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SURFACTANT APPLICATION ON GROWTH CHARACTERISTICS OF ONION (CRYSTAL WHITE VAR.) UNDER SALINE WATER IRRIGATION CONDITION

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ABSTRACT

Successful management of saline water could have significant potential for agricultural development inmany areas, particularly in water-scarce regions. The experiment with a factorial arrangement for treatments was conducted based on a randomized complete block design with four replications at the Research Greenhouse of California State Polytechnic University, Pomona in 2016. Two levels of salinity were employed in the irrigation water during the growth period which maintained the electrical conductivity (EC) of soil at: 0 (control), and 4 dS/m. Also, different non-ionic surfactant types (ACA1848 and ACA2994) and surfactant rates (0, 1, 2, 4 ppm) were treated to the plots. The results of the experiment showed that saline water (4 dS/m) reduced plant height, shoot dry weight, fresh bulb weight, dry bulb weight compared to fresh water condition. Irrigation water treatment by surfactant type 1848 was beneficial for onion growth and development in fresh and saline irrigation water conditions. Surfactant application had a moderating effect against the adverse condition of saline water. Also, Fresh water irrigation with surfactant types 1848 and 2994 were most beneficial at 4 and 2ppm rates, respectively. However, in saline water irrigation, only application of surfactant type 1848 at 2ppm showed a beneficial effect on onion growth and development. In fact, the surfactant application significantly improves all growth traits of onion which indirectly enhances the tolerance of plants to salinity stress.

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INTRODUCTION

Onions (*Alliumcepa* L.) are the third most economically important crop worldwide with a total production of 85 million tons per year (Faostat, 2013). Its consumption as food orethnomedicine is mainlyattributed to the medicinal properties, including antiasthmatic, antichlolesterolemic and antimicrobial (Caruso *et al.*2014). However, a large portion of the world's onion producing areas (e.g., Mediterranean to semiarid climates) are in regions that currently suffer, or are expected to encounter in future environmental stresses (Faostat, 2013). Unfavorable environmental growth factors, such as salinity constitute a major limitation to onion production (Enciso *et al.* 2015), which is estimated to increase drastically due to global climate change, affecting the agricultural system in general and onion production, yield, quality and market value of the crop in particular (Nakabayashi and Saito, 2015). In arid and semi-arid regions, water salinization is an important problem which causes limitation in plant growth and productivity (Osakabe *et al.* 2011; Jamil *et al.* 2010), and is identified as the major seedbed factor influencing the seedling establishment (Almansouri *et al.* 2001). A high average content of salt in soil or in irrigation water has a devastating effect on plant metabolism with major uncoupling physiological deteriorations, disrupting cellular homeostasis, and biochemical processes. Plants usually take up salts with water they suck with Na^+ and Cl^- ions which are toxic for the germinating of seeds (Atak *et al.* 2006; Kaya *et al.* 2006). The up taken salts can damage the plant internally, affecting the plant's physiological processes and growth, and lead to leaf burn and eventually plant death. The effect of salt stress depends on the concentration, exposure time, plant genotypes and environmental factors. The plant growth in saline dry and semi-dry soils can be further damaged by water

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scarcity due to high osmotic pressure (Sharifi Rad, 2013) which prevents the water uptake. There have been numerous reports on the adverse effects of salt stress on seed germination and establishment (Erdal *et al.* 2011; Fethi *et al.* 2011; Othman *et al.* 2006). Seed germination, emergence rates and the growth of young seedlings of sugar beet (Wang *et al.* 2011; Ghoulam and Fares, 2001), *Phaseolus mungo* (Garg, 2010), *Dianthus chinensis* L. (He *et al.* 2009),Carrot (Nagaz *et al.* 2012), Tomato (Chaichi *et al.* 2016;Cao *et al.* 2016), Cucumber (Cao *et al.* 2016) and Pepper (Rameshwaran *et al.* 2016) were decreased by salinitystress. To improve plant growth under stress conditions, and for sustainable crop production, it is necessary to either improve salt stress tolerance or apply technologies which moderate adverse effects of salinity in crops. However, there are few technologies which could moderate the adverse effects of salinity on plants. Some nonionic surfactants can reduce soil water repellency, uniformity of soil moisture distribution and rootzone moisture holding capacity and therefore improve crop yield.

Surfactants are wetting agents that lower surface tension of a liquid, allowing it to spread out more easily. By changing the flow dynamics of water in irrigation, surfactants improve the hydrological behavior in soils allowing a better growing environment for plants and water conservation (Moore *et al.* 2010). It has been shown that, surfactant can improve uniformity of soil moisture distribution and root zone moisture holding capacity, thus; improve crop yield (Wolkowski *et al.* 1985;Dadrasan *et al.* 2015;Chaichi *et al.* 2016). Application of surfactant at the rate of 1 mg/l had positive effects on plant height, leaf number per plant, leaf dry weight, stem dry weight, shoot dry weight, and root dry weight in tomato (Chaichi *et al.* 2015).Also, Dadrasan *et al.* (2015) reported that application of surfactant with 1 ppm concentration improved the photosynthetic pigments under high salinity stress. However, the potential of surfactant application to improve soil-plant water relations under salinity stress has received insufficient attention from researchers and the authors are not aware of any documents regarding the effect of surfactant application on onion growth characteristics under salinity stress. This study was conducted to determine which surfactant type (1848 or 2994) and which concentration more efficiently improves onion crop growth under saline water irrigation.

MATERIALS AND METHODS

Experimental Site and design: The experiment was conducted at the Research Greenhouse of California State Polytechnic University, Pomona. The experiment with a factorial arrangement for treatments was conducted based on a randomized complete block design (RCBD) with four replications in 2016. Three levels of salinity were employed in the irrigation water during the growth period which maintained the electrical conductivity (EC) of soil at: 0 (Control), 4, and 8 dS/m. Also, different non-ionic surfactant types (ACA1848 and ACA2994) and surfactant rates (1, 2, 4 ppm) were treated to the plots. Irrigation water comprised of control (tab water) and diluted sea water (Pacific Ocean) to different salinity levels of 4 and 8 ds/m treated with different non-ionic surfactant types and surfactant rates. Plants were irrigated either by tab water (Control) or saline sea water + surfactant in corresponding treatments since the seeds were placed in the soil and continued all through the growing season. The surfactant type 1848 was a non-ionic surfactant formulated as: 10% alkyl polyglycoside, 7% Eo/Po Block Copolymer, 83% water. However, the formula of the surfactant type 2994 was not disclosed. The surfactant rates were S0 (control with no surfactant application), S1, S2, and S4, representing concentrations of 1, 2, and 4 ppm in irrigation water, respectively. To prepare S1 (1ppm), S2 (2 ppm), S4 (4 ppm) level of surfactant, 5.5, 11, 22 ml of surfactant were applied to 5500 ml of tab water.

Plantation

A Crystal White Variety onion (*Alliumcepa* L.) was chosen for this experiment. Onion seeds were purchased from Eden Brothers Seed Company, North Carolina, U.S.A. Each individual plot was 8 Kg pot with 25cm diameter. All pots were filled by native non-saline soil (EC = 1.2 dS/m) from Bakersfield, California. Soil characteristics is presented in Table 1. For each treatment 5 Seeds were directly planted per pot in native soil on April 28, 2016 and irrigated by tab water for transplanting in case if plants failed due to direct seeding and irrigation by saline water. Tab and saline water were added to the pots according to the prescribed treatments to achieve 100% FC (Field Capacity). During the experimental procedure, all the pots were kept inside a glass greenhouse under natural light. The average day and night temperatures of the greenhouse were measured as 20 and 25°C, respectively, and the RH was maintained at ~50%.

Harvest and studying the characteristics

After plants reached physiological maturity (After 130 days), all the plots were harvested on September 4th, 2016. The growth parameters including Plant height (cm), Shoot weight (g), Fresh bulb weight (g), Dry bulb weight (g), Bulb/shoot Ratio were measured in each treatment. Samples were dried at 72 ^{o}C for 48 hours, and their mean dry weight were recorded for each treatment at each replicate.

Statistical Analysis

Analysis of variance (ANOVA) was used to compare salinity and surfactant type and concentration of surfactant treatment with using PROC GLM of SAS 9.1 software. Duncan test was applied to compare means of each trait at 5 % probability level. Excel software was used to draw figures.

RESULTS AND DISCUSSION

The effects of saline irrigation water treated with different surfactant types and rates on onion growth characteristics in a non-saline soil conditions are presented in figures 1 to 6. Water salinity adversely influenced all growth characteristics in Onion. In fresh water treatment, the highest plant was achieved by both surfactant types 1848 (68.0 cm) and 2994 (62.6 cm) treatment at 1 ppm rate which showed 15% and 6% increase over control, respectively (Fig. 1). In saline water treatment, the maximum plant height (54.0 cm) was achieved by surfactant type 1848 at 1ppm application rate which followed a decreasing trend as a higher concentration of surfactant was applied. However, 2994 application was not beneficial for plant height at saline water condition, but it decreased the plant height to the lowest at 4 ppm application rate (26.6 cm) which decreased it by 62% compared to control (43.0 cm)(Fig. 1).Onion is classified as salt sensitive crop that has a 1.2 dS/m electrical conductivity (EC) threshold (Chang and Randle, 2004). Osmotic potential and nutritional imbalance induce stress in plants and consequently adversely impact its growth (Singh *et al.* 2014). Chartzoulakis and Klapaki (2000) and Yildirim and Guvenc¸ (2006) also found decreases in height of peppers with increasing salinity. Positive effects of surfactant application on salinity stress alleviation and increasing plant height was reported by other researchers (Baath *et al.* 2017; Chaichi *et al.* 2015; Brumbaugh and Petersen, 2001).

growth, leaf burn and even plant death (Almansouri *et al.* 2001). By using surfactant on corn, total dry matter and ear yield increased up to 10.5% and 13.9% compared to untreated plots, respectively (Chaichi *et al.* 2015).It has been shown that, surfactant can improve uniformity of soil moisture distribution and root zone moisture holding capacity, thus; improve crop yield (Chaichi *et al.* 2015). In fresh water treatment, the fresh bulb weight followed an increasing trend as surfactant type 1848 application rate increased.

Table 1. The native non-saline soil characteristics collected from Bakersfield, California used for this experiment

Soil Depth (cm)	Soil Texture	SP %	pH	EC dS/m	Ca meq/l	Mg meq/l	Na meq/l	K meq/l	SAR	Lime Qual.	SO4 mg/l	B mg/l
0-30	Silty loam	48	7.5	1.2	3.5	1.0	12.2	0.3	8.15	Medium	3.1	0.85

Half Saturation %= approximate field moisture capacity. Salinity, saturation extract = ECe (dS/m at 25 degree C), SAR = Sodium Adsorption Ratio. Ca - calcium, Mg - magnesium, K - potassium, Na - sodium, B - boron, SO- sulfate 4

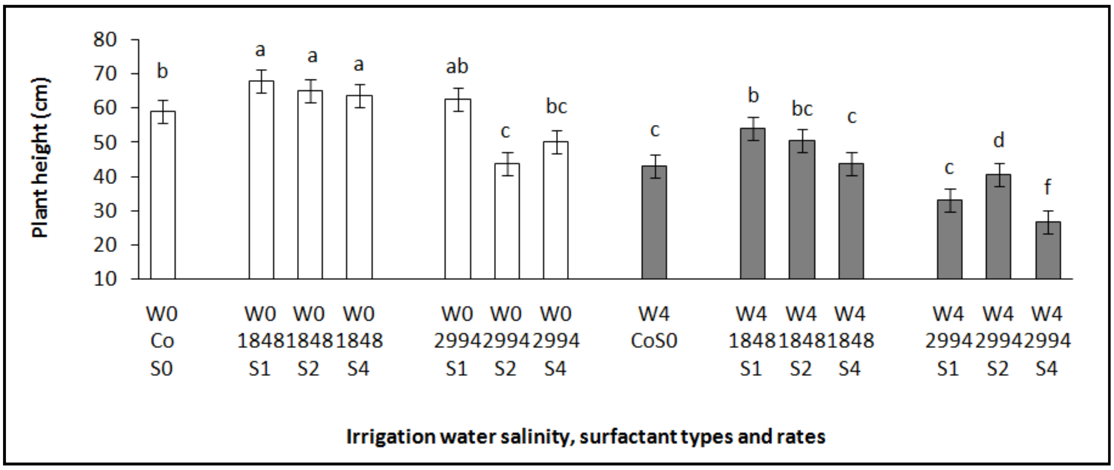

Fig. 1. Effect of irrigation water, surfactant type and rate on onion plant height W0: fresh water, W4: saline water (4 dS/m); S0, S1, S2, S4: 0, 1, 2, 4 ppm concentration of surfactant, respectively

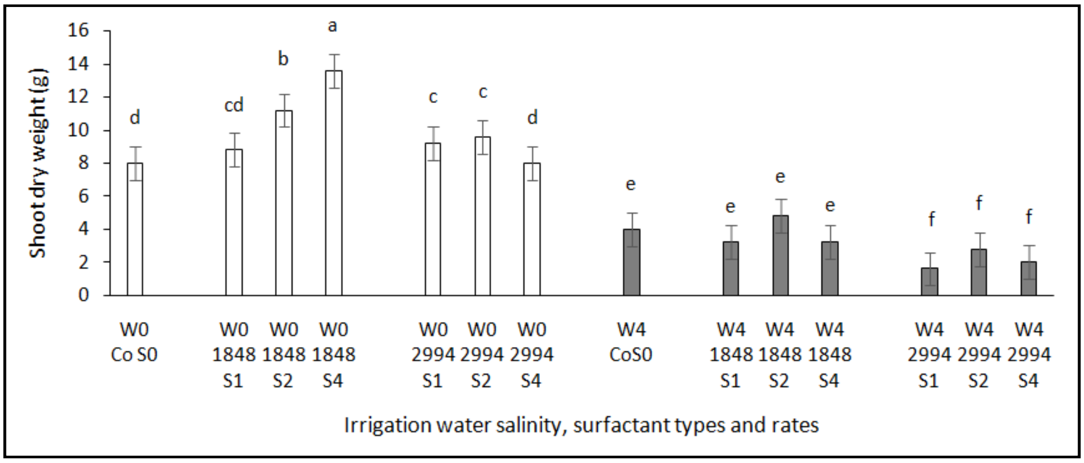

Fig. 2. Effect of irrigation water, surfactant type and rate on onion shoot dry weight W0: fresh water, W4: saline water (4 dS/m); S0, S1, S2, S4: 0, 1, 2, 4 ppm concentration of surfactant, respectively

In fresh water treatment, the shoot dry weight at control was significantly less than surfactant type1848 treatment at 2ppm and 4ppm application rates (Fig. 2).Surfactant type 1848 treatment at 1, 2 and 4ppm application rates increased the shoot dry weight in onion by 10, 40 and 70%, respectively (Fig. 2). In saline water treatment, the only positive but not significant effect was observed from surfactant 1848 at 2ppm application rate which could increase the shoot dry weight by 20%. Plants take up salts with the water that they use, and often these salts can damage the plant internally affecting the plant's physiological processes and often resulting in reduced

The highest fresh bulb weight (217.5 g) was achieved at 4ppm of surfactant rate for 1848 which increased bulb fresh weight by 69% compared to control (Figs. 3, 4).In saline water treatment, the maximum bulb fresh weight was obtained by surfactant type 1848 at 2ppm application rate which increased the fresh bulb weight by 16%. For the other rates, no advantage was observed neither for 1848 nor 2994. These results correspond to results of Chaichi, *et al.* (2015) reporting increase in corn seed yield and seed components by surfactant application in fresh irrigation water. Brumbaugh and Petersen (2001)found that corn yield increased by 13-17% depending on surfactant utilization rate in compacted soil which corresponds to the results of this study. The only positive result of application of surfactant type 2994 on bulb fresh weight in fresh water treatment was seen at 1ppm application rate which increased the bulb fresh weight by 38% compared to control (Figs. 3,4).

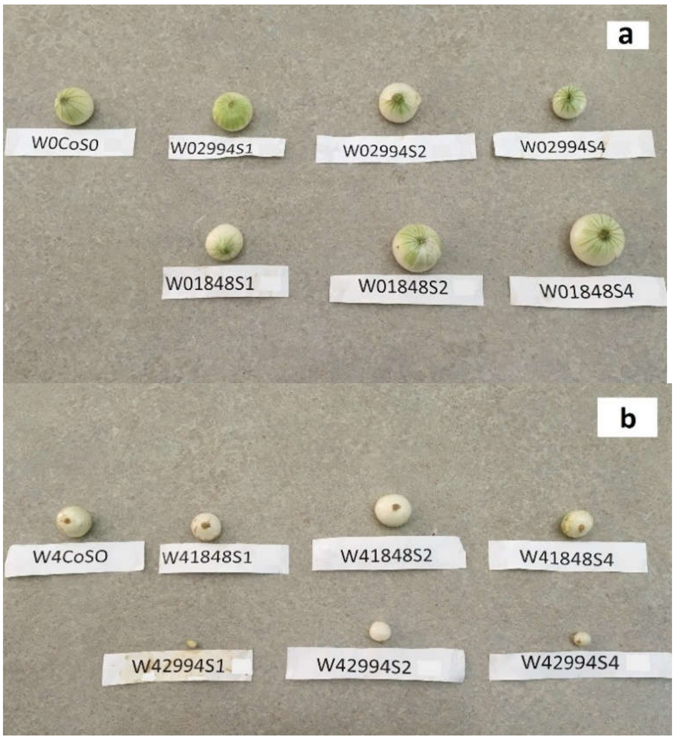

Fig. 3. Effect of irrigation water (a: fresh water, b: saline water), surfactant type and rate on onion Bulb W0: fresh water, W4: saline water (4 dS/m); S0, S1, S2, S4: 0, 1, 2, 4 ppm concentration of surfactant, respectively

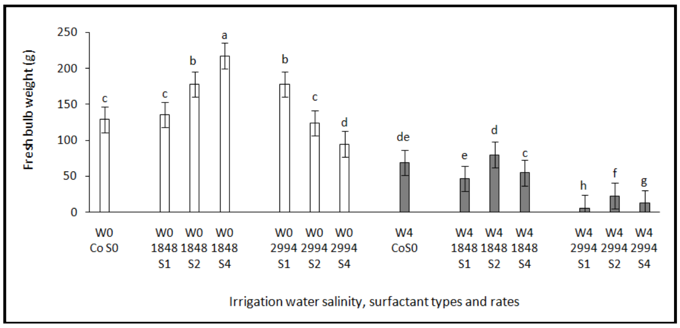

Fig. 4. Effect of irrigation water, surfactant type and rate on onion bulb fresh weight W0: fresh water, W4: saline water (4 dS/m); S0, S1, S2, S4: 0, 1, 2, 4 ppm concentration of surfactant, respectively

Similar results as observed for fresh bulb weight was also observed for dry bulb weight (Fig.5). High salt concentration in the soil or in the irrigation water have a devastating effect on plant metabolism, disrupting cellular homeostasis and uncoupling major physiological and biochemical processes. Many researches have shown that in response to water salinity, seedling growth, leaf area, root and shoot biomass have all been reduced (Redmann *et al*., 1994; Ghollarata and Raiesi, 2007). However, in our study onion plants received surfactant 1848 type at 2ppm application rate were more resistance to water salinity throughout the course of their growth and development (Fig. 5). In soils with high salinity problem, because of high Na concentration and soilaggregates dispersion, water movement and wettability is restricted. Where the soil wettability is less than optimal, the use of surfactant in combination with appropriate irrigation and soil cultivation practices, improves the soil hydrological behavior resulting in an improved irrigation efficiency and water conservation (Kostka *et al.* 2007).

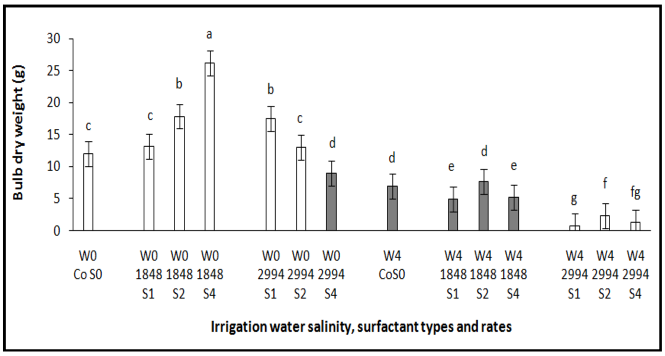

Fig. 5. Effect of irrigation water, surfactant type and rate on onion dry bulb weight W0: fresh water, W4: saline water (4 dS/m); S0, S1, S2, S4: 0, 1, 2, 4 ppm concentration of surfactant, respectively

The result showed under fresh water irrigation, bulb/shoot ratio increased by application of surfactant type 1848 at 4 ppm and 2994 at 1 ppm concentration (1.92 and 1.90, respectively) (Fig. 6). However, under salinity water condition the highest bulb/shoot ratio was observed under control condition. Also, application of surfactant type 1848 had positive effect on bulb/shoot ratio compared to 2994 surfactant type.

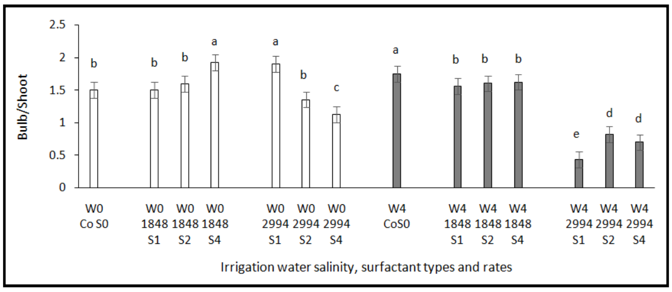

Fig. 6. Effect of irrigation water, surfactant type and rate on onion bulb dry weight W0: fresh water, W4: saline water (4 dS/m); S0, S1, S2, S4: 0, 1, 2, 4 ppm concentration of surfactant, respectively

Conclusions

Saline water (4 dS/m) reduced plant height, shoot dry weight, fresh bulb weight, and dry bulb weight compared to fresh water condition. Irrigation water treatment by surfactant type 1848 is beneficial for onion growth and development in fresh and saline irrigation water conditions. However, Surfactant type 2994 was not beneficial either in fresh or saline water treatments on onion growth and development. Surfactant application has a moderating effect against the adverse condition of saline water. Also, Fresh water irrigation with surfactant types 1848 and 2994 were most beneficial at 4 and 2ppm rates, respectively. However, in saline water irrigation, only application of surfactant type 1848 at 2ppm showed a beneficial effect on onion growth and development. In fact, the surfactant application significantly improves all growth traits of onion which indirectly enhances the tolerance of plants to salinity stress.

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