Int. Agrophysics, 1992, 6, 19-25

EFFECTS OF ACRYHOPE AND AQUASTORE POLYMERS ON WATER REGIME AND POROSITY IN SANDY SOIL

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A b s t r a c t. Laboratory experiments were conducted to investigate the effects of Acryhope and Aquastore-B polymers on water regime and void ratio in sandy soil (Typic Torriorthents). It was found that both polymers decreased the water flux in the treated soils as compared to the control. The effect was dependent on polymer type, depth of placement, and rate of application. In general, the deeper the treated layer the slower the water flux. Aquastore was more effective in reducing water flux as compared to Acryhope. The effect of polymer placement on the flux followed the order of, top treatment > middle treatment > bottom treatment > whole treatment.

A strong positive correlation was found between void ratio and swelling which indicates that swelling increased the porosity and consequently, increased the void ratio. But swelling also decreased water flux. The tested polymers increased the available water in sandy soil many times higher than that of the untreated soil. Moreover, they decreased water losses through evaporation.

INTRODUCTION

Sandy soils are of widespread occurrence in the Middle East and North Africa as well as in other arid and semi-arid regions of the world. The production of these soils are usually low and expensive. This is attributed mainly to the rapid percolation of water and the low water retention capacity of such soils. In addition, plant nutrients could quite possibly be wasted beyond the root zone.

Attempts to improve their productivity and decrease its expense were made by mixing organic matter or farm manure with soil surface or forming layer from different materials at different depths of the soil [2]. The application of organic manure is a customary practice but under arid and semi-arid climates its beneficial effects becomes rather short lived. Besides that the huge amount required raised its labor cost.

Incorporation of synthetic polymers within sandy soil is one of approaches to reduce the adverse effects of coarse texture. During the past decade a renewed interest in synthetic soil conditioners, that can improve productivity of sandy soil, has been revived especially after the developments in the field of surface and polymer chemistry which have introduced unforeseen possibilities for controlling soil water relationship. Soil conditioners could largely improve productivity of sandy soils with a modest capital input [4].

Polyacrylamide increased available water of coarse sand, and the effects were varied with the type of commercial product used [8]. Miller [14] found that super slurper increased soil swelling and decreased infiltration rates. The effect of swelling on water movement was studied by many researchers [5,6,7,10,13]. They found that swelling and aggregation may influence hydraulic conductivity, infiltration rate, capillary rise, redistribution of water and evaporation. El-Amir [4] and Sherwood and

Engibous [16] proved that, treatment of the soil surface with polymers increased the infiltration rate by many centimeter per hour. In other studies Martin *et al.* [11] and Martin [12] reported that soil conditioners increased both soil porosity and permeability. Agafonov [1] found that evaporation from soil was decreased by about 60% when 0.1% of polyacrylamide polymer was applied to the upper soil layer.

The aim of this work was to investigate the effects of two polymers (Aquastore-B and Acryhope) on water flux, porosity, available water and evaporation in sandy soil. Aquastore is a synthetic polymer developed by Cyanamid whereas, Acryhope was provided from Japan. Both polymers are newly introduced to our area and have not been tested before. Thus, it was worthy to investigate their effects on sandy soils under controlled conditions in the laboratory.

MATERIALS AND METHODS

Two polymers were used, Acryhope and Aquastore-B, with sandy soil (98.2% sand, 1.2% silt and 0.6% clay). The soil is classified as Typic Torriorthents [17] and it contains 2.0% $CaCO_3$. To study the effect of the two polymers on water flux and porosity, thirty four aluminum columns (5 cm ID and 30 cm height) were packed with sandy soil at bulk density of 1.70 Mg m^{-3}. The soil height was 15 cm in each column. Each polymer was incorporated separately in the soil at two rates (0.5 and 1.0% w/w), as dry granules, and at four different depths as follows:

a - the polymer was mixed in the lower 5 cm of the soil column and called "bottom treatment"

b - the polymer was mixed in the middle 5 cm of the soil column and called "middle treatment"

c - the polymer was mixed in the upper 5 cm of the soil column and called "top treatment"

d - the polymer was mixed in the whole soil column (15 cm) and called "whole treatment"

The four treatments were compared to the control where there was no polymer added to the soil column.

The columns were vertically placed in a stand, and the volume of leachate was measured under constant water head as described by Klute and Dirksen [9]. When nearly constant discharge (Q) was reached, the water flux (J) was calculated ($J = Q/A$, where A is the cross sectional area of the soil column). At the end of the experiment the change in soil columns' height due to swelling was measured and subsequently the change in bulk density (BD) was calculated. On the other hand the particle density (PD) was measured by a pycnometer as described by Blake and Hartge [3]. It was found that the particle density is 2.70 Mg m^{-3}. From both the BD and PD, the porosity (P) and then the void ratio (VR) were calculated as follow:

$$P = 1 - (BD/PD),$$

$$VR = P/(1 - P).$$

The second experiment was carried out to study the effect of the two polymers on water retention of sandy soil. Stainless steel cores (5 cm ID, and 2.5 cm height) were packed with the soil treated with either Acryhope or Aquastore polymers at 0.0, 0.25, 0.50, 1.0 and 1.5% rate of application. The cores were saturated with water by capillary rise, then subjected to different pressure on ceramic plates. The moisture contents at different pressure were measured and the available water was calculated from the differences between the moisture content at field capacity and wilting point.

The third experiment was carried out to investigate the effects of the two polymers on evaporation from soil surface. The polymers were mixed with the soil at two rates (0.5 and 1.0%) in plastic pots. Four replicates were prepared. Each pot contained 500 g of soil. Enough water was added and the pots were covered and left for 48 h to drain out the free water. Then, the pots were left uncovered and weighed daily to measure the evaporation from the soil surface under evaporativity demand of about 15 mm/day.

RESULTS AND DISCUSSION

The effects of two polymers on water flux in sandy soil at two rates of application are presented in Fig. 1. It is obvious that both polymers decreased the water flux in all treatments compared to the untreated soil columns (control). The effect depends on type of polymer, depth of placement, and rate of application. In general, the deeper the treated layer the slower the water flux. The effect of application rate was soundly noticed with Aquastore polymer than Acryhope.

At 0.5% Acryhope treatments the flux was 8.0 cm h-1 at the whole treated colums and went up to 8.8 cm h-1 at the bottom treated columns whereas, the middle treated columns reached to 9.7 cm h-1 and finally the top treated columns showed the highest flux value (12.5 cm h^{-1}). Increasing the rate of application from 05.% to 1.0% decreased slightly the water flux in all treatments except the whole treated columns where the reduction was more pronounced.

The second polymer - Aquastore was more effective in reducing the water flux as compared to Acryhope. The effect of placement depth showed the same trend as it was noticed with Acryhope. At 0.5% rate the flux was 1.9, 3.5 and 5.8 cm h^{-1} at whole, bottom and middle treatment, respectively. Similarly, the top treated columns produced a higher flux rate (10.4 cm h^{-1}). Increasing the application rate from 0.5% to 1.0% decreased the flux sharply and shortly prevented the water movement through the soil columns completely in all treatments. Therefore, its flux was considered to be zero and not presented in Fig.1.

The different behavior between the two polymers is mainly due to the difference in their water holding capacities. The Acryhope absorbs water 34 times of its weight whereas the Aquastore absorbs 95 times of its weight, as it was determined in the labo-

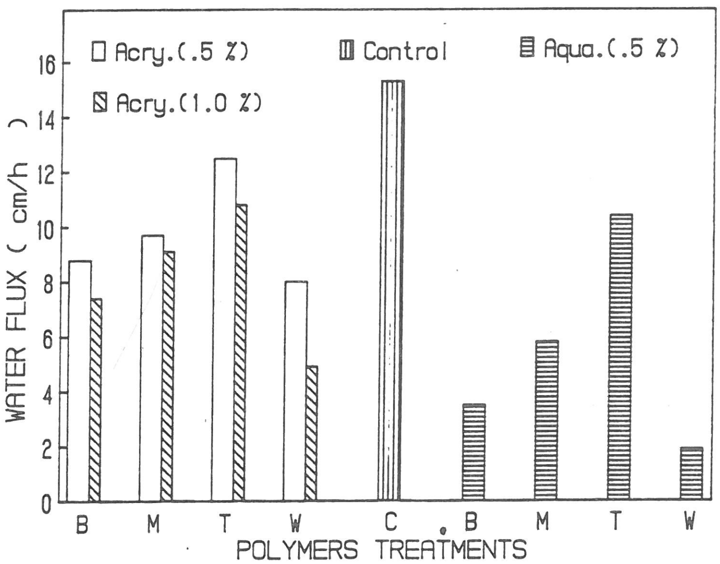

Fig. 1. Effects of two polymers at two rates of application on water flux in sandy soil. The letters B, M, T, and W refer to bottom, middle, top, and whole treated soil respectively, while the letter C refers to untreated soil (control).

ratory. Consequently, the higher the water holding capacity of the polymer the lower the water flux obtained. That could be due to the swelling of the polymers which affects the macropores continuity and restricts the water paths. The swelling of both polymers was visible during determination of their water holding capacities. The Acryhope formed a tiny granules whereas, the Aquastore formed big granules with diameter of about 0.5-1.0 cm in tap water.

Table 1 lists the swelling (SW) of sandy soil under different polymer treatments and its subsequent void ratios (VR). Vertical swelling was measured as the height in cm. The results show that the swelling value depended on the depth of the treated layer as well as on the rate of polymer application. Maximum swelling was found in whole treated columns whereas, other treatments followed the order of, top treatment>middle treatment>bottom treatment, i.e., the swelling increased as the treated layer was placed near the surface and this could be called free swelling. In other words, swelling decreased as the weight of the soil above the treated layer increased, consequently this kind of swelling could be called restricted swelling which is affected by the weight of the overlying soil.

Increasing the rate of application increased the swelling in all treatments due to the increase in water stored in both polymers and the higher storage of Aquastore induced higher swelling compared to Acryhope.

In the soil subjected to a change in its volume as a result of compaction, swelling or shrinking, Pagliai [15] recommended using the void ratio (VR) instead of porosity. The VR shown in Table 1, indicated that the VR increased as the swelling increased. The positive linear relationship between VR and swelling (SW) for each polymer under different treatments was calculated as follow:

$$VR = 0.448 + 0.125\ SW \quad (r = 0.987),$$

for Acryhope and,

$$VR = 0.539 + 0.127\ SW \quad (r = 0.996),$$

for Aquastore.

The strong positive correlation between VR and SW indicated that swelling increased the porosity and consequently increased the VR. Therefore, the reduced flux in the treated columns is not due to decreasing in soil porosity but mainly due to clogging and discontinuity of the macropores.

The available water (AW) is defined as the moisture retained in the soil between field capacity (FC) and wilting point (WP). The FC is the moisture retained at 0.10 bar while the WP is the moisture retained at 15 bar. The effect of the two polymers on AW is shown in Fig. 2. Incorporation of the polymers into sandy soil increased its available water. The AW is increased by increasing the rate of polymer application.

Table 1. Effects of two polymers at two rates of application on swelling (SW) in centimeters and void ratio (VR) in sandy soil

Treatments	Acryhope				Aquastore			
	0.5 %		1.0 %		0.5 %		1.0 %	
	SW	VR	SW	VR	SW	VR	SW	VR
Bottom treatment	1.1	0.63	2.0	0.68	1.8	0.78	3.0	0.94
Middle treatment	2.0	0.66	2.5	0.74	2.6	0.89	6.5	1.40
Top treatment	2.6	0.75	3.5	0.88	3.0	0.87	7.1	1.49
Whole treatment	4.0	0.97	4.9	1.08	7.3	1.51	14.6	2.34
Control	0.8	0.57	0.8	0.57	0.8	0.57	0.8	0.57

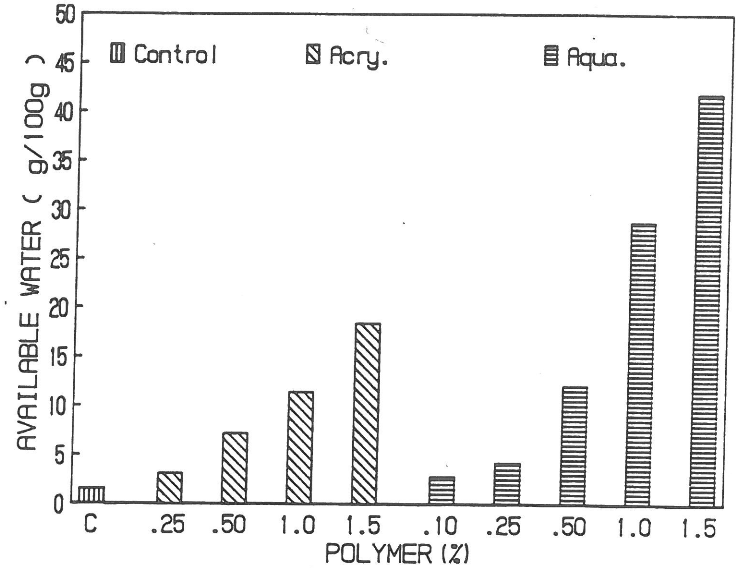

Fig. 2. Effects of two polymers at different application rates on available water in sandy soil.

The Aquastore polymer is more effective in increasing the AW than Acryhope at comparable application rates. The AW was 3.15, 7.23, 11.45 and 18.43 g/100g with incorporated Acryhope at rate of 0.25, 0.5, 1.0 and 1.5%, respectively. The lowest application rate (0.25%) increased the AW two times that of the untreated soil, whereas 0.5 to 1.5% increased the AW from 4 to 12 times that of the untreated soil.

The second polymer Aquastore produced even more response with AW. The AW at rate of 0.1, 0.25, 0.5, 1.0 and 1.5% was 2.8, 4.24, 12.07, 28.77 and 41.9 g/100g, respectively. Similarly at 0.25% rate the AW increased about 3 times that of the untreated soil. The response increased as the polymer rate increased. It reached up to 27 times that of the untreated soil at 1.5% application rate.

Thus, both polymers increased the AW which is a limiting factor for cultivating sandy soils. An increase in AW could decrease the percolation losses and reduces the irrigation frequency in such soils.

Effect of the two polymers on water losses by evaporation was studied. Cumulative evaporation as a percentage of the amount of water retained in the soil is presented in Fig.3. Incorporating the polymers in the soil decreased water loss percentage through evaporation from soil surface compared to the untreated soil. The magnitude of reduction is dependant on the polymer type and rate of application. The Aquastore polymer is more effective in reducing evaporation than Acryhope at a comparable application rate as shown in the figure. For example, 50% of water stored in the soil was lost after 3.5, 6 and 7.5 days at untreated, Acryhope 1.0%, and Aquastore 1.0%, respectively. Increasing the rate of polymer application decreased the percentage of water losses.

On the other hand, the absolute amount of water losses by evaporation was increased by incorporation of polymers and increasing the rate of application.

In conclusion, the two polymers absorb water at different ratios and their swelling increased the soil porosity but reduced the water flux. The reduction in flux was due to the discontinuity of the macropores. That is not desirable in heavy soil but it will be

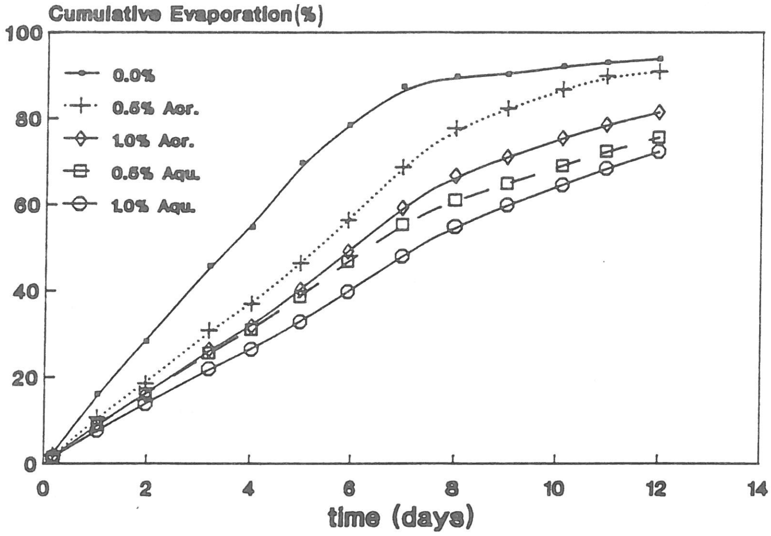

Fig. 3. Effects of two polymers at two rates of application on cummulative evaporation percentage in sandy soil.

beneficial in sandy soil where most of its water drains very quickly beyond the root zone. That effect increased the AW of the treated soil many times higher than that of the untreated one at low polymer application rate. Moreover the cumulative evaporation percentage was suppressed by increasing the polymer rate. Thus, this study could be a good base for further investigations under field conditions for increasing the productivity of cultivated sandy soil in arid regions.

CONCLUSIONS

Laboratory studies on the effect of two polymers on water regime and void ratio in sandy soil allow us to draw the following conclusions:

1. Both polymers, i.e., Acryhope and Aquastore-B decreased water flux in treated soil as compared to control. The effect depended on polymer type, depth of placement, and rate of application. In general, the deeper the treated layer, the slower the water flux. Aquastore was more effective in reducing water flux followed the order of: top treatment>middle treatment>bottom treatment>whole treatment.

2. A strong positive correlation was found between void ratio and swelling, which indicates that swelling increased the porosity and, consequently, increased the void ratio.

3. The tested polymers significantly increased the amount of available water in sandy soil as compared to control and they decreased water losses through evaporation as well.

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