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Surfactant application improves growth and development of onion (crystal white var.) in saline soil

Abstract

Successful management of saline water could have significant potential for agricultural development in many areas, particularly in water-scarce regions. This experiment with a factorial arrangement of treatments was conducted based on a randomized complete block design with four replications at the Research Greenhouse of California State Polytechnic University, Pomona in 2015-2016. Two types of surfactant (1848 and 2994) with different rates (0, 1, 2, 4, 8ppm) were employed in a saline soil condition during the growth. The results of the experiment showed the interaction of surfactant type and the rate had a significant effect on the shoot length, dry shoot weight, and fresh and dry bulb weight of the onion. The maximum fresh bulb weight was achieved under surfactant type 1848 application at 1ppm concentration. Bulb fresh weight increased by 5.52 % at surfactant level of 1ppm for 1848 compared to control. Surfactant type 1848 application was more efficient in all growth parameters compared to 2994 type. Surfactant application showed a moderating effect on the adverse effects of saline soil on onion growth and development. Also, irrigation water with surfactant types 1848 was most beneficial at 1ppm rate. In fact, the surfactant application significantly improved all growth traits of onion which indirectly enhanced the tolerance of plants to salinity stress.

Keywords: Surfactant, saline soil, shoots length, bulb dry weight, bulb fresh weight

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Abbreviations: S0, 0ppm surfactant; S1, 1ppm surfactant; S2, 2ppm surfactant; S4, 4ppm surfactant; S_8, 8ppm surfactant

Introduction

Plants are exposed to various abiotic stresses throughout the course of their growth and development.[1] Abiotic stresses such as drought and salinity are among the major factors around the world limiting plant growth and productivity.[2–4] About 77 million hectares of agricultural lands (5%) are suffering from saline conditions.[5] Decreasing average yields and quality for major crops by more than 50%.[6] are the other consequences of harsh environmental conditions which result in threatening the sustainability of the agricultural industry.[7] Salinity disrupts cellular processes through several mechanisms such as osmotic stress by limiting water absorption, and ionic stress because of high concentrations of toxic salt ions.[8] Several physiological processes are affected by salinity stress which results in a decreased growth and productivity in crops.[9] There have been numerous reports on the adverse effects of salt stress on seed germination and establishment and the growth of young seedlings of sugar beet,[10] carrot,[11] tomato[12,13] cucumber[13] and pepper.[14] Onion (*Alliumcepa* L.) is the third most economically important crop worldwide with a total production of 85 million tons per year.[15] The world onion producing areas are in regions that currently suffer, or are expected to encounter in future environmental stresses.[15] Unfavorable environmental growth factors, such as salinity constitute a major limitation to onion production,[16] which is estimated to increase drastically due to global climate change. These changes will be affecting the agricultural system in general and onion production, quality and market value in particular.[17] 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 root zone 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.[18] Application of surfactant at the rate of 1 mg/l had positive effects on plant height, leaf number per plant, leaf, stem, shoot, and root dry weight in tomato.[19] Also, Dadrasan et al.[20] reported that application of surfactant with 1ppm concentration improved the photosynthetic pigments under high salinity stress. The potential of surfactant application to alleviate salinity stress has received insufficient attention from researchers. This study was conducted to determine which surfactant type (1848 or 2994) and which concentration more efficiently improves onion crop growth under saline soil condition.

Materials and methods

Experimental site and design

The experiment with a factorial arrangement of treatments was conducted based on a randomized complete block design with four replications at the Research Greenhouse of California State Polytechnic University, Pomona in 2015-2016. Two types of surfactant (1848 and 2994) with different application rates (0,1,2,4, 8ppm) were employed in a saline soil condition during the plant growth. The surfactant type 1848 was a non-ionic surfactant (10% alkyl polyglycoside, 7% Eo/Po Block Copolymer, 83% water). However, the formula of the surfactant type 2994 was not disclosed.

Plantation

A Crystal White variety onion (*Alliumcepa* L.) was chosen for this experiment. Onion seeds were purchased from Eden Brothers Seed Company, North Carolina, USA. Each individual plot was a 3-gallon pot with 25cm diameter. All pots were filled by native saline soil (EC=5.2 dS/m) from Lost Hill city in Bakersfield, California. Irrigation water was treated by a factorial combination of different surfactant types and surfactant rates and applied on the onion (Crystal White Variety). Irrigation was done either by tap water or tap water + surfactant in corresponding treatments when plants reached 5 leaf growth stage and continued all through the growing season. Saline soil characteristics are presented in Table 1. For each treatment, 5 Seeds were directly planted per pot in native soil on 07 October2015. Pots were immediately irrigated by tap water until the plants reached 5 leaf growth stage which since then they were irrigated by treated water (different types and rates of surfactant application). Irrigation water was added to the pots according to the prescribed treatments to achieve 100% FC (Field Capacity). During the experimental period, all the pots were kept inside a greenhouse under natural light. The average day and night temperatures of the greenhouse were measured as 24 and 18°C, respectively, and the RH was maintained at ~50%.

Table 1 The native soil characteristics collected from Lost Hill city in Bakersfield, California

Soil Depth (cm)	Soil Texture	SP%	pH	ECdS/m	Cameq/l	Mgmeq/l	Na meq/l	Clmeq/l	ESP%	Lime+\-	NO3-Nmg/l	Bmg/l
0-30	Silty loam	54	7.7	5.2	31.8	4.5	13.2	14.3	2.2	+++	5.3	0.5

Harvest and plant characteristics

After plants reached physiological maturity (After 170 days), all the plots were harvested on March 30, 2016. The growth parameters including plant height (cm), shoot weight (g), fresh bulb weight (g), dry bulb weight (g), and bulb/shoot ratio was measured in each treatment. Samples were dried at 72^{o}C for 48 hours, and the mean dry weight was recorded for each treatment at each replication.

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. LSD test was applied to compare means of each trait at 5% probability level. Excel software was used to draw figures.

Results and discussion

The ANOVA of the studied traits of onion is presented in Table 2. Surfactant treatment had a significant effect on leaf number per plant, dry shoot weight, fresh and dry bulb weight. Surfactant rate significantly affected shoot length and fresh bulb weight. Also, the interaction of surfactant type and rate showed significant effect on shoot length, dry shoot weight, and fresh and dry bulb weight of the onion (Table 2). The tallest shoot length (79.75cm) was achieved by surfactant type 2994 with 2ppm concentration (Figure 1). In 1848 surfactant type, increasing the surfactant rate increased shoot length compared to control (without surfactant application). However, in 2994 surfactant type, increasing of surfactant rate up to 8ppm decreased the shoot length of onion compared to control (Figure 1). Onion is classified as a salt sensitive crop which has a 1.2 dS/m electrical conductivity (EC) threshold.[21] Osmotic potential and nutritional imbalance induce stress in plants and consequently adversely impact its growth.[22] Positive effects of surfactant application on salinity stress alleviation and increasing plant height was reported by other researchers.[19,23,24] The highest leaf number per plant was achieved by surfactant type 1848 treatment which showed 7.12 % higher leaf number compared to surfactant type 2994 (Table 3). By using surfactant on corn, total dry matter and ear yield increased up to 10.5% and 13.9% compared to control plots, respectively.[19] It has been shown that surfactant can improve the uniformity of soil moisture distribution and root zone moisture holding capacity, thus; improve crop yield.[19] Shoot dry weight with surfactant type 1848 was significantly higher than surfactant type 2994 (Table 3). Surfactant type 1884 at 1ppm had the maximum shoot dry weight (8.75g). Surfactant type 1848 treatment at 1ppm rate increased the shoot dry weight in onion by 13% (Figure 2); Lehrsch et al.[25] working 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 stated that this phenomenon is caused by the reduction of the contact angle of water droplets on the soil surface.

Table 2 Analysis of variance of onion characteristics as affected by irrigation water treated with different surfactant types and rates in a saline soil condition.

S.O.V.	DF	Shoot Length	Leaf Number per Plant	Shoot dry weight	Bulb fresh weight	Bulb dry weight	Bulb/Shoot Ratio
Replication	3	2.29	0.89	1.85	134.33	3.52	0.09
Surfactant type	1	7.22	0.16 **	6.89**	5616.90**	36.58**	0.11
Surfactant rate	4	16.65*	0.89	1	1118.97**	2.11	0.09
Surfactant type × rate	4	18.47*	0.16	3.31**	1475.27**	14.18**	0.16
Error	27	5.01	0.62	0.71	61.68	2.71	0.08
C.V.	-	2.89	6.87	11.8	8.07	17.07	20.24

Table 3 Main effects of irrigation water treated with different surfactant types and rates on onion growth characteristics in a saline soil condition

Treatments	Shoot Length(cm)	Leaf Number per Plant	Shoot dry weight(g)	Bulb fresh weight(g)	Bulb dry weight(g)	Bulb/Shoot Ratio
Surfactant type						
1848	77.95a	11.85a	7.55a	109.15a	10.60 a	1.42a
2994	77.10a	11.06b	6.72b	85.45 b	8.69 b	1.31a
Surfactant Rate						
S0	75.50b	10.91b	7.17ab	117.40a	10.26a	1.44a
S1	78.50a	11.63ab	7.62a	94.63b	9.25a	1.18a
S2	78.75a	11.64ab	7.13ab	93.63bc	9.75a	1.39a
S4	78.38a	11.75a	7.12ab	95.00b	9.96a	1.43a
S8	76.50ab	11.38ab	6.62b	85.88c	9.00a	1.39a

S_0, S_1, S_2, S_4, and S_8 are surfactant levels of 0 (control),1,2,4 and 8ppm in irrigation water, respectively.

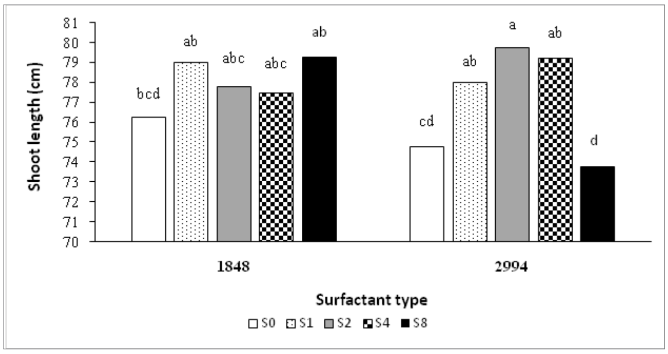

Figure 1 Interaction effect of fresh irrigation water treated by surfactant types and surfactant rates on shoot length of onion (Crystal White Var.) in saline soil condition.

S_0, S_1, S_2, S_4, and S_8 are surfactant levels of 0 (control),1,2,4 and 8ppm in irrigation water, respectively.

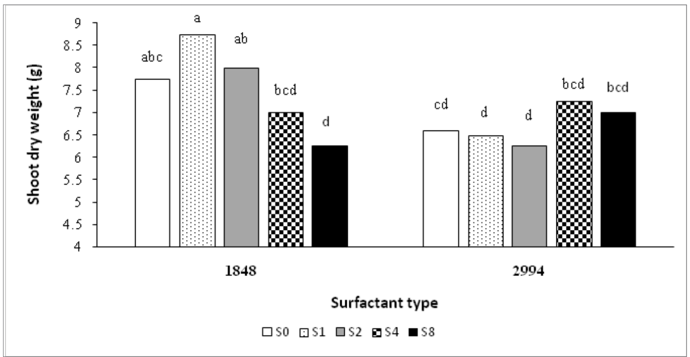

Figure 2 Interaction effect of fresh irrigation water treated by surfactant types and surfactant rates on shoot dry weight (g) per plant of onion (Crystal White Var.) in saline soil condition.

S_0, S_1, S_2, S_4, and S_8 are surfactant levels of 0 (control),1,2,4 and 8ppm in irrigation water, respectively.

The maximum bulb fresh weight was achieved under surfactant type 1848 application at 1 ppm concentration. Bulb fresh weight increased by 5.52 % at surfactant level of 1ppm for 1848 compared to control (without application of surfactant) (Figure 3). These results correspond to results of Chaichi, et al.[19] reporting increase in corn seed yield and seed components by surfactant application in irrigation water. Brumbaugh & Petersen[23] found that corn yield increased by 13-17% depending on surfactant utilization rate in a compacted soil which corresponds to the results of this study. Application of surfactant type 2994 had no positive effect on bulb dry weight (Figure 3). Similar interaction results were observed for bulb fresh and dry weight (Figure 4). High salt concentration in the soil or in the irrigation water has a devastating effect on plant metabolism, disrupting cellular homeostasis and uncoupling major physiological and biochemical processes. Many researchers have shown that in response to soil salinity, seedling growth, leaf area, root, and shoot biomass is reduced.[26,27] In this study, onion plants received surfactant 1848 type at 1ppm application rate were more resistance to saline soil condition throughout the course of their growth and development. In soils with high salinity problem, because of high Na^+ concentration and soil aggregates dispersion, water movement and wet ability is restricted. Where the soil wet ability is less than optimal, the use of surfactant in combination with appropriate irrigation and soil cultivation practices improve the soil hydrological behavior resulting in an improved irrigation efficiency and water conservation.[28]

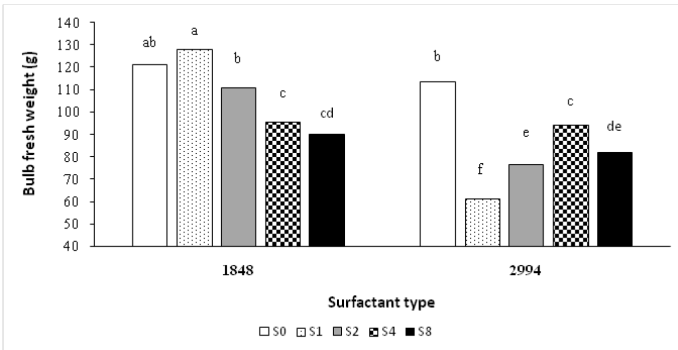

Figure 3 Interaction effect of fresh irrigation water treated by surfactant types and surfactant rates on bulb fresh weight (g) of onion (Crystal white Var.) in saline soil condition.

S_0, S_1, S_2, S_4, and S_8 are surfactant levels of 0 (control),1,2,4 and 8ppm in irrigation water, respectively.

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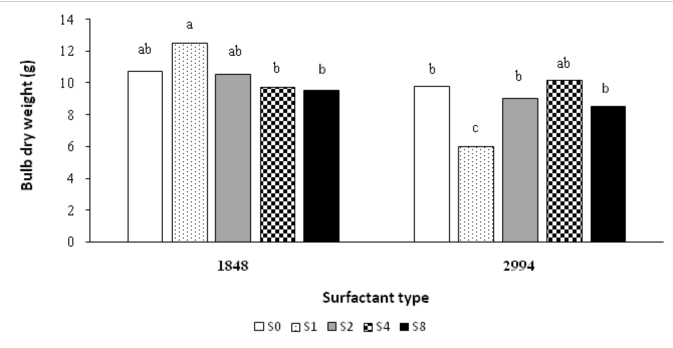

Figure 4 Interaction effect of fresh irrigation water treated by surfactant types and surfactant rates on bulb dry weight (g) of onion (Crystal white Var.) in saline soil condition.

S_0, S_1, S_2, S_4 and S_8 are surfactant levels of 0 (control), 1, 2, 4 and 8ppm in irrigation water, respectively.

Conclusion

The results of this experiment showed that surfactant type 1848 application was more efficient in all growth parameters compared to 2994 type in saline soil condition. Surfactant application played a modifying role on the adverse effects of saline soil on onion growth and development. Also, fresh irrigation water treated by surfactant type 1848 at 1ppm rate was most beneficial for onion growth and development. Surfactant type 1848application significantly improved all growth traits of onion which indirectly enhanced the tolerance of plants to salinity stress.

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Conflict of interest

The authors declared there is no conflict of interest.

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