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Integrated Management of Wheat under Dry Land Conditions

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ABSTRACT

Under arid and semi-arid conditions, increasing wheat (*Triticum aestivum* L.) productivity by using less water is a great challenge of the agricultural sector. A field experiment was conducted in Om-Elrakham, Marsa Matrouh Governorate, Egypt during winter season 2016-2017 and repeated in 2017-2018 to examine the effect of various farming practices on wheat production under dryland condition. The treatments were 1) supplemental irrigation treatments (rainfed, 60% of water requirement (SI_1) and full requirement (SI_2)), 2) two hydrogel applications (with hydrogel (H) and without hydrogel (H_0) addition) and 3) three fertilization treatments (control (F_0), traditional mineral fertilizers (TF) and slow release fertilizer (SRF) application) on wheat production. The obtained results indicated that wheat production increased gradually with applied supplemental irrigation in the following order: $SI_2 > SI_1 >$ rainfed. Hydrogel treatment led to an increase in wheat grain yield by 19.1, 14.8 and 9.4% under rainfed, SI_1 and SI_2, respectively compared with H_0 treatment. Generally, the addition of hydrogel enhanced the studied soil physical properties. Slow release fertilizer superior to traditional fertilizers that enhanced wheat yield compared with control (F_0). Although increasing applied water led to decrease IWUE, the addition of hydrogel and slow-release fertilizer raised both of irrigation water use efficiency (IWUE) and economic water productivity (EWP). Interestingly, the interaction SI_1xHxSRF (1274.5 and 1276.0 kg/fed.) produced higher grain yield than SI_2x H_0x F_0 (928.0 and 995.1 kg/fed.) and SI_2x H_0xTF (1207.0 and 1206.7 kg/fed) in the first and second season, respectively. Thus, it can reserve about 40% of added water by using hydrogel and slow release fertilizers with SI_1 (60% of water requirements) under the studied soil conditions. It can address the challenges of wheat production under dryland conditions by the integration between supplemental irrigation, hydrogel, and slow-release fertilizers.

Keywords: Dryland; supplemental irrigation; hydrogel; fertilization; wheat

INTRODUCTION

Dryland regions are characterized by high temperatures, low rainfall, high evapotranspiration and poor soils in fertility, chemical, biological and hydro-physical properties. Drought is one of the most important factors that reduces wheat production, thus its grain yield is highly positively affected by supplemental irrigation (Al-Ghzawi *et al*., 2018). The combination between supplemental irrigation and fertilization is a promising management of wheat under rainfed condition in a semi-arid region (Tadayon *et al*., 2012). Climatic change in coastal zone of Egypt (with 500 km long and 20 km width) would increase drought with high fluctuation in precipitation (FAO, 2008).

The precipitation at the coastal zone is highly changeable and less than water consumption of wheat, so supplemental irrigation could be obvious way for improve wheat yield in these regions, which suffering from drought, and lack of fresh water especially under climatic change and rainfall scarcity (Abderrazzak *et al*., 2013 and Attia and Barsoum 2013). Supplemental irrigation decreases damage caused by drought conditions (Ali *et al*., 2019). Wheat growth gradually increased by I2 treatment (two supplemental irrigations) which was superior to I1 treatment (one supplemental irrigation) and rainfed (Singh *et al*., 2017).

Hydrogel is water absorbing material. Agricultural-hydrogel is used to as water retention particles that swell many times higher than their original size once come in contact with irrigation water. It has been using to mitigate drought stress on plant (Neethu *et al*., 2018). Hydrogel was effective for increasing maize yield, its nutrient concentration, content, and both of water and nutrients use efficiency more than control (Ibrahim *et al*., 2015). Application of hydrogel at rate of 3.75 kg ha-1 enhanced the soil porosity (Kumar *et al*., 2018).

Although tradition mineral fertilizers play a very important role in increasing soil fertility and productivity, they are too costly to be used in large quantities under rainfed condition. Many efforts have been devoted to reducing chemical fertilizers use and replace it by slow-release fertilizers (agriglass) to be environmental friendly solution without affecting productivity (Ouis *et al*., 2018 and Abou-Baker *et al*., 2018). There are different kinds of slow-release fertilizers based on its composition (Chandra *et al*., 2009). Addition of the slow release fertilizer enhanced maize yield more than traditional mineral fertilizer (Abou-Baker *et al*., 2018). Hassanein *et al*. (2013) reported that application of 90 kg N/fed. using Enciabien as a slow-release N fertilizer led to raises in plant height, number of spikes/m2, weight of spikes/m2 grain, straw and biological yield (ton/fed.) and harvest index in comparison to 120 kg N/fed and control (without N addition).

Therefore, the aim of this study is evaluating different agricultural practices (rainfed or supplemental irrigation, hydrogel and slow release fertilizers application) on wheat (*Triticum aestivum* L.) production under dryland conditions.

MATERIALS AND METHODS

A field experiment was established at Om-Elrakham in Marsa Matrouh Governorate, Egypt (Latitude: 31° 24' 46.39" and Longitude: 27° 00' 27.46") during 2016-2017 and repeated in 2017-2018. The experiments were subjected to three factors; 1) supplemental irrigation treatments (rainfed, rainfed + supplemental irrigation to reach to 60% of water requirement (SI1) and rainfed + supplemental irrigation to reach to full requirement (SI2)), 2) two hydrogel applications (with (H) and without hydrogel (H0) addition) and 3) three fertilization treatments (control (F0), traditional mineral fertilizers (TF) and slow release fertilizer (SRF) application) as integrated management of wheat productivity under dry land conditions. Wheat cultivar (Sakha-8) was supplied by the Agriculture Research Center, Ministry of Agriculture. Grains were sowed on November 15th and harvested on 5 May.

The experimental design was split-split plot in three replicates, and the plot area was (5m x 5 m) each, with an alley of 1m between hydrogel and fertilization plots and 2 m between the main plots (irrigation). Soil samples were collected at the depths of 0-10, 10-20, 20-30 and 30-40 cm from soil surface. The physical properties such as (bulk density, total porosity, hydraulic conductivity, soil moisture constant and pF curve) were determined at the end of two seasons in hydrogel treatments under rainfed conditions according to Klute (1986).

Some physical and chemical properties of initial soil were analyzed as described by Page *et al.* (1982) and Klute (1986) as shown in Table (1).

Straw-based hydrogel, free of acrylamide was used as an environmentally friendly product at rate of 60kg/fed. The slow release fertilizer is a mixture between agriglass (55 % P_2O_5, 30% K_2O, 5% Fe_2O_3, 5% CuO) at rate of 80kg/fed. as a source of phosphorus and potassium and Enciabien (40 % N) at rate of 100kg/fed. as a source of nitrogen. Mineral fertilization was carried out just for TF treatment according to Ministry of Agriculture recommendations. Ammonium sulphate (20.6% N) was added at a rate of 120kg N /fed. in two equal portions; before cultivation, after six weeks from cultivation. 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.

Water requirements (WR) were calculated according to the 10 years average of meteorological parameters using CROPWAT computer model (FAO 1992). Penman Monteith' equation and the KC values presented in the program and illustrated in FAO-56 (Allen *et al.* 1998). Meteorological data obtained from Central Laboratory for Agriculture Climate and showed 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 . ET0 according to FAO-56 (Allen *et al.* 1998)

Where;

ETc = crop evapotranspiration in mm/day.
ET0 = potential evapotranspiration in mm/day.
KC = crop coefficient.

Table 1. Some physical and chemical characteristics of the investigated soil.

Characteristics	Depths		
	0-30 cm	**30-60 cm**	**60-100 cm**
pH (1: 2.5 soil: water ratio)	7.98	8.05	8.17
EC (Soil paste extraction) dSm^{-1}	3.5	4.2	4.6
Organic matter	0.28	0.2	0.11
Calcium carbonate	26.7	28.9	32.4
Soluble cations (meq/L):			
Calcium	8.5	7.8	8.0
Magnesium	5.7	4.7	5.5
Potassium	0.4	0.3	0.2
Sodium	20.4	29.2	32.3
Soluble anions (meq/L):			
Bicarbonate	1.4	1.6	1.8
Chloride	28.0	36.1	41.8
Sulphate	5.6	4.3	2.4
Physical properties (%):			
Coarse sand	32.1	34.5	39.4
Fine sand	36.7	39.6	41.2
Silt	19.9	17.3	14.4
Clay	11.3	8.6	5.0
Texture	Loamy sand	Loamy sand	Loamy sand
F.C	27.5	26.2	21.4
W.P	9.2	8.4	8.2

Table 2. Meteorological data of Marsa Matrouh area (2005- 2015)

Month characters	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Precipitation (mm)	31.0	13.0	11.0	4.0	3.0	0	0	0	3.0	16.0	25.0	33.0	139.0
Tem. Average (°C)	12.9	13.7	15.1	17.5	20.4	23.5	25.7	25.9	24.5	22.0	18.9	14.7	19.5
Tem. mean max. (°C)	18.3	19.0	20.4	23.0	25.8	27.5	29.4	30.1	28.5	27.2	23.5	19.3	24.3
Tem. mean min. (°C)	8.1	8.4	9.8	12.0	14.9	18.3	20.5	21.6	19.4	16.3	13.4	10.2	14.4
Tem. mean day (°C)	14.7	15.3	16.5	19.3	22.2	24.5	26.8	26.4	25.3	23.5	20.0	16.8	20.9
Tem. mean night (°C)	11.2	11.9	13.0	15.0	17.8	21.0	22.3	23.5	22.4	19.0	15.4	12.0	17.0
Vapor pressure (mb)	9.3	9.2	10.3	12.0	15.8	20.4	23.7	23.9	20.2	17.5	14.3	10.2	15.6
Relative humidity %	68	66	67	68	71	76	77	75	72	70	71	67	70.7
Wind speed 2m (m/sec.)	4.3	4. 5	4.4	4.1	3.5	3.6	3.8	3.5	3.3	3.2	3.4	4.7	3.5
Sunshine %	63	66	65	70	80	83	87	90	83	77	78	65	75.6
Total radiation	235	319	425	520	566	585	588	550	460	342	240	233	421.9
ET_0 mm day^{-1}	2.2	2.7	3.8	4.9	5.4	5.7	5.9	5.6	5.0	3.9	3.0	2.3	4.2

Table 3. Monthly crop evapotranspiration (ET_0) of wheat plants

Growing months	ET_0 (mm/day)	Kc	ETc (mm/day)
Nov.	3.0	0.30	0.9
Dec.	2.3	0.35	0.8
Jan.	2.2	0.89	1.95
Feb.	2.7	1.15	3. 1
March	3.8	1.13	4.29
April	4.9	0.67	3.28
May	5.4	0.32	1.72

The yield parameters like grain, straw and biological yield were recorded. 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-photometerically as described by Cottenie *et al.* (1982). Macronutrient content (kg/fed.) of grains and straw was calculated in both seasons. Irrigation water use efficiency IWUE and economic water productivity EWP, in the both seasons were calculated as follows:

Irrigation Water use efficiency (IWUE kg/m^3) was calculated using the following formula:

IWUE = Grain yield (kg/fed.)/total irrigation water applied (m^3/fed.)

Economic water productivity (EWP) was computed as shown in following formula: EWP = The income from economic part (Egyptian pound/fed.)/total irrigation water applied (m^3/fed.) as calculated by Abou-Baker *et al.* (2012).

The results were statistically analyzed through analysis of variance (ANOVA) and least significant difference ($LSD_{0.05}$) to compare among treatments' means according to Gomez and Gomez (1984).

RESULTS

1. Hydro-physical properties

The bulk density, total porosity, hydraulic conductivity and pore size distribution are important measurements for the physical arrangement of solids, which used to evaluate the performance of hydrological properties of soils under dryland conditions. The physical properties were determined at the end of the two seasons in different depths of hydrogel-treated soil under rainfed condition irrespective of supplemental irrigation and fertilization treatments.

Bulk density

There is no doubt that soil bulk density is a major product of the changes in the soil and field conditions. It is affected by variations in soil texture, structure, soluble salts and exchangeable sodium percentage. Soil bulk density is the ratio between the mass and the total volume of dry soil gm/cm^3. Data in Table (4) showed that the values of soil bulk density (g/cm^3) of the treated hydrogel treatments. The results revealed that using hydrogel led to a decrease of soil bulk density by 6.04, 5.00% compared with no hydrogel addition. Bulk density of the second layer (10-20 cm) and third layer (20-30 cm) decreased by 5.04 and 5.36%, respectively compared with no hydrogel addition.

Total porosity

The results presented in Table (4) showed that the total porosity follows an opposite trend of bulk density and markedly increased with hydrogel application compared with H_0 treatments (Table 4). Total porosity was higher in the soil layers 0-10 cm, 0-20 cm and 0-30 cm compared with the deepest one.

The increase percentages were 9.6, 6.7 and 8.7% in the first, second and third soil layer, respectively compared with H_0.

Hydraulic conductivity

Hydraulic conductivity (cm/h) is an important factor for planning and design projects of land reclamation especially for irrigation and a measure of its ability to transmit water. The results presented in (Table 4) revealed that using hydrogel led to a decrease in hydraulic conductivity by 26.4, 26.6 and 17.3% in the first, second and third soil layer, respectively compared with no hydrogel treatment.

Table 4. Soil bulk density, total porosity and hydraulic conductivity as affected by hydrogel treatments

Depth (cm)	Bulk density		Total porosity %		hydraulic conductivity cm/h	
	H_0	H	H_0	H	H_0	H
0-10	1.49	1.38	43.7	47.9	5.3	3.9
10-20	1.47	1.39	44.5	47.5	5.2	3.6
20-30	1.50	1.41	43.3	47.1	4.6	3.8
30-40	1.52	1.47	42.6	44.5	3.8	3.8
40-100	1.53	1.53	42.2	42.2	3.8	3.8

Retained moisture percentages

The Soil moisture retention percentages mainly depends on some soil properties as texture, structure, soluble salts content and exchangeable cations. The investigated soil layers show a slightly decrease in moisture released with depth under different applied tensions (Table 5). There is an increase in the moisture retention percentages with hydrogel application especially in the first (0-10 cm), second (10-20 cm) and third layers (20-30 cm) compared with deepest one.

Table 5. Retained moisture percentage (per volume) in soil profile under different tensions and different treatments.

Hydrogel Treatments	Depth (cm)	Different tensions (atm.)						
		0.001	0.1	0.33	0.66	1.0	5.0	15.0
H_0	0-10	42.7	28.4	26.0	23.3	21.5	15.6	10.2
	10-20	42.7	29.5	26.7	23.6	20.6	14.5	10.4
	20-30	40.9	29.6	25.2	22.3	18.2	12.8	10.0
	30-40	38.2	26.6	23.4	20.0	17.5	12.0	9.2
	40-100	38.5	26.2	22.7	18.6	16.0	11.3	8.2
H	0-10	43.7	33.9	30.9	27.4	23.5	19.0	11.6
	10-20	44.2	34.0	31.2	27.9	23.8	19.4	11.9
	20-30	44.8	33.8	30.5	27.2	23.0	18.2	11.5
	30-40	38.2	26.7	24.0	21.9	18.6	15.3	10.1
	40-100	38.5	26.2	23.0	18.6	16.0	11.3	8.2

Moisture content, field capacity, wilting point and available water

The amount of water hold in the soil after irrigation and drainage of the excess gravitational water is referred to the field capacity (F.C). Field capacity and wilting point (W.P) are the extremes of available soil moisture (A.W). The available water capacity is the difference between field capacity (0.1atm) and wilting point (15atm). Results in Table (6) showed that F.C, W.P and A.W values were increased with adding hydrogel compared with H0. The increase percentages of F.C, W.P and AW were 19.4, 13.7 and 22.5% for first layer, 15.3, 14.4 and 15.7% for second layers and 14.2, 15.0 and 13.8% for third layer, respectively.

Pore size distribution

The changes in pore size distribution due to hydrogel treatments are identical in the studied area. From the data in Table (6), values of quickly drainable pores (Q.D.P.) are higher in hydrogel treatments in the layers (0-10), (0-20) and (0-30) compared with no hydrogel treatments. Values of slowly drainable pores (S.D.P.) under investigation were very small. Variations in water holding pores (8.62 – 0.19µ) values between hydrogel-treated soil and control are very clear.

Table 6. Field capacity (F.C), wilting point (W.P) and pore size distribution (µ) in soil profile under different tensions and different hydrogel treatments.

Hydrogel Treatments	Depth (cm)	Water constant			Pore size distribution (µ)			
		F.C.	W.P	A.W.	Q.D.P. >30µ	S.D.P. (9-30µ)	W.H.P. (9-0.2µ)	F.C.P. <0.2µ
H_0	0-10	28.4	10.2	18.2	14.3	2.4	15.8	10.2
	10-20	29.5	10.4	19.1	13.2	2.8	16.3	10.4
	20-30	29.6	10.0	19.6	11.3	4.4	15.2	10.0
	30-40	26.6	9.2	17.4	11.7	3.2	14.2	9.2
	40-100	26.2	8.2	18.0	12.3	3.5	14.5	8.2
H	0-10	33.9	11.6	22.3	9.8	3.0	19.6	11.6
	10-20	34.0	11.9	22.1	10.2	2.8	19.3	11.9
	20-30	33.8	11.5	22.3	11.0	3.3	19.0	11.5
	30-40	26.7	10.1	17.2	11.5	2.7	13.9	10.1
	40-100	26.2	8.2	18.0	12.3	3.3	14.2	8.2

2. Rainfall characteristics

Rainfed agriculture areas in Egypt are characterized as a fragile desert ecosystem that depends mainly on rainfall as a source of water. Rainfall analysis and characteristics are of great importance in this context. Table (2) shows the average of meteorological data through ten years. Rainfall starts from the second half of October and ends in March where 92.1% of the rains falls during the period from late

November until middle February, 46.0% of rainfall occur during December and January, whereas March receives about 7.9 % of the annual quantity of rain. Dry season extends from April until September.

3. Evapotranspiration (ET_0)

Comparing the monthly values of both rainfall and evapotranspiration revealed that, there is a reduction in water quantity needed for different growth stages of wheat plants through mid of November to mid of May. Also, in this period, rainfall is 139.0mm (583.8m^3/fed.) while evapotranspiration is 617mm (Table 2).

4. Critical periods of rainfall

Table (7) shows average rainfall data for every ten days through the month for ten years from 2005 to 2015. It is obvious that 46% of annual rain (64 mm) fall in both of December and January. Also 27.3% (38.0 mm) fall during November and February. About 26.8% fall in the rest of rainy season.

Wheat planting starts in 15 November and harvested in 5 may. It is observed during critical growth stages of wheat that: 22.3% of annual rainfall drops in January, but only 3.5% drops in the critical growth stage (from 20 to 30 January), on the other hand, 1.4% of annual rainfall drops from 20 to 28 February. While 3.5% of annual rainfall drops from 10 to 31 March. It is also found that, 2.8% of annual rainfall drops through April totally until the harvest. So, supplemental irrigation is important to supply crop water requirements during the critical growth stages of wheat.

5. Soil moisture content

Variation of soil moisture content with time following rainfall events was evident within the first 10 cm of soil depth. Figure (1 a and b) can be classified into three main parts. First portion, that observed during about the first 60 days of recording, values of soil moisture content was gradually increased due to the adding via rainfall process. Second part of the figure covered about the next 60 days. This period was featured with the maximum moisture content. The last portion (from 120 to 160 days after planting) is characterized by high losses of moisture content.

Table 7. Analysis of annual rainfall (average of ten years).

Month	Days	Precipitation (mm)	Precipitation (%) per month	Precipitation (%) per year	Monthly precipitation (%) per year
January	0-10	15.0	48.38	10.7	22.3
	10-20	11.0	35.48	7.9	
	20-30	5.0	16.12	3.5	
February	0-10	8.0	61.53	5.7	9.3
	10-20	3.0	23.07	2.1	
	20-30	2.0	15.38	1.4	
March	0-10	6.0	54.54	4.3	7.9
	10-20	3.0	27.27	2.1	
	20-30	2.0	18.18	1.4	
April	0-10	4.0	100	2.8	2.8
	10-20	0	-	-	
	20-30	0	-	-	
May	0-10	3.0	100	2.1	2.1
	10-20	0	-	-	
	20-30	0	-	-	
September	0-10	0	-	-	2.1
	10-20	0	-	-	
	20-30	3.0	100	2.1	
October	0-10	0	-	-	11.5
	10-20	5.0	31.25	4.0	
	20-30	11.0	68.75	7.9	
November	0-10	5.0	20.0	3.5	17.9
	10-20	12.0	48.0	8.1	
	20-30	8.0	32.0	5.7	
December	0-10	7.0	21.21	5.0	23.7
	10-20	12.0	36.36	8.6	
	20-30	14.0	42.42	10.0	

The most effective soil layer in water depletion and consequently in feeding or supplying the growing plants with water and nutrients is the upper two soil layers of 20 cm. On the other hand, soil moisture decreased gradually by time, but never reaches wilting point.

Under 0-10 cm, 0-20 cm and 0-30 cm layers, the peaks in figure (1b) that received hydrogel were higher than that in figure (1a) that presented control treatment.

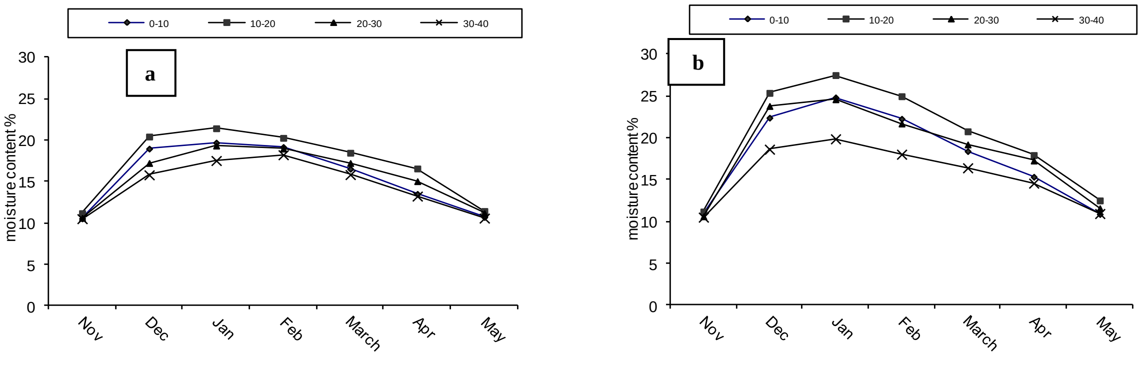

Fig. 1. Soil moisture content at different depths and time as affected by hydrogel (b) and no hydrogel (a) treatments.

Statistically, the highest values of moisture content in soil profile are associated with months of high rainfall (Table 8). Hydrogel treatments retain more moisture content compared with no hydrogel application. Accordingly, it seems that hydrogel catches some amounts of rainfall that promote plant growth. In this concern, Neethu *et al*. (2018), reported that hydrogel can absorb irrigation and rainwater and released it for crop requirements gradually.

6. Irrigation schedule

The calculated water requirement (WR) (average of 10 years) for wheat crop along the growth season reached to 424.4mm (Table 9 a and b). These obtained values are distributed along the crop season from November to May to be concomitant with the different crop growth stages. The amount of water received by the plant from rainfall represents 107.6 and 115.1mm for the two studied years, respectively. Rainfall was distributed all over the growing season with the exception in April and May in the first season and only in May in the second year. Supplemental irrigation of 60% WR (SI_1) and full irrigation were conducted (SI_2). They represent 252.82 and 244.02mm for SI_1 and 372.2 and 376.8 for SI_2 in the two growing seasons, respectively. The total actual amounts of water applied to the wheat crop all over the growing season ranged between 107.6 to 372.2mm; representing 25.35 and 87.7% from the total calculated water requirement, for the first season and ranged between 115.1 to 376.8mm; representing 27.12 and 88.78% for the second season. These amounts of water are not including leaching fraction and irrigation efficiency for supplemental irrigation. The data showed that the full supplemental irrigation treatment almost does not reach the calculated Etc values.

Table 8. Statistical analyses to detect the effect of hydrogel treatment on soil moisture content at different depths and time (season 2017-2018).

Hydrogel treatments	Depth (cm)	Time							Mean
		14 /11	20/12	18 /1	15 /2	17 /3	13 /4	2 /5	
H_0	0-10	10.53	18.97	19.70	19.17	16.53	13.50	10.70	15.59
	10-20	11.17	20.43	21.43	20.27	18.47	16.57	11.43	17.11
	20-30	10.60	17.23	19.33	18.97	17.23	15.03	11.17	15.65
	30-40	10.50	15.80	17.53	18.23	15.83	13.23	10.57	14.53
	Mean	10.70	18.11	19.50	19.16	17.02	14.58	10.97	15.72
H	0-10	10.87	22.40	24.83	22.27	18.40	15.33	10.87	17.85
	10-20	11.17	25.37	27.50	24.97	20.77	17.93	12.50	20.03
	20-30	10.60	23.80	24.60	21.70	19.20	17.27	11.57	18.39
	30-40	10.50	18.63	19.87	18.03	16.40	14.57	10.93	15.56
	Mean	10.78	22.55	24.20	21.74	18.69	16.28	11.47	17.96
Mean	0-10	10.70	20.68	22.27	20.72	17.47	14.42	10.78	16.72
	10-20	11.17	22.90	24.47	22.62	19.62	17.25	11.97	18.57
	20-30	10.60	20.52	21.97	20.33	18.22	16.15	11.37	17.02
	30-40	10.50	17.22	18.70	18.13	16.12	13.90	10.75	15.05
Mean		10.74	20.33	21.85	20.45	17.85	15.43	11.22	
$LSD_{0.05}$		H=0.11 T=0.20 D=0.15 HxT=0.28 HxD=0.22 TxD=0.40 HxTxD=0.60							

Table 9. Irrigation schedule from rainfall and supplemental irrigation for the two seasons.

(a) season 2016-2017

Month	Rainfall mm/month	60% WR mm	Full mm	W.R mm
November	16.3	-	-	13.5
December	28.5			24.8
January	32.0		20.7	60.45
February	20.2	27.32	58.0	86.8
March	10.6	65.4	98.4	132.44
April	-	52.5	87.5	98.4
May	-			8.6
Applied irrigation	107.6	145.22	264.6	424.4
Total water applied	107.6	252.82	372.2	
% from WR	25.35	59.57	87.70	

(b) season 2017- 2018

Month	Rainfall mm/month	60% WR mm	Full mm	W.R mm
November	18.5	-	-	13.5
December	26.7			24.8
January	29.8	3.6	25.9	60.45
February	16.4	31.12	62.8	86.8
March	17.2	48.2	92.0	132.44
April	6.5	46.0	81.0	98.4
May	-			8.6
Applied irrigation	115.1	128.92	261.7	424.4
Total water applied	115.1	244.02	376.8	
% from WR	27.12	57.50	88.78	

7. Grain, straw and biological yield

Statistical analysis showed that, supplemental irrigation (I), hydrogel (T) and fertilizers (F) application had significant effects on grain, straw and biological yield. Full supplemental irrigation (S12) had the highest values of wheat yield, with a significant difference compared with other irrigation treatments (Tables 10, 11 and 12). The increase percentage of grain yield resulted from adding SI_1 and SI_2 compared with rainfed were 28.3 and 45.5% for first season and 26.3 and 46.1% for second season, respectively. Addition of hydrogel (H) was better than H_0 and gave the maximum values of yield component. Wheat grain yield increased by 13.8 and 14.1% compared with control (without H application) in first and second season, respectively. Data also show that slow release fertilizers resulted in increased grain, straw and biological yield significantly followed by traditional fertilization treatments compared with control (F_0). Using the slow release fertilizers led to increment grain yield by 36.2 and 35.5% followed by traditional fertilizers application that improved grain yield by 24.2 and 23.9% in a first and second season, respectively.

Table 10. Effect of irrigation hydrogel and fertilization treatments grain yield (kg/fed.) of wheat in two different seasons.

Hydrogel treatments	Fertilization treatments	First season				Second season			
		Irrigation treatments			Mean	Irrigation treatments			Mean
		Rainfed	SI_1	SI_2		Rainfed	SI_1	SI_2	
H_0	F_0	596.7	896.1	928.0	806.9	597.2	832.7	995.1	808.3
	TF	803.2	996.7	1207.0	1002.3	811.1	994.5	1206.7	1004.0
	SRF	905.5	1123.5	1374.3	1134.4	904.6	1123.8	1373.1	1133.8
	Mean	768.5	1005.4	1169.8	981.2	771.0	983.7	1191.5	982.1
H	F_0	769.0	1004.5	1045.0	939.5	788.2	1006.3	1045.6	946.7
	TF	973.3	1185.0	1342.6	1167.0	977.2	1184.6	1347.8	1169.9
	SRF	1003.4	1274.5	1452.2	1243.4	1003.1	1276.0	1454.3	1244.5
	Mean	915.2	1154.7	1279.9	1116.6	922.8	1155.6	1282.6	1120.4
Mean	F_0	682.8	950.3	986.5	873.2	692.7	919.5	1020.3	877.5
	TF	888.3	1090.8	1274.8	1084.6	894.2	1089.6	1277.1	1087.0
	SRF	954.5	1199.0	1413.3	1188.9	953.8	1199.9	1413.7	1189.1
Mean		841.9	1080.0	1224.8		846.9	1069.7	1237.1	
$LSD_{0.05}$		I=12.9 H=10.6 F=11.3 IxH=18.3 IxF=19.6 HxF=16.0 IxHxF=27.8				I=12.8 H=9.1 F=8.7 IxH=15.7 IxF=15.0 HxF=12.3 IxHxF=21.0			

The second interactions between treatments were significant except for straw and biological yield in the first season. Irrespective of the fertilization effect, adding of hydrogel resulted in raised grain yield from 768.5 to 915.2kg grain/fed. (19.1%) under rainfed, from 1005.4 to 1154.7 kg grain /fed. (14.8%) with SI_1 application, and from 1169.8 to 1279.9kg grain /fed. (9.4%) with SI_2 addition.

The highest values were obtained by the interaction SI_2 x H x SRF, it reached to 1452.2 and 1454.3 kg/fed. for grain, 3007 and 3050 kg/fed. for straw and 4459 and 4504kg/fed. for biological yield in first and second season, respectively. These combinations among the three studied factors could multiplicate the grain yield (2.1 times) compared with rainfed x H_0 x F_0 treatment. The interaction SI_2 x H_0 x SRF lay in the second rank followed by SI_2 x H x TF and the next is SI_1 x H x SRF.

Interestingly, the interaction SI_1xHxSRF (1274.5 and 1276.0 kg/fed.) produced higher grain yield than SI_2x H_0x F_0 (928.0 and 995.1 kg/fed.) and SI_2x H_0xTF (1207.0 and 1206.7 kg/fed) in the first and second season, respectively. Thus, it can reserve about 40% of added water by using hydrogel and slow release fertilizers with SI_1 (60% of water requirements) under the studied soil conditions.

Table 11. Effect of irrigation, hydrogel and fertilization treatments straw yield (kg/fed.) of wheat in two different seasons.

Hydrogel treatments	Fertilization treatments	First season				Second season			
		Irrigation treatments			Mean	Irrigation treatments			Mean
		Rainfed	SI_1	SI_2		Rainfed	SI_1	SI_2	
H_0	F_0	2116.0	2594.3	2722.0	2477.4	2130.7	2625.3	2736.3	2497.4
	TF	2194.3	2925.0	2045.0	2388.1	2201.7	2937.0	2930.0	2689.6
	SRF	2117.0	2722.3	2879.3	2572.9	2127.0	2738.7	2893.7	2586.4
	Mean	2142.4	2747.2	2548.8	2479.5	2153.1	2767.0	2853.3	2591.1
H	F_0	2226.3	2896.7	2996.3	2706.4	2235.3	2904.3	3007.0	2715.6
	TF	2221.3	2904.7	2996.3	2707.4	2239.7	2922.7	3108.0	2756.8
	SRF	2213.3	2900.0	3007.0	2706.8	2236.0	2938.7	3050.0	2741.6
	Mean	2220.3	2900.4	2999.9	2706.9	2237.0	2921.9	3055.0	2738.0
Mean	F_0	2171.2	2745.5	2859.2	2591.9	2183.0	2764.8	2871.7	2606.5
	TF	2207.8	2914.8	2520.7	2547.8	2220.7	2929.8	3019.0	2723.2
	SRF	2165.2	2811.2	2943.2	2639.8	2181.5	2838.7	2971.8	2664.0
Mean		2181.4	2823.8	2774.3		2195.1	2844.4	2954.2	
$LSD_{0.05}$		I=333.6 H=ns F=ns IxH=ns IxF=ns HxF=ns IxHxF=ns				I=4.0 H=2.6 F=2.1 IxH=4.6 IxF=3.7 HxF=3.0 IxHxF=5.26			

Table 12. Effect of irrigation, hydrogel and fertilization treatments biological yield (kg/fed.) of wheat in two different seasons.

Hydrogel treatments	Fertilization treatments	First season				Second season			
		Irrigation treatments			Mean	Irrigation treatments			Mean
		Rainfed	SI_1	SI_2		Rainfed	SI_1	SI_2	
H_0	F_0	2712.7	3490.4	3650.0	3284.3	2727.8	3458.1	3731.4	3305.8
	TF	2997.5	3921.7	3252.0	3390.4	3012.8	3931.5	4136.5	3693.6
	SRF	3022.5	3845.8	4253.7	3707.3	3031.6	3862.4	4266.7	3720.2
	Mean	2910.9	3752.6	3718.5	3460.7	2924.1	3750.7	4044.9	3573.2
H	F_0	2995.4	3901.2	4041.3	3646.0	3023.5	3910.7	4052.6	3662.3
	TF	3194.7	4089.6	4338.9	3874.4	3216.9	4107.3	4455.8	3926.7
	SRF	3216.7	4174.5	4459.2	3950.1	3239.1	4214.7	4504.3	3986.0
	Mean	3135.6	4055.1	4279.8	3823.5	3159.8	4077.5	4337.6	3858.3
Mean	F_0	2854.0	3695.8	3845.6	3465.2	2875.7	3684.4	3892.0	3484.0
	TF	3096.1	4005.7	3795.5	3632.4	3114.9	4019.4	4296.1	3810.1
	SRF	3119.6	4010.1	4356.5	3828.7	3135.4	4038.6	4385.5	3853.1
Mean		3023.3	3903.9	3999.2		3042.0	3914.1	4191.2	
$LSD_{0.05}$		I=341.6 H=241.5 F=243.9 IxH=ns IxFns HxF=ns IxHxF=ns				I=11.3 H=11.1 F=9.0 IxH=19.3 IxF=15.6 HxF=12.7 IxHxF=22.02			

8. Macro-nutrients concentration and content in grains and straw yields

Insignificant differences were observed between the two seasons in concentration and content values of N, P and K (Figures 2 and 3). Nitrogen and phosphorus concentrations are more in grains than those in straw. The reverse was true in K, whereas its concentration is higher in straw than that in grains. The content values of N, P and K in straw are higher than those in grains.

Increasing the rate of supplemental irrigation led to raise the concentration and content of macronutrients in both grains and straw. Irrespective of fertilization and irrigation effect, application of hydrogel resulted in increased N, P and K concentration and content.

Both of traditional fertilizers and slow release fertilizers led to increase macro-nutrients concentration and content of grains and straw compared with F_0, while the SRF was the superior.

The highest values of concentration and content of macronutrient were recorded in the third interaction between the irrigation with full water requirements plus addition of both hydrogel and the used mixture of slow release fertilizers.

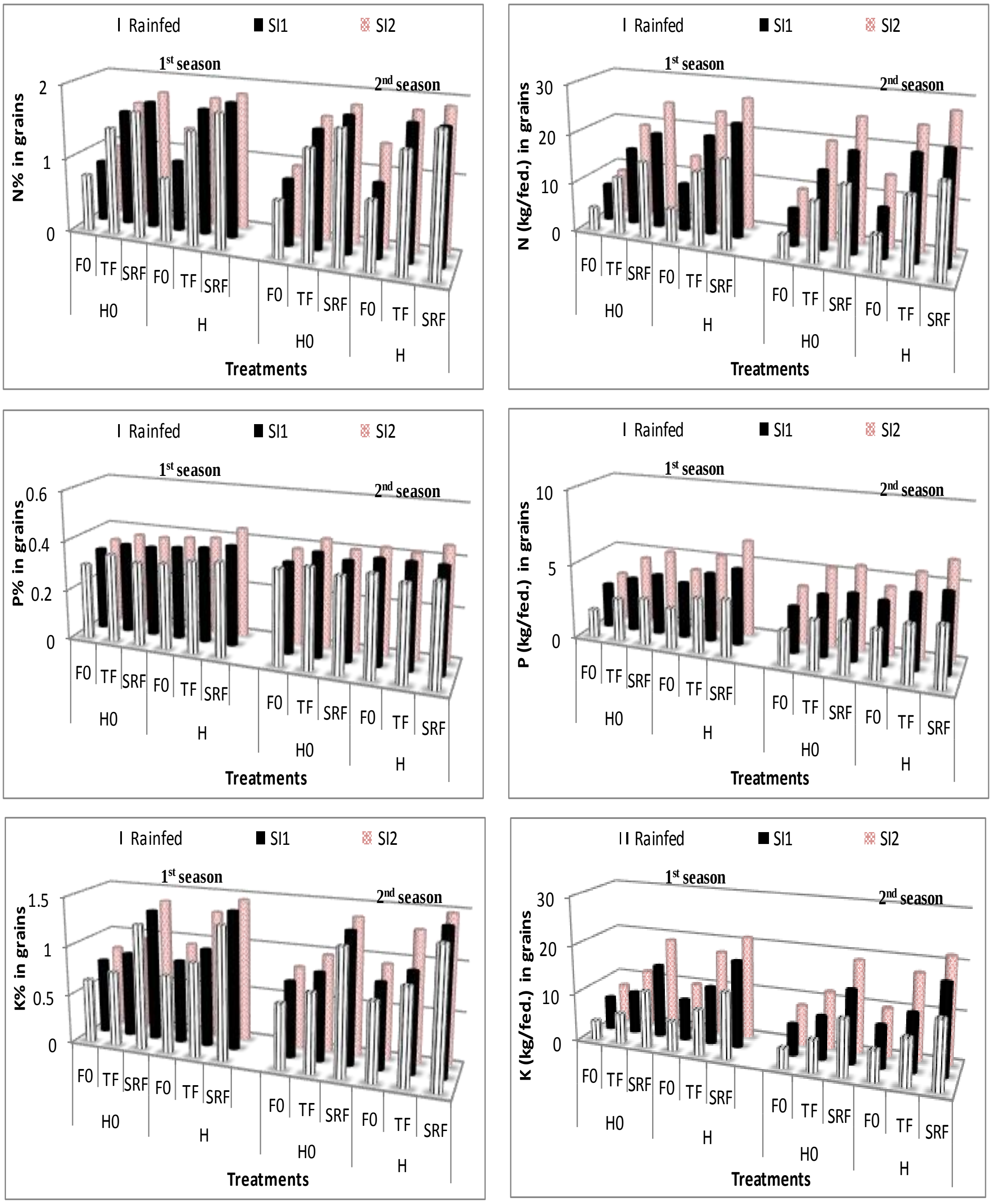

Fig. 2. Effect of irrigation, hydrogel and fertilization treatments on N, P and K concentration % and content (kg/fed.) in grains.

At the end of two seasons, the increase percentages of nitrogen content were 33.3 and 67.4% in grains, 42.4 and 63.9% in straw by adding SI_1 and SI_2 compared with rainfed, 24.0% in grains, 14.0% in straw by H application compared with H_0 and 105.9 and 146.8% in grains, 30.5 and 42.0% in straw by using TF and SRF compared with F_0, respectively. AS for phosphorus content the increase percentages were 32.7 and 61.1% in grains, 34.3 and 48.1 % in straw by adding SI_1 and SI_2 compared with rainfed, 19.5% in grains, 16.6% in straw by H application compared with H_0 and 28.6 and 39.9% in grains, 15.2 and 17.4% in straw by using TF and SRF compared with F_0, respectively. Regarding of potassium content, the increase percentages were 36.0 and 74.4% in grains, 38.0 and 49.4% in straw by adding SI_1 and SI_2 compared with rainfed, 29.2% in grains, 8.7% in straw by H application compared with H_0 and 52.5 and 129.8% in grains, 59.0 and 62.6% in straw by using TF and SRF compared with F_0, respectively.

9. Irrigation water use efficiency (IWUE) and economic water productivity (EWP)

In areas with limited water resources, where water is a limiting factor to production, IWUE and EWP are the important evaluating factors in performance of agricultural production systems. The price of wheat grain (Egyptian pound) in June 2018 was used in EWP calculation. In the two seasons, both of IWUE and EWP are gradually decreased by addition of supplemental irrigation and follow the rank: rainfed > SI$_1$ > SI$_2$ (Figures 4 and 5). Regardless of irrigation water quantity and fertilization treatments, the mean of IWUE values were increased by addition of hydrogel by 15.9 and 16.4% in the first and second season, respectively. Both of TF and SRF enhanced IWUE by 25.7 and 36.6% in the first season and 25.0 and 35.0 % in the second season, respectively. These data clear that SRF is better than TF in its effect on IWUE. The same trend was observed by EWP values.

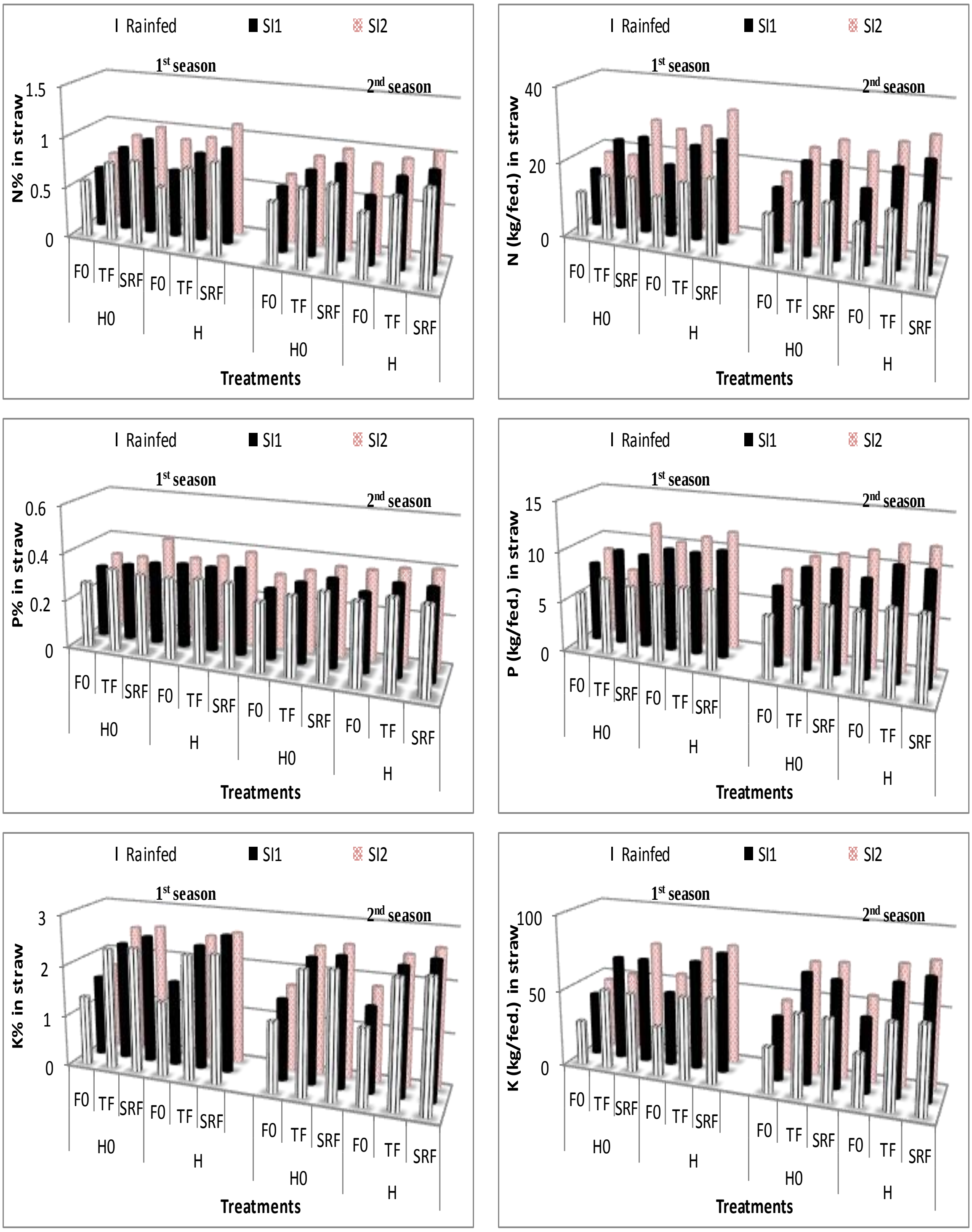

Fig. 3. Effect of irrigation, hydrogel and fertilization treatments on N, P and K concentration % and content (kg/fed.) in straw.

The interaction effects of the studied factors are on IWUE and EWP were significant. The maximum IWUE and EWP was attained by adding hydrogel with SRF under rainfed condition, but the minimum values of them were obtained by applying full irrigation without fertilization or hydrogel application.

Under rainfed condition, application of hydrogel and slow release fertilizers improved the economic water productivity of wheat grains from 5.28 to 8.88 EGP/m^3 with increasing percentage 68.2% in the first season. Few differences were observed between the two seasons.

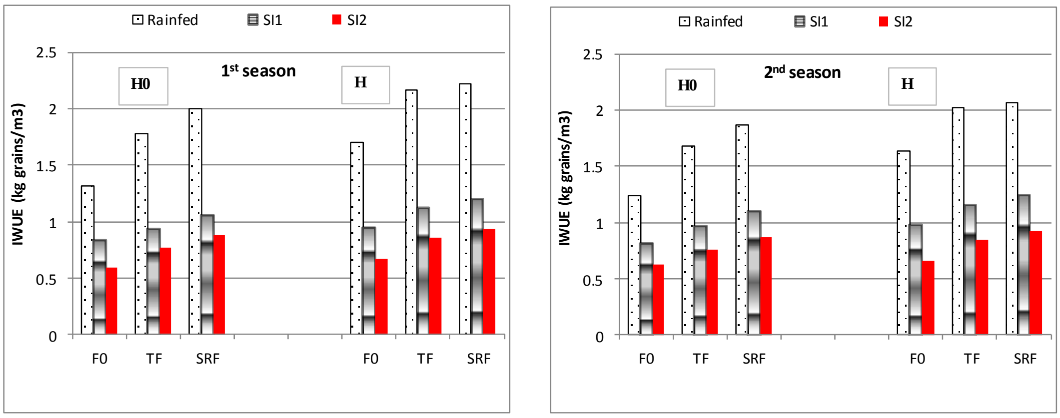

Fig. 4. Irrigation water use efficiency as affected by irrigation, hydrogel and fertilization treatments in two seasons.

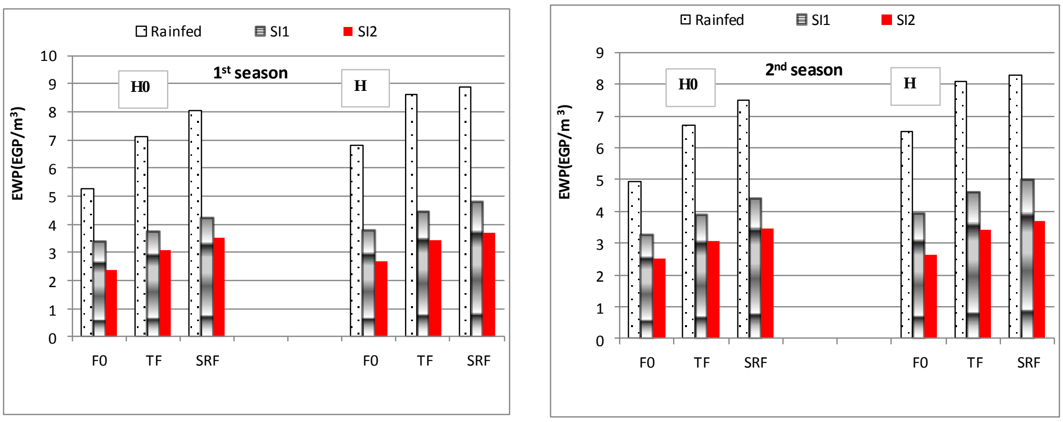

Fig. 5. Economic water productivity as affected by irrigation, hydrogel and fertilization treatments in two seasons.

DISCUSSION

Under dryland conditions using hydrogel is a promising recommendation. Hydrogel application enhanced the physical properties of sandy soil. Bulk density decreased by hydrogel addition, this may be due to the soil particles are displaced and rearranged around the swollen particles of the hydrogel. So, the soil volume increases and hence the ratio of the dry mass of the soil to its volume decreases (El-Hady *et al*., 2006).

The enhancement in total porosity with hydrogel addition may be due to the increase in the pore space between coarse sand particles re-oriented around the swollen hydrogel particles (Choudhary *et al*., 1998).

The decrease in the hydraulic conductivity values in hydrogel treated-soil may be due to the swelling of the hydrogel enhanced aggregates formation and pores distribution among soil particles that reflect on hydraulic conductivity. This result was enclosed agreement with this obtained by El-Hady and Abo-Sedera (2006), El-Hady *et al*., (2006) and Hussien *et al*. (2012).

Increasing the soil moisture content in the first and second part of Figure (1) (first 60 days and the following 2 months) may be due to 1) the young wheat plants with their small roots that characterized with less transpiration. 2) evapotranspiration ET_0 has the lower values for December and January months. While the depression is soil moisture values in the third part could be attributed to the following reasons: 1) this period represent flowering and yield formation stages thus the highest photosynthesis process that matched this period led to increasing losses by evapotranspiration, 2) rainfall was getting lower gradually. The depression in soil moisture in the third part of this figure could be due to 1) rainfall was stopped in this period, 2) high evaporation encountered with April and May months. The reasons of the pronounced variation in soil moisture content at the top 20 cm are 1) this layer is the most affected depth with the climatological elements especially for both energy and aerodynamic factors that caused the evapotranspiration, 2) This layer is the soil depth of seedbed environment. With regard to the change in moisture with time, data clearly showed that, change was related to 1) atmospheric factors especially temperature and wind speed that was differing from a month to another, 2) the growth stage and its water requirements had an effective role on the change of moisture content. The rate of increase in moisture content is associated with hydrogel application. The changes in moisture content are due to the enhancement in soil physical properties in hydrogel-treated plots compared with H_0 treatment. The productivity of wheat depends on the prevailing weather conditions and soil-moisture regime during crop-growth period (Shivani *et al*., 2001).

The analysis of annual rainfall are in accordance with those obtained by Zhang and Oweis (1999) where they mentioned that the crop yield is primarily water-limited in areas of North Africa with a Mediterranean climate through ten years of supplemental irrigation (SI) experiments which were conducted to evaluate water–yield relations for wheat and optimal irrigation scheduling was proposed for various rainfall conditions. The sensitive growth stages of wheat to water stress were from stem elongation to booting, followed by anthesis, and grain-filling. Water stress to which crop subjected depends on rainfall and its distribution during the growing season. The stress started from early March (stem-elongation stage) or even in seedling stage in a dry year, and from mid-April (anthesis) in an average or wet year.

Grain, straw and biological yield take the same trend and it can be interpreted in the same manner. Supplemental irrigation (SI) enhanced wheat yield compared to rainfed. The depression in yield under rainfed condition may be due to drought that occurred during the reproductive stage of wheat had negative effect on photosynthesis (Luo *et al*., 2011), decrease pre- and post-flowering dry matter accumulation (Qiu *et al*., 2008), thus gradually reduces winter wheat production (Ali *et al*., 2019). The superiority of wheat yield under SI could be due to the effect of water on promoting cell division, elongation and turgidity which in turn to raise dry matter yield (Karrou and Oweis, 2012 and Attia and Barsoum 2013). The increase in grain yield and yield components not only due to the positive influence of water in plant physiology, but it also attributes to water effect on nutrient availability (Ibrahim *et al*., 2015 and Al-Ghzawi *et al*., 2018). These results are closely associated with Oweis and Hachum (2001) where they found that substantial increases in rainfed crop yields in response to SI.

Irrespective of hydrogel and fertilizers amendments, both of IWUE and EWP take an opposite trend of that obtained by grain yield. Increasing the amount of total water received to soil caused a decrease in IWUE and EWP values. This inferiority may be attributed to increasing of the denominator of equation. The hydrogel resulted in preserved more moisture content than Ho treatment, thus the plant absorbed more water consequently improved growth, yield, IWUE and EWP values. The optimum use of irrigation water to gain the economic grain yield depended upon the cost of all used units of input for cultivation (Abou-Baker *et al*., 2012). In the dryland areas where irrigation water scarcity is a vital problem EWP calculation to most strategic crops could be help in selection of cultivated crops ultimately improve food security (Ibrahim *et al*., 2015). Sezen *et al*. (2006) reported that IWUE values decreased with increasing irrigation interval. Hassanli *et al*. (2010) concluded that IWUE can be increased by improving agronomic practices which led to yield increase. Generally, 1m^3 of water produces from 0.59 to 2.22 kg grains in first season and from 0.63 to 2.07 kg grains, that can be increase than that recorded by Zwart and Bastiaanssen (2004) where reported that globally measured average IWUE is ranged between 0.6 to 1.7 kg wheat grains/ m^3).

Increasing nitrogen and phosphorus concentrations of grains than those of straw in a apposite trend of potassium, whereas K% is higher in straw than that in grains, may be due to the high translocation of nitrogen and phosphorus from leaves to grains compared with potassium. The importance of N and P in germination process led plants to store high concentration of them. In the opposite line K plays a role in osmotic regulations of leaves (Rasheed *et al*., 2010). Application of hydrogel resulted in increased N, P and K concentration and content, this may be due to hydrogel is reducing leaching of fertilizers and increasing the use efficiency of macronutrients as discussed by Ibrahim *et al*. (2015). Also, El-Hady and Abo-Sedera (2006) reported that the H has a positive effect on most of soil properties, where they reflect on nutrient availability in soil and its content in plants. In another hand, using traditional fertilizers and slow release fertilizers led to increase N, P and K% and they content in grains and straw compared with F_0, this could be due to the poor in fertility of the soil under dryland condition. The reason of the superiority of SRF may be attributed to the ability of agriglass to attract water that broken the network of phosphate glass thus turns to HPO_3 resulting in decreases in pH value, as well as controlled solubility in time for plant needs, in addition to the composition of the SRF that contain Enciabien as a source of slow release nitrogen and agriglass that contain P, K, Fe, and Cu. These results are in agreement with those obtained by (Ouis *et al*., 2018 and Abou-Baker *et al*., 2018) where they reported that agriglass application led to an increment in maize grain yield and its content of macronutrients. Hassanein *et al*. (2013) reported that the addition of slow-release N fertilizer (90 kg Enciabien/fed) resulted in a significant increase in wheat growth compared with 120 kgN/fed.

CONCLUSION

Under dryland conditions, the addition of supplemental irrigation increases wheat yield. Using hydrogel increases wheat grains by 14% compared with H_0. Replacing traditional fertilizers (Ammonium sulphate, super-phosphate, and potassium sulfate) by Enciabien as a source of slow release nitrogen and agriglass as a source of P and K led to increasing wheat grain yield by 71% and 10% compared with F_0 and TF, respectively. It can address the challenges of wheat production by the interaction between supplemental irrigation, hydrogel and slow release fertilizers as an environmentally friendly solution.

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الإدارة المتكاملة للقمح تحت ظروف الأراضي الجافة

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مركز البحوث الزراعية ، معهد بحوث التربة و المياه و البيئة

يشكل زيادة إنتاجية القمح باستخدام كمية أقل من المياه تحديًا كبيرًا للقطاع الزراعي خاصة في المناطق الجافة وشبه الجافة. لذلك أجريت تجربة حقلية في منطقة أم الرخم محافظة مرسى مطروح- جمهورية مصر العربية خلال موسمى شتاء متتاليين 2016-2017 و 2017-2018 لدراسة مجموعة من الممارسات الزراعية المؤثرة على انتاج القمح تحت ظرف المناطق الجافة. وكانت المعاملات التى استخدمت فى التجربة كالتالى: 1- معاملات الري التكميلي (الزراعة المطرية ، اضافة رى تكميلى للوصول الى 60%(SI_1) و 100% (SI_2) من متطلبات المياه لنبات القمح،2- اضافة هيدروجيل (H) و بدون إضافة هيدروجل (H_0)،3- ثلاثة معاملات تسميد هى الكنترول (F_0) ، والأسمدة المعدنية التقليدية (TF) والأسمدة البطيئة الانطلاق(SRF) . وقد اظهرت النتائج زيادة إنتاجية محصول القمح بالتدريج مع الري التكميلي المضاف كما ادت اضافة الهيدروجيل إلى زيادة محصول الحبوب بنسبة 19.1 و 14.8 و 9.4٪ تحت الأمطار البعلية و المعدل الاول من الرى التكميلى (الوصول بماء المطر الى 60% من الاحتياجات المائية المحسوبة SI_1) و المعدل التانى من الرى التكميلى (الوصول بماء المطر الى 100% من الاحتياجات المائية SI_2) على التوالى بالمقارنة مع H_0 في ظل معدلات الري المختلفة. كما اثبتت النتائج المتحصل عليها ان كلا من الاسمدة بطيئة الانطلاق و الأسمدة التقليدية عززت إنتاجية القمح مقارنة بالكنترول ولكن الاسمدة بطيئة الانطلاق تفوقت على الاسمدة التقليدية فى زيادة المحصول . من ناحية اخرى وجد انه على الرغم من أن زيادة معدل المياه المضاف أدى إلى انخفاض IWUE ، فإن إضافة هيدروجيل وأسمدة بطيئة الإطلاق اثرت على كلا من IWUE و EWP تأثيرا ايجابيا. ومن المثير للاهتمام أن التحليل الاحصائى للنتائج اثبت ان التداخل بين المعاملات $SI_1xHxSRF$ أدى الى انتاج محصول حبوب أعلى من $SI_2xH_0xF_0$ و SI_2xH_0xTF. وبالتالي يمكن توفير حوالي 40 ٪ من الماء المضاف باستخدام هيدروجيل وأسمدة بطيئة الإطلاق مع اضافة رى تكميلى للوصول الى 60% فقط من الاحتياجات المائية تحت ظروف المنطقة محل الدراسة.ومن هنا يمكن مواجهة تحديات إنتاج القمح في ظروف الأراضي الجافة عن طريق التكامل بين الري التكميلي والهيدروجيل والأسمدة بطيئة الإطلاق.