

Polyacrylamide Polymer and Salinity Effects on Water Requirement of *Conocarpus lancifolius* and Selected Properties of Sandy Loam Soil

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Abstract

Plant production in Kuwait is constrained by extreme aridity of the climate and low water-holding capacity (WHC) of the soil. Excess water is applied through irrigation to overcome these limitations. Thus, the efficient management of the soil and water under these situations essentially requires increase in the WHC and reduction losses due to deep percolation. For this purpose, five cross-linked polyacrylamide (PAM) polymers (Hydrosorce, Hydrogel, Agrihope, Broadleaf P₄, and Aquasorb) were applied at 0, 0.1, 0.2, or 0.4% w/w by weight for improving the WHC and some soil properties of a typical sandy loam soil widely used for growing ornamental plants in Kuwait. Two kilograms of polymer-amended soil was placed in five-liter polyethylene containers and single plant of *Conocarpus lancifolius* was grown in each container. Experimental plants were maintained under nonlimiting soil moisture regime in an evaporatively cooled greenhouse, and were irrigated with salinized (1.6, 2.5 or 5.0 dS/ m) Hoagland nutrient solution to attain field capacity, as per their need. Results indicated that soils amended with polymers other than Broadleaf required as much as 57% more water than the control soil to saturate initially, but required lower amounts of water to reach the field capacity subsequently. Incorporation of polymers increased the available water capacity of the soil from 7.29% in control to 18.75% in 0.4 % Agrihope. *Conocarpus* plants in soils amended with 0.4 % Agrihope required 50% less water than those in the control soil. The polymer effects were reduced when the irrigation water salinity was increased to 2.5 dS/ m and above. Plants irrigated with 5 dS/ m water [3,200 ppm (Total Dissolved Salts)] utilized approximately 42.0 % less water than those irrigated with 1.6 dS/ m (1024 ppm TDS) water. The effects of polymer on soil properties varied with the each parameter.

Keywords: Hydrophilic polymers, irrigation water salinity, water holding capacity, evapotranspiration, arid climate.

Introduction

Due to a surge in greenery activities in Kuwait, demands for irrigation water have increased dramatically in recent years and are expected to be over 6.0×10^6 m³/ d soon (KISR, 1996). While the groundwater resources in the country are depleting rather rapidly, the use of desalinated water in landscape irrigation is cost prohibitive. The native soil is predominantly sandy with CaCO₃ hardpan layer occurring at varying depths from surface to 1- 2 m (KISR, 1999). Because of the extreme aridity of the climate and sandy nature of the soil, plant growth is severely constrained by low water-holding capacity (WHC) and high evapotranspiration rates. Therefore, it is a common practice to apply excess irrigation water. Thus, the management of these soils must aim at increasing WHC and reducing losses due to deep percolation and evapotranspiration. The WHC of coarse-textured soils can be improved with the addition of hydrophilic polymers that can absorb water up to hundreds of times of their dry weight. The large quantity of water retained by these polymers provides extra available water to the plants to promote better growth while reducing the losses due to deep percolation and evaporation from the soil surface. More available water in soil also means less frequent watering or irrigation and reduced salt build up in the root zone under the arid climatic conditions (Bhat et al., 2006).

Recently introduced hydrophilic polymers have high molecular weights, low application rates, and important environment, soil conservation and irrigation efficiency benefits for general agriculture, making the use of these products economically feasible (Sivapalan, 2006). Sivapalan (2006) demonstrated that the amount of water retained by a sandy soil increased by 23 and 95% by adding very small amounts (0.03 and 0.07% by weight, respectively) of polymer to the soil. This increase in

water retention can reduce the amount of water otherwise lost by deep percolation. The polymers are also effective in improving soil aggregates, preventing capillary rise of water, reducing cumulative evaporation and improving establishment, growth and water-use efficiency of a wide range of crops (Johnson and Veltkamp, 1985; Choudhary et al., 1995; Al-Omran and Al-Harbi 1997; Sivapalan, 2006). However, the expansion of polyacrylamide (PAM) polymers in soil can be limited by soil physical conditions and other factors. Johnson (1984a; 1984b) reported that the water storage properties of these products were significantly affected by the nature and concentrations of dissolved salts in irrigation water. The soil conditioners were also shown to induce changes in some properties of arid soils (Falatah and Omran, 1993; Falatah et al., 1996; Al-Omran and Al-Harbi, 1997; Falatah, 1998).

Although the use of hydrophilic polymers has good potential for improving the WHC of sandy soils and enhancing the growth of landscape plants, the feasibility of treating the soil with these substances has not been exploited in the past in Kuwait. Therefore, studies reported here were conducted to select the most promising PAM polymers to improve the WHC of the sandy soil and determine their effects on selected soil properties under Kuwait's environmental conditions.

Materials and Methods

Polymers

Five cross-linked PAM polymers, Aquasorb (cross-linked copolymers of acrylamide and potassium acrylate from SNF Floerger, France), Agrihope (Gel-conditioner, cross-linked sodium polyacrylate, Nippon Shokubai Co., Japan), Broadleaf P₄ (high molecular weight, cross-linked PAM, Agric. Polymers Ltd. UK), Hydrogel (starch copolymer, Potassium acrylate, Finn Corporation, USA) and Hydrosorce (a cross-linked PAM, potassium or sodium acrylate, Western Polyacrylamide, Inc., USA) were evaluated in the study. The average particle size ranged from 0.25 – 1.00 mm (Aquasorb, AS; Agrihope, AH; Broadleaf P₄, BL; Hydrogel, HG) to 2.0 – 4.0 mm (HydroSource, HS)

Soil Characterization

Locally available agricultural soil was obtained into which PAM polymers were thoroughly incorporated at different rates. Representative samples from each polymer treatment were analyzed for various physical and chemical parameters.

Experimental Conditions

The experiment was conducted from June to October in an evaporatively cooled greenhouse. The indoor conditions during the initial phase of the experiment (July- August) were warm with average maximum and minimum temperatures ranging between 33 - 42⁰C and 28 - 32⁰C, respectively, moderately dry (relative humidity ranging between 50 and 70%) and high light intensity (92 – 252 mol/ m² /s)). The conditions became slightly moderate from September to October.

Experimental Details

Measured quantities of the polymer (0, 0.1, 0.2, or 0.4% by weight) were thoroughly mixed with soil and uniform quantities (2 kg) of this soil were placed in five-liter polyethylene containers. One plant of *Conocarpus lancifolius* (a widely-used ornamental plant with high water requirements) was planted in the center of each pot. The soil was irrigated with water of different salinity levels (1.6, 2.5 or 5.0 dS/ m) and the volume of water required to saturate the soil was recorded. Salinity levels were established by using chlorides of calcium and sodium. Subsequent irrigations were applied when a prefixed reading was indicated on the potentiometer. The amount of water required to attain field capacity was recorded. Moisture content in the soil was determined by oven-drying the soil sample at 110⁰C. Soil

samples were collected at two month intervals and analyzed for important chemical and physical parameters using recommended procedures (USDA, 1996; Page et al., 1982).

Data Analysis

In all, 46 treatments (5 polymers, 3 concentrations and 3 salinity levels; one control) were arranged in complete randomized block design with five containers per treatment and three replications. Data on height, plant cover and physical condition of experimental plants were recorded at monthly intervals. Chlorophyll index of upper and lower leaves was measured twice during the investigations using a chlorophyll meter (model No. COM – 200, Opti- Sciences, USA). Evapotranspiration rate was recorded using the gravimetric method. The total amount of water used for irrigation was determined upon completion of the study.

Data were analyzed by Analysis of Variance (ANOVA) procedure using the R method (R).

Results

Plant Performance

The height and canopy growths in *Conocarpus* plants were not influenced by incorporation of polymer into the soil (Table 1). In contrast, the increase in salinity reduced the growth of plants. Treatment of the sandy soil with polymers did not have any effect on chlorophyll content in leaves (data not presented); however, increase in the salinity of irrigation water reduced its level.

Table 1: Height and Canopy Growth and Water Used by *Conocarpus* Plants in Polymer Amended Soil

Polymers and Concentration	Height Growth Rate(%)			Canopy Growth (%)			Water Applied to Soil (l) ^c		
	1.6 ^b	2.5	5.0	1.6	2.5	5.0	1.6	2.5	5.0
No Polymer	25.7	18.5	5.7	22.4	12.2	2.8	5.50	4.07	3.20
Aquasorb 0.1	32.9	23.5	18.3	20.0	-4.7	6.9	5.22	4.23	3.33
Aquasorb 0.2	48.6	19.5	13.3	17.5	3.9	3.9	5.00	3.99	3.23
Aquasorb 0.4	45.1	24.0	17.2	24.2	9.2	10.7	5.25	3.85	3.12
Agrihope 0.1	47.1	25.4	15.9	26.8	0.8	2.8	4.43	3.43	3.11
Agrihope 0.2	48.0	24.5	15.4	33.7	10.0	9.6	4.23	3.62	2.63
Agrihope 0.4	62.3	31.9	16.1	36.2	30.0	26.6	4.05	3.15	2.75
Broadleaf P ⁴ 0.1	38.4	24.5	6.1	26.8	15.2	15.6	4.80	3.80	3.02
Broadleaf P ⁴ 0.2	49.5	32.5	16.2	37.0	30.6	10.5	4.83	3.73	2.96
Broadleaf P ⁴ 0.4	60.2	23.7	10.7	34.2	13.1	10.1	4.86	3.81	3.04
Hydrogel 0.1	40.8	22.3	8.4	32.7	13.8	-5.6	4.57	3.88	2.90
Hydrogel 0.2	33.4	20.6	9.6	35.2	29.3	6.8	4.86	3.73	3.03
Hydrogel 0.4	27.0	14.4	8.7	23.0	14.1	11.7	4.95	3.35	3.00
Hydrosorce 0.1	32.7	17.3	11.1	17.9	23.9	14.4	4.97	3.98	3.03
Hydrosorce 0.2	22.9	18.7	10.2	22.1	12.9	-7.5	5.35	3.92	3.10
Hydrosorce 0.4	32.5	28.1	20.3	29.3	9.0	5.2	5.89	4.36	3.13
Significance ^d									
Polymer	NS			NS			* (0.09)		
Conc. (C)	NS			NS			NS		
Salinity (S)	** (5.0)			** (1.2)			*(0.05)		
P X C	NS			NS			*		
P X S	NS			NS			*		
P X C X S	NS			NS			NS		

a. Polymer was thoroughly mixed with the soil at various concentrations before planting *Conocarpus*.

b. Plants were irrigated with salinized nutrient solution. Chlorides of sodium and calcium were used to obtain salinity levels of 1.6, 2.5 or 5.0 dS/m.

c. Total amount of water applied to *Conocarpus* plants during the 90-d duration of the study.

d. Data on amount of water used were statistically analyzed using analysis of variance (ANOVA) procedures. *, ** = significant at $P \leq 0.05$ or $P \leq 0.01$, respectively

Plant Water Needs

Conocarpus plants grown in Agrihope, Broadleaf and Hydrogel-amended growing substrates required significantly less irrigation water than those grown in control soil or in soils amended with Hydrosorce and Aquasorb. Treating the soil with 0.4% Agrihope reduced the water requirement by 26.4% (water salinity 1.6 dS/ m) compared to the control (Table 1). In general, the ability of polymer in reducing water needs was reduced when the salinity of irrigation water was increased from 1.6 to 5 dS/ m.

Physical Properties of the Growing Medium

Incorporation of Hydrogel, Hydrosorce and Broadleaf P₄ into the soil lowered its bulk density (Table 2). In contrast, treating the soil with 0.1 and 0.2% Aquasorb and Agrihope increased the bulk density slightly, but these substances at 0.4% had no effect. Amendment of soils with Agrihope and Broadleaf increased the porosity, whereas treatment with Aquasorb and Hydrogel had negative effects. The soils amended with 0.4% Agrihope had the highest available water capacity (difference between moisture levels at 0.1 and 15 bar pressure) at the beginning of the study. The WHC of the soil did not increase linearly with the increase in polymer concentration.

Table 2: Physical Properties of Polymer-amended Sandy Loam Soil at the Beginning of the Study

Polymers and Concentration ^a	Bulk Density (g/ cm ³)	Porosity (%)	Saturation Water Volume (ml) ^b	Soil Moisture After Irrigation ^c
No Polymer	1.33	72.37	350	19.48
Aquasorb 0.1	1.46	67.68	350	22.34
Aquasorb 0.2	1.64	48.05	425	28.29
Aquasorb 0.4	0.92	59.86	450	31.36
Agrihope 0.1	1.05	87.09	325	21.61
Agrihope 0.2	1.30	88.75	400	23.40
Agrihope 0.4	1.49	90.93	450	33.52
Broadleaf P ₄ 0.1	1.69	82.47	300	23.14
Broadleaf P ₄ 0.2	0.91	90.76	325	24.74
Broadleaf P ₄ 0.4	1.09	83.74	350	32.51
Hydrogel 0.1	1.03	64.36	350	20.76
Hydrogel 0.2	1.33	66.57	425	23.70
Hydrogel 0.4	1.31	77.59	550	24.42
Hydrosorce 0.1	1.21	28.03	300	19.54
Hydrosorce 0.2	0.93	78.30	350	20.25
Hydrosorce 0.4	1.04	74.42	475	27.74
Significance ^c	**	**		
SEM	0.06	4.2		

a. Polymer was thoroughly mixed with the soil at various concentrations before planting *Conocarpus*.

b. Saturation Volume was determined for a composite sample prior to the initiation of study.

c. Moisture content was determined by oven drying the soil samples at 110°C to a constant weight.

d. Data on amount of water used were statistically analyzed using analysis of variance (ANOVA) procedures. * = significant at $P \leq 0.05$, ** = Significant at $P \leq 0.01$.

Saturation Water Volume

The amount of water needed to saturate the soil was influenced by both the concentration and type of polymer (Table 2). The soils amended with Agrihope, Aquasorb, Hydrogel and Hydrosorce required as much as 57% more water than the control soil to attain initial saturation (Table 2).

Moisture Content

After irrigation, the soils amended with 0.4% Agrihope and 0.4% Broadleaf contained 72.0 and 66.9% higher moisture content, respectively than the control soil (19.48%).

Available Water Capacity

At the time of initiation of the study, the available water capacity (AWC) ranged between 7.29% in control and 19.38% in the soil that was treated with 0.4% Agrihope. After 90 d of planting (DAP), the AWC was highest in the soil that was treated with either 0.4% Agrihope or 0.4% Broadleaf (Table 3).

Table 3: Available Water Capacity of Soils Amended with Various Polymers

Polymers and Concentrations ^a	Time 0	Available Water Capacity (%) ^b		
		90 DAP		
		1.6	2.5	5.0
No Polymer	7.29	4.34	3.62	3.40
Aquasorb 0.1	13.16	9.25	5.35	4.42
Aquasorb 0.2	13.36	6.69	5.73	5.02
Aquasorb 0.4	18.79	3.88	5.29	4.77
Agrihope 0.1	12.86	5.74	7.47	8.36
Agrihope 0.2	15.04	5.17	3.14	3.22
Agrihope 0.4	19.38	8.21	8.70	6.54
Broadleaf P ₄ 0.1	9.29	6.66	5.66	4.08
Broadleaf P ₄ 0.2	12.99	6.66	5.70	5.08
Broadleaf P ₄ 0.4	14.09	8.01	6.47	6.34
Hydrogel 0.1	10.75	4.46	6.26	5.10
Hydrogel 0.2	8.68	9.11	8.80	8.60
Hydrogel 0.4	11.32	4.81	5.49	4.82
Hydrosorce 0.1	16.85	6.08	9.37	7.27
Hydrosorce 0.2	17.01	2.37	2.70	3.05
Hydrosorce 0.4	17.68	4.67	4.66	4.59
Significance ^c				
Polymers	** (0.99)		* (2.9)	
Concentrations	NS		NS	
Salinity			NS	
P X C			NS	
P X S			NS	
P X C X S			NS	

a. Polymer was thoroughly mixed with the soil at various concentrations before planting *Conocarpus*.

b. Available water capacity is the difference between moisture content at field capacity (0.1 bar) and wilting point (15 bar). Pressure plate apparatus was used to determine the moisture levels at various pressure levels.

c. Data on amount of water used were statistically analyzed using analysis of variance (ANOVA) procedure. * = significant at $P \leq 0.05$, ** = Significant at $P \leq 0.01$.

Chemical Properties of Growing Media

At time zero (before planting), the addition of Agrihope, Aquasorb and Hydrogel at all concentrations, and Hydrosorce at 0.2 and 0.4% increased electrical conductivity, cation exchange capacity and HCO₃ levels of the substrate (Table 4). The addition of Agrihope also increased the levels of Mg, K, CO₃ and SO₄ in the substrate. Similarly, the addition of Hydrogel increased the levels of Ca, Mg, CO₃ and SO₄, whereas Aquasorb addition increased the levels of Na, HCO₃, CO₃ and exchangeable sodium percentage.

Table 4: Chemical Properties of Polymer-amended Sandy Loamy Soil at the Beginning of the Study

Polymer ^a	pHs	ECe	Cation (meq/l)			Anion (meq/l)					CEC meq/100g	ESP (%)
			Ca ⁺²	Mg ⁺²	K ⁺	Na ⁺	CO ₃ ⁻²	HCO ₃ ⁻¹	Cl ⁻¹	SO ₄ ⁻²		
NP	8.1	1.67	9.13	1.88	0.53	7.91	<0.01	0.20	3.86	15.58	2.34	4.81
AH 0.1	7.7	2.12	12.88	2.50	4.05	8.72	1.00	0.50	4.69	21.96	2.87	4.51
AH 0.2	7.8	2.26	11.38	3.63	6.65	5.39	1.00	0.50	6.07	19.48	3.28	2.87
AH 0.4	8.1	2.10	7.75	2.63	11.61	5.22	1.00	2.50	3.09	20.62	3.42	3.32
AS 0.1	7.6	2.41	5.75	1.00	0.55	17.82	2.00	3.50	3.77	15.85	3.22	12.70
AS 0.2	8.2	2.56	4.25	1.50	0.44	19.98	2.00	5.50	1.03	17.65	3.64	15.02
AS 0.4	8.1	2.65	5.62	1.38	0.41	21.12	3.00	4.00	3.76	17.77	3.15	14.48
BL 0.1	8.3	1.29	7.25	1.25	0.35	7.64	1.00	1.50	2.69	11.31	3.86	5.27
BL 0.2	8.2	1.83	4.50	1.75	0.69	12.87	2.00	3.00	3.31	11.51	2.63	9.85
BL 0.4	8.3	1.65	6.75	1.00	0.42	10.55	<0.01	5.50	2.22	11.01	6.35	7.44
HG 0.1	7.1	4.31	29.75	8.50	9.75	8.82	1.00	4.00	2.70	49.12	2.72	2.94
HG 0.2	7.0	3.50	24.25	5.88	5.22	8.75	1.00	3.00	5.52	34.58	3.33	3.27
HG 0.4	7.3	4.56	28.75	7.00	14.64	12.25	1.00	1.00	5.45	55.18	3.64	4.17
HS 0.1	7.8	1.38	7.25	1.25	1.24	2.53	<0.01	1.50	5.65	5.12	2.55	1.81
HS 0.2	7.8	1.94	10.38	4.38	0.89	8.99	<0.01	1.00	3.99	19.65	2.61	4.73
HS 0.4	7.9	2.45	13.50	3.50	6.16	8.21	1.00	0.50	4.90	24.97	5.65	4.05
Sign. ^b Polymer (P)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Concentration (C)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P X C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

a. NP = No polymer (control); AS = Aquasorb; AH = Agrihope; BL = Broadleaf P₄; HG = Hydrogel; HS = Hydrosorb incorporated in to the sandy soil at 0.1% (0.1), 0.2% (0.2) or 0.4% (0.4) by weight. EC = Electrical conductivity; ESP = Exchangeable sodium percentage.

b. Data were analyzed using the ANOVA procedures; NS = Non significant at P=0.05.

At 90 DAP, the effects of polymer addition on chemical properties were noticeable only in respect to pH, Na, SO₄ and Exchangeable sodium percentage (ESP) (Table 5). However, use of saline water for irrigation led to the build up of salts in the soil and consequently, produced higher values of ECe, Na, Cl, SO₄, and ESP than those irrigated with freshwater.

Table 5: Chemical Properties of the Growing Medium 90 d after Planting

Polymer ^a	Salinity	Cation (meq/l)				Anion (meq/l)				CEC	ESP
	(dS/m)	Ca ⁺²	Mg ⁺²	K ⁺	Na ⁺	CO ₃ ⁻²	HCO ₃ ⁻¹	Cl ⁻¹	SO ₄ ⁻²	(meq/100g)	%
NP	1.6	48.75	26.75	18.52	14.72	<0.01	2.90	18.17	87.66	1.68	3.47
	2.5	93.00	31.00	21.00	59.64	<0.01	1.90	127.7	75.05	2.10	10.20
	5.0	123.00	32.50	18.45	100.91	<0.01	1.90	221.8	51.16	2.25	14.65
AS 0.1	1.6	50.50	27.75	20.92	21.71	0.50	1.40	27.87	91.11	2.10	4.95
	2.5	63.00	33.50	18.41	47.37	0.50	1.40	100.9	59.48	2.25	9.28
	5.0	106.00	30.00	17.76	83.43	0.50	1.65	182	53.04	2.28	13.18
AS 0.2	1.6	46.00	24.50	19.35	13.59	<0.01	1.90	17.37	84.17	2.71	3.32
	2.5	65.00	20.00	18.29	32.99	0.50	1.40	73.58	60.80	2.83	7.05
	5.0	107.50	26.00	21.98	77.70	0.50	0.90	180.5	51.28	2.64	12.48
AS 0.4	1.6	49.75	26.75	22.59	15.74	1.00	1.40	21.46	90.97	2.55	3.68
	2.5	75.00	29.00	27.45	41.27	0.50	1.15	93.28	77.79	3.01	7.91
	5.0	113.50	46.50	35.51	93.09	1.00	2.15	211.2	74.25	2.70	13.50
AH 0.1	1.6	28.00	19.50	12.21	13.12	0.50	2.40	9.19	60.74	2.21	3.88
	2.5	38.00	27.50	9.27	30.88	0.50	2.90	53.23	49.02	2.32	7.49
	5.0	55.00	21.50	8.56	46.29	1.00	0.40	88.81	41.14	2.46	10.09
AH 0.2	1.6	30.00	13.75	8.59	11.84	1.00	1.65	9.63	51.90	2.75	3.66
	2.5	45.75	23.25	12.55	46.97	0.50	1.15	73.66	53.21	3.01	10.71
	5.0	72.00	23.50	9.99	92.07	0.50	0.40	153.2	43.45	3.15	16.66
AH 0.4	1.6	30.75	26.00	16.97	43.18	0.50	0.65	29.9	85.85	3.55	10.84
	2.5	44.50	36.50	13.51	76.67	0.50	4.40	106.6	59.68	3.65	15.31
	5.0	55.00	36.00	11.23	107.22	1.00	0.15	163.2	45.10	3.19	19.25
BL 0.1	1.6	31.00	15.00	9.45	9.04	0.50	2.15	8.05	53.79	2.10	2.75
	2.5	69.00	11.50	11.51	35.53	1.00	0.90	72.08	53.56	2.10	7.75
	5.0	49.00	34.50	9.15	57.33	1.00	0.90	113.5	34.58	1.86	11.75
BL 0.2	1.6	30.00	14.50	8.37	8.93	<0.01	2.90	10.03	48.87	2.43	2.76
	2.5	37.00	12.50	9.27	21.15	<0.01	3.40	39.4	37.13	2.07	6.00
	5.0	108.00	29.50	16.12	99.52	0.50	1.65	194.7	56.29	2.00	15.26
BL 0.4	1.6	31.00	21.25	11.78	16.21	1.00	1.40	14.09	63.75	2.28	4.54
	2.5	56.00	24.50	13.10	37.37	0.50	1.65	76.12	52.70	2.62	8.12
	5.0	100.00	33.50	12.99	94.24	0.50	2.15	193.3	44.78	2.74	14.75

Table 5: (Cont'd).

Polymera	Salinity (dS/m)	Cation (meq/l)				Anion (meq/l)				CEC (meq/100g)	ESP %
		Ca ⁺²	Mg ⁺²	K ⁺	Na ⁺	CO ₃ ⁻²	HCO ₃ ⁻¹	Cl ⁻¹	SO ₄ ⁻²		
HG 0.1	1.6	46.00	18.25	11.89	11.51	0.50	1.40	15.41	70.34	2.10	2.96
	2.5	45.50	13.25	12.56	23.80	1.00	1.40	43.55	49.16	1.89	6.18
	5.0	95.00	30.50	20.85	64.95	<0.01	2.15	161.9	47.25	2.03	10.95
HG 0.2	1.6	35.50	7.25	8.08	6.16	1.00	1.90	9.06	45.03	2.28	1.96
	2.5	55.50	49.50	19.19	39.57	0.50	2.15	103.7	57.40	2.64	7.57
	5.0	93.00	42.00	21.08	75.55	<0.01	1.65	192	37.98	2.68	12.12
HG 0.4	1.6	58.75	26.25	25.18	15.27	0.50	3.15	32.88	88.92	3.01	3.39
	2.5	70.00	35.50	26.71	42.54	0.50	1.40	118.7	54.16	2.86	8.08
	5.0	92.00	41.00	16.95	71.43	0.50	1.90	180.4	38.58	2.46	11.61
HS 0.1	1.6	33.00	29.00	12.57	7.89	0.50	2.40	13.76	65.80	2.15	2.08
	2.5	46.00	39.00	10.90	33.98	<0.01	3.40	95.28	31.19	2.41	7.25
	5.0	70.00	53.50	14.04	74.61	0.50	1.15	156.4	54.10	5.24	12.47
HS 0.2	1.6	33.00	20.00	9.39	7.29	0.50	1.65	9.16	58.37	1.96	2.08
	2.5	54.50	30.00	12.22	34.04	0.50	1.65	94.47	34.14	2.04	7.28
	5.0	76.00	46.50	18.38	84.93	<0.01	2.40	177	46.42	1.99	14.00
HS 0.4	1.6	46.00	21.75	12.72	13.17	1.00	2.40	29.03	61.22	3.01	3.28
	2.5	49.50	21.00	13.01	26.26	1.00	1.15	69.39	38.23	2.86	6.22
	5.0	75.00	33.00	23.05	55.32	0.50	1.15	118.5	66.22	3.41	10.15
Significance ^b		* (5.9)	NS	NS	* (4.9)	NS	NS	NS	*(4.6)	NS	* (0.9)
Polymer (P)											
Conc. (C)		NS	NS	NS	* (79.2)	NS	NS	NS	NS	NS	* (13.9)
Salinity (S)		** (6.5)	** (3.5)	NS	** (5.4)	NS	* (0.3)	** (11.8)	* (5.1)	NS	** (0.9)
P X C		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P X S		** (1.3)	NS	NS	NS	NS	NS	NS	NS	NS	NS
P X C X S		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

a. NP = No polymer (control); AS = Aquasorb; AH = Agrihope; BL = Broadleaf P4; HG = Hydrogel; HS = Hydrosorb was incorporated into the soil at 0.1% (0.1), 0.2% (0.2) or 0.4% (0.4) by weight. CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage.

b. Data were analyzed using ANOVA procedure; NS = Nonsignificant at P = 0.05, * = significant at P = 0.05, ** significant at P = 0.01. Figures in parenthesis are standard errors of mean.

Discussion

Results of the present study clearly showed the positive effects of polymer application on water retention without any adverse effect on plant growth even when saline water was used for irrigation. The use of polymer in the substrate also reduced the total amount of water used by *Conocarpus* plants. The effectiveness of polymer was affected when saline water was used for irrigation. Similar observations were made by other researchers, who demonstrated that polymers can absorb up to 500 times their own weight in distilled water (Johnson, 1984a, b; Johnson and Velkamp, 1985), increase the WHC of soils by up to 400% (Johnson, 1984a), decrease water stress, and delay the onset of wilting (Gehring and Lewis, 1980).

Studies by Johnson and Leah (1990) with lettuce, radish and wheat seedlings indicated that the gel-stored moisture in the rhizosphere of the plant is utilized with a greater efficiency than the conventional forms of water. They also found that the evapotranspiration ratio in polymer-treated plants was 21 to 56% lower than it was in control plants. In sweet pepper and cabbage, Chien and Woo (1994) found hydrophilic polymer Water Lock 100 to minimize diurnal variations in the leaf-water potential and to maintain higher turgor pressure in leaf cells even after 72 h of water stress.

Results of studies reported here demonstrated the beneficial effects of cross-linked polymers in general, and of Agrihope in particular, in conserving irrigation water and promoting plant growth.

Acknowledgement

The authors thank the Kuwait Foundation for the Advancement of Sciences (KFAS) and the Kuwait Institute for Scientific Research (KISR) for supporting this research. The assistance provided by the department staff in executing the study is gratefully acknowledged.

Mention of trade name of the product does not imply that they are endorsed or recommended by the authors over other similar products.

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