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Water and Fertilizer Use Efficiency by *Cucumber* Grown under Stress on Sandy Soil Treated with Acrylamide Hydrogels.

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Abstract: A two successive years (2004, 2005) completely randomized field experiment with cucumber (*Cucumis Sativus L.* ; *var. Madina*) as an indicator plant, was conducted at El-Katta, Giza governorate to study the effect of treating a virgin sandy soil with hydrophilic polymers on yield and water and fertilizer use efficiency by plants. The hydrogel used was a mixture of an anionic "polyacrylamide K polyacrylate 30% anionicity "and a cationic "polyacrylamide allylamine hydrochloride 20% cationicity" hydrogel at the ratio of 2:3. Examined application rates of the hydrogel were 2, 3 and 4g / plant pit. Drip irrigation was adopted. Four irrigation regimes were applied namely, 100, 85, 70 and 50% of the water requirements by the crop. Produced yields by the unit of either irrigation water or added fertilizers refer to the beneficial effects of the examined hydrogel for reducing water consumption and increasing both water and fertilizers use efficiency by plants. Obtained results may prove the importance of using such products for conserving irrigation water and increasing the agricultural potentialities of sandy soils under the severe conditions of our deserts, i.e. the limited water resources and the inadequate water retention and low fertility of such soil. Under the conditions of conducted experiment, incorporating 2g of the hydrogel in the plant pit (i.e.≈ 20 kg / fed) and reducing the amount of irrigation water by 15% or 3g (i.e.= 30 kg /fed) under 70% irrigation may be profitable for the growers compared with other examined treatments.

Key words: Hydrophilic polymers, drip irrigation, irrigation regimes, water requirements, water and fertilizers use efficiency

INTRODUCTION

Previous work with hydrogel (super absorbent materials) indicated that such hydrophilic organic polymeric products, when mixed with sandy soils, associated quickly with irrigation water to form gels resulting in an increase of the soils capacity to store water. The water stored in this way is available to plants for some considerable time. Due to the bonding effect of hydrogel molecules with soil particles and their swellability, an improved and stable structure of the soil is obtained. Besides, beneficial changes in soil porosity, particularly the amount of the water retaining pores, were achieved by the conditioning process[1-4].Moreover, the germination process, the plant growth, the nutrients uptake, the yield and both the water and fertilizer use efficiency were beneficially increased by mixing the plant pits in sandy soil with hydrogels[5-7]

This research work presents the effect of treating a virgin sandy soil with a hydrophilic polymer at different application rates on quantities of irrigation water needed for crop production from one side and yield and both water and fertilizer use efficiency on the other side.

MATERIALS AND METHODS

A two successive years (2004, 2005) completely randomized field experiment with four replications for each treatment was conducted as follows:

Location: at a private farm, El-Katta, Giza governorate.

Soil: Virgin sandy soil of which more than 90% consists of particles >20µ. The main analytical data of the soil are presented in Table 1[8,9].

Size of each experimental plot: 1/100 feddan, i.e.100 plant pits.

Soil treatments:

1 untreated soil.

2 treated soil with the polymer (mixture of an anionic "polyacrylamide K polyacrylate 30% ionicity" and a cationic "polyacrylamide allyamine hydrochloride 20% cationicity" hydrogels at the ratio of 2:3) at the rates of 2, 3 and 4g per plant pit (about 2 kg soil). Gel crystals were incorporated to a depth of 15 cm. Description of the main constituents and properties of the used hydrogels is presented in Table 2.

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Table 1: Some soil properties a.Mechanical analysis.

Sand				
Coarse>200u (%)	Fine 200-20u (%)	Silt20-2u (%)	Clay<2u (%)	Soil texture
50.6	41.4	4.4	3.6	Sandy

b. Chemical analysis

				Cations (meq/L) 1:5 extract				Anions (meq/L) 1:5 extract		
pH (1:2.5)	EC (dS/m)	CaCO3 (%)	O.M (%)	Ca^{++}	Mg^{++}	K^{+}	Na^{+}	Cl^{-}	HCO_3^{-}	$SO_4^{=}$
7.8	1.1	6.2	0.1	3.0	1.6	0.2	7.2	6.8	1.9	3.3

c. Hydrophysical analysis

Bulk density (g/cm3)	Total porosity (%)	Water holding capacity* (%)	Field capacity* (%)	Wilting percentage*	Hydraulic conductivity(m / day)
1.61	39.25	19.61	6.27	1.32	11.6

*On weight basis.

Table 2: Description of the main constituents and properties of hydrogel used.

a- Main constituents		
Ionicity	Anionic	Cationic
Active substance	Propeneamide Propionic acid Co-polymer (k-salt)	Propeneamide Allylamine Co-polymer (Cl-salt)
Ionization degree	30 mole%	20 mole%
Cross linker	Divalent vinyl monomer	
Cross-linking ratio	$1:10^{-4}$ mole / mole	
Percentage of active substance	Greater than 88%	
Monomer content	Not higher than 300 ppm	
b- Properties		
Appearance	White to slightly yellow grains	
Grain size	0.25-1mm	
Bulk density	≈ 600 kg /m^3	
Solubility	Insoluble in water and organic solvents	
pH 0.1% in distilled water	7±0.5	
CEC (C mole kg^{-1})	2045	2175
c- Absorption capacity in g /g hydrogel		
Deionized water	≈ 525	≈ 430
0.9% NaCl	≈ 44	≈ 35
0.4% $CaCl_2$	≈ 41	≈ 36
Saline water (1500 ppm)	≈ 64	≈ 54
Absorption time Up to 50%	20 minutes	
Total absorption	60 minutes	

Indicator plant: Cucumber (*Cucumis Sativus L.,var. Madina*) was chosen as the indicator plant.

Date of transplanting: the last week of February.

Irrigation:

1 System:
Drip irrigation (agro drip). Distance between laterals 1.5 m, distance between drippers 50 cm, drippers discharge 4 l /h. and No of drippers / feddan ≈ 5000.

2 Analysis of the irrigation water used: is given in Table 3.

3 Water requirements for the crop: Water requirements for the cucumber crop are presented in Table 4. (Doorenbos [10] and [11])

4 Treatments: Four irrigation treatments were examined namely; 100, 85, 70 and 50% of the water requirements for the crop.

Table 3: Analysis of irrigation water used.

		Cations (meq / L)				Anions (meq /L)			
pH	EC (dS/m)	Ca^{++}	Mg^{++}	K^{+}	Na^{+}	Cl^{-}	HCO_3^{-}	SO_4^{-2}	Adj SAR
7.05	1.35	9.0	6.5	0.2	8.3	5.9	3.5	14.6	7.33

*Source: Well
**Fe: traces<3ppm

Table 4: Water requirements for cucumber plants grown on a sandy soil at El-Katta, Giza governorate (Drip irrigation).

Month	F	M	A	M		J
Period	25-28	1-31	1-30	1-25	25-30	1-9
No. of days	4	31	30	25	5	9
E pan mm/day	4.5	6.4	8.5	11.2		12.8
Kp	0.7	0.65	0.65	0.65		0.65
ET_0 mm/day	3.15	4.16	5.53	7.28		8.32
Kc	0.9		1.0		0.8	
Kr	0.6	0.8	1.0		1.0	
ETcrop mm/day	1.701	2.995	5.53	7.28	5.824	6.656
Ks	1.15 (87%)					
Eu	1.11 (90%)					
Lr	10%					
IRg mm/day	2.39	4.21	7.66	10.22	8.18	9.35
IRg l/day/plant	0.956	1.684	3.064	4.088	3.272	3.74
IRg l/season/plant	3.824	52.204	91.92	102.2	16.36	33.66
m^3/season /fed.	300.168 ≈300 L $3000m^3$					

* ET_0=reference crop evapotranspiration, Kc =crop coefficient, Kr =reduction factor for the influence of ground cover, Ks =a coefficient for the water storage efficiency of the soil,Eu =application uniformity, Lr =leaching requirements ; IRg =gross irrigation requirements.

Fertilization:

1 Fertilizers added as a basal dose: Organic compost at the rate of 5 ton / fed, superphosphate (15.5% P2O5) at the rate of 100 kg / fed potassium sulphate (48-52% K2O) at the rate of 100 kg / fed, ammonium sulphate (20.5% N) at the rate of 50 kg / fed. and agricultural sulpher at the rate of 50 kg / fed.were added to the soil before transplantation.

2 Fertilizers added through irrigation system (Fertigation):(40 units of N as ammonium sulphate, 15 units of P2O5 as phosphoric acid and 50 units of K2O as potassium sulphate were applied.

3 Fertilizers added as foliar application: Micronutrients were sprayed twice as chelates at the rate of 100,100 and 200g / fed. of Mn (EDTA) 13%Mn, Zn (EDTA) 14% Zn and Fe (EDTHA) 6% Fe.

Examined Parameters:

1 Marketable yield, total growing period was 104 days.

2 Water use efficiency by plants calculated as kg of the marketable yield produced by each m3 of irrigation water. (Hillel[12])

3 Fertilizer use efficiency by plants calculated as kg of the marketable yield produced by each unit of fertilizers nutrients used.

RESULTS AND DISCUSSIONS

As the obtained yields of both successive years were not significantly different, their average was taken into consideration.

Data presented in Table 5 illustrate the effect of the used hydrogel on the productivity and the water and fertilizers use efficiency by cucumber plants. For the same irrigation amount, the higher the application rate of the

Table 5: Marketable yield, water and fertilizers use efficiency as affected by hydrogel and irrigation treatments.

Treatments		Marketable yield		Water use efficiency (kg/m^3)	Fertilizers use efficiency (kg/unit of added nutrients)		
Hydrogel treatment g/plant pit	Irrigation treatment in % of the normal irrigation	Tons/feddan	% of the control treatment		N	P_2O_5	K_2O
0	100 (3000m^3/fed.)	13.650 h	100.0	4.550	273.0	447.5	136.5
2		17.963 e	131.6	5.988	359.2	589.0	179.6
3		20.038 c	146.8	6.679	400.8	657.0	200.4
4		21.212 b	155.4	7.071	424.2	695.5	212.1
2	85 (2550m^3/fed.)	18.919 d	138.6	7.419	378.4	620.3	189.2
3		21.048 b	154.2	8.254	421.0	690.1	210.5
4		24.338 a	178.3	9.544	486.8	798.0	243.4
2	70 (2100m^3/fed.)	16.298 f	119.4	7.761	326.0	534.4	164.0
3		18.673 d	136.8	8.892	373.4	612.2	186.7
4		19.670 c	144.1	9.367	393.4	644.9	196.7
2	50 (1500m^3/fed.)	13.813 h	101.2	9.209	276.2	452.9	138.1
3		15.166 g	111.1	10.111	303.4	497.2	151.7
4		16.189 f	118.6	10.793	323.8	530.8	161.9

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

hydrogel, the higher is the marketable yield produced. On the other hand, reducing the irrigation amount from 100% to 85% of the crop water requirements has caused an increase in the marketable yield of cucumber relative to that of the control equals to 38.6, 54.2 and 78.3% when 2,3 and 4g of the hydrogel crystals were respectively incorporated. By further decrease in the irrigation amount to 70% and 50% of the crop water requirement, the yield tends to decrease but in all cases, the production was still much higher than that under the control.

The values of the water or the fertilizers use efficiency which reflect the relation between the production and the total seasonal water or fertilizer uses show the same trend. It is obvious that the highest water use efficiency value lies at 4g hydrogel / plant pit when only 50% of the crop water requirements was added. This is about 2.37 times that of the untreated sandy soil. With respect to the efficiency of the fertilizers used, it reached about 1.78 times that of the control treatment when 4g hydrogel mixed with the plant pit and 85% of the crop water requirements were added for irrigation.

The presented data are largely due to the improving effect of the applied conditioner on soil structure, the water holding capacity of the rooting medium and consequently on the availability of the nutrients [13-16].The high release of K from the added conditioner [4] may be another reason. The higher moisture retention in the treated soil over the needs of the growing plants and its adverse effect on the aeration of the root zone may explain why the yield decreased by an increased amount of irrigation water, i.e. yield of 100% was lower than that under 85% of the normal irrigation [6].

The obtained results prove the importance of using such conditioner for conserving irrigation water and increasing the agricultural potentialities of sandy soils under the severe conditions of our desert, i.e. the limited water resources, the inadequate water retention and the low fertility of these soils. Using such conditioner on a large scale depends on: a) the quantities of hydrogel crystals required for soil conditioning and their price. Under the study conditions, 2-4g /plant pit (i.e., 20-40 kg of the hydrogel crystals were used / fed. b) the quantities of irrigation water saved during the growing season which range here between 15 and 50 % of the irrigation water used for the untreated soil. This means that the planted area could be doubled using the same amount of irrigation water and c) The ease of application taking into consideration that hydrogels-if compared with other types of soil conditioners-do not need special instrumentation for their distribution in the soil nor prehydration or post drying of the soil before its plantation. Moreover, the crosslinkers which are essential for the insolubilization of water soluble polymers are not needed. When evaluating the use of such products as conditioners for sandy soils, one has to take into consideration the improvement of the hydrophysical properties and the nutritional status of the soil, the increase in yield and the saving coasts of irrigation water and fertilizers on one side and the coasts of the product itself and coasts of the conditioning process on the other side. With this respect, incorporating 2g of the hydrogel in the plant pit (i.e.≈20kg /fed.) and reducing the amount of irrigation water by 15% or 3g (i.e. ≈ 30kg /fed.) under 70% irrigation may be profitable for the growers compared with other examined treatments.

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