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NEUTRALIZATION OF DROUGHT STRESS AND IMPROVING GROWTH, WATER STATUS, YIELD AND QUALITY OF JERUSALEM ARTICHOKE (*Helianthus tuberosus* L.) USING COMPOST, HUMIC ACID AND SUPERABSORBENT POLYMER

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ABSTRACT

Drought is the most serious problem in agriculture wide world, especially in arid and semiarid regions. Application of soil conditioners could increase water retention and decrease leaching of water and fertilizers from the soil. This study was conducted on Jerusalem artichoke (JA) cv. Fuseau in Baramoon Research Station, Dakahlia Governorate, Egypt during the growing seasons of 2013-2014. Two irrigation regimes (10 and 20 days' intervals starting after 1^{st} irrigation) in combination with compost, humic acid and superabsorbent polymer (SAP) were evaluated to increase irrigation efficiency under drought stress.

The vegetative growth parameters, water status, marketable and total tuber yield, dry matter production, inulin yield, nitrogen and proline contents and water use efficiency of JA plants were investigated. Under drought stress (irrigation at 20 days), all the studied parameters except for leaf water deficit, proline content and water use efficiency (WUE) tend to decrease in both seasons. Dual application of SAP with compost or humic acid led to significant increases in all studied criteria, compared to check or other treatments.

Under normal irrigation period (10 days' intervals), all tested criteria were found to be significant, especially at application of compost as soil amendments, in both seasons. Additionally, incorporating SAP dually with compost or humic acid under deficient irrigation water improved WUE and decreased water requirement by 50%. Also, the tuber yield and physiological quality characters were found to be equivalent to the control treatment under normal irrigation conditions. This in turn encourages such amendments to reduce water consumption.

Keywords: Water stress, Sun-choke, organic, polymers, leaf water deficit, K-humate

INTRODUCTION

The herbaceous Jerusalem artichoke (JA)(*Helianthus tuberosus* L.) is an underutilized crop that originated in the temperate regions of North America. This plant shows strong stress tolerance with high yield potential, so it can be grown in a wide range of environments (Pimsean *et al*., 2010), compared with other inulin producing crops such as root chicory (*Chicorium intybus* var. *sativum*) and globe artichoke (*Cynara cardunculus* var. *scolymus*), which have a rather limited production range in the temperate regions or high altitude areas (Burke, 2005; Robert *et al*., 2007). JA stores inulin in stems and tubers, which can be used as raw material for supplementing various value-added and health food products (Roberfroid, 2000). Its protein has high food value due to the presence of almost all essential amino acids in good balance (Rakhimov *et al*., 2003). So this "potato for the poor" plant has been consumed as vegetable and livestock feed. Additionally, it is used in various purposes, such as fructose production and pharmaceuticals aspects (Saengthongpinit and Sajjaanantakul, 2005; Kays and Nottingham, 2008; Ma *et al*., 2011). In the last decades JA also has been considered as a biomass crop for ethanol production (Denoroy, 1996).

JA is a C_3 warm-season crop characterized by high tolerances to drought and salinity (Gao *et al*., 2011). The plant consumes 556 mm of irrigation water to produce 11.3 ton ha^{-1} of tuber dry matter (Losavio *et al*., 1997; Ma *et al*., 2011). Water is becoming scarce in the quantity and the quality not only in arid and drought prone areas, but also in regions where rainfall is abundant. The sustainable uses of water-resource conservation, environmental friendliness, appropriateness of technologies, economic viability and social acceptability of development issues have therefore priorities for agriculture in water-scarce regions (Oweis and Hachum, 2003). However, in such situations, like that exist in Egypt, drought stress is one of the most important environmental limitations affecting the plant growth and productivity (Tamer, 2014). Moreover, increasing concern over the effects of climate change on water resources requires that water should be used more effectively in irrigated agriculture to increase and sustain productivity. In crop production, instead of achieving maximum yield from a unit area by full irrigation, water productivity can be optimized within the concept of deficit irrigation (Fereres and Soriano, 2007; Geerts and Raes, 2009). Certainly, JA was considered as more hardy against drought, but some studies have indicated it is sensitive to water stress. Under drought condition, the height, LAI and tuber weight will all be influenced (Denoroy, 1996).

When considering a watering regime for a crop, it is wise to understand the sensitive growth stages for water stress, and the water requirements of the crop, in order to achieve maximum yield and maintaining adequate soil moisture conditions during moisture sensitive stages of growth, so irrigation water may be saved during certain growth stages without affecting yield. Applying accurate managements and advanced techniques to improve soil water capacity is of effective procedures to increase irrigation efficiency. This could be achieved by organic fertilizers, artificial and plant mulch, development of vegetation and/or applying ameliorative materials like humate and polymers (Tolk *et al*., 1999).

Superabsorbent polymers (SAR) are made of hydrocarbon. These materials absorb water several hundreds or even more than a thousand times more that their weight and lose it gradually in dry conditions (Fazeli Rostampour, 2013), and has repeatedly absorbing function (Sabbagh *et al*., 2015), thus, soil remains moist for a long time without renewed-irrigation requirement (Mehri *et al*., 2013). Polymers are environmentally clean and do not have any poisonous and deleterious impacts on soil. They finally decompose to CO_2, water and ammonium and potassium ions (Fazeli Rostampour *et al*., 2012). Also, superabsorbent can cause improvement in physical traits of soil, prevention from soil erosion and nutrient leaching and they also enhance quality of gravity water (Shainberg *et al*., 2003).

Humic acid is resistance to soil moisture deficient and has been considerable an economic and efficient in drought-prone areas, where appropriate management practices to reduce water losses are needed (Pereira and Shock, 2006). Besides, humic acid has number of potential benefits for plants, e.g. increases nutrient holding capacity; enhances solubility of phosphorus, zinc, iron, manganese, and copper; increases resistance to soil pH change; improves soil aggregation; enlarges root system and stimulates of plant-growth (Bryan and Stark, 2003; Mikkelsen, 2005).

Maintenance of sufficient levels of organic matter in soil is prerequisite for sustainable and high yield of JA (Kays and Nottingham, 2008). The effect of organic matter was no doubt in part due to the higher level of nutrients available in the soil at the onset and throughout the growing season. Tuber yields of JA in the high-organic-matter plots were double or greater than those of the other treatments. Likewise, in the high-organic-matter soil, there was a substantial shift in the size distribution of the tubers. Larger, faster-growing plants produced substantially larger tubers (Fernandez *et al*., 1988). Depletion of nutrients and poor organic matter contents of Egyptian soils can be replenished by applying rice straw compost to these soils. Use of rice straw compost as an organic fertilizer, might be play a vital role not only in improving soil physical condition and water holding capacity but also in improving the plant nutrients (Esawy *et al*., 2009).

The aim of the present investigation was to improve water use efficiency of JA grown under drought stress conditions, without reverse effect on growth, quality and yield of JA, in this respect compost, humic acid and superabsorbent polymer were also applied.

MATERIALS AND METHODS

1. Plant materials and growth conditions:

The experiments were conducted with Jerusalem artichoke (JA) cv. Fuseau at Baramoon Research Station, Mansoura, Dakahlia Governorate, Egypt (latitude 30°11′ N, longitude 28° 26′ E and altitude +7 m above sea level), during seasons of 2013 and 2014. Analyses of the soil are presented in Table 1 a & b (Page, 1982; El-Hady and El-Sherif, 1988). Air temperatures during the growing periods are presented in Fig. 1. The source of this data is Agric. Res. Center, Central Management of Agriculture Guideline, Bulletin of agricultural meteorological data.

Table 1: Analytical data of El-Baramoon Research Station clay loam soil (a) Mechanical and chemical analysis.

Physical properties	Value		Chemical Properties	Value	
	2013	2014		2013	2014
Sand (%)	26.8	27.2	pH value	7.8	8.1
Silt (%)	32.5	31.8	EC $dSm^{-}1$(in soil paste)	0.8	0.9
Clay (%)	40.7	41.0	Total N (%)	0.04	0.03
Texture class	Clay-loam	Clay-loam	Available P (ppm)	11.8	11.2
$CaCO_3$	3.0	3.1	Available K (ppm)	306	295
Organic matter (%)	1.4	1.2			

(b) Hydrophysical analysis.

Constants depth (cm)	Saturation percentage S. (%)		Field capacity (%)		Wilting point (%)		Available water (%)	
	2013	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**
0-15	80.3	80.5	40.0	40.1	16.4	16.4	18.6	19.2
15-30	81.7	81.4	40.5	40.7	16.7	16.6	19.2	19.3
30-45	82.8	82.4	41.3	41.2	16.9	16.8	20.1	20.0

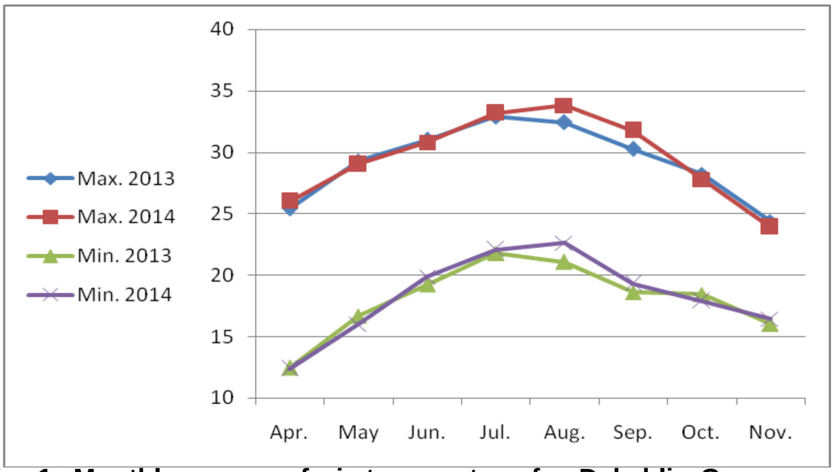

Fig. 1: Monthly means of air temperature for Dakahlia Governorate in 2013 and 2014 seasons.

2. Experimental arrangement, Treatments and Crop management

A split plot design based on randomized complete blocks design with three replicates was used. Two irrigation regimes (every 10 or 20 days' intervals starting after 1st irrigation) were assigned to main plots. The irrigation numbers were totally 17 and 9 times, respectively. The sub-plots were devoted to three effective procedures that increase irrigation efficiency including compost, humic acid and superabsorbent polymer (SAP) alone or combined with others as well as check treatment. Each experimental sub-plot consisted of three rows. Each row was 6 m long and 1 m width. Sprouted seed tubers were planted at hills 50 cm apart on one side of the ridges. Whole tubers within the weight range of 20 to 25 g each were sown on April 7th in both seasons. Irrigation treatments were applied after the first irrigation which was 10 days after planting.

The rice straw compost was prepared according to the methods of El-Hammady et al., (2003) and El-Shatoury (2006). Some properties of the used compost were determined by using standard methods described by AOAC (1990). Rice straw compost was added (7 ton fed^{-1}) to the soil and left two weeks before planting. The compost is a fine-textured, with 25.3% organic matter, N 1.2%, C/N ratio 18.6 and pH 6.9. Extractable P and K levels in the average 2-yr trial were 0.18 and 0.86 %, respectively.

Soluble humic acid as potassium-humate (80% humic acid, 11-13% K_2O) was used after diluted 1: 100 beside JA plants. Humic acid were dissolved in tap water to make a liquid humic acid solution and added at the rate of 200 ml plant^{-1} before 1st irrigation.

The SAP used was a corn starch-based cationic cross-linked copolymer of acrylamide and potassium acrylate manufactured in the Ins. Agric. Facilities and Equipment, Jiangsu Acad, Agric. Sci. (Nanjing, China). The SAP is a fine white powder with 0.2 mm in particle size, 0.7 g m^{-3} bulk density, 9 x 10^4 % water holding capacity and 4.5 dSm^{-1} E.C. The SAP was applied beside the plant at the rate of 20 ml with 1st irrigation. The polymer gel was prepared as 85 g/3.78 L of water. The mixture was stirred frequently to maintain suspension of the gel.

Nitrogen (ammonium nitrate 33.5% N), phosphorus (mono-superphosphate 15.5% P_2O_5) and potassium (potassium sulphate 48% K_2O) were applied in the rates of 90 + 45 + 75 kg fed^{-1}, respectively. Nitrogen fertilizer was added at three equal doses, i.e., the first after emergence, and then the second and third doses were applied with 2nd and 3rd irrigation. Moreover, calcium superphosphate was thoroughly mixed within the upper soil layer (0-25 cm) before planting. Potassium was added at two times, one half was added with the second addition of N-fertilizer, and the second half was added with the third doses of N-fertilizer.

The other agricultural practices were carried out according to the recommendation of Ministry of Agriculture.

3. Data and measurements

I. Vegetative growth characters:

A random sample of three plants from each experimental plot was taken at flower initiation stage (at 120 days after planting) to estimate shoot fresh weight and convert to shoot dry weights/plant (g). Leaf area/plant was recorded according to Koller (1972). Chlorophyll contents were determined by A Minolta SPAD chlorophyll Meter (Yadava, 1986). The SPAD readings were made on young leaves with fully expanded blades in the upper part of the main stem of the plants.

II. Water status of the plant:

(a) Leaf total water content (TWC) of the leaves: it was registered after 2 days of the 11rd and 7rd irrigation of both water regimes using the following equation:

TWC% = (wet weight - dry weight)/wet weight x 100 (1)

(b) Relative transpiration rate (RTR): it was measured by taking a fixed area (100 cm^2) of the leaves and an equal water surface in glass dishes; the samples were left at 30 °C for 6 h period and then measured the loss weight from each, using the following equation to calculate the relative transpiration:

RTR% = (weight of water loss from plant leaves/weight of water loss from water surface) x 100 (2)

(c) Leaf water deficit (LWD): it was estimated by weighing a plants leaves taken randomly at the early morning (wet weight); then placed on the surface of distilled water for 1 h until saturated and then weighed again (saturated weight); then dried in oven and weighed (dry weight). The LWD was calculated as follows:

LWD% = (saturated weight - wet weight) / (saturated weight - dry weight) x 100 (3). (Schlemmer et al., 2005)

III. Marketable & total tuber yield:

At harvest time, 180 days after planting, the total tuber yield/feddan (ton) was recorded. Marketable yield/feddan was recorded using good shapes healthy tubers more than or equal 40 g.

IV. Tuber quality & chemical composition:

Percentage of tuber dry matter (calculated by drying 100 grams of fresh tubers in oven at 70^{o} C tills a constant weight). Inulin content was determined in tubers according to the method of Winton and Winton (1958). The tuber samples were oven-dried at 70^{o} C and ground. Tissue analyses were performed by Kjeldahl for nitrogen content. Proline content in fresh tuber was determined by ninhydrin assay at A_{520} nm according to the method of Bates et al. (1973).

V. Water use efficiency (WUE)

It was calculated according to equation of Begg and Turner (1976) as follows:

Water use efficiency=Yield (kg fed^{-1})/Water quantity(m^{3} fed^{-1}) = kg m^{-3} (4)

Water consumptive use computed as the difference in the soil moisture content before and after irrigation according to the following equation by Israelson and Hansen (1962):

$$Cu = D \times Bd \times 4200 \times (\theta 2 - \theta 1)/100 \quad (5),$$

where Cu is the water consumptive use m fed^{-3}, D is the soil depth, Bd is the soil bulk density (g cm^{-3}), θ1 is the soil moisture content before irrigation (% by weight), θ2 is the soil moisture content after irrigation or after 48 hours (% by weight). Seasonal applied water is the sum of the figures computed for each irrigation application.

4. Statistical analysis

Data were analyzed using analysis of variance technique and the differences between individual pairs of treatment means were compared using Duncan Multiple Range Test at 5% according to Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

1. Vegetative growth:

The differences in growth and biomass of JA plants over two seasons of study may be related to higher temperature (Fig.1) and improved light conditions during the vegetative growth phase (Kays and Nottingham, 2008). The soil chemical, physical and hydrophysical properties were slightly different among experimental years (Table 1a, b). The soil in the first season was higher in total N, available phosphorus (P) and exchangeable potassium (K) than in the second season. The chemical properties indicated that soil fertility was lower than optimum conditions for production of Jerusalem artichoke. EC values in both years were lower than 4 dS m^{-1}, indicating that the soil was not saline.

The interaction effect between water regimes and soil amendments, had significant differences on shoot dry weight, leaf area and chlorophyll index of JA plant, in both seasons (Table 2). Application of compost exhibited significant positive effects on shoot biomass under normal irrigation (10 days' intervals) compared with other treatments.

Reducing the irrigation intervals from 20 d to 10 d led to a significant increase in all vegetative growth parameters. These increases could be due to the fact that the more availability of water, the more availability of nutrient, which improves nitrogen and other macro- and micro-elements absorption as well as enhancing the production and translocation of the dry matter content from source to tubers (Kays and Nottingham, 2008). On the other side, water stress causes losses in tissue water content (Table 2), which reduce turgor pressure in cell, thereby inhibiting enlargement and division of cell causing of reduce of plant growth and dry mass accumulation (Delfine *et al*., 2002).

When water regimes were kept constant, soil amendments had a significant effect on biomass characters. Dual application of compost and superabsorbent polymer (SAP) exhibited significant positive effects on the previous parameters compared with other both treatments (Table 2). The beneficial effect of compost on growth characteristics may be due to improving the soil structure conditions, which encouraged the plant to have a good root development by improving soil water holding capacity and this permitted favorable plant supply with water and nutrients which in turn, increases the amount of plant biomass produced (Esawy *et al*., 2009). Super absorbents absorb water hundreds times of its own weight and being converted to long lasting gels, have a special place in agriculture, landscaping, erosion control and desert reduction (Sabbagh *et al*., 2015). The addition of superabsorbent polymers can increase soil's water holding capacity with delaying water stress in plants and providing a buffer against the product loss during the time between two irrigations, which in turn reflects on biomass accumulation (Johnson and Leah, 1990).

2. Water status:

Irrigation intervals and soil conditioners had a significant effect on water status of JA plants (Table 2). The interaction effect of irrigation at 10 d and incorporating SAP dually with compost or humic acid on leaf total water content (TWC) was significant. Accordingly, under normal irrigation, the highest TWC (84.88 and 84.10 %, in both seasons, respectively) was observed by applying SAP with compost. The lowest TWC (80.72 and 79.68 %) was obtained by control treatment (without soil amendments) under drought stress. The relative transpiration rate (RTR) significantly increased (0.202 and 0.198%) with control treatment under normal irrigation (10 d intervals). The highest leaf water deficit (LWD) (24.12 and 23.92 %) was obtained from the interaction of control under drought stress. Due to reduction in the amount of irrigation, leaf TWC reduces (Fazeli Rostampour *et al*., 2012). By increasing in the amount of superabsorbent in soil, amount of leaf TWC rises (Mao *et al*., 2011).

t-2

In both seasons, results in Table 2 indicated that water stress significantly affected on TWC, RTR and LWD. There was an increase in TWC and RTR and a decrease in LWD in leaves of JA plants under normal irrigation as compared to drought stress. However, Dual application of SAP with compost or humic acid had the highest values on TWR and the lowest on RTR and LWD, in comparison with other treatments (Table 2).

The TWC has been reported as an important indicator of water stress in leaves which is directly related to soil water content. This indicated greater resistance to water flow at the soil-root interface or decreased hydraulic conductivity of soil at low soil moisture (Fazeli Rostampour and Ghamari, 2014). Water stress inhibits cell enlargement more than cell division. It reduces plant growth by affecting various physiological and biochemical processes, such as photosynthesis, respiration, translocation, ion uptake, carbohydrates, nutrient metabolism and growth promoters (Jaleel *et al*., 2008; Farooq *et al*., 2008). In addition, Ranney *et al*. (1991) proved that with osmotic adjustment mechanism, there is lowering osmotic potential of the cells and hence participates in maintaining of full turger of tissue under water stress conductions. Osmotic adjustment is an active accumulation of solutes within the plant in response to decrease in soil water potential, thus reducing the harmful effects of water deficit. Under stressed conditions cell membranes are subject to changes often associated with the increase in the cell permeability (Iqbal, 2009). Bai *et al*. (2010) found that soil moisture increased by 6.2-32.8% with SAP application, while soil bulk density was reduced by 5.5-9.4% relative to the control, especially with a moderate water deficit when the relative soil moisture contents were about 40-50%, which it turns reflect on plant water relationships. Moreover, SAP have a good properties for decreasing bulk density and increasing soil porosity and hydraulic conductivity (Zhang *et al*., 2010). Since, Water-absorbing polymers, which are classified as hydrogels when cross-linked (Kabiri, 2003), absorb aqueous solutions through hydrogen bonding with water molecules.

3. Marketable and total tuber yield:

The interaction effect between water regimes and soil amendments had significant effects on total and marketable tuber yield of JA plants (Table 3). Highest tuber yield and marketable yield being 24.620 and 23.478 ton fed^{-1}, respectively, in 1st season was obtained from sole application of compost and dual application of compost with SAP and being 23.718 and 22.693 ton fed^{-1}, respectively, in 2nd season under normal irrigation. Tuber size grade over 40 g appeared to respond to water regimes and soil amendments (data not shown) in a similar manner to total yield. Total tuber yield increase was due to primarily the increase in tuber size in larger grade and decrease of the small grade.

Data in Table 3 also reveal significant differences in tuber and marketable yields among the various treatments under drought stress, in both seasons. However, under these conditions, application of soil conditioners (SAP dually with compost or humic acid), total tuber and marketable yields were found to be equivalent to the control treatment under normal irrigation conditions. Meaning that such treatments were neutralized the negative stress of drought. Dual application of SAP with compost or humic acid gave the highest values, in this respect, in comparison with other treatments (Table 3).

There was obvious relationship between JA plant survival and the various treatments (Fig. 2a, b and c). Since, irrigated plants that are more susceptible to *Sclerotium* stem and tuber rot diseases caused by causative pathogens of *Sclerotinia sclerotiorum* and *Rhizoctonia solani* (Ezzat *et al*., 2015), especially when incorporation of some materials that increase the retention of the soil water. So, it is better to minimize the amount of water, especially in the presence soil conditioner.

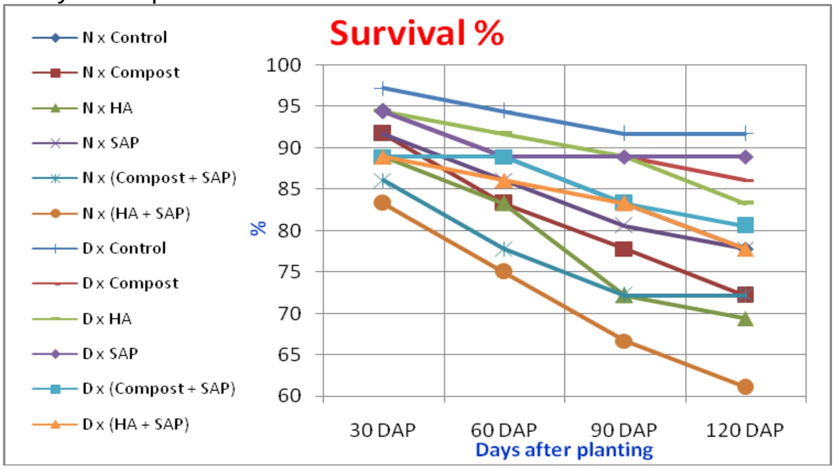

Fig. 2 a: Survival percentage of Jerusalem artichoke plants at different periods as affected by compost, humic acid and superabsorbent polymer under irrigation and drought stress in (average two seasons of study); N: Normal irrigation at 10 days intervals, D: Drought stress, i.e., irrigation at 20 days intervals

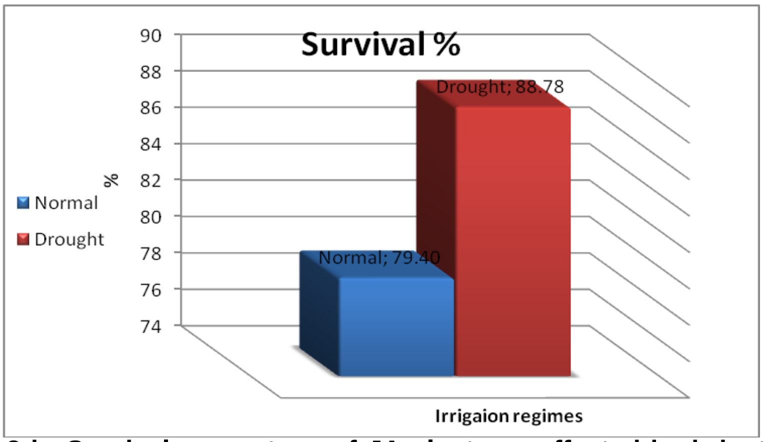

Fig. 2 b: Survival percentage of JA plants as affected by irrigation regimes (average two seasons).

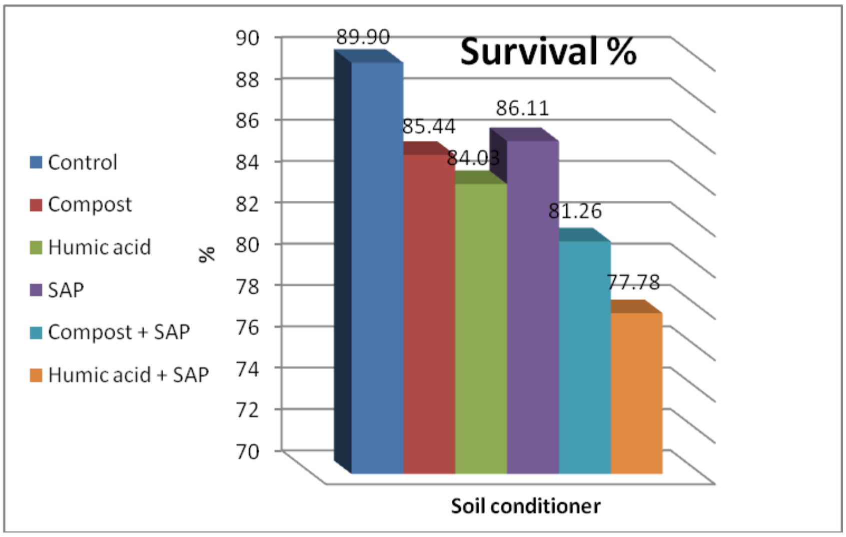

Fig. 2 c: Survival percentage of JA plants as affected by soil conditioner treatments (average two seasons).

Many crops are considered to be relatively resistant to drought, although, to achieve optimum growth or yield, sufficient water for irrigation is required (Denoroy, 1996; Gao *et al*., 2011). In general, water stress will influence nutrient uptake by roots and transport from roots to shoots, due to restricted transpiration rates and membrane permeability (Wien, 1997). Water stress is one of the most important limitations to photosynthesis and then plant productivity (Tezara *et al*., 2005). In this study, it is shown that water can influence growth and yield of JA too (Tables 2 and 3).

It is apparent that yield and its attributes were reduced due to affected by draught condition (Table 3). When water regimes were kept constant, soil amendments had significant effects on total tuber yield and marketable yield, in both seasons. Dual application of SAP with compost or humic acid gave the highest values, in this respect, in comparison with other treatments (Table 3).

There were significant difference between irrigation and no irrigation and the height and weight (including leaf, stem, root and tuber) can be significantly reduced without irrigation. So irrigation is necessary to obtain optimum yield (Gao *et al*., 2011). The increase in tuber yield and marketable yield may be due to the increase water content and porosity as well as acceptable pH and EC levels under the combined effect of SAP and compost (Ruqin *et al*., 2015).

In this regard, Conde *et al*. (1988) reported that good yield and maximum water use efficiency of JA could be achieved under half stressed for all period of growth (542 mm of irrigation water). Furthermore, Neri *et al*. (2002) evaluated the restoration of 100 % ET to the only supplemental irrigation, to study the effect of very little irrigation on JA. They found that biomass and sugar yields were increased in the aerial parts compared to the non-irrigated treatment. Mastro *et al*. (2004) found that the higher water supply always induced an increase in tuber yield of JA; on the other hand, in the years characterized by wet spring seasons, an increased water supply negatively affected sugar yield, due to the lower accumulation capacity in storage organs. Yang *et al*. (2010) reported that the best amount of total irrigation water of JA was 340 mm. In corn plants, Khadem *et al*. (2010) found that grain and biological yield increased by using animal manure and superabsorbent polymer together as maximum yield grain was obtained by using 65% animal manure and 35% superabsorbent polymer. Improved plant development, nutrient uptake, and yield following SAP addition in this study were partly due to the direct and indirect effects of improved water conditions in the soil characterized by low water-buffering capacity, where water availability is a key factor in determining agricultural productivity (Rodionov *et al*., 2012). The added SAP was also reported to function as a nutrient (mainly N and K) absorption enhancer and enhance dry matter accumulation, besides the positive effects on water retention (Liu *et al*., 2013).

4. Dry matter production and inulin yield:

The interaction between water regime and soil conditioners had significant effects on D.M. % production and inulin yield (Table 3). The D. M. production (6.1 and 5.5 ton fed^{-1}) and inulin yield (3.6 and 3.3 ton fed^{-1}) in both seasons, respectively increased with application of compost under normal irrigation. Tuber D.M. production and percentage, and inulin yield and content were reduced when the stress situation was induced. The quality of JA plants that subjected to drought stress were negatively affected (Table 3). However, the data clearly revealed that sole application of compost or with SAP gave the best results of D.M. and inulin content (Table 3).

Water stress reduced leaf TWC, chlorophyll index CI and tuber yield. Reduction in leaf TWC leads to decrease in stomatal conductivity and CO_2 availability and finally the quantity of plant photosynthesis. The later results in lack of optimum leaf area development and dry matter accumulation per leaf area. Combination of these factors cause decrease in leaf area duration and net photosynthesis quantity at critical stage of tuberization, consequently increase in amount of assimilates remobilization at this period (Wien, 1997). In the present study, compost and superabsorbent improved leaf TWC and CI (Table 2) which led to a higher assimilate accumulation in vegetative organs and thus reduced the quantity and portion of assimilates remobilization in tuber yield, especially under draught stress. Similar results were obtained by Fazeli Rostampour and Ghamari, 2014. These results are also in accordance with those reported by Losavio *et al*., 1997.

5. Water use efficiency:

The interaction between water regime and material that reducing water consumption was significant for water use efficiency WUE (Table 4). The lowest values of WUE were recorded for control under both water regimes. WUE in both seasons depended largely on water regime, in which the highest WUE was observed for drought stress and the lowest WUE was recorded for normal irrigation. Application of SAP with compost or humic acid improved WUE.

t-3

In general, the cultivars with high yield potential under optimum conditions had acceptable yield under stressed environments, but, under a particular environmental stress, cultivars with high potential had lower yield than certain cultivars with lower yield potential (Blum, 2005). Therefore, high yield potential and low yield reduction under water stressed conditions are important for sustaining yield under drought. In JA, water application of 50% of ET caused yield reductions by 50% (Losavio *et al*., 1997), and, therefore, drought caused higher water use efficiency (Janket *et al*., 2013).

6. Nitrogen and Proline content:

The results presented in Table 4 show significant depressions in N content in JA tuber as a result of drought conditions. Irrigation increased nitrogen content. This could be due to more NPK uptake from the soil with normal irrigation. When irrigation regimes kept constant, incorporating of SAP with compost and humic acid had the highest effect on nitrogen content in comparison with check or other treatments, in both seasons of study. Dual application of compost and SAP (1^{st} season) and compost only (2^{nd} season) under normal irrigation had a significant effect on nitrogen content.

Organic fertilizers contain not only the various nutrients that crops need, but also release these nutrients gradually in step with the changing demand of developing crop. The compost ratio affected the total and available N, P, and K content and the mineralization rates in the substrate. In general, as more compost was included in the substrate, the quantity of available N, P, and K increased along with the mineralization rate (Kays and Nottingham, 2008; Esawy*et al*., 2009). Liu *et al*. (2013) found that SAP could be used as a nutrient absorption enhancer (mainly N and K) in forest container seedlings, aside from being a water absorbent material.

It is obvious from Table 4 that there is a remarkable increase in leaf proline content under drought condition when compared with irrigated plants. Proline not only acts as an osmolyte but also contributes in stabilizing subcellular structures (e.g. membranes and proteins), scavenging free radicals, and buffering cellular redox potential under stress conditions (Iqbal, 2009). Furthermore, Pedersen *et al*. (1996) reported that there was a positive correlation between proline concentration and membrane integrity of tobacco leaves and proline believed to stabilize membrane phospholipids which helps the plants to overcome periods of drought stress.

Concerning effects of soil conditioners, results in Table 4 indicate that these treatments caused a significant reduction in proline content compared to control plants in both seasons. The highest depression was recorded with the application of SAP with humic acid or compost. Generally, the application of our substances with drought significantly decreased proline concentration compared to untreated plants. These compounds are thought to play a pivotal role in plant cytoplasmic osmotic adjustment in response to osmotic stress. These results confirm those reported by Safarnejad (2008). The interaction effect of water regimes and soil conditioner had significant effect on leaf proline, compost alone or with SAP were the most effective treatments (Table 4).

t-4

It can be concluded that dual application of superabsorbent polymer and compost or humic acid helped improving water status of Jerusalem artichoke plants exposed to drought stress conditions and subsequently improved drought tolerance. Compost, humic acid and polymers can be applied before an expected drought period for improving drought tolerance of Jerusalem artichoke plants. Using these substrates in combination with other technological tools, such as e.g., the application of drip irrigation, can minimize the problems of water shortage with particular emphasis on sustainable resource management and environmental protection. Under the conditions of our study application of superabsorbent (85 g/3.78 L of water) and/or compost (7 ton fed^{-1}) is recommended.

REFERENCES

AOAC. 1990. Association of Official Analytical Chemists. Official Methods of Analysis. 15^{th} Ed. Washington, DC, USA.

Bai, W.; H. Zhang; B. Liu; Y. Wu and J. Q. Song. 2010. Effects of super-absorbent polymers on the physical and chemical properties of soil following different wetting and drying cycles. 26 (3): 253-260.

Bates, L. S.; R. P. Waldren and I. D. Teare. 1973. Rapid determination of free proline for water-stress studies. Plant and Soil, 39: 205-207.

Begg, J. E. and N. C. Turner. 1976. Crop water deficits. Advances in Agron., 28, pp.189.

Blum, A. 2005. Drought resistance, water-use efficiency, and yield potential-are they compatible, dissonant, or mutually exclusive? Aust. J. Agi. Res., 56:1159-1168.

Bryan, H. and J. Stark. 2003. Humic acid effects on potato response to phosphorus. Idaho Potato Conference, USA, January 22-23,5 pp.,pp. 59-64.

Burke, D. 2005. The Complete Burke's Backyard: The Ultimate Book of Fact Sheets. Kay Scariett, Australia.

Conde, J. R.; J. L. Tenorio; B. Rodriguez-Maribona; R. Lansac and L. Eyerbe. 1988. Effect of water stress on tuber and biomass productivity. In: G. Grassi and G. Gosse (Eds.) Jerusalem artichoke. Commission of the European Communities, Luxemburg, Report, EUR 11855

Delfine, S.; R. Tognettir; F. Loreto and A. Alvino. 2002. Physiological and growth responses to water stress in field grown bell pepper (*Capsicum annuum* L.). J. Hort. Sci. Biotechnol., 77 (6): 697-704.

Denoroy, P. 1996. The crop physiology of *Helianthus tuberosus* L.: A model oriented view. Biomass Bioenerg., 11(1): 11-32.

El-Hady, O. A. and A. F. El-Sherif. 1988. Egyptian bentonitic deposits as soil amendments. II. Hydro-physical characteristics and mechanical strength of sandy soils treated with bentonites. Egypt. J. Soil Sci., 28: 215–33.

El-Hammady, A. M.; A. F. Abo–Hadid; Sh. M. Selim; H. I. El–Kassas and R. Negm. 2003. Production of compost from rice straw using different accelerating amendments. J. Environ. Sci. Ain Shams University, 6 (3): 112-116.

El-Shatoury, S. A. 2006. Enhancement of rice straw composting by *Lignocellulolytic Actinomycete* strains.Eur. J. Sci. Res., 14 (4): 473-479.

Esawy, M.; M. Ibrahim; P. Robin; N. Akkal-Corfini and M. El-Saka. 2009. Rice straw composting and its effect on soil properties. Compost Sci. Utilization, 17 (3): 146-150.

Ezzat, A. S; K. M. Ghoneem; W. I. A. Saber, and A. A. Al-Askar. 2015. Control of wilt, stalk and tuber rots diseases using arbuscular mycorrhizal fungi, *Trichoderma* species and hydroquinone enhances yield, quality and storability of Jerusalem artichoke (*Helianthus tuberosus* L.). Egyptian Journal of Biological Pest Control, 25 (1):11-22.

Farooq, M.; S. M. A. Basra; A. Wahid; Z. A. Cheema; M. A. Cheema and A. Khaliq. 2008. Physiological role of exogenously applied glycinebetaine in improving drought tolerance of fine grain aromatic rice (*Oryza sativa* L.). J. Agr. Crop Sci., 194: 325–333.

Fazeli Rostampour, M. 2013. The effect of irrigation regimes and polymer on several physiological traits of forage sorghum. Asian J. Agric. Food Sci., 1 (5): 274-280.

Fazeli Rostampour, M. and M. Ghamari, 2014. The effects of water deficit and polymer on some physiological traits in corn (*Zea mays* L.). Ent. App. Sci. Let., 1 (2): 31-39.

Fazeli Rostampour, M.; M. Yarnia; K. R. Farokhzadeh; M. J. Seghatoleslami and G. R. Moosavi. 2012. Effect of superab A200 and drought stress on dry matter yield in forage sorghum. Amer. Eur. J. Agric. Environ. Sci., 12: 231-236.

Fernandez, J.; M. D. Curt and M. Martinez. 1988. Productivity of several Jerusalem artichoke (*Helianthus tuberosus* L.) clones in Soria (Spain) for two consecutive years (1987 and 1988). *In*: Gosse, G. and Grassi, G., (eds.). Topinambour (Jerusalem artichoke). Report EUR 13405, Commission of the European Communities (CEC). Luxembourg, pp. 61–66.

Fereres, E. and M. A. Soriano. 2007. Deficit irrigation for reducing agricultural water use. J. Exp. Bot., 58(2): 147-159.

Gao, K.; T. Zhu and G. Han. 2011. Water and nitrogen interactively increased the biomass production of Jerusalem artichoke (*Helianthus tuberosus* L.) in semi-arid area. African J. Biotech., 10 (34): 6466-6472.

Geerts, S. and D. Raes. 2009. Deficit irrigation as an on-farm strategy to maximize crop water productivity in dry areas. Agric. Water Manag., 96: 1275–1284.

Israelson, O. W. and V. E. Hansen. 1962. Irrigation Principles and Practices. 3^{rd} Ed., John Willey and Sons, lnc, New York.

Iqbal, S. 2009. Physiology of wheat (*Triticum aestivum* L.) accessions and the role of phytohormones under water stress. Ph.D. Thesis, Fac. Biological Sci., Quaid-i-azam Univ., Islamabad, pp. 83–154.

Jaleel, C. A.; R. Gopi; B. Sankar; M. Gomathinayagam and R. Panneerselvam. 2008. Differential responses in water use efficiency in two varieties of *Catharanthus roseus* under drought stress. Comptes rendus Biologies, 331: 42–47

Janket, A.; S. Jogloy1; N. Vorasoot; T. Kesmala; C. C. Holbrook and A. Patanothai. 2013. Genetic diversity of water use efficiency in Jerusalem artichoke (*Helianthus tuberosus* L.) germplasm. Australian J. Crop Sci., 7(11):1670-1681.

Johnson, M. S. and R. T. Leah, 1990. Effects of superabsorbent polyacrylamides on efficiency of water use by crop seedlings. J. Sci. Food Agric., 52: 431-434.

Kabiri, K. 2003. Synthesis of fast-swelling superabsorbent hydrogels: effect of crosslinker type and concentration on porosity and absorption rate. Eur. Polymer J., 39 (7): 1341-1348.

Kays, S. J. and S. F. Nottingham. 2008. Biology and Chemistry of Jerusalem artichoke (*Helianthus tuberosus* L.). CPC Press, Taylor & Francis Group, 487 pp.

Khadem, S. A.; M. Galavi; M. Ramrodi; S. R. Mousavi; M. J. Rousta and P. Rezvani-moghadam. 2010. Effect of animal manure and superabsorbent polymer on corn leaf relative water content, cell membrane stability and leaf chlorophyll content under dry condition. Australian J. Crop Sci., 4 (8): 642-647.

Koller, H. R. 1972. Leaf area-leaf weight relationships in the soybean canopy. Crop Sci., 12 (3/4): 180-183.

Liu, F. C.; H. L. Ma; S. J. Xing; Z. Y. Du; B. Y. Ma and D. W. Jing. 2013. Effects of super-absorbent polymer on dry matter accumulation and nutrient uptake of *Pinus pinaster* container seedlings. J. Forest Res., 18 (3): 220-227.

Losavio, N.; N. Lamascese and A. V. Vonella. 1997. Water requirements and nitrogen fertilization in Jerusalem artichoke (*Helianthus tuberosus* L.) grown under Mediterranean conditions. Acta Hort., 449:205–209

Ma, X. Y.; L. H. Zhang; H. B. Shao; G. Xu; F. Zhang; F. T. Ni and M. Brestic. 2011. Jerusalem artichoke (*Helianthus tuberosus*), a medicinal salt-resistant plant has high adaptability and multiple-use values. J. Medicinal Plants Res., 5 (8): 1272-1279.

Mao, S.; M. R. Islam; X. Xue; X. Yang; X. Zhao and Y. Hu. 2011. Evaluation of a water-saving superabsorbent polymer for corn (*Zea mays* L.) production in arid regions of Northern China. African J. Agric. Res., 6 (17): 4108-4115.

Mastro, G. D.; G. Manolio and V. Marzi. 2004. Jerusalem Artichoke (*Helianthus tuberosus* L.) and Chicory (*Cichorium intybus* L.): Potential crops for inulin production in the Mediterranean area. Acta Hort., 629: 365: 374.

Mehri, S.; M. Fazeli Rostampoor and M. H. Ansari. 2013. The effect of different levels of superabsorbent on efficiency of the photosynthetic matter the remobilization and portion of remobilization in seed yield of corn (*Zea mays* L.) under drought stress. Ann. Biol.Res.,4 (1): 170-176.

Mikkelsen, R. L. 2005. Humic materials for agriculture. Better Crops, 89 (3): 6-10.

Neri, U.; P. Scandella; R. Lauciani and G. Mecella. 2002. Yielding results of two year period on a Jerusalem artichoke crop as a function of low input irrigation and of the utilization type (aerial part and tubers). Rivista di Agronomia, 36 (3): 221-225.

Oweis, T. and A. Hachum. 2003. A: Improving water productivity in the dry areas of West Asia and North Africa. *In*: Water Productivity in Agriculture: Limits and opportunities for Improvement. Edited by: Kijne J. W., Barker R., Molden D. J. Wallingford, UK: CABI; 2003:179-198.

Page, A. L. 1982. Methods of Soil Analysis. 2nd Ed., Part 1, Soil Sci. Soc. Amer., Madison, Wisc., USA.

Pedersen, A. L.; H. C. Feldner and L. Rosendahl. 1996. Effect of proline on nitrogenase activity in symb0iosomes from root nodules of soybean (*Glycine max* L.) subjected to drought stress. J. Exp. Bot., 47 (303): 533–1539.

Pereira, A. B. and C. C. Shock. 2006. Development of irrigation best management practices for potato from a research perspective in the United States. Sakia. Org e-publish, 1: 1-20.

Pimsean, W.; S. Jogloy; B. Suriharn; T. Kesmala; V. Pensuk and A. Patanothai. 2010. Genotype by environment (G×E) interactions for yield components of Jerusalem artichoke (*Helianthus tuberosus* L.). Asian J. Plant Sci., 9: 11–19.

Rakhimov, D. A.; A. O. Arifkhodzhaev; L. G. Mezhlumyan; O. M. Yuldashev; U. A. Rozikova; N. Aikhodzhaeva, and M. M. Vakil. 2003. Carbohydrates and proteins from *Helianthus tuberosus*. Chem. Nat. Comp., 39 (3): 312-313.

Ranney, T. G.; N. L. Bassuk and T. H. Whilow. 1991. Osmotic adjustment and solute constituents in leaves and roots of water-stressed cherry pruns tress. J. Am. Soc. Hort. Sci., 116 (4): 648-688.

Roberfroid, M. B. 2000. Prebiotics and probiotics: are they functional food? American Am. J. Clin. Nutr., 71:1682-1687.

Robert F.; C. Barnes; N. Jerry; K. J. Moore and C. Michael. 2007. Forages: The science of grassland agriculture. Blackwell publishing, Iowa.

Rodionov, A.; S. Nii-Annang; O. Bens; M. Trimborn; S. Schillem; B. U. Schneider; T. Raab; and R. F. 2012. Impacts of soil additives on crop yield and C-sequestration in post mine substrates of Lusatia, Germany. Pedosphere. 22: 343–350.

Ruqin, F.; J. Luo; S. Yan; Y. Zhou and Z. Zhang. 2015. Effects of biochar and super absorbent polymer on substrate properties and water spinach growth. Pedosphere, 25(5): 737-748.

Sabbagh, E.; J. Daneshian; S. S. Zadeh; S. K. S. S. Abadi and H. R. Fanaei. 2015. Influence of super absorbent, drought stress and nitrogen fertilizer on some characteristic of *Trachyspermum ammi*. Biological Forum - An International Journal, 7 (1): 1023-1029.

Saengthongpinit, W. and T. Sajjaanantakul. 2005. Influence of harvest time and forage temperature on characteristics of inulin from Jerusalem artichoke (*Helianthus tuberosus* L.) tubers. Postharvest Biol. Technol., 37: 93-100.

Safarnejad, A. 2008. Morphological and biochemical responses to osmotic stress in alfalfa (*Medicago sativa* L.). Pak. J.Bot., 40: 735-746.

Schlemmer, M. R.; D. D. Francis; J. F. Shanahan and J. S. Schepers. 2005. Remotely measuring chlorophyll content in corn leaves with differing nitrogen levels and relative water content. Agron. J., 97: 106-112.

Shainberg, I.; A. I. Mamedov and G. J. Levy. 2003. The role of wetting role and rain energy in seal formation and infiltration and erosion. J. Soil Sci., 194: 301-307.

Snedecor, G. W. and W. G. Cochran. 1989. Statistical Methods, 8th ed. 2nd Printing. Lowa State Univ. Press, Ame, USA.

Tamer, A. N. 2014. Drought condition and management strategies in Egypt. Egyptian Meteorological Authority. 10 p.

Tezara, W.; O. Marín; E. Rengifo; D. Martínez and A. Herrera. 2005. Photosynthesis and photoinhibition in two xerophytic shrubs during drought. Photosynthetica, 43(1): 37-45.

Tolk, J. A.; T. A. Howell and S.R. Evett. 1999. Effect of mulch, irrigation, and soil type on water use and yield of maize. Soil and Tillage Research, 50 (2): 137-147.

Wien, H. 1997. Physiology of Vegetable Crops. Department of Fruit and Vegetable Science, College of Agriculture and Life Sciences, Cornell University, USA

Winton, A. L. and K. B. Winton. 1958. The Analysis of Foods. John Wiley and Sons. Inc. London. 857 p.

Yadava, U. L. 1986. A rapid and non-destructive method to determine chlorophyll in intact leaves. HortSci., 21: 1449-1450.

Yang, B.; Z. Heng-jia; L. You-xian and X. Yan-ling. 2010. Effects of different irrigation on development and water use efficiency of Jerusalem artichoke. J. Irrigation and Drainage, 2010-04.

Zhang, W.; H. Bai; B. Liu; Y. Wu and J. Song. 2010. Effects of super-absorbent polymers on the physical and chemical properties of soil following different wetting and drying cycles. Soil Use and Management, 26: 253–260.

تحييد إجهاد الجفاف وتحسين النمو والحالة المائية والمحصول والجودة لنباتات الطرطوفة باستخدام إضافات الكمبوست والأحماض الدبالية والبوليمرات

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يمثل إجهاد الجفاف المشكلة الأكثر أهمية للزراعة في المناطق الجافة والشبه جافة في جميع أنحاء العالم. تطبيق استخدام بعض المواد في التربة مثل مهيئات التربة يمكن أن تزيد من قدرة احتفاظ التربة بالماء وتقليل الرشح من المياه والأسمدة. لذلك أجريت هذه الدراسة على نبات الطرطوفة صنف فيوزا في أرض طميية طينية بالمزرعة البحثية بالبرامون، محطة بحوث البساتين بالمنصورة - محافظة الدقهلية خلال موسمي النمو ٢٠١٣-٢٠١٤م بغرض دراسة نظامين من فترات الري وهما: الري كل ١٠ أيام (ظروف الري العادية)، والري كل ٢٠ يوم (ظروف إجهادات الجفاف) تبدأ بعد الرية الأولي، واستخدمت مواد فعالة تزيد من كفاءة استخدام مياه الري وتشمل: إضافات الكمبوست، الأحماض الدبالية والبوليمرات المحبة للماء بصورة منفردة أو مجتمعة بالإضافة إلي معاملة الكنترول (بدون إضافات) بالإضافة إلي التفاعل بينهما (انظمة الري ومهيئات التربة) . استخدم تصميم القطع المنشقة مرة واحدة في ثلاث مكررات، حيث وزرعت معاملات الري علي القطع الرئيسية بينما اشتملت القطع الشقية علي المواد التي تزيد من كفاءة استخدام المياه.

تم تسجيل البيانات التالية لقياسات النمو الخضري، الحالة المائية، المحصول الكلي والمحصول القابل للتسويق من الدرنات، نسبة المادة الجافة ومحصول المادة الجافة، نسبة الإنيولين والمحصول من الإنيولين، المحتوي من النيتروجين والحامض الأميني البرولين وأخيرا كفاءة استخدام المياه.

اظهرت معاملة إجهاد الجفاف (الري كل ٢٠ يوما) وجود نقص معنوي في جميع الصفات محل الدراسة باستثناء النقص المائي في الورقة (LWD)، محتوي البرولين وكفاءة استخدام المياه (WUE) في كلا الموسمين. أدى تطبيق استخدام البوليمرات SAP مع الكمبوست أو الأحماض الدبالية إلى زيادات كبيرة في جميع الصفات المدروسة، مقارنة بالمعاملات الأخرى.

أوضحت معاملات التفاعل بين فترات المياه والمواد التي تزيد من كفاءة استخدام المياه وجود فروق معنوية كبيرة علي جميع الصفات محل الدراسة علي نبات الطرطوفة. أفضل النتائج التي تحققت كانت مع معاملة الري العادي (كل ١٠ يوم) مع تطبيق استخدام الكمبوست كمحسنات للتربة تحت ظروف هذه الدراسة في كلا الموسمين.

أظهرت النتائج أيضا أن تطبيق استخدام البوليمرات المحبة للمياه SAP والكمبوست أو الأحماض الدبالية في ظل ظروف اجهادات الجفاف أدت إلي زيادة كفاءة استخدام مياه الري WUE وتقليل الاحتياجات المائية لنبات الطرطوفة بقدر ٥٠٪ وتحقيق محصول وصفات جودة فسيولوجية من الدرنات تعادل معاملة الكنترول (بدون إضافات) تحت ظروف الري العادي.

Table 2: Vegetative growth and water status of Jerusalem artichoke plants as affected by compost, humic acid and superabsorbent polymer under irrigation and drought stress in 2013 and 2014 seasons.

Treatments		Shoot dry weight/plant (g)		Leaf area/plant (m^2)		Chlorophyll index (CI) (SPAD)		Leaf total water content (TWC) (%)		Relative transpiration rate (RTR) (%)		Leaf water deficit (LWD) (%)	
Irrigation	Soil conditioners	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**
Irrigation frequency (10 days)	Control	583.10 cd	528.86 e	3.60 c	3.50 de	33.18 e	34.00 cd	82.32 bcd	82.00 b-e	0.202 a	0.198 a	22.94 bc	22.14 bc
	Compost	622.42 a	618.37 a	3.82 a	3.70 a	42.20 a	38.82 ab	83.86 ab	83.80 abc	0.191 bcd	0.184 bcd	19.65 e	19.06 fg
	Humic acid (HA)	616.31 a	590.60 b	3.80 ab	3.67 ab	40.80 ab	40.10 a	83.60 abc	83.50 abc	0.188 cde	0.180 cde	20.36 e	20.11 ef
	SAP*	592.22 bc	548.30 d	3.63 c	3.52 cde	34.52 de	34.11 cd	82.40 bcd	82.40 a-d	0.196 abc	0.193 ab	21.46 d	20.70 de
	Compost + SAP*	613.78 a	580.17 bc	3.75 ab	3.60 bc	38.40 bc	36.36 bc	84.88 a	84.10 a	0.174 fgh	0.154 f	18.38 f	18.96 g
	HA + SAP*	608.22 ab	571.30 c	3.72 b	3.59 bcd	36.62 cd	36.08 bc	84.62 a	84.02 ab	0.170 gh	0.150 fg	19.45 ef	17.83 h
Drought stress (20 days)	Control	501.18 h	430.82 j	3.30 f	3.10 i	28.00 g	26.30 g	80.72 d	79.68 f	0.201 ab	0.195 ab	24.12 a	23.92 a
	Compost	540.11 fg	470.50 h	3.42 e	3.32 j	29.20 fg	28.10 fg	81.18 d	81.00 def	0.180 efg	0.169 e	23.41 ab	22.71 bc
	Humic acid (HA)	527.70 g	450.36 i	3.38 ef	3.20 h	28.80 fg	26.00 g	81.10 d	80.65 def	0.182 def	0.176 de	23.76 ab	22.63 bc
	SAP*	553.32 ef	490.76 g	3.51 d	3.40 fg	31.78 ef	30.20 ef	80.90 d	80.08 ef	0.193 abc	0.191 abc	23.87 ab	22.96 ab
	Compost + SAP*	579.32 cd	526.28 ef	3.60 c	3.48 ef	33.10 e	33.80 cd	82.00 bcd	82.00 b-e	0.165 h	0.144 fg	21.86 cd	21.93 bc
	HA + SAP*	565.16 de	508.12 fg	3.55 cd	3.40 fg	32.80 e	32.40 de	81.94 cd	81.86 cde	0.154 i	0.142 g	22.82 bc	21.78 cd
Normal		606.01 A	572.93 A	3.72 A	3.60 A	37.62 A	36.58 A	83.61 A	83.30 A	0.187 A	0.177 A	20.37 B	19.80 B
Draught		544.47 B	479.47 B	3.46 B	3.32 B	30.61 B	29.45 B	81.34 B	80.87 B	0.179 B	0.170 B	23.31 A	22.66 A
	Control	542.14 D	479.84 D	3.45 D	3.30 D	30.59 C	30.15 C	81.52 B	80.84 C	0.202 A	0.197 A	23.53 A	23.03 A
	Compost	581.27 BC	544.44 AB	3.62 ABC	3.51 AB	35.70 A	33.46 AB	82.63 AB	82.40 AB	0.186 B	0.176 B	21.53 CD	20.89 BC
	Humic acid (HA)	572.01 C	520.48 C	3.59 BC	3.44 C	34.80 AB	33.05 AB	82.35 AB	82.08 ABC	0.185 B	0.178 B	22.06 BC	21.54 B
	SAP*	572.77 C	519.53 C	3.57 C	3.46 BC	33.15 B	32.16 BC	81.65 B	81.24 BC	0.195 A	0.192 A	22.67 B	21.67 B
	Compost + SAP*	596.55 A	553.23 A	3.68 A	3.54 A	35.75 A	35.08 A	83.44 A	83.05 A	0.170 C	0.149 C	20.12 D	20.45 CD
	HA + SAP*	586.69 AB	539.71 B	3.64 AB	3.50 ABC	34.71 AB	34.24 AB	83.26 A	82.94 A	0.162 D	0.146 C	21.14 D	19.81 D

Means of each column for every separate factor and interaction followed with the same letters are not significantly different according to Duncan multiple range test at the probability of 0.05 levels

***SAP: Superabsorbent polymer**

Table 3: Marketable and total tuber yield, dry matter production and inulin yield of Jerusalem artichoke tubers as affected by compost, humic acid and superabsorbent polymer under irrigation and drought stress in 2013 and 2014 seasons.

Treatments		Total tuber yield (ton fed.$^{-1}$)		Tuber dry matter (ton fed.$^{-1}$)		Tuber dry matter (%)		Inulin in tubers (ton fed.$^{-1}$)		Inulin in tubers mg g^{-1}D.W.		Marketable yield (ton fed.$^{-1}$)	
Irrigation	Soil conditioners	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Irrigation frequency (10 days)	Control	20.532 de	20.230 de	4.606 def	4.478 e	22.43 cd	22.13 cde	2.834 de	2.782 cde	13.80 c	13.75 de	18.345 de	18.126 de
	Compost	24.620 a	23.122 ab	6.062 a	5.504 a	24.62 a	23.80 a	3.604 a	3.330 a	14.64 a	14.40 a	23.478 a	21.997 ab
	Humic acid (HA)	23.376 ab	21.211 bcd	5.724 ab	4.977 c	24.48 a	23.46 a	3.414 ab	3.012 abc	14.60 ab	14.20 ab	22.309 ab	19.861 cd
	SAP*	20.760 cde	20.530 cde	4.739 de	4.706 d	22.82 c	22.92 b	2.870 de	2.911 bcd	13.82 c	14.18 b	19.244 cde	19.122 cde
	Compost + SAP*	22.742 abc	23.718 a	5.414 bc	5.345 b	23.80 b	22.53 bc	3.254 bc	3.339 a	14.30 b	14.08 bc	20.609 bc	22.693 a
	HA + SAP*	21.508 bcd	22.618 abc	5.062 cd	5.041 c	23.53 b	22.28 cd	2.991 cd	3.144 ab	13.90 c	13.90 cd	20.202 bcd	20.491 bc
Drought stress (20 days)	Control	12.361 h	11.226 h	2.636 i	2.296 j	21.30 g	20.46 i	1.538 i	1.417 h	12.42 f	12.62 h	10.118 g	10.210 g
	Compost	17.557 fg	19.682 de	3.870 gh	4.155 f	22.03 ef	21.10 gh	2.255 gh	2.578 ef	12.84 e	13.10 g	15.371 f	17.336 e
	Humic acid (HA)	15.626 g	14.217 g	3.404 h	2.963 i	21.78 f	20.82 hi	1.978 h	1.820 g	12.65 ef	12.80 h	14.380 f	13.196 f
	SAP*	18.810 ef	16.375 fg	4.160 fg	3.491 h	22.11 def	21.30 fg	2.427 fg	2.194 f	12.90 e	13.40 f	17.843 e	15.260 ef
	Compost + SAP*	20.428 de	20.100 de	4.577 def	4.426 e	22.40 de	22.00 de	2.820 de	2.754 cde	13.80 c	13.70 de	18.310 de	18.228 de
	HA + SAP*	19.836 de	18.640 ef	4.430 ef	4.059 g	22.33 de	21.76 ef	2.663 ef	2.544 de	13.42 d	13.65 e	18.265 de	17.532 e
Normal		22.256 A	21.904 A	5.268 A	5.009 A	23.61 A	22.85 A	3.16 A	3.09 A	14.18 A	14.09 A	20.698 A	20.382 A
Draught		17.436 B	16.707 B	3.846 B	3.565 B	21.99 B	21.24 B	2.28 B	2.22 B	13.01 B	13.21 B	15.720 B	15.315 B
	Control	16.447 D	15.728 C	3.621 C	3.387 C	21.87 D	21.30 C	2.19 C	2.10 C	13.11 D	13.19 C	14.232 B	14.168 C
	Compost	21.089 AB	21.402 A	4.966 A	4.830 A	23.33 A	22.45 A	2.93 A	2.95 A	13.74 B	13.75 A	19.425 A	19.732 A
	Humic acid (HA)	19.501 C	17.714 B	4.564 B	3.970 B	23.13 AB	22.14 AB	2.70 B	2.42 B	13.63 B	13.50 B	18.361 A	16.529 B
	SAP*	19.785 BC	18.453 B	4.449 B	4.099 B	22.47 C	22.11 B	2.65 B	2.55 B	13.36 C	13.79 A	18.544 A	17.191 B
	Compost + SAP*	21.585 A	21.909 A	4.996 A	4.885 A	23.10 AB	22.27 AB	3.04 A	3.05 A	14.05 A	13.89 A	19.459 A	20.461 A
	HA + SAP*	20.672 ABC	20.629 A	4.746 AB	4.550 A	22.93 B	22.02 B	2.83 AB	2.85 A	13.66 B	13.78 A	19.234 A	19.012 A

Means of each column for every separate factor and interaction followed with the same letters are not significantly different according to Duncan multiple range test at the probability of 0.05 levels

***SAP: Superabsorbent polymer**

Table 4: Water use efficiency and nitrogen in tubers of Jerusalem artichoke tubers as affected by compost, humic acid and superabsorbent polymer under irrigation and drought stress in 2013 and 2014 seasons.

Treatments		Irrigation numbers		Water quantity at 1st irrigation (m^3 fed^{-1})		Total water quantity (m^3 fed^{-1})		Water use efficiency (ton $fed.^{-1}$)		Proline content (ug g^{-1} F.W. leaves)		Nitrogen content (g 100 g^{-1} D.W. tuber)	
Irrigation	**Soil conditioners**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**
Irrigation frequency (10 days)	Control	17	17	650	550	7551	7341	2.72 ^{gh}	2.76 ^{de}	16.3 ^{fg}	15.4 ^{f}	3.82 ^{e}	3.80 ^{c}
	Compost							3.26 ^{cd}	3.15 ^{cd}	11.6 ^{ij}	11.3 ^{gh}	4.06 ^{ab}	4.02 ^{a}
	Humic acid (HA)							3.10 ^{def}	2.89 ^{bcd}	13.2 ^{hi}	13.6 ^{fg}	3.96 ^{cd}	4.00 ^{a}
	SAP*							2.75 ^{fgh}	2.80 ^{cde}	14.1 ^{gh}	14.0 ^{fg}	3.90 ^{d}	3.96 ^{ab}
	Compost + SAP*							3.01 $^{d-g}$	3.23 ^{bc}	9.6 ^{jk}	8.5 ^{hi}	4.08 ^{a}	3.92 ^{b}
	HA + SAP*							2.85 ^{efg}	3.08 ^{bcd}	8.4 ^{k}	6.3 ^{i}	4.00 ^{bc}	3.90 ^{b}
Drought stress (20 days)	Control	9	9	650	550	4964	4774	2.49 ^{h}	2.35 ^{e}	45.4 ^{a}	44.6 ^{a}	3.48 ^{h}	3.42 ^{g}
	Compost							3.54 ^{bc}	4.12 ^{a}	30.8 ^{d}	29.8 ^{c}	3.76 ^{ef}	3.66 ^{e}
	Humic acid (HA)							3.15 ^{de}	2.98 ^{bcd}	38.4 ^{c}	37.6 ^{b}	3.65 ^{g}	3.50 ^{f}
	SAP*							3.79 ^{ab}	3.43 ^{b}	42.6 ^{b}	41.8 ^{ab}	3.52 ^{h}	3.72 ^{de}
	Compost + SAP*							4.12 ^{a}	4.21 ^{a}	23.6 ^{e}	24.2 ^{d}	3.80 ^{e}	3.80 ^{c}
	HA + SAP*							4.00 ^{a}	3.90 ^{a}	18.2 ^{f}	18.8 ^{e}	3.71 ^{fg}	3.78 ^{cd}
Normal		17		600		7446		2.95 ^{B}	2.98 ^{B}	12.20 ^{B}	11.52 ^{B}	3.97 ^{A}	3.93 ^{A}
Draught		9		600		4869		3.51 ^{A}	3.50 ^{A}	33.17 ^{A}	32.80 ^{A}	3.65 ^{B}	3.65 ^{B}
	Control	--	--	--	--	--	--	2.61 ^{D}	2.55 ^{C}	30.85 ^{A}	30.00 ^{A}	3.65 ^{D}	3.61 ^{C}
	Compost	--	--	--	--	--	--	3.40 ^{AB}	3.64 ^{A}	21.20 ^{C}	20.55 ^{BC}	3.91 ^{A}	3.84 ^{A}
	Humic acid (HA)	--	--	--	--	--	--	3.12 ^{C}	2.94 ^{B}	25.80 ^{B}	25.60 ^{AB}	3.80 ^{B}	3.75 ^{B}
	SAP*	--	--	--	--	--	--	3.27 ^{BC}	3.11 ^{B}	28.52 ^{AB}	27.90 ^{A}	3.71 ^{C}	3.84 ^{A}
	Compost + SAP*	--	--	--	--	--	--	3.56 ^{A}	3.72 ^{A}	16.60 ^{D}	16.35 ^{CD}	3.94 ^{A}	3.86 ^{A}
	HA + SAP*	--	--	--	--	--	--	3.42 ^{AB}	3.49 ^{A}	13.30 ^{D}	12.55 ^{D}	3.85 ^{B}	3.82 ^{A}

Means of each column for every separate factor and interaction followed with the same letters are not significantly different according to Duncan multiple range test at the probability of 0.05 levels

***SAP: Superabsorbent polymer**