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Effects of Super Absorbent Polymer A_{200} on the Growth, Yield and Some Physiological Responses in Sweet Pepper *(Capsicum Annuum L.)* Under Various Irrigation Regimes

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Abstract

Drought stress is one of the most important limitations of agricultural productions in arid and semi-arid regions including Iran. By applying some of the additives such as super absorbent polymers (SAP) we can achieve good planning for irrigation and optimize use of water resources as an important strategy in these regions. To investigate effects of various levels of SAP and irrigation intervals on quantity and quality properties of sweet pepper in greenhouse of Agriculture Faculty of Ilam University, an experiment was carried out in factorial layout based on complete random blocks design (CRBD) with three replications. The factors were five SAP (0, 0.2, 0.3, 0.4, 0.5 weight percent) and four irrigation levels (5, 7, 9, 11 days). Results of statistical analysis showed SAP, irrigation levels and their interactions had a significant effect on morphological, physiological and biological parameters of sweet pepper. By increasing irrigation intervals and drought stress, growth parameters, yield, chlorophyll and relative water content (RWC) of leaf were reduced and total soluble solids (TSS) electrolytes leakage and proline content increased. In this study, SAP application reduced prolonged irrigation effects on pepper by increasing growth rate, yield, leaf chlorophyll content and RWC and by reducing TSS, electrolyte leakage and proline accumulation. The results of this study showed that SAP can store and absorb considerable water and reduce negative effects of water shortage on plants.

Keywords: *Irrigation interval, Drought stress, Quality, Proline, Chlorophyll.*

1. Introduction

Among agricultural crops, vegetables belong to cash crop group. The important properties of this group are that the produced crops were supplied as final products in the market and capital return period of the products of this group is very short. Thus, the farmers are more inclined to plant this group of crops. On the other hand, vegetable crops are more sensitive to water shortage and any deficit in providing water requirement of plant leads to considerable reduction of yield (Sadreghaen et al. 2010). Pepper is an important vegetable from the family of Solanaceae, genus of Capsicum and annuum species. Based on the vitamin C in bell pepper, that has the highest amount after parsley, this product is very valuable in terms of increase in body strength and feeding physiology. It has been observed that pepper production is confined to warm and semi-arid countries where water is often a limiting factor for production, necessitating the need to optimize water management (Dorji *et al.*, 2005). Pepper has also been reported to be amongst the most susceptible horticultural plants to

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drought stress because of its wider range of transpiring leaf surface and high stomatal conductance (Alvino, *et al*., 1994) and having a shallow root system (Dimitrov and Ovtcharrow, 1995). The negative effects of soil moisture stress on both quantity and quality of pepper fruits have been reported in some studies (Abayomi *et al*., 2002; Dorji et al., 2005; Dimitrov and Ovtcharrow, 1995).

Iran has arid and hot climate and most of the regions are arid and semi-arid and its annual rainfall is low. In addition to low rainfall, its spatial and temporal distribution is very unsuitable as even the high rainfall areas of Iran need irrigation during summer. Thus, it is required to save water. On the other hand, one of the most important factors of costs in production and maintenance of plants is irrigation. One method of water conservation and reduction of irrigation costs is using SAP as soil improvement substances. SAPs are hydrogels that can absorb considerable amount of water, saltwater or physiological solutions. These polymers besides having high speed and capacity of water absorption also act as miniature water storage place and give water easily, if required. Optimizing use of water, fertilizer and chemical, avoiding the stresses of humidity fluctuations, can make plantation in arid regions and ramp levels possible, better aeration in the soil and increasing product return are the benefits of using agricultural SAP (Montazar, 2008).

The studies showed that using these SAP doesn't create any complications for human beings, plants, soil and environment. These substances absorb about 200 to 500 times as much water as their weight and after 5 to 12 years are gradually destroyed because of microbial disintegration or sun ray effect and are changed into some substances as water, carbon dioxide and ammonium (Poresmaiil et al., 2007).

Yazdani et al. (2007) reported that using SAP in drought stress and water shortage conditions can increase the yield of soybean and found that using adequate amount of SAP not only under irrigation conditions but also under water stress can compensate its purchase costs and gain profit and increase yield. Based on the results of Bers and Veston (1993), by adding 3gr per litre SAP to tomato cultivation bed, water storage capacity and nutrient elements are increased and washing amount of the elements is reduced. The yield and nutrient storage in greenhouse cucumber is increased by increasing SAP to cultivation bed, as by mixing 4 gm SAP in 1 kg soil, the highest yield is achieved and irrigation is reduced (Abedi Kopaii and Masferosh, 2007). Using SAP in the production of tomato increased the yield by 35% and facilitated the fruits ripening (El-Hadi and Camelia, 2004). Using SAP in sunflower in drought stress conditions reduced proline and increased RWC and chlorophyll (Nazarli et al., 2010). Khadem et al. (2010) showed that using SAP in drought stress conditions increased RWC of leaf, chlorophyll content and cytoplasm membrane stability in corn. Similarly the positive effect of SAP in reducing the bad effects of drought stress was reported in corn (Islam eta l. 2011) and sunflower (Nazarli et al. 2010).

Thus, based on positive properties of SAP, the objectives of this study was to evaluate the effects of applying SAP on pepper plant under drought stress conditions. Our specific objectives were: (1) The determination of the best amount of SAP application in soil, and (2) Determining the best irrigation interval for pepper with or without super absorbent.

2. Materials and Methods

2.1. Cultivation of Plants and Treatments

This study was carried out as factorial experiment in completely random blocks design (RCBD) with five levels of SAP A_{200} (0, 0.2, 0.3, 0.4, 0.5 weight percent) and four irrigation intervals (5, 7, 9, 11 days) in greenhouse of Agriculture Faculty of Ilam University in 2011. Each treatment was done in three replicates and each replicate consisted of three pots and each pot contained a pepper seedling. By considering factors level (treatment 5×4=20) and replication number (3) and the number of observations (3), 180 pots were used.

At first, to provide the seedling for experiment, pepper seeds were planted in bed of greenhouse. Irrigation operation was done for some days based on avoiding the dryness of bed and seeds daily. Weeding was done 2 or 3 times. After germination and emergence of true leaves, thinning operation and re-plantation were done in the second bed to produce strong seedlings and avoid photo competition between the seedlings. The pots (20×23×18) were filled with equal rations of garden soil, fine sand and aged animal manure (ratio 2:1:1) and 6 kg and then polymer dry matter in values 0, 2, 3, 4 and 5 g/kg soil (equal to 0, 0.2, 0.3, 0.4 and 0.5 weight percentage) were added and after being mixed, were poured into the pots. Among the produced seedlings, strong uniform seedlings were selected and two seedlings were planted in each pot. In the first week, to reduce drought stress and assure of the location of seedlings, the pots were irrigated each day. Irrigation treatment was done after the total establishment of seedlings and the selection of the best transplant. Irrigation operation was done each day in different levels 5, 7, 9, 11. During the experiment, from cultivation to harvest, cultivation cares included weeding, irrigation based on treatments schedule table, prevention of insects and usage of complementing chemical fertilizers.

2.2. Properties Measurement

2.2.1. Total Yield and the Number of Fruits

To measure total yield of each of the plant after fruits harvest, by a digital scale, the weights of fruits were registered in consecutive harvest. After estimation of the average yield of three plants of each replicate, the average yield of each plant was recorded. To calculate the number of fruits in the plant, the total number of harvested fruits of each plant was recorded and averaged for each replicate.

2.2.2. Fresh and Dry Weight of Root and Shoot, Diameter and Height of Stem

The measurement of dry and fresh weight of shoots and roots was done at the end of harvest. The fresh weight of shoot was recorded after the complete cut of plants from the soil surface by digital scale. To measure fresh weight of the root, it was weighed after washing. The shoots and roots were put in the oven at 70 ºC for 48 h and after weighing, their dry weight was recorded. The diameter (soil surface) and plant height were measured by caliper and ruler, respectively.

2.2.3. Total Soluble Solids (TSS) and Leaf Area

TSS of the fruit was measured by manual refractometer (ATC-IE, Atago of Japan). To measure the content of TSS of the fruit, a drop of juice was poured on refractometer prism and its number was read. Leaf area was measured by leaf area meter of completely developed leaves of each plant.

2.2.4. Photosynthetic Pigments

Photosynthetic pigments content was determined by taking fresh leaf samples (0.1 g) from young and fully developed leaves. The samples were homogenized with 5ml of acetone (80% v/v) using pestle and mortar and centrifuged at 3,000 rpm. The absorbance was measured with a UV/visible spectrophotometer at 663 and 645nm and chlorophyll contents were calculated using the equations proposed by Strain and Svec (1966) given below:

$$\mathbf{Ch.a = mg/g\ F.W = \{12.7(A_{663}) - 2.69(A_{645})\}}$$

$$\mathbf{Ch.b = \{22.9(A_{645}) - 4.68(A_{663})\}}$$

$$\mathbf{Ch.total = \{20.2(A_{645}) + 8.02(A_{663})\}}$$

2.2.5. Relative Water Content

Leaf discs (1 cm in diameter) from randomly chosen plants per replicate were taken from the middle portion of fully developed leaf. Discs were weighed (FW) and then immediately floated on distilled water for 5 hrs in the dark. Turgid weights (TW) of leaf discs were obtained after drying excess surface water with paper towels. Dry weights (DW) of discs were measured after drying at 75 ºC for 48 hrs. Relative water content (RWC) was calculated using the following formula (Korkmaz et al., 2010):

$$RWC = \left(\frac{FW - DW}{TW - DW}\right) \times 100$$

2.2.6. Electrolyte Leakage

In order to assess membrane permeability, electrolyte leakage was determined according to Korkmaz et al. (2010). Leaf discs (1cm in diameter) from randomly chosen plants per replicate were taken from the middle portion of fully developed leaf and washed with distilled water to remove surface contamination. The discs were placed in individual vials containing 10 ml of distilled water. After incubating the samples at room temperature on a shaker (150 rpm) for 24 h, the electrical conductivity (EC) of the bathing solution (EC1) was determined. The same samples were then placed in an autoclave at 121 ºC for 20 min and a second reading (EC2) was determined after cooling the solution to room temperature. The electrolyte leakage was calculated as EC1/EC2 and expressed as percent.

2.2.7. Proline Content Determination

Proline content was determined according to the method described by Bates et al. (1973). Fresh leaf material (0.5 g) was homogenized in 10 ml of 3% aqueous sulfosalicylic acid and the homogenate was centrifuged at 10,000 rpm. 2 milliliter of the supernatant was mixed with 2ml of acid ninhydrin and 2ml of glacial acetic acid in a test tube. The mixture was placed in a water bath for 1 hr at100 ºC. The reaction mixture was extracted with 4ml toluene and the chromophore containing toluene was aspirated, cooled to room temperature, and the absorbance was measured at 520nm with a UV/visible spectrophotometer. Appropriate proline standards were included for the calculation of proline in the samples.

2.3. Statistical Analysis

Data were analyzed for significant differences using a factorial analysis of variance with irrigation intervals and SAP levels as main factors. Statistical analysis was performed using SAS and MSTATC software programs and the means compared using the Duncans Multiple Range Test at $P<0.05$.

3. Results

The results of variance analysis (Table 1) showed that the effect of irrigation intervals and application of SAP on all the evaluated properties were significant at 1% probability. The interaction effects of irrigation intervals and SAP was significant ($P<0.01$) in total yield, the total number of fruits in the plant, electrolyte leakage and proline. The comparison of the average simple effects of irrigation interval on the studied attributes (Table 2) showed that by increasing irrigation interval and drought stress total yield, the number of fruits, plant height, stem diameter, leaf area, fresh and dry weight of root and shoot, chlorophyll, RWC of the leaf were reduced and electrolytes leakage, TSS and proline were increased. The highest total yield (262 g in plant), total number of fruits in plant (10), stem diameter (0.91 cm), plant height (31 cm), RWC (93 %), chlorophyll a (2.40 mg/g F.W), chlorophyll b (1.264 mg/g F.W), total chlorophyll (1.900 mg/g F.W), leaf area (24 cm^2), fresh weight of root (23 g), dry weight of root (7 g), shoot fresh weight (48g) and dry weight of shoot (11g) were obtained in irrigation interval every 5 days and highest electrolyte leakage (41%) and proline (27.174 µm/g F.W) were achieved in irrigation interval every 11 days.. The highest TSS (13%) was achieved in irrigation interval every 9 days and it didn’t have significant difference with11 day’s irrigation.

The comparison of the average of simple effects of SAP on the studied properties (Table 2) showed that positive effect of this substance in increasing growth parameters and yield as the highest total yield (171 g in plant), the total fruits in the plant (6), RWC (85%), chlorophyll a (2.205 mg/g F.W), chlorophyll b (1.275 mg/g F.W), total chlorophyll (1.764 mg/g F.W), leaf area (22 cm^2), root fresh weight (21 g), root dry weight (6 g), shoot fresh weight (44 g), shoot dry weight (11 g) by applying 0.5% super absorbent and highest electrolyte leakage (37%), TSS (13%) and proline (22 µm/g F.W) in control was achieved. The highest total yield (352 g per plant) and total number of fruits in the plant (13) were achieved in treatment composition of irrigation interval every 5 days and applying 0.5% of SAP. In treatment composition of irrigation interval of every 11 days and without applying SAP (control), both attributes were zero (Fig. 1 and 2). The highest electrolyte leakage (44%) in treatment composition of irrigation interval every 11 days and 0.3% SAP and the lowest value (21%) in treatment composition of irrigation interval every 5 days and applying 0.4% SAP were achieved (Fig. 3). The highest proline value (32 µm/g F.W) in treatment composition of irrigation interval of every 11 days and without applying SAP (control) and the lowest value (µm/g F.W) was in treatment composition of irrigation interval of every 5 days and applying 0.5% SAP (Fig. 4).

Table 1

ANOVA for Dependent Variable for Treatment Applied, Superabsorbent Polymer (SAP), Irrigation and Their Interactions for Sweet Pepper Plant

Source of variation	Mean Square				
	Replication	Superabsorbent	Irrigation	Superabsorbent × Irrigation	Error
Df	2	4	3	12	38
Yield	13	25935.054**	140070**	1752**	107
Number of fruit	0.200	35.44**	188.95**	2.46**	0.53
Diameter	0.004	0.029**	0.110**	0.005^{ns}	0.005
Plant height	0.41	48.07**	206.52**	5.36^{ns}	2.8
RWC	0.002	0.18**	0.151**	0.003^{ns}	0.001
Chl a	0.09	0.38**	1.38**	0.02^{ns}	0.04
Chl b	0.008	0.158**	0.304**	0.023^{ns}	0.027
Total chlorophyll	0.04	0.24**	0.80**	0.01^{ns}	0.02
Leaf area	0.83	59.04**	173.19**	4.212^{ns}	2.78
EL	3.62	198.74**	656.86**	13.91**	4.07
TSS	1.17	12.93**	14.93**	1.21^{ns}	0.64
Fresh root	2.93	101.63**	387.62**	4.65^{ns}	7.01
Dry root	1.19	9.21**	31.80**	0.43^{ns}	0.63
Fresh shoot	11	141**	1023**	11^{ns}	6
Dry shoot	0.15	19.10**	66.20**	0.95^{ns}	2.41
Proline	2.27	163.78**	979.70**	16.67**	1.37

** and * represent significant at the 0.01 and 0.05 levels, respectively, and ns represent non- significant

Table 2:

Effect of Superabsorbent Polymer (SAP) Levels and Irrigation Intervals on Characteristics of Sweet Pepper Plant

Treatments	Levels of treatment	Yield (g/plant)	Number of fruit per plant	Stem diameter (mm)	Plant height (Cm)	RWC (%)	Chl a (mg/g F.W)	Chl b (mg/f F.W)	Total chlorophyll (mg/g F.W)	Leaf area (Cm^2)	EL (%)	TSS (%)	Fresh root (g)	Dry root (g)	Fresh shoot (g)	Dry shoot (g)	Proline (µm/g F.W)
SAP	0 percent	57^{c}	2.66^{c}	0.74^{b}	24^{c}	75^{d}	1.76^{a}	0.09^{b}	1.40^{c}	16^{c}	37^{a}	13^{a}	14^{c}	4^{c}	35^{d}	8^{c}	22^{a}
	0.2 percent	123^{b}	5.41^{b}	0.80^{ab}	25^{c}	80^{c}	1.90^{b}	1.13^{a}	1.53^{bc}	19^{b}	35^{b}	13^{b}	15^{c}	4^{c}	38^{c}	9^{bc}	21^{b}
	0.3 percent	128^{b}	5.41^{b}	0.81^{a}	27^{b}	$81b^{c}$	1.94^{b}	1.20^{a}	1.56^{b}	21^{a}	32^{c}	12^{b}	17^{b}	5^{b}	39^{bc}	9^{bc}	18^{c}
	0.4 percent	170^{a}	6.83^{a}	0.87^{a}	29^{a}	84^{ab}	2.13^{a}	1.25^{a}	1.71^{a}	21^{a}	28^{d}	11^{c}	18^{b}	5^{ab}	40^{a}	9^{b}	18^{c}
	0.5 percent	171^{a}	6.91^{a}	0.86^{a}	29^{a}	85^{a}	2.20^{a}	1.27^{a}	1.76^{a}	22^{a}	28^{d}	11^{c}	21^{a}	6^{a}	44^{a}	11^{a}	13^{d}
Irrigation	5 days	262^{a}	10^{a}	0.91^{a}	31^{a}	93^{a}	2.40^{c}	1.26^{a}	1.90^{a}	24^{a}	25^{d}	11^{c}	23^{a}	7^{a}	48^{a}	11^{a}	8^{d}
	7 days	132^{b}	5^{b}	0.85^{a}	28^{b}	84^{b}	1.98^{b}	1.25^{a}	1.60^{b}	20^{b}	29^{c}	12^{b}	18^{b}	5^{b}	43^{b}	10^{b}	16^{c}
	9 days	87^{c}	4^{c}	0.79^{b}	24^{c}	80^{c}	1.89^{b}	1.20^{a}	1.53^{b}	19^{b}	33^{b}	13^{a}	17^{b}	4^{b}	36^{c}	8^{c}	23^{b}
	11 days	37^{d}	1^{d}	0.74^{c}	23^{d}	68^{d}	1.67^{c}	0.96^{b}	1.34^{c}	16^{c}	41^{a}	13^{a}	11^{c}	3^{c}	29^{d}	6^{d}	27^{a}

Means with the same letters within the same row are not significantly different at $p < 0.05$ using Duncan's Multiple Range Test.

4. Discussion

Drought stress as a disturbing factor in plant physiology affects growth parameters of the plant. The results of this study showed that increasing irrigation interval has negative effect on growth parameters and pepper yield. By increasing irrigation interval, stem diameter, plant height, leaf area, fresh weight and dry weight of root and shoot were reduced (Table 2). The effect of water stress in reducing the growth of various parts of plant and yield in pepper was reported in Doraji et al. 2005 and Abayomi et al. 2012 studies that are in agreement with the findings of this study.

Due to water shortage, total sizes of the plant, dry and fresh weight of the plant were reduced as the total criteria of growth. The first signs of water shortage in the plants was the reduction of turgor pressure leading into the reduction of growth of cells namely in the stem and leaf. The growth of cells is the most important process being affected in water stress. The reduction of cell growth leads to the reduction of plant height and reduction of leaf size. By reducing turgor pressure due to water shortage, cell growth is reduced due to the pressure inside the cell. Thus, there was a significant relation between the reduction of cell size and reduction of water in plant tissues. By cell growth reduction of the organs and leaves are reduced. Because of this, the first tangible effect of drought on the plants is the small size of leaves or low size of plants. On the other hand, water reduction leads to the reduction of elements absorption and the growth of leaves is reduced. Thus, by reduction of leave area, plant transpiration level is reduced and this is the first plant mechanism to cope with drought. By reducing leaf area, sun light absorption and photosynthesis level of the plant is reduced and it leads to the reduction in production of dry matter and plant yield (Hong-Bo et al., 2008). The observed reduction in growth parameters due to drought stress in this study is due to the disturbance in metabolic process of the plant including photosynthesis and transpiration, chlorophyll destruction and the cell division. The results of this study showed that applying SAP to the lack of using it had positive and significant (P<0.01) effect on most of the tested attributes in irrigation interval. In the current study, by applying 0.5 weight percentage of super absorbent, the maximum fresh and dry weight of the root and shoot, leaf area, diameter and plant height were achieved. Also, the total maximum l yield and total number of fruits in each plant by applying 0.5% weight percent SAP was achieved and showed significant (P<0.01) increased compared to the lack of using it. The positive effect of SAP in increasing yield in the tomato (El-Hadi and Camelia, 2004), sunflower (Nazarli et al., 2010) and soybean (Yazdani et al, 2007) reported it and it was consistent with these findings. By applying SAP, humidity fluctuations were reduced, irrigation intervals were increased and plant growth was increased. It is obvious that by continuing plant growth and reduction of drought stress effects on the plant, its yield is increased.

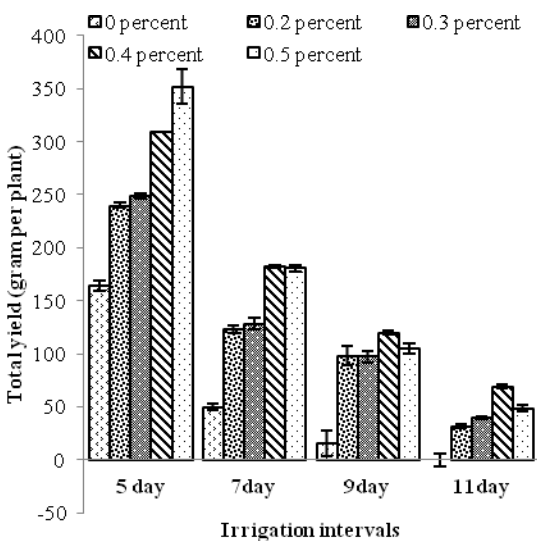

Figure 1: Effect of Superabsorbent polymer (SAP) on total yield of sweet pepper under irrigation intervals

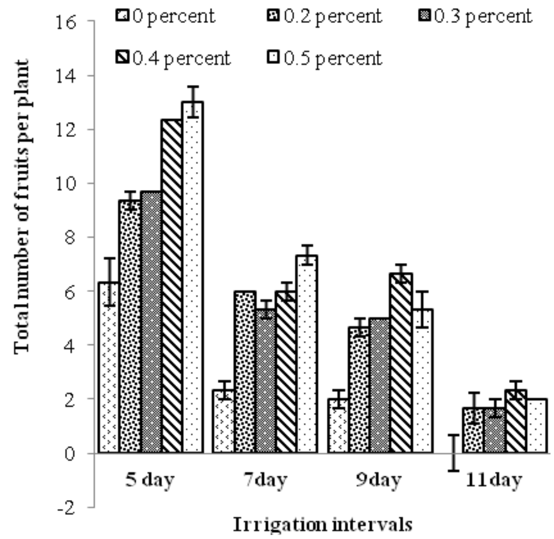

Figure 2: Effect of Superabsorbent polymer (SAP) on fruit total number of sweet pepper under irrigation intervals

Measuring plant water status is an important physiological index in identification of plant response to drought stress. One of the indices showed the status of water of plant is RWC. In this study, by increasing irrigation interval, RWC of leaf was reduced (Table 2), it is in line with the results of Khadem et al. (2010). Reduction of RWC of the leaf due to drought stress is related to the reduction of soil humidity; in these conditions close the stomata to avoid more water waste. The reason of stomata closure is Abscisic acid that is made in the root in drought stress conditions and is accumulated in stomata cells (Chaves et al., 2002). The reduction of RWC of the leaf has direct relation with water reduction in soil (Nautiyal et al., 2002). Using absorbent substances as SAP with storage of considerable water can keep humidity in the soil and the amount of water is increased in the plant. The results of this study supported the above items as applying 0.5 of this polymer increased the average of this attribute as 26% to the control that is in line with the results of Khadem et al. (2010) in corn and Nazerli et al. (2010) in sunflower plant.

Some of the environmental stress signs in plants are reduction of chlorophyll and this reduction depends upon the plant genotype (Colom and Vazzana, 2001). There was significant reduction trend in chlorophyll a and chlorophyll b and total chlorophyll by increasing irrigation interval and drought stress (Table 2). Based on the theory of Schutz and Fangmir (2001), the reduction of chlorophyll due to drought stress is related to the increase of production of free oxygen radicals in the cell. These free radicals cause peroxidation and disintegration and by reduction of chlorophyll, considerable changes are produced in the plants. The results of comparing the average of simple effects of SAP showed that this substance keep chlorophyll. Pasaraki (1999) showed that keeping chlorophyll and durability of photosynthesis of the leaf under stress conditions including strength physiological indices to stress are considered. Avoiding the stress of humidity fluctuations namely in arid regions, that polymer by putting water gradually for the plant, the stress levels of humidity fluctuations are minimized and it is one of the most important applications of these substance in agriculture (Nazarli et al., 2010) and through this increase the better growth of plants in stress conditions. Durability of chlorophyll in stress conditions by SAP materials in the sunflower (Nazarli et al., 2010) and corn (Khadem et al., 2010) are shown.

Water shortages as other bad environmental conditions create oxidative stress and via closure of stomata and shortage of CO2 cause blockage (preservation) of photosynthesis and lead to Reactive Oxygen Species (ROS) in chloroplast and damage the membrane due to lipid peroxidation (Mascher et al., 2005). In this study, increasing electrolyte leakage was observed by increasing irrigation interval (Table 2). It showed the increase of damage to cell membrane and increase of electrolyte leakage of the membrane and a criterion of the damage to the plant in water shortage conditions. It seems that reactive radicals produced due to drought stress can increase peroxidation reaction and increase electrolyte leakage in pepper under drought stress. The results of this study showed that super absorbent via reducing humidity fluctuations can reduce electrolyte leakage (Fig 3). In other words, the drought stress severity is reduced by applying SAP.

The amount of TSS is one of the quality parameters defining the concentration of total soluble solid in the fruit. The results of the comparison of the averages showed that by increasing irrigation interval, TSS of the fruit pepper was increased and it was in agreement with the results of Doraje et al. (2005) in pepper.

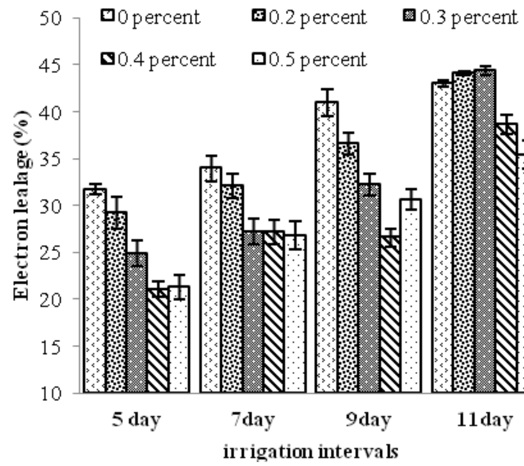

Figure 3: Effect of Superabsorbent polymer (SAP) on electrolyte leakage of sweet pepper under irrigation intervals

The main reason of concentration of TSS in the cell due to the shortage of irrigation water was coping with reduction of osmosis potential and the stored water was reduced and TSS was increased (Mishell et al., 1991). In the current study, based on the above scientific justification, the maximum TSS (13.44, 13.38%) respectively in irrigation interval 9, 11 days and minimum (11 %) were observed in the lowest experiment stress level (5-day irrigation interval). Using polymer substances with storing the humidity in the soil and its gradual access for the plants avoided the drought effects including the increase of TSS. The results of this study supported the above items as applying this matter in all the levels reduces this attribute due to the lack of application.

The plants, during the encounter with drought conditions, have various physiological mechanisms. One of the efficient mechanisms of the plant in drought conditions is osmosis control. Osmosis control is a physiological phenomenon during which osmosis potential of stressed tissues are reduced due to the accumulation of osmosis substances including mineral elements (e.g. potassium, sodium and calcium) and some of the metabolites as sugar, amino acids (proline) and organic acids. Thus, turgor pressure of the cells is kept well (Irigoyen et al., 1992). These metabolites don't have any contradiction with normal biochemical reactions of the cells and are called compatible solutes (Bohnert et al., 1995). The increase of the concentration of proline helps osmosis control and is reported due to some factors including the prevention of proline disintegration, avoiding proline participate in protein structure or increase of protein disintegration (Kao, 2005). Proline via osmosis control, avoiding enzymes destruction and removal of hydroxyl radicals, increased the tolerance of the plants against stresses (Kuznetsov and Shevykova, 1999). Similarly, by applying of humidity super absorbent, the reduced proline accumulation in sun flower was found (Nazarli et al., 2010). In this study, using this matter reduced proline accumulation in all irrigation intervals (Fig 4).

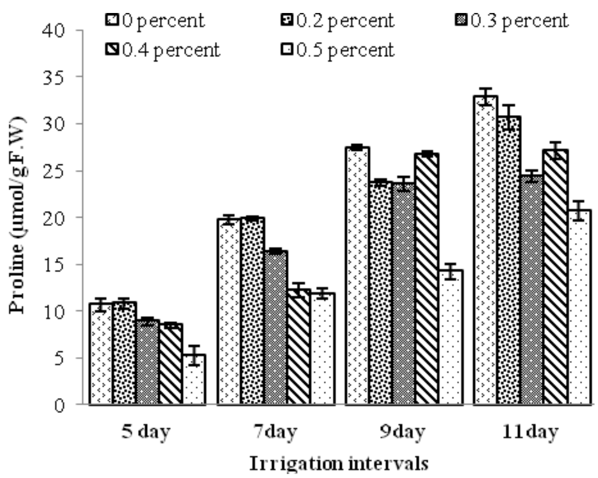

Figure 4: Effect of Superabsorbent polymer (SAP) on fruit Proline content of sweet pepper under irrigation intervals.

By the increase of the ratio of using SAP, proline accumulation was reduced in plant leaves. Lowest amount of proline with an average of 13 µm/g F.W was achieved in using 0.5 weight percent of SAP (Table 2). These substances, by giving gradual water for the plant and avoiding humidity fluctuations, avoided drought stress in the plant and provided the background to reduce proline accumulation in the plants under stress. The results of this study supported this item.

5. Conclusion

The results indicated that water stress significantly (P<0.05) decreased yield, growth parameters, RWC, photosynthetic pigments and electrolyte leakage and increased TSS and proline content, whereas the application of SAP moderated the negative effect of deficit irrigation on plant growth and productivity. This effect is due to the considerable absorption of water in super absorbent structure and putting gradual absorbed water to surrounding soil and plant root. Based on the results of this study and durability of super absorbent polymer in soil, we can say that using this matter not only under drought stress conditions but also under adequate irrigation conditions can increase the yield besides compensating its purchase costs and benefits.

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