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Response of Snap Bean Plants to Super Absorbent Hydrogel Treatments under Drought Stress Conditions

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ABSTRACT

Application of super absorbent hydrogel (SAH) on snap bean plants (*Phaseolus vulgaris* L.) was examined under drought stress conditions. Snap bean plants were grown in pots containing mixtures of sand and different levels of SAH (0.1, 0.3, 0.5, 0.7 and 0.9 %) and all plants were subjected to drought stress. Total chlorophyll content of leaves and soil water potential (which is an indicator of soil moisture) were recorded. After drought stress, plants were watered again and kept well-watered to follow the post-stress observations on growth, quality and yield. The results indicated that application of super absorbent hydrogen maintained higher total chlorophyll content and soil water potential compared to control plants (without hydrogel). Post-stress observations on growth and productivity indicated that growth and productivity parameters were enhanced by hydrogel application. The possible explanations of the effects of SAH on snap bean plants exposed to drought stress are discussed.

Key words: Superabsorbent hydrogel, snap bean, sandy soil

Introduction

Arid land reclamation program in Egypt is a central component in the Egyptian social and economic development strategies in the last decades. Advanced chemical technologies enabled commercial production of new soil conditioners that match the requirements of desert land reclamation (Enas *et al.,* 2013)**.**

Bean plants (*Phaseolus vulgaris* L.) are considered as important protein source world-wide. However, these plants are sensitive to drought conditions. It is indicated that growth and productivity of bean plants are extremely affected by water stress (Millar and Gardner, 1972). Water stress resulted in a decline of leaf water potential, stomatal conductance, photosynthesis rate and all growth, productivity and quality parameters of bean plants **(**El-Tohamy *et al.,* 1999). Also, El-Tohamy *et al*. (2013) indicated a significant reduction in relative water content of leaves as well as growth and yield as affected by drought stress. Moreover, finding relatively safe tools and treatments to overcome the negative effects of drought stress or improve drought tolerance of sensitive plants could be of great value especially under arid and semi-arid conditions as shortage of water becomes a limiting factor for plant growth and productivity in such conditions. Super absorbent hydrogel (SAH) may provide an excellent solution for plants grown in newly-reclaimed land in sandy soils and for plants that may suffer even partially from drought stress in the field.It has been indicated that the addition of SAH significantly increased the soil water retention of sandy loam soils (Yang *et al.,* 2014). Dabhi *et al.* (2013) stated that several previous research indicated the effectiveness of soil conditioning with super absorbent polymers and their applications in the agriculture. These superabsorbent polymers are able to absorb large amounts of water, typically more than traditional absorbent material (Enas *et al.,* 2015).

Practically, hydrophilic polymers can be applied to improve the water status of plants as well as their nutritional status. These hydrophilic polymers are capable of retaining water up to 500 times of their weight, building an additional water reservoir for the plant–soil–system and subsequently can reduce water stress in plants (Andry *et al.,* 2009).

El-Tohamy *et al*. (2014) examined the effects of SAH on physiological changes, growth and yield of squash plants subjected to drought stress. However, little work has been conducted on the effect of SAH on snap bean under drought stress conditions.

The present study aimed to evaluate the application of superabsorbent hydrogel (SAH) on drought tolerance of snap bean plants. Several physiological, growth, productivity and quality parameters are measured in this study to explore the impact of SAH on snap bean plants subjected to drought stress.

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Materials and Methods

Materials for SAH preparation

The following reagents were used as laboratory grade chemicals and without further purification: Acrylic acid (AAc) in the monomeric form was produced by Panreac CQ uimica, Spain; N-N'-methylene bisacrylamide (MBAAm) as a crosslinking agent was purchased from Sigma–Aldrich, Chemie, GmbH, Germany; potassium persulphate (KPS) as initiator was supplied by Sisco Research Lab. Pvt. Ltd., India; potassium hydroxide (KOH) was provided by SDFCL, India.

Preparation of Polyacrylic/acrylate Superabsorbent hydrogel

The Preparation of polyacrylic/acrylate superabsorbent hydrogel was carried out according to a modified procedure (Enas *et al.,* 2015). A mixed solution of acrylic acid monomer and potassium acrylate was prepared by mixing the monomer with N, N-methylene bisacrylamide as a cross linker in presence of potassium hydroxide in distilled water under ambient conditions. The mixture solution was stirred at 350 rpm and heated to 70ºC in a water bath for 15 min., followed by addition of the initiator. The reaction mixture was kept under stirring for few minutes to complete the polymerization reaction. The prepared hydrogel was then immersed in excess distilled water to remove any impurities then dried at 80ºC for about 3 hours. A bench scale experiment was carried out according to the optimum conditions by which the swelling ratio of the SAH was in a maximum rate and economic (Enas *et al.,* 2013) and the product was used for bean planting.

Plant material

The study was conducted at the National Research Center. Seeds of snap bean (*Phaseolus vulgaris* L.) cv. ‘Bronco’ were sown in 5 liter pots containing mixtures of sand and different levels of hydrogel (0.1 to 0.9 %) in addition to control plants (grown in sand without hydrogel) in the second week of September, 2014. All plants were kept well-watered at the beginning of the experiment. One month after sowing, plants were subjected to drought stress by withholding water for 4 days and the soil moisture was monitored by tensiometer. After stress period, all stressed-plants were re-watered and kept at field capacity for post stress observations on vegetative growth, generative development and yield as well as some quality parameters of pods. All plants were fertilized by using a nutrient solution (15-5-25, NPK) during the entire experiment.

The following parameters were recorded:

Soil water potential:

The soil water potential was monitored by tensiometer (Irrometer Company, Riverside, Calif.) and was recorded at the end of drought stress.

Physiological parameters:

The total chlorophyll content of leaves (2nd fully expanded leaves) was measured at the end of drought stress period using TYS-A chlorophyll Meter (Zhe Jang Top Instrument Co. LTD., China), total soluble solids of pods measured by refractometer.

Post-stress growth, quality and productivity observations

Plant height, number of leaves and plant fresh weight per plant were recorded 60 days after sowing. Productivity measurements (weight of pods and pods number per plant) were recorded as well as pod characteristics (length and diameter) at the end of the experiment. A complete randomized block design with 4 replicates was used in this study and analysis of variance was calculated according to Snedecor and Cochran, (1967). Least significant difference (L.S.D.) at 5% was used to compare the means.

Results and Discussion

SAH levels resulted in increasing the soil water potential (Figure 1) which can be attributed to the enhancement of soil water holding capacity compared to control plants. The levels of 0.7 and 0.9 had the best results in this respect. Dabhi *et al.* (2013) indicated that the applications of super absorbent polymers are strongly recommended in agriculture as they may work as water storage reservoirs in the soil. As mentioned by Ekebafe *et al.* (2011) superabsorbent hydrogels potentially influence soil permeability, density, structure, texture, evaporation and infiltration rates of water through the soils. The results of Casquilho *et al.* (2013) indicated the effective role of the polymer both in the improvement of the water regime in the soil and in the substantial increment of grassland productivity.

Plants grown in sand mixed with hydrogel showed higher levels of total chlorophyll than control plants indicating that hydrogel levels maintained enough available water for plants to overcome drought stress injuries (Fig. 2). The effects were more pronounced with the highest levels of SAH. Similar results were obtained regarding total soluble solids of pods, as the application of SAH resulted in improving quality of snap bean pods (Fig. 3). Nnadi and Brave, (2011) found that the plants exposed to drought with no amendment with SAP to the soil stopped growing after the first two weeks and showed signs of dehydration while all the plants in the amended soil continued to grow after the first two weeks and they looked much healthier. On the other hand, El-Tohamy *et al*. (2014) found that SAH levels resulted in increasing the soil water potential as SAH enhanced the soil water holding capacity compared to control plants. They also found that this enhancement of water holding capacity caused positive effects on the physiological changes, growth and productivity of squash plants exposed to drought stress.

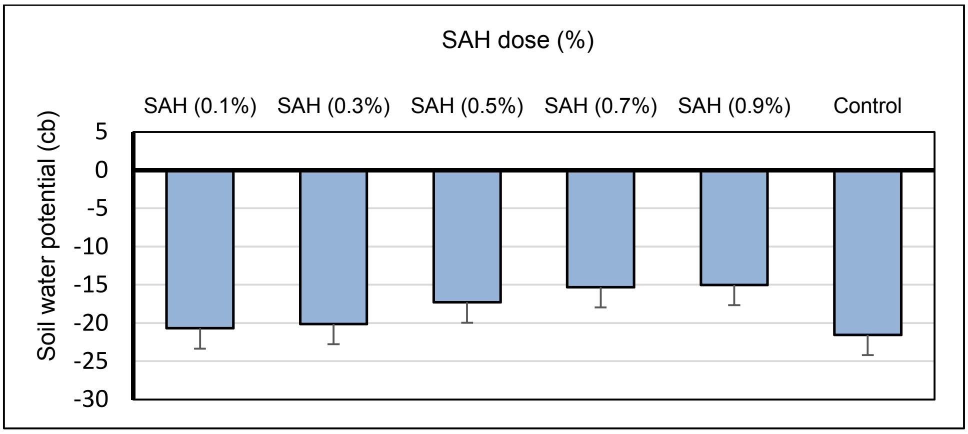

Fig. 1: Effects of different levels of hydrogel on soil water potential (at the end of drought stress period).Vertical bars present LSD value at 5%.

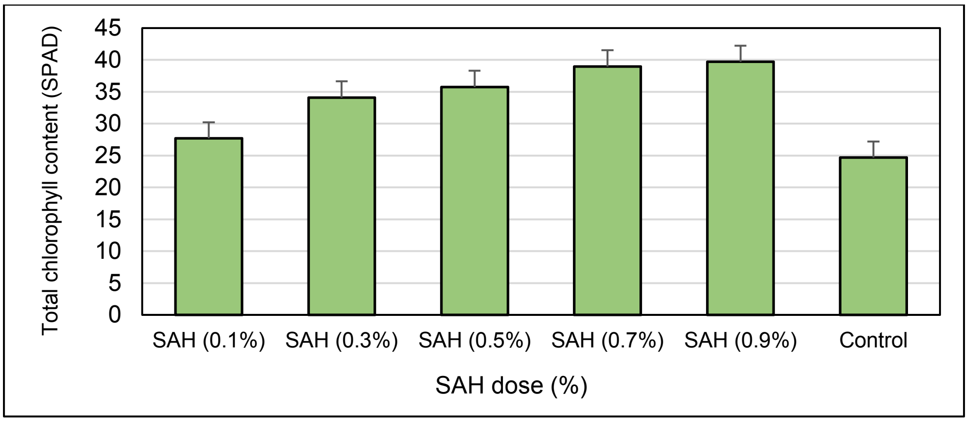

Fig. 2: Effects of different levels of hydrogel on total chlorophyll content of leaves. Vertical bars present LSD value at 5%.

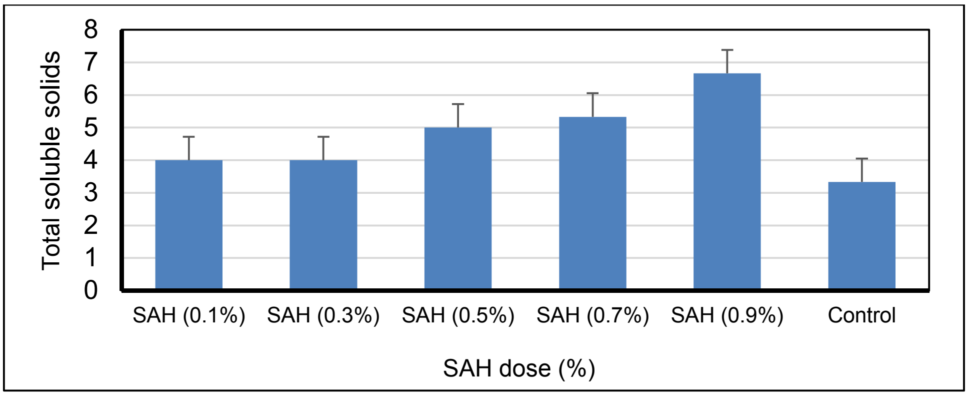

Fig. 3: Effects of different levels of hydrogel on total soluble solids (T.S.S.) of pods. Vertical bars present LSD value at 5%.

SAH resulted in enhancement of plant growth (as indicated by high values of plant height and number of leaves). Moreover, the total yield (as indicated by fresh weight of pods per plant and number of pods) and other pod quality characters (pod length and diameter) were significantly improved especially by the higher levels of SAH (Table 1).The results revealed that SAH improved water holding capacity of the sand and subsequently enhanced growth and productivity of snap bean plants under water deficit conditions.

Table 1: Effects of different levels of hydrogel on growth characters and total yield and quality characters of pods (at the end of the experiment) of snap bean plants subjected to drought stress.

SAH dose (%)	Plant height (cm)	Number of leaves/plant	Number of pods/plant	Pod length (cm)	Pod diameter (cm)	Fresh weight of pods (g/plant)
SAH (0.1%)	20.33	9.33	14.00	9.83	0.73	128.33
SAH (0.3%)	24.00	10.67	14.67	10.33	0.80	135.50
SAH (0.5%)	26.00	11.33	17.33	10.67	0.90	139.10
SAH (0.7%)	26.67	13.33	18.00	11.83	0.93	142.40
SAH (0.9%)	27.00	14.00	19.33	12.00	0.97	146.50
Control	19.00	8.00	13.33	9.00	0.67	126.07
L.S.D. at 5 %	1.87	1.11	0.84	0.66	0.08	4.3

Figure 4 shows the photos besides its added percent of SAH. It is clear that increasing doses of SAH improve bean germination and growth. So comparing each plant with the control one (0 % SAH) it is clears that maximum addition of SAH (0.9%) gave the best plant growth after 25 days as represented in Table 2**.** It may be concluded that bean plant is more sensitive to water amount trapped in SAH and this enhancement of water holding capacity caused positive effects on the physiological changes, growth and productivity of bean plants.

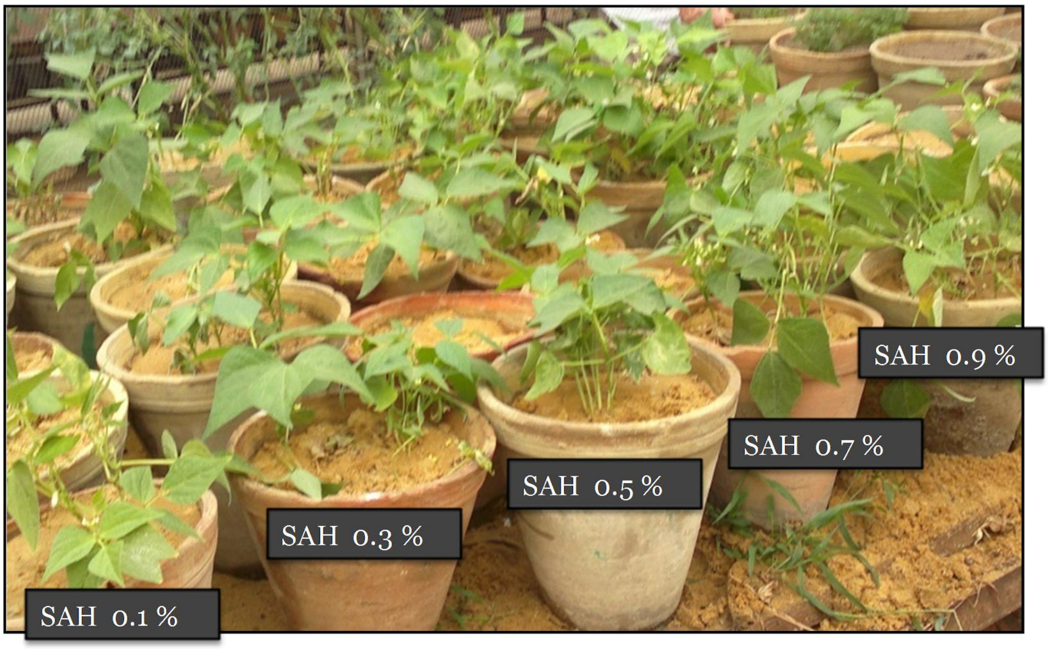

Fig. 4: All sample pots (the closer pots of bean plants shorter where the amount of SAH added to sandy soil is less)

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Table 2: Bean plant after 25 days from sowing.

SAH content in sandy soil	Control sample compared with treated one
0.1 %	
0.3%	
0.5 %	
0.7 %	
0.9 %	

Conclusion

Snap bean plants were grown in pots containing mixtures of sand and different levels of SAH (0.1, 0.3, 0.5, 0.7 and 0.9 %) and all plants were subjected to drought stress. Application of super absorbent hydrogen maintained higher total chlorophyll content and soil water potential compared to control plants. Bean plant is more sensitive to water amount trapped in SAH and this enhancement of water holding capacity caused positive effects on the physiological changes, growth and productivity of bean plants. Maximum addition of SAH (0.9%) gave the best plant growth after 25 days**.**

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