EFFECTS OF IRRIGATION SYSTEMS AND COMPOST ADDITIONS ON POTATO YIELD AND CALCAREOUS SOIL-PHYSICAL PROPERTIES

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ABSTRACT

Two-seasons field experiment was carried out in 2004-2005 (1st. season) and 2005-2006 (2nd. season) at Maryut Experimental Station of the Desert Research Center, to evaluate the effects of irrigation systems and compost application amounts on potato yield; irrigation water use efficiency (IWUE) and some calcareous soil-physical properties. The source of irrigation water was ground shallow well and the average water salinity was 2.12 and 2.03 dS/m through 1st. and 2nd. seasons, respectively. The experiment was carried out in split plots design, main treatments consisted of four irrigation systems: Traditional short furrows (TF), Gated-pipe long furrows (GF), Surface drip (D); and Subsurface drip at 20-cm depth (SD), with four submain treatments of compost application amounts: without (C0); (C1); (C2); and (C3) as 0, 10, 20, and 30 m^3/fed., respectively. The obtained results indicated that both irrigation systems and compost amounts had significant influences on potato yield; IWUE and some soil physical properties. The average values of water application efficiency (AE%) with C3 in 2nd. season were 88.7; 91.1; 91.4; and 94.6% by TF; GF; D; and SD, respectively, with non-significant differences compared with the 1st. season. Distribution uniformity (DU) with C0 at 1st. season obtained values 0.53; 0.54; 0.88; and 0.91 by TF; GF; D; and SD, respectively, with non-significant differences existed compared to 2nd. season, meanwhile, DU with C3 in 1st. season: 0.55; 0.69; 0.90; and 0.95, respectively, whereas, in 2nd. season: 0.63; 0.75; 0.95; and 0.96, respectively. Under the fertilizer doses (without N) and soil experiment conditions, the maximum avg. yield of potato tubers in 1st. season were 10.88; and 6.8 t/fed. obtained by C3 under SD; and GF treatments, respectively. Meanwhile, in 2nd. season they were 11.62; and 7.09 t/fed., respectively, under the same irrigation and compost treatments.

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SD irrigation had high significant effect on average IWUE values among the irrigation treatments at any compost application amount, by C3 giving the maximum mean values of 6.49 and 7.07 kg/m^3 in 1$^{st.}$ and 2$^{nd.}$seasons, respectively. Compost amounts, subsurface drip and gated furrow irrigation treatments led to good decrease in avg. values of soil bulk density and good increase in avg. values of total porosity, and hydraulic conductivity. Such trends enhanced by increasing the compost application amounts.
Keywords: drip, subsurface drip, gated-pipe long furrows, traditional short furrows, irrigation performance, compost, water use efficiency, calcareous soil physical properties, potato productivity.

INTRODUCTION

With increasing demands on limited water resources and the need to minimize adverse environmental consequences of irrigation and chemical fertilizers, modern irrigation technology and compost applications will undoubtedly play an important role in the future in the Egyptian agriculture. It provides many unique agronomic benefits that address many of the challenges facing irrigated agriculture. Management of calcareous soils is still a problem in several locations as many unsuitable practices are still applied and cause retarding productivity. The high content of $CaCO_3$, especially in the active fraction, promotes different problematic soil characters, such as pudlling, compaction, poor aeration, nutrient fixation, surface crusting (El-Sherbiny, 2002).

Field evaluation of irrigation system performance is an essential to improve irrigation management. Volumetric water control and distribution uniformity in irrigation system are essential factors in achieving accurate water applications, (Smith and Watts, 1986). Surface irrigation is the most widely used irrigation method; this is due to its low capital and maintenance costs, and low energy requirements (Walker and Skogerboe, 1987). The efficiency of surface (furrow) irrigation is a function of the field design, infiltration characteristics of the soil, and irrigation management practices such as application rate and time (Hanson *et al.*, 1993).

Subsurface drip irrigation (SDI) is the most advanced method of irrigation, which enables the application of the small amounts of water to the soil through the drippers placed below the soil surface with discharge rates generally in the similar range as surface drip irrigation. The performance of the drip irrigation system should be quantified in relation to its design, management, operation and efficient use of water. Quantification allows the users to determine and control the discharge, amount and timings of water application, so that the crop water requirements are most important in a planned and effective manner (Ayars *et al.*, 1999).

Potatoes (*Solanum tuberosum L.*) are one of the most important crops in the world. They are also very sensitive to moisture stress because their root system is relatively sparse; approximately 85% of the root length is concentrated in the upper 30 cm of the soil layer (Kang *et al.*, 2002).

The objectives of this study were (1) to estimate the performance of mentioned irrigation systems, (2) to study the effect of different amounts of compost application under mentioned irrigation systems and its interaction on potato yield and its components (3) to determine the changes of some soil physical properties by the interactions between the considered treatments.

MATERIALS AND METHODS

1. Location and soil of experimental field:

Two field experiments were carried out during winter seasons of 2004/2005 and 2005/2006 at Maryut Experimental Station of Desert Research Center (31^{o} 00` 45`` N - 29$^{o}$ 47` 44`` E), Alexandria Governorate. Representative soil samples were collected as initial, before sowing and during the harvesting for determination some soil properties. Some physical properties determined according to the methods described by Klute (1986). The soil experimental site was deep, well-drained calcareous sandy clay loam in texture, Table (1). Some soil chemical properties represented in Table (2) were determined according to the methods described by Black (1965) and N was determined using Kjeldahl method as described by *FAO* (1970). Some basic properties of the input materials before composting are shown in Table (3). Some properties of the applied compost represented in Table (4). Average values of some chemical properties of irrigation water along each season represented in Table (5).

Table 1: Some physical properties of experimental soil site.

Season	Soil depth (cm)	Particle size distribution (%)				D_p (g/cm^3)	D_b (g/cm^3)	S_t (%)	F.C (V%)	W.P (V%)	A.W (V%)
		Coarse sand	Fine sand	Silt	Clay						
1st.	0-15	24.51	31.84	22.84	20.81	2.32	1.51	34.91	20.44	7.99	12.45
	15-30	23.58	32.09	22.66	21.67	2.33	1.53	34.33	20.54	8.16	12.38
	30-45	24.05	31.97	22.75	21.23	2.34	1.54	34.19	19.38	8.55	10.83
2nd.	0-15	24.05	31.97	22.75	21.24	2.33	1.50	35.62	20.62	8.12	12.5
	15-30	23.5	32.16	22.61	21.73	2.35	1.52	35.32	20.78	8.14	12.64
	30-45	23.45	31.73	23.72	21.1	2.35	1.53	34.89	20.09	8.58	11.52

D_p: Particle density; D_b: Bulk density; S_t: Total porosity; FC: Field capacity; WP: Wilting point; A.W: Available water

Table 2: Some chemical properties of experimental soil site.

Season	Soil depth (cm)	$CaCO_3$ (%)	Total N (ppm)	pH	OM (%)	EC (dS/m)	Soluble Cations (meq/l)				Soluble Anions (meq/l)			
							Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
1st.	0-15	25.47	42.50	7.41	0.49	2.77	4.30	1.95	20.62	0.83	-	1.64	18.48	7.58
	15-30	27.48	50.36	7.36	0.39	2.41	4.81	1.34	17.55	0.40	-	1.86	17.59	4.65
	30-45	28.12	61.21	7.39	0.28	2.53	4.83	1.18	19.07	0.22	-	2.26	17.52	5.52
2nd.	0-15	24.77	39.10	7.43	0.41	2.75	5.65	2.07	18.47	1.31	-	1.53	18.05	7.92
	15-30	26.88	52.12	7.35	0.45	2.56	5.62	1.57	17.83	0.58	-	2.10	17.95	5.55
	30-45	29.32	55.51	7.38	0.31	2.61	4.13	1.52	20.10	0.35	-	2.01	19.07	5.02

pH: Soil pH (soil paste 1:5); OM: Organic matter; EC: Electrical conductivity (soil paste 1:5)

Table 3: Some properties of input materials before composting.

Property	Rice straw	Sugar cane residue	Farmyard manure	Mean
Organic Carbon (%)	38.5	32.8	35.6	35.6
Total Nitrogen (%)	0.5	0.65	2.07	1.1
C/N ratio	77:1	50.5:1	17:1	48.2:1
Organic Matter (%)	66.22	56.42	61.23	61.3

Table 4: Average values of some properties of applied compost.

Season	Stability or Maturity	D_b (g/cm^3)	O M (%)	pH	EC (dS/m)	Total O.C (%)	Total N (%)	C/N ratio	Water holding capacity (w %)	Fineness (%)	
										0.1- 0.5 (mm)	0.5 -2.0 (mm)
1st	Mature	0.72	60.32	7.41	2.24	31.70	1.72	18.43	109.5	44.08	55.92
2nd	Mature	0.66	61.32	7.43	2.41	33.67	2.17	15.52	117.5	59.78	40.22

Table 5: Average values of some chemical properties of irrigation water.

Season	pH	SAR	EC (dS/m)	Soluble Cations (meq/l)				Soluble Anions (meq/l)			
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
1st.	7.07	9.95	2.12	2.46	2.56	15.76	0.42	-	0.94	17.20	3.06
2nd.	7.11	8.11	2.03	2.22	3.65	13.89	0.54	-	0.91	15.43	3.96

2. Irrigation systems installation and experimental treatments:

The experiment was laid out following the split plot design and three replications of each treatment at random procedure. The experiment area divided into four equal main plots of 6.75 by 48.0 m to represent the four irrigation systems. The irrigation systems were represented as: Traditional short surface furrows (TF); Gated-pipe long surface furrows (GF); and Drip irrigation represented as: Surface drip (D); and Subsurface drip (SD) at 20 cm depth from soil surface. Each main plot divided into four equal subplots representing compost application amounts (6.75 x 12.0 m): 0; 10; 20; and 30 m^3/fed. (designated as C0; C10; C20; and C30, respectively).

Each subplot arranged into two parts, one part used for sampling and the other one used for yield assessment.

Average inflow rate in furrows was 1.12 lps/furrow for both GP and TF, checked by volumetric methods during several irrigation events, according to Walker (1989). Soil surface slope was 0.2%. Irrigation runoff was negligible, as the furrows had closed-ends. Thus, the net amount of irrigation water was the amount of water added to the field. The amounts applied during each irrigation event coincided with the crop's growth stage. Surface Irrigation Simulation Model SRFR Ver. 4.06 used to simulate the interactive data with a series of performance indicators, Strelkoof and Clemmens (1999), such as application efficiency (AE%), distribution uniformity (DU), and adequacy of irrigation. These indicators are the baseline to compare between the irrigation methods, Vazquez (2006).

Installation of drip irrigation treatments established in Sep. 2004. Each subplot had one valve, one pressure gauge and one flow meter to measure the irrigation water volume. Control head facilities included double sand media filters; double disk filters 130 micron, and main flow meter with other safety tools. Polyethylene (PE) drip lines 16 mm diameter were installed and/or buried manually at depths of 0.0 and 20 cm in the middle of ridges. Care was taken to place the drip lines straight on the center of the ridges. Three inline GR drippers per 1.0 m length, with 11.86 lph/m flow rate operated at 1.1 bar pressure. Tests for drip lines uniformity of water were carried out according to the method described by Bralts *et al.* (1981) in terms of coefficient of variation (CV), distribution uniformity (DU) and statistical uniformity (SU).

Only recommended potassium (as potassium sulphate) and phosphorus (as triple super phosphate) fertilizers were added during soil preparation at the rate of 50 and 150 kg/fed., respectively, while nitrogen fertilizer was not applied throughout cultivated seasons to assess the effects of compost treatments on both crop yield and soil properties.

Whole tubers of potato (*Solanum tuberosum L.*) cv. Sponta sown on first of October, in each season at the depth of 10 cm in raised furrow ridges. The experiment plant densities were 4 - 4.5 plants/m^2 in average.**3. Estimation of water requirements and irrigation schedule:**

The irrigation water applied when the available soil moisture content depleted to nearly 50% in the upper 60 cm of soil profile in order to raise the soil moisture content to field capacity. Weather data collected from an automatic weather station located in Maryut Experiment Station. Reference crop evapotranspiration (ET_o) was calculated using Penman–Monteith's formula and the methodologies formulated by Allen *et al.* (1998) to workout the crop evapotranspiration (ET_c), leaching requirements and determining the irrigation schedule. The amount of irrigation water calculated according to the equation given by James (1988):

$$ET_C = I + P \pm \Delta S - R - D$$

Where: ET_c = crop evapotranspiration (mm);

I = irrigation amount (mm);

P = precipitation (mm);

ΔS = change of soil water storage (mm);

R = surface runoff (mm); and

D = deep percolation below crop root zone (mm).

Since the precipitation in the growing season was small, the deep percolation and surface runoff could be ignored under the experiment conditions. Therefore, the irrigation amount estimated using the field balance equation as follows:

$$I = ET_C \pm \Delta S$$

4. Estimation of soil moisture content:

Neutron probe scattering was calibrated and used for soil moisture determination. Four access tubes were pressed at the center of the row to a depth of 1.2 m. Measurements of volumetric soil moisture content in all treatments were started at depth of 0.3 m from ridge surface with increments of 0.15 m till 1.05 m to follow the soil moisture at $1^{st.}$, $2^{nd.}$, $3^{rd.}$ and $4^{th.}$ growth stages of potato crop along 3^{rd}, 5^{th}, 6^{th} and 8^{th} irrigation events under furrow, and with 4^{th}, 8^{th}, 14^{th} and 19^{th} irrigation events by drip. At the same time, soil samples were collected using soil auger sampler from six points perpendicular the furrow ridge, selected randomly from each treatment to determine soil moisture distribution gravimetrically, starting at ridge surface down to 1.05 m with increment of 0.15 m and it calculated on volumetric basis (Walker, 1989).

Application efficiency (AE%) calculated for the 60 cm soil depth according to James (1988). As an average value for considered irrigation events in the $1^{st.}$ and $2^{nd.}$ seasons.

Distribution uniformity (DU) is the ratio of the average of the lowest one-fourth of measurements of water infiltrated depths divided by the average depth of water infiltrated over actual field length, the DU were calculated according to the method described by Burt *et al.*, (1997). Data were analyzed statistically according to Snedecor and Cochran (1982).

5. Potato tubers yield:

At harvest, (120 day after sowing) fresh tubers from each plot were collected, weighed and counted, and the following parameters were intended in each season: number of tubers per plant; avg. tuber mass (g.); tubers yield per plant (g.); and total yield (ton/fed.). Analysis of variance (ANOVA) used to evaluate the effects of the treatments on the yield and to determine the significance of the main treatments and its interaction with sub treatments. Least significance differences (LSD) test used for comparing ($P < 0.05$) according to Snedecor and Cochran, (1982).

6. Irrigation water use efficiency (IWUE):

IWUE was measured according to James (1988) as follows:

$$IWUE = \frac{Y}{W_a}$$

Where: IWUE = irrigation water use efficiency, kg/m^3;

Y = total tubers yield, kg/fed.; and

W_a = total applied water, m^3/fed.

Data of IWUE were statistically analyzed according to Snedecor and Cochran, (1982).

RESULTS AND DISCUSSIONS

1. Uniformity of irrigation systems:

With drip irrigation, the performance parameter of the drip laterals estimated before installation; the coefficient of variation (CV) was 0.052. The low CV indicated good performance of the systems throughout cropping seasons. Decroix and Malaval (1985) had concluded that a CV between 0.05 and 0.066 indicated a good performance of the drip system. Average values of statistical uniformity (SU) and distribution (DU) were 94.77% and 0.93, respectively. According to Bralts *et al.* (1981), SU and DU greater than 90.0% and 0.87, respectively, implied an excellent functioning of the drip lines. Average irrigation water application efficiency (AE%) are shown in Fig. (1). It is clear that with different compost application amounts under TF treatment, about 11.4 to14.4% of the applied irrigation water were not available for the crop, these losses with GF treatment were about 8.7 to 11.1% of the applied irrigation water. Meanwhile, these losses with the drip treatment (D) were about 8.4 to10.5% and with SD, these losses were from 4.9 to 5.7%, of the applied irrigation water.

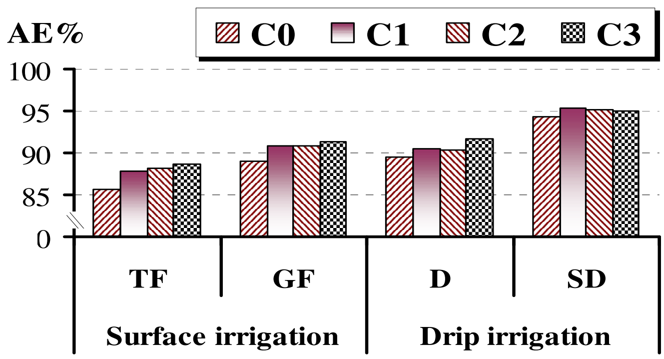
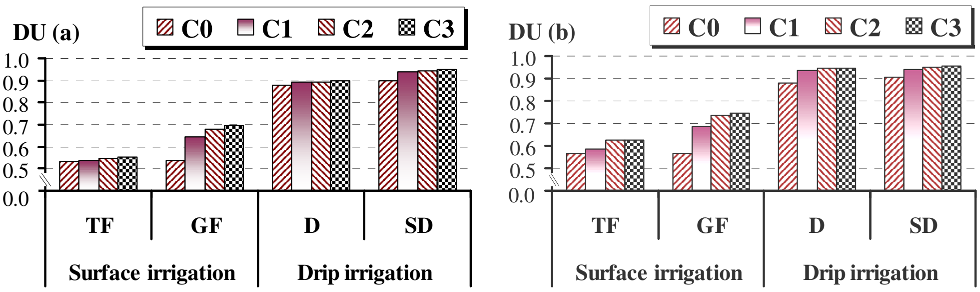


Fig. 1: Average values of AE% in $2^{nd.}$ season with compost amounts under irrigation system treatments.

Meanwhile, in $2^{nd.}$ season, no-significant differences existed in the avg. obtained values of AE% compared with $1^{st.}$ season. AE% had significantly affected by irrigation system with compost application

amounts ($P < 0.05$). In treatment TF, there was significant decrease in AE% in comparison to all irrigation treatments. Also, C3 had significant increase in AE% in comparison to all compost amounts. The interaction effect of irrigation system and compost application amount on AE% in two seasons had non-significant effect.

The average values of water distribution uniformity (DU) for treatments under considered irrigations are shown in Fig. (2). The maximum average values of DU were 0.95 and 0.97 in 1st. and 2nd. seasons, respectively, obtained by SD with treatment C3, representing a significant



difference by comparing with other compost amounts in the two seasons.

Fig. 2: Average values of DU at 1st. (a) and 2nd. (b) seasons using compost amounts under irrigation system treatments.

In the same time, addition C2 had no-significant differences in avg. DU values compared to C3 with all irrigation treatments in the two seasons. Surface furrow treatment GF had high significant differences of avg. DU values by all compost application amounts comparing with C0 treatment in both 1st. and 2nd. seasons, the increments reached to 29.6; 26.7; and 20.3% with C3; C2 and C1, respectively, in 1st. season, Fig. (2-a), and the increments reached to 32.3; 30.5; and 21.1% under the same amounts, respectively, in 2nd season, Fig. (2-b).

SD and D had no-significant differences on avg. DU values obtained by applying C3; C2; and C1 compost amounts in 1st. or 2nd. season. These results regarding to the compost amount, indicate that the GF irrigation has to be determined for each field situation according to inflow rate, slope, advance phase, intake opportunity time and depth of application, Merriam *et* *al.* (1983). Pordeus *et al.* (2003) indicated that in some cases where the infiltration rate was lower, the infiltrated water depths at the end of the field were larger than at the beginning of the field, allowing a more adequate management with a smaller water application time.

2. Effect of irrigation systems on potato tuber yield:

The effect of irrigation systems on the potato tuber yield is shown in Table (6).

Table 6: Average values of tuber mass, potato yield and IWUE with compost amount under irrigation system treatments.

Irrigation system	Compost amount	1st. season (04/2005)			2nd. season (05/2006)		
		Tuber mass (g.)	Yield (t/fed.)	IWUE (kg/m^3)	Tuber mass (g.)	Yield (t/fed.)	IWUE (kg/m^3)
TF	C0	47.10	3.46	1.23	51.48	4.73	1.77
	C1	53.28	4.21	1.49	55.08	4.76	1.78
	C2	57.88	5.24	1.86	55.68	5.43	2.04
	C3	66.23	5.90	2.09	56.58	5.84	2.19
GF	C0	49.41	3.79	1.50	56.55	5.90	2.41
	C1	56.77	4.98	1.96	60.67	5.70	2.33
	C2	58.85	5.80	2.29	62.53	7.21	2.95
	C3	69.57	6.80	2.68	64.11	7.09	2.90
D	C0	50.41	4.77	2.26	59.55	6.41	3.14
	C1	62.47	6.37	3.01	66.86	7.60	3.73
	C2	68.33	7.41	3.51	68.80	8.32	4.08
	C3	75.30	8.16	3.86	73.05	9.76	4.79
SD	C0	52.48	5.70	3.40	65.19	7.59	4.62
	C1	65.82	7.85	4.68	69.86	7.95	4.83
	C2	70.51	9.51	5.67	79.26	10.48	6.37
	C3	79.82	10.88	6.49	82.36	11.62	7.07
L.S.D (< 0.05)		1.07	0.13	0.06	2.64	0.30	0.16
TF		56.12	4.70	1.67	54.70	5.19	1.95
GF		58.65	5.34	2.11	60.96	6.48	2.65
D		64.13	6.68	3.16	67.07	8.02	3.93
SD		67.16	8.49	5.06	74.17	9.41	5.72
L.S.D (< 0.05)		0.31	0.04	0.02	1.28	0.08	0.04
C0		49.85	4.43	2.09	58.19	6.16	2.99
C1		59.59	5.85	2.79	63.12	6.50	3.17
C2		63.89	6.99	3.33	66.57	7.86	3.86
C3		72.73	7.93	3.78	69.02	8.58	4.24
L.S.D (< 0.05)		0.27	0.03	0.06	0.66	0.07	0.04

SD treatment significantly increased the yield regardless the compost amount. The maximum avg. yields were 10.879 and 11.624 t/fed.

obtained by SDxC3 treatment in 1st. and 2nd. seasons, respectively. In general, the highest values of avg. yield were associated with drip systems, where the increments significantly increased with increasing of compost amounts. TF treatment had the lowest value of average yield, followed by GF irrigation treatments. The main reasons maybe that GF irrigation has caused good water distribution to roots in soil and high compost rate enhanced structure of the soil and soil moisture content, (Chambal and Shukla, 2006). Meanwhile, lower yield under TF maybe attributed to irrigation water ponds at the furrows after irrigation event. Consequently, too much water might have caused partially poor aeration of roots, and soil nutrients leaching, (Xiao *et al.*, 2004).

3. Effect of compost application amounts on potato tuber yield:

The effect of compost application amounts on the potato tuber yield is shown in Table (6). The application of compost significantly increased the tuber yield, where the rate of increment increased with the compost amount. Under SD treatment, the avg. increments between the two seasons reached to 72.0, 42.4 and 12.6 % above non-compost C0 treatment due to applying C3, C2 and C1 treatments, respectively. The same trend obtained with D irrigation treatments with increments 61.7, 28.3, and 13.7%, respectively. GF resulted in the same trend too, where the increments reached to 49.8, 30.5, and 7.8%, respectively. Meanwhile, in using TF irrigation, the increments reached to 47.0, 31.4, and 10.1% due to applying C3, C2 and C1 treatments, respectively.

The positive effect of compost application on increasing the tubers yield of potato is a true reflection of improving soil water retention due to its effect on pore size distribution i.e., water holding in pores (Gouda, 1984) and decreasing soil pH values which lead to increasing nutrient availability and supply (Dahdoh and El-Hassanin, 1994).

4. Effect of the interaction between irrigation system and compost amounts on potato yield:

Regarding the interactions among the considered treatments, data in Table (6) showed different trends that varied widely due to the rate of compost application and irrigation system, with high significant differences between the average yield values. Generally, in 1st. season, the efficiency of the applied compost treatments in increasing the tubers yield of potato under the experiment conditions, could be arranged in the following treatments order: (SDxC3) > (SDxC2) > (DxC3) > (SDxC1) > (DxC2) > (GFxC3) > (DxC1) > (TFxC3), whereas in 2nd. season: (SDxC3) > (SDxC2) > (DxC3) > (DxC2) > (SDxC1) > (DxC1) > (SDxC0) > (GFxC3) > (DxC0) > (GFxC0) > (TFxC3).

The positive effect of studied treatments on increasing the yield is a true reflection of improving some physical and chemical properties of the calcareous soil under investigation. (Tate, 1987; Beheiry, 2001; and Beheiry and Hiekal, 2007) they discussed the role of organic manure on the supply of nutrients, where the decomposition of such materials induced the slow release of nutrients in available forms accessible to plants for better growth and productivity.

5. Irrigation water use efficiency (IWUE):

The average values of IWUE are shown in Table (6). Generally, the maximum average values of 6.49 and 7.07 kg/m^3 obtained by SD irrigation and C3 treatment in 1st. and 2nd. seasons, respectively, by comparing with DxC3 treatment. The declines reached to 68.1 and 47.6% in 1st. and 2nd. seasons, respectively. Meanwhile, in the case of surface furrow GF, the maximum avg. values were 2.68 and 2.9 kg/m^3 obtained using C3 treatment in 1st. and 2nd. seasons, respectively. By comparing with TF xC3, the declines reached to 28.3 and 32.3% in 1st. and 2nd. seasons, respectively. Regarding to compost application amounts, in 1st. and 2nd. seasons, significant differences in avg. IWUE values existed between the compost application amounts regardless irrigation system. Regarding irrigation treatments, in 1st. and 2nd. seasons, significant differences obtained in IWUE avg. values between irrigation treatments. Because the amount of water applied under SD irrigation system (Table 7) were about 1677 and 1644 m^3/fed. in 1st. and 2nd. seasons, respectively, and a good performance of irrigation water distribution uniformity resulted in highest average values of both yield and consequently IWUE compared to all treatments of compost application amounts under the experiment conditions. On the other side, for water conservation realization, which could be obtained under SD under any level of addition compost amount, the declines in irrigation water applied reached to 26.1and 24.0%, compared with D irrigation system in 1st. and 2nd. seasons, respectively.

Table 7: Irrigation water applied at different growth stages of potato crop under different irrigation system treatments.

Season	Crop growth stage	Furrow irrigation		Drip irrigation	
		TF	GF	D	SD
1st.	Initial	760.75	671.05	515.25	470.33
	Crop dev.	945.45	848.77	866.15	675.55
	Mid. Season	520.75	485.00	345.72	205.00
	Mat.	595.70	530.00	386.86	325.95
	Sum (m^3/fed.-season)	2822.65	2534.82	2113.98	1676.83
2nd.	Initial	760.75	671.05	496.80	447.50
	Crop dev.	945.45	848.77	856.40	640.85
	Mid. Season	520.75	485.00	440.22	378.00
	Mat.	438.90	440.70	245.90	178.00
	Sum (m^3/fed.-season)	2665.85	2445.52	2039.32	1644.35

In the same time, furrow irrigation GF treatment, the declines in irrigation water applied compared with TF irrigation system reached to 11.4 and 9.0%, in 1st. and 2nd. seasons, respectively. The main reasons may be attributed to good distribution uniformity with both SD and GF irrigation treatments, and aeration of roots mainly with superior soil physical properties conditions, and high compost application rate enhanced structure of the calcareous soil and soil moisture content, (Chambal and Shukla, 2006). The lower obtained values of IWUE by TF irrigation maybe attributed to irrigation water ponds at the furrow ends after traditional irrigation events. Too much water might have caused partially poor aeration of roots, and soil nutrients leaching, (Xiao *et al.*, 2004). Generally, the efficiency of the applied treatments in maximizing IWUE in 1st. season under the experiment conditions could be arranged in the following treatments order: (SDxC3) > (SDxC2) > (SDxC1) > (DxC3) > (DxC2) > (SDxC0) > (DxC1) > (GFxC3), whereas in 2nd. season: (SDxC3) > (SDxC2) > (SDxC1) > (DxC3) > (SDxC0) > (DxC2) > (DxC1) > (GFxC3).

6. Effect of compost application amounts on soil physical properties:

6.1. Soil bulk density (D_b): the changes in soil bulk density differ between soil textures, but for the same texture, it expresses the variation in soil compatibility. Table (8) clarifies that under any type of considered irrigation system, there is a good reducing in D_b as compared to the initial soil condition. The avg. percent of decrease in D_b values due to compost addition of C3 are 7.24; 10.46; 12.52 and 13.7% with TF; GF; D; and SD treatments, respectively, compared with non-compost treatment C0.

Those declines were in the same trend with non-significant differences compared to 2nd. season. These results are in accordance with El-Sherbiny (2002) who showed that the compost produced measurable changes in the soil physical properties, the magnitudes of the changes in most cases were small and depended on the addition amounts of compost.

Table 8: Average values of soil D_b; S_t; and $K_{sat.}$ resulted in 2nd. season by compost addition under different irrigation system treatments.

Irrig. system	Soil depth (cm)	Bulk density[$], D_b (g./cm^3)				Total porosity, S_t (%)				*Hydraulic cond., $K_{sat.}$ (cm/h)			
		Compost application amounts (m^3/fed.)											
		C0	C1	C2	C3	C0	C1	C2	C3	C0	C1	C2	C3
TF	0-15	1.48	1.39	1.38	1.36	36.21	40.09	40.52	41.38	1.97 MS	2.96 M	3.74 M	3.39 M
	15-30	1.53	1.42	1.4	1.38	34.33	38.79	39.91	40.77				
	30-45	1.58	1.55	1.56	1.52	32.48	33.76	33.05	35.04				
GF	0-15	1.46	1.39	1.37	1.33	37.07	40.09	40.95	42.67	1.98 MS	3.39 M	4.02 M	5.60 M
	15-30	1.55	1.36	1.34	1.33	33.48	41.63	42.49	42.92				
	30-45	1.57	1.51	1.52	1.44	32.91	35.90	35.04	36.32				
D	0-15	1.50	1.35	1.34	1.31	35.33	41.81	42.24	43.97	1.98 MS	3.41 M	4.05 M	5.87 M
	15-30	1.55	1.37	1.32	1.32	33.48	41.20	43.35	43.35				
	30-45	1.59	1.53	1.44	1.43	32.05	34.62	38.46	38.89				
SD	0-15	1.48	1.36	1.35	1.32	36.21	41.38	41.81	45.10	1.98 MS	3.59 M	4.25 M	6.31 MR
	15-30	1.52	1.33	1.31	1.30	34.76	42.92	43.78	44.21				
	30-45	1.58	1.35	1.34	1.33	32.48	42.3	42.74	43.16				

[$]Initial values of D_b, D_p, and S_t at soil depths represented in Table (1).
*$K_{sat.}$ in sandy clay loam soil >MS = Moderately slow (0.5-2cm/h); M = Moderate (2-6.25 cm/h); MR = Moderately rapid (6.25-12.5 cm/h), according to Klute (1986).

6.2. Total porosity (S_t%): data presented in Table (8) show the effect of compost application amounts under the considered irrigation systems on soil porosity. the avg. increments in S_t values due to compost addition of C3 are 13.64; 17.89; 25.09 and 28.21% with TF; GF; D; and SD treatments, respectively, compared with C0 treatment. The data clarifies a good increase in S_t pertaining to the compost amounts under SD treatment; SDxC3 achieved steady increments from 24.6 to 32.9% compared with C0 till 45 cm soil depth. Meanwhile, DxC3 treatment achieved 29.5% increase for the middle layer (15-30 cm) compared with C0 followed by 21.3% increase at deeper layer (30-45 cm). On the other hand, GFxC3 treatment achieved 28.2% increase for the middle layer (15-30 cm) compared with C0 followed by 10.4% increase at deeper layer (30-45 cm).

The avg. total soil porosity did not exceed 18.8% increases by TFxC3 for the middle layer (15-30 cm) compared with C0. Significant difference is noted in avg. total porosity by SD, the increments were continuing with successive soil layers at any compost application rate. This result is in agreement with that obtained by Ghezzehei and Or (2000), who observed similar findings, that wetting the aggregates weakens the cementing forces between particles inside the aggregate and renders the aggregates easier to break down, and the tendency of increase in soil porosity accompanied the interaction effect of compost and irrigation system.

6.3 Hydraulic conductivity, K_{sat} (cm/h): the saturated hydraulic conductivity $K_{sat.}$ means that most soil pores are filled with water, this occurs in the soil after heavy rains or during irrigation, where water at this condition is tension free. Therefore, the data in Table (8) illustrate the avg. values of soil water movement, with different compost application amounts under different irrigation system treatments. The mean increasing percent took the following order: SD (219%); D (197%); GF (183%); and TF (171%) using C3 compared with C0 treatment. Concurrently, the results declare a tendency of increasing K_{sat} of the soil upon compost addition rates. By increasing compost addition rate from C0 to C3 under SD treatment, these variations of increase correspond to soil water movement transmission from moderate (M) to moderately rapid (MR), i.e., from 1.98 to 6.31 cm/h. Meanwhile, those increments in $K_{sat,}$ due to irrigation systems and applying compost stimulate favorable conditions for increasing soil specific surface, structural units and root growth with good conditions of microbial activity. These data results are concomitant with the reported results by Sirjacobs *et al.* (2001) who showed that during the slow water rate and high antecedent moisture content, increasing in cohesion between soil particles took place. In addition, aggregate stability could be affected by soil properties like organic matter, clay, and $CaCO_3$ content or exchangeable sodium percentage (Kay and Angers, 1999). Improved of some physical and chemical properties of the calcareous soil under positive effect of studied treatments on increasing the contents of such nutrients is a true reflection. (Tate, 1987 and Beheiry, 2007), they illustrated the role of organic manure on the supply of nutrients, where the decomposition of such materials induced the slow release of nutrients in available forms accessible to plants for better growth and productivity. In addition, these results are in good agreement with the reported by Lado *et al.* (2004) who observed the physicochemical dispersion of clay particles, which migrate into the soil with the infiltrating water, and clog the pores immediately beneath the surface to form the "washed-in" zone.

CONCLUSION

The obtained results indicated that under the conditions of the experiment, it could be recommended to use soil amendments such as plant residues compost to enhance the organic agriculture and consequently maximize the edible vegetables (potato tubers) yield under any of mentioned irrigation systems using different compost application amounts under similar conditions of newly reclaimed desert land in Egypt. Generally, the efficiency of the applied treatments in increasing the potato yield could be arranged in the following order: (SDxC3) > (SDxC2) > (DxC3) > (SDxC1) > (DxC2) > (GFxC3) > (DxC1) > (GFxC2).

There were noticeable increases in irrigation water use efficiency (IWUE) by SD irrigation system compared with all irrigation treatments regarding the compost application amounts, because the amounts of applied water were 1677 and 1644 m^3/fed. in $1^{st.}$ and $2^{nd.}$ seasons, respectively, with good distribution uniformity resulted in highest average values of IWUE (6.49 and 7.07 kg/m^3 in $1^{st.}$ and $2^{nd.}$ seasons, respectively). Good avg. values of application efficiency (AE%) obtained by TF; GF; D; and SD were 88.7; 91.1; 91.4; and 94.6%, respectively, with applying C3, meanwhile, avg. values of distribution uniformity (DU) were 0.55; 0.69; 0.90; and 0.95, respectively, in 1^{st} season and about 0.63; 0.75; 0.95; and 0.96, respectively, in 2^{nd} season.

From the aforementioned results, compost application, subsurface drip and gated furrow irrigation led to good decrease in avg. values of soil bulk density and good increase in avg. values of total porosity, and hydraulic conductivity. The avg. percent of decreasing in soil bulk density (D_b) values due to addition compost C3 were 7.24; 10.46; 12.52 and 13.7% under TF; GF; D; and SD treatments, respectively, compared with C0. Meanwhile, SDxC3 treatment achieved steady increments of D_b from 24.6 to 32.9% compared with C0 along soil depths until 45 cm. The mean increasing percent of soil water movement ($K_{sat.}$) took the following increasing order: SD (219%); D (197%); GF (183%); and TF (171%) using C3 compared with C0. The tendency of increasing K_{sat} of the soil upon compost addition amounts. Such trends enhanced with increasing the application rate of compost. Consequently, the number of tubers per plant; average tuber mass; and tubers yield per plant increased under SD more than D, as well as, GF was superior to TF in respect to the aforementioned soil physical properties and experiment conditions.

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الملخص العربى

تأثيرات نظم الرى وإضافات المكمورة على إنتاج البطاطس والخصائص الطبيعية للأرض الجيرية

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أجريت تجربة حقلية لموسمين متتابعين (2005/2004 و 2006/2005م) بمحطة بحوث مريوط التابعة لمركز بحوث الصحراء، بهدف تقييم تأثير نظم الرى مع معدلات إضافة مختلفة من المخلفات النباتية المكمورة على إنتاج محصول البطاطس، وكفاءة استخدام مياه الرى، و بعض الخصائص الطبيعية للتربة الجيرية. مصدر مياه الرى بئر سطحى، ومتوسط ملوحة المياه به 2.12 ، و 2.03 ديسيمنز/م على مدار الموسمين الأول والثانى، على الترتيب.

أجريت التجربة بنظام القطع المنشقة حيث تمثل نظم الرى القطع الرئيسية باستخدام أربع معاملات للرى: رى الخطوط القصيرة التقليدى (TF)، رى الخطوط الطويلة ذات الأنابيب المبوبة (GF)، والتنقيط السطحى (D)، والتنقيط تحت السطحى على عمق 20 سم من سطح التربة (SD). أما القطع الفرعية فيمثلها أربع معاملات إضافة للمكمورة بمعدل صفر،10، 20،و 30 م^3/ ف وهى (C0)، (C1)، (C2)، (C3) على الترتيب. وقد أشارت النتائج المتحصل عليها الى أن كلاً من نظام الرى ومعدل إضافة المكمورة ذات تأثير معنوى على محصول البطاطس، وكفاءة استخدام مياه الرى، وبعض الخصائص الطبيعية للتربة.

كانت متوسطات قيم كفاءة الإضافة (AE%) بدون إضافة مكمورة (C0) هى 85.6 و88.9 و89.5 و94.3% لكلا من (TF)، (GF)، (D)، (SD) خلال الموسم الأول، على الترتيب، بينما كانت 88.7 و 91.1 و 91.4 و 94.6% على الترتيب مع استخدام (C3). ولم توجد فروق معنوية بالمقارنة مع القيم المتحصل عليها خلال الموسم الثانى. أما متوسطات قيم انتظام توزيع المياه (DU) خلال الموسم الأول بدون إضافة مكمورة (C0) كانت 0.53 و0.54و0.88 و 0.91 لكلا من (TF)، (GF)، (D)، (SD) على الترتيب. ولم توجد فروق معنوية بالمقارنة مع القيم المتحصل عليها خلال الموسم الثانى. بينما كانت مع معدل الإضافة (C3) للموسم الأول 0.55 و0.69و0.90 و 0.95 على الترتيب. وخلال الموسم الثانى كانت 0.63 و0.75و0.95 و 0.96 على الترتيب. مع اتباع منهج التسميد المعدنى (بدون تسميد أزوتى) وظروف أرض التجربة. كانت أعلى متوسطات لمحصول الدرنات بالموسم الأول مع معاملة (C3) هى 10.88و 6.8 طن/ف تحت نظامى الرى (SD) و (GF) على الترتيب. وبلغت بالموسم الثانى 11.62 و 7.09 طن/ف تحت نفس نظامى الرى على الترتيب. أظهر نظام التنقيط تحت السطحى (SD) بالموسم الأول والثانى تأثيراً معنويا فى متوسطات قيم IWUE بين معاملات الرى المختلفة عند أى معدل إضافة للمكمورة، حيث سجلت معاملة الإضافة (C3) أعلى متوسط 6.49 و 7.07 كج/م^3 تحت ظروف الدراسة للموسم الأول والثانى على الترتيب. كان لاستخدام معدلات المكمورة مع معاملات الرى بنظامى التنقيط تحت السطحى (SD) والخطوط الطويلة ذات الأنابيب المبوبة (GF) تأثير معنوى واضح أدى لخفض متوسطات قيم الكثافة الظاهرية وزيادة معنوية لمتوسطات قيم المسامية الكلية، والتوصيل الهيدروليكى للتربة، وأن هذه القيم تقل وتزيد متأثرة بمعدلات إضافة السماد العضوى المكمور.

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