Results
And
Discussion

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# 4. RESULTS AND DISCUSSION

# 4.1. Effect of incorporating hydrogels in sandy soil on its hydrophysical properties (laboratory studies);

# 4.1.1. Structure stability and maintenance:

Along lasting stable structure against destructive wind or water on one hand or the different tillage operations, on the other hand, is of supreme importance, which would enable beneficial cropping. this work, the stabilization of sandy soil structure either in the dry or in the wet state - after its treatment with the hydrogel was studied. Maintenance of the formed structure was also determined. Several indices were chosen for structure evaluation namely: a) Mechanical stability using a rotating dry sieving machine, (El-Hady, 1984). Different criteria were used to evaluate the conditioning process. These were: the total and the most stable structural units > 0.84 mm in diameter, the relative values of either instability parameter (SP) and deaggregation rate (DR) and the destructive mechanical action expressed by the number of rotations ( $W\infty$ ) or the time:  $(t_{\infty})$  of dry sieving in minutes needed to return the conditioned soil to its original state, i.e. the control. Moreover, wind erosion parameter was also calculated (El-Hady and El-Sherif, 1988. b) Water stable aggregate size distribution by wet sieving and erosion index. Maintenance of structure was revealed by three cycles of destruction of the formed structure to < 2 mm and reforming it again by wetting and drying. The stable structural units > 0.5 mm and erosion index were determined.

#### 4.1.1.1. Stability of soil structure in the dry state:

Data given in Table (4) present the percentages of total strucutral units > 0.84 mm in diameter and the most stable struutural units having the same size for the untreated sandy soil and that treated with the hydrogel at different application rates. Data reveal that the soil structure was improved with the amounts of applied conditioners. The higher the application rate of the hydrogel was, the higher was either the total structural units or the most stable ones that having a diameter of As soils having a content of non-erodible >0.84 mm. structural units > 0.84 mm exceeding 60% are considered as soils resistant to wind erosion (Pasak, 1974); gel addition to sandy soil at the rate of 0.2% seems to be the stable treatment (structural units > 0.84 mm = 76.6%).

Wind erosion parameter was calculated as the ratio between the percentage content of the non-erodible structural units > 0.84 mm in diameter of the untreated soil and those of the treated ones. Values of calculated

Table (4) Structural units > 0.84 mm and wind erosion parameter\* of sandy soil as affected by hydrogel treatments.

Application rate mg/100 g soil	structu > 0.	l total ral units 84 mm o)	struct ) (	ost stable cural units ).84 mm Y <sub>2</sub> }	Wind ex parame	
	*	% of increase relative to untreated sand	*	% of increase relative to untreated sand	Parameter	\$ of decrease relative to untreated sand
0.0 (Untreated soil)	7.6	-	3.2	-	1.0	0.0
100	26.4	247.4	14.2	343.8	0.23	77.0
150	42.3	456.6	20.8	550.0	0.15	85.0
200	76.6	907.0	32.3	909.0	0.10	90.0

<sup>\*</sup> Wind erosion parameter =

<sup>%</sup> of structural units > 0.84 mm in untreated sand

<sup>%</sup> of structural units > 0.84 mm in treated sand

wind erosion parameters are also presented in Table (4). Data reveal also that soil structure in the dry state was improved with the amounts of hydrogel applied. Wind erosion parameter was reduced by 77, 85 and 90% by treating the soil with 0.1, 0.15 and 0.2% hydrogel, respectively.

Moreover, the deaggregation charactersitics of sandy with different conditioning soil before and after application rates of hydrogel were calculated after El-Hady, 1984. Data given in Table (5) presents the values of the instabilty parameter (SP) and the deagregation rate (RD) of sandy soil either untreated or treated with the hydrogel at different rates of application. It is worthy to note that the value of instability parameter (SP) or deagregation rate (RD) varies from minus infinity for spontaneously degraded soils to zero for absolutely stable The least the values of both indicies are, the more stable is the soil. Accordingly, incorporating hydrogel in improves its structure in the dry state. sandy soil application rates of the hydrogel Moreover, higher coinside with better structure. The reduction in values of SP or RD due to incroporating 0.2% hydrogel in the sandy soil reached 24.2 or 26.3%, respectively.

The destructive mechanical action expressed by the number of rotations (W $_\infty$ ) or the time of dry sieving (t $_\infty$ )

Table (5) De-aggregation characteristics of sandy soil as affected by hydrogel treatments.

Application rate mg/100 g soil	SP×10 <sup>2</sup>	RDx10	Was	t <sub>w</sub>
().0 (untreated soil)	1.996	0.513	_	-
1.00.0	1.749	0.436	318.0	2.11
150.0	1.649	0.410	364.0	2.46
200.0	1.513	0.378	428.0	2.85

SP = Instability parameter

No = De-aggregation rate.

(Wω) or (tω) = The destructive mechanical action expressed by the number of rotations (or the time of dry sieving in minutes) needed to return the conditioned soil to its original state, i.e. the untreated sand, (El-Hady, 1984).

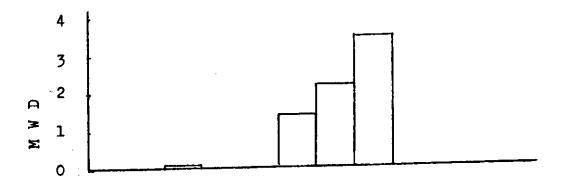
needed for destroying the formed structural units in the treated soil and returning it to its original state (i.e. the untreated soil) were calculated and inserted in Table (5). It is obvious that the more the time of sieving (to) or the number of mechanical units (Wo) needed, the more stable is the treated soil. Data in hand reveal a gradual improvement in the structured dry sandy soil by increasing the applied hydrogel from 0.05% to 0.2% where the number of rotations (or the time of dry sieving in minutes) needed to return the conditionied soil to its original state, i.e. the control, was increased by about 35%. Similar results were previously obtained by Azzam and El-Hady, 1983-II).

#### 4.1.1.2. Water stability of soil structure:

units as well as the mean weight diameter (MWD) of such distribution for the untreated or the treated sandy soil with different rates of hydrogel up to 0.2% are presented in Table (6) and illustrated in Fig. (1). Data indicate the stability of sandy soil structure in the wet state by its conditioning with the hydrogel. The higher the application rate of such hydrogel is, the more stable is the obtained structure. This is revealed from the data of water stable structural units > 2 mm, > 1 mm and > 0.5 mm

Table (6) Size distribution of water stable structural units and its MWD for sandy soil treated with different rates of hydrogel.

Application rate %	Structural units >2 mm in diameter %	Structural units 2-1 mm in diameter %	Structural units 1-0.5 mm in diameter \$	Structural units (0.5 mm in diameter \$	Ħ. W. D.
0.0 (untreated se	0.0 pil}	2.3	4.9	92.8	0.071
0.10	24.8	5.4	6.3	63.5	1.369
0.15	41.2	6.1	6.8	45.9	2.203
0.20	65.6	8.8	7.9	17.7	3.471



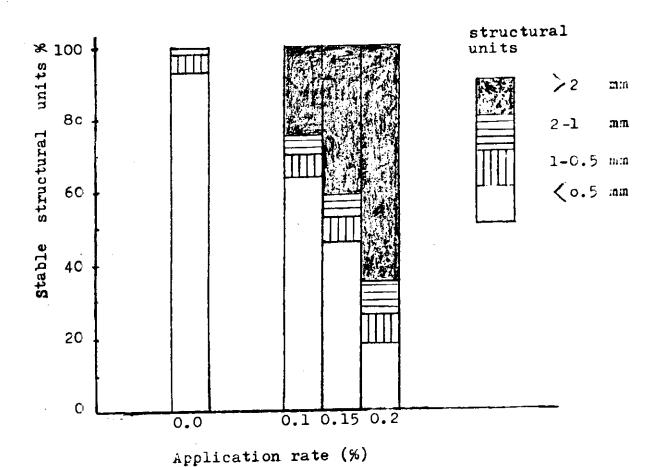


Fig. (1): Size distribution of water stable structural units and its MwL for sandy soil treated with different rates of hydrogel.

in diameter where they reached more than 65, 74 and 82%, respectively by treating it with 0.2%, hydrogels while those of the untreated sandy soil were 0, 2.3 and 7.2%, respectively. At that rate of application, the MWD of the water stable structural units reached its maximum, i.e. 3.471 compared with 0.071 for that of the control treatment.

#### 4.1.1.3. Maintenance of structure:

The structure of sandy soil treated with hydrogel is highly maintained within the three studied cycles of complete destruction of the formed structre to < 2 mm and reforming it again by wetting and drying. Table (7) shows that the decrease in the percentage of water stable structural units > 0.5 mm for the soils treated with hydrogel ranged only between 6.8 and 18.3 after the 2nd cycles of destruction and reforming the structure and between 4.6% and 15.8% for the 3rd one being lower with increasing the rate of applied hydrogel. Similarly, the reduction in the values of erosion indices were 15.8, and 6.0% after the 2nd cycle, of destruction and reforming the structure and 13.8, 5.5 and 3.6% after the 3rd one for treated sandy soil with 0.1, 0.15 and 0.2%, hydrogel, This indicates the resistance of the respectively. conditioned sandy soil to break down by tillage as well as to water erosion.

Table (7) Water stable structural units >0.5 mm and erosion index during three cycles of destruction and re-forming the structure by soil wetting and drying.

pplication rate %	Water stable > 0.5 mm	structu after		Erosion index after the			
	1 <u>st</u> cycle	2 <u>nd</u> cycle	3 <u>rd</u> cycle	l <u>st</u> cycle	2 <u>nd</u> cycle	3 <u>rd</u> cycle	
0.0 (untreated soil)	7.2	6.8	6.2	0.303	0.299	0.296	
0.10	36.5	29.8	25.1	1.527	1.286	1.109	
0.15	54.1	48.1	42.9	2.318	2.109	1.992	
0.2	82.3	76.7	73.2	3.515	3.305	3.186	

## 4.1.2. Porosity and pore size distribution:

Values of total bulk density of soil at saturation after drying; void ratio, soil porosity, micro and macro porosity as affected by treating sandy soil with hydrogel at different rates of application are given in Table (8). The data reveal that the hydrogel decreased the bulk density of the soil in both wet and dry state as well as the macro porosity relative to the control. More reduction was obtained with increasing the application rate. This decrease reached 0.21, 2.17 and 4.66% for the total bulk density, 1.3, 3.04 and 4.22% for the dry bulk density and 8.07, 14.53 and 30.24% for the macro porosity by applying 0.1, 0.15 and 0.2% hydrogel to sandy soil, respectively. In regard to the effect of the hydrogel on void ratio, total porosity and micro pores, the data took an opposite trend relative to that of bulk density and macro pores. In other words, a considerable increase that reached 11.3% in void ratio; 6.6% in total porosity and 137.1% in micro pores were obtained in the conditioned soil, relative to those of the control. The macro and micro pores are of great importance in revealing the rate of water retention and water movement in soils. Ιt interesting to note that addition of hydrogel to sandy soil modified the macro: micro porosity ratio in it. It reached about 1:1 (1.04:1) by increasing the rate of

Table (8) Bulk density, void ratio and porosity of sandy soil treated with hydrogel at different rates of application.

Applica- tion rate	Dry sp weigh	ecific *	Total densit satura	y at	Soil	voids			Soi	l poresit	<b>. y</b>		
mg/100 g soil	<u></u>		<del></del>				Total	porosity	Nacro	pores t	Kicro	pores	Micro
	g/c <b>n³</b>	\$ of contor1	g/cm³	* of contorl	ratio	t of contorl	1	\$ of control	*	\$ of control	*	\$ of control	total \$
0.0	1.890	100.0	1.610	100.00	0.646	100.00	39.25	100.00	30.62	100.0	8.63	100.0	21.99
100	1.886	99.79	1,589	98.70	0.668	103.34	40.65	102.04	28.15	91.93	11.90	137.89	29.71
150	1.849	97.83	1.561	96.96	0.698	108.85	41.10	104.71	26.17	85.47	14.93	173.00	36.33
200	1.802	95.34	1.542	95.78	0.719	111.30	41.82	106.55	21.36	69.76	20.46	237.08	48.92

<sup>\*</sup> The macro porosity was taken as the air filled porosity when the soil water system was in equilibrium with 100 cm suction, (Loveday, 1974).

application of the hydrogel to 0.2% indicating slow water movement and more water retention in the soil.

The pore size distribution curves for sandy soil treated with different rates of hydrogel are shown in Fig. These are classified in percentages of porosity in Table (9). Data reveal that increasing hydrogel concentration in the soil, increased, the water holding pores, i.e. the coarse capillary pores (28.8 -0.19 µ in diameter) by 46.8, 90.0 and 157.2%, the fine capillary ones (<0.19  $\mu$  in diameter) by 12.9, 18.2 and 56.5% by incorporating the hydrogel into sandy soils at the rates of 0.1, 0.15 and 0.2%, respectively. On the other hand, the drainable pores (>28.8 \u00bc in diameter) decreased by 9.9, 18.4 and 34.5% relative to that of the untreated sandy soil for the three application rates of hydrogel mentioned above, respectively. The increase in water storage pores are vital to insure water reservation in sandy soil under dry farming conditions. These changes in bulk density, void ratio and pore system could be the swelling of gel fine particles. attributed to Deswelling or drying diminishes the volume ge l of On rewatering the particles leaving voids in the soil. soil, water goes through soil voids to get in contact with gel particles. So, it swells again. This may also explain why the retained water remains nearly the same through

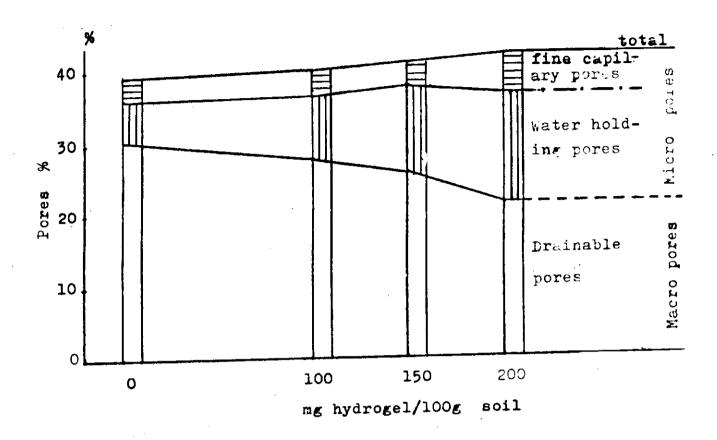


Fig. (2):Pore size distribution in sandy soil treated with different rates of hydrogels.

Table (9) Pore size distribution as a percent of total porosity in sandy soil treated with hydrogel at different rates of application.

Application rate	Drainable pores > 28.8 µ	Water holding pores 28.8-0.19 µ	Fine capillary (non- useful) pores <0.19 \( \mu \)
0.0 (untreated sand)	78.01	14.41	7.58
100	70.29	21.15	8.56
150	63.67	27.38	8.96
200	51.08	37.06	11.86

' several cycles of wetting and drying as will be mentioned.

### 4.1.3. Moisture retention in the soil:

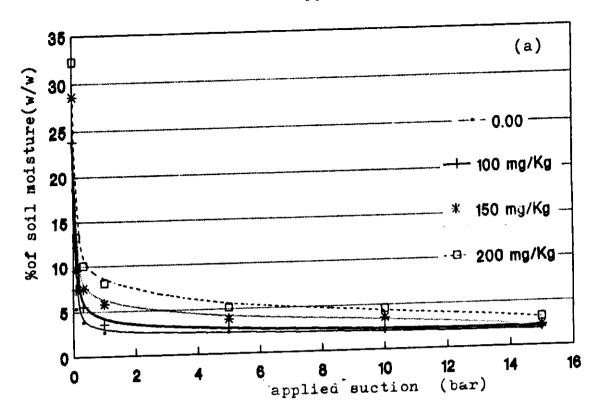
Retained moisture in sandy soil under different suctions from zero to 15 bars, as affected by incorporating the hydrogel in sandy soil is presented in Table (10) and illustrated in Fig. (3 a & b). Data in hand refer to an increase in the percentage of retained moisture at all suctions under study due to soil conditioning being higher with increasing the application rate of the hydrogel.

At saturation i.e. at pF=0, the total water holding capacity (WHC) of the soil was increased by 28.4, 53.4 and 73.2% when incorporating 0.1, 0.15 and 0.2% hydrogel in the soil, respectively. At field capacity (Fc) i.e. at pF=2.01, values of retained moisture show an increase of 39.7, 78.4 and 147.6% relative to that of the control, by incorporating the same application rates of hydrogel in the soil, respectively. Because the increase in water retained at field capacity (i.e. at pF= 2.01) is far beyond that at wilting percentage (WP) i.e. at pF=4.19, the available water increased (Table (11) and Fig. (4). Incorporating 0.1, 0.15 and 0.2% hydrogel in the soil raised its available moisture to be about 1.5, 2.1 and 2.9 times that of the untreated soil, respectively.

Table (10) Percentage of moisture contents at different tension values for sandy soil treated with hydrogel.

Application		Perce	UC OL 2011 m			sion values*	
rate mg/100 g soil	0.0 atm. pF= 0	0.1 atm. pF= 2	0.33 atm. pF= 2.54	1.0 atm. pF= 3.0	5.0 atm. pF= 3.7	10.0 atm. pF= 4.0	15.0 atm pF= 4.2
0.0 (Untreated soi	18.62  }	5.36	3.76	2.61	2.35	2.01	1.65
100	23.86	7.49	6.58	3.52	2.78	2.25	2.16
150	28.63	9.56	7.52	5.80	3.86	3.55	2,35
200	32.24	13.27	10.05	8.07	5.10	4.50	3.22

<sup>\*</sup> On weight basis.



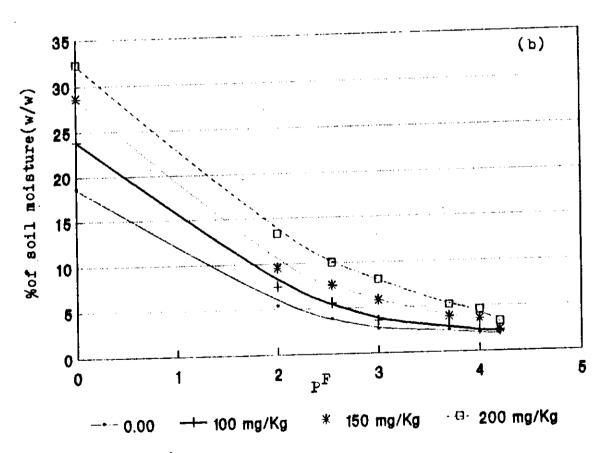


Fig. (3 a,b): Moisture desorption curves for sandy soil treated with hydrogels .

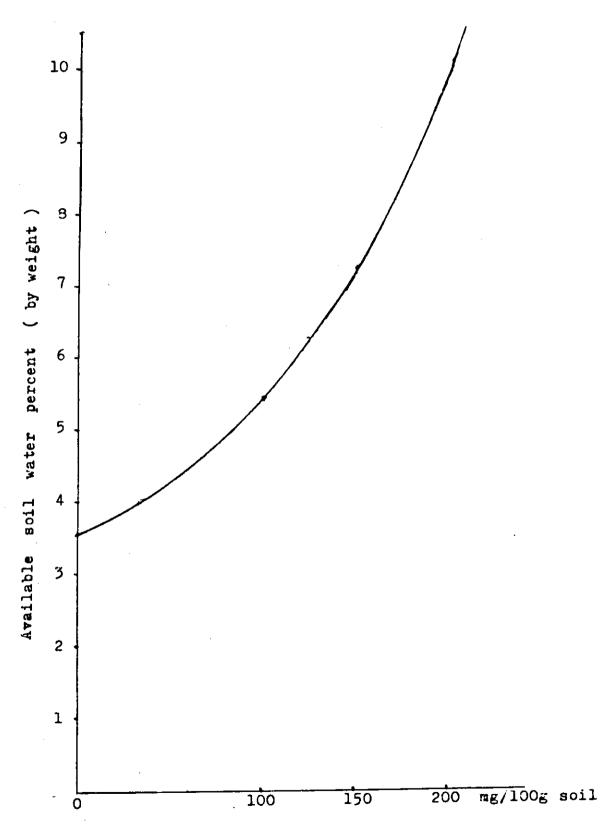


Fig. (4): available water in sandy soil as affected by hydrogel addition.

Obtained results could be explained on the basis of increasing the smaller pores (water holding pores 28.8-0.19  $\mu$ ) and decreasing the large ones (drainable pores >28.8 $\mu$  in diameter) with increasing the application rate of the hydrogel as previously mentioned.

It is well known that increasing available moisture for plants elongates irrigation frequencies, and in turn, decreases the quantities of irrigation water needed and costs of irrigation process.

The relative amounts of water present at different determines the air-filled porosities suctions diffusion rates at these suctions (Marshall, 1959). filled porosity in sandy soil treated with different rates of the hydrogel at pF 2, 2.54 and 4.2 are presented in Table (12). Data reveal that changes in air filled porosity at wilting percentages (at suction of 15 bar) are not noticiable. Air filled porosity decreses at 0.1 and 0.33 bar. At field capacity (at a suction of 0.1 bar) the decrease in air filled porosity reached 30.2% relaive to that of the control. This decrease in air-filled porosity could be attributed to the increase in moisture retained in the soil at that suction. Under such conditions, the decrease in air-filled porosity is not likely to become limiting to plant growth, since the air-filled porosity did not reach 10% (Hillel, 1971).

Table (12) Air filled porosity at different soil moisture content as affected by hydrogel addition.

Application rate	Ai	r filled prosity	*
mg/100 g soil	At 0.1 atm	At 1/3 atm	At 15 atm
0.0 (untreated soil)	30.62	33.20	36.29
100	28.15	29.60	36.63
150	26.17	29.36	37.42
200	21.36	26.32	36.86

# 4.1.4. Water loss from the soil through evaporation: Laboratory experiment I:

In this experiment, columns were prepared to cover four different treatments as follows: a) Untreated soil as the control treatment, (b),(c) and (d) where 0.1, 0.15 and 0.2% hydrogel were respectively incorporated in the soil.

The columns were saturated with water. After equilibrium, they were subjected -in a growth chamber- to evaporation until reaching the wilting percentage of each soil. Water loss via evaporation was periodically determined. Evaporation from free water surface-under the same conditions of the conducted experiment - was also determined and used for comparison as it is the resultant of the different factors affecting the evaporation process in the growth chamber.

The effect of added hdydrogel on cumulative evaporation from sandy soil versus time needed to reach the wilting percentage of the soil is graphically illustrated in Fig. (5). According to Kijne (1974) evaporation is characterized by three stages. In the 1st stage, evaporation rate is rapid, constant and governed by the external conditions. Sooner, the rate of water loss is governed by soil hydraulic poroperties and evaporation decreases with time (a falling rate stage). During the

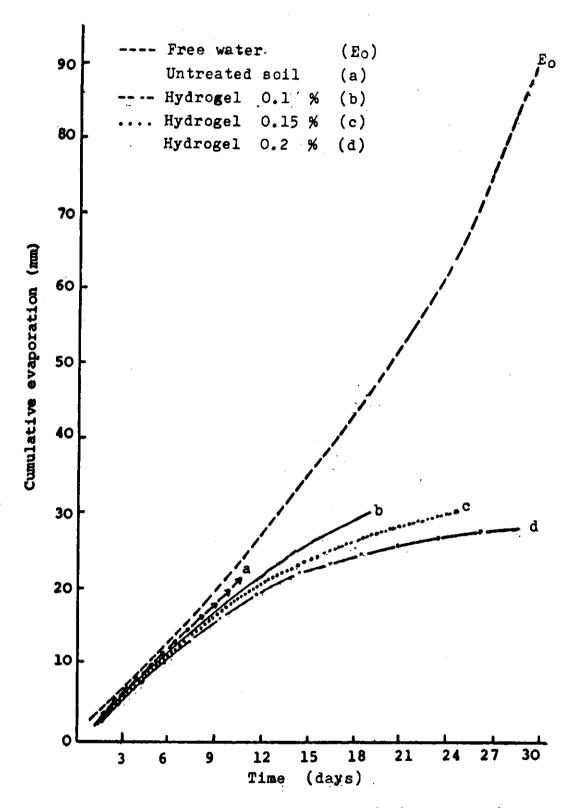


Fig.(5): Cumulative evaporation (mm) versus time as affected by Hydrogel.

third stage of drying, evaporation depends on temperature profile of the soil. For better interpretation of the cumulative evaporation in the early stage of evaporation, the cumulative evaporation (E) versus the cumulative potential evaporation, i.e. evaporation from a free water surface (Eo) as affected by sandy soil conditioning are plotted in Fig. (6). An early response in E reduction was observed in the case of incorporating 0.2% hydrogel in the soil. The effect of the other treatments could be arranged in the folliwing descending order: Hydrogel 0.15% > Hydrogel 0.1% > untreated soil.

Table (13) summarizes the data extracted from Figs. (5 and 6). It is obvious that the loss of water from sandy soil through evaporation is reduced by soil conditioning. Under the conditions of the conducted experiment, incorporating hydrogel in the soil at the rate of 0.1% can raise the time needed for the soil to reach its wilting percentage by 8.6 days. Under such conditions, this time was raised by another 5.2 or 8.9 days when 0.15 or 0.2% hydrogel was incorporated in the sandy soil.

Taking the evaporated water from the soil into consideration, the average evaporation rate mm day<sup>-1</sup> i.e. the total evaporation in mm from each treatment divided by the time needed for the treated soil to reach its WP in days - was reduced from 2.086 mm day<sup>-1</sup> for the untreated

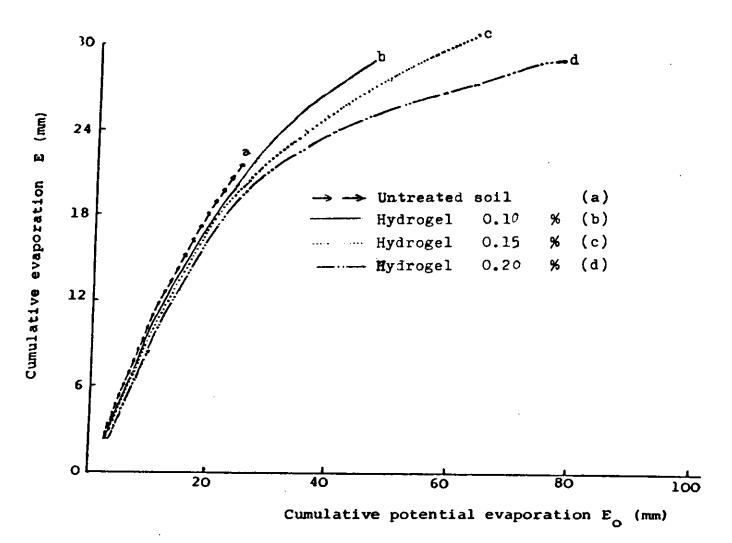


Fig. (6): Cumulative evaporation (E) from sandy soil versus cumulative potential evaporation  $(E_0)$  from a free water surface as affected by soil conditioning.

Table (13) Relative evaporation\* as affected by soil conditioning.

	Time needed to reach WP (days)		•	Relative	evaporation*
Treatments	reach we (usys)	soil (mm)	water surface (mm)	dimension less	as a % of the untreated soi
a) Untreated sand	10.5	21.9	24.8	0.883	100.0
b) Hydrogel 0.1%	19.1	28.3	45.6	0.621	70.0
c) Hydrogel 0.15%	24.3	30.4	63.5	0.479	54.2
l) Hydrogel 0.2%	28.0	29.6	86.0	0.344	39.0

total evaporation in mm from free water surface

sandy soil to be 1.482, 1.251 and 1.057 mm  $day^{-1}$  by treating the soil with 0.1, 0.15 and 0.2% hydrogel, respectively.

Because the time required for the soil to reach its WP varied among the treatments; total evaporation in mm from free water surface which corresponds to the duration of evaporation for each treatment, was taken as a reference. Accordingly, the so-called relative evaporation was calculated by dividing the total evaporation in mm from the treatment by the total evaporation in mm from free water surface. Obtained vales were also inserted in Table (13). The data reveal that the relative evaporation was the highest in the untreated sandy soil. By treating the soil with conditioners, values of relative evaporation were decreased by 29.7, 45.8 and 61.0% for the treatments b, c and d, respectively.

#### Laboratory experiment II:

In this columns experiment, also, the columns were prepared to cover the 4 different treatments, i.e. treatments a, b, c and d previously mentioned in experiment I. The saturated soil columns, besides those filled with water to the same height, were exposed in the growth chamber to successive eight wetting and drying cycles at one week intervals, i.e. the columns were

re-saturated weekly. Water loss through evaporation was (7) and Table (14) periodically detremined. Fig. illustrate the influence of conditioning treatments on the 7 days cyclic cumulative evaporation (Emm) versus time relationship for the sandy soil. Potential evaporation vfrom free water surface (Eo mm) was also included. obvious that all the treatments under study were effective in reducing cumulative evaporation by varying degrees. By the end of the  $4\underline{th}$  wetting and drying cycle, evaporated water from sandy soil could be ranked in the following ascending order: 0.2% hydrogel < 0.15% hydrogel < 0.1%hydrogel < untreated soil with a relative evaporation (i.e. E mm/Eo mm) of 0.845, 0.859, 0.884 and 0.904 for the aforementioned treatments, respectively. Similarly, by the end of the 8th cycle, evaporated water from the soil still having the same consequency with more or less the same values of relative evaporation.

Due to the fact that the total water holding capacity of the soil varied among the treatments, Table (15), the comparison between the common values of cumulative evaporation obtained from the treated soil and from the control seems to be inaccurate. Therefore, the ratios between cumulative evaporation and soil moisture content at saturation for both the treated and the untreated soil must be taken into consideration. The so-called adjusted

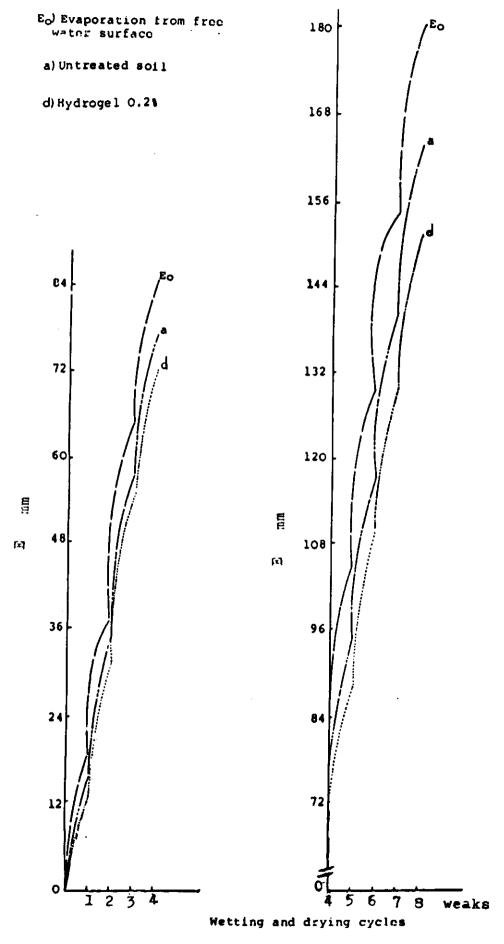


Fig. (7): Intermittent evaporation as affected by soil conditioning.

Table (14): Cumulative evaporation (mm) from soil columns as affected by soil conditioning.

			No of	No of evaporation		cycles		
Treatments	1st	2 <sup>nd</sup>	3rd	4th 5th	5th	6th	7 <u>th</u>	8th
a) Untreated sand	16.4	34.9	58.1	77.5	94.9	117.7	117.7 140.7 163.9	163.9
b)Hydrogel 0.1 %	15.3	33.1	56.4	75.8	92.7	115.2	115.2 137.1 158.4	158.4
c)Hidrogel 0.15 %	14.8	32.6	55.9	73.6	61.6	113.2	113.2 134.3 155.6	155.6
d)Hydrogel 0.2 %	13:6	32.2	55.5	72.4	88.8	110.0	130.7 151.9	151.9
Free water (E <sub>O</sub> )	18.7	37.7	18.7 37.7 :65.3 85.7 105.0	85.7	105.0	130.1	154.9 180.5	180.5

evaporation (Eadj) was calculated using the following formula:

Eadj =  $(E_{er}/WHC_{er})$ . (WHCs/Es)

Where;

 $E_{tr}$  = cumulative evaporation from the treated soil.

Es = cumulative evaporation from the untreated soil.

WHC<sub>tr</sub> = total water hodling capacity of the treated soil.

WHCs = total water holding capacity of the untreated soil.

The calculated Eadj values from sandy soil as affected by soil conditioning are presented in Table (15). Mean values of Eadj for the eight wetting and drying cycles are graphically plotted in Fig. (8). In this case and for all the studied cycles of wetting and drying, the conditioning treatments could be arranged descendingly according to their Eadj as follows:

0.2% hydrogel < 0.15% hydrogel < 0.1% hydrogel < untreated soil.

It is worthy to notice that Eadj is nearly constant over successive eight cycles of wetting and drying (Table 15) revealing that the conditioning treatments remained fully effective in the soil during the whole period of the experiment. This indicates the stability of the formed streutre due to the applied conditioners and

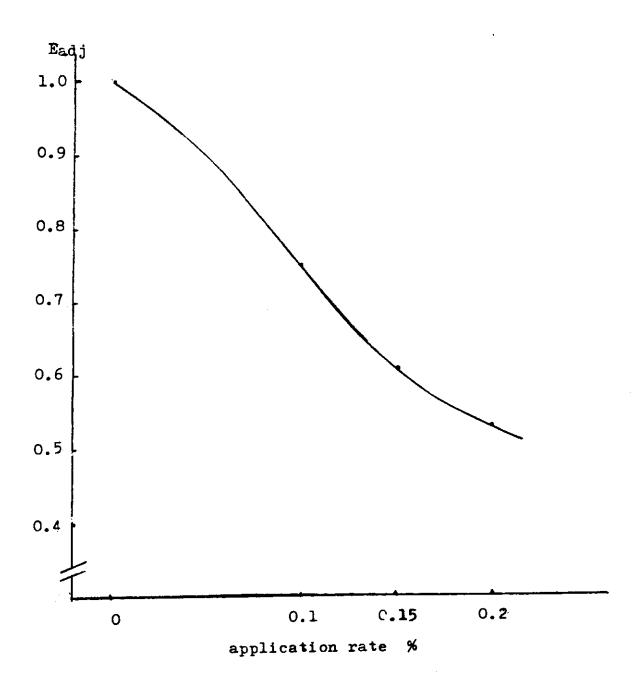


Fig.(8): Adjusted evaporation (Eadj) for sandy soil treated with hydrogel at different application rates.

Table (15) Adjusted evaporation (Eadj)\* from sandy soil as affected by soil conditioning.

	No. of evaporation cycels								Hean	
Treatments	1 <u>st</u>	2 <u>nd</u>	3 <u>rd</u>	4 <u>th</u>	5 <u>th</u>	6 <u>th</u>	7 <u>th</u>	8 <u>th</u>		
a) Untreated sand	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
b) Hydrogel 0.1%	0.728	0.739	0.757	0.763	0.762	0.764	0.760	0.753	0.753 <u>+</u> 0.013	
c) Hydrogel 0.15%	0.586	0.607	0.625	0.618	0.627	0.625	0.621	0.617	0.616±0.014	
d) Hydrogel 0.2%	0.479	0.533	0.552	0,539	0.541	0.540	0.536	0.535	0.532 <u>+</u> 0.622	

<sup>\*</sup> Eadj = (Etr/WHCTr) . (WHCs/Es) where E and WHC are the cumulative evaporation and total water holding capacity, respectively, while tr and s are the treated soil and control respectively.

the very slow biodegradability of the examined conditioners.

#### 4.1.5. Infiltration rate:

In the columns experiment (II) previously mentioned in 4.1.4. and for each of the eight cycles of intermittent evaporation, the time required for the water to infiltrate into the soil was recorded. Infiltratin rates of each treatment were calculated. Table (16) presents the effect incroporating the hydrogel in sandy soil at different application rates on its infiltrability expressed in cm min-1 for the eight successive cycles of wetting and drying. Mean values of the infiltration rate for the different treatments are illustrated in Fig. (9). It is generally noticed that the values of infiltration rate estimated at the beginning of the experiment, i.e. at the 1<u>st</u> cycle of wetting and drying are higher than those measured for the other cycles. This is expected due to the dependence of soil infiltration rate on the moisture content initially found in. The lower the moisture content in the soil is, the rapid is the water percolation into the soil and the higher is its infiltration rate (Donahue et al., 1977 and Michaeal, 1978). Data also reveal to the relatively high infiltration rate of the untreated sandy soil that ranges between 1.14 and 0.74 cm  $\min^{-1}$  with an

Table (16) Effect of sandy soil conditioning on its infiltration rate (cm min-1).

Treatments		<del>,</del>	No. of	evaporat io	e cycles			<del></del>	Heas
A	1 <u>st</u>	2 <u>nd</u>	3ले	4 <u>th</u>	5 <u>th</u>	6 <u>th</u>	7 <u>th</u>	8 <u>th</u>	
) Untreated sand	1.14	0.84	0.74	0.84	0.78	0.78	0.90	0.78	0.85±0.127
) Hydrogel 0.1%	1.01	0.76	0.69	0.61	0.72	0.70	0.74	0.66	0.76 <u>+</u> 0.111
) Hydrogel 0.15%	0.93	0.71	0.66	0.59	0.64	0.61	0.67	0.60	0.68 <u>+</u> 0.110
Hydroge 10.2%	0.84	0.60	0.60	0.48	0.60	0.54	0.60	0.54	0.60 <u>+</u> 0.106

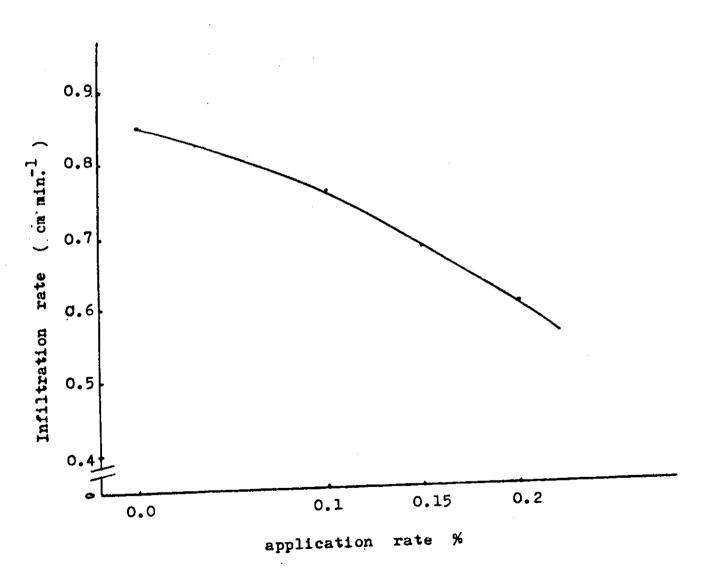


Fig. (9): Infiltration rate ( cm min<sup>-1</sup>) for sandy soil treated with hydrogel at different application rates.

average of  $0.85\pm0.127$  cm min<sup>-1</sup>. Incorporating hydrogel in the soil lowered its infiltration rate to reach about 70% of that for the untreated soil by applying 200 mg hydrogel to each 100 g of the soil. The descending infiltration rate order due to the treatments under study could be ranked as follows: untreated sand >0.1% hydrogel >0.15% hydrogel >0.2% hydrogel.

The decrease in infiltration rate and consequently the slow advancement of the wetting front could be attributed to the increase in soil micro porosity and in turn, the increase in the hydraulic resistivity of the treated sandy soil on one hand, and the high moisture content of the treated soil at the time of infiltration trials on the other hand.

# 4.1.6. Hydraulic conductivty and mean diameter of soil pores:

Table (17) presents the hydraulic conductivity (m day-1) and mean diameter of soil pores (microns) of West Sinai sandy soil as affected by hydrogel additions at different application rates. Values show that incorporating hydrogel in sandy soil decreases its mean pore diameter and in turn, its hydraulic conductivity decreases. Data in hand reveal that the decrease in soil hydraulic conductivity due to the addition of the hydrogel

Table (17) Hydraulic conductivity (m.day-1) and mean diameter of soil pores (microns) for sandy soil treated with hydrogel at different application rates.

Application rate	Hydraulic	conductity	Mean diamet	er of soil
*	m day-1	% of untreated soil	щ	% of untreated soil
0.0 (Untreated soil)	<b>1</b> 0.15	100.0	19.68	100.0
0.1	5.89	67.9	16.22	82.4
0.15	5.31	<b>52.</b> 5	14.24	72.4
0.2	3.92	38.6	12.23	62.1

under study to sandy soil were 32.1, 47.7 and 61.4% relative to the untreated soil, for the rate of 0.1, 0.15 and 0.2%, respectively. Regarding the mean diameter of soil pores, the decrease reached 37.9% (relative to the untreated sandy soil) for the examined hydrogel at the rate of 0.2%.

4.1.7. Mechanical strength of air dry soil: As seeds germination and seedlings emergence, root growth management practices are directly affected by the strength of soil surface, it is of importance to study the incorporating hydrogels at different influence of application rates on the maximum strength of the soil, i.e. the dry soil. Three different measurements were used to assess the changes in soil strength due to gel treatments namely, the unconfined compressive strength, the resistivity to a penetrating probe and the modulus of rupture. Table (18) presents the effect of different application rates of hydrogel on the three aforementioned properties. Gel addition increases the strength of treated soil. The higher the percentage of the added hydrogel is the higher is the strength of the soil. By raising the gel application rate up to 0.2%, the values of the unconfined compressive strength, penetration resistance and modulus of rupture reached almost 4.5, 4.8 and 1.9 times the

values of the untreated soil, respectively. It is interesting to note that this increase in the mechanical strength of air dry soil, if compared with other conditioning treatments for sandy soils such as mixing the soil with bentonitic clays, is not too much to adversely affect seedling emergence, root growth and management practices. (El-hady and El-Sherif, 1988).

Table (18) Mechanical strength of air-dry sandy soil as affected by hydrogel treatments.

Application rate mg hydrogel/ 100 g soil	Compressive strength kg/cm <sup>2</sup>	% of increase relative to wn-treated sand	Modelus of repture a bar	% of increase relative to un- treated sand	needed to	Penetration resistance kg/cm²	% of increase relative to un-treated send
0.0 (Untreated sand)	2.15	-	820.5	-	15.0	6.20	-
100.0	3.42	59.1	965.7	17.7	36.0	13.62	119.7
150.0	5.76	167.9	1217.6	48.4	58.0	21.69	249.8
200.0	9.63	347.9	1564.3	<del>9</del> 0.7	97.0	29.72	379.4

4.2. Field studies on the effect of hydrogels used as

conditioners for sandy soil on the growth response

and water and fertilizers use efficiency by some

crops:

#### 4.2.1. A vegetable crop (Cucumber):

#### 4.2.1.1. Germination:

Values showing the effect of the studied treatments on germination of Cucumber in West Sinai sandy soil are given in table (19) and illustrated in figures (10 a and 10 b) for the irrigation intervals 8 and 12 days, respectively. They clarify that addition hydrogels to sandy soil enhances the germination process. This was clearly reflected on the time needed for emergence  $(T_{50})$ . While this time was 7.3 days for the untreated plots, it was reduced to 5.2 and 6.0 days for the treated ones with the hydrogels "Evergreen 500" and "DWAL", respectively, and irrigated every 8 days. By increasing the irrigation intervals to be 12 days, increased by only few hours (2.4-3.6 hrs) to be 6.15 days for the two examined hydrogels, respectively. Moreover, percentages of emergence were also increased by more or less 10% relative to that of the control treatment (untreated soil normaly irrigated every 4 days). There is no doubt that shortening the period during which the seeds are susceptible to some diseases and drought period is of great importance.

Table (19) Germination of Cucumber seeds in West Sinai sandy soil as affected by hydrogels addition and irrigation treatments.

en A A	Emergeno	e % after		T 50*
Treatments	7 days	14 days	of the control treatment	
Control treatment (O hydrogel, normal irrigation "irrigation interval 4 days")	48.6	74.4	100.0	7.3
DWAL 0.24 m²/plant pit "irrigation interval 8 days"	56.3	81.2	109.14	6.0
Evergreen 500 4 g/plant pit. "irrigation interval 8 days.	64.6	83.6	112.37	5.2
DWAL 0.24 m²/plant pit "irrigation interval 12 days"	55.2	80.1	107.66	6.15
Evergreen 500 4 g/plant pit. "irrigation interval 12 days".	61.4	82.3	110.62	5.3
L.S.D.	4.6	5.3		

<sup>\*</sup> Time in days needed for 50% emergence.

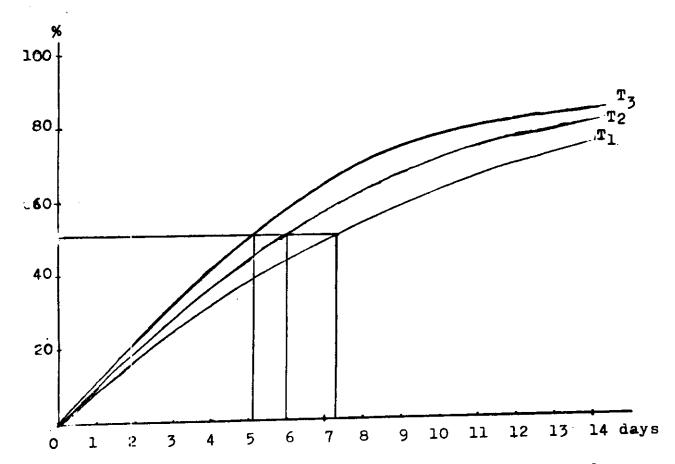


Fig. (10a): Germination of Cucumber seeds in West Sinai sandy soil treated with hydrogel .

(irrigation interval for control treament 4 days  $T_1$  and the treated soils 8 days  $T_2$  DWAL,  $T_3$  Eve. 500)

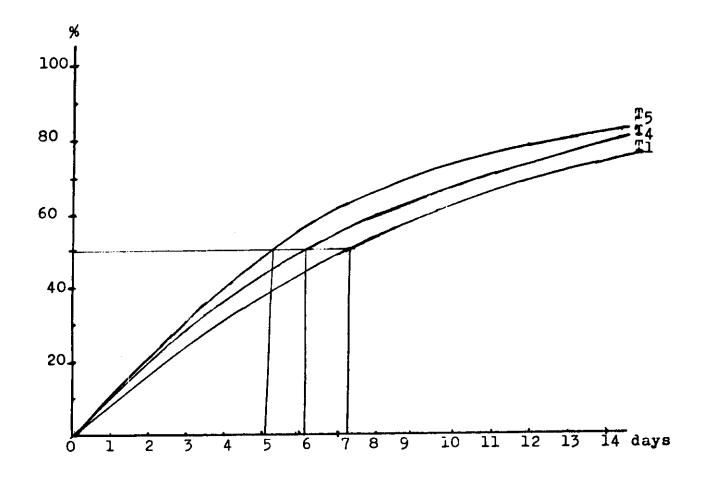


Fig.(10b): Germination of Cucumber seeds in West Sinai sandy soil treated with hydrogels .

(irrigation interval for control treatment 4 days  $T_1$  and the treated soils 12 days  $T_4$  LWAL,  $T_5$  Eve. 500)

#### 4.2.1.2. Growth parameters:

Similarly, plant growth expressed by the plant height, number and area of leaves and the dry weight of plants continued increasing significantly higher by sandy soil conditioning. Data presented in table (20) show an increase in the dry weight of plants equal to 121 and 85% and 154 and 107% over that of the control treatment by treating the plant pits of West Sinai sandy soil with 0.24 m² of "DWAL" and 4 g of "Evergreen 500" at two irrigation intervals namely 8 and 12 days, respectively.

#### 4.2.1.3. Nutrients uptake by plants:

The positive effect of the examined treatments on the uptake of nutrients by cucumber plants is shown in table (21). When watering the soil every 12 days, the uptake of N by plants has reached 173 and 193% of that of the untreated soil with the application of "DWAL" and shortening "Evergreen 500", respectively. By the irrigation interval to be 8 days, N uptake by plants (compared with the control i.e. 100%) has reached 262 and 287%. using the two hydrogels mentioned above, respectively. Also, the increase in P uptake due to sandy soil conditioning with the examined hydrogels has ranged between 90 and 181% according to the type of hydrogel and the irrigation interval. Regarding K, the increase in its

Table (20) Vegetative data of vegetable Cucumber\* grown in West. Sinai sandy soil as affected by hydrogels addition and irrigation treatments.

				Dry	weight
Treatments	Plant Number length of (cm) leaves/ plant	Leaves area cm²/plant	g/plant	% of control treatment	
Control treatment (O hydrogel, normal irrigation "irrigation interval 4 days")	75.8	18	1965.7	20.164	100.0
DWAL 0.24 m²/plant pit "irrigation interval 8 days"	92.6	24	3046.8	44.518	220.78
Evergreen 500 4 g/plant pit. *irrigation interval 8 days.	103.2	28	3815.2	51.130	253.57
DWAL 0.24 m²/plant pit "irrigation interval 12 days"	84.3	26	2605.7	37. 216	184.57
Evergreen 500 4 g/plant pit. "irrigation interval 12 days".	91.8	23	2805.0	41.735	206.98
S.D. 0.05	8.4	2.3	215.6	3.974	

<sup>\*</sup> At the beginning of the flowering stage.

Table (21) Nitrogen, phosphorus and potassium uptake by Cucumber plants grown in West Sinai sandy soil as affected by hydrogels addition and irrigation treatments.

	K	1		P		K
Treatments	mg/plant	% of control treatment		% of control treatment	mg/plant	% of control treatment
Control treatment (O hydrogel, normal irrigation "irrigation interval 4 days")	241.9	100.0	31.4	100.0	205.1	100.0
DWAL 0.24 m²/plant pit "irrigation interval 8 days"	634.8	262.42	79.8	254.14	586.3	285.86
Evergreen 500 4 g/plant pit. *irrigation interval 8 days.	695.3	267.43	88.3	281.21	615.6	300.15
DWAL 0.24 m²/plant pit "irrigation interval 12 days"	418.6	173.05	59.7	190.13	398.2	194.15
Evergreen 500 4 g/plant pit. "irrigation interval 12 days".	466.2	192.72	80.2	255.41	428.6	208.97

<sup>\*</sup> At the beginning of the flowering stage.

uptake arrived to 200% compared to the untreated soil by incorporating 4 g of "Evergreen 500" into the plant pit and doubling the irrigation intervals to be 8 days.

#### 4.2.1.4. Yield:

The effect of the treatments under study on the marketable yield of cucumber is illustrated in table (22). It is obvious that the use of hydrogels -as conditioners for sandy soil - raises markedly its productivity. These increases differ also by the type of added hydrogel and the used irrigation regime. In other words, treating the sandy soil with the hydrogel "DWAL" increases the obtained yield by 36.7 and 21.4% when the soil was irrigated every 8 and 12 days, respectively. Relevant values for the "Evergreen 500" were 57.2 and 29.1%. hydroge l respectively.

#### 4.2.1.5. Water use efficiency by plants:

Water use efficiency by the growing plants was calculated as kg of the marketable yield obtained by each cubic meter of the irrigtion water used. Values presented in table (22) show that both the studied hydrogels have exerted beneficial effects on the efficiency of water use by plants. Increments in the water use efficiency were calculated to be 105.1 and 264.2% for the treatments of

Table (22) Yield, water and fertilizers use efficiency by Cucumber grown in West Sinai sandy soil as affected by hydrogel addition and irrigation treatments.

	Yie	eld			Fertilizers efficiency kg/unit of added matrients			
Treatments	ton/fed.	% of control treatment	Water use effici- ency kg/m <sup>3</sup>	control				control treatment
Control treatment (O hydrogel, normal irrigation "irrigation interval 4 days")	4.350	100.0	2,589	100.0	212. 24	280.65	174.0	100.0
DWAL 0.24 m²/plant pit "irrigation interval 8 days"	5.947	136.7	5,310	205.1	290.10	383.68	237.68	136.7
Evergreen 500 4 g/plant pit. *irrigation interval 8 days.	6.836	157.2	6.103	235.7	333.46	441.03	273.44	157.4
DVAL 0.24 m²/plant pit "irrigation interval 12 days"	5. <i>2</i> 80	121.4	9, 429	364.2	257.56	340.65	211.2	121.4
Evergreen 500 4 g/plant pit. "irrigation interval 12 days".	5.618	129.1	10.032	387.5	2/3.95	362.32	224.64	129.1
L.S.D. 0.05	0.365							

"DWAL" and 135.7 and 287.5% for those of "Evergreen 500" at the two irrigation intervals under study namely 8 and 12 days, respectively.

# 4.2.1.6. Fertilizers use efficiency by plants:

The fertilizers use efficiency data, i.e., the produced yield by the unit of added nutrients shown in table (21) also indicate the beneficial effect of treating sandy soil with hydrogels. With this respect, fertilizers use efficiency values for the conditioned soil have ranged between 1.37 and 1.57 times and 1.21 and 1.29 times that of the untreated one by irrigating the soil every 8 and 12 days, respectively.

# 4.2.2. Some summer forage crops: (Guar and Cowpea)

As the obtained fresh and dry weight yields of both successive years were not significantly different, their average were taken into consideration.

#### 4.2.2.1. Guar:

### 4.2.2.1.1. Growth parameters:

## a- Fresh weight yields and seed production:

The average fresh weight yields of Guar (tons/fed) as well as the produced seeds (kg/fed) as influenced by the hydorgel addition and the irrigation

treatments are presented in table (23) and illustrated in figure (11). Percentages relative to the control treatment (untreated soil with hydrogel and normally irrigated i.e. irrigation intervals were 4days) are also inserted in the table.

Under the same irrigation regime, fresh weights were increased by increasing the application rate of the hydrogel. This increase ranged between 77 and 93.7% when using the lowest application rate of the hydrogel (33.3g/m² of the soil). By doubling or tripling the rate of applied hydrogel, i.e. applying 66.6 or 100.0 g/m² of the soil, the increase in the fresh weight of the forage yield ranged between 978 and 108.7 or between 103.9 and 125% relative to the untreated soil, respectively.

On the other hand, doubling the irrigation intervals for the plants grown in the soils treated with hydrogels (I<sub>2</sub> treatment) has increased the fresh weights to reach their maximum when 100 g of the used hydrogel/m<sup>2</sup> soil was applied. In other words, the increase in the fresh weight of the plants were 94.5, 110.2 and 124.8% when 33.3; 66.6 and 100 g of the hydrogel/m<sup>2</sup> of the soil were respectively added. Reducing the applied irrigation water to one third (I<sub>3</sub> treatment), resulted in a little decrease in the fresh weight yield relative to those obtained under I<sub>2</sub> treatment. However, the production was still much higher

Table (23) Average fresh weight forage yield and seeds of Guar as influenced by hydrogel and irrigation treatments.

	Treatments	1		9	Paka 1	% of	Seeds	; <del>-</del>
treatment		Irrigation intervals days	1 <u>st</u> cut tons/fed.	2 <u>nd</u> cut tons/fed.	Total tons/fed	control	kg/fed.	* of control
00.0	(I <sub>1</sub> )	4	2.961 f	7.081 f	10.042 f	100.0	777.42 f	100.00
33.3			6.405 c	13.045 d	19.450 d	193.7	1408.26 c	181.12
66.6			7.203 b	13.759 с	20.962 b	208.7	1480.50 b	190.40
100.0			7.728 a	14.864 a	22.592 a	225.0	1797.18 a	231.20
33.3	(12)	8	5.935 d	13.595 d	19.530 d	194.5	1094.52 d	140.80
66.6			6.930 b	14.175 b	21.105 b	210.2	1370.88 c	174.70
100.0			7.287 a	15.292 a	22.579 a	224.8	1456.98 b	187.40
33.3	(I <sub>3</sub> )	12	5.649 e	12.142 e	17.791 e	177.2	1065.12 e	137.00
66.6			6.216 d	13.646 d	19.882 đ	197.8	1093.00 d	140.70
.00.0			6.552 c	13.923 с	20.475 c	203.9	1116.36 d	143.60

<sup>-</sup> Number followed by the same letter don't differ significantly (P = 0.05) according to Duncan's multiple range.

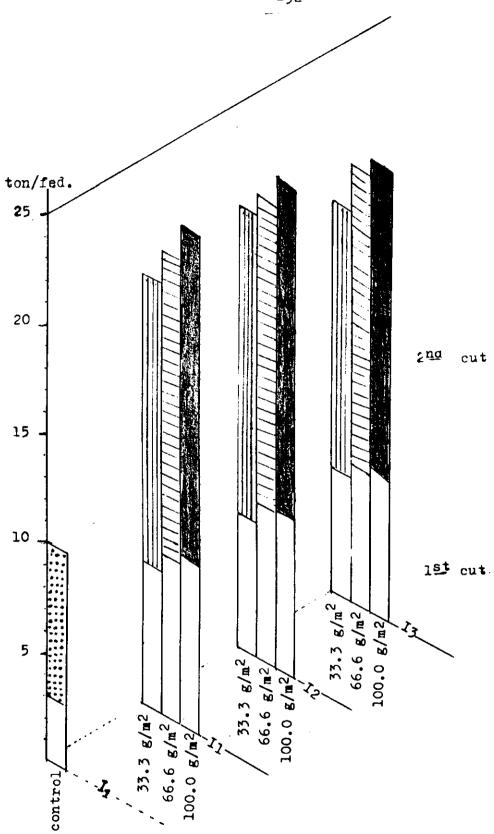


Fig.(11): Average fresh weight forage yield of Guar as influenced by the application rate of hydrogel and irrigation treatments.

(I<sub>1</sub>,I<sub>2</sub> and I<sub>3</sub> refer to irritation intervals of 4,8 and 12 days, respectively).

than that under the control. In this case when 100 g of the hydrogel were added to each m<sup>2</sup> of the soil, the increase in the fresh weight yield compared to that of the control treatment was 103.9%.

Yield of seeds as affected by hydrogel additions and irrigation treatments took similar trend. Under the same irrigation regime, produced seeds were increased by increasing the application rate of the hydrogel to reach their maximum when the highest application rate of hydrogel (100 g/m² soil) were added. This increase reached 131.2% under I<sub>1</sub> treatment. On the other hand, doubling the irrigation intervals (I<sub>2</sub> treatment) or tripling them (I<sub>3</sub> treatment) did not decrease the production of seeds by more than 18.9 or 37.9%, respectively, but the yield of seeds was still higher than that of the control by more than 87% and 43% when I<sub>2</sub> and I<sub>3</sub> treatments were respectively applied.

#### b- Dry weight yields:

The average dry weight yields of Guar (kg/fed) as influenced by hydrogel additions and irrigation treatments are shown in Table (24) and illustrated in Fig. (12). Percentages relative to the control treatment are also inserted in the table.

Under the same irrigation treatment, dry weights were

Table (24) Average dry weight yield of Guar (kg/fed) as influenced by hydrogel and irrigation treatments.

	Treatments		lat out	2nd out	Total	% of control	
Hydrogel g/m²	7		Irrigatiom intervals days	1 <u>st</u> cut	2 <u>nd</u> cut	10141	
00.0	(I <sub>2</sub> )	4	627.732 e	_1310.022 f	1937.754 g	100.00	
33.3			1441.125 b	2582.950 d	4023.075 d	207.67	
66.6			1577. 247 Б	2606.803 с	4274.260 c	220.58	
100.0			1785.168 a	3106.534 a	4891.702 a	252.44	
33.3	(c1)	8	1192.855 с	2623.912 c	3816.767 e	196.97	
66.6			1462.230 b	3090.150 a	4552.380 b	234.93	
100.0			1654.149 a	3173.024 4	4827.173 a	249.11	
33.3	(I <sub>a</sub> )	12	1101.555 d	2477.009 e	3578.564 f	184.68	
66.6			1274.280 c	2701.868 c	3976.148 d	205.19	
100.0			1447.992 Ъ	2840. 292 b	4288.284 c	221.31	

Numbers followed by the same letter don't differ significantly (P = 0.05) according to Duncan's multiple range.

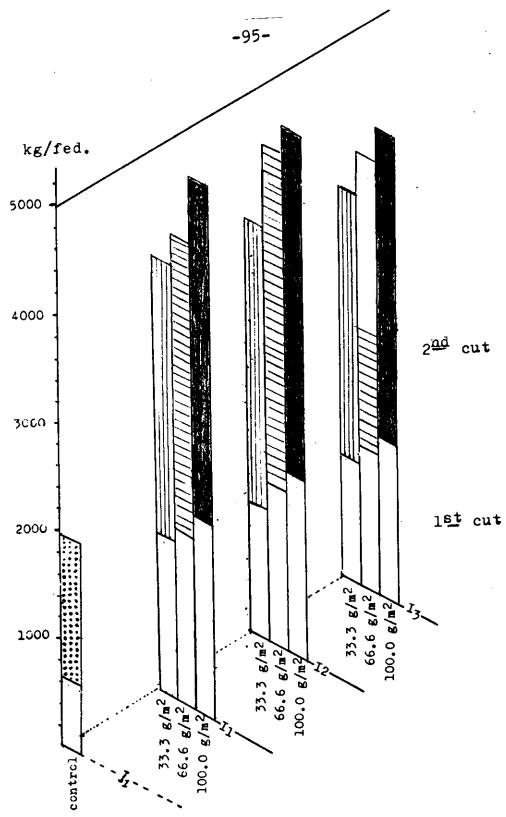


Fig.(12): Average dry weight of Guar as influenced by the application rate of hydrogel and irrigation treatments.

(I<sub>1</sub>,I<sub>2</sub> and I<sub>3</sub>refer to irrigation intervals of 4,8 and 12 days , respectively).

increased by incorporating the examined hydrogel into sandy soil. This increase ranged between 107.7 and 152.4%, 97.0 and 149.1% and 84.7 and 121.3% by aplying I<sub>1</sub>, I<sub>2</sub> and I<sub>3</sub> treatments, respectively. Noteworthy that the former and the later values refer to the increase in the dry weights relative to that of the control treatment when 33.3 and 100.0 g hydrogel were respectively added to each m<sup>2</sup> of the soil.

On the other hand, doulding the irrigation intervals for the plants grown in the treated soil with hydrogel to be 8 days (I<sub>2</sub> treatment) has increased the dry weight yields to reach 249.1% that of the control by applying 100 g of the examined hydrogel to each m<sup>2</sup> of the soil. By irrigating the soil each 12 days (I<sub>3</sub> treatment), the obtained dry weights have increased by 84.7, 105.2 and 121.3 when 33.3, 66.6 and 100.0 g hydrogel were respectivley applied to each m<sup>2</sup> of the soil.

## 4.2.2.1.2. Water use efficiency by Guar plants:

The values of water use efficiency by Guar plants which reflect the relation between the production and the seasonal water used are presented in table (25). It is obvious that the highest water use efficiency value lies at 100 g hydrogel/m² soil when only 1/3 of the quantity of irrigation water was added i.e. when the soil

Table (25) Effect of hydrogel and irrigation treatments on the water use efficiency (kg/m³) by Guar.

			Irrigati	on intervals		
Hydrogel treatments	4 d	ey5*	8 da	ys*	12	days*
g/m² soil	kg/ <b>=</b> 5	\$ of control	kg/m³	\$ of control	kg/m³	\$ of control
1. <u>Green for</u>	ige yield:					
00.0	2.511	100.0				
33.3	4.863	193.7	9.765	388.9	12.708	506.1
66.6	5.241	208.7	10.553	420.3	14.187	565.0
100.0	5.648	224.9	11.290	449.6	14.625	582.4
2. <u>Seeds pro</u>	duction (q/	<u> p³):</u>				
00.0	194.355	190.0				
33.3	352.063	181.1	547.89	281.9	760.8	391.4
66.6	370.125	190.4	679.64	349.4	781.2	401.9
100.0	441.295	231.2	728.49	374.8	797.4	410.3

<sup>\*</sup> Quantities of the seasonal irrigation water were 4000, 2000 and  $1400 \text{ m}^3/\text{Fed.}$  at the irrigation intervals of 4, 8 and 12 days, respectively.

was irrigated every 12 days. This is about 5.8 and 4.1 times that of the untreated sandy soil irrigated every 4 days for the green forage yield and seeds production, respectively.

# 4.2.2.1.3. Fertilizers use efficiency by Guar plants:

The fertilizers use efficiency data, i.e. produced yield of Guar by the unit of added nutrients, are shown in Table (26). Data also indicate the beneficial effect of treating sandy soil with hydrogels. With this respect values of fertilizers use efficiency by Guar produced in conditioned sandy soil were more or less the same by irrigating the soil every 4 or 8 days, i.e. by treatments. Under applying either I<sub>1</sub> or Ιa conditions, the increase in fertilizers use efficiency relative to control treatment were 94, 110 and 125% when 33.3, 66.6 and 100.0 g hydrogel/m2 soil were respectively added. By applying Is treatment, i.e. irrigating the soil every 12 days. fertilizers use efficiency by plants grown in conditioned soil were lower than that irrigated every 4 or 8 days by only 8.8, 5.9 and 9.4% when the same rates of hydrogel were respectively applied.

Table (26) Effect of hydrogel and irrigation treatments on the fertilizers use efficiency kg/unit by Guar.

% of control		use efficiency /unit				Treatments
treatmen	<b>K</b> ₂0	P <sub>2</sub> 0 <sub>5</sub>	I		Irrigation treatments	Hydrogel g/m² soil
					- <u> </u>	
100.0	401.7	647.9	251.1	4	(I <sub>1</sub> )	00.0
193.7	778.1	1254.9	486.4		, <u>_</u> ,	33.3
208.7	838.3	1325.2	524.0			66.6
225.0	903.8	1457.8	555.0			100.0
194.5	781.8	1260.2	488.4	8	(I <sub>2</sub> )	33.3
210.2	844.4	1361.9	527.8			66.6
224.8	903.0	1456.5	564.5			100.0
177.2	711.8	1148.1	444.9	12	(I <sub>3</sub> )	33.4
197.8	794.6	1281.1	496.7			66.6
203.9	819.1	1321.1	512.0			100.0

#### 4.2.2.2. Cowpea:

#### 4.2.2.2.1. Growth parameters:

## a- Fresh weight yield:

The average fresh weight yields of Cowpea (tons/fed) as influenced by the hydrogel addition and the irrigation treatments are presented in table (27) and illustrated in Fig. (13). Percentages relative to the control treatment (untreated soil with hydrogel and normaly irrigated, i.e. irrigation intervals were 4 days) are also inserted in the table.

Under the same irrigation regime, fresh weights were increased by increasing the application rate of the hydrogel. This increase ranged between 16.5 and 29.2% when using the lowest application rate of the hydrogel (33.3 g/m² of the soil). By doubling or tripling the rate of applied hydrogel, i.e. applying 6.66 or 100.0 g/m² of the soil, the increase in the fresh weight of the forage yield ranged between 48.6 and 62.9 or between 63.6 and 100.2% relative to the untreated soil, respectively.

On the other hand, doubling the irrigation intervals for the plants grown in the treated soils with hydrogel (I2 treatment) has increased the fresh weight to reach their maximum when 100 g of the examined hydrogel/m² soil was applied. In other words, the increases in the fresh weight of the plants were 29.7, 62.9 and 100.2% when 33.3;

Table (27) Average fresh weight yield of Cowpea (tons/fed.) as influenced by hydrogel and irrigation treatments.

\$ of contro	Total	2 <u>nd</u> cut	1 <u>st</u> cut	Treatments		
				Irrigation intervals days	Irrigation treatments	Hydrogel g/∎² soil
100.00	8.190 f	5.565 f	2.625 f	4	(I <sub>2</sub> )	00.0
129.20	10.586 e	7.384 e	3.203 e			33.3
153.76	12.590 c	8.520 c	4.070 c			66.6
181.3	14.844 b	9.695 b	5.149 Þ			100.0
129.7	10.600 e	6.920 e	3.680 đ	8	(I <sub>2</sub> )	33.3
162.9	13.341 c	8.948 c	4.393 c			66.6
200.2	16.393 æ	10.863 a	5.530 a			100.0
116.5	9.541 e	6.573 e	2.968 e	12	(I <sub>3</sub> )	33.3
148.6	12.168 d	8.360 d	3.808 d			66.6
163.6	13.398 c	9.271 c	4.127 c			100.0

Number followed by the same letter don't differ significantly (P = 0.05) according to Duncan's multiple range.

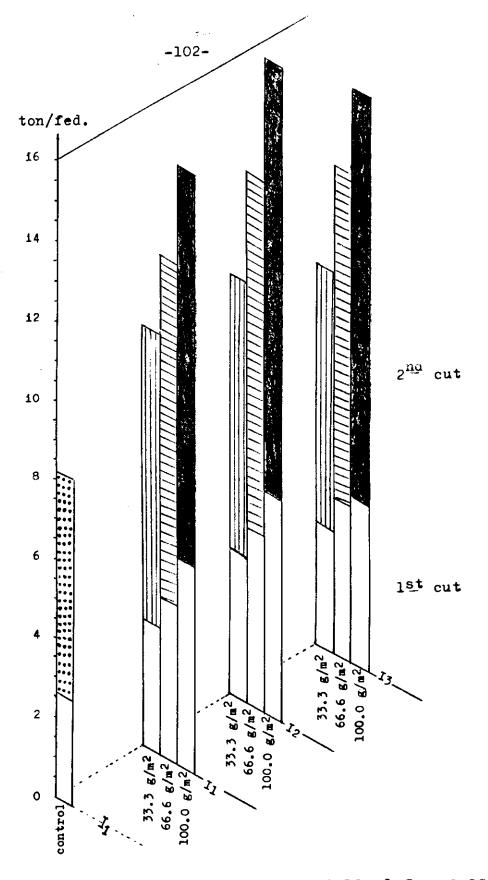


Fig.(13): Average fresh weight forage yield of Cowpea; as influenced by the application rate of hydrogel and irrigation treatments.

(I<sub>1</sub>,I<sub>2</sub> and I<sub>3</sub>refer to irrigation intrervals of 4,8 and 12 days, respectively).

66.6 and 100 g of the hydrogel/m² of the soil were respectively added. Reducing the applied irrigation water to the third (I<sub>3</sub> treatment), resulted in a little decrease in the fresh weight yields relative to those obtained under I<sub>2</sub> treatment. However, the production was still much higher than that under the control. In this case when 100 g of the hydrgel were added to each m² of the soil, the increase in the fresh weight yield compared to that of the control treatment was 63.6%.

#### b- Dry weight yields:

The average dry weight yields of Cowpea (kg/fed) as influenced by the hydrogel addition and the irrigation treatments are shown in Table (28) and illustrated in Fig. (14). Percentages relative to the control treatment are also inserted in the table.

Under the same irrigation treatment, dry weights were increased by incorporating the examined hydrogel into the sandy soil. These increase ranged between 29.1 and 80.6%, 29.4 and 109.9% and 15.5 and 64.8% by applying  $I_1$ ,  $I_2$  and  $I_3$  treatments, respectively. Noteworthy referring that the former and the later values represent the increase in the dry weights relative to that of the control treatment when 33.3 and 100.0 g hydrogel were respectively added to each  $m^2$  of the soil.

Table (28) Average dry weight yield of Cowpea (kg/fed.) as influenced by hydrogel and irrigation treatments.

Trea	tments		1 <u>st</u> cut	2 <u>nd</u> cut	Total	% of control
	Irrigation treatments	Irrigation intervals days				
00.0	(I <sub>1</sub> )	4	459.375 e	1012.83 e	1472.205 e	100.00
33.3			579.653 d	1320.910 c	1900.563 c	129.10
66.6			771.300 b	1609.827 b	2381.127 Ъ	161.74
100.0			942.113 a	1716.141 b	2658.254 b	180.5
33.3	(I <sub>2</sub> )	8	659.012 c	1245.510 d	1904.522 c	129.36
66.6			795.176 b	1637.506 b	2432.682 b	165.24
100.0			1040.624 a	2049.327 a	3089.951 a	209.88
33.3	(I <sub>3</sub> )	12	536.582 d	1163.421 d	1700.003 d	115.47
66.6			693.326 c	1460.739 c	2154.065 c	146.32
100.0			776.150 b	164.466 b	2425.616 b	164.76

Number followed by the same letter don't differ significantly (P = 0.05) according to Duncan's miltiple range.

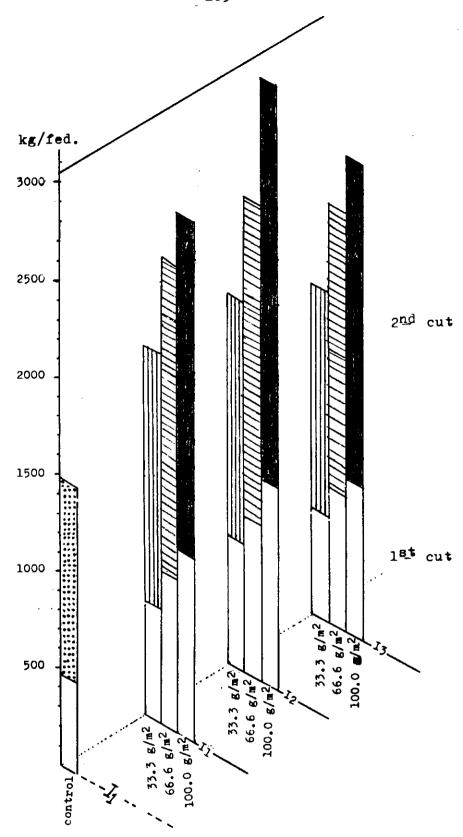


Fig.(14): Average dry weight of Cowpea as influenced by the application rate of hydrogel and irrigation treatements.

( $I_1$ , $I_2$  and  $I_3$  refer to irrigation intervals of 4,8 and 12 days, respectively).

On the other hand, doubling the irrigation intervals for the plants grown in the treated soil with hydrogel to be 8 days (I<sub>2</sub> treatment) has increased the dry weight yields to reach 209.9% that of the control by applying 100 g of the examined hydrogel to each m<sup>2</sup> of the soil. By irrigating the soil each 12 days (I<sub>3</sub> treatment), the obtained dry weights have increased by 16.5, 46.3 ad 64.8 when 33.3, 66.6 and 100.0 g hydrogel were respectively applied to each m<sup>2</sup> of the soil.

## 4.2.2.2.2. Water use efficiency by Cowpea plants:

The values of water use efficiency by Cowpea plants which reflect the relation between the production and the seasonal water used are presented in Table (29). It is obvious that the highest water use efficiency value lies at 100 g hydrgel/m² soil when only 1/3 of the quantity of irrigation water was added, i.e. when the soil was irrigated every 12 days. This is about 4.8 times that of the untreated sandy soil irrigated every 4 days for the green forage yield production.

#### 4.2,2.2.3. Fertilizers use efficiency by Cowpea plants:

The fertilizers use efficiency data, i.e. the produced yield of Cowpea by the unit of added nutrients, are shown in Table (30). Data also indicate the beneficial

Table (29) Effect of hydrogel and irrigation treatments on the water use efficiency by Cowpea.

Hydrogel treatments g/m² soil	Irrigation intervals									
	4 days*		8 days*		12 days*					
	kg/m³	\$ of control	kg/m³	% of control	kg/m³	\$ of control				
00.0	2.340	100.0	-	-	-	-				
33.3	3.024	129.2	5.901	252.2	7.951	339.8				
66.6	3.596	153.7	7.412	317.1	10.140	433.3				
100.0	4. 225	180.6	9.107	389.2	11.165	477.1				

<sup>\*</sup> Quantities of the seasonal irrigation water were 3500, 1800 and 1200 m³/Fed. at the irrigation intervals of 4, 8 and 12 days, respectively.

Table (30) Effect of hydrogel and irrigation treatments on the fertilizers use efficiency by Cowpea.

Treatments			Pertilizers use efficiency kg/unit			\$ of
	Irrigation treatments		N	P 205	K 20	- control treatment
00. D	(I <sub>1</sub> )	4	204.75	527.90	327.60	100.0
33.3			264.55	682.70	423.25	129.2
66.6			314.70	812.15	503.50	153.7
100.0			369.80	954.30	591.65	180.6
33.3	(I <sub>2</sub> )	8	265.55	685.35	424.90	129.7
66,6			333.55	860.75	528.65	162.9
100.0			409.90	1057.85	655 . 85	200.2
33.3	(I <sub>3</sub> )	12	238.55	615.60	381.65	116.5
66.6			304.25	785.20	486.80	148.6
100.0			334.95	864.45	535.95	163.6

increase in fertilizers use efficiency relative to control treatment were 29.2, 53.7 and 80.6% for I<sub>1</sub> treatment and 29.7, 62.9 and 100.2% for I<sub>2</sub> treatment when 33.3, 66.6 and 100 g hydrogel/m<sup>2</sup> soil were respectively, added. By applying I<sub>3</sub> treatment, i.e. irrigating the soil every 12 days, fertilizers use efficiency by cowpea plants grown in conditioned soil were lower than that irrigated every 8 days by only 10.2, 7.9 and 18.3% when the same rates of hydrogel mentioned above were respectively applied.

The present data are largely due to the improving effect of the applied hydrogel on soil structure, holding water capacity of the rooting medium consequently on the availability of the nutrients. and El-Hady, 1981, El-Hady et al., 1981 b, El-Hady and Azzam, 1983 and El-Hady, 1987). The high release of K from the added hydrogel (El-Hady et al., 1987) may be another reason. The higher moisture retention in the treated soil over the needs of the growing plants and its effect on the aeration of the rootzone may explain why the yield decreased by an increased amount of irrigation water. Irrigating the treated soil every 4 days produced lower yields than that obtained by treating the soil every 8 or even 12 days. (El-hady and Azzam, 1983 and El-Hady et al., 1990 and 1991-b).

The obtained results prove the importance of using such hydrogels for conserving irrigation water and increasing the agricultural potentialities of sandy soils under the severe conditions of deserts, i.e. the limited water resources, the inadequate water retention and the low fertility of these soils. When evaluating the use of such products as conditioners for sandy soils, one has to take in consideration the improvement of the hydrophysical properties and the nutritional status of the soil, the increase in the produced yields and the saving costs of irrigation water and fertilizers on one side and the costs of the product itself and costs of the conditioning process on the other side.

#### 4.3. General discussion and conclusions:

Sandy soils have their own problems which can be assembled in their single grain structure, high water requirements, susceptibility to erosion and drought and loss of both irrigation water and plant nutrients.

Incorporating super absorbent material (hydrogels) in sandy soils is one of the new techniques in sandy soils conditioning. Presented data on the effects of the hydrogel on properties of sandy soils on one side and germination, growth, uptake of nutrients by plants and water and fertilizers use efficiency by the plants grown

in such soils form the other side show that the hydrogel has a three fold effect. It works physically, chemically and biologically. The combination of these effects on the properties of sandy soils has resulted in an integrated influence on the aforementioned soil and plant parameters. These effects could be attributed to the following:

- a) Improving the stability of soil structure under both dry and wet conditions and increasing the resistance of the soil against the breakdown by tillage. The formed structure maintains several cycles of complete destruction and reformation without significant changes in the erosion idex, (Azzam and El-Hady, 1983-II).
- b) Improving the dynamic soil-water characteristics i.e. decreasing the downward movement of water through infiltration and the upward movement of it through evaporation. Water loss through evaporation was constant over several cycles of wetting and drying revealing that the gel remains fully effective in the soil during this period, (Tayel and El-Hady, 1981; and Azzam and El-Hady, 1983-III). Moreover, gel addition decreases the hydraulic conductivity, intrinsic permeability and the mean diameter of soil pores. An inverse relation between the average hydraulic conductivity and/or transmissivity and both

- gel application rate and depth of the treated soil layer was obtained, indicating that the gel application rate and depth of the treated layer are additive in their effect on the above mentioned parameters, (Tayel and El-Hady, 1981).
- Increasing the ability of the soil to retain water c) due to the swellability of the hydrogel particles its effect on pore size from hand and one distribution towards fine ones, i.e. water hodling pores on the other hand. The gel increases the void ratio, total porosity, the micro pores relative to the total or the macro ones, water holding pores, the coarse and the fine capillary pores. It decreases soil bulk density and quickly drained pores. Although the hydrogel addition leads to an increase in the water held both at the wilting percentage and at field capacity, the latter is usually increased more. Thus, the total available water in soil is increased and the increase is at tensions at which plants can most easily withdraw water, (Tayel and El-Hady, 1981; El-Hady and Azzam, 1983 and Khafagi and Al-Gosaibi, 1990).
- d) The contribution of hydrogels to the chemical properties and the nutritional status of sandy soil. This includes: 1) Increasing the low exchange capacity

It is essentially due to the high of sandy soil. cation excannge capacity of the hydrogel that reached meg/100 g, (Azzam and El-Hady, 1983-III). 2)Hydrogels retain fertiizer's can nutrients. Therefore, the loss of added nutrients-by leaching or deep percolation- from soils treated with hydrogels is low. Hence they remain in soil within the reach of the plant root system for a long period, (El-hady et al., 1989 and 1991-a). 3) Improving the nutritional status of sandy soil. With this respect, either the nutrients consituting the gel molecule such as K, (El-Hady et al., 1987) or that adsorbed by the hydrogel could be easily used by growing plants. Hydrogels also affect nutrients uptake indirectly by increasing the moisture in the soil and subsequently ion mobility. Therefore, the availability of some nutrients either present in the soil or added in the form of relatively insoluble fertilizers will be Moreover, the partial retardation of gas increased. exchange between soil and atmosphere as a result of increasing soil moisture and decreasing soil macro porosity may favour transformation of micro nutrients to the available form, (El-Hady et al., 1981 b).

e) The increase in the activity of the enzymes in sandy soils such as urease and phoshatase indicating the

improvement in the biological activity of such soils (El-Hady  $et\ al.$ , 1981 b).

Data obtained from several laboratory, greenhouse and nursery experiments and field applications conducted at different locations in Egypt (Sinai, Salhia, Inshas. Ismailia and Belbis deserts) on different crops (field crops, forage crops, vegetables, fruit trees, wind breaks, medicinal and ornamental plants) in the open or under protected cultivation and under different irrigation systems (drip, sprinkler and controlled surface) using different hydrogels (RAPG "Egyptian", Super Hydro "Swiss", Super Slurper and "DWAL", "American" and Evergreen 500, 703 and 7255 "Austrian" indicated the beneficial effects, previously mentioned. The combination of these effects leads to an increase in germimation percent and rate, plant growh and dry matter production. A considerable consumption was obtained. water the reduction in Therefore, a significant improvement in the water use efficiency by plants was gained. The uptake of either macro nutrients (N, P and K) or micro nutrients (Fe, Cu, Zn and Mn) was increased. The produced yield by a unit of added nutrients refered to the beneficial effects of hydrogels for increasing the fertilizers use efficiency by (El-hady, 1988 a). The higher moisture plants, retention in the treated soil over the needs of the

growing plants and its adverse effects on the aeration of the rootzone may explain why the dry weight of the plants grown in gel treated soils, nutrients uptake and water and fertilizers use efficiency by the plants decreased by an increased amount of irrigation water i.e. the aforementioned paramters under the normal irrigation  $(I_1)$  were lower than that undr 50%  $(I_2)$  or 33.3%  $(I_3)$  of the normal irrigation (El-Hady and Azzam 1983; El-Hady et al., 1983IV and 1990).

such products ā S the use of When evaluating to take in conditioners for sandy soils, one has improvement of the hydrophysical consideration the properties and the nutritional status of the soil, increase in plant growth and the savings in the prices of irrigation water and fertilizers and in the irrigation and fertilization processes on one side and the the conditioners used and costs of the prices of conditioning process on the other side.

Since the examined hydrogels "Evergreen 500" and "DWAL" were received from both the production companies as samples for research work, the costs of soil conditioning could not be evaluated. So, prefering one of the two examined conditioners or any other hydrogel depends on:

a) Quantities of hydrogels required for soil conditioning and their price. The absorption capacity

of the hydrogel used is an important factor. Under the conditions of the 1st experiment in this study 4 g/plant pit i.e., about 50 kg of the hydrogel "Evergreen 500"/feddan and 0.24 m²/plant pit i.e., 2800 m² (about 8 rolls of the laminates of 600 m length and 0.6 m wide) of the hydrogel "DWAL"/feddan were examined. In the 2nd experiment 33.3-100 g/m² soil, i.e. 133.2-400 kg of the hydrogel "Evergreen 500"/fed. were investigated.

- b) Quantities of irrigation water saved during the growing season which ranges in the case of this study between 50 and 66.6% of the irrigation water used for the untreated soil. This means that the planted area could be doubled or tripled by the same quantity of irrigation water.
- hydrogels if compared with other types of soil conditioners do not need special instrumentation for their distribution in the soil nor pre-hydration or post drying of the soil before its plantation.

  Besides, saving the crosslinkers which are essential for the insolubilization of water soluble polymers.
- d) The increase in the obtained yields and the savings in the costs of irrigation and fertilization processes are another benefits.

Synthesis of hydrogels in Egypt from Egyptian raw materials may reduce the prices of the used conditioners and in turn will raise the cost benefit of the conditioning process.