Journal of Genetic and Environmental Resources Conservation, 2014, 2(1): 54-64.
www.jgerc.com

Evaluation of supplemental irrigation and fertilization as integrated management of wheat under rainfed conditions in Egypt

Abd-Eladl M.

Soils, Water and Environment Research Institute (SWERI), Agriculture Research Centre (ARC), Egypt.
Corresponding author: abdeladle34@gmail.com

Abstract

A field experiment was carried out at Alexandria Governorate during 2009-2010 and repeated in 2010-2011 to evaluate usage of supplemental irrigation (SI) and organic or mineral fertilization (NPK) as integrated management of wheat under rainfed condition. The treatments include two irrigation practices (rain and rain+supplemental irrigation (SI) and three fertilizers applications (control, OM and NPK) in a split plot design. The results showed that organic matter (OM) promote the porosity, hydraulic conductivity and soil moisture constant while bulk density take an opposite trend. Grain, straw and biological yield were increased significantly with either rain+SI irrigation or OM application or interaction of both, while NPK came after. In both seasons, nitrogen, phosphorus and potassium concentrations (%) and content (kg/fed.) in grain and straw increased significantly by adding rain+SI compared to rain treatments only. The lowest values were found in case of control followed by applying the recommended dose of mineral fertilizer. Total nutrients content in above ground portions (grain+straw) (kg/fed.) or harvest index (HI) increased with rain+SI or OM individually or interaction, economic water productivity (EWP) was higher when irrigated with rain than rain+SI treatment and this trend was similar to those of Water use efficiency (WUE). The promising treatment is the combination between fertilizer application (compost or mineral) and supplemental irrigation.

Keywords*:* Compost, Dryland, Irrigation schedule, Mineral fertilization

Introduction

With climatic change and rainfall scarcity, supplemental irrigation could be an opportunity to enhance wheat grain yields and respond to population food demand (Abderrazzak *et al.,* 2013). The great challenge of the agricultural sector is to produce extra food using less water, which can be achieved by increasing crop water productivity (Zwart and Bastiaanssen, 2004).

Egypt is characterized by high temperatures, high evapotranspiration and low rainfall. Coastal zone of Egypt is 500 km long and 20 km width. Climatic change pattern in Mediterranean region would increase drought frequency with high fluctuation in precipitation (FAO, 2008). The rainfall in the growing season at the coastal zone is highly variable and less than wheat water requirements, consequently conservation is essential to stabilize the water availability for maximum crop production and increase yields (Salem *et al.,* 2003). The water deficiency promotes biochemical changes in plants as accumulation of organic compounds (Costa *et al.,* 2008) and promotes strong decrease in stomatal conductance (Lobato *et al.,* 2009). Irrigation is an obvious way for increasing yields in those regions, which regularly suffer drought, but lack of fresh water and/or the cost of its application generally restrict the amount of irrigated wheat (Attia and Barsoum 2013).

Fertilizers play a very important role in increasing land productivity and fertility. Although mineral fertilizers can be used to replenish soil nutrients removed by crop harvests, they are too costly to be used in large quantities for profitable production in developing countries (Fan *et al.,* 2005). Water and nitrogen use should be carefully managed to avoid losses (Behera *et al.,* 2009). Both of them are considered the most limiting factors in wheat production in most parts of the world, especially in arid and semi-arid region (Gonzalez-Dugo *et al.,* 2010).

The gap between cereal production and demand could be more than double in the next 30 years. In addition, changes in lifestyles and income levels may affect food security throughout the developing world. FAO expects the irrigated areas in 93 developing countries to expand by 0.6 percent per year between 1996 and 2030, for an overall increase of 23 percent. Additional production would come from increased yields and an increase in the effective harvested area. Both of these sources of increased production depend on water and fertilizer inputs (FAO, 2002).

The objective of this study is to determine the effect of applying supplemental irrigation, mineral and organic fertilizers to enhance wheat *(Triticum aestivum* L.) productivity and water use efficiency under rainfed condition in Alexandria Governorate.

Materials and Methods

A field experiment was carried out at Alexandria Governorate (Latitude: 31° 12", Longitude: 29° 57" and Elevation: 3.4m) during 2009-2010 and repeated in 2010-2011 to evaluate the use of supplemental irrigation and mineral fertilization as suitable management of wheat under rainfed condition. The experiments design includes two factors; l) two irrigation practices (rain and rain + supplement) and three fertilizer applications (control, NPK and organic fertilizer), where the following treatments were studied: T1= Rain T2=Rain + Mineral fertilization (NPK) T3=Rain + Organic fertilization (OM) T4=Rain + Supplemental irrigation (SI) T5=Rain + Supplemental irrigation (SI) + NPK T6=Rain + Supplemental irrigation (SI) + OM The experimental design was split plot (SP) in three replicates, and the area was divided into 18 plots (5m x 3.5 m) each, with an alley of lm between adjacent plots and 2 m between main plots. Initial soil analyses and compost characteristics are shown in table (1).

Table (1): The analyses of some studied soil and used organic matter (compost) properties

Properties	**Soil**			**Organic matter (compost)**	
	0-30 cm	**30-60 cm**	**60-100 cm**		
pH (1:2.5)	8.1	8.19	8.23	pH (1:2.5)	7.5
EC (soil paste extraction) dS/m	4.4	4.2	4.7	EC dS/m (1:5)	5.5
$CaCO_3$ (%)	39.6	39.5	42.8	OM (%)	25.21
O.M (%)	1.2	0.65	0.23	C/N	11.9
				N (%)	1.23
Soluble cations mg/l					
Na^+	22.3	0.82	25.7	P (%)	0.82
K^+	1.2	1.0	0.8	K (%)	2.20
Ca^{2+}	11.8	13.0	12.2	WHC (%)	115
Mg^{2+}	8.7	7.5	8.3		
Soluble anions mg/l					
HCO_3^-	2.0	1.9	1.8		
Cl^-	39.5	37.8	43.3		
$SO_4^=$	2.5	2.3	1.9		
Physical properties					
Clay (%)	16.5	19.3	14.7		
Silt (%)	23.6	22.6	23.0		
Fine sand (%)	39.4	39.5	42.8		
Coarse sand (%)	20.5	18.6	19.5		
Soil texture	Sandy loam	Sandy loam	Sandy loam		
F.C (%)	25.4	25.5	24.3		
W.P (%)	7.8	7.9	7.6		

Grains of Sakha-8 wheat cultivar were used in both seasons, supplied by the Wheat Research Division, Agriculture Research Center, Ministry of Agriculture. Grain prepared by soaking in tap water for 24 hours followed by air drying. Wheat grains were drilled on November 15*, and the crop was harvested on 5 May.

Nitrogen, phosphorus and potassium fertilization was carried out in case of T2 and T5 treatments. Ammonium sulphate (20.6% N) was added at a rate of 120kg N /fed. in three equal portions before cultivation, after three weeks from cultivation and after three weeks from second addition. Super-phosphate (15.5% P_2O_5) and potassium sulfate (48% K_2O) were added before planting at the rate of 150 and 50 kg/fed., respectively.

Organic fertilizer (compost) was added for T3 and T6 treatments based on its total N concentration and followed the recommendations for fertilization of wheat plants in Egyptian new reclaimed soils *(*~ 9.8 ton/fed.). Some physical and chemical properties of the compost are shown in Table (1).

Water requirement was calculated according to the 10 years average of meteorological parameters using CROPWAT computer model (FAO 1992). Penman Monteith equation and the KC values were presented in the program and also illustrated in FAO-56 (Allen *et al.,* 1998). Metrological data obtained from Central Laboratory for Agriculture Climate are show in Table (2). Monthly evapotranspiration (ETo) data and crop coefficient of wheat plants are presented in Table (3). Crop evapotranspiration (ETc) was calculated according to the following formula:

$ETc = Kc . ET_0$ FAO-56 (Allen *et al.,* 1998) Where;

ETc = crop evapotranspiration in mm/day.

ET_0 = potential evapotranspiration in mm/day.

KC = crop coefficient.

Table (2): Metrological data of Alexandria area (1999-2008).

Month	T-air-max	T-air-min	T-soil-max	T-soil-min	Relative humidity	Wind speed	Rain-fall	ETo mm
January	19.0	9.1	10.1	21.5	84.0	3.1	54.9	2.2
February	20.1	10.1	10.5	22.0	79.0	3.0	26.5	2.6
March	24.1	12.2	10.2	26.8	76.0	3.2	12.9	3.6
April	25.6	13.2	11.5	29.6	72.0	2.9	4.2	4.8
May	29.5	17.3	10.5	31.9	74.0	2.8	1.5	5.4
June	30.5	19.6	9.5	28.5	79.0	2.8	-	5.9
July	31.6	22.3	8.7	30.8	79.0	3.0	-	6.2
August	32.9	22.2	12.5	29.9	78.0	2.7	-	5.4
September	32.3	20.4	13.0	30.5	77.0	2.5	-	5.0
October	29.4	17.5	19.5	30.1	76.0	2.2	9.3	3.7
November	26.6	13.5	14.1	26.9	77.0	2.8	32.6	2.8
December	20.8	10.0	11.6	22.9	80.0	2.8	53.6	2.3
Average	26.9	15.6	11.8	27.6	77.6	2.8	195.5	4.2

Table (3): Monthly evapotranspiration (ETo) and crop coefficient of wheat plants.

Month	Nov.	Dec.	Jan.	Feb.	March	April	May
ET_0 (mm/day)	2.80	2.30	2.20	2.60	6.30	4.80	5.40
KC	0.30	0.35	0.89	1.15	1.13	0.67	0.32
Water requirements (mm/day)	0.84	0.80	1.95	2.99	4.06	3.21	1.72

Soil samples were collected at the depths of 0-30, 30-60 and 60-120cm. and physical properties (bulk density, total porosity, hydraulic conductivity and soil moisture constant) were determined according to Klute (1986).

Thus, the influence of these treatments on the following parameters like grain, straw and biological yield, water use efficiency (WUE), harvest index (HI) in both seasons was determined. Finally, N, P and K concentrations and content of straw and grains were determined and calculated as an average of the two seasons. Total nutrients content in above ground portions (kg/fed.) and N P K harvest index was calculated as follows:

Nitrogen harvest index (NHI) = N content in grain / total above-ground plant N content xl00 (Sun *et al.,* 2013).

Water use efficiency (WUE kg/m) is expressed in gross weight of product (kg) per water supplied (m), and was calculated for each treatment using the following formula:

WUE = Grain or biological yield (kg/fed.)/total water applied (m^3/fed.)

Economic water productivity (EWP) was expressed in gross income in Egyptian pound per gross water supplied in m^3 computed from the estimated irrigated area, obtainable yield and from the seasonal price of the main product and bi-product as shown in the following formula: EWP = Gl/ GIWR (Araya *et al.,* 2011)

Where, Gl is gross income from the sale of grains (Egyptian pound); GIWR is gross irrigation water requirement (m^3).

Portions of grains and straw at maturity in both seasons were dried at 70°C to a uniform moisture level, ground and then wet-digested as described by Chapman and Pratt (1978). The digested aliquot was analyzed for nitrogen by microkjeldahl apparatus, phosphorus by ascorbic acid method and potassium by flame-photometer as described by Cottenie et al. (1982).

The obtained data from this study were statistically analyzed through analysis of variance (ANOVA) and least significant difference (LSD) at 0.05 probability level to make comparisons among treatment means according to Gomez and Gomez (1984).

Results and Discussion

Effect of supplemental irrigation and fertilization on soil properties: Data of bulk density, porosity, hydraulic conductivity and soil moisture constant (FC, WP and AW) are shown in tables (4a, b, c and d). The values of bulk density decreased in contrary to porosity and hydraulic conductivity which increased by applying organic fertilizer, whether under rain or rain + supplemental irrigation (T3 and T6), compared to the other treatments. Similar results were obtained by Abou-Baker (2008), who reported that application of compost decreased soil bulk density (BD) and increased total porosity, water holding pores, subsequently increased field capacity and available water.

Soil moisture constants (FC, WP and AW) increased under treatments of rain+ organic fertilizer (T3 treatment) and rain + SI with organic fertilizer (T6 treatment) in case of 0-30 and 30-60 cm depths, while the deepest one was not affected.

Irrigation schedule: Data of the two years in Table (5) showed that the calculated (average data of 10 years) water requirement for wheat crop along the growth season reaches 410.4 mm. The values obtained are distributed along the crop season (November -May) according to the different wheat growth stages. The amount of water received by plant from rainfall reached 104.7 and 110.4 mm for the two seasons, respectively. Rainfall was distributed all-over the growing season with the exception of March and April in the first and second seasons. Supplemental irrigation was conducted, which represents 377.2 and 384.9mm for first and second seasons, respectively. The total actual amount of water applied to the wheat crop all-over the first growing season ranged between 104.7 to 377.2mm representing 25.5 and 91.9%, and ranged between 110.4 to 384.9mm representing 26.9 and 93.8% for second season of the total calculated water requirement, not including leaching fraction and irrigation efficiency for SI. The data presented that the full application treatment almost does not reach the water requirement of wheat crop.

Yield of wheat crop: The yield of grain, straw and biological yield, are presented in Table (6). These parameters increased significantly with supplemental irrigation (SI) treatments compared to rainfed, and also increased significantly by the addition of OM followed by NPK fertilizers in both seasons. Thereby, the effect of interaction of irrigation and fertilizer application showed that OM with rain+SI increased the wheat grain, straw and biological yield followed by NPK with rain+SI compared to the other treatments in the two seasons. Also, OM with rain+SI had the same effect of NPK with rain+SI on grain, straw and biological yield, which they represented 2, 1.6 and 1.7 fold compared with rain treatments, in the two seasons respectively. The superiority of grain yield under SI in both seasons may be due to the effect of water on encouraging cell division, elongation and turgidity which in turn increase dry matter (Karrou and Oweis, 2012; Attia and Barsoum 2013). With the increasing of N fertilizer application, the wheat yield was increased (Kumar *et al.,* 1995; Sun *et al.,* 2013 ; Salem *et al.,* 2003).

Table (4): Effect of treatments application on soil properties (Bulk density, total porosity (%), hydraulic conductivity (cm/h) and soil moisture constant

(A). Bulk density (g/cm^3)

Depth	Application treatments					
	Rain			Rain + Supplement		
	Control	NPK	OM	Control	NPK	OM
0-30	1.53	1.55	1.39	1.54	1.54	1.36
30-60	1.55	1.57	1.48	1.56	1.55	1.43
60-120	1.57	1.57	1.57	1.56	1.57	1.56

(B).Total porosity (%).

Depth	Application treatments					
	Rain			Rain + Supplement		
	Control	NPK	OM	Control	NPK	OM
0-30	42.4	41.7	47.7	42.1	42.1	48.8
30-60	41.7	40.9	44.3	41.3	41.7	46.2
60-120	40.9	40.9	40.9	41.3	40.9	41.3

(C).Hydraulic conductivity

Depth	Application treatments					
	Rain			Rain + Supplement		
	Control	NPK	OM	Control	NPK	OM
0-30	4.2	4.3	5.6	4.3	4.3	5.8
30-60	4.2	4.3	4.5	4.3	4.2	4.8
60-120	4.2	4.2	4.2	4.0	4.1	4.1

(D).Soil moisture constant.

Irrigation	Treatments	Depth (cm)	F.C (%)	W.P (%)	A.W (%)
Rain	Control(T1)	0-30	25.5	7.9	17.6
		30-60	25.7	8.0	17.7
		60-120	24.3	7.8	16.5
	NPK (T2)	0-30	25.7	7.9	17.8
		30-60	25.8	7.9	17.9
		60-120	25.0	7.7	17.3
	OM (T3)	0-30	28.9	9.5	19.4
		30-60	28.3	9.9	19.4
		60-120	25.7	7.6	18.1
Rain+supplement	Control(T4)	0-30	25.7	7.8	17.9
		30-60	25.5	7.9	17.6
		60-120	24.8	7.6	17.2
	NPK (T5)	0-30	25.5	7.9	17.6
		30-60	25.3	7.8	17.5
		60-120	25.4	7.9	17.5
	OM (T6)	0-30	30.6	10.2	20.4
		30-60	30.0	10.0	20.0
		60-120	25.4	7.9	17.5

Harvest index (HI) is defined as percentage of grains in the total plant biomass (Donaldson *et al.,* 2001). Although, harvest index increased by applying SI than rainfed, also it increased with OM than NPK, in the two seasons (Table 6). As for the interaction effect, harvest index under rain with OM and rain + supplemental irrigation at control were the same and higher than other application treatments for the two seasons. Kumar *et ai* (1994) indicated that irrigated treatments increased significantly harvest index compared with un-irrigated treatment. Also, Sushila and Giri (2000) reported that they were favorably affected by increased irrigation and nitrogen levels. **Nutrients concentrations (%) and content (kg/fed.):** In both seasons, nitrogen, phosphorus and potassium concentrations (%) and content (kg/fed.) in grain and straw increased significantly by adding SI compared with rainfed treatments (Table 7). This increase may be interpreted by: 1) more efficiency of nutrients in soil treated with SI compared with the other, 2) this water quantity is more suitable for exporting the photosynthesis products to grains resulting in more grain filling and weight as well as grain yield, 3) improving soil chemical and biological properties, 4) role of water in increasing nutrient availability (Abou-Baker, 2008). Significant effect of fertilization on nutrients concentration and content in grain and straw exists in the two seasons.

Nitrogen use by cereals is the second factor after water, which determines the level of intensification of the production. Indeed, the addition of high amounts of nitrogen in dry years and this element deficiency in wet years often cause considerable falls in cereal yields (Karrou, 1996). The lowest values were found in case of control followed by full recommended dose of mineral fertilizer. The highest values of these parameters were obtained by adding compost. Almost these findings may refer to one or more of the following reasons 1) improving soil physical, chemical and biological properties, 2) the ability of compost to conserve water, 3) the solubility effect of compost upon native and applied nutrients, 4) the biodegradation of compost produce several organic acids which are able to reduce soil pH subsequently increasing nutrients availability. 5) compost contains various balanced nutrients In practice, not only N, P and K nutrients but a combination of all the essential elements from the amendments was contributing to final yield values (Darwesh *et al.,* 2010). The interaction between irrigation and fertilization on nutrients concentration was insignificant. While, nutrients content were affected significantly with the interaction between the studied factors.

Generally, nitrogen and phosphorus concentrations in grains were higher than those in straw. In contrast, potassium concentration in grains was lower than that in straw. This could be due to the high translocation of N and P from shoot to grains because of role of N and P in grain germination after wards. The plant may follow this direction for the importance of K in germination which is less than its importance in other stages. It is known that, K plays vital role in osmotic regulations, production of high (ATP) energy and translocation of sugars (Eissa, 1996). In addition to most of quality features depend on potassium, also, plants depend upon K to regulate the opening and closing of stomata so it's concentrated in shoots. There was a slight difference of wheat yield between 2010 and 2011. However, the changes tendency was practically similar and the average for both had been tabulated.

Total nutrients content and nutrients harvest index: Total nutrients content in above ground portions (kg/fed.) and Nutrients harvest index as affected by supplemental irrigation and fertilization are shown in Table (8). Total nutrients content in above ground portions is defined as the summation of nutrients content in grains and shoots. It follows the same trend of both grain and shoots nutrient content and showed the, importance of K supply under rainfed condition where, the values of K content were higher than both of N and P content.

Nutrient harvest index was calculated as N, P or K content in grains divided on total nutrient content in above ground portions and multiplied by 100 (Sun *et al.,* 2013). Nitrogen and P harvest index (NHI and PHI) are not affected significantly by fertilization. However, the effect of SI and the interaction between the studied factors were significant in case of NHI and PHI. Potassium harvest index (KHI) is not affected significantly by any studied factors or the combination between them.

Both of NHI and PHI values increased by addition of SI compared to rainfed only. Concerning the interaction between the two factors, compost application gave the highest values of NHI and PHI under rainfed condition only, in contrast to SI, the highest values recorded by control followed by mineral fertilization and the next is the compost application. This may be due to the high mass of yield in case of compost application followed by NPK fertilization treatments under SI, consequently rising the denominator of equation and tend to decrease the net result.

Table (5) Irrigation schedule from actual rainfall and supplemental irrigation for the two years.

Month	Rain fall (mm/month)		Supplemental irrigation (mm)		Total water applied (mm)		Water requirement (mm)
	2009/ 2010	2010/ 2011	2009/ 2010	2010/ 2011	2009/ 2010	2010/ 2011	
November	27.9	10.0	-	-	27.9	10.0	12.6
December	20.5	26.3	-	-	20.5	26.3	24.8
January	25.5	47.6	33.0	10.6	58.5	58.2	60.4
February	30.8	13.5	48.9	65.9	79.7	79.4	83.7
March	-	9.0	112.6	112.5	112.6	121.5	125.8
April	-	4.0	78.0	85.5	78.0	89.5	96.3
May	-	-	-	-	-	-	6.8
Applied irrigation	104.7	110.4	272.5	274.5	377.2	384.9	410.4
% from WR	25.5	26.9	66.4	66.9	91.9	93.8	100

Table (6): Grain, straw, biological yield and harvest index (HI) as affected by supplemental irrigation and fertilization application in the two season 1st and 2nd years.

Irrigation application	Fertilizer application	Grain yield (Kg/fed)		Straw yield (kg/fed)		Biological yield (kg/fed)		HI	
		Season		Season		Season		Season	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
		Irrigation – Fertilizer application							
Rain	Control	545	559	1817	1832	2362	2391	23.1	23.4
	NPK	720	729	2120	2142	2840	2871	25.3	25.4
	OM	996	1001	2451	2462	3447	3462	28.9	28.9
Rain+Si	Control	987	997	2428	2470	3415	3467	28.9	28.8
	NPK	1115	1123	2976	2987	4091	4110	27.3	27.3
	OM	1125	1135	2997	2999	4122	4134	27.3	27.5
LSD at 5%		3.3	5.9	19.3	5.9	19.3	6.1	0.2	0.1
		Irrigation							
Rain		754	763	2129	2145	2883	2908	25.8	25.9
Rain+SI		1076	1085	2800	2819	3876	3904	27.8	27.9
LSD at 5%		7.2	3.7	8.3	2.7	2.1	1.1	0.1	0.1
		Fertilizer application							
Control		766	778	2122	2151	2888	2929	26.0	26.1
NPK		917	926	2548	2565	3465	3490	26.3	26.4
OM		1060	1068	2724	2730	3784	3798	28.1	28.2
LSD at 5%		2.3	4.2	13.8	4.1	13.7	4.3	0.1	0.1

Table (7): Nitrogen, phosphorus and potassium concentrations (%) and content (kg/fed) as affected by supplemental irrigation and fertilization applications.

(A):grain .

Irrigation treatments	Fertilizer application	Concentration (%)			Content (kg/fed)		
		N	P	K	N	P	K
		Irrigation – Fertilizer application					
Rain	Control	0.95	0.43	0.63	5.26	2.37	3.48
	NPK	1.48	0.51	0.83	10.72	3.72	5.99
	OM	1.66	0.56	0.89	16.61	5.59	8.88
Rain+SI	Control	1.17	0.46	0.70	11.61	4.56	6.94
	NPK	1.73	0.59	0.98	19.32	6.60	10.97
	OM	1.77	0.65	1.13	20.00	7.35	12.80
LSD at 5%		Ns	Ns	Ns	0.79	0.30	0.32
		Irrigation					
Rain		1.37	0.50	0.78	10.86	3.89	6.12
Rain+SI		1.56	0.57	0.94	20.00	6.17	10.24
LSD at 5%		0.09	0.01	0.04	0.83	0.11	0.43
		Fertilizer application					
Control		1.06	0.45	0.67	8.43	3.47	5.21
NPK		1.60	0.55	0.90	15.02	5.16	8.48
OM		1.72	0.61	1.01	18.31	6.47	10.84
LSD at 5%		0.06	0.02	0.03	0.56	0.21	0.23

(B): Straw.

Irrigation treatments	Fertilizer application	Concentration (%)			Content (kg/fed)		
		N	P	K	N	P	K
		Irrigation – Fertilizer application					
Rain	Control	0.60	0.30	1.33	10.89	5.53	24.32
	NPK	0.79	0.42	2.00	16.91	8.95	42.62
	OM	0.87	0.45	2.23	21.45	11.14	54.86
Rain+SI	Control	0.67	0.35	1.73	16.49	8.57	42.36
	NPK	1.06	0.46	2.40	31.70	13.72	71.55
	OM	1.29	0.51	2.56	38.58	15.39	76.75
LSD at 5%		0.10	Ns	ns	2.70	0.90	5.10
		Irrigation					
Rain		0.75	0.39	1.86	16.41	8.54	40.60
Rain+SI		1.01	0.44	2.23	28.92	12.56	63.55
LSD at 5%		0.10	0.03	0.20	2.80	0.85	3.70
		Fertilizer application					
Control		0.64	0.33	1.53	13.69	7.05	33.34
NPK		0.93	0.44	2.20	24.30	11.33	57.09
OM		1.08	0.48	2.40	30.01	13.26	65.80
LSD at 5%		0.07	0.03	0.17	1.9	0.61	3.60

Table(8): Total nutrients content in above ground portions (kg/fed) and nutrients harvest index as affected by supplemental irrigation and fertilizer application.

Irrigation treatments	Fertilizer application	Total nutrient content in above ground portions (kg/fed)			Grain nutrients harvest index (%)		
		N	P	K	N	P	K
		Irrigation – Fertilizer application					
Rain	Control	16.15	7.91	27.80	32.66	30.05	12.78
	NPK	27.63	12.67	48.61	38.80	29.38	12.32
	OM	38.06	16.73	63.74	43.63	33.42	13.94
Rain+SI	Control	28.10	13.13	49.31	41.30	34.76	14.10
	NPK	51.02	20.32	82.51	37.97	32.52	13.30
	OM	58.58	22.73	89.56	34.15	32.31	14.30
LSD at 5%		2.90	0.91	5.00	3.00	2.67	Ns
		Irrigation					
Rain		27.28	12.44	46.72	37.81	30.95	13.01
Rain+SI		45.90	18.73	73.79	38.36	33.20	13.90
LSD at 5%		3.50	0.85	3.80	0.54	1.96	Ns
		Fertilizer application					
Control		22.12	10.52	38.55	36.98	32.41	13.44
NPK		39.32	16.49	65.56	38.39	30.95	12.81
OM		48.32	19.73	76.65	38.89	32.87	14.12
LSD at 5%		2.00	0.64	3.50	Ns	Ns	Ns

Water use efficiency (WUE): Optimizing water is a major challenge for improving crop productivity and maximizing water use efficiency. The WUE is defined as biomass accumulation, i.e. grains, or biological yield, divided on irrigation water applied and it is considered one of the parameters used to evaluate the performance of agricultural production systems. Figures (1 and 2) illustrated the values of WUE which were calculated using grain and biological yield. It was noticed that values of WUE were greater at rainfed and decreased by SI. Sezen *et al.* (2006) concluded that WUE values decreased with increasing irrigation interval. Hassanli *et al.* (2010) reported that WUE can be increased by improving irrigation technology, irrigation scheduling and agronomic practices which led to yield increase.

Higher WUE was recorded in case of compost addition followed by mineral fertilization and then the control. Values of WUE calculated by grain yield were 1.24 and 1.21 for rain treatment, 1.64 and 1.58 for rain+NPK, 2.26 and 2.16 for rain + OM, 0.62 and 0.61 for SI, 0.71 and 0.69 for SI + NPK and 0.71 and 0.70 for SI+OM in first and second season, respectively. Generally, under rainfed condition, application of compost led to better water usage and less water losses. Fan *et al.* (2005) suggested that addition of organic materials could increase water holding capacity and, in return, improves water availability to plants and prevents grain yield declines, and sustains productivity.

One cubic meter of water produces from 0.61 to 2.26 kg wheat grains, which is higher than that recorded by Zwart and Bastiaanssen (2004) who reported that globally measured average crop water productivity value per unit water depletion is 1.09 kg m^{-3} and the range is very large (0.6-1.7kgm^{-3}) for wheat grains. This may be refer to the progress in wheat cultivars, fertilization, soil water and plant management from 2004 till now or due to using compost.

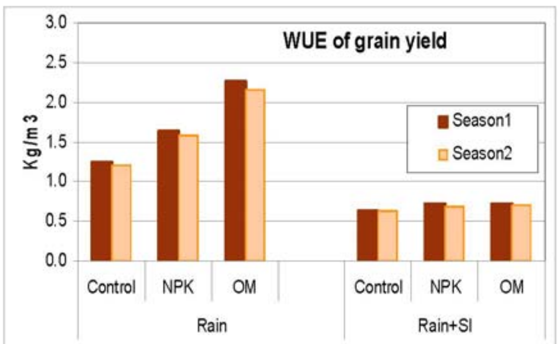

Figure (1): Water use efficiency calculated by grain yield (Kg) in the first and second seasons as related to rain or rain+SI (m^3) that affected by fertilizer application.

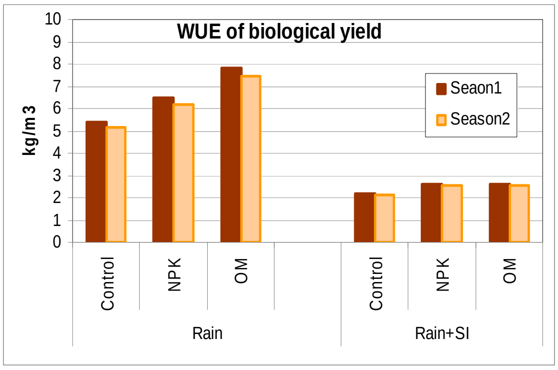

Figure (2): Water use efficiency calculated by biological yield (kg) in the first and second seasons as related to rain or rain+SI (m^3) that affected by fertilizer application.

Economic water productivity (EWP): Figure (3) depicted the economic water productivity calculated by gross income from grain yield (Egyptian pound) in the first and second seasons as related to gross irrigation water requirement (m) (the price in June 2011). Increase in crop production per unit of water does not necessarily result into an increase in the farmer's income because of the non-linearity of crop yield with the price of products. The figure showed that OM was preserved more moisture than NPK treatments or control, which the wheat plant absorbed more water and by turn improved the growth and yield, while the same unit of water let the grain under NPK treatment followed that of the OM especially in the second season. EWP was higher when irrigated with rain than rain-SI treatment and this trend was identical to those of WUF. Araya *et al.* (2011) mentioned that evaluation of crops based on their water productivity would improve the productivity of irrigation schemes and ultimately improve food security in the arid and semi-arid areas where water scarcity is critical problem and irrigation is a necessity for crop production.

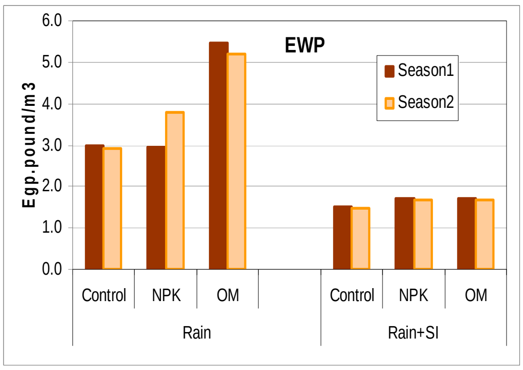

Figure (3): Economic water productivity calculated by gross income from the price of grain yield (Egyptian pound) in the first and second seasons as related to gross irrigation water requirement (m^3).

Conclusion

It is hoped this study could laid the optimum regulation manner for wheat production under dryland condition. Most of measured parameters increased with adding supplemental irrigation more than rain treatment and increased with adding organic matter (compost) followed by NPK fertilization then the control. Generally, the integrated treatment for wheat grain production is the combination between supplemental irrigation and compost application under rainfed areas of Egypt.

References

Abderrazzak, B.; Daoui, K.; Kajji, A.; Dahan, R. and Ibriz, M. 2013. Effects of supplemental irrigation and nitrogen applied on yield and yield components of bread wheat at the Sa'is region of Morocco. American J. Exper. Agric, 3(4): 904-913.

Abou-Baker, N.H. 2008. Effect of organic fertilization on reducing pollution and rationalization of irrigation water in Egypt and Libya. Ph.D. Thesis. Institute of African Researches and Studies, Cairo University Egypt.

Allen, R.G.; Pereira, L.S.; Raes, D. and Smith, M. 1998. Crop evapotranspiration guidelines for computing crop water requirements. Irrigation and drainage, FAO, Rome, Italy. 56 P. 300.

Araya, A.; Solomon, H.; Mitiku, H.; Sisay, F. and Tadesse, D. 2011. Determination of local barley *(Hordeum Vulgare)* crop coefficient and comparative assessment of water productivity for crops grown under the present pond water in Tigray, Northern Ethiopia. CNCS, Mekelle University, 3(1): 65-79.

Atria, M.A. and Barsoum, M.S. 2013. Effect of supplementary irrigation and bio-fertilization on wheat yield productivity under rainfed conditions. Alexanderia J. Agric. Res., 58(2): 149-157.

Behera, S.K. and Panda, R.K. 2009. Effect of fertilization and irrigation schedule on water and fertilizer solute transport for wheat crop in a sub-humid sub-tropical region. Agric. Ecosys. Environ., 130: 141-155.

Chapman, H.D. and Pratt, P.F. 1978. Methods of analysis for soils, plants and waters. 50, California Univ. Div. Agriculture Science Priced Publication 4034.

Costa, R.C.L; Lobato, A.K.S.; Oliveira Neto, C.F.; Maia, P.S.P.; Alves, G.R.A. and Laughinghouse, H.D. 2008. Biochemecal and physiological responses in 2 *(Vigna unguiculata* L) walp.

cultivars under water stress. J. Agron., 7(1): 98-101.

Cottenie, A.; Verio, M.; Kiekeus, L; Velghe, G. and Camerlynck, R. 1982. Chemical analysis of plants and soils. Laboratory of analytical and agrochemistry state Univ., Ghent-Belgium.

Darwesh, M.A.; Abou-Baker, N.H. and El-Ashry, S. 2010. Impact of compost, mineral fertilization and irrigation regime on wheat and sequenced zea maize plants. Minufiya J. Agric. Res., 35(6): 2245-2262.

Donaldson, E.; Schillinger, W.F. and Dofing, S.M. 2001. Straw Production and Grain Yield Relationships in Winter Wheat. Crop Sci., 41: 100-106.

Eissa, N.M. 1996. Studies on sustainable agriculture for some vegetable crops using animal manure. M.Sc. Thesis Inst. Environ. Studies and Res. Ain Shams Univ., Egypt.

Fan, T.; Stewart, B.A.; Payne, W.A.; Yong, W.; Luo, J. and Gao, Y. 2005. Long-term fertilizer and water availability effects on cereal yield and soil chemical properties in Northwest China. Soil Sci. Soci. American J., 69: 842-855.

FAO, 1992. Waste water treatments and use in agriculture. Irrigation and drainage paper 47: 125.

FAO, 2002. Water and fertilizer use in selected countries. Food and Agriculture Organization of the United Nations, Rome, 79.

FAO, 2008. Climate change, water and food security. Technical background document from expert consultation held. FAO, Rome.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for agricultural research. 2n ed., Jon Willey and Sons Inc. New York, U.S.A.

Gonzalez-Dugo, V.; Durand, J.L and Gasta F. 2010. Water deficit and nitrogen nutrition of crops. A review. Agron. Sustain. Dev., 30: 529-544.

Hassanli, A.M.; Ahmadirad, S. and Beecham, S. 2010. Evaluation of the influence of irrigation methods and water quality on sugar beet yield and water use efficiency. Agric. Water Manage., 97:357-362.

Karrou, M. 1996. Variation genotypique de I'efficience d'utilisation de I'azote chez le ble tendre. Al Awamia 95: 39-51. French (In: Abderrazzak et al., 2013).

Karrou, M. and Oweis, T. 2012 Water and land productivities of wheat and food legumes with deficit supplemental irrigation in a Mediterranean environment. Agric. Water Manage., 107: 94-103.

Klute, A. 1986. Methods of soil analysis: Part I: Physical and mineralogical methods. 2nd ed., American Soc. Agron. Monograph No. 9, Madison, Wisconsin. U.S.A.

Kumar, A.; Sharma, D.K. and Sharma, H.C. 1994. Growth, yield and water-use efficiency of wheat as influenced by irrigation and nitrogen in sodic soils. Indian J. Agron., 39 (2): 220-224.

Kumar, A.; Sharma, D.K. and Sharma, H.C. 1995. Response of wheat (*Triticum aestivum* L.) to irrigation and nitrogen in sodic soils. Indian J. Agron., 40(1): 38-42.

Lobato, A.K.S.; Coimbra, G.K.; Neto, M.A.M.; Costa, R.C.L.; Santos Filho, B.G.; Oliveira Neto, C.F.; Pereira, B.W.F.; Alves, G.A.R.; Monteiro, B.S. and Marochio, C.A. 2009. Protective action of silicon on water relations and photosynthetic pigments in paper plants Induced to water deficit. Res. J. Biol. Sci., 4(5): 617-623.

Salem, E.M.; Ashoub, M.A.; Salem, M.O. and Hamed, M.F. 2003. Response of wheat to supplemental irrigation and fertilizer under North Western Coast of Egypt. Zagazig J. Agric. Res. 30 (4): 1343-1363.

Sezen, S.M.; Yazar, A. and Eker, S. 2006. Effect of drip irrigation regimes on yield and quality of field grown bell pepper. Agric. water manage., 81: 115-131.

Sun, M.; Gao, Z.; Yang, Z.; He, L.; Ren, A.; Ge, X.; Wen, F. and Zhao, W. 2013. Nitrogen absorption and utilization characteristics in different wheat cultivars and its regulation effect by nitrogen fertilizer under irrigated and dryland conditions. J. Food Agric. Environ., 11 (1): 598-603.

Sushila, R. and Giri, G. 2000. Influence of farmyard manure, nitrogen and biofertlizers on growth, yield attributes and yield of wheat under limited water supply. Indian J. Agron., 45(3): 590-595.

Zwart, S.J. and Bastiaanssen, W.G.M. 2004. Review of measured crop water productivity values for irrigated wheat, rice, cotton and maize. Agric. Water Manage., 69(2): 115-133.