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Evaluate the effect of different rates of super absorbent polymer (SAP) on soil properties and yield components of sesame crop with desert soil

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Abstract

So far, no method has been introduced to improve the water holding capacity of sandy soil in the Pakistan's Thar Desert. Meanwhile, other countries such as Iran, China, Europe, and the United States have worked on mixing SAP to improve water holding capacity, and improving water use efficiency to increase crop production on low permeability soils. The same study was conducted on Thar soil of Pakistan to improve water holding capacity and crop production. In this regard, pot experiments were conducted to assess the effect of different proportions of SAP, including four treatments: i) T_0 = control (no mixing of SAP), ii) T_1 = SAP mix with soil @ 6 kg ha^{-1}, iii) T_2 = SAP mix with soil @ 9 kg ha^{-1} and iv) T_3 = SAP mix with soil @ 12 kg ha^{-1}, every treatment was related with three replications. The irrigation water requirement was determined using CROPWAT (8.0) Model. Results indicated that the soil physical properties was significant affected and soil holding capacity was increased from 24 % to 35 % with application of SAP. Similarly, soil pH and EC was significantly decreased. Moreover, crop yield and water use efficiency was slightly increased along with the increase of SAP as compared to control. Statistical analysis indicates that plant height is significant and stem circumference, capsule number, capsule length and test weight are not significant (p = 0.05). As a concern for climate change forecasting, the application of an SAP dose of 12 kg ha-1 is suitable for sesame production in desert soils.

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Introduction

Arid and semi-arid areas are faced with uncertain and deficient rainfall problems. Particularly remarkable soil features, lack of agricultural land and poor conditions of producers allow them to adopt more efficient and economical instruments of micro-irrigation practices like conventional methods and sprinkler and drip irrigation. However, Pakistani researchers have not addressed the use of materials to improve the water holding capacity of sandy soil using Super Absorbent Polymers. Like as, researchers from other countries such as Iran, China, Europe, USA and others countries have been working on using of SAP to progress the water retention capacity, water utilization efficiency and crop yield of low permeability soil. Keshavars *et al.* (2012) strongly recommended that the application of SAP with soil increase irrigation duration of the crops. According to the literature, 10.57% of the total land of this word is in the desert (sandy soil), or the area of arable land is widest among the areas with very little annual precipitation. Since one-third of the land area is covered with deserts, it is necessary to effectively irrigate desert areas to meet future and current food requirements. The Tar Desert is the 17th largest desert in the world and has an area of 200,000 square kilometers. It is 75% in India and 25% in Pakistan (Singhvi and Kar, 1992). The central problem in the desert soil is its high permeability, most water used for irrigation penetrates deeply, meetings groundwater, rises the groundwater level.

In contrast, water relies heavily on rainfall. This precious water can be used in a well-organized way to reduce the permeability of the sandy soil and as a result it is possible to increase the water retention capacity of the soil crop root zone over a long period of time and the irrigation interval can be lengthened.

Despite the harsh living environment, these areas of the desert were engaged by significant figures of livestock and people. People in the desert mainly live semi-nomadic life, move continually from one place to another and look for water and animal feed (Sinha *et al.,* 1996). For the soil and climate conditions to consider, research and resolution in a retrograde field like Thar Desert, where livelihoods are based entirely on rainwater utilization, in contrast to what is very incomplete, the second serious threat in the desert is very porous soil. It is recommended by research evidence that soil moisture content increases significantly when soil is mixed with SAP, so that sedimented water is not constrained to soil as soil dries. Furthermore, fertilization is also possible by application of SAP to the soil as it can absorb fertilizer and release it with water (Lawrence *et al.,* 2009; Islam *et al.,* 2011; Rajiv *et al.,* 2014).

Sesame (*Sesamum indicum* L.) is the largest conventional oil seed cultivated for its edible oil on the subcontinent. It contains a lot of oil (50% to 60%), hence it is recognized as the king of oil seeds (Toan *et al.,* 2010). Such kinds of crops can be grown in Thar Desert because of the small accessibility of water. In 2006, sesame was cultivated in Sindh Province about 34000 hectares, in Punjab 75,000 hectares, in KPK about 100 hectares and in Balochistan about 3400 hectares, with the production of 1400, 31600, 100 and 2000 tons respectively (Saleem *et al.,* 2008). In this paper, the effect of different proportions of SAP has been evaluated at field from the viewpoint of water use efficiency, irrigation application efficiency, soil salt concentration and plant growth parameter.

Materials and methods

Study Area

This experiment was carried out at field station of department of Irrigation and Drainage, Sindh Agricultural University, Tando jam. GPS coordinates of experiment site are latitude: 25 ° 25'40.21 "N; longitude: 68 ° 31'40.40" E, altitude: 26 m. The aim of this study is to improve the water holding capacity of Thar Desert soil using SAP with different mixing ratios.

Super Absorbent Polymers Treatments

The study is based on complete randomized block design (CRBD), which includes 4 treatments: i) T_0 = control (no mixing of SAP), ii) T_1 = SAP mix with soil @ 6 kg/ha, iii) T_2 = SAP mix with soil @ 9 kg/ha and iv) T_3 = SAP mix with soil @ 12 kg/ha, every treatment was related with three replications. A total of 12 pots were used in the experiment. The dimension each pot was of 0.5 m in depth and 0.4 m in diameter.

The bottom of these pots was provided with permeable materials and the top was filled with soil of Thar Desert. Water quality of irrigation water plays an important role in the soil's water retention capacity when SAP is added and also affects the yield of crops. When water is applied to the SAP mixing field, the water holding capacity is directly proportional to the water quality.

If SAP applications are employed, salt water is not recommended (Rousta *et al.,* 2013). In this study, groundwater was used as irrigation in all treatments during the experiment. The water samples collected throughout the experiment were analyzed in the soil-water laboratory of the irrigation drainage division.

Table 1. Irrigation scheduling for sesame crop under different treatments.

Irrigation	Date of Irrigation	Volume of water applied under each treatments (cubic meter)		
		Depth (m)	Area (m^2)	Volume (m^3)
Soaking	23/06/2017	0.1	0.122	0.0122
1st	1/7/2017	0.021	0.122	0.002562
2nd	11/8/2017	0.022	0.122	0.002684
3rd	16-08-2017	0.022	0.122	0.002684
4th	20/08/2017	0.022	0.122	0.002684
5th	26-08-2017	0.025	0.122	0.00305
6th	30/08/2017	0.0256	0.122	0.003123
7th	5/9/2017	0.0226	0.122	0.002757
8th	10/9/2017	0.0256	0.122	0.003123
9th	16/09/2017	0.0256	0.122	0.003123
10th	20-09-2017	0.0256	0.122	0.003123
11th	30/09/2017	0.0315	0.122	0.003843
	Total	0.3685		0.044957
Total volume of water applied in m^3 ha^{-1} under each treatment				3685

The chemical quality parameters of irrigation water, i.e., TDS, EC and pH and their average values were found within the ranges of EC <1.50 µS /m^{-1}, TDS = 1000 ppm or less and pH = 6.5 to 8.5.

As a result, all of the above parameters values were termed as good quality water, because all above parameters are within maximum contamination (MCL) as standard level.

Soil Samples and Collections

The soil was collected from suburban areas near Mithi City, District Tharparkar of Sindh province. The textural class of soil was loamy sand, which was taken at a depth of 0- 30 cm from the top soil. To determine the physical and chemical properties of soil such as dry bulk density, soil porosity and water holding capacity before and after experiment. Likewise the soil samples were taken for the analysis, from each treatments plot at depth of 0-15 cm. Bouyoucous Hygrometer method was used for determination texture class of soil (Bouyoucos, 1962).

Plant Growth Measurements

The laboratory was visited every other day and measurements of different parameters of crop growth after experiment were recorded.

The height of each plant, circumference of the stem, at a height of 10 cm from the bottom, the number of branches and the number of capsules in each plant were counted.

The number of each five plants randomly selected in each treatment of control and other treatments of SAP mixed plots was counted. In order to determine the amount of seed per capsule, they were threshed at maturity from the specific five plants in each of treatment, and the amount of seeds was recorded. 1000 seeds from seed lots separated in each treatment of control and other SAP treatments were recorded and weighed.

Table 2. ANOVA results for growth parameters of plant.

Source	DF	SS	MS	F	P
			Height of Plant		
Replication	2	47.62	23.81	1.24	0.2972
Treatment	3	4000.06	1333.35	69.50	0.0000
Error	54	1036.02	19.19		
Total	59	5083.70			
Grand Mean 61.862		CV 7.08			
			Stem Girth		
Replication	2	0.01377	0.00689	0.84	0.4364
Treatment	3	0.27282	0.09094	11.12	0.0000
Error	54	0.44151	0.00818		
Total	59	0.72810			
Grand Mean 1.7439		CV 5.19			
			Leaves per plant		
Replication	2	4.233	2.117	0.36	0.7027
Treatment	3	340.850	113.617	19.06	0.0000
Error	54	321.900	5.961		
Total	59	666.983			
Grand Mean 17.183		CV 14.21			
			Capsules per plant		
Replication	2	30.905	15.453	1.46	0.2421
Treatment	3	729.441	243.147	22.92	0.0000
Error	54	572.909	10.609		
Total	59				
Grand Mean 16.127		CV 20.20			
			Length of Capsule		
Replication	2	0.07803	0.03901	3.5	0.3072
Treatment	3	0.16800	0.05660	5.02	0.0038
Error	54	0.60197	0.01115		
Total	59				
Grand Mean 1.8125		CV 5.83			
			Seed index		
Replication	2	0.64702	0.32351	3.31	0.4401
Treatment	3	0.28786	0.09595	0.98	0.4085
Error	54	5.28123	0.09780		
Total	59	6.21611			
Grand Mean 4.3704		CV 7.16			

Note: DF= Degree of Freedom, SS= Sum of Square, MS= Mean of Square, F = F test values, CV= Compare the Variability and P = Probability.

Irrigation Plan

Irrigation scheduling based on soil moisture reduction of 50% soil under all treatment for sesame, CROPWAT model was used. As plants consume water through the roots, it is essential that enough water remains in the depth of the root area. The CROPWAT model was used to determine total water volume and irrigation water volume for all sesame treatments. The model will be executed in the last year's weather data etc. To that end, we collected data from weather stations DRIP Tandojam. Tandojam's average weather data is shown in Fig. 1 and Fig. 2.

Water Use Efficiency

Water use efficiency (WUE) was calculated by the total yield per water consumed during the crop term equations given by Majumdar (2000).

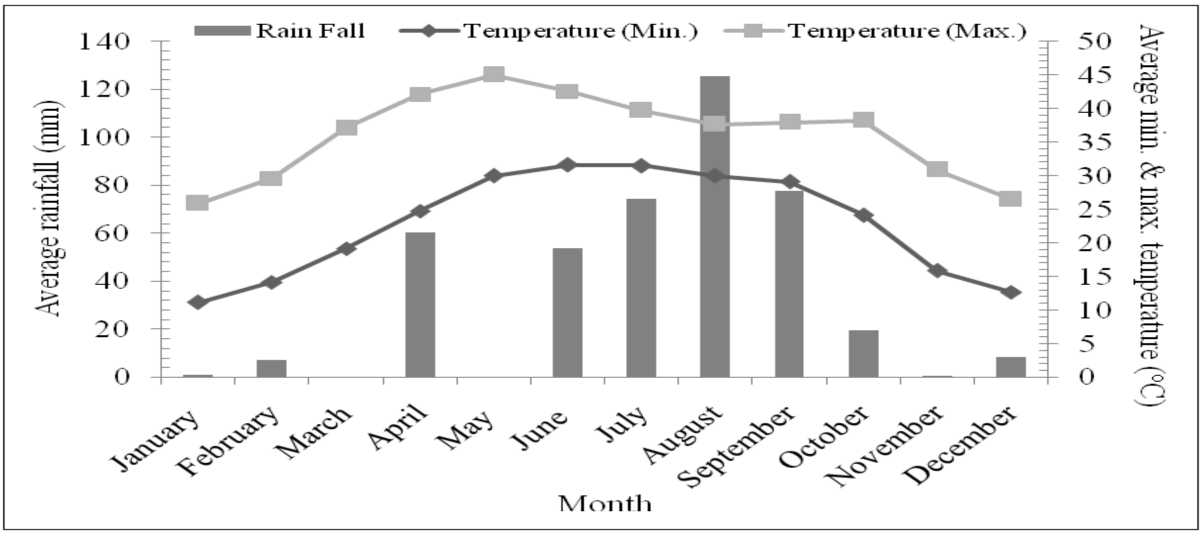

Fig. 1. Ten years average Rainfall, mimnum and maxium temperature.

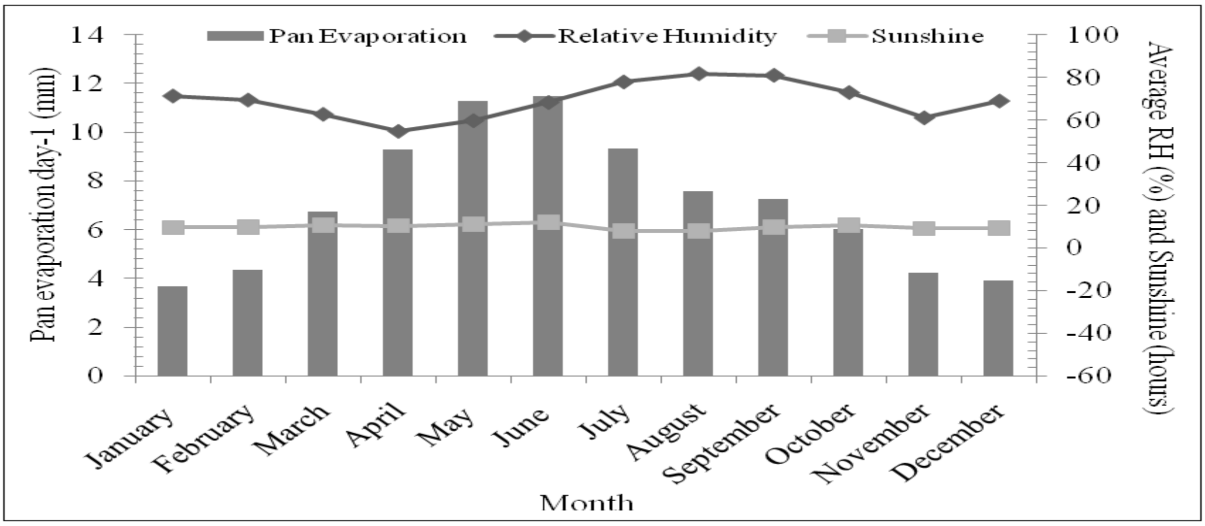

Fig. 2. Ten years average pan evaporation per day, relative humidity and sunshine hours.

Data Analysis

The required data were statistically analyzed using ANOVA (analysis of variance) procedure followed by fully randomized design (CRD) in field trials. The t-test test was conducted to observe the significance of each plant growth parameter, yield component and water utilization efficiency separately using the average in this experiment.

The means were associated by Tukey test at $p < 0.05$. Software STATISTIX 8.1 was used for statistical analysis.

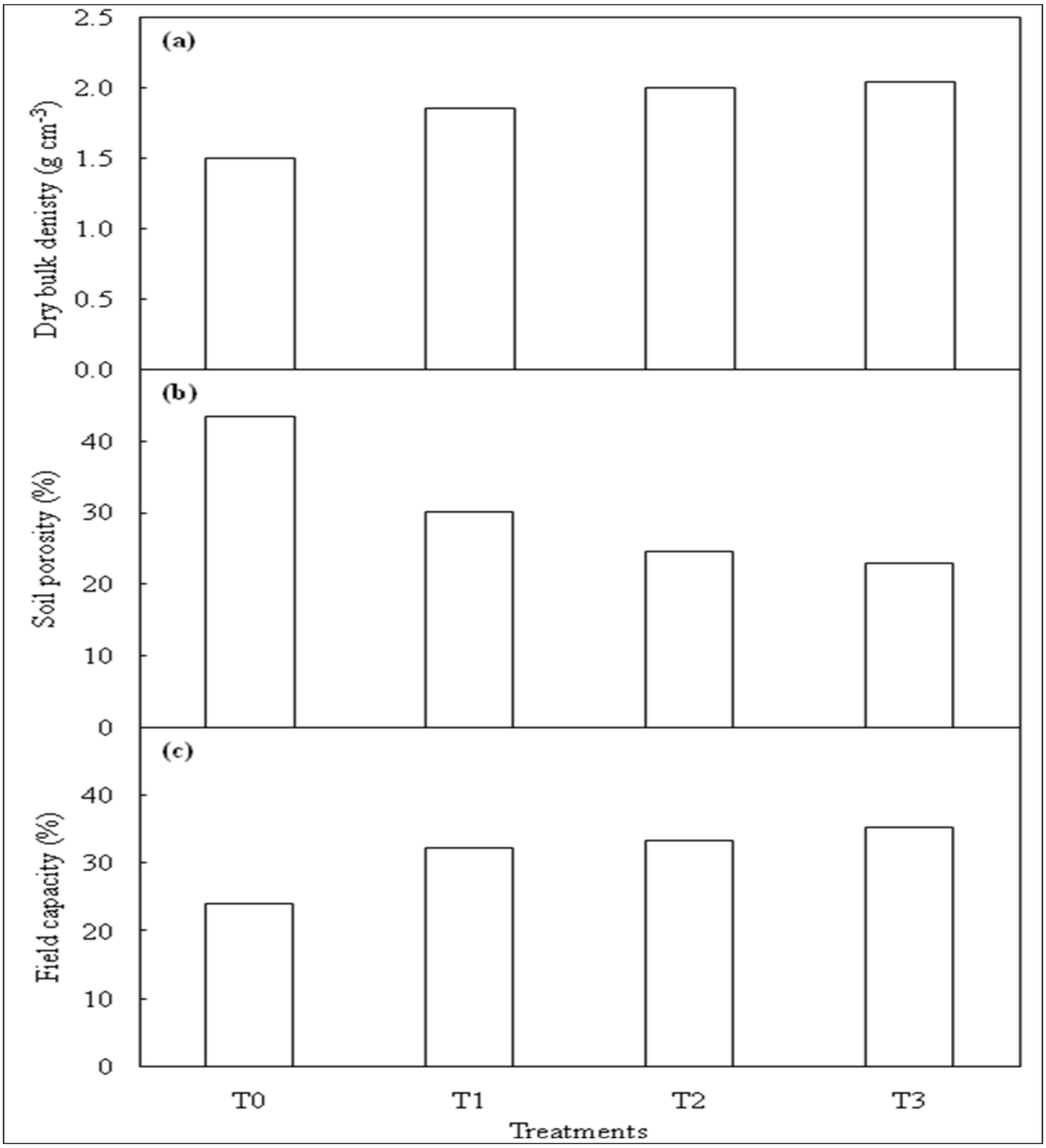

Fig. 3. Average values for dry bulk density, soil porosity and water holding capacity under different treatments.

Results and discussion

Applied Irrigation Water

Table 1 shows applying water to sesame under various treatments. The total amount of irrigation water applied to the crop in each treatment is 0.0449 m^3, which corresponds to 3685 m^3 ha^{-1}. It remains constant under different treatments

Soil Physical Properties

After the experiment, the average value of the dry bulk density of soil for control treatment at the depth of 0 to 15 cm was determined as 1.50 g/cm^3, whereas for the remained treatments values were 2.01, 2.02 and 2.04 g/cm^3 for T_1, T_2 and T_3 respectively (Fig. 3a). Similarly, the average values of porosity for control treatment was determined as 43.40 % at the depth 0-15 cm whereas for the treatment T_1, T_2 and T_3 were calculated as 24.2, 23.8 and 23 % respectively (Fig. 3b). In addition, the calculated average value of water holding capacity for the control treatment was determined 24%, and for the remaining treatments, i.e., T_1, T_2 and T_3 were determined 32.25, 33.35 and

35.2%, respectively (Fig. 3c). Rousta *et al.* (2013) reported that water holding capacity depends upon the irrigation water quality; otherwise it can be reduced in case saline irrigation water. Bai *et al.* (2010) reported that soil moisture is increased from 6.20 % to 32 % with the application of SAP. SAP as hydro-gel is a water saving material and soil conditioners, these materials are hydrophilic networks that can take in and maintain huge water quantity (Mohammad *et al.,* 2008).

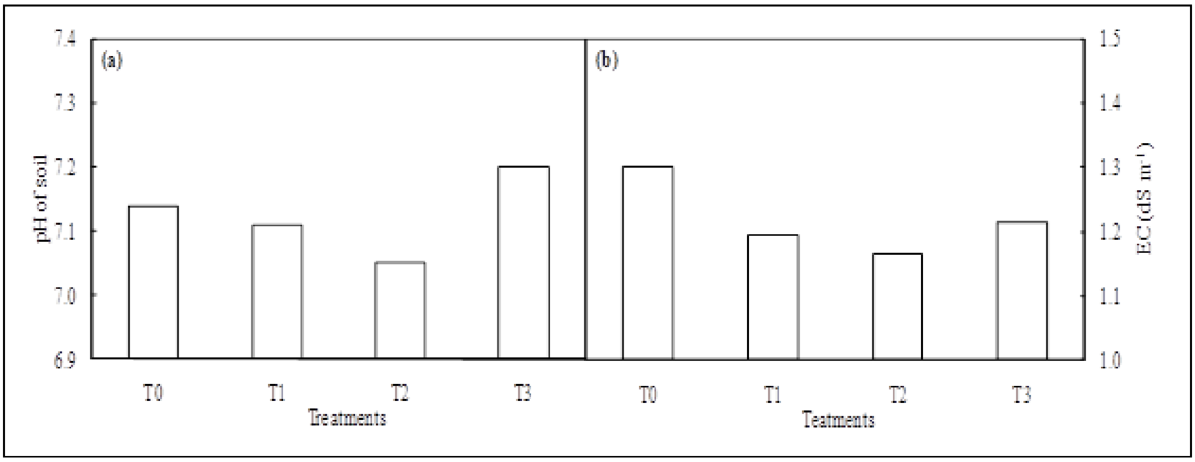

Fig. 4. Average values for pH and EC of soil under different treatments.

Soil Chemical Proprieties

SAP was applied to the pots in different proportions under all treatments; it was collected at derived depth as well as in root zone and exaggerated the soil chemistry and other crop growth parameters. Fig. 4 shows the average values of ECe and pH for collected soil samples at depth of 0 to 15 cm depth under all treatments.

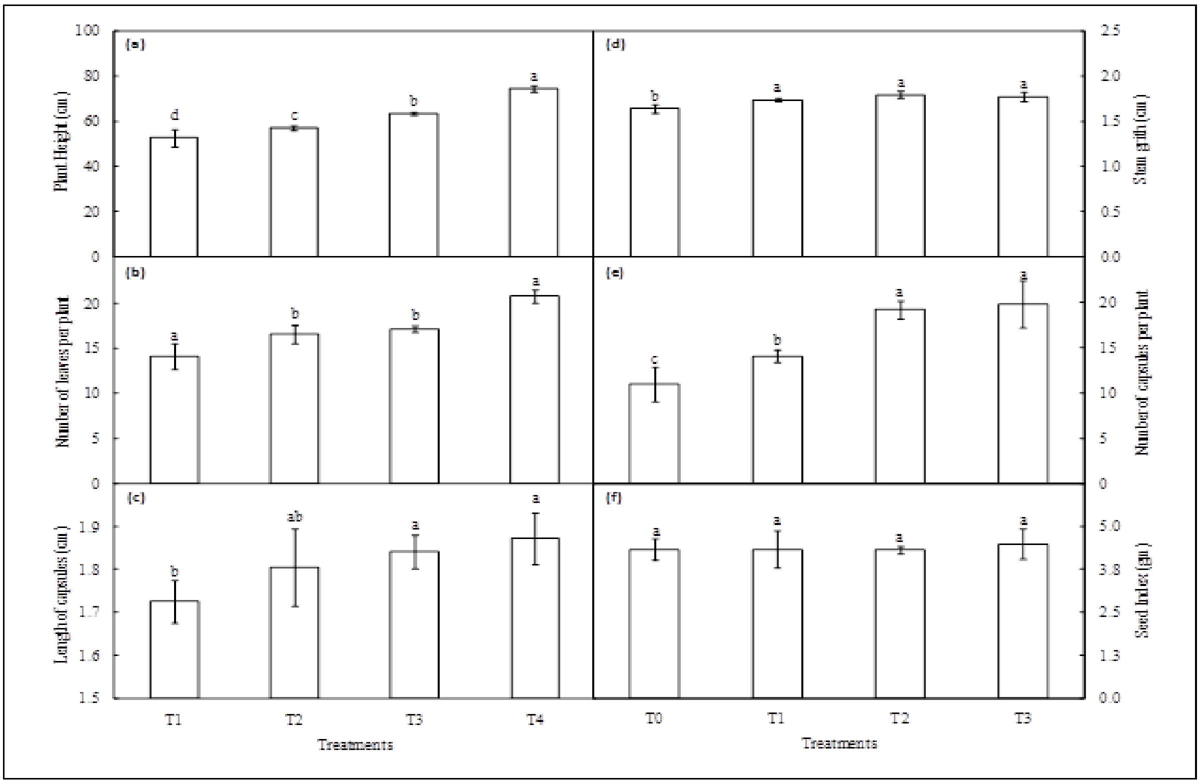

Fig. 5. Plant height, stem girth, number of leaves per plant, capsules per plant, length of capsule and seed Index under different treatment.

The average pH obtained for the control treatment was 7.14 and for other treatments i.e. T_1, T_2 and T_3 obtained were 7.11, 7.05 and 7.20 respectively. Similarly, the average ECe obtained for the control treatment was 1.30 dS m^{-1} and for other treatments i.e. T_1, T_2 and T_3 were 1.20, 1.17 and 1.22 dS m^{-1} respectively. The results revealed that ECe is decreasing due to the absorption of water and physiological solution by SAP, which is identical with the value of Deraji *et al.* (2010).

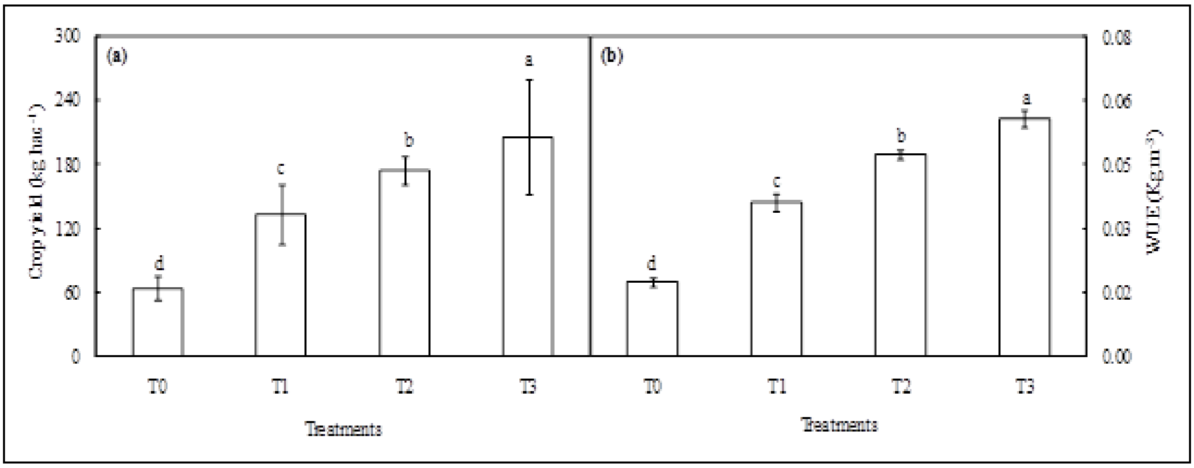

Fig. 6. Crop yield and water use efficiency under different treatments.

Plant Growth Parameters

The experimental results of average values for plant growth parameters are depicted in Fig. 5. The average value of plant height for the control treatment was obtained 53 cm and for other treatments i.e. T_1, T_2 and T_3 were obtained 57, 63 and 74 respectively. The average value of plant stem girth for the control treatment was observed 1.64 cm and for other treatments i.e. T_1, T_2 and T_3 were observed 1.74, 1.79 and 1.81 respectively. Similarly, the numbers of leave per plant for control treatment was perceived 14.1, and for other treatments i.e. T_1, T_2 and T_3 were perceived 16.6, 17.2 and 20.8 respectively. In addition, 11 capsules per plant were observed in the control treatment, and 14, 19 and 20 capsules per plant were observed in treatments T_1, T_2 and T_3 respectively. The length of the capsule per plant was observed 1.73 cm in the control treatment whereas, this plant parameter other treatments T_1, T_2 and T_3 were detected 1.81, 1.84 and 1.87 cm respectively. It is apparent from Fig. 5a and Fig. 5e, that the plant height and the number of capsules are often more SAP mix application as compared to the control treatment. Khalilpour (2001) reported that the application of SAP improves the plant growth parameters by increasing the water holding capacity in the soil.

Crop Yield and Water Use Efficiency

Yield parameters were determined after harvesting i.e. seed index and crop yield. The average values of seed index of control treatment i.e. T_o was 4.33 grams, 4.34 grams for T_1, 4.32 grams for T_2 and 4.49 grams for T_3 respectively as shown in Fig. 5(f). The result shows that T_3 treatment have produced higher seed index as compared to other treatments, it is due to because of more application of SAP is used in the treatment. The average values of the yield of crop under all treatments were 63.77 kg ha^{-1} for control treatment, 133.21 kg ha^{-1} for T_1, 174.67 kg ha^{-1} for T_2 and 205.22 kg ha^{-1} for T_3 respectively as shown in Fig. 6(a). Result shows that yield of crop under SAP mix application treatments were higher than control treatment. This is might be due to that T_3 provided more rate of SAP as compared to other, which provide better conditions of moisture. These results are very small as suggested by the researches. But higher yield can be achieved, if it is practiced in the ordinary field conditions. WUE (Water use efficiency) of sesame crop under different treatments are shown in Fig. 6(b). They resulted that WUE in control treatment was 0.02 kg m^{-3}, 0.04 kg m^{-3} in T_1, 0.05 kg m^{-3} in T_2

and 0.06 kg m^{-3} in T_3 respectively. Therefore it is clear from the results that water use efficiency in treatment T_3 is higher as compared to other treatments and also gave higher yield respectively. Further, the ANOVA was used to confirm significantly effect on WUE of the dissimilar treatments at $p < 0.05$.

Statistical Analysis

ANOVA results for plant growth parameters are shown in Table 2. F-test resulted that plant height was statistical significant different from one another under all treatments at $P < 0.05$, the F-test values showed that seed index was not statistical significant, whereas, yield of crop was statistical significant from one another. Furthermore, ANOVA results for yield and WUE were statistically significant from one another and resulted shows in the Fig. 6a and Fig. 6b. Means were divided into four classes (A, B, C and D) and groups were significant at $p < 0.05$. Above parameters were significant affected, whereas, comparison test was performed for determination of the significance of stem of the plant girth, quantity of capsules per plant, length of capsule, quantity of leaves and seed index at desired significant level ($p < 0.05$), which were not statistically significant from one another.

Conclusion

Application of SAP at rate of 12 kg ha^{-1} in T_3 treatment gave better results, increased water holding capacity and crop yield as compared to other treatments. SAP application is benefit for crop productivity, because SAP provides additional moisture and healthy environment to soil and increased soil physical properties as well as water holding capacity. The results of this study on the application of SAP give overall better results in soil properties with relation to field capacity. It is recommended that the application of SAP at the rate of 12 kg ha^{-1} is appropriate for sesame crop production in the arid and semi-arid regions of the Thar Desert soil could be an effective drought mitigation strategy for field crop production.

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