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EFFECT OF IRRIGATION LEVEL AND SEED RATE ON WHEAT PRODUCTIVITY

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ABSTRACT

An experiment was conducted at El-Mattaana Agricultural Research Station of Upper Egypt. A split-split plot design experiment was employed to investigate three factors: irrigation scheduling based on cumulative evapotranspiration (CPE) using ratios ($I_{1,2,3}$) of 1.2, 1 and 0.8 in the main plots. The average amount of water added based on these rates was 2502, 2306 and 2022 m^3 during the two seasons, respectively.; seed rates ($S_{1,2,3}$) of 40, 60, and 80 kg/fed in the sub plots; and two varieties of durum wheat (Triticum durum Desf.) ($V_{1,2}$), namely Beni Suef-7 and Beni Suef-8, in the sub- sub plots. The irrigation levels, seed rates, and wheat varieties showed a significant or highly significant impact on all the studied traits in both seasons, and specifically, the second level of irrigation treatment (I_2) demonstrated superior results in terms of wheat yield, its components, and water use efficiency compared to the other two irrigation levels. Additionally, the seed rate of 60 kg/fed showed the highest performance in most traits during both seasons. Moreover, the Beni Suef-7 cultivar demonstrated its superiority in all characteristics examined in this investigation with the exception of the number of grains per spike, where the Beni Suef-8 cultivar excelled in both growing seasons. the second-order interaction between the medium level of irrigation, the seed rate of 60 kg/fed, and the Beni Suef-7 variety resulted in the highest grain productivity and water use efficiency, with values of 25.89 and 25.67 ard/fed, and 1.68 and 1.67 kg/m^3 in the first and second seasons, respectively.

Key words: ***Triticum durum*, irrigation level, seeding rate, wheat variety, water use efficiency.**

INTRODUCTION

Wheat is an important cereal crop and staple food in many countries. It is divided into bread wheat and durum wheat. The global wheat cultivation area is 525.4 million feddan, while Egypt's area is 3.4 million feddan. The world's wheat production is 770.8 million tons, with Egypt producing 9.3 million tons. The average wheat production per feddan is 9.7 ard/fed globally and 18.28 ard/fed in Egypt (FAO STAT 2021).

Water is the utmost crucial element that impacts the productivity of wheat. Consequently, there is an imperative necessity to enhance the efficiency of irrigation practices for wheat cultivation. Moreover, the regulation of plant density represents a significant measure to be taken into consideration. Additionally, the interplay of irrigation intensity and seed rate has a profound effect on the growth of wheat cultivars. (Alam *et al* 2022) reported that wheat inconsistent use of available irrigation water is a contributing factor to reduced wheat yield. For achieving maximum wheat production, it is widely recognized that effective water management plays a crucial role in attaining higher crop yields.

Rajanna *et al* (2017) obtained that the implementation of irrigation at the CRI + IW:CPE ratio of 0.75 resulted in the highest water use efficiency (WUE) values of 129.0 and 140.0 kg ha-cm–1, as well as the highest irrigation water productivity (IWP) values of 4.2 and 4.4 kg m–3. Furthermore, these outcomes were achieved while utilizing the least amount of water, with measurements of 37.41 and 36.22 cm during the respective crop seasons.

Determining the seed rate in wheat cultivation is considered one of the essential factors for raising productivity, especially in conditions of climate change in hot regions. When compared between three seeding rates: [67.5 kg ha^{-1} (SR67.5), 90 kg ha^{-1} (SR90), and 112.5 kg ha^{-1} (SR112.5)], the results of the study, conducted by Ren *et al* (2019), revealed that the productivity of wheat, as measured by grain yield and spike number, was the highest at SR90 and the lowest at SR112.5 in all three seasons. Choudhary *et al* (2023) studied the impact of different levels of seed rate on the yield of durum wheat. Their results of the three-year pooled analysis showed significantly higher growth and yield parameters with a seed rate of 90 kg ha^{-1} in terms of plant height (114.98 cm), no. of grain per spike (54.84) with S_3 treatment (110 kg seed rate ha^{-1}) produced significantly higher grain yield (3419 kg/ha^{-1}). Chhokar *et al* (2017) reported that to improve the wheat yield through adjustments in seed rate, the results showed that seed rate from the present recommendations of 100 kg/ ha^{-1} can be reduced to 75 kg/ha^{-1}; however, further reduction in seed rate caused yield reductions.

Wheat varieties are characterized by great diversity in response to high yields under different irrigation conditions and seeding rates. El-Seidy *et al* (2022) said that the genotypes of wheat were different between tolerant to drought and were suitable for normal conditions. El-Hendawy (2016) reported that grain yield and yield components of Sakha 94 were gradually decreased by decreasing irrigation rates and increasing seeding rates. The values of IWUE and harvest index were decreased also by decreasing irrigation rate, while the highest values for both parameters were achieved at 350seeds/m^2. The seeding rates of 350 and 250 seeds/m^2 were the most effective to obtain the lowest value for seasonal yield response factors under

0.75 and 0.50 ET, respectively. Based on the production functions of grain yield versus seeding rates for each irrigation rate, the optimum seeding rate for the maximum grain was 411 and 425 seeds/m^2 for 1.00 ET, 362 and 378 seeds/m^2 for 0.75 ET and 315 and 350 seeds/ m^2 for 0.50 ET in the first and second season respectively.

El-Seidy *et al* (2022) studied the effect of seed rates and wheat cultivars on the yield and growth of bread wheat. They found that Wheat plant height, tillers/m^2 biological yield, and straw production were all significantly impacted by the interaction between wheat cultivars and seed rate.

In order to determine the most optimal level of irrigation and seeding rate to achieve a high grain yield and water use efficiency (WUE) for three of durum wheat, Othmani *et al* (2020) found that irrigation level (10% field capacity (FC)) gave the highest grain yield, number of spikes per square meter, number of kernels per spike and 1000-kernel weight and biomass yield. The highest water use efficiency of grain yield (WUEg) and biomass yield (WUEb) were observed under the moderate irrigation treatment (40% (FC)).

This study aimed to improve water use efficiency for wheat crop by identifying the optimal irrigation level for increasing wheat yield, determining the ideal seed rate for agricultural purposes, and finding the optimal combination of irrigation level, seed rate, and variety to maximize wheat productivity in the Upper Egypt region.

MATERIALS AND METHODS

This experiment was conducted in a split split-plot design with randomized complete block design with arrangement in three replications at El-Mattaana Agric. Res. St., ARC, Egypt. For the seasons 2021/22 and 2022/23, wheat was planted in plots measuring 1.5x3.5 m^2 on a Furrow Irrigated Raised Bed (FIRB). The irrigation planning for this study was based on the cumulative pan evaporation (CPE) and the irrigation applied using CPE ratios ($I_{1,2,3}$) of 1.2, 1, and 0.8. The irrigation treatments were devoted to the main plots. Wheat was grown at seed rates ($S_{1,2,3}$) of 40, 60, and 80 kg/fed, and the seed rates were applied in the sub-plots. Two varieties Beni Suef-7 (V_1) and Beni Suef-8 (V_2) (*Triticum durum* Desf.)

were planted in the sub-sub-plots. All other intercultural operations, such as weeding and fertilizer application, were kept consistent. The data were recorded included the following:

1) Number of spikes/m^2. 2) Number of grains/spikes. 3) Grain weight/spike (g).
4) Grain yield (ard/fed). 5) Biological yield (ton/fed). 6) Water use efficiency (WUE).

Soil attributes of the experimental site

The soil samples were carefully chosen to exemplify the designated site at depths (0-15), (15–30), (30– 45) and (45–60) cm. Soil samples were collected and processed from various experimental sites to ascertain the soil physical characteristics of the experimental area (Table 1). Physical and chemical properties of the experimental field are presented in Tables (1 and 2).

Table 1. Some soil physical properties of the experimental site.

Properties		Depths				Method employed
		0-15 cm	15-30 cm	30-45 cm	45-60 cm	
Textural composition	Sand (%)	34.89	33.70	33.00	33.00	International pipette method (Piper, 1966).
	Silt (%)	30.08	30.10	30.60	30.58	
	Clay (%)	35.03	36.20	36.40	36.42	
	Texture	Clay loam				
Bulk density (mg m^{-3})		1.09	1.21	1.26	1.29	Core method (Singh, 1980).
Field Capacity (FC) (%)		47.96	41.73	40.33	35.27	Field method (FAO, 2008).
Permanent Wilting (PW) (%)		18.96	17.16	16.22	15.2	(Singh,1980)
Available water (%)		29	24.57	24.11	20.07	FC - PW

Table 2. Some soil chemical properties of the experimental site.

Properties	Depth		Method employed
	0-30	30-60	
Soil pH	**7.7**	**7.7**	**(1:2.5, soil: water) (Brower and Zar, 1984)**
EC_e (dS/m)	**1.12**	**1.19**	**(Rowell, 1994)**
Calcium carbonate	**3.5**	**4.1**	**(FAO. 1980)**
Available N (ppm)	**7.9**	**8**	**(FAO. 1980).**
Available P (ppm)	**20**	**22**	**(FAO, 2008).**
Available K (ppm)	**67**	**62**	**(FAO, 2008).**
Organic matter (O.M) (%)	**1.9**	**1.4**	**(FAO, 2008).**

Irrigation scheduling

The top soil (60 cm) was irrigated to reach its field capacity. The water amount applied to each plot was equal to the difference between the moisture content at field capacity and the present soil moisture during irrigation time with an additional 10% of water applied to ensure a good distribution uniformity of water through the plots. Irrigation time and water volumes for each irrigation treatment were determined as described:

Irrigation time

- Collected daily Pan Evaporation data (in mm/day) from a standard Class-A-Pan situated near the experimental field were acquired and documented.
- The cumulative pan evaporation data for each irrigation treatment were computed by multiplying the daily evaporation rate with the corresponding evaporation pan coefficients investigated in this study (1.2, 1.0, and 0.8).
- The determination of irrigation timing entails establishing the cumulative pan evaporation to correspond with the allowable depletion of the accessible soil moisture (at a rate of 50%).

Calculating irrigation requirements and supplying water

The irrigation requirements (m^3) as affected by irrigation scheduling and planting rates in the two studied seasons are presented in Table (3).Soil samples were collected at intervals of 15 cm depth up to a depth of 60 cm, both immediately prior to irrigation and 48 hours after irrigation.

Table 3. The irrigation requirements (m^3) as affected by irrigation scheduling and planting rates in the two studied seasons.

Irrigation treatment	Planting rate	2021/2022	2022/2023	Average
I_1 (1.2)	S1	2493	2491	2492
	S2	2500	2500	2500
	S3	2506	2508	2507
Average		2503	2500	2502
I_2 (1)	S1	2300	2302	2301
	S2	2310	2312	2311
	S3	2317	2319	2318
Average		2300	2311	2306
I_3 (0.8)	S1	2014	2010	2012
	S2	2022	2025	2024
	S3	2028	2033	2031
Average		2021	2023	2022

The irrigation water was applied using a water meter to compensate for the difference in soil moisture content at the time of irrigation and the desired content for each irrigation treatment, with an additional 10% of water added to ensure a uniform distribution.

The quantity of water for each irrigation treatment was calculated using the following formula:

$$Q = R \times D (\times Bd/\rho_w) \times (F.C. - S.M.I.)/ 100$$

Where:

Q = the quantity of water (m^3).
R = area that would be irrigated (m^2).
D = the soil depth required to be irrigated (m).
Bd = bulk density of the soil (kg m^{-3}).
ρ_w = water density (kg/m^{-3}).
F.C = the soil moisture at field capacity is measured in percentage.
S.M.I = the soil moisture percentage measured gravimetrically prior to irrigation.

Water Use Efficiency (WUE)

WUE was calculated according to the following formula:
WUE (kg m^{-3}) = Output derived from water use (grain yield kg/fed)/Water input (m^3) (Molden, 1997)

Statistical analysis

The data underwent appropriate statistical analysis using the analysis of variance (ANOVA) technique within a split-split plot design, following the method described by Gomez and Gomez (1984). Treatment means were compared utilizing the Least Significant Difference (LSD) test, following the guidelines detailed by Waller and Duncan (1969).

RESULTS AND DISCUSSION

Irrigation level

Irrigation levels had a highly significant effect on all the studied traits in the two seasons, and the second level of irrigation treatment (I_2) was better for growing wheat varieties by increasing the yield, its components, and water use efficiency in the two seasons compared to the other two irrigation levels, as shown in Tables (4 and 5).

The medium irrigation treatment (I_2) was the highest in all traits and their values in the first and second seasons were 428.00, 397.64; 57.11, 56.11; 2.63, 2.60; 10.62, 10.15, for traits number of spikes/m^2, number of

grains/spikes, grain weight/spike (g) and biological yield (ton/fed), respectively.

Table 4. Effect of irrigation level, seeding rate and variety on number of spikes/m^2, number of grains/spikes and grain weight/spike. (g) at harvest in 2020/2021 and 2021/2022 seasons.

Traits	Number of spikes/m2		No. of grain/spike		Grain weight /spike (g)	
Treatments	Season	Season	Season	Season	Season	Season
	2021/22	2022/23	2021/22	2022/23	2021/23	2022/24
I: Irrigation levels						
I_1	420.47	396.75	56.39	55.17	2.55	2.59
I_2	428.00	397.64	57.11	56.11	2.63	2.60
I_3	371.22	350.23	52.83	48.78	2.33	2.27
F-test	**	**	**	**	**	**
LSD at 0.05	9.88	3.36	2.09	0.40	0.06	0.02
S: Seed rates						
40 kg/fed	392.29	368.79	54.83	53.39	2.52	2.52
60 kg/fed	410.99	386.17	57.22	55.83	2.56	2.53
80 kg/fed	416.42	389.66	54.28	50.83	2.44	2.42
F-test	**	**	*	**	**	**
LSD at 0.05	6.19	5.44	2.25	0.30	0.06	0.01
V: Varieties						
V_1	426.11	400.07	51.48	51.41	2.57	2.56
V_2	387.02	363.01	59.41	55.30	2.44	2.42
F-test	**	**	**	**	**	**
LSD at 0.05	4.95	3.67	1.43	0.33	0.04	0.004

***, **: significant at 0.05 and 0.01 levels of probability, respectively.**

Table 5. Effect of irrigation level, seeding rate and variety on grain yield (ard/fed), biological yield (ton/fed) and water use efficiency at harvest in 2020/21 and 2021/2022 seasons.

Traits	Grain yield (ard/fed)		Biology yield (ton/fed)		Water use efficiency	
Treatments	Season					
	2021/23	2022/24	2021/23	2022/24	2021/23	2022/24
I: Irrigation levels						
I_1	21.27	19.65	9.98	9.15	1.28	1.18
I_2	22.11	21.02	10.62	10.15	1.44	1.36
I_3	14.18	13.37	6.63	6.32	1.05	0.99
F-test	**	**	**	**	**	**
LSD at 0.05	0.35	0.18	0.93	0.53	0.09	0.04
S: Seed rates						
40 kg/fed	18.17	17.03	8.49	8.10	1.19	1.12
60 kg/fed	19.91	18.99	9.42	8.99	1.30	1.24
80 kg/fed	19.49	18.02	9.31	8.53	1.27	1.18
F-test	**	**	**	**	**	**
LSD at 0.05	0.14	0.22	0.70	0.79	0.03	0.05
V: Varieties						
V_1	20.13	19.09	9.59	9.00	1.32	1.25
V_2	18.25	16.93	8.57	8.08	1.19	1.11
F-test	**	**	**	**	**	**
LSD at 0.05	0.12	0.15	0.45	0.52	0.03	0.03

***, **: significant at 0.05 and 0.01 levels of probability, respectively.**

Regarding the grain yield, the overall average for the irrigation treatments was in the first season 19.19 (ard/fed) and in the second season 18.01(ard/fed).The highest grain yield was 22.11, 21.02 (ard/fed) for the medium irrigation treatment I_2, and the lowest grain yield was 14.18, 13.37 (ard/fed) for the low irrigation treatment I_3, the differences between the highest value and the lowest value were 7.93 and 7.65 (ard/fed) in the initial and subsequent seasons, respectively. With regard to water use efficiency, the general average for the irrigation treatments was 1.26 and 1.18 (kg/m^3), the highest values were 1.44 and 1.36 (kg/m^3) for the medium irrigation treatment (I_2) and the lowest values were 1.05 and 0.99(kg/m^3) for the low irrigation treatment I_3, the differences between the highest value and the lowest value were 0.39 and 0.37 (kg/m^3) in the first and second seasons, respectively. This study obtained the optimum use of available irrigation water is important factor to increased wheat yields water controls the efficiency of vital processes within the plant at different growth stages, These results are in agreement with those reported by El-Sanatawy and Zedan (2020), Abou-Elwafa (2021), Shah *et al* (2021), Tegenu (2021), Jemal (2022), and Singh *et al* (2023). Alam *et al* (2022) reported for wheat inconsistent use of available irrigation water is a contributing factor to reduced wheat yield. The managing water is one of the important variables in getting a higher grain yield. The results showed the Irrigation scheduling with CRI + IW/CPE= 1.0 evidenced to have significantly higher growth and yield parameter as compared to 0.8 and 1.2 IW/CPE ratio.

Seeding rate

Seed rates had a significant or highly significant effect on all studied traits in the two seasons, as shown in Tables (4 and 5). The seed rate treatment (60 kg/fed) had the highest value in the all traits except for the number of spikes/m^2, where the highest value was the seed rate (80 kg/fed). As for grain yield, the highest grain productivity was 19.91, 18.99 (ard/fed) for the sowing seed rate (60 kg/ fed), and the lowest grain productivity was 18.17, 17.03 (ard/fed) for the sowing seed rate (40 kg/fed), the difference between the highest and lowest value was 1.74 and 1.96 (ard/fed) in the first and second seasons, respectively. For water use efficiency, the highest values reached 1.30, 1.24 (kg/m^3) with the seed rate for sowing (60 kg/fed),

and the lowest values were 1.19, 1.12 (kg/m^3) for sowing with seed rate (40 kg/fed), and the difference between the highest and lowest value was 0.11 and 0.12 (land/fed) in the first and second seasons, respectively. These results are in agreement with Ren *et al* (2019), El-Sanatawy and Zedan (2020), Li *et al* (2020), Othmani *et al* (2020), Shah *et al* (2021), Tegenu (2021), Mohiy and Salous (2022) and Choudhary *et al* (2023). Optimal seed rate is a major challenge for maintaining wheat productivity under changing environments.

Wheat variety

The results in Tables (4, 5) showed that the cultivar had a highly significant effect on all traits in the two seasons. The Beni Suef-7 cultivar showed its superiority in all traits in this study, except for the number of grains/spike, in which the Beni Suef-8 cultivar excelled in both seasons. The Beni Suef-7 variety had the highest value in all traits except for the number of grains/spike, in which the Beni Suef-8 variety had the highest value (59.41 and 55.30). For grain yield traits, the Beni Suef-7 variety was the highest with values of 20.13 and 19.09 ard/fed, and the Beni Suef-7 variety was the lowest with values of 18.25 and 16.93 ard/fed, the difference between the highest value and the lowest value was 1.88 and 2.16 in the first and second seasons, respectively. In terms of water use efficiency, the Beni Suef-7 variety was the highest with values of 1.32 and 1.25 (kg/m^3), and the Beni Suef-7 variety was the lowest with values of 1.19 and 1.11(kg/m^3). The difference between the highest and lowest values was 0.13 and 0.14 (kg/m^3) in the first and second seasons, respectively. These results are in harmony with those reported by Abou-Elwafa and Shehzad (2021), Safina *et al* (2021), El-Seidy *et al* (2022) and Khodadoost *et al* (2022). It can be said that the difference between wheat varieties may be due to the genetic makeup of the different wheat varieties. Interaction

The first- and second-order interactions (I*S, I*V, S*V, I*S*V) for all traits under study in the two seasons are presented in Tables (6 to 12).

The interactions between irrigation levels and seed rates (I*S) were significant or highly significant with regard to the number of spikes/m^2, grain yield, and biological yield in the two seasons, while water use efficiency was highly significant in the first season, and the traits of the

number of grains/spike and weight of grains/spike were highly significant in the second season, as shown in Tables (6 and 7). The interaction between the medium irrigation level (I_2) and the seed rate of 60 kg/fed was the highest value in all the traits studied during the two seasons. While the interaction between the low level of irrigation (I_3) and the seed rate of 40 kg/fed was the lowest value in most traits in the two growing seasons, except for the number of grains/spike and the weight of grains/spike in the two seasons.

Table 6. Effect of interaction between irrigation level and seeding rate (I*S) on number of spikes/m^2, number of grains/spikes and Grain weight/spike (g) in two seasons.

Treatments		Number of spikes/m^2		No. of grain/spike		Grain weight/spike (g)	
Irrigation levels	Seeding rates	Season					
		2021/22	2022/23	2021/22	2022/23	2021/22	2022/23
I_1	40 kg/fed	411.80	392.45	57.00	55.33	2.62	2.56
	60 kg/fed	424.06	399.88	55.83	55.67	2.55	2.59
	80 kg/fed	425.56	397.93	56.33	54.50	2.49	2.64
I_2	40 kg/fed	416.53	385.71	55.50	55.83	2.59	2.73
	60 kg/fed	438.13	408.71	60.67	60.00	2.73	2.55
	80 kg/fed	429.33	398.50	55.17	52.50	2.58	2.53
I_3	40 kg/fed	348.53	328.22	52.00	49.00	2.35	2.29
	60 kg/fed	370.77	349.91	55.17	51.83	2.39	2.44
	80 kg/fed	394.36	372.55	51.33	45.50	2.25	2.08
F-test		**	**	NS	**	NS	**
LSD at 0.05		10.73	9.43	Ns	0.53	Ns	0.01

NS = non- significant, *, **: significant at 0.05 and 0.01 levels of probability, respectively.

Table 7. Effect of interaction between irrigation level and seeding rate (I*S) on grain yield, biological yield and Water use efficiency in two seasons.

Treatments		Grain yield (ard/fed)		Biology yield (ton/fed)		Water use efficiency	
Irrigation levels	Seeding rates	Season					
		2021/22	2022/23	2021/22	2022/23	2021/22	2022/23
I_1	40 kg/fed	20.04	18.94	9.14	8.79	1.21	1.14
	60 kg/fed	22.11	20.55	10.30	9.48	1.33	1.23
	80 kg/fed	21.66	19.44	10.50	9.18	1.30	1.16
I_2	40 kg/fed	21.08	19.44	10.12	9.31	1.37	1.27
	60 kg/fed	23.44	22.89	11.29	11.19	1.52	1.49
	80 kg/fed	21.82	20.72	10.46	9.94	1.41	1.34
I_3	40 kg/fed	13.38	12.70	6.23	6.19	1.00	0.95
	60 kg/fed	14.17	13.53	6.68	6.29	1.05	1.00
	80 kg/fed	15.00	13.89	6.97	6.48	1.11	1.02
F-test		**	*	*	*	**	NS
LSD at 0.05		0.23	0.38	1.21	1.38	0.05	Ns

NS = non- significant, *, **: significant at 0.05 and 0.01 levels of probability, respectively.

Regarding the grain yield, the interaction between the medium irrigation level (I_2) and the seed rate of 60 kg/fed was the best, as the values were 23.44 and 22.89 ard/fed, and in the interaction between the low level of irrigation (I_3) and the seed rate of 40 kg/fed, the values were 13.38 and

12.70 ard/fed and the difference between the highest and lowest values was 10.06 and 10.19 ard/fed in the first and second seasons, respectively.

The best water use efficiency was when the interaction between the medium irrigation level and the seed rate of 60 kg/fed, with a value of 1.52 and 1.49 kg/m^3 in the first and second seasons, respectively. These results are in full agreement with those of Akol *et al* (2021) and Gao *et al* (2021). Li *et al* (2020) found that one major strategy to increase wheat productivity with limited irrigation is to control plant density. Three plant densities and three irrigation levels were used in field tests. The findings demonstrated that, with restricted watering, a high density produced more spikes and a higher yield than a low density. Thus, (1) in conditions of low water availability, yield loss could be offset by raising the rate at which pre-anthesis is storage material is contributed to grain as plant density increases. (3) In wet years, medium plant density (Dm) is advised due to water use efficiency; high plant density (Dh) may be considered to increase wheat yield in dry years.

The interaction between irrigation levels and varieties (I*V) was highly significant for the number of grains/spike and weight of grains/spike in both seasons, while the interaction between irrigation levels and varieties was significant or highly significant for grain yield and water use efficiency in the first season, as shown in Tables (8 and 9).The interaction between the medium irrigation level and the Beni Suef-7 variety was the highest value in all the studied traits during the two seasons, except for the number of grains/spike, where the interaction between the medium irrigation level and the Beni Suef-8 variety was the best during the two seasons, while the grain weight/spike was the best in the first season for the same interaction. While the weight of grains/spike in the second season was the best as a result of the interaction between the high level of irrigation and the Beni Suef -7.

With regard to the grain yield, the interaction between the medium irrigation level and the Beni Suef-7 variety was the best, as the values reached 23.42 and 22.33 ard/fed, as was the efficiency of water use was the best in this reaction with a value of 1.52 and 1.45 kg/m^3 in the first and second seasons, respectively.

Table 8. Effect of interaction between irrigation level and variety (I*V) on number of spikes/m^2, number of grains/spikes and grain weight/spike (g) in two seasons.

Treatments		Number of spikes/m2		No. of grain/spike		Grain weight/spike (g)	
Irrigation levels	Seeding rates	Season					
		2021/22	2022/23	2021/22	2022/23	2021/22	2022/23
I_1	V_1	440.0	415.6	51.78	53.78	2.5	2.8
	V_2	400.9	377.9	61.00	56.56	2.6	2.4
I_2	V_1	450.0	418.6	51.56	54.00	2.6	2.7
	V_2	406.0	376.7	62.67	58.22	2.7	2.6
I_3	V_1	388.3	366.0	51.11	46.44	2.6	2.2
	V_2	354.1	334.4	54.56	51.11	2.0	2.3
F- test		NS	NS	**	**	**	**
LSD at 0.05%		Ns	Ns	2.47	0.57	0.1	0.0

NS = non- significant, *, **: significant at 0.05 and 0.01 levels of probability, respectively.

Table 9. Effect of interaction between irrigation level and variety (I*V) on grain yield, biological yield and water use efficiency in two seasons

Treatments		Grain yield (ard/fed)		Biology yield (ton./fed)		Water use efficiency	
Irrigation levels	Seeding rates	Season					
		2021/22	2022/23	2021/22	2022/23	2021/22	2022/23
I_1	V_1	21.79	20.72	10.46	9.59	1.31	1.24
	V_2	20.75	18.57	9.50	8.71	1.25	1.11
I_2	V_1	23.42	22.33	11.19	10.78	1.52	1.45
	V_2	20.80	19.70	10.06	9.52	1.35	1.28
I_3	V_1	15.17	14.23	7.11	6.64	1.13	1.05
	V_2	13.19	12.52	6.14	6.00	0.98	0.93
F- test		*	NS	NS	NS	**	NS
LSD at 0.05%		0.20	Ns	Ns	Ns	0.04	Ns

NS = non- significant, *, **: significant at 0.05 and 0.01 levels of probability, respectively.

The reason for these results can be attributed to the appropriate seeding method and cultivar creating optimal conditions and the lack of competition between plants.

The interactions between the seeding rate and varieties (S*V) for the number of grains/spike, weight of grains/ spike and grain yield were significant or highly significant in both seasons, while the interactions between the varieties and seeding rates for the number of spikes/m^2 and biological yield were significant in the first season, as shown in Table (10 and 11).

Table 10. Effect of interaction between seeding rate and varietyS*V) on number of spikes/m^2, number of grains/spikes, and grain weight/spike (g) in two seasons.

Treatments		Number of spikes/m^2		No. of grain/spike		Grain weight/spike (g)	
Seeding rates	Cultivars	Season					
		2021/22	2022/23	2021/22	2022/23	2021/22	2022/23
40 kg/fed	V_1	409.9	386.9	49.22	51.44	2.6	2.5
	V_2	374.7	350.7	60.44	55.33	2.4	2.5
60 kg/fed	V_1	434.8	406.5	54.67	54.56	2.7	2.7
	V_2	387.2	365.8	59.78	57.11	2.4	2.4
80 kg/fed	V_1	433.6	406.8	50.56	48.22	2.4	2.5
	V_2	399.2	372.5	58.00	53.44	2.5	2.4
F- test		*	NS	**	**	**	**
LSD at 0.05%		8.6	Ns	2.47	0.57	0.1	0.0

NS = non- significant, *, **: significant at 0.05 and 0.01 levels of probability, respectively.

Table 11. Effect of interaction between seeding rate and variety(S*V) on grain yield, biological yield and water use efficiency in two seasons.

Treatments		Grain yield (ard/fed)		Biology yield (ton./fed)		Water use efficiency	
Seeding rates	Cultivars	Season					
		2021/22	2022/23	2021/22	2022/23	2021/22	2022/23
40 kg/fed	V_1	18.74	17.84	8.82	8.47	1.23	1.17
	V_2	17.59	16.22	8.17	7.73	1.15	1.06
60 kg/fed	V_1	21.15	20.51	10.14	9.57	1.38	1.34
	V_2	18.67	17.46	8.71	8.41	1.22	1.14
80 kg/fed	V_1	20.51	18.93	9.80	8.97	1.34	1.23
	V_2	18.47	17.11	8.83	8.09	1.20	1.12
F- test		*	*	*	NS	*	*
LSD at 0.05%		0.20	0.26	0.79	Ns	0.04	0.06

NS = non- significant, *, **: significant at 0.05 and 0.01 levels of probability, respectively.

The interaction between the seed rate of 60 kg/fed and the Beni Suef-7 variety was the highest value in most of the traits studied during the two seasons, except for the number of spikes/m^2 in the second season where the interaction between the seed rate of 80 kg/fed with the Beni Suef-7 variety was the best. No of grain/spike in the first season with the interaction between a seed rate of 40 kg/fed with the Beni Suef-8 variety was the best, while in the second season, the interaction between seed rate of 60 kg/fed with the Beni Suef-8 variety was the best in this trait. With

regard to the grain yield trait, the interaction between the seed rate of 60 kg/fed and the Beni Suef-7 variety was the best, with values of 15.21 and 20.51 ard/fed, while the interaction between the seed rate of 40 kg/fed with the Beni Suef-8 variety was the lowest, with a yield value of 17. 59 and 16.22, and the difference between the highest and lowest values were 0.56 and 4.29 in the first and second seasons, respectively. These results are in full agreement with those of Intsar and Wahid (2017) and Hussain *et al* (2018). These results may be due to the ability of the genotype to adapt to different rates of seeding and better productivity for the optimal rate of seeding.

The interaction between irrigation levels, seeding rates, and varieties (I*S*V) for all studied traits was significant or highly significant in both seasons, as illustrated in Figures (1 to 6).

The interaction between the medium irrigation level (I_2), the seed rate of 60 kg/fed (S_2) and the Beni Suef-7 variety (V_1) was the highest value in all of the studied traits, except for the number of grains/spike, where the interaction between the medium irrigation level, the seed rate of 60 kg/fed and the Beni Suef-8 variety was the best during the two seasons. In the second season, the interaction between the highest irrigation level, the seed rate of 60 kg/fed and the Beni Suef-7 variety was the best.

The interaction between the medium irrigation level and seed rate of 60 kg/fed and the Beni Suef-7 variety gave the best grain yield as well as water use efficiency with values of 25.89 and 25.67 ard/fed and 1.68 and 1.67 kg/m^3 in the first and second seasons, respectively, these results are in accordance with those obtained by Othmani (2020) and El-Seidy et al (2022). Thus, the optimal choice of irrigation level, seeding rate, and variety can greatly affect the increase in wheat yield and water use efficiency.

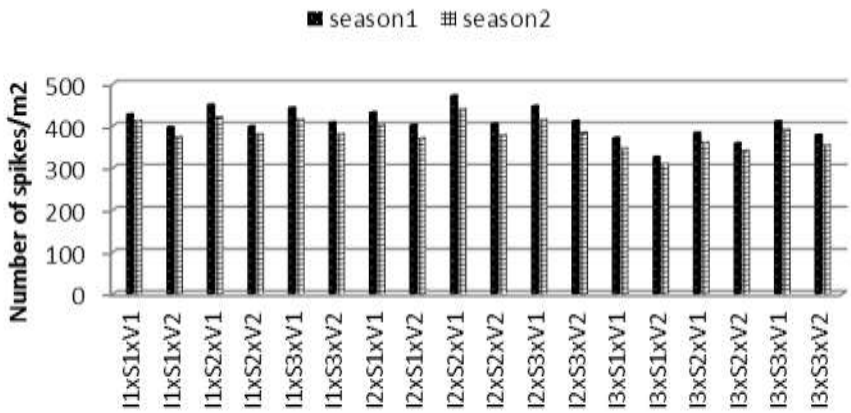

Fig.(1) Effect of interaction among irrigation level, seeding rate and variety (I*S*V) on number of spikes/m2 in two seasons.

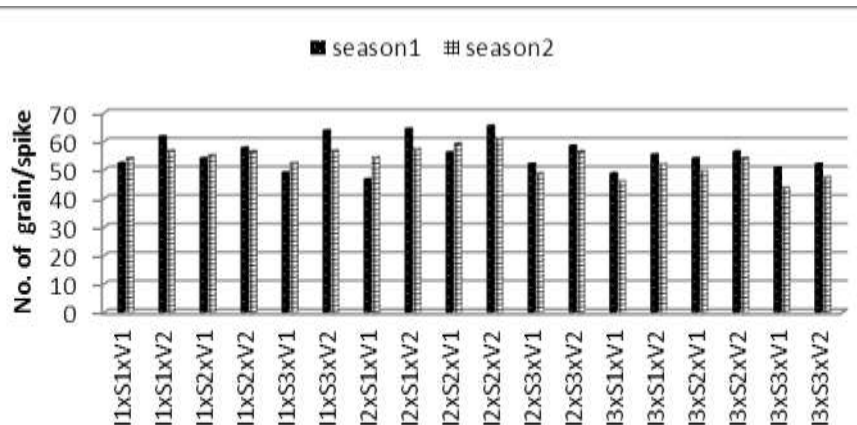

Fig.(2) Effect of interaction among irrigation level, seeding rate and variety (I*S*V) on number of grains/spikes in two seasons.

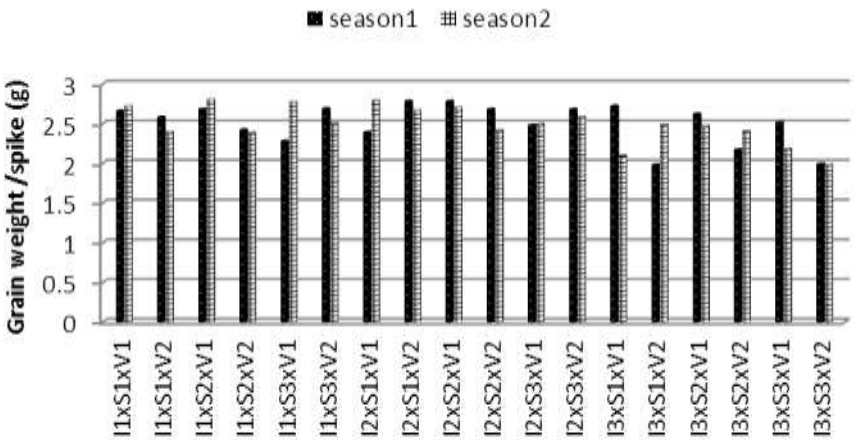

Fig.(3) Effect of interaction among irrigation level, seeding rate and variety (I*S*V) on grain weight /spike in two seasons.

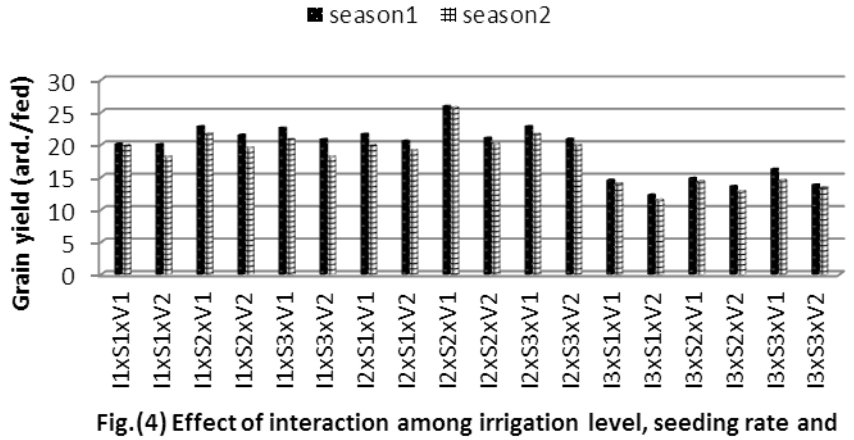

Fig.(4) Effect of interaction among irrigation level, seeding rate and variety (I*S*V) on grain yield in two seasons.

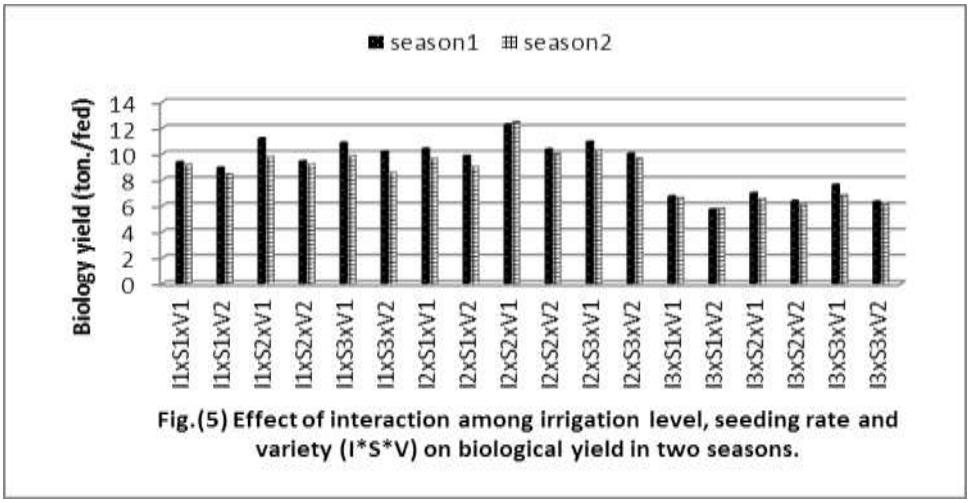

Fig.(5) Effect of interaction among irrigation level, seeding rate and variety (I*S*V) on biological yield in two seasons.

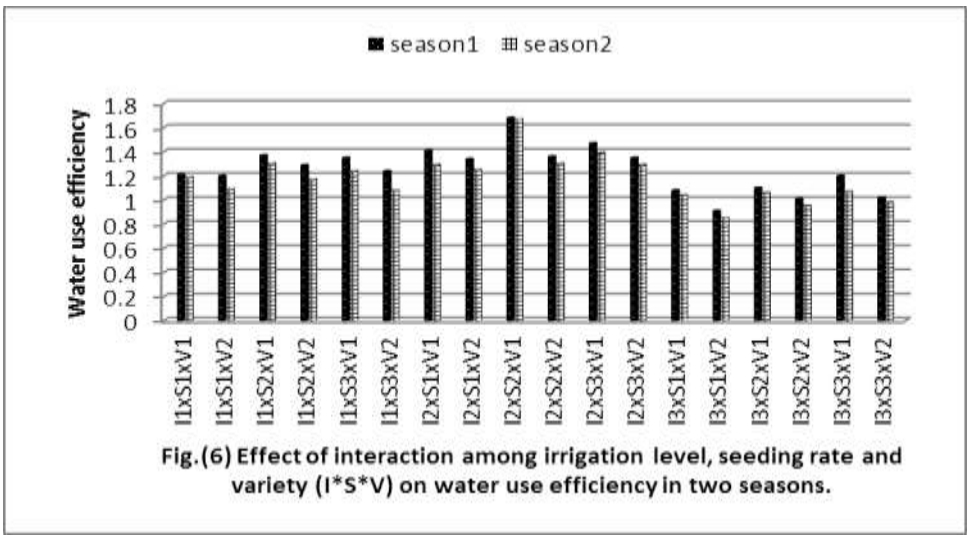

Fig.(6) Effect of interaction among irrigation level, seeding rate and variety (I*S*V) on water use efficiency in two seasons.

CONCLUSION

According to this study, it is preferable to use the irrigation level (I_2) with a seed rate of 60 kg/fed for the Beni Suef-7 variety, as it was the best treatment combination to increase grain productivity and raise water use efficiency under the conditions of Upper Egypt.

REFERENCES

Abou-Elwafa, S. F., andT. Shehzad (2021). Genetic diversity, GWAS and prediction for drought and terminal heat stress tolerance in bread wheat (*Triticum aestivum* L.). Genetic Resources and Crop Evolution 68: 711-728.

Akol, A. M., N. Nassif, K. A.Jaddoa, H. M. Zwain, K. Radhi, andN. Al-Ansari (2021). Effect of irrigation system, tillage system, and seeding rates on wheat (*triticumaestivum* l.) growth, grain yield and its water consumption and efficiency. Engineering 13(11): 574-59

Alam, M. S., R. K. Naresh, K. S. Vivekand H. L. Singh (2022). Effect of sowing methods and irrigation scheduling on production and productivity of wheat crop. Biol. Forum Int. J. 14(2):445-452.

Brower, J. E. and J. H. Zar (1984). Field and laboratory methods for general ecology. Wm. C. Brown Publishers Dubuque, Iowa, USA, pp: 226.

Chhokar, R. S., R. K. Sharma, S. C. Gilland R. Kumar (2017). Influence of tillage, cultivar, seed rate and planting geometry on wheat yield. Journal of Wheat Research 9(1): 12-20.

Choudhary, R. N., K. J. Suthar, C. J. Patel, N. R. Bumbadiyaand N. J. Jadav (2023). Effect of levels of nitrogen and seed rate on yield and yield attributes of durum wheat under restricted irrigation in rainfed condition of Bhal Region of Gujarat. The Pharma Innovation Journal 12(2): 1306-1311.

El-Hendawy, S. (2016). Optimal coupling combinations between irrigation and seeding rates for improving production and water use efficiency of wheat grown under arid conditions. Journal of Plant Production Sciences *5*(1): 1-11.

El-Sanatawy, A. M., and A. T. M. Zedan, (2020). Seed treatment for improving wheat productivity under deficit irrigation conditions in arid environment. Soil and Environment *39*(1): 38-49.

El-Seidy, E. H., U. A. Abd El-Razek, A. A. Morad, M. A. Habow and T. M. Abd Allah (2022). The use of modern and new agricultural methods for yield and its components of wheat. In 2nd International Conference on Sustainable Ecological Agriculture 2. UluslararasıSürdürülebilirEkolojikTarımKongresi (p. 183).

FAO (1980). Soil and plant testing as a basis of fertilizer recommendations, FAO Soils. Bulletin No.38/ 2, Rome.

FAO (2008). FAO Fertilizer and Plant Nutrition Bulletn(19).

FAO STAT (2021). Food and Agricultural Organization of the United Nation Resources,Rome,Italy:http://www.fao.org/ faostat/en/data.

Gao, Y., M. Zhang, C. Yao, Y. Liu, Z. Wangand Y. Zhang (2021). Increasing seeding density under limited irrigation improves crop yield and water productivity of winter wheat by constructing a reasonable population architecture. Agricultural Water Management 253: 106951.

Gomez, K. A., and A. A. Gomez (1984). Statistical procedures for agricultural research. John wiley and sons.

Hussain, I., E. A. Khan, U. K. Sadozai and I. Baksh (2018). Metric traits studies in wheat varieties as affected by sowing techniques. Pak. J. Bot 50(4): 1373-1378.

Intsar, H. H., and S. A. Wahid (2017). Seeding Rates influence on growth and straw yield of some bread wheat cultivars and their relationship with accumulated heat units. American Eurasian Journal of Sustainable Agriculture 11(5): 49-58.

Jemal, M. H., R. B. Fikadu, N. Kebede, T. A. Wondimu, A. Nigusieand M. T. Tesema (2022). Effects of irrigation levels and nitrogen fertilizer rate on grain yield of wheat (*Triticum aestivum* L.) at Amibara, Middle Awash, Ethiopia. Journal of Soil Science and Environmental Management 13(1): 11-16.

Khodadoost, F., B.Pasari, A. Abdulahi, A. Rokhzadi and K. Mohammadi (2022). The evaluation of two promising rainfed wheat cultivars as affected by different seeding rate in conventional and conservation tillage systems. Agricultural Engineering International: CIGR Journal, 24(2):1-14.

Li, D., D. Zhang, H. Wang, H. Li, Q. Fang, H. Liand R. Li (2020). Optimized planting density maintains high wheat yield under limiting irrigation in North China Plain. International Journal of Plant Production 14: 107-117.

Molden, D. (1997). Accounting for water use and productivity (No. 42). Iwmi**.**

Mohiy, M., and M. S. Salous(2022). Comparison between wheat conventional planting methods and raised beds method using three seeding rates under Upper Egypt conditions. SVU-International Journal of Agricultural Sciences 4(2): 34-40**.**

Othmani, A., S. Ayed, M. Rezgui, M. Melkiand J. A. T. da Silva (2020). Water r**e**gimes and seeding rates influence grain yield and water use efficiency of three durum wheat varieties. Asian Journal of Research in Biosciences: 88-97

Piper, C.S. (1966). Soil and plant analysis. Hans Publishers, Bombay, India.

Rajanna, G. A., A. S. Dhindwaland R. K. Nanwal (2017). Effect of irrigation schedules on plant-water relations, root, grain yield and water productivity of wheat (*Triticum aestivum* L.) emend. Flori and Paol] under various crop establishment techniques. Cereal Research Communications 45(1): 166-177.

Ren, A. X., S. U. N. Min, P. R. Wang, L. Z. Xue, M. M. Lei, J. F. Xueand Z. P. Yang (2019). Optimization of sowing date and seeding rate for high winter wheat yield based on pre-winter plant development and soil water usage in the Loess Plateau, China. Journal of Integrative Agriculture 18(1): 33-42.

Rowell, D. L. (1994). Soil science: method and applications. Longman publishers. Singapore: 350 pp.

Safina, S. A., E. S. M. Gheith, M. A. Saboon and O. L. A. Z. El-badry(2021). Response of three wheat varieties to nitrogen levels, seeding rates and their combination: 3-straw yield and its components. Plant cell biotechnology and molecular biology: 497-505.

Shah, W. A., Z. Hayat, R. Amin, S. Anwar,and M. Islam (2021). 29. Effect of irrigation levels and seed rates on wheat production. Pure and Applied Biology 5(4): 895-905.

Singh, R. A. (1980). Soil Physical analysis. Kalyani publishers, New Delhi. Ludhiana, India.

Singh, S., V. Singh, R. Pal, H. Trivedi, A. Narayanand M. Gautam (2023). Effect of sowing methods and irrigation levels on wheat (*Triticum aestivum* L.).Eco. Env. and Cons. 29 (January Suppl. Issue) : S170-S176.

Tegenu, G. (2021). Response of Wheat on Seed Rate and Irrigation Levels. Journal of Resources Development and Management Vol.72: 2021

Waller, R. A., and D. B. Duncan (1969). A Bayes rule for the symmetric multiple comparisons problem. Journal of the American Statistical Association 64(328): 1484-1503.

تأثير مستوى الري ومعدل التقاوى على إنتاجية القمح

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أجريت هذه التجربة بمحطة البحوث الزراعية بالمطاعنة بصعيد مصر. تم استخدام تصميم القطع المنشقة مرتين المنشقة مرتين لدراسة ثلاثة عوامل وهى : جدولة الري على أساس البخر نتح التراكمي (CPE) باستخدام معامل الوعاء (I_1= 1.2، I_2 = 1، I_3= 0.8) ووضعت في القطع الرئيسية وبلغ متوسط كمية المياه المضافة على أساس هذه أساس هذه المعدلات 2502، 2306، 2022 م3 خلال الموسمين على التوالي. ومعدلات تقاوى (S_1= 40، S_2 = S_2= 60، S_3 = 80 كجم/فدان) تم وضعها في القطع المنشقة و صنفين من قمح المكرونة (V_1= بني سويف٧، V_2 = V_2= وبني سويف ٨) والتي تم وضعها في قطع تحت المنشقة. كان لمستويات الري ومعدلات التقاوى وصنفي القمح تأثير القمح تأثير معنوي أو عالي المعنوية على جميع صفات المدروسة في الموسمين، وتحديدا اظهر المستوى الثاني من من معاملة الري (I_2) نتائج متفوقة فى المحصول ومكوناته وكفاءة استخدام المياه مقارنة بمستويي الري الآخرين، كما كان الآخرين ، كما كان معدل التقاوى 60 كجم/فدان في الموسمين هو الأعلى اداء في معظم صفات. علاوة على ذلك، أظهر أظهر صنف بني سويف 7 تفوقه في جميع صفات في هذا البحث ما عدا عدد حبوب/سنبلة حيث تفوق صنف بني سويف 8 بني سويف 8 في كلا الموسمين. أدى التـ فاعل من الدرجة الثانية بين مستوى الري المتوسط (I_2) ومعدل التقاوى 60 60 كجم/فدان (S_2) وصنف بني سويف 7 (V_1) الى أفضل إنتاجية الحبوب واعلى كفاءة في استخدام المياه بقيم بقيم 25.89 و 25.67 أردب/فدان، و1.68 و1.67 كجم/م3 في الموسمين الأول والثاني على التوالي.