International Journal of Plant and Animal Sciences Vol. 1 (3), pp. 042-048, June, 2013. Available online at http://internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Yield and Growth Response of Maize (Zea *Mays* L. S. C. 704) to Surfactant under Deficit Irrigation

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Accepted 8 April, 2013

The increasing scarcity of water for irrigation is one of the major challenges for forage producers in all arid and semi-arid regions. Surfactants can be used to mitigate this problem by increasing the speed of water penetration in the soil and reducing water loss through evaporation. A pot experiment was conducted to determine the ability of surfactant to hold water in the soil to promote forage corn growth and development under water deficit irrigation regimes. Pots were arranged in a three-replicated factorial design with three irrigation regimes of irrigation after 30%, 60%, and 90% of field capacity water depletion combined with and without application of surfactant. The results showed that application of surfactant increased plant height. The highest plant dry matter was obtained from irrigation after 30% and 60% field capacity depletion along with surfactant application, respectively. Moreover, application of surfactant positively and significantly influenced leaf dry matter, stem dry matter, root dry matter, and leaf/stem ratio under deficit irrigation regimes.

Key words: Corn, growth characteristics, surfactant, water deficit, Irrigation regimes

INTRODUCTION

Agricultural sector with consumption of 75% of water can be deemed as the greatest water consumer in the world. The number of countries with water deficiency will reach to 35 by 2020 (Morid et al., 2004). Water stress acts as a limitation factor for crop yield in arid areas (Begg and Turner, 1976; Boyer and McPherson, 1975; Hanson and Nelsen, 1980). Approximately at 30% of the world, agricultural products reduce due to the water deficit (FAO/UNSCO Soil Map of the World, 1998).

Corn (Zea Mays L) after wheat and rice is the most significant nutrient product in the world. Corn is a C_4 crop which has more photosynthetic and water use efficiency (Asghari et al., 2002). It seems that the significance of corn increases in the near future since it is the principle food for poor countries. Moreover, it is necessary for production of livestock protein in developed countries (Emam 2004). The global field under cultivation of corn approached to 137.6 million hectares and the global production of that reached to 609.1 million ton (FAO, 2001). The field under cultivation of the grain corn in 2009-2010 cropping seasons in Iran was equal to 224761 hectares with average yield of around 7289.68 Kg (the information section of ministry of agriculture of Iran).

Crops obtain most of their water needs from precipitation. Now a day, there is no rational mechanism for increasing the precipitation during dry periods. As a result, the best way to control of water deficit is adjustment which means enhancing the agronomy cultivation in a way that the ability of soil in holding water increases. Water plays an important role in crop production particularly in corn (Edmeades et al., 2000).

The yield of corn correlated with the availability of water to this crop. However, other factors such as fertilizer consumption can have impact on the yield (Zsófia Mózner et el., 2002) These factors typically regulated with the water availability during the growth period. Under

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water stress, nutrients absorption by roots reduces due to the lack of moisture content of the soil which leads to reduction of (Viets, 1972; Pinkerton and Simpson, 1986). Imbalance in plant growth adjustment hormones in the way that cause the reduction in the concentration of Oxin, Gibberellic acid, Kinetin and cause to increase acid abscisic and Etilen. Water stress have impact on adsorb and nutrient consumption (Heydari, sharif Abad 2001). Furthermore, drought has negative effect on phosphor concentration and phosphatase enzyme activation in plant (Sardans et al., 2006).

Surfactants are big group of chemical substance witch name as wetting agent. Surfactants reduce surface tension of water by surface tension of the air interface – water. Also they reduce tension of water and oil by surface tension liquid – liquid. A large number of surfactant molecules can be connected together and form a mass called a micelle. the Concentration in which micelle start to form called the critical concentration of the micelle formation. When micelle start to build up, their tails form a core, like a drop of oil and their iron head make outer shell witch improve a good contact with the water.

Despite the great diversity of surfactants in shape, size and molecular weight are all molecules are bipolar, so they have a head and a hydrophilic polar head and the other is non-polar and hydrophobic. This characteristic lead to when it soluble in water go to water surface, hydrofoil head of it stay in inside of water and hydrophobia train orient to outward of water. So throw away the surface water molecules and also due to the force from the inside out, reducing the surface tension of water is significantly. This causes the movement of water in the soil get faster and with a certain volume of water, wider profile of the soil is wet (James K. Ferri, 2000) Surfactant function in clay soils with high organic matter is remarkable. This causes the water in heavy soil will penetrate and move faster and reach the root zone so that prevent from surface evaporation.

Nowadays, Surfactant is utilized in herbicides and pesticides. Today, enormously changes in ingredients of surfactants for better influences. Regarding to the benefits of utilization of surfactant in reduction of water surface tension, it can be the best way in increase of available water for plants (Ferri, Stebe, 2000) Also, this material increases the rate of water penetration (Miller, 1990). There is surfactant adsorbing from an infinite solution to a freshly formed planar interface In the other hand, delay in the water penetration to the soil was one of the principal's wastes of water fields via evaporation (Thomas C. Winter., 1998). As a result of that, surfactant can be effective steps in the way of increase in the water efficiency. This investigation was conducted with the aim of study on the effect of surfactant on holding of water in soil.

MATERIAL AND METHODS

The experiment was conducted in 2011 cropping season in pots and the agricultural research station of Tehran University, karaj campus with the location of 35° E and 47° 5´ N and 1312 higher than sea level. Mean of annual precipitation was reported 265.9 mm with minimum of 108.2 and maximum of 469.9 in the last 38 years. The maximum and minimum temperature was reported 40 C° and 15 C° respectively and the average of temperature 25 C° was recorded. The soil texture in pots was clay loam with pH 7.66 (33% sand, 36% silt and 31% clay) with Ec = 2.41ds/m. The soil organic carbon content was 1.02 %. The soil had no salinity and drainage problem, and water Table was more than 7m deep. Some chemical properties of the soil are presented in followed Table.

Chemical properties of the soil

The experiment was conducted in Factorial design in randomize completely in 3 replication. The first factor was two water treatments: A) Control (without Surfactant) B) Water and Surfactant. The second factor was three irrigation treatment included: A) irrigation after 30% of discharging water from field capacity (control) B) irrigation after 60% discharging of field capacity C) irrigation after 90% discharge of field capacity.

The soil was selected from the soil of Agricultural research farm of University of Tehran, Campus of Karaj. The soil was selected of 0-30 cm deep of the soil and sieved twice with 5 mm sieve and sterilization for experiment. Pots were sterilized with 70% ethyl alcohol According to soil analysis test, the proposed treatments received recommended amounts of Urea and K20 and P205 fertilizers. The weight of pots was 300g which had capacity of 7000g soil. In all 5 pots, 704 SC corn were cultivated and the corn was Think in 2 to 3 leaf and the number of corn was reached to 2 corns per pot. After cultivation, each pot regarding to 22% moisture content reached to 22% of field capacity and the irrigation continued to 5-6 leaf stage. After that stage, the pots were irrigated in which in 30% treatment, pots with 1200 g water reached to field capacity and approached to 8500g. While the weight of pots reached to 8100g and the rest of treatments irrigated with 50% water and 50% water with surfactant.

Due to creation of equal condition for all pots, pots were moved randomly on each replication. The variety of corn was 704 SC which was well adapted and cultivate in wide climatic conditions. Plants about three months covered in the conduction of the study. The cultivation date was 03/06/2011.

The surfactant used for the experiment was non ionic and one litter per hectare was applied in each irrigation time. The amount of surfactant per pot was determined by calculation of water usage in field capacity. Hand weeding applied to combat with weeds. In 05/31/2011 all plants harvested in Physiologic maturity and the eco-physiology characteristics were measured. Due to differ-ences in the number of plants per pot, first covariance

Chemical properties of the soil

Cu	Mn	Zn	Fe	K	P	N	SAR	Mg^{++}	Ca^{++}	Na^{+}	T.N.V
	Available		(mg/kg)			%		soluble	(meq/l)		
1.58	12.7	1.25	6.43	237	14	0.09	1.9	8.2	20	7.1	5.5

Table 1. Analysis of variance of different corn traits in Surfactant and water deficit pot experiment, Karaj, Iran 2011.

S.O.V	df	Plant height	Plant dry matter	leaf dry matter	Stem dry matter	Root dry matter	leaf /stem ratio
Surfactant treatments	1	22.222*	26.161*	12.836*	2.347*	0.109 ns	0.132*
Irrigation regimes	2	604.500*	29.060*	5.711*	10.087*	5.762 ns	0.028*
Irrigation regimes* surfactant treatments	2	25.722*	2.802*	4.201*	0.254*	2.816 ns	0.128*
Error	12	4.444	0.117	0.079*	0.031	0.049	0.002

Table 2. The effects of irrigation regimes and water treatments on different corn traits in surfactant and water deficit experiment, Karaj, Iran 2011.

Treatments	Plant height (cm)	Plant dry matter (g/plant)	leaf dry matter (g/plant)	stem dry matter (g/plant)	Root dry matter (g/plant)	leaf /stem ratio
Irrigation Regimes						
Normal irrigation (control)	70.1[a]	16.6[a]	7.6[a]	9.0[a]	11.0[a]	0.8 [a]
Moderately limited irrigation	58.6[b]	14.5[b]	6.2[b]	8.3[a]	10.5[a]	0.7 [b]
Severely limited irrigation	50.1 [c]	12.2 [c]	5.7 [c]	6.5 [b]	9.1 [b]	0.6 [c]
Water Treatments						
W	58.6 [b]	13.311[b]	5.700[b]	7.611[b]	10.144[a]	0.74[b]
W+S	60.8 [a]	15.722[a]	7.389[a]	8.333[a]	10.300 [a]	0.91[a]

analysis was applied on the data through MSTATC program. Duncan test was applied to means for finding the significant statistically differences. All graphs were designed by Excel program.

RESULTS AND DISCUSSION

Statistical analysis results for plant height, plant biomass, leaf dry weight, stem dry weight, root dry weight and leaf/stem ratio in Table 1 and also mean compare results of treatments are presented in Tables 2 and 3.

Plant Height

Effect of different irrigation regimes on plant height was significant. With increasing severity of water stress, decreased the plant height, so the height was decreased from 70.1 cm in the non-stress conditions to 50.1 cm in the severe stress conditions (Table 1). Also the interaction between irrigation regime and surfactant treatments on plant height was significant (Table 1). In severe stress conditions use of surfactant increase plant height in compare with lack of surfactants conditions. These results indicate that surfactants can increase water availability in the soil in time duration. Because treatments under severe stress condition received water with the more interval time than those under mild stress condition, so it can be resulted that this substance can increase the ability of holding water in the soil. Also Pulter and colleagues in 2009 during a study of surfactant imply that the surfactant decrease the surface tension of water and in this way the penetration of water through the soil surface get easier and wetting area of soil increased. Compensatory effect of surfactant in this experiment, especially in conditions of severe stress showed him well. So the height was 53.67 cm in the use of surfactant

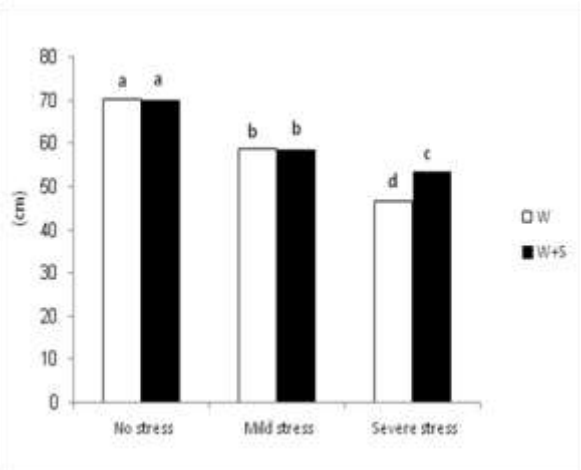

Figure 1. Interaction effect of irrigation regimes and surfactant treatments on Plant height of corn.

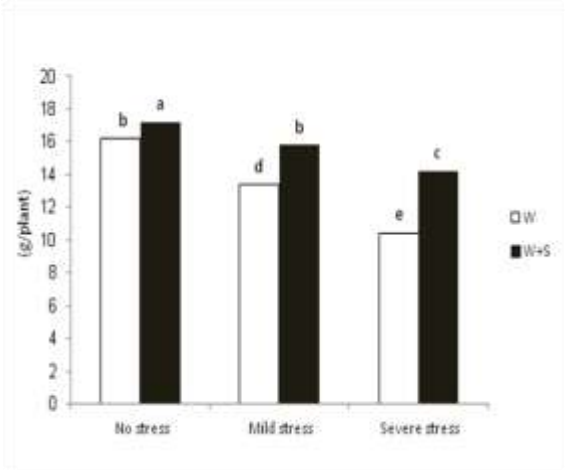

Figure 2. Interaction effect of irrigation regimes and Surfactant treatments on Plant dry matter of corn

condition and 46.67 in the lack of surfactant conditions (Figure 1). The use of this material could compensate damage caused by severe water stress on the plant to an accepTable level. Stoker in 1960 reported that drought change ratio of growth of various parts of the plant and it lead to Increasing the ratio between roots and foliage (stocker, 1960).

Irrigation Regimes

Normal irrigation (control): Substitute irrigation water after 30% by weight of water content at FC is lost moderately limited irrigation system: Substitute irrigation water after 60% by weight of water content at FC is lost
Severely limited irrigation system: Substitute irrigation water after 90% by weight of water content at FC is lost

Water treatments
W: water
W+S: water + Surfactant

Biomass weight Plant

Effect of different irrigation regimes on plant biomass weight was significant. With increasing severity of water stress, plant biomass weight was reduced so that the weight was 16.6 g in non-stress conditions and 12.2 g in severe stress conditions (Table 2). Also the interaction between irrigation regime and surfactant treatments on the weight of plant biomass was significantly (Table 1). Comparing the results of the different characteristics shows that the plant biomass weight more that other characteristic affected by water as even in no stress conditions the use of surfactant increased the weight of plant biomass. Admyds and colleagues in 2000 stating that water is the most important factor limiting maize production worldwide (Edmeades et al., 2000). With increasing stress intensity, the weight difference of plant biomass in the use and lack of surfactant increased as plant biomass weight in severe stress and use of surfactant condition was 14.17 which had significant difference together. The reason of this matter was increase possibility of appearance of role of surfactant in stress conditions (Figure 2). Koocheki and colleagues in 1994 mention that the potential for corn production under conditions of soil fertility and correct management, mainly be determined by capacity for water storage in soil and supply it for plants. Also Kaufmann and Jackson during a study on Effect of wetting agent on the water use rate of Merion Kentucky bluegrass resulted that surfactant has a significant effect on it. The plant biomass weight in average stress and the use of surfactants was 15.80 (g/plant) which in compare with no stress and lack of surfactant condition doesn`t have significant difference (Figure 2). It can be concluded that the surfactant can be considered a good option to compensation of water stress and play a significant role in deficit condition. Mitra (2003) conducted an experiment on the effect of surfactants on water use optimization on lawns and concluded that the surfactant help to more survival water in soil profile. Also Demi more and colleagues in 2004 during a study on the effect of surfactants on soil hydrological behavior, imply that positive effect of surfactants on soil water movement in soil, consequently improving the plant growth environment in was of increasing water storage in soil.

Leaf dry weight

Effect of different irrigation regimes on leaf dry weight was significant. The leaf dry weight decreased with increa-

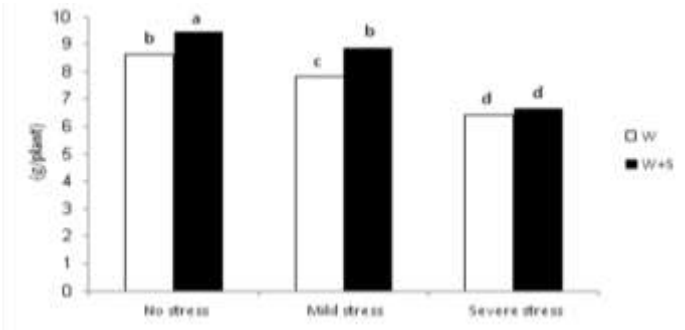

Figure 3. Interaction effect of irrigation regimes and surfactant treatments on Leaf dry matter of corn.

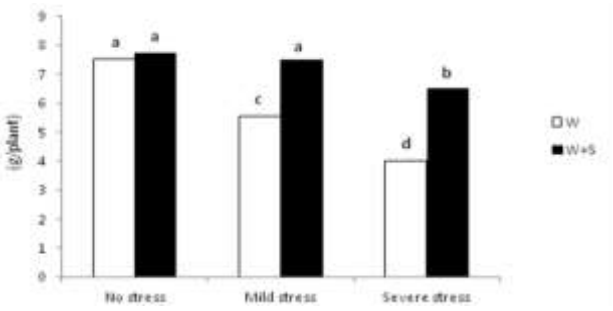

Figure 4. Interaction effect of irrigation regimes and surfactant treatments on Stem dry matter of corn.

sing severity of water stress, so leaf dry weight was 7.6 g in stress-free conditions and 5.7 g under severe stress condition (Table 2) also the interaction between irrigation regime and surfactant treatments on leaf dry weight was significant (Table 1). Comparison of results of scientific studies stating that the dry weight of leaves more than other plant organs affected by water deficit stress. Reduction in leaf area is an Initial reaction to the water shortage, at the beginning of water stress, inhibition of cell growth leading to a reduction in leaf development. The lower leaf surface lead to lower water absorption and reduce transpiration and available water content is kept in the soil for uses efficiently in a longer period. Limitation of leaf area can be the first barrier of defense against dryness. Water scarcity also stimulates leaf abscission. If plants are exposed to water stress after full leaf, leaves become old and finally shed. This leaves adjustment is the long-term change which lead to improvement in plant adaptation to the environment is faced with water shortages. The process of leaf abscission during water stress is mostly the result of increased synthesis and sensitivity to the hormone ethylene in the inside of plant also the stomata are closed during water stress in response to abscisic acid. abscisic acid form continuously and make in low values in the mesophil cells and most of it accumulate in chloroplasts. When the mesophilic be dehydrated mildly occur two things. First, the amount of stored acid abscisic in the cells of mesophilic is released which transpiration stream transport may amount of it to the guard cells. Second, the speed of construction net acid abscisic increased. Stomatal closure begins with redistribution of stored acid abscisic from mesophil chloroplasts to inside of apoplast. Construction of acid abscisic be begun after stomata closure and it seems that it Cause severe or prolonged blocking effect produced by stored acid abscisic. In a study on the effects of drought stress on wheat was concluded that water stress significantly decrease photosynthesis, stomata conductance, transpiration, chlorophyll and leaf relative water percentage (mohesen zadeh and et al, 2004). In this study, with increasing severity of dehydration (especially in the severe stress), decreasing trend in leaf dry weight was more severe than mild stress condition which use of surfactant compensate it as well (Figure 3). Reduced availability of nutrients is one of the most important factors limiting plant growth under drought conditions. Under these conditions, nutrient uptake decreased by the roots and transportation them from roots to stems caused by decrease the rate of transpiration and active transport (Hsiano, 1973; Kramer and Boyer, 1995). Effect of surfactant on increasing water availability has shown itself well in moderate and severe stress and can be able to reduce water stress to an accepTable level (Figure 3). So the use of this material could compensate damage caused by severe water stress on this organ of the plant as well. Lerch and colleagues in 2010 during of conduction of an experiment on the effect of surfactants on soil wetting punctures confirmed the positive effect of this substance on the increasing water penetration in the soil they state that this phenomenon is caused by reduces the contact angle of water droplets with the soil surface. Also Soldat and colleagues in 2010 after study of effect of surfactants in the drought conditions concluded that surfactant in the way of increasing the uniformity of the water content in soil play his positive effect.

Stem dry weight

Effect of different irrigation regimes on shoot dry weight was significant. The stem dry weight decreased with increasing severity of water stress, so it was 9g in no stress condition and 6.5 in severe stress condition (Table 2). Also the stem dry weight was significantly affected by interaction of surfactant treatment and irrigation regimes (Table 1). Comparison of effect of water deficit stress in the different characteristics stated that stem dry weight is affected by water less than other characteristics so the compensatory role of surfactant in severe stress conditions seems less than others. Shonali Laha et al., imply that Surfactants are amphiphilic molecules that

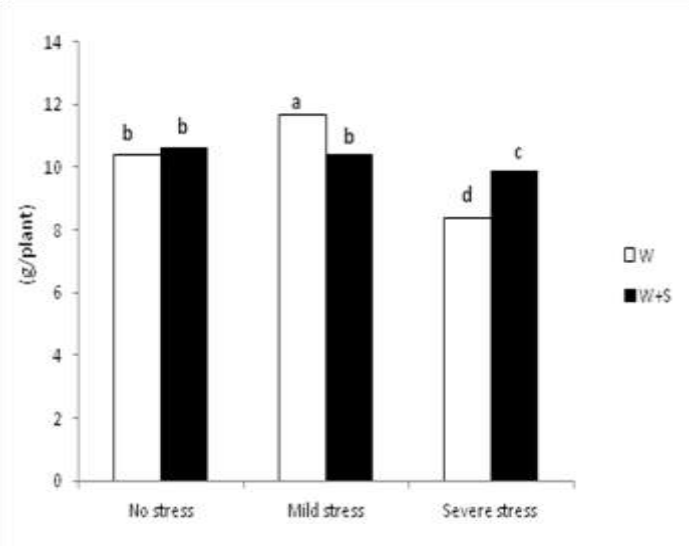

Figure 5. Interaction effect of irrigation regimes and surfactant treatments on root dry matter of corn.

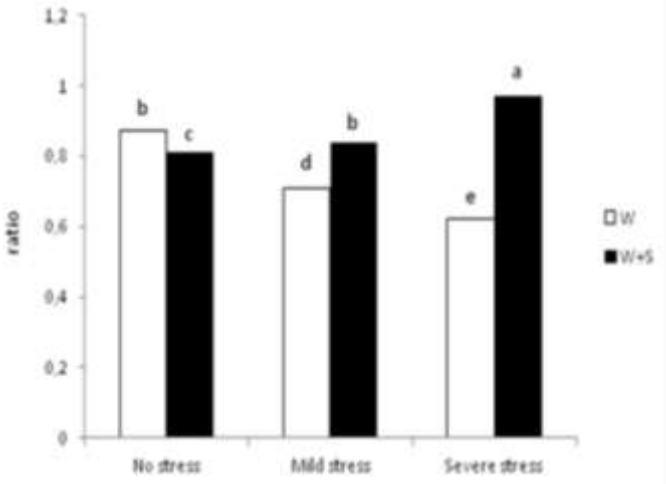

Figure 6. Interaction effect of irrigation regimes and surfactant treatments on Leaf/stem ratio of corn. on Root dry matter of corn.

reduce aqueous surface tension Hi And Gilbert in 2001 point to further the effect of drought stress on grain weight and stated that drought stress reduces photosynthetic production capacity of storage them in the during of grain filling stage. Another visible result in regard to effect of surfactants on water availability increase and increase the weight of the stem is that stem dry weight in no stress and lack of surfactant was 8.63 which had no significant difference with moderate stress and use of surfactant condition (8.86 g) (Figure 4). So the use of this material could compensate the damage resulting from water stress on stem dry weight. In another study on the effect of surfactant was performed by Sandrmn in 1983, concluded that the use of surfactants in water increases the dry weight.

Also During a study on the effects of surfactant on the germination and establishment of seedlings in repellent soil was determined that the surfactant also increased germination and establishment of plant in the way of increasing of available moisture content (azborn, 1967).

Root dry weight

Effect of different irrigation regimes on root dry weight was significant. With increasing the intensity of water stress, root dry weight was reduced from 11.0 g in no stress condition to 9.1 g in severe stress condition (Table 2). The interaction between irrigation regime and surfactant treatment on root dry weight was significant (Table1). Moderate drought stress lead to relative increasing in root dry weight. In another study on the effects of drought stress on root growth of corn was concluded that moderate drought stress lead to relative increasing in lengths of root and severe drought stress lead to relative reduction in root length (sakinezhad and et al, 2010). The noTable point that is different from the results of the different characteristics that at first glance seems in Moderate stress surfactant reduced the root dry weight but in regard to the fact that the average stress increased the root dry weight should stated that surfactant loss of this effect so in moderate stress and us of surfactant root dry weight was 10.40 g/plant which had no significant difference with no stress and lack of surfactant condition (Figure 5). So it can be concluded that in the process of creation of mild stress with the geol of increasing of root growth, the use of surfactants is not recommended because it neutralize that effect. But surfactant can play an effective role in severe stress condition. Ernest bromba and Michael Peterson in 2001 in the during of doing an experiment on study of surfactant effect on root growth of corn, concluded that surfactants can increase the depth of the root.

Leaf/ stem weight ratio

Effect of different irrigation regimes on leaf to stem weight ratio was significantly. Also Kazaz1 et al., (2010) during an experiment on Effects of different irrigation regimes on yield and some quality parameters of carnation have resulted that the treatments with higher irrigation intervals produced higher flowers yield and Quality. With increasing severity of water stress ratio of leaf weight to stem had decreased trend so it was 8 in no stress condition and 6 in severe stress (Table 2). The interaction between irrigation regime and surfactant treatments on leaf to stem weight ratio was significantly (Table 1). Achieving the maximum difference between

use and non use of surfactant in severe stress conditions can shows the maximum effect of water deficit stress on leaf dry weight and the other hand less affecting stem dry weight by water stress compare with other traits. (Figure 6). Feng and colleagues in 2002 stating that the surfactant increases the water infiltration in soil. In this regard, park and colleagues during of conduction of an experiment in South Florida emphasis to the effect of surfactants on increasing water infiltration in soil. Also kostca and colleagues in 2005 confirmed the effect of surfactant on uniform distribution of water in the soil.

CONCLUSION

In this experiment in regard to applying stress at various time intervals and derived results in regard to the role of compensating surfactant in reducing water stress damage, it can be emphasis on compensate role of surfactant in reducing water stress damage and also on the ability of surfactant to hold water in the soil. And noted the need to conduct further research on this matter. For instance, on different levels of irrigation, different plants or different kind of surfactant. In regard to the importance of irrigation management in increase crop yield and also the fact that the agriculture sector in Iran uses about 5 / 93% of the total water (heydarisharifabad, 2004) it can be stated that Any attempt to optimize water use management in the country without special attention to this sector cannot be coincided with the success. Agricultural sector is faced with this reality that produce should be more along with less water use in the future (Rijsberman, 2002). Iran is in Arid and semiarid regions in the world with limited water resources and consecutive droughts threaten the food security of its residents. So the research and study about strategies of optimize water use efficiency play a vital role in increasing the yield per unit area and also increase surface of water land.

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