76.00$^{A}$ | 57.67$^{B}$ | 121.67$^{B}$ | 26.70$^{AB}$ | 1.73$^{A}$ | 0.20$^{B}$ | 0.082$^{A}$ | 0.56$^{A}$ | 45.03$^{A}$ |
| | $S_2$ | 87.5$^{A}$ | 86.67$^{A}$ | 58.33$^{B}$ | 134.67$^{AB}$ | 27.80$^{AB}$ | 1.93$^{A}$ | 0.24$^{A}$ | 0.081$^{A}$ | 0.52$^{AB}$ | 47.68$^{A}$ |
| | $S_3$ | 87.5$^{A}$ | 76.00$^{A}$ | 58.00$^{AB}$ | 147.67$^{AB}$ | 39.60$^{A}$ | 1.90$^{A}$ | 0.25$^{A}$ | 0.068$^{B}$ | 0.53$^{AB}$ | 34.44$^{B}$ |
| $I_3$ | $S_0$ | 50$^{B}$ | 66.67$^{A}$ | 50.33$^{B}$ | 104.50$^{B}$ | 22.77$^{AB}$ | 1.50$^{A}$ | 0.20$^{B}$ | 0.067$^{B}$ | 0.46$^{B}$ | 31.04$^{B}$ |
| | $S_1$ | 62.5$^{AB}$ | 76.00$^{A}$ | 60.00$^{AB}$ | 148.00$^{AB}$ | 25.80$^{AB}$ | 1.93$^{A}$ | 0.20$^{B}$ | 0.072$^{B}$ | 0.55$^{A}$ | 29.40$^{BC}$ |
| | $S_2$ | 87.5$^{A}$ | 87.67$^{A}$ | 50.67$^{B}$ | 161.67$^{A}$ | 27.90$^{AB}$ | 2.10$^{A}$ | 0.20$^{B}$ | 0.060$^{c}$ | 0.56$^{A}$ | 31.83$^{B}$ |
| | $S_3$ | 75$^{AB}$ | 81.33$^{A}$ | 63.00$^{AB}$ | 150.67$^{AB}$ | 26.73$^{AB}$ | 2.03$^{A}$ | 0.18$^{B}$ | 0.060$^{C}$ | 0.50$^{B}$ | 29.08$^{C}$ |

***Offshoot height***

Results showed that there was no significant difference between applying 100% Etc compared with applying 80% and 60% Etc on the offshoot height (Table 3). Increase in offshoot height was due to application of superabsorbent. Applying 40, 80 and 120 g of superabsorbent led to a 22.65, 33.90 and 32.69% increase in offshoot height, respectively (Table 4). The maximum offshoot height observed when 80 and 120 g of superabsorbent was used. However, there was no significant difference between application of 80 and 120 g of superabsorbent with 100 and 80% ETc. On the other hand, application of 80 and 120 g of superabsorbent under 60% Etc affected offshoot height. Application of 80 g of superabsorbent with 80 and 100% Etc led to a 32% increase in offshoot height in comparison with control (Table 5). With increase in superabsorbent content from S0 to S3 a 33% increase in offshoot height was observed, however, the offshoots height didn't significantly differ with either application of 80 or 120 g of superabsorbent (Table 3).

***The number of leaflets per leaf***

There was no significant difference in number of leaflets upon application of 60, 80 or 100% ETc (Table 3). A significant difference was observed between application of 60 and 100% ETc. A 16% decrease in number of leaflets was observed by application of 60% Etc (Table 3). Application of superabsorbent significantly affected the number of leaflets. However, no significant difference was observed between application of 40, 80 and 120 g superabsorbent (Table 4).

***Length of the leaflet***

There was no significant difference between length of the leaflet by application of 60, 80 and 100% Etc. Moreover, no significant differences were observed among applications of 0, 40, 80 and 120 g superabsorbent (Table 4).

***Width of the leaflet***

There was no significant difference in width of the leaflets between application of 60, 80 and 100% ETc. In addition, there was no significant difference between the width of leaflets among application of 40, 80 and 120 g of superabsorbent (Table 4). Based on the obtained results, the highest width of the leaflet (2.13 cm) was observed at 100% ETc irrigation and 120 g polymer.

***Nitrogen concentration in the leaflets***

There was no significant difference in nitrogen concentration of the leaflets between applying 60, 80 and 100% Etc (Table 3). Superabsorbent also didn't significantly affect the concentration of nitrogen in leaflets (Table 4).

***Phosphorous concentration in the leaflets***

There was no significant difference in phosphorous concentration of the leaflets by applying 60, 80 and 100% Etc (Table 3). Application of superabsorbent resulted in a significant increase in phosphorous concentration of the leaflets. However, the effect of applying 80 g of superabsorbent was not significantly different from application of 40 g superabsorbent in regard of phosphorous concentration of leaflets (Table 4). Based on results, the highest phosphorus concentration of leaflets (0.082) obtained at 80% ETc irrigation and using 40 g polymer.

***Potassium concentration in the leaflets***

There was no significant difference in potassium concentration of the leaflets between applying 60, 80 and 100% ETc (Table 3). Application of superabsorbent didn't significantly affect potassium concentration in the leaflets (Table 4). The results showed that the highest potassium concentration in the leaflets (0.056) obtained at 60% ETc irrigation and by applying 80 g polymer. However, there is no significant difference between application of 80 g superabsorbent and 60% ETc.

***Superoxide dismutase (SOD)***

The analysis of variance showed that superabsorbent had a significant effect on SOD. 100% ETc and deficit irrigation had also significant effects on SOD. The maximum (41.24) and minimum (25.37) SOD activities were obtained under 80% and 100% ETc, respectively (Table 3). A 62% increase in SOD observed in comparison to 100% ETC. Application of 40 or 80g superabsorbent resulted in an increase in SOD, however, there was no significant different among these treatments (Table 4). The maximum (35.32) and minimum (29.14) SOD is related to 80 and 120 g superabsorbent, respectively (Table 3). Application of 80 gr superabsorbent resulted in a 12% raise in SOD in comparison with $S_0$. 60% ETc resulted in 62% increase in SOD in comparison with 100% ETc. Results showed that, the highest (45.03) and the lowest (23.90) SOD activities were detected in 80% ETc with 40 g superabsorbent and also 100% ETc with 80 g superabsorbent, respectively (Table 5).

## Discussion

***Establishment percentage and vegetative growth***

Based on the obtained data from present study it was revealed that increase in superabsorbent content resulted in an increase in the percentage of seedling establishment. On the other hand, as water deficiency increased, the percent of seedling establishment diminished. Concomitant application of severe drought stress with a low amount of superabsorbent cannot lead to rescue from stress condition and result in drying leaf and offshoots. In comparison, the scenario of medium drought with high contents of superabsorbent is a promising strategy to rescue medium drought stress. In this regard, it was reported that, application of superabsorbent resulted in increase in yield of forage maize (Karimi and Naderi, 2007). It was also reported that, using superabsorbent resulted in improvement of all agronomic traits and chlorophyll content but it was not affected the weight of a thousand grain. In addition, cell growth is one of the most drought-sensitive physiological processes, because drought stress directly results in the reduction of cell turgid pressure (Taiz and Zeiger, 2006). In addition, reduced biomass production in plant species have been reported (Ashrafi, et al., 2018).

***Trunk perimeter and Offshoot height***

The superabsorbent had a significant effect on the seedling trunk perimeter. This study revealed that application of the superabsorbent result in increase in offshoots perimeter and height. Using high contents of superabsorbent and medium irrigation provided appropriate condition for plant growth and resulted in increased trunk perimeter in date palm offshoots. As water deficit increased, a reduction in trunk perimeter observed. In this regard, Abedi and Asadkazemi reported that, irrigation regime significantly affected shoot diameter. In addition, it was shown that, application of 4 g/kg superabsorbent A200 resulted in a 33% decrease in irrigation requirement than that of plants under the control condition (Abedi-Koupai and Asadkazemi, 2006). It was reported that water stress reduced stem diameter, while application of zeolite and selenium increased stem diameter which is due to improved water and nutrition availability (Zahedi 2011). Application of superabsorbent resulted in an increase in height of offshoots. Using 80 g superabsorbent with 80% and 100% Etc resulted in a 32% increase in the height of offshoots in comparison with the control. Keshavarz et al. reported that drought stress had a significant effect on plant height (Keshavarzet al., 2012). The positive effect of superabsorbent on stem elongation could result from the high potential of superabsorbent to absorb water and preserve water in the soil (Boman and Evans, 1991). Furthermore, the positive effect of superabsorbent on stem elongation is reported (Brar et al., 2001). Reduction in water supply has shown to cause a decrease in cell elongation (Yang et al., 2006). Drought stress reduces plant height via reduction in cell growth (Yang et al., 2006). Cell growth is one of the most drought-sensitive physiological processes because it is so much related to turgor pressure (Taiz and Zeiger, 2006). Interruption of water flow from the xylem to the surrounding elongating cells, during water deficiency period can be considered as an inhibiting factor for cell elongation of higher plants (Nonami, 1998). It was reported that cell elongation reduced plant height, leaf area and crop growth under drought stress (Kaya et al., 2006). Sadeghipour and Aghaei (2012) found that in common bean, plant height was decreased by drought pressure and application of superabsorbent enhanced plant growth. Umebese et al., (2009) reported that the positive effect of superabsorbent on height of tomato stem was due to the capability of this compound to stimulate antioxidant activity that protects the plants from adverse effects of drought stress. It was also reported that, combined effects of irrigation management and humic acid application were significantly affected plant height, leaf area, and dry weight of Roselle. It was found that; water deficit reduced all morphological parameters, yield, and yield component indices. In addition, humic acid application remained positive effects on growth and yield indices of Roselle under water deficit conditions (Fallahi et al., 2016).

### *Vegetative growth of leaves and leaflets*

Number of leaflets per leave and length of the leaflet was not significantly affected by irrigation but applying superabsorbent significantly affected the number of leaflets. Based on the obtained results, as drought stress increased, leaf number and area decreased, in such a way that, leaf number and area was decreased as the intervals between watering was extended. Such a reduction in leaf number and area caused by water stress can be attributed to direct effect of drought on cell division (Ashraf et al., 1996). Agamy reported that, application of superabsorbent increased the number of leaves under stress conditions (Agamy et al., 2013). The positive effect of superabsorbent can be related to the increase in $CO_2$ assimilation, photosynthetic efficiency and increasing of mineral uptake in the stressed plant under SA application (Szepesi et al., 2005). Khan et al. (2003) reported that, application of superabsorbent increased leaf area in corn and soybean plants. It was also reported that, increase in amount of superabsorbent resulted in increase in the yield of forage maize (Karimi and Naderi, 2007). Moreover, studding the effects of irrigation regime on the length of above-ground parts of plant revealed the positive effect of applying superabsorbent on plant height. The application of 4 g/kg superabsorbent A200 could result in a 66% reduction in requirement of irrigation water in comparison to control (Abedi-Koupai and Asadkazemi, 2006).

### *Nitrogen, Phosphorous and Potassium concentration in the leaflets*

According to obtained results of present study, irrigation regime or application of superabsorbent polymer did not significantly affect nitrogen concentration. Irrigation regime did not also affect leaflet phosphorous content. However, phosphorus concentrations in the leaflets were affected by superabsorbent polymer. Potassium concentration was affected by neither irrigation water nor superabsorbent polymer. In this regard it has been reported that application of superabsorbent increases all agronomic traits and chlorophyll content (Karimi and Naderi, 2007). It was also argued that, the effect of exogenous superabsorbent is affected by the species, developmental stages of the plant, type and concentration of superabsorbent (Joseph et al., 2010). Superabsorbent affect synthesis of carotenoids, xanthophyll and the rate of de-epoxidation but decreased the level of chlorophyll pigments in wheat (Moharekar et al., 2003). Moreover, it was demonstrated that, superabsorbent increased the concentration of chlorophyll and carotenoid in maize (Khodary, 2004). Furthermore, application of superabsorbent may cause a temporary increase in induction of oxidative stress in plants, which can improve the anti-oxidative activity of the plants which induces the synthesis of protective compounds such as carotenoids (Hayat and Ahmad, 2007).

***Superoxide dismutase (SOD)***

Both irrigation regime and application of superabsorbent significantly affected SOD. SOD activity increased under the 80% deficit irrigation in comparison with the full-irrigated condition. However, The SOD activity decreased when date palms irrigated with 60% deficit irrigation. Previous research has shown that SOD plays an important role in scavenging harmful oxygen species (Larson, 1988; Burke and Mahan, 1991); and altered the activity of antioxidant enzymes when plants were subjected to stress. Among all the irrigated conditions such as 100, 80 and 60%, the highest and the lowest SOD activities were obtained by application of 40 and 80 g superabsorbent, respectively. It was reported that, increase in superabsorbent led to an increase in yield of forage maize (Karimi and Naderi, 2007). Abedi and Asadkazemi (2006) showed that irrigation regime can affect shoot diameter significantly. Multiple comparisons by Post Hoc least significant difference (LSD) test showed, 66% Etc significantly affected shoot diameter and led to a more increase in this trait in comparison to 33% ETc. In a related study, it was shown that applying 6 kg polymer increased shoot diameter significantly. However, there was no significant difference in shoot diameter between application of 4 and 6 g/kg superabsorbent with 66% ETc and control (100% ETc). Therefore, application of 4 g/kg superabsorbent A200 could result in 33% reduction in required irrigation water in comparison with the control (Abedi-Koupai and Asadkazemi, 2006). Previous researchers have shown that, water stress significantly decreased stem diameter, while application of zeolite and selenium resulted in increase in stem diameter. Increase in stem diameter can be related to improved water and nutrition availability provided by application of zeolite (Zahedi, 2011). It was demonstrated by Keshavarz et al. (2012) that, drought stress significantly affect plant height in such a way that increases in drought stress reduces plant height. In their study, the highest plant height (53.11cm) obtained in 100% FC and the lowest value (29 cm) was achieved in 40% FC (Keshavarz et al., 2012). It was also reported that, reduction of water supply caused a decrease in cell elongation (Yang et al., 2006). Furthermore, reduction in cell turgidity, cell growth, cell volume and the number of stem cells was shown to reduce plant height under drought stress (Yang et al., 2006). As well, reduction in length of internodes caused a reduction in plant height under drought (Yang et al., 2006). The positive effect of superabsorbent on stem elongation was also reported (Brar et al., 2001), which is supposed to be due to high potential of superabsorbent to preserve water content of the soil (Boman and Evans, 1991). Significant effect of irrigation regime on plant height was also reported. Growth indices were significantly different between 66% and 33% ETc. In agreement with our results, it was reported that applying 6 g/kg superabsorbent resulted in the maximum plant height. However, application of 4 and 6 g/kg with 66% Etc was not significantly different from control plants (100% ETc). This suggests that applying 4 g/kg superabsorbent A200 leads to a 33% reduction in water requirement in comparison to control (Abedi-Koupai and Asadkazemi, 2006), this is in agreement with results of previous study that has shown a sharp increase in yield of forage maize through using super absorbent (Karimi and Naderi, 2007). A significant correlation between droughts and 3-way interactions of drought level, SA and the variety have been observed in the amounts of catalase (CAT) and guaiacol peroxidase (GPX) activities. Increasing irrigation intervals, significantly enhanced carotenoids content, total protein, APX and CAT, in Rasha cultivar, in such a way that these parameters were higher in Rasha compared with the Bidane sefid cultivar. Moreover, applying exogenous SA as a potential growth regulator was shown to result in improving water stress tolerance in grapevine (Abbaspour and Babaee, 2017).

According to the result of current study, application of superabsorbent in all irrigation regimes resulted in a significant increase in establishment percentage. Application of 40, 80 and 120 g superabsorbent in date palm offshoot resulted in a 16, 47 and 41% increase in establishment percentage compared to the control. Therefore, applying superabsorbent under drought stress conditions positively affect establishment of seedling and enhance agronomic traits. Therefore, because of water scarcity and cultivation of date palm in arid zones, the application of superabsorbent can be a promising approach for increasing accessible water in root zone in order to improve production of the date palm and decreasing the cost of production. Superabsorbent can preserve soil water content and improve plant growth and yield in dry zones. According to results obtained in the current study, application of superabsorbent in all irrigation regimes including 100, 80 and 60% ETc evaporation from the class A pan (normal irrigation, mild stress, and severe stress, respectively) significantly increased percentage of seedling establishment. Application of 40, 80 and 120 g of superabsorbent respectively increased establishment percentage of date palm seedling to 16, 47 and 41%, more than control and also improved agronomic traits.

Therefore, due to the water resource constraint and also cultivation of date palm in arid zones, the superabsorbent application could increase the efficiency of available water sources by preserving them in soil texture and thus enhancing the production of the date palm and decreasing the cost of production. Plants respond to drought stress through alterations in physiological and biochemical processes. The results showed that the activity of SOD increased under the 80% irrigation compared to full-irrigated condition. The SOD activity was lower in the extreme water deficit than in the full-irrigated water.

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