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Hydrophilic Polymers for Improving the Conditioning Effect of Manures and Organic Composts. I.Production and Water and Fertilizers Use Efficiency for Tomato grown in Sandy Soil

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A TWO successive years (2004 and 2005) completely randomized field experiment with trickle irrigated tomatoes (*Lycopersican esculentum, var.* 448) as the indicator plant was conducted on a sandy soil at El-katta, Giza governorate to study the conditioning effect of hydrogels when mixed with or grafted on organic composts on production and water and fertilizers use efficiency by growing plants. Examined treatments were: a) untreated soil, b) soil treated with 0.5 kg and 1 kg organic compost (OM) / plant pit, c) soil treated with 2g and 4 g polyacrylamide K polyacrylate gel (G)/plant pit, d) soil treated with mixtures of 0.5 kg OM + 1g G, 0.5 kg OM + 2g G, 1kg OM + 1 g G and 1 kg OM + 2 g G /plant pit, and e) soil treated with 12.5 g and 25 g polyacrylamide K polyacrelate grafted on organic compost (grafted G)/plant pit.

Produced yields by the unit of irrigation water or added fertilizers prove the importance of using either OM or G or both together for 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 soils. Grafting G on OM leads to the production of an effective soil conditioner. Incorporating this conditioner in sandy soil improves its productivity and both water and fertilizers use efficiency by growing plants.

The conditioning effect of studied treatments could be descendingly arranged as follows: 25g grafted G ≅ 1kg OM +2g G > 0.5kg OM + 2g G ≥4g G > 1kg OM + 1g G ≥12.5g grafted G > 0.5kg OM + 1g G ≅ 2g G > 1kg OM > 0.5kg OM / plant pit.

Keywords: Compost, Acrylamide hydrogels, Sandy soil, Water use efficiency, Fertilizer use efficiency, Tomato.

For the urgent need to meet food and dress demands in Egypt, more desert areas either sandy or sandy calcareous have to be put under cultivation. Such soils are poor with respect to their physico-bio-chemical properties, soil water plant relationships as well as their nutritional status. Reclamation and land utilization of such soils are faced by several difficulties namely: low humus and clay content and loss of added nutrients via leaching or deep percolation together with the yield levels are difficult to attain. Proper management of these soils calls for specialized approaches for sustainable productivity (Balba, 1999).

Of the natural soil conditioners which have been used in Egypt for reclaiming sandy soils are organic manures and composts. Application rates in addition to chemical fertilization ranged between 10 and 20 tons/fed. (Badran, Nadia, 1983; Montasser, 1987 and Sakr, 1992). Due to shortage that occurred in the quantities of such conditioners, particularly that organic materials are usually decomposed and needed to be added more frequently, the problem of finding substitutes has been posed. Considerable attention has been paid in the last few decades to use synthesized conditioners to avail suitable environment for planting sandy soils. Among these conditioners are super absorbent materials, *i.e.*, hydrogels. Application rates ranged between 6 and 200 kg/fed. (El-Hady, 1987a and b; El-Hady *et al.*, 1990 & 1991 and Rasheed *et al.*, 1997).

It is expected that applying the proper hydrogel mixed with or grafted on organic materials to the soil may be more effective and economic than using each of them alone. (Abd El-Hameed *et al.*, 1995; El-Hady *et al.*, 2000a & b and 2002a & b and Shaaban, 2002). The present work aims to study the conditioning effect of hydrogels when mixed with or grafted on organic compost on production and water and fertilizers use efficiency by growing plants in sandy soil. As tomato (*Lycopersican esculentum* L.) is one of the main vegetable crops that is needed to be planted under the severe conditions of Egyptian Deserts, it was chosen as the indicator plant.

Material and Methods

Two successive years (2004 & 2005) completely randomized field experiment with four replications for each treatment was conducted on a sandy soil at EL-Katta, Giza governorate, Egypt, as follows:

Soil: A virigin sandy soil of which more than 90% consists of particles $>20\mu$. The main analytical data of the soil are presented in Table1.

Soil conditioners:

a. Compost (OM): Fine compost produced by aerobic composting of some local organic wastes, *i.e.*, town refuse, sawdust, plant residues and organic manure at the ratio of 1:1:1:1 respectively was applied. Table 2 presents the main chemical properties of applied compost.

b. Hydrogels (G): Two types of hydrogels (30% anionicty) were prepared to be examined as soil conditioners or improvers for organic waste composts. These are: 1) polyacrylamide K polyacrylate gel (G). It was prepared at the Polymers and Pigments Department, National Research Center. Ammonium peroxy di sulphate $(NH_4)_2S_2O_8$ was used as the initiator (initiator ratio = 0.14%) while tri ethanol amine $(CH_3\text{-}CH_2)_3N$ was used as the cross linker (cross linker ratio = 1.7 %).

TABLE 1. The main analytical properties of the soil.

1-Mechanical analysis

Sand		Silt %	Clay %	Soil Texture
Coarse >200 μ %	Fine 200-20 μ %	**20-2 μ**	**<2 μ**	
50.6	41.4	4.4	3.6	Sandy

2-Chemical analysis

PH (1:2.5)	EC (dSm^{-1} at 25^0)	$CaCO_3$ %	OM %	Cations (meq/L) 1:5 extract				Anions (meq/L) 1:5 extract		
				Ca^{++}	Mg^{++}	K^+	Na^+	Cl^-	HCO_3^{-1}	SO_4^{-2}
7.8	1.1	6.2	0.1	3.0	1.6	0.2	7.2	6.8	1.9	3.3

3-Hydrophysical analysis

Bulk density ($kg\ m^{-3}$)	Total porosity (%)	Total water holding capacity* (%)	Field capacity* (%)	Wilting percent age* (%)	Hydraulic conductivity $m\ day^{-1}$
1.61	39.25	19.61	6.27	1.32	11.6

*On weight basis.

Temperature and time of polymerization were 30 ° and 1.5 hr, respectively, (Abd El-Hady *et al.*, 1997). 2) polyacrylamide K polyacrylate gel grafted on wooden waste compost (grafted G). It was prepared by ionizing radiation at the National Center for Radiation Research and Technology, Atomic Energy Authority of Egypt, Nasr City, Cairo. Aqueous solution of water-soluble acrylamide – acrylate co-polymer was stirred with the water saturated organic waste compost. Few milliliters of Conc. H_2SO_4 were added to accelerate graft copolymerization. The reaction mixture was subjected to Co^{60} gamma cell. The gellation dose was met at an absorbed dose of 10 K Gy for 3 hr. The polymer grafted on organic compost was thoroughly washed with water to extract residual monomers and H_2SO_4 before drying under vacuum at 50^0 for 24 hr. (Abd El-Rehim *et al.*, 2004). The main properties of both hydrogels are presented in Table 3.

Indicator plant: Tomato (*Lycopersican esculentum, var.*448), was chosen as the indicator plant. This choice was for its capability to fruit setting under severe conditions of our deserts particularly drought and salinity (Wahba, 2005).

TABLE 2. Some chemical properties of applied compost.

PH (H_2O)	7.32
Salinity: EC dSm^{-1}	1.3
Na^+ %	0.02
Moisture %	4.11
Mineral content: (Ash) %	28.80
Organic component: OM %	67.09
OC %	38.91
ON %	2.09
C:N	18.62
Macro elements: $NH^+_4 + NO_3$ %	0.02
P_2O_5 %	0.38
K_2O %	0.48
Secondary elements: Ca^{+2} %	1.12
Mg^{+2} %	0.36
Micro elements: Fe ppm	116.0
Mn ppm	51.0
Zn ppm	45.0
Cu ppm	12.5
Heavy metals: Cd ppm	0.40
Co ppm	0.60
Ni ppm	2.02
CEC c mole kg^{-1}	135

TABLE 3. Main properties of applied hydrogels.

Property	polyacrylamide K polyacrylate Gel	gel grafted on wooden waste compost.
Appearance	White to slightly yellow grains	yellow to light brown grains
Grain size	0.25 - 1 mm.	2 - 5 mm
Bulk density	~ 600 kg m^{-3}	~ 450 kg m^{-3}
Solubility	Insoluble in water and organic solvents	
pH(0.1%) in distilled water	7.1	7.5
CEC c mole kg^{-1}	2045	445
Absorption capacity(g/g gel):		
deionized water	567	151
Irrigation water (500 ppm)	296	82
Absorption time		
up to 50%	20 minutes	15 - 20 minutes
Total absorption	~ 60 minutes	30 - 60 minutes

Experimental design

Size of each experimental plot: 1/100 feddan, *i.e.*,120 plant pits.

Soil treatments:

- Treatment no 1: non-conditioned soil (mineral fertilization only).
- Treatments no 2 and 3: soil of treatment no 1 conditioned with 0.5 and 1kg compost (OM)/plant pit, *i.e.*, 6 and 12 tons/fed, respectively.
- Treatments no 4 and 5: soil of treatment no 1 conditioned with 2g and 4g hydrogel (G)/plant pit, *i.e.*, 24 and 48 kg/fed, respectively.
- Treatments no 6 and 7: soil of treatment no 1 conditioned with 12.5g and 25g grafted hydrogel (grafted G) /plant pit, *i.e.*, 150 and 300 kg/fed, respectively.
- Treatment no 8: soil of treatment no 1 conditioned with 0.5kg OM +1g G/plant pit, *i.e.*, 6 ton OM +12kg G/fed.
- Treatment no 9: soil of treatment no 1 conditioned with 1kg OM +1g G/plant pit, *i.e.*, 12 ton OM +12kg G/fed.
- Treatment no 10: soil of treatment no 1 conditioned with 0.5kg OM +2g G/plant pit, *i.e.*, 6 ton OM +24kg G/fed.
- Treatment no 11: soil of treatment no 1 conditioned with 1kg OM +2g G/plant pit, *i.e.*, 12 ton OM +24kg G/fed.

Irrigation system: Trickle irrigation (agro drip.). Distance between laterals is 1.0m. Distance between drippers is 33.3cm. Drippers discharge is 2 l/h. No of drippers/fed are ~12000.

Irrigation water: The source of irrigation is a well, which was dug inside the farm. Regarding its quality, it was classified as no problem water (Ayers & Westcot, 1976). Analysis of irrigation water used is presented in Table 4.

TABLE 4. Analysis of irrigation water used.

Source	pH	EC	Soluble cations(meq/l)				Soluble anions(meq/l)			
		dSm-1	Na^+	K^+	Ca^+	Mg^{++}	CO_3^{-2}	HCO_3^{-1}	Cl^-	SO_4^{-2}
Well	7.05	1.35	8.3	0.2	9.0	6.5	0.02	3.6	5.9	14.6

*Adj.SAR=7.33 **Fe = traces (< 3 ppm).

Water requirements for the crop: Water requirements for the crop determined after Doorenbos & Pruitt, 1977 and Vermeiren & Jobling, 1980 are 3660 m^3/fed, *i.e.*, ~300 l/plant. Table 5 presents the Water requirements for trickle irrigated tomatoes grown on sandy soil under the agro-climatological conditions of EL- Katta area taking into consideration that:

- Date of transplanting was 22 February.
- Date of the beginning of flowering was 1*st* week of April.
- Date of the beginning to pick fruits was 1-15 May according to the conditioning treatments.
- Date of the end of fruit picking was the last week of June.

Therefore, growing season was ~ 125 days divided into three periods, *i.e.*, 40, 55 and 30 days for vegetative growth, flowering and fruit setting and complete ripening of the fruits, respectively.

TABLE 5. Water requirements for trickle irrigated Tomatoes grown on a sandy soil at El Katta, Giza Governorate.

Month	F	M	A	M		J
Period	22-28	1-31	1-30	1-25	25-30	1-25
No.of days	7	31	30	25	5	25
Epan mm day^{-1}	4.5	6.4	8.5	11.2		12.8
Kp	0.7	0.65	0.65	0.65		0.65
ET mm day^{-1}	3.15	4.16	5.53	7.28		8.32
Kc	0.7		1.2		0.65	
Kr	0.6	0.8	1.0		1.0	
ET crop/loc. mm day^{-1}	1.323	2.330	6.636	8.736	4.732	5.408
Ks **Eu** **Lr**	1.15 (87%) 1.11 (90%) 10 %					
IRg mm day^{-1}	1.86	3.27	9.32	12.27	6.64	7.59
IRg l/day/plant	0.614	1.079	3.076	4.048	2.193	2.505
IRg	4.298	33.449	92.28	101.200	10.963	62.625
l/season/plant	304 815 l ≈305 l					
m^3/season/fed	≈3660 m^3					

* **ET_0** = reference crop evaporation, **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.

The soil was irrigated three times/week, *i.e.*, Saturday, Monday and Wednesday. Table 6 presents the distribution of irrigation requirements among the growth season.

TABLE 6. Distribution of irrigation requirements among the growth season.

Growth stage	Time of irrigation hr	No of irrigations	Quantity of irrigation water L/ plant	Quantity of irrigation water m^3/ fed
Vegetative growth (40 days)	1.2	17	40.8	490
Flowering and fruit setting (55 days)	4.0	24	192	2304
Ripening and picking fruits (30 days)	2.75	13	71.5	858

*Drippers discharge = 2 l/hr

Fertilization: Super phosphate (15.5% P_2O_5) at the rate of 100kg/fed and potassium sulphate (48-52% K_2O) at the rate of 100kg/fed were added as a basal dose before transplanting. Ammonium nitrate (33.5% N) was applied at the rate of 50 kg/fed through the irrigation system (fertigation). Micro nutrients were sprayed twice as chelates at the rate of 100,100 and 200 g/fed of respectively, Mn (EDTA) 13%Mn, Zn (EDTA) 14%Zn and Fe (EDTHA) 6%Fe.

Other agricultural practices: The normal cultural practices for tomatoes were properly applied.

Examined parameters:.

- Marketable yield (total growing period was ≈125 days).
- Water use efficiency by plants calculated as kg of the marketable yield produced by each m3 of irrigation water used (Hillel, 1971).
- Fertilizers use efficiency by plants calculated as kg of the marketable yield produced by each unit of fertilizer nutrients used.

Experimental design and statistical analysis: The field experiment was designed on a completely randomized system.. collected data were exposed to the proper statistical analysis according to Steel & Torrie (1980).

Results and Discussion

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

Marketable yield

Data presented in Table 7 show the effect of conditioning the sandy soil with OM, G, grafted G and OM+G on the productivity of the soil. Marketable yields of tomato were significantly increased to be 1.21 and 1.30 times or 1.35 and 1.46 times that of the control treatment (non-conditioned soil) by incorporating 0.5 and 1kg OM or 2 and 4g G, in the plant pit, respectively.

More increase was obtained in the marketable yield of tomato due to mixing OM with G before incorporating into the soil or applying grafted G on OM. Under these conditions, marketable yields were 1.36, 1.42, 1.49, and 1.61 times that of control treatment by treating the soil with 0.5kg OM + 1g G, 1kg OM + 1g G, 0.5 kg OM + 2g G, and 1kg OM + 2g G, in sequence. Relevant values for applying grafted G were 1.4 and 1.62 times by treating the soil with 12.5 and 25g grafted G/plant pit, respectively.

Water and fertilizers use efficiency by tomato plants

Values of the water or fertilizers use efficiency which reflect the relation between the production and the total seasonal water or fertilizers used are presented in Table 7. Data show that treating the sandy soil with examined conditioners led to an increase in water or fertilizers use efficiency by growing plant, *i.e.*, yield produced in kg by each cubic meter of irrigation water used or each unit of added nutrients. Obtained increases were 21.3 and 29.6% for OM at rates of 0.5kg and 1kg/plant pit, respectively. The corresponding increase for 2 and 4g G/plant pit were respectively 34.8 and 45.6%.

TABLE 7. Marketable yield, water and fertilizers use efficiency by tomato plants as affected by soil conditioning.

Treatments			Marketable yield tons/ fed	Water use efficiency (kg/m^3)	Fertilizers use efficiency (kg/unit of added nutrients)		
No.	OM Kg / plant pit	G g/plant pit			N	P_2O_5	K_2O
1	-	-	18.975g	5.184	1130	1224	380
2	0.5	-	23.010f	6.392	1370	485	461
3	1.0	-	24.585e	6.830	1464	1586	492
4	-	2	25.275d	6.987	1523	1650	512
5	-	4	27.63 b	7.671	1644	1782	552
6	12.5 g grafted G		26.580c	7.263	1583	1715	531
7	25 g grafted G		30.735a	8.397	1830	1983	615
8	0.5	1	25.785d	7.046	1535	1664	516
9	1.0	1	27.00 c	7.377	1607	1742	540
10	0.5	2	28.245b	7.718	1682	1823	566
11	1.0	2	30.600a	8.319	1812	1965	609
L.S.D 0.05			0.600				

Regarding the combined effect of both types of soil conditioners on the values of water or fertilizers use efficiency by tomato plants, data indicate better yields by the same quantity of water or added fertilizers. With this respect, water or fertilizers use efficiency increased by 35.9, 42.3, 48.9 and 61.3% that of untreated soil by incorporating 0.5kg OM mixed with 1g G; 1kg OM mixed with 1g G, 0.5kg OM mixed with 2g G and 1kg OM mixed with 2g G in the plant pit, respectively. Corresponding values when applying grafted G were 40.1 and 62.0% using 12.5g and 25g grafted G/plant pit in sequence.

The conditioning effects of organic composts as natural soil conditioners or /and acrylamide hydrogels as synthesized ones on physico- bio- chemical properties of the sandy soil under study after tomato plantation were evaluated in part II of this study (El-Hady *et al.*, 2006). Data indicate that synthetic hydrogels can be viewed as analogous to the soil organic matter. The positive effects of each of the studied conditioners on soil properties could be considered as a basis for discussing the beneficial effects that gained on crop production, and both water and fertilizers use efficiency by the plants. Regarding hydro physical properties of the soil, the effect of both types of soil conditioners (OM or G) include: 1) promoting good soil structure that protects the soil surface against wind and water erosion through improving soil structurization and increasing the percentages of water stable structural units. 2) Increasing soil water holding capacity and the ability of the soil to retain water due to their effect on pores size distribution towards the finer ones, *i.e.,* water holding pores, from one hand and the swellability of conditioners particularly the hydrogels, on the other hand and 3) Improving the dynamic soil water characteristics, *i.e.*, decreasing downward movement of water through infiltration and the upward movement of it via evaporation. Concerning the bio-chemical properties of the soil, the improving effects of applied conditioners include: 1) Lowering soil pH that leads to more solubilization of nutrients and increasing nutrients availability. 2) increasing the low exchange capacity and specific surface area of the soil that raises its nutrients retention abilities and in turn minimizing the loss of such nutrients by leaching or deep percolation and 3) increasing soil microbial biomass and enzymes activity indicating an improvement in biological fertility of the soil.

As expected, incorporating OM mixed with hydrogels or applying grafted hydrogels on OM in the plant pits was more effective than using each of them alone. The combined and interacted effects of applying both technologies for the sandy soil conditioning together on hydro-physical, chemical and biological properties of the soil were practically proved (El-Hady *et al.,* 2006). The beneficial effects of mixing 6 ton OM with 24kg G/fed on all the studied hydro-physical properties of the soil and most of its chemical and biological properties, has exceeded that of 12 ton OM or 48kg G /plant pit if each of them was solely applied. Although mixing 12 ton OM with 24 kg G cause better improvement in soil properties, obtained yields did not highly increase. The higher moisture retention in the treated soil over the needs of the growing plants and its adverse effects on the aeration of the root-zone as a result of increasing the soil micro-porosity on the expense of its macro-ones-may be the explanation for this phenomenon (El-Hady, 1987a) and indicate the importance of using lower rates of G. Moreover, obtained results refer that grafting polyacrylamide hydrogel on organic composts leads to the production of an effective soil conditioner. Incorporating this conditioner in sandy soil improves its properties on one hand and its productivity and water and fertilizers use efficiency by growing plants on the other hand.

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البوليمرات المحبة للماء لرفع الكفاءة التحسينية للأسمدة العضوية
١- إنتاجية الطماطم النامية فى أرض رملية وكفاءة إستخدامها لمياة الرى والأسمدة

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* قسم الأراضى وإستغلال المياة و ** قسم العلاقات المائية والرى الحقلى – المركز القومى للبحوث – القاهرة – مصر .

أجريت تجربة حقلية بمنطقة القطا بمحافظة الجيزة لمدة عامين (٢٠٠٤، ٢٠٠٥) تحت نظام الرى بالتنقيط على أرض رملية لم تزرع من قبل (نسبة الحبيبات الأكبر من ٢٠ ميكرون فيها يزيد عن ٩٠٪) أستخدم فيها الطماطم هجين ٤٤٨ كنبات دليلى لدراسة الأثر التحسينى للبوليمرات المحبة للماء عند خلطها بالكمبوست أو تطعيمها علية على الانتاجية وكفاءة إستخدام النباتات النامية لمياة الرى والأسمدة المضافة.

كانت معاملات التجربة كالأتى:

١- تربة غير معاملة بالمحسنات (الكنترول).

٢، ٣ – تربة معاملة ب ٠,٥ كجم، ١كجم كمبوست (OM) / جورة نبات.

٤، ٥ - تربة معاملة ب ٢، ٤ جم بولى أكريلاميد بوتاسيوم بولى أكريلات هيدروجيل (G) / جورة نبات.

٦، ٧- تربة معاملة ب ١٢,٥ ، ٢٥ جم بولى أكريلاميد بوتاسيوم بولى أكريلات هيدروجيل مطعم على الكمبوست grafted G / جورة نبات.

٨، ٩، ١٠، ١١ - تربة معاملة بخليط من ٠,٥ كجم OM + ١جم G ، ٠,٥ كجم OM + ٢جم G ، ١كجم OM + ١جم G ، ١كجم OM + ٢جم G / جورة نبات على الترتيب.

تشير النتائج إلى:

١- المحصول الناتج من وحدة مياه الرى أو العناصر السمادية المضافة تثبت أهمية إستخدام أى من الكمبوست أو مركب الهيدروجيل أو إستخدام كلا التقنيتين معا سواء بخلط المحسنين سويا أو تطعيم مركب الهيدروجيل على الكمبوست فى زيادة القدرة الانتاجية للأراضى الرملية تحت الظروف القاسية لصحارينا والتى تتمثل فى محدودية مصادر المياة وقلة قدرة إحتفاظ التربة بالماء وإنخفاض خصوبتها.

٢- يؤدى تطعيم مركب الهيدروجيل على الكمبوست لانتاج محسن تربة مؤثر يؤدى إضافتة للتربة الرملية الى رفع إنتاجيتها وزيادة كفاءة إستخدام النباتات النامية فيها لكل من مياة الرى والأسمدة المضافة.

٣- ويمكن ترتيب الأثر التحسينى للمعاملات تحت الدراسة تنازليا كالأتى:

٢٥ جم grafted G ≅ ١كجم OM + ٢جم G > ٠,٥ كجم OM + ٢جم G ≥ ٤جم G > ١كجم OM + ١جم G ≥ ١٢,٥ جم grafted G > ٠,٥ كجم OM + ١جم G ≅ ٢جم G > ١كجم OM > ٠,٥ كجم OM / جورة نبات.