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EFFICIENCY OF COMPOST APPLICATION FOR MAIZE UNDER DEFICIT IRRIGATION AND TWO TILLAGE SYSTEMS; AND THE IMPLICATIONS ON YIELD AND SOIL PHYSICAL PROPERTIES.

BY

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ABSTRACT

A field experiment executed for 2 seasons (2006-2007)on maize (*Zea mays*) was carried out to asses effect of compost application as organic amendment at rates of 0, 5.5, 11.0, and 16.5 Mg fed^{-1} (1 Mg "megagram" = 10^6 g i.e. *metric ton*) designated as C_0, C_1, C_2, and C_3 respectively; under irrigation using 2 water-amount treatments of full irrigation of 3300 (I_1), and deficit irrigation (I_2) of 2640 m^3 fed^{-1} (80% of full irrigation). The tillage cultivation methods being M_1 (seeding using row tillage) and M_2 (seeding using strew tillage, i.e. placing seeds in localized hole-spots on untilled field surface). Grain yield in non- amended treatments was 1.766 to 2.318 Mg fed^{-1} and 2.594 to 6.062 Mg fed^{-1} in compost-treated soil. Water-use efficiency (in kg grains/m^3 water) was 0.617 to 1.165 for un-amended treatments and 1.389 to 2.770 for those amended with compost causing, average increases of 33.3, 40.1, and 15.5% for the C_1, C_2, and C_3 respectively. The deficih irrigation I_2 surpassed the I_1 by 57.2%; and the M_1 surpassed the M_2 by 8.0 %. Soil moisture curves at *tensions* of 0.01 up to 15.00 atm, and available water (AW) were determined with compost increasing water retention at most tensions, particularly the 0.33 atm and slightly AW. Compost had a slight effect on bulk density and total porosity, but affected the distribution of pore size fractions creating more water-useful pores (i.e. the quickly drainable-, slowly-drainable-, and water-holding-pores), and decreasing the less- water-useful ones (i.e. the fine capillary pores). Aggregation and aggregate stability increased by compost; the high rate gave 7% large aggregates while the no compost gave 4% only.

Key words: Deficit irrigation, method of agriculture (tillage), organic amendment, compost application, maize, aggregation, soil moisture curve, bulk density, porosity,

INTRODUCTION

Irrigated agriculture is extremely vital for Egypt where rain fed agriculture does not represent any significant part of arable farming in Egypt. Therefore, maximizing the return obtained from irrigation water is very important. Organic manuring has a significant positive effect on improving soil fertility even under conservation tillage (Reeves 1997); it also could increase the efficiency of water application beside its positive effect on yield increase and soil improvement (Bhattacharyya *et al.*, 2007). The use of different equations to determine irrigation water application is practiced and a number of different equations were proposed for irrigation of arable crops such as maize and other field crops. Elmarsafawy (1991) observed that water evapotranspiration calculated by equation was greater than actually given as consumptive use for maize grown in an alluvial soil.

The aim of the current study is to rationalize irrigation water and assess response in terms of yield of maize, water use efficiency, and some soil parameters. The response is assessed under conditions of compost application and ordinary row cultivation or strew cultivation. Deficit irrigation of 2640 m^3fed^{-1} (80 % of full irrigation) was compared with a reference full irrigation of 3300 m^3fed^{-1}

MATERIALS AND METHODS

Field experiments were conducted at South of Sahl El-Hosainiya Research Station in Port-Said Governorate, during two successive seasons of 2006 and 2007 on a rather saline clay loam soil (Table 1) newly reclaimed from excessive salinity. Maize "*Zea mays*" cv. single Hybrid 10" was sown on June 1st, and harvested on September 18th. The design was a randomized complete block design, factorial in 3 replicates. Factors and treatments of the experiment were as follows:.

Factor A: Irrigation (surface irrigation) (I): Two water applications: I_1: irrigation with 3300 m^3fed^{-1} considered as full irrigation treatment for maize in the areas similar to the one of the current study (Vereiren and Gopling 1984 and Allen *et al.*, 1998); I_2 deficit irrigation treatment of 2640 m^3fed^{-1} which is 80% of I_1.Water was given through surface application using a water pump, and the amount of water was measured in the light of the discharge rate of the water from the pump (Vermeiren and Gopling 1984). Irrigation was done at 15-day intervals.

Factor B: Method of cultivation (M): Two methods: M_1: cultivation of maize on ridges on which seeding was performed, designated as "row cultivation tillage"; M_2: placing seeds in localized hole-spots on untilled field surface, designated as "strew cultivation tillage".

Factor C: Compost (C): Four treatments: C_0, C_1, C_2, and C_3 being: no compost application, 5.5 Mg compost fed^{-1}, 11 Mg fed^{-1}, and 16.5 Mg fed^{-1} respectively (one megagram "Mg" = 1000 kg).Compost was added before seeding. Properties of the compost are given in Table 2.

The execution of the experiment was done in a randomized complete block design (Gomez and Gomez 1984), split-plot with irrigation as the main plots and the combination of cultivation –compost treatments as subplots The main plots representing irrigation were separated by 2m. The area of the experimental plot was 10.5 m^2. The experiment was done in three replicates. Application of compost at C_2 represents the recommendations for organic amendment application for maize in soils reclaimed from salinity. All plots received recommended doses of chemical fertilizers per feddan as follows: 120 kg N as ammonium sulphate '20.6 %N'+ 13.1 kg P as calcium super phosphate '6.6 % P' + 20 kg K as potassium sulfate '40 % K'. Application of P and K was done before sowing. Application of N was done in three equal splits; before sowing, two weeks and five weeks after sowing. Properties of El-Salam canal water (used for irrigation) are given in Table 3.

A composite representative soil sample was taken from the field of the experiment to represent the initial status of the soil. After harvest of maize, soil samples were taken from each plot in order to assess the effect of treatments. The samples were taken form the 0-15 cm surface.

Parameters measured for assessment of the treatment effects are as follows:-

1- **Grain yield; measured at harvest of the crop.**
2- **Water use efficiency (WUE); calculated using the following formula:**

WUE= Grain yield (in kg/fed^{-1})/seasonal consumptive use (in m^3fed^{-1}) = kg m^{-3}
i.e. kg grains/m^3 water.

3-Soil measurements:

Particle size distribution was carried out for characterization of the soil texture by the pipette method (Piper 1942 and Gee and Bauder 1986); Soil pH, salinity, organic matter and total calcium carbonate (Page *et al.*, 1982) were also measured. Other parameters and properties measured for soil characterization as well as for assessing the effect of treatments include the followings:

A) Moisture contents retained at tensions of 0.01, 0.10, 0.33, 0.66, 1.00, and 15 atm; carried out as described by Richards and Weaver (1944) and Ascrof and Taylor (1952) using the pressure membrane apparatus (Richards 1947).

B) Bulk density (BD)using undisturbed soil cores (Richards 1954).

C) Total Porosity(TP) calculated by equation using bulk density and particle density (PD) values as follows: TP = PD - (BD/PD).

D)Pore size distribution into 4 categories determined as QDP (quickly drainable pores of >28.84µ ϕ; SDP (slowly drainable pores of 28.8-8.62µ ϕ) WHP (water holding pores of 8.62-0.19µ ϕ) and FCP (fine capillary pores of <0.19µ ϕ); according to Deleenher and De Boodt (1965). (E) aggregation and aggre-gate size distribution; done on dry basis (Richards 1954) and wet basis (Yoder 1936 and Ibrahim 1964).

4- irrigation water analyses

Analysis include salinity soluble ions and pH (Richards 1954).

Table (1): Properties of the soil of the experiment site.

Property	Value	Property	Value
Sand %	20.1	**Moisture %(w/w) at:**	
Silt %	14.9	0.01 atm	36.88
Clay %	65.0	0.10,,,	28.33
Texture	**Clay Loam**	0.33,,,	25.66
O M %	1.66	0.66,,,	21.25
Ca-carbonate %	4.48	1.00,,,	20.78
pH	8.12	15.00,,,	13.22
SP %	81.24	**Available moisture%**	12.44
EC dSm^{-1}	6.65	**Bulk density (g cm-3)**	1.12
Soluble ions*		**Total porosity %**	54.84
(mmol$_c$L^{-1}):		**Pore-size distribution:**	
Ca^{+2}	7.0	**QDP %**	5.00
Mg^{+2}	16.0	**SDP %**	5.93
Na^{+1}	41.9	**WHP %**	15.06
K^{+1}	0.5	**FCP %**	13.34
HCO$_3^{-1}$	4.5		
Cl^{-1}	45.0		
SO$_4^{-2}$	14.9		
SAR	12.1		

Notes: no CO_3^{-2} was detected.; pH (1:2.5 w/v soil water suspension); EC (saturation extract.)OM (organic matter); QDP(quickly drainable pores); SDP(slowly drainable pores;(WHP (water holding pores); FCP (fine capillary pores)

Table (2): Properties of the compost used in the experiment and the El-Salam canal water used for irrigation.

(A) Compost properties.

EC (dSm^{-1}) 1:5	pH (1:2.5)	Total N, P, and K			C/N ratio	OM %	BD gcm^{-3}	Moisture %	Ash %	WHC %
		N %	P %	K %						
5.50	7.44	1.10	0.82	2.20	17.8	37.69	0.35	11.8	42	160

(B) Irrigation water properties.

pH	EC (dSm^{-1})	Cations (mmol$_c$ L^{-1}):				Anions (mmol$_c$ L^{-1})*			SAR	RSC
		Ca^{+2}	Mg^{+2}	Na^{+1}	K^{+1}	HCO$_3^{-1}$	Cl^{-1}	SO$_4^{-2}$		
7.11	3.53	2.00	4.50	26.4	0.42	8.00	22.5	2.82	14.67	1.50

* no Carbonate was detected.

Table (3): **Maize grain yield (megagram/feddan "Mg f^{-1} ";1 Mg=10^6 g; i.e. metric ton") and water use efficiency (kg m^{-3}) as affected by compost addition under irrigation and cultivation treatments (average of 2 seasons; 2006 - 2007)**

Cultivation method (M)	Compost (C)	Irrigation Treatment (I)					
		I_1	I_2	Mean	I_1	I_2	Mean
		Grain yield			Water use efficiency		
M_1	C_0	1.766	2.647	2.206	0.776	1.165	0.970
	C_1	2.922	2.921	2.921	1.015	1.405	1.210
	C_2	4.930	6.602	5.766	1.705	2.770	2.238
	C_3	3.668	5.370	4.519	1.526	2.498	2.012
Mean		3.321	4.385	3.853	1.256	1.960	1.733
M_2	C_0	1.810	2.318	2.064	0.617	1.035	0.826
	C_1	2.594	3.163	2.878	0.976	1.389	1.182
	C_2	4.799	6.029	5.414	1.577	2.592	2.085
	C_3	3.565	3.956	3.760	1.438	2.279	1.858
Mean		3.192	3.867	3.529	1.152	1.824	1.488
G. Mean		3.257	4.126	3.691	1.204	1.892	1.612
		Means of compost			Means of compost		
	C_0	1.788	2.482	2.135	0.696	1.100	0.898
	C_1	2.757	3.042	2.900	0.996	1.397	1.196
	C_2	4.864	6.316	5.590	1.641	2.681	2.161
	C_3	3.616	4.657	4.196	1.482	2.388	1.935
LSD at 0.05		I= 0.052 M= 0.052 C= 0.074 IM=0.074 IC= 0.105 MC= 0.105 IMC= 0.148			I= 0.020 M= 0.020 C= 0.028 IM= ns IC= 0.040 MC= 0.040 IMC=0.057		

Notes: I_1: full irrigation 3300 m^3f^1; I_2: deficit irrigation 2640 m^3f^1 (80% of full irrigation); cultivation method: M_1 (rows), M_2 (Strew i.e. zero tillage with seeds sown in little holes on non-tilled soil); C_0(no compost), C_1, C_2 and C_3 compost at, 5.5, 11.0, and 16.5 Mg f^{-1} respectively

RESULTS AND DISCUSSION

The soil is medium-textured, loamy, moderately saline, moderately alkaline, tending to be rather sodic (Richards 1954);and containing calcium carbonate

Grain yield (Table 3):

Compost caused marked increase in grain yield particularly with the medium rate (C_2). Increases due to C_1, C_2, and C_3 averaged 35.8, 161.9, and 93.9 % respectively. This shows that the increase was progressive up to the rate of 11 Mg f^1 thus being the most appropriate rate for compost application. The highest rate of 16.5 Mg f^1 may have encouraged more immobilization of mineral available nutrients (particularly N) since its effect, though giving greater yield than the 5.5 Mg f^1 was of less magnitude than the medium rate of 11 Mg fed^1.The superiority of the medium rate over the high rate was most pronounced under conditions of the deficit irrigation. Under the standard irrigation the superiority of the medium rate over the high rate was of less magnitude. Beside its favourable effect due to its available nutrients, (Gupta 2007) compost was reported to increase soil organic matter, particularly the soluble fraction of organic matter in soils (Wright *et al.*, 2008).

Deficit irrigation I_2 (80% of the full amount 'I_1') gave greater yield. It surpassed I_1 by an average of 29.3%, and such superiority was particularly marked under conditions of the medium rate of compost (which was the most efficient rate) giving about 30% more yield. Under conditions of the low compost rate it gave 10% over I_1. Deficit irrigation may have been more appropriate in creating more suitable conditions for plant growth improving aeration and reducing leaching losses of soluble nutrients. These results show that 2640 m^3fed^{-1} are more appropriate for yield than 3300 m^3fed^{-1}.

Row cultivation tillage (M_1) gave 9.2% greater yield over the strew method (M_2).The row method of cultivation is thus an efficient method of many crops which are most suited to row-tillage (Abd El-Salam *et al.*, 2006) including maize (Elmarsafawy 1991).

Water use efficiency (WUE), Table 3:

Compost application increased water use efficiency (WUE) by an overall average of 29.7 %.The highest increase was under the medium rate of compost C_2 giving an average increase of 40.1% as compared with 33.3% under the low compost rate C_1, or 15.6% under the high compost rate C_3. Thus, as occurred with grain yield, the medium rate of compost proved the most efficient rate of organic matter addition with regard to WUE; the least effective compost rate was C_3. Superiority of C_2 over C_1 was most considerable under conditions of I_2 (giving 91.9% increase over C_1) rather than under conditions of I_1 (giving 64.8 % increase over C_1). This indicates that with deficit irrigation, applying compost at the proper C_2 rate increased the efficiency of water use. The positive effect of compost was greater where the method of cultivation was strew (M_2) than where the method was the ordinary row tillage (M_1). This means that the decrease caused by the strew method could be alleviated by applying the optimum compost rate.

Deficit irrigation I_2 surpassed the full irrigation I_1 by an average of 57.2 %. The increase was most prominent under the optimum C_2 compost rate (where I_2 surpassed I_1 by 63.7%) than under the low C_1 compost rate (where the comparable surpass was 40.3 %).Also the increase caused by I_2 over I_1 was rather greater under conditions of the strew cultivation than under the row cultivation method (an increase of 58.3 compared with 56.0 %). This indicates that deficit irrigation would alleviate the decrease in WUE caused by strew cultivation, particularly where compost was applied at an optimum rate. Organic matter addition increases water use efficiency by many crops including grass type canopy (Stroosnijder 2008)) and improves fertility of arable soils particularly those under continuous cropping systems (Reeves 1997) such type of systems is commonplace in Egyptian agriculture.

Row tillage (M_1) gave 16.4 % greater WUE than strew tillage.

Soil moisture constants (Table 4):

The most effective factor which affected soil moisture content was compost. Thus, presentation of results will be confined to its effect.

The pattern of response to compost addition indicates marked increases in moisture contents at nearly all points of the moisture retention curve upon adding compost. The most pronounced effect was that at the optimum rate of compost (C_2) where contents of moisture increased by about one third to about more than nine tenths by compost application.

Increases were particularly marked at the points of saturation (0.01 atm), near saturation (0.10 atm), and field capacity (0.33 atm). Increased capacity for water retention as a result of adding organic matter is a clear indication of its positive effect in modifying porosity and physical conditions of soil.

Therefore, compost, particularly when applied at the optimum C_2 rate, increased the capacity of soil to retain greater amounts of water within the soil matrix, a characteristic feature of the positive effect of organic matter addition (Tejada and Gonzalez 2008).Such effects of compost occurred under all conditions of irrigation and cultivation.

Considering available water as the difference between moisture at 0.33 atm and that at 15.00 atm, results show a tendency for increase upon compost addition where the method of cultivation was M_1, and a tendency for a decrease by compost addition where the method was M_2.However taking the overall average for the experiment, results show an increase by compost addition: the overall average of available water with no compost was 17.71%, compared with 18.33 %, 18.51%, and 19.80% for the compost-treated soils of C_1, C_2, and C_3 respectively.

Increased available water is a direct result of the increased moisture capacity particularly field capacity (i.e. the 0.33 atm moisture tension): the no compost treatments showed a range of field capacity moisture of about 22% to about 30% contrasted with a range of about 27 % to 39 % for the compost treated soils. The positive effect of compost application in increasing available water reflects the high capacity of organic amendments in retaining more moisture in the soil through creating more medium size pores in the soil in particular as well as increasing soil porosity in general.

Table (4): Soil moisture percent, (w/w) at different tensions (atm), and available water in samples taken after harvest from the different treatments of compost addition, irrigation and cultivation tillage (average of 2 seasons -2006 - 2007)

Treatment			Moisture tension (atm)						
			0.01	0.10	0.33	0.66	1.00	15	AW
I_1	M_1	C_0	33.77	23.71	21.81	20.24	19.33	7.56	14.25
		C_1	43.81	32.66	29.73	26.57	26.21	11.78	17.95
		C_2	52.15	41.48	38.14	34.45	31.16	16.99	21.15
		C_3	44.80	37.36	31.81	31.96	24.98	15.54	16.27
	M_2	C_0	41.17	31.14	29.99	28.93	20.42	8.75	21.24
		C_1	39.82	31.61	29.47	26.94	25.64	11.27	18.20
		C_2	50.50	36.10	33.42	30.17	25.84	15.08	18.34
		C_3	42.68	33.99	32.96	31.17	26.35	11.84	21.12
I_2	M_1	C_0	37.41	26.64	24.25	22.03	18.40	8.84	15.41
		C_1	45.79	40.57	38.71	36.44	28.85	16.16	22.55
		C_2	48.57	34.43	32.69	30.85	33.44	15.87	16.82
		C_3	43.91	36.17	32.86	29.63	29.63	8.44	12.42
	M_2	C_0	41.02	28.71	29.12	23.53	18.03	9.17	19.95
		C_1	43.61	32.70	26.66	23.53	20.24	12.06	14.60
		C_2	48.21	36.00	32.70	29.42	25.69	14.99	17.71
		C_3	44.15	33.96	31.39	23.44	19.64	13.99	17.40

See footnotes of Table 3 for treatment designations. Values are means, without statistical analysis

Bulk density and porosity (Table 5):

The two properties of bulk density and total porosity are closely related and linearly inversely correlated and decreased bulk density is a direct function of increased total porosity (Black *et al.*, 1965). The results of the current study shows no definite trend of the effect of compost on bulk density. There was a tendency for increased bulk density by compost application in many cases and a decrease in some others.

Pore size distribution (Table 5):

There was an effect on the distribution of the different fractions of pores. The most positively affected categories of pores were the Quickly-drainable pores (QDP) and the water-holding pores (WHP).These two categories also represent major portions of soil porosity, and they are of a very important significance in soil fertility and plant growth. Both were increased by compost application, particularly marked with the C_2 by as much as about 100% in some cases. The QDP average values obtained in the current study are 7.78, 10.93, 15.53, and 12.67 % due to C_0, C_1, C_2, and C_3 respectively. The WHP averages are 18.89 %, 20.77, 24.37, and 23.03 % respectively. Increased values of such types of pores is an evident manifestation of the positive effect of organic matter addition in creating favourable soil structure and forming pores which hold water useful for plant roots. The slowly drainable pores (SDP) decreased by compost addition; the average values were 3.28 %, 2.02, and 2.52 % for the C_0, C_1, C_2, and C_3 treatments respectively. The capillary pores (FCP) increased by applying compost with average values of 9.92%, 13.71, 15.76 and 14.04 % for C_0, C_1, C_2, and C_3 respectively.

Therefore, the positive effect of compost addition from the viewpoint of porosity is in terms of redistribution of pore size fractions so as to increase the water-useful fractions in particular, which represent a significant portion of the pores and hold easily available water for plants. Such changes in the pattern of pore size distribution would be reflected in increased water holding capacity, and would most certainly contribute in greater plant growth and ultimately higher grain yields as shown by the relevant data of these parameters. The most effective compost treatment was that of C_2. Increased proportions of water useful pores as a result of adding organic soil conditioners was observed by Mostafa (1986), and Abdel-Salam *et al.* (1988) who applied organic manure of up to 27 Mg fed^{-1}, and Evanylo *et al.* (2008) who reported increased porosity as well as decreased bulk density upon adding rates of organic composts equivalent to 70 to 340 Mg fed^{-1} under different organic farming systems. Compost addition with reduced tillage was reported by Ouattara *et al.* (2007) to have modified pore size distribution in a manner that increased water infiltration in soils of very heavy texture.

Table (5): Bulk density(BD), total porosity(TP), pore size distribution in soil after maize harvest (average of 2 seasons - 2006 - 2007).

Treatment			BD g cm^{-3}	TP %	Pore size distribution (%)			
					QDP	SDP	WHP	FCP
I_1	M_1	C_0	1.06	55.83	8.98	2.82	19.99	5.01
		C_1	1.16	49.57	9.82	2.34	20.10	12.20
		C_2	1.19	48.26	15.80	1.37	27.36	12.64
		C_3	1.12	53.14	11.93	1.16	23.90	14.32
	M_2	C_0	1.09	56.22	7.48	3.54	16.95	14.17
		C_1	1.09	52.61	11.31	4.12	19.51	15.18
		C_2	1.19	50.21	13.60	2.27	21.60	15.40
		C_3	1.13	50.87	11.97	3.23	19.83	16.57
I_2	M_1	C_0	1.13	53.88	8.51	3.42	23.70	3.95
		C_1	1.18	48.92	11.61	4.45	24.29	12.85
		C_2	1.16	49.57	18.72	2.42	28.30	17.38
		C_3	1.14	50.43	14.52	3.01	27.75	10.17
	M_2	C_0	1.16	52.07	6.16	3.74	14.92	16.54
		C_1	1.13	52.12	10.99	2.20	19.18	14.60
		C_2	1.18	48.70	14.01	2.03	20.23	16.01
		C_3	1.14	51.28	12.28	2.72	20.66	15.10

See footnotes of tables 3, and 4; **QDP** (quickly drainable pores; 28.84μϕ); **SDP** (slowly drainable pores;28.8-8.62μϕ); **WHP** (water holding pores 8.62-0.19μϕ); **FCP** (fine capillary pores <0.19μϕ).

Soil aggregation (Tables 6 and 7):

Aggregation was affected by treatments. Distribution of stable aggregates showed marked variation associated with different treatments. The aggregate categories studied in this experiment are of the following diameters (mm ϕ): 10-2, 2-1, 1-0.5,0.5-0.25, 0.25-0.125, 0.125-0.063 and < 0.063. For reasons of data presentation they are designated as follows, respectively: very large, large, medium, sub-medium, small, very small, and extremely small. Dry aggregation covered the 7 categories, but wet aggregation (because of its nature) covered the first 6 categories.

Table (6): Size distribution fractions (%) of dry- sieved aggregates, in soil after maize harvest (Average of 2 seasons- 2006 - 2007) *.

Dry aggregate diameter (mm)			10-2	2-1	1-0.5	0.5-0.25	0.25-0.125	0.125-0.063	< 0.063
Initial Soil >>**			70.03	28.04	1.48	0.17	0.09	0.11	0.08
I_1	M_1	C_0	72.94	10.07	9.75	4.76	1.23	1.10	0.15
		C_1	78.12	8.50	7.78	3.60	1.15	0.75	0.10
		C_2	78.40	21.29	0.16	0.04	0.03	0.06	0.02
		C_3	51.96	24.46	12.30	8.10	2.07	1.06	0.05
	M_2	C_0	64.71	15.03	10.13	4.07	5.02	1.01	0.03
		C_1	67.65	18.76	8.68	2.98	0.71	0.62	0.60
		C_2	55.82	19.87	13.87	6.21	3.09	1.05	0.09
		C_3	57.79	25.29	10.40	3.35	2.05	1.02	0.10
I_2	M_1	C_0	82.10	4.80	6.38	5.30	0.74	0.52	0.16
		C_1	68.91	30.56	0.41	0.04	0.03	0.03	0.02
		C_2	57.05	12.35	10.30	10.15	7.07	3.06	0.02
		C_3	59.58	20.33	15.88	2.13	2.03	0.03	0.02
	M_2	C_0	62.28	17.55	12.12	5.04	1.71	1.03	0.27
		C_1	60.94	25.51	9.51	2.45	1.20	0.18	0.03
		C_2	51.76	12.47	12.34	10.00	9.60	3.73	0.10
		C_3	59.51	26.34	8.80	2.05	2.07	1.18	0.05

See footnotes of tables 3 for treatment designations; **: values for soil before executing the experiment. Values are means, without statistical analysis

Table (7): Percentage of total of stable wet sieved aggregates "TSA", and their different size fractions in soil after harvest (Average of 2 seasons- 2006 - 2007).*

wet aggregate diameter (mm)			10-2	2-1	1-0.5	0.5-0.25	0.25-0.125	0.125-0.063	Total (TSA)
Initial Soil			7.61	10.94	8.38	16.07	8.03	6.28	57.31
I_1	M_1	C_0	3.27	10.10	15.10	9.69	5.01	5.63	48.80
		C_1	2.64	8.14	10.17	12.63	3.24	4.43	41.25
		C_2	1.30	5.36	17.91	13.23	5.20	8.16	51.16
		C_3	6.53	12.97	10.62	10.15	3.31	5.31	48.89
	M_2	C_0	7.59	14.73	11.17	8.56	2.62	4.52	49.19
		C_1	6.71	13.25	9.29	14.85	4.09	5.41	53.60
		C_2	3.64	9.84	12.29	18.94	3.76	7.20	55.67
		C_3	6.11	12.72	12.94	18.01	3.58	3.48	56.84
I_2	M_1	C_0	1.85	5.81	19.76	16.79	2.46	2.77	49.44
		C_1	1.61	6.49	17.76	14.40	5.71	5.42	51.39
		C_2	1.89	6.87	11.32	10.14	7.55	5.96	43.73
		C_3	8.74	13.28	9.93	4.85	1.62	3.79	42.21
	M_2	C_0	4.61	10.68	11.17	19.52	4.06	7.54	57.58
		C_1	5.41	12.75	14.05	14.88	2.47	4.53	54.09
		C_2	4.92	10.75	11.34	16.50	7.09	3.84	54.44
		C_3	5.78	14.61	10.81	15.00	5.32	6.14	57.66

*See footnotes of tables 3 and 6.

Data show marked changes in all categories. Discussion will cover the three aggregate categories of " very large, sub-medium, and very small aggregates as representatives for the effect of treatments on aggregation. discussed here to assess implications of treatments on soil aggregation.

Different size fractions of dry-sieved aggregates (Table 6):

Before cultivation, data for the initial values of dry aggregate size distribution for the 3 categories of the very large, (10-2 mmϕ) sub-medium, (0.5-0.25 mmϕ) and very small (0.125-063 mmϕ) aggregates show respective averages of70.03 %, 0.17% and 0.11 %. After cultivation average values for all treatments were 64.35 %, 4.39 %, and 1.03 % for the three aforementioned categories respectively. The decrease in very large aggre-gates due to cultivation reflects the influence of tillage on breaking the massive structure of soil. The increase in the sub-medium and very small aggregates may indicate the effect of tillage as well as the rooting system of plants in improving soil structure.

The very large aggregates shown by different treatments at harvest ranged from about 51.96 % ($I_1M_1C_3$ treatment) to 82.10% ($I_2M_1C_0$ treatment). The sub-medium aggregates ranged between 0.04 % ($I_1M_1C_2$) and 10.15 % ($I_2M_1C_2$); comparable values for the very small aggregates were 39.69 ($I_2M_2C_2$)and 58.26 % ($I_2M_2C_0$).

Deficit irrigation, I_2 caused a decrease in the very large as well as the very small aggregates, giving respective averages of 62.77, and 8.38 %, compared with 65.92 and 14.25 % respectively caused by the higher I_1 irrigation. On the other hand the sub-medium aggregates were decreased by deficit irrigation.

Compost caused a decrease in the distribution percentage of the very large aggregates. The average values due to C_0, C_1, C_2, and C_3 were 70.52, 68.91, 60.76, and 57.21 respectively. Concerning the sub-medium aggregates, there was a decrease due to C_1 and C_3 but an increase due to C_2; the distribution values were 4.79, 2.27, 6.60, and 3.91 respectively. The very small aggregates showed an increase due to compost addition and this increase progressed with increasing the rate of application. Averages of distribution were 1.53, 1.88, 5.75, and 5.50 % for C_0, C_1, C_2, and C_3 respectively. The positive and favorable effect of compost on soil physical properties is a manifestation of the influence of organic matter in creating soil structure favorable for plant growth.

Cultivation by the row method caused an increase in the distribution of the very large aggregates, giving an average value of 68.63 % as compared with 60.06% for the strew treatment. Sub-medium aggregates and particularly very small aggregates of the row cultivation were lower than those of the strew cultivation, with averages of 4.27 % sub-medium and 0.83% very small aggregates found in the row method compared with 4.52 % and 1.23% found in the strew method.

Different size fractions of wet-sieved aggregates (Table 7):

Before cultivation, data for the initial values of wet aggregate size distribution for the 3 categories of the very large, sub-medium, and very small aggregates show respective averages 7.61 %, 16.07% and 6.28 %. After cultivation average values over all treatments were 4.54 %, 13.63 %, and 5.26 % for the three aforementioned categories respectively

Value of total stable (wet) aggregates before cultivation was 57.31 %.After execution of the experiment such values ranged between 41.25% ($I_1M_1C_1$ treatment) to 57.66 % ($I_2M_2C_4$ treatment).

Comparison between the different compost treatments concerning total of stable aggregates show little difference between the no compost and the compost treatments. The no compost treatment gave an average of 51.25% stable aggregates, while those receiving the low, medium and high compost rates gave very comparable averages of 50.08, 51.25, and 51.40% respectively. The effect was rather clearer concerning distribution of different sizes of aggregates. The C_0, C_1, C_2, and C_3 gave values for very large aggregates of 4.33, 4.09, 2.94, and 6.79 % respectively, and sub-medium aggregates of 13.64, 14.19, 14.70, and 12.00 % respectively, and very small aggregates of 5.12, 4.95, 6.29, and 4.68 % respectively. Thus there was a tendency for increase by compost addition, particularly by C_3 regarding large aggregates and C_2 regarding medium and small aggregates.

Deficit irrigation (I_2) gave average of 51.32% total aggregates while full irrigation (I_1)gave 50.68%.Also I_2 gave more very small, sub-medium and very large aggregates (averaging 4.35, 14.01, and 5.00% respectively) than given by I_1 (4.74, 13.26, and 5.52 respectively).

Row cultivation M_1 gave lower values than strew cultivation M_2 with regard to large medium and small aggregates. The M_1 treatment gave averages of 3.5, 11.5, and 5.2 % for very large, sub-medium and very small aggregates respectively as compared with 5.6, 15.0, and 5.3 % respectively given by the M_2 treatment.

Overall effect on aggregation:

Compost tended to aggregation and aggregate stability in soil particularly with row cultivation. There was no maked difference between full and deficit irrigation. positive effect of compost and row tillage is a direct consequence of organic matter addition and tillage. Increased aggregation and aggregate stability were demonstrated by Mostafa (1986) and Abdel-Salam (1988) assessing effects of some organic conditioners on some Egyptian clay loam soils. Increased aggregate stability was also demonstrated by Tejada and Gonzales (2008) upon addition of plant residue compost as well as chicken manure to soils in arid regions.

CONCLUSIONS

Compost increased grain yield markedly particularly with the medium rate causing up to 162% increase by the medium rate (11 Mg fed^{-1}) rendering it an appropriate rate above which an immobilization of mineral available nutrients may have occurred. The increase was also reflected in water use efficiency WUE by an average of 30 % particularly where the medium rate was applied (40% increase). Smaller increases occurred with the high rate (16% increase) or the low one (33% increase). Compost favourably modified porosity. The effect was considerable on the redistribution of pore size fractions increasing the more-water-useful pores of QDP, SDP, and WHP, and decreasing the less- water-useful ones such as the FCP).This caused more retention of available water, hence greater plant growth and ultimately higher grain yields. Compost affected aggregation through distribution of seven aggregate categories ranging from "the very large" to "the extremely small" aggregates with marked variation associated with different treatments. The changes in the 3 aggregate categories of "the very large (10-2 mm ϕ)", "the sub-medium (0.50 -0.25 mm ϕ)", and "the very small (0.125 – 0.063 mm ϕ)" were marked. Concerning dry sieving, "the very large aggregates" ranged from 52 % (given by high compost + full irrigation, strew or row cultivation) to 82% (given by the no compost + full irrigation with row cultivation). Deficit irrigation decreased "the very large" as well as "the very small" aggregates being 63 %, and 8% respectively for I_2 compared with 66% and 14 % respectively for I_1.Compost decreased "the large" aggregates in particular by up to more than two thirds, and to a less extent "the medium" aggregates but slightly increased "the small" aggregates. Concerning wet sieving, the total percentage of stable aggregates for I_1 and I_2 were rather comparable with averages of about 50%. Aggregate categories were also comparable by the two treatments. Compost tended to increase aggregates of these categories. The high compost rate gave 7% of very large aggregates while the no compost gave 4% only. The medium compost rate gave 15 % and 6 % sub-medium and small aggregates respectively.

Deficit irrigation (I_2), which is 80% of the full irrigation (I_1) of 3300 m^3fed^{-1} gave more yield than the full irrigation particularly under conditions of the medium compost rate of 11 Mg fed^{-1} when it increased the yield by about one third. It may have created more suitable conditions for plant growth such as improved aeration. Deficit irrigation also surpassed full irrigation regarding the water use efficiency WUE by an average of 57 %, most markedly under medium compost rate (64% increase) and more so under strew cultivation than under row cultivation.

There was no particular difference between the two irrigation treatments with regard to bulk density, porosity, water retention parameters or aggregation.

Row cultivation gave lower values than strew cultivation with regard to "the large, medium and small aggregates. The row method proved more efficient for maize, and if the need arises to use strew cultivation, compost application would improve its efficiency.

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كفاءة استخدام معدلات مختلفة من سماد المكمورة (الكومبوست compost) على الذرة الشامية تحت ظروف رى ناقص ونظامى زراعة على خطوط rows أو بالنقرة strew وتأثره على المحصول وخصائص فيزيائية بالتربة

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تمت زراعة الذرة فى تجربة حقلية على موسمين (٢٠٠٦ و ٢٠٠٧) لدراسة اثر استخدام الكومبوست كمصلح عضوى وتمت إضافته على اربع معدلات C_3, C_2, C_1, C_0 (٠,٠، ٥,٥، ١١، ١٦,٥ مججم/ف (ميجا جرام للفدان) على الترتيب (الميجاجرام "Mg" megagram= مليون جرام اي"طن مترى") واستخدام كميتين لماء الري هما: ري كامل = ٣٣٠٠ م^{٣}/ ف ((I_1 و ري ناقص= ٢٦٤٠ م^{٣}/ ف ((I_2 والري الناقص = ٨٠% من الري الكامل) والزراعة تمت بطريقتين هما الزراعة على خطوط "rows" (M_1) و الزراعة فى نقر على ارض بلاط "strew" (M_2). تراوح محصول الحبوب فى المعاملات التى لم تستخدم المصلح العضوى بين ١,٧٦٦ الى ٢,٣١٨ مججم/ف اما فى المعاملات المستخدم بها المصلح العضوى فتراوح بين ٢,٥٩٤الى ٦,٠٦٢ مججم/ف. وتراوحت كفاءة استخدام المياة (كجم حبوب/ م^{٣} ماء) بين ٠,٦١٧ الى ١,١٦٥ فى المعاملات التى لم يستخدم بها المصلح العضوى في مقابل ١,٣٨٩ الى ٢,٧٧٠ فى المعاملات التى استخدم فيها المصلح العضوى بزيادة مئوية ٣٣,٣، ٤٠,١، ١٥,٥% نتيجة استخدام معدلات كمبوست C_3, C_2, C_1 على الترتيب. وكانت كفاءة استخدام المياة فى معاملة I_2 أعلى من تلك الخاصة بمعاملة I_1 بمقدار ٥٧,٢ % أما كفاءة المياه في معاملة M_1 فكانت أعلى من لتي تخص معاملة M_2 بمقدار ٨,٠ %. كذلك تم قياس الرطوبة علي مدي نقاط التوتر الرطوبي (منحنيات رطوبة التربة) بدءا من نقطة التشبع (سالب ٠,٠١ جوي) الى نقطة الذبول(سالب١٥,٠٠ جوى) وتسبب الكمبوست في زيادة المحتوى الرطوبي عند اغلب النقاط و خاصة عند نقطة سالب ٠,٣٣ جوى (السعة الحقلية تقريبا)و كذا زيادة في الماء الميسر. الكثافة الظاهرية و التجميعات الأرضية aggregation تم تقديرها ولم يؤثر الكمبوست كثيرا على الكثافة االظاهرية.ولكن كان اثره على تغيير توزيع فئات المسام بما رفع من نسب المسام المفيدة مائيا كما رفع من التجميعات الأرضية وثباتها فعند المعدل العالي منه كانت نسبة التجميعات الكبيرة (التجميعات المبتلة) ذات الأقطار من ٢ الى ١٠ مم ٧% مقارنة بـ ٤ % فقط في الأرض التي لم تتلقى كمبوست.