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WATER HOLDING CAPACITY AND EVAPORATION OF CALCAREOUS SOILS AS AFFECTED BY FOUR SYNTHETIC POLYMERS

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ABSTRACT: Four soil conditioners, Broadleaf P4, Agrihope, Aquasorb, and Hydrogel, were used in a laboratory study to evaluate the effectiveness of these polymers on water holding capacity (WHC), evaporation, and water conserved in calcareous sand and loam soils. Four rates of these polymers, 0.0, 0.2, 0.4, and 0.6% (on dry weight basis), were added to these two soils. All treatments were irrigated weekly to 60% WHC for a total of 16 wetting-drying cycles. An increase in polymer applied increased the WHC, decreased evaporation, and as a result increased the amount of water conserved in both the soils. Broadleaf P4 was more effective even at lower rates. The effectiveness of the polymers used could be arranged in the following order: Broadleaf P4 > Aquasorb > Agrihope > Hydrogel.

INTRODUCTION

In agriculture development and land scaping in Saudi Arabia, water management is of almost unique importance both from the conservation and commercial point of view. Water is often of very limited supply and is always expensive. Effective conservation of water is, therefore, of primary importance in any landscape or agricultural development. Most of the soils in Saudi Arabia are light textured and have low water holding capacity and deep percolation losses (1). Considerable amounts of soil water, in both irrigated and unirrigated soils, are lost

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atmosphere by evaporation process. In arid and niarid zones, poor al and chemical characteristics of the soils restrict the retention of soil ure and evaporation losses may reach to 60% or more of the total precipitation (2). Therefore methods or practices that reduce evaporation of soil water are of paramount importance for conserving soil moisture in the uppermost layer to provide the plants with greater opportunity to utilise the water efficiency.

The introduction of synthetic superabsorbant polymers that serve as slow-release water reservoir are a significant new development to aid plant growth under conditions of moisture stress (3). These additives are capable of absorbing several hundred times their own weight of water (4,5) and now are widely used for crop production in arid and semi-arid climate (6).

When a soil is treated with conditioners, the moisture is released more slowly than the rate of loss by normal evaporation from soil-plant surfaces, and this minimises growth loss of planting stock, optimises plant recovery of water, and dramatically improves efficiencies in fresh weight production per unit of water supplied (7,8,9).

The addition of a polymer to soil can improve not only its water holding capacity (6,10), more importantly the supply of plant available water (11,12), and in addition even at temperature of 40°C, evaporation rates may be reduced considerably in polymer treated soils, especially those of coarse texture and high permeability (4,13,14,15,16,17). Johnson (1984) reported that polyacrylamide gels when added to coarse textured sand at a rate of 2 g/kg increased the water holding capacity 171% to 402%. Al Omran et al. (1987) showed that the amount of water conserved by loamy sand using Jalma (super gel) at rates of 0.4, 0.8, and 1.6% were 4.3, 5.3, and 3.3 times those of non-treated soil. Agafonov (1983) reported that evaporation from soil was decreased by about 60% when 0.1% of a polyacrylamide polymer was applied to the upper soil layer. Because of a lucrative market of agricultural products in Saudi Arabia, a number of new synthetic polymers are being marketed.

The objective of this study was to evaluate the effectiveness of these different types of polymers and to determine the appropriate rate of application on water holding capacity, evaporation loss, and amount of water conserved in two representative calcareous soils.

MATERIALS AND METHODS

Soils

Two surface (0-25 cm) calcareous soils differing in texture were collected from the College Experimental Station at Deriab, Saudi Arabia. The soils were air dried, crushed, and passed through a 2-mm sieve. Taxonomy and other characteristics determined by described procedures (18) are reported in Table 1.

Gel-forming Synthetic Polymers

Four soil conditioners, Broad P4, Agrihope, Aquasorb, and Hydrogel, were used in this study. The identification and description of these materials as provided by the manufacturers are given in Table 2. The required weights of the polymers were thoroughly mixed with 2 kg of air dried soils to have four rates of 0.0, 0.2, 0.4, and 0.6% on a dry weight basis. Sub-samples weighing 500 gm were taken from each treatment into a plastic container (11x11x8 cm). Based on predetermined maximum WHC for each treatment, the required amount of deionized water was added to each container to bring moisture content of the soils at 60% WHC. Each treatment was replicated three times. The containers were kept at a room temperature of 21±1°C and subjected to sixteen wetting-drying cycles to stimulate a normal crop season. Loss of water was determined by weighing the containers weekly and the required amount of distilled water was added to bring back the treatments to 60% of WHC. After sixteen weeks, the containers were irrigated back to 60% WHC and daily water loss due to evaporation was recorded for two weeks or till there was no difference in weights measured.

The WHC of the treated soils was determined by using plastic rings (40-mm in diameter) in which the bottom was fitted with stainless screen having openings of <2-mm. Rings were filled with soils (approx. 25 g) to a unifom compaction and immersed to half in deionized water for 24 hours to obtain maximum saturation. Excess water was drained by keeping the covered rings over glass funnels. After half an hour, soils with water absorbed were weighed and were dried for over night to determine the WHC.

RESULTS AND DISCUSSION

The WHC of sand and loam affected by four rates of different synthetic polymers is drawn in Figures 1 and 2. Water held in sand for the control treatment was 24.08 % which increased to 97.34 % when treated with 0.6% of Broadleaf P4, i.e. an increase of 73.20% compared to control. The second best performance was

TABLE 1. Physical and Chemical Properties of Studied Soils.

Soil sub-group	Texture	Sand	Silt	Clay	O.M	pH	EC_e	$CaCO_3$
			%		%		dS/m	%
Typic Torripsamments	Sand	90	4	6	0.12	8.08	0.76	27.90
Typic Torriorthents	Loam	43	38	19	0.25	7.15	0.90	36.50

shown by Aquasorb where the water absorption capacity was 36.64, 61.81 and 83.82% for corresponding conditioners rates of 0.2, 0.4, and 0.6%. Here the increases in water absorbed were 12.56, 37.73 and 59.74% over the control. Water holding capacities of the other two polymers, Agrihope and Hydrogel, were more or less the same but relatively lower as compared to Broadleaf P4 and Aquasorb. At lower polymer rate of 0.2%, the increases over the control were only 5.5% for Agrihope and 7.45% for Hydrogel, alhough with increasing polymer rates, there was an increase in water holding capacity, but the increase was only 25.1 % when sandy soil was treated with 0.6% Agrihope and 34.52% when treated of 0.6% Hydrogel.

The loamy soil followed more or less the same trend as discussed for the sand. Although the total amount of water absorbed by loam was higher than the sandy soil, but when calculated as percentage change over the control, it was obvious that in all the treatments the water absorbed was less than the sand. At higher rate (0.6%), the percent change in WHC over the control in loamy soil for the four conditioners were 66.01, 52.86, 17.27, and 19.22%, respectively, while these values in sandy soil were 73.26, 57.94, 25.10, and 34.52% for Broadleaf P4, Aquasorb, Agrihope, and Hydrogel, respectively. These results showed that the

TABLE 2. Some Characteristics of Polymers Used in Experiment.

Product Name	Chemical Characteristics	Manufacturer	Water absorption in deionzede water	
			Reported	Determined
Broadleaf P4	High molecular weight, x-linked poly-acrylamide, granular,insoluble,non-hazaradous	Agricultural Polymers Ltd. Pillar & Lucky House, Merchant Rd Gloucester GL1 5RG UK	400	380
Agrihope	Gel-conditioner, cross linked, Na-polyacrylate water insoluble	Nippon Shokubai Co. Japan	250	200
Aquasorb	x-linked poly-acrylamide, water insoluble	Estefaa Co. Agri-& Foresttree Services P.O.Box 9564,Riyadh Saudi Arabia	350	320
Hydrogel	Synthetic, Starch co-polyemer,K-acrylate	Finn corporation PO Box 806825 Cincinnati, Ohio 45208 USA	200	215

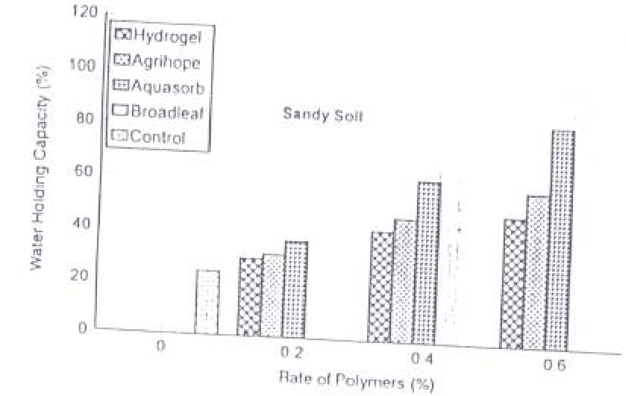

FIGURE 1. Effect of Type and Rate of Polymers on WHC of Sand.

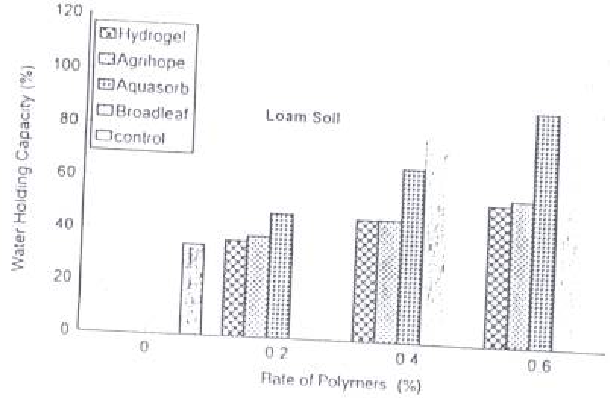

FIGURE 2. Effect of Type and Rate of Polymers on WHC of Loam.

TABLE 3. Weekly Evaporation as Percentage of Total Water Added to Sand and Loam Soils as Affected by Types and Rates of Different Soil Polymers.

Conditioner rate (%)	Broadleaf P4	Agrihope	Aquasorb	Hydrogel
		Sand		
0.0	98.80	98.80	98.80	98.80
0.2	88.89	96.22	87.81	98.39
0.4	68.82	80.77	72.40	93.95
0.6	55.99	69.00	60.07.	79.05
LSD.05	4.16	6.95	4.47	3.32
		Loam		
0.0	96.57	96.57	96.57	96.57
0.2	93.79	95.06	93.16	94.46
0.4	82.45	91.78	84.12	92.37
0.6	62.90	81.29	69.17	90.63
LSD.05	4.1	1.63	5.93	2.59

effectiveness of conditioners to absorb water in sandy soil was higher than loam soil.

Total water loss from the surface of sand and loamy soils for a period of seven days is given in Table 3. The data presented was calculated as a percentage of the initial water added to bring all the treatments to 60% of WHC. This data clearly indicated that with an increase in the polymers' rates, there was a decrease in evaporation. Evaporation from the sandy soil when treated with 0.6% Broadleaf P4, was 55.99%, a reduction of 42.81% over the control. In general, all the other polymers followed the same trend. The evaporation losses for Agrihope were 96.22, 88.77, and 69% from the amount of water added. When the sand was treated with 0.2, 0.4 ...

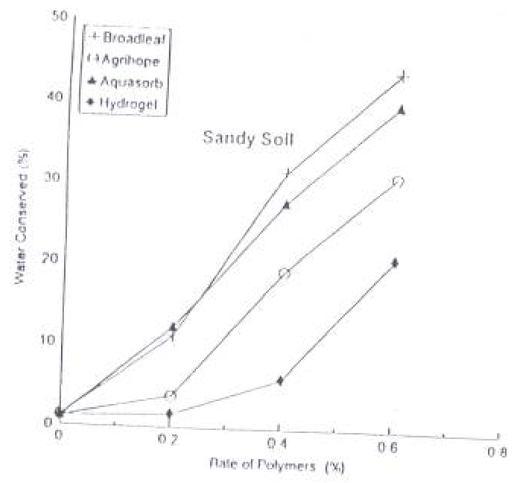

FIGURE 3. Effect of Rate of Polymers on Amount of Water Conserved in Sand.

over the control. The evaporation losses for Aquasorb were 10.91, 26.4, and 38.73%; while these losses for Hydrogel were 0.44, 4.85, and 19.75% for the respective rates. These trends showed that Broadleaf P4 was the most effective soil conditioner in reducing evaporation followed by Aquasorb, Agrihope, and Hydrogel.

Evaporation data for the loam soil treated with four different synthetic polymers behaved similarly to the sandy soil. Generally, the percentage of reduction in evaporation loss relative to the control in the loamy soil was less than the sandy soil. Total water evaporation after one week at a higher rate of 0.6% was only 5.24% for Hydrogel while the corresponding figure was 33.67% for Broadleaf P4, 15.28% for Agrihope, and 24.5% for Aquasorb. However these results indicated that at higher rates, the water loss by evaporation was significantly lower than the other rates which may be due to the aggregation and swelling effects of conditioners. Their application promoted the infiltration rate, limited capillary rise, and

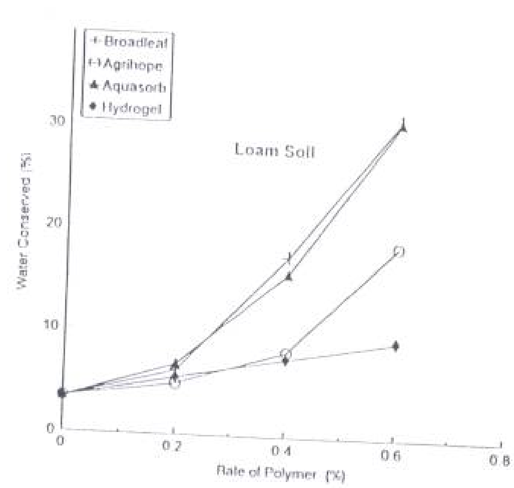

FIGURE 4. Effect of Rate of Polymers on Amount of Water Conserved in Loam.

consequently suppressed evaporation (Al-Omran et al., 1987). A significant ability in promoting aggregation and suppressing water evaporation in loose sandy soil was also observed by Canarutto and Pini (1992) when using hydrophilic swelling chemical cross-linked polyacrylamide named Evergreen 500.

Effectiveness of conditioner types and application rates in sand and loam soils were further illustrated when rates of each conditioner used were plotted against percentage of water conserved. These results are illustrated in Figures 3 and 4. In the sandy soil, all the polymers showed an increase in percentage water conserved with an increase in polymer rate. The maximum amount of water conserved in sand was by Broadleaf P4 when applied at 0.6% rate. Aquasorb followed also the similar trend whereas Agrihope and Hydrogel at an application rate of 0.2% conserved a very little amount of water when compared to the control, while the higher rates of these polymers are required to increase their effectiveness in sandy soils. In the loamy soil, Broadleaf P4 and Aquasorb were equally effective in conserving moisture at 0.4 and 0.6% rates. All the polymers at the 0.2% rates were of little effectiveness in loamy soil. Higher rates (>0.2%) of Agrihope and Aquasorb were required to have the same efficiency as that of Broadleaf P4 and Aquasorb.

The results obtained in this study indicated that Broadleaf P4 was the most effective synthetic polymer for increasing the WHC, suppressing evaporation losses, and conseving higher amount of water in sand and loam soils. This conditioner could be used with low rates on a wide scale such as in sports fields, interior gardening and landscaping, and in greenhouse and nurseries.

CONCLUSION

An increase in the WHC, decrease in water evaporation losses, and subsequent increase in soil moisture conserved was observed by two soils when four synthetic polymers, Broadleaf P4, Agrihope, Aquasorb and Hydrogel, were applied at four rates 0.0, 0.2, 0.4 and 0.6%. The WHC increased with an increase in the amount of conditioners both in the sand and loam soils. The evaporation losses decreased significantly with increases in application rates of soil polymers. Therefore, a correspondent increase in amount of water conserved was observed in the sand and loam soils. In terms of the effectiveness of the polymers, Broadleaf P4 performed better than the other polymers as the polymers can be arranged in the following order: Broadleaf P4 > Aquasorb > Agrihope > Hydrogel.

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