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Impact of Skipping Irrigation at Different Growth Stages of Wheat on Crop Water Productivity in North Nile Delta

1- Vegetative Growth and Water Relationships

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ABSTRACT

A field trial was carried out through the two consecutive wheat growing times of year, 2020/21 and 2021/22, at Sakha Agriculture Research Station in Kafr El-Sheikh Governorate, situated in the middle northern region of the Nile Delta area. The study aims to determine the most critical growth stage of some wheat cultivars (Misr 1, 3, Sakha 95, Giza 171, Gemmeiza 9,and 10) for skipping watering. Furthermore, five irrigation treatments were implemented ; Treatment A, involved full irrigation, with no skipping of irrigation at any growth stage. Treatments B, C, D, and E involved skipping irrigation at the tillering, elongation, booting, and milking stages, respectively. Obtained results revealed that Sakha 95 followed by Giza 171 are the most suitable wheat cultivars for the area of study. The control treatment, which involved full irrigation, exhibited the greatest crop return, yield components, and water associations. Skipping irrigation at the milking stage is more tolerant to skipping watering.The crop-water function of PIW and WP were analyzed. Suitable wheat cultivars should be cultivated in the middle north of Nile Delta area are Sakha 95, Giza 171 and Gemmeiza 9 under this investigation. The study recommends that the Sakha 95 variety, followed by Giza 171 and Gemmeiza 9, are the most suitable for the northern Delta region of Egypt. When irrigation water is available, we recommend not preventing irrigation at any stage of growth. In the event of a shortage of irrigation water, irrigation can be prevented in the milky phase, as the crop loss is very slight.

Keywords: wheat, cultivars, skipping irrigation and crop- water function

INTRODUCTION

Wheat (*Triticum aestivum* L.) holds a pivotal position among cereal crops cultivated in Egypt. Its significance extends to global food security, driven by rising demand and elevated prices in the world market. Egypt annually produces approximately 50% local consumption of wheat. Hence, enhancing the output of this crop stands as the primary objective of wheat research endeavors, aimed at narrowing the gap between production and consumption of wheat.

In Egypt, the farmers depended on water sourced from the Nile River, with more than 84% of the available water resources (El-Beltagy & Abo-Hadeed, 2008). Water availability serves as a limiting factor for the production of various field crops. Achieving higher grain yields with minimal irrigation water usage is essential for promoting sustainable agriculture practices. The majority of wheat cultivation areas are concentrated along the River Nile, spanning from southern Egypt to the northern Delta region, where irrigation systems are prevalent.

For wheat cultivar variation and according to El-Hag (2017), reported that the highest values for the physiological, and yield and its components were recorded with Sids 12 compared with other cultivars. The same results were found by Singh & Singh (2013), Omar *et. al.*, (2014), El Hag (2016), and Kandil *et. al.*, (2016)

Egypt is the only country globally where agricultural production primarily relies on irrigation, known as irrigated agriculture, owing to its high aridity. Water availability in Egypt exhibits unique characteristics, notably relying heavily on the River Nile as the main source of renewable water, along with its tributaries originating from beyond the country's borders. Egypt has a specific allocation of its water resources, amounting to 55.5 billion cubic meters per annum. However, due to the high annual increase in population, the per capita water share for various purposes is declining, falling below the poverty threshold of 1000 cubic meters and rapidly approaching the scarcity line of less than 500 cubic meters in the coming decades. Irrigated agriculture stands as the main sector in terms of water consumption, accounting for about 85% of the total water supply (FAO, 2017). Furthermore, Egypt is highly vulnerable to the adverse impacts of climate change in the agricultural sector, characterized by increasing crop water requirements and decreasing yields. Consequently, effective on-farm irrigation management becomes imperative, ranking as the priority. Therefore, irrigation management plays a pivotal role in the agricultural strategy, given the limited water resources and the expanding water demand.

Drought stands as the most dominant environmental stress, affecting 32% of the 99 million hectares of wheat cultivation in developing countries (Rajaram, 2000).

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Regulated deficit irrigation, which adjusts water application according to the crop's growth stage, has been shown to result in minimal yield losses or no losses at all during non-critical stages (Shao *et.al.*,2005). Additionally, a stage-based deficit irrigation approach was reported to have an insignificant negative impact on crop productivity (Chai *et. al.*,2016). Skipping one irrigation at tillering, elongation and heading stages decreased agronomic characters and yield and its components compared with skipping at the filling stage Mehasen *et.al.*,(2014).

El Hag (2017) documented that the impact of irrigation significantly influenced agronomic traits and income and its components. Islam *et.al,*.(2018) suggested that watering during the initial three growth stages would be most beneficial for wheat production under the non-saline conditions examined in their study. Abdou *et.al.*,(2022) mentioned that wheat is one of the most consumed cereal crops. Egypt is ranked 12th globally in terms of wheat productivity among countries. Specifically, they observed a 6% yield reduction when 50% of the crop's evapotranspiration demand (ETc) was applied at the booting stage. Furthermore, wheat yield loss was further reduced to 4% or 6% when 95% or 90% of the crop's evapotranspiration demand were applied, respectively. Thus, this research was proposed to study Impact of skipping irrigation at different growth stages of wheat on crop water productivity in North Nile Delta.

MATERIALS AND METHODS

Characteristics of the experimental site

A field trial was conducted during 2020/21 and 2021/22, at Sakha Agricultural Research Farm in Kafr El-Sheikh Governorate, located in the middle north Nile Delta. The Latitude of the site is 31.113228, the longitude is 30.949099 and the altitude is 6 meters above mean sea level.

Climatic condition:

From the agro-meteorological station at trial, such elements were recorded as presented in Table 1.

Table 1 . Climatic elements at Sakha: temperature (T,$_0$C), relative humidity (RH%), Wind speed(u_e m sec^{-1}), Pan evaporation (EP, mm day^{-1}) and rainfall (Rf, mm day^{-1}).

Month	2020/21					2021/22				
	T,$_0$C	RH,%	μ_2, meter/sec	EP mm /day	Rf Millimeter/ day	T, $_0$C	RH, %	U_2, m sec-1	EP Millimeter /day	Rf Millimeter/ day
Nov.	21.5	71.7	0.54	2.3	12.4	22.7	73.1	0.75	3.9	12.7
Dece.	18.5	72.5	0.53	2.4	19.0	16.2	74.0	0.72	4.0	20.7
Janu	17.3	73.1	0.46	2.5	14.1	13.8	75.4	0.72	3.9	50.4
Febr.	16.6	72.6	0.68	3.6	-	15.1	70.7	0.96	3.5	25.3
Marc	18.5	65.0	0.90	4.0	5.4	15.1	69.1	1.14	3.8	5.3
Apri	23.5	60.0	1.10	6.3	-	23.6	60.3	1.33	5.5	-
May	28.0	58.3	1.13	8.9	-	25.9	60.6	1.45	6.5	-
Mean	20.6	67.6	0.76	4.3	50.9	18.9	69.0	1.01	4.4	114.3

Soil properties:

Before wheat cultivation, physical, soil-water constants and chemical analysis were determined. The soil texture, determined from particle size distribution, was analyzed according to the method described by Gee and Bauder (1986). The soil-water constants, including field capacity (FC) and permanent wilting point (PWP), were determined using the pressure membrane method, as outlined by Klute (1986). Bulk density (Db) was determined following the method outlined by Black et al. (1965). In addition, chemical analysis was conducted following the procedure outlined by Jackson (1973). tables (2) and (3) counting soil analysis.

Table 2. Particle size distribution and soil-water constants of the Sakha studied experiments site.

Soil depth cm	Particle size distribution			Texture	Soil-water constants			
	Sand%	Silt%	Clay%		F.C.,%	W.P.%	A.W.,%	Db.,Mgm^3
0-15	17.9	28.7	50.4	Clay	44.3	24.1	20.2	1.1
15-30	20.4	28.4	49.3	Clay	39.6	21.5	18.1	1.2
30-45	26.8	20.6	48.6	Clay	36.7	19.9	16.8	1.3
45-60	24.6	25.0	42.8	Clay	34.2	18.6	15.6	1.3
Mean	22.4	25.7	47.8	Clay	38.7	21.0	17.7	1.2

Where: F.C.,% = soil field capacity, A.W.,%= available soil water Db,Mgm^{-3}=Soil bulk density. W.P.,%=wilting point,

Table 3. Chemical properties of the trial site.

Soil depth cm	Soluble ions,mmo1c*							
	Cations				Anions			
	Ca^{++}	Mg^{++}	Na^+	K^+	Co_3^-	Hco_3^-	Cl^-	So_4^-
0-15	4.2	2.1	7.9	0.1	0.0	2.8	7.6	3.9
15-30	8.6	3.9	8.5	0.2	0.0	2.9	8.8	9.5
30-45	7.7	4.8	9.1	0.2	0.0	2.4	6.7	12.7
45-60	10.4	5.2	11.0	0.2	0.0	2.3	6.0	18.8
Mean	7.7	4.0	9.1	0.2	0.0	2.6	7.3	11.2

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Field trial layout:

A split-plot design with three replicates was used. The irrigation treatments were assigned as the main plots, while wheat cultivars were the subplots.

irrigation treatments were implemented as follows:

A = without skipping (control)
B = skipping irrigation (SI) at the tillering stage
C = SI at the elongation stage
D = SI at the booting stage
E = SI at the milking stage

Six wheat (*Triticum aestivum* L.) cultivars of Misr 1, 3, Sakha 95, Giza 171, Gemmeiza 9 and 10 (Table 4) were grown.

Dates of sowing were the last week of November 2020 and 2021, while the harvesting dates were at last week of May 2021 and 2022 during the two seasons of the study.

Table 4 . Name and pedigree of six bread wheat cultivars.

Name	Pedigree
1-Misr 1	OASIS/SKAUZA//4*BCN/3/2*PASTOR CMSSOOYO1881T-OSOM-O50M-O3OY-O3OM-O30WGY-33M-OY-OS
2-Misr 3	CMSS00Y01881T-050M-30Y-030M-030WGY-33M-0Y-0S CM58924-1GM-OGM
3-Sakha 95	PASTOR//SITE/MO/3/CHEN/AEGILOPS SQUARROSA(TAUS)//BCN/4/WBLL1 CMAO1YY158S-04O0POY-040M-030ZTM-040SY-26M-OY-OS
4-Giza 171	SAKHA 93/GEMMEIZA 9 S.6-1GZ-4GZ-1GZ-2GZ-OS
5-Gemmeiza 9	Ald"S"/Huas//Cmh 74A. 630/Sx CGM 4583-5GM-1GM-OGM
6-Gemmeiza 10	MAYA74'S"/ON//1160-47/3/BB/GLL/4/CHAT"S"/5/CROW"S". CGM5820-3GM-1GM-2GM-OGM

Plot area (3.5m x 0.2 m x 6 rows) = 4.2 m^2

All agronomic performs were carried out by the recommendations provided by the Agricultural Research Centre (ARC), except irrigation, for which five .

Data collected :

Agronomic parameters

*Number of days to 50% heading.

*Number of days to physiological maturity.

*Grain filling period.

*Plant height at harvest.

*TGW.(1000 Grain weight)

*Biological yield. (ton/fed.)

*Straw yield (ton/fed.)

*Grain filling rate.

*No. of spikes/m$^{2.}$

*No. of kernels/spike.

*Grain yield. (ton/fed.)

* Harvest index.

A. Water relations

Applied irrigation water

Soil moisture depletion or crop consumptive use

C. Crop-water functions

*Productivity of irrigation water

*Water productivity

D- Water relations

Applied irrigation water

Irrigation water was controlled and measured by the rectangular weir as follows Michael (1978):

$$Q = 1.84\ L\ H^{1.5} \ldots\ldots\ldots\ldots\ldots\ldots\ldots..1$$

Where:

Q = water discharge (m^{3}sec^{-1})
L = width of weir (cm)
H = head above weir crest (cm)

Consumptive use (CU)

Consumptive use or so-called actual consumed water by the growing crop using soil moisture depletion in the effective root zone as follows Hansen *et. al,*. (1979):

$$CU = S_2\text{-}S_{1/100} *D_b *d *A \ldots\ldots\ldots\ldots\ldots2$$

Where:

CU = water consumed by the growing crop
S_2 = soil moisture percentage, 48 hours after irrigation
S_1 = soil moisture percentage before next irrigation as well as at Harvesting
$^D{}_{b}$ = bulk density (Mgm^{-3}) in the effective root zone
d = effective root zone of 60(cm)
A = irrigated area(m^2).

Crop-water functions:

Water productivity (WP)

Water productivity reflects the capability of the crop consumed water to produce the marketable yield Ali *et.al*,.(2007):

$$WP = Y/CU \ldots\ldots\ldots\ldots\ldots\ldots3$$

Where:

WP = water productivity (kgm^{-3} consumed water)
Y = marketable yield(kg)
CU = seasonal consumptive use(m^3)

Productivity of irrigation water (PIW)

Production of irrigation water reflects the capability of applied irrigation water in producing the marketable yield Ali *et. al*,. (2007):

$$PIW = Y/IW \ldots\ldots\ldots\ldots\ldots\ldots4$$

Where:

PIW = productivity of irrigation water (kgm^{-3}) irrigation water Applied.
Y = marketable yield (kg)
IW = applied irrigation water(m^3).

Statistical analysis

The agronomic data collected were subjected to analysis of variance, following the procedure outlined by Gomez and Gomez (1984), utilizing the MSTAT-C (1990) computer software. Means of cultivars and irrigation treatments were compared using the Duncan Multiple Range Test, as described by Duncan (1955).

RESULTS AND DISCUSSION

A. Effect of skipping irrigation treatments (SK):-

Data presented in Table (5) shows that the highly significant effects for days to heading and maturity were observed with the skipping of irrigations and significant and highly significant effects were observed on the grain filling period and highly significant for grain filling rate in 2020/21 and 2021/22 growing seasons, respectively. Early heading was due to skipping irrigation at the elongation and booting stages in both seasons. The earliest heading were (105.1 and 101.3 days) in the 2020/21 and 2021/22 seasons, respectively. Meanwhile skipping irrigation at elongation stage cased to early maturity (151.7 and 147.7 days) in 2020/21 and 2021/22 Skipping irrigation at the elongation caused lowest grain filling period in 2020/21 and 2021/22 seasons. The lowest values were (46.6 and 44.5 days) in the 2020/21 and 2021/22. The effect of skipping irrigation or reducing the number of irrigations led to a decrease in vegetative and maturing periods. This decrease might be attributed to adequate soil moisture (well-watered conditions) and optimal nutrient levels. Conversely, the treatment (Sk o) showed an increase in the period of vegetative growth and the number of days of maturity. Skipping irrigation at the elongation stage caused the lowest grain filling rate in 2020/21 and 2021/22 (Table 7). The lowest values were (47.348 and 46.374 kg/day/fed.) compared with well irrigation (Sk o) which recorded (68.699 and 66.570 kg/day/fed.) in 2020/21 and 2021/22. The effect of skipping irrigation was caused to a decreased grain-filling period. Variants in the tallest plant due to skipping irrigation were highly significant and significant in 2020/21 and 2021/22 (Table 6). Skipping at the elongation stage (Sk2) resulted in the shortest wheat plant heights (100.8 and 99.7 cm), while Sk 0 resulted in the tallest plant heights (107.7 and 106.1 cm) in 2020/21 and 2021/22 seasons, respectively (Table 7). Reducing irrigations at this stage leads to a decrease in available nutrition, and a decrease in plant height due to decreasing both size and number of cells between the internodes, which results in decreasing plant height. Data presented in Table (6) indicated that the impact of skipping irrigation on the number of spikes/m2 was highly significant in 2020/21 and 2021/22. Skipping irrigation treatment at the elongation stage (Sk 2) had recorded the lowest number of spikes/m2 (297.4 and 291.3), meanwhile, well irrigation (Sk 0) recorded the highest number of spikes/m2 (350.9 and 325.7) in and 2021/22, respectively. It is well known that tiller initiation occurs in the early stages of growth, but the number of spikes/m2 is influenced by the availability of nutrients and moisture in subsequent stages. The effects of skipping irrigation were significant on TGW and number of grains/spike in the 2020/21 season and insignificant in the 2021/22 season (Table 7). Skipping irrigation at the booting stage reduced TGW (39.9 g) compared with control treatment (well irrigation) which recorded(41.7g) in the 2021/22 season. Skipping irrigation at all growth stages reduces the number of grains/spike. The lowest number of grains/spike was recorded when skipping irrigation at the tillering stage compared with the control treatment (46.4 and 53.8). Skipping irrigation has a highly significant effect on biological yield in 2020/21 and 2021/22. Skipping irrigation at the elongation stage reduced the biological yield to 6.767 and 6.630 ton/fed., compared with the control at 8.265 and 8.020 ton/fed. in the 2020/21 and 2021/22 seasons, as shown in Table (8). Skipping irrigation at various stages plays a critical role in wheat productivity, as demonstrated in Tables (7 and 8). Grain yield in the 2020/21 and 2021/22 seasons was affected significantly by skipping irrigations. Skipping irrigation at the elongation stage resulted in reduced grain yield, recording (2.206 and 2.140 ton/fed.), compared with the control (3.208 and 3.080 ton/fed.) in the 2020/21 and 2021/22 seasons, respectively. The decrease in grain yield due to skipping irrigation at tillering, elongation, booting and after heading was (24.1, 31.2, 13.3 and 5.2%) in 2020/21t season and (26, 31, 12 and 3%) compared with control treatment in the 2021/22 season. Skipping irrigation affected highly significant on straw yield in the 2020/21 and 2021/22 seasons, respectively (Table 8). Skipping irrigation at the elongation stage reduced the straw yield and recorded(4.561 and 4.490 tons/fed.), compared with control (5.057 and 4.940 tons/fed.) ,in both seasons, respectively.

Data shown in Table (9) illustrates that skipping irrigation significantly affected highly significant on harvest index in both seasons. skipping irrigation at the elongation stage reduced the harvest index and recorded (32.6 and 32.3%) compared with full irrigation (control) which recorded(38.8 and 38.4%) in both seasons, respectively.

Jamal *et.al.,* (1996) found that the grain yield of different wheat cultivars was significantly compacted by water deficit at different growth stages, with the greatest loss occurring at the anthesis stage. Water deficit during anthesis reduces pollination, resulting in a lower number of grains/spike, which ultimately leads to a reduction in grain yield (Ashraf, 1998). Water stress imposed during later stages may also lead to a reduction in the number of kernels/spike and TGW (Gupta *et.al.,* 2001). Onyibe (2005) found that increasing the irrigation regime, however, led to an increase in days to maturity. Zhang *et. al.,* (2007) observed that irrigation should be applied, once at the tillering and once at the heading. Hassan *et.al.,*(2013) observed that increasing the number of irrigations significantly improved plant height and yield components. Avoiding an irrigation at the tillering, elongation, and heading stages resulted in decreased heading, plant height, number of spikes/m^2, TGW, grain yield, and straw yield compared with skipping irrigation at the filling stage. Mubeen *et.al.,*(2013) noticed that watering at the tillering, elongation, booting, and grain-filling stages resulted in higher yields.

Omitting irrigation during tillering, elongation, and heading stages resulted in reduced heading, plant height, number of spikes/m^2, TGW and yield compared to treatments where irrigation was skipped during the filling stage (Mehasen *et. al.,* 2014). El-Hag (2017) found that an increased number of irrigation increased yield and its components. Islam *et.al.,* (2018) suggested that irrigating during the initial three growth stages would provide the most beneficial irrigation regime for wheat production in the studied non-saline conditions. This finding is corroborated by similar results reported by Onyibe (2005), Monclus *et.al.,* (2009), Hossein *et. al.,* (2012), Mubeen *et.al.,* (2013), Omar *et.al,.* (2014), Singh and Singh (2013), El- Hag (2016) and El-Hag (2017).

B-Varietal Difference:

Data in Tables (5, 6, 7, and 8) show varietal differences which a highly significant in all traits Throughout 2020/21 and 2021/22 seasons of the investigation, Gmmaiza 9 has the highest number of days to heading, 109.1 and 105.6 days, while Gemmeiza 10 and Sakha 95 displayed the lowest number of days to heading at 103.9 & 101.2 days, respectively, in the 2020/21 and 2021/22 seasons. Regarded the maturity date Gemmeiza 10 was documented as the lowest days to maturity 148.6 and 146.5 days in the 2020/21 and 2021/22 seasons, respectively. Conversely, Gemmeiza 9 and Giza 171 demonstrated the highest values, with 156.8 and 151.1 days, respectively, recorded in the 2020/21 and 2021/22 seasons. For the grain-filling period Sakha 95 and Giza 171 were recorded as the highest values (48.7 and 48.5 days), Meanwhile, Gemmeiza 10 exhibited the lowest grain-filling period, with 44.7 and 44.8 days recorded in both seasons, respectively. Sakha 95 wheat cultivar recorded the highest values for grain filling rate (26.156 & 25.704 kg/day/fed.) in the 2020/21 and 2021/22 seasons. The lowest grain filling rate recorded by Gemmeiza 9 (22.526 kg/day/fed.) in the 2020/21 season and Misr 1 (21.988 kg/day/fed.), in the 2021/22 season (Table 6). Data presented in Table (6) showed the varietal difference for plant height, Sakha 95 recorded the tallest plant (109.0 & 110.3 cm) and Misr 3 recorded the shortest plant (95.3 and 93.8 cm) in the 2020/21 & 2021/22 seasons. Sakha 95 consistently recorded the highest number of spikes/m2, 342.3 and 349.5 in the 2020/21 and 2021/22 seasons. Misr 1 and Gemmeiza 10 verified the lowest number of spikes/m2 (306.7and261) in the 2020/21 & 2021/22 seasons, Data shown in Table (7). There was a clear varietal difference observed for TGW, with Giza 171 recording the highest values of 46.7 and 43.8 g, while Misr 1 verified the lowest weight of 34.7 & 31.8 g in the 2020/21 and 2021/22 seasons. Sakha 95 and Gemmeiza 10 exhibited the lowest number of grains per spike, with values of (45.6 and 58.3), respectively. Conversely, Giza 171 and Gemmeiza 9 displayed the highest number of grains per spike, 51.7 and 66.9 in the 2020/21 and 2021/22 seasons. The findings outlined in Table (7) demonstrate a significant effect on wheat cultivars on biological in the 2020/21 & 2021/22 seasons. Giza 171 exhibited the highest biological yield, producing (8.044 and 7.850 ton / fed.) in 2020/21 and 2021/22 seasons. The lowest biological yields of (7.178 and 7.000 ton/fed.), were achieved with Gemmeiza 10 in the 2020/21 and 2021/22. Furthermore, Table (8) data illustrates a highly significant effect of wheat cultivars on grain yield in the 2020/21 % 2021/22. Sakha 95 is superior the highest grain yield 3.033 and 2.930 ton/fed. in the 2020/21 & 2021/22. Meanwhile, Gemmeiza 10 exhibited the lowest grain yield, with values of 2.520 and 2.440 ton/ fed. , compared to other cultivars. Conversely, Misr 1 and Giza 171 demonstrated the highest straw yield, recording values of 5.129, 5.020, 5.138, and 5.040 ton/fed.), in the 2020/21 and 2021/22 seasons. At the same time Misr 3 was recorded (4.442 and 4.360 ton/fed. in the 2020/21 and 2021/22 seasons. Misr 3 recorded the highest harvest index 38.5 and 38.2% and Misr 1 recorded the lowest harvest index 33.3 and 33.0% in 2020/21 and 2021/22 seasons. Similar results were obtained with Gupta et.al., (2001), Ali and Amin (2007), Monclus, et. al.(2009),and Ghanbari (2010). Hossein, et.al.,(2012),.Hassan et.al., (2013), Mubeen et. al., (2013), Singh and Singh (2013), Mehasen, et. al., (2014) . Omar et. al., (2014), Kandil, et.al., (2016), El hag- Dalia (2017) and Islam et.al.,(2018).

Table 5. Effect of skipping irrigation (Sk) at different growth of wheat on the number of days to heading, maturity and grain filling period on some wheat cultivars in 2020/21 and 2021/22 growing seasons

Trait	No. days to heading		No. days to maturity		Grain filling period	
Treatment	2020/21	2021/22	2020/21	2021/22	2020/21	2021/22
Irrigation treatments						
Sk 0	106.9a	103.4a	153.6a	151.4a	46.7a	48.1a
Sk 1	105.5c	101.9b	152.6b	148.1c	47.1d	46.2b
Sk 2	105.1c	103.2a	151.7c	147.7c	46.6e	44.5c
Sk 3	106.2b	101.3b	153.4a	149.1b	47.2c	47.7a
Sk4	106.4b	103.1a	153.6a	151.2a	47.2b	48.1a
F test	**	**	**	**	*	**
Wheat cultivars						
Misr 1	107.3b	102.7b	153.5b	150.8a	46.3c	48.1a
Misr 3	106.3c	101.7c	152.7c	148.6c	46.5c	46.9b
Sakha 95	104.1e	101.2c	152.8c	149.4b	48.7a	48.2a
Giza 171	105.6d	102.6b	153.3bc	151.1a	47.7b	48.5a
Gemmeiza9	109.1a	105.6a	156.8a	150.6a	47.7b	45.0c
Gemmeiza 10	103.9e	101.7c	148.6d	146.5d	44.7d	44.8c
F test	**	**	**	**	**	**
Interaction effects						
Sk x Cu	NS	**	NS	**	NS	**

Table 6 . Effect of skipping irrigation at different stages of wheat on grain filling rate, plant height, and number of fertile tillers on some wheat cultivars in 2020/21 and 2021/22 growing seasons

	Grain filling rate		Plant height (cm)		No. spikes / m^2	
	2020/21	2021/22	2020/21	2021/22	2020/21	2021/22
Irrigation treatments						
SK 0	68.699a	66.590a	107.4a	106.1a	350.9a	325.7a
SK 1	51.729d	48.221d	101.9b	100.3b	314.1c	297.7b
SK 2	47.348e	46.374e	100.8b	99.7b	297.4d	291.3c
SK 3	58.901c	57.768c	107.2a	105.2a	335.3b	325.7a
SK 4	64.477b	63.704b	103.6ab	105.2a	339.5b	325.7a
F test	**	**	**	*	**	**
Wheat cultivars						
Misr 1	55.682e	52.352b	107.3ab	110.0a	306.7c	338.3a
Misr 3	60.496c	59.854a	95.3d	93.8c	333.9ab	347.4a
Sakha 95	62.276a	61.200a	109.0a	110.3a	342.3a	349.5a
Giza 171	60.846b	60.503a	104.7bc	103.0b	319.7bc	290.3b
Gemmeiza9	53.634f	52.453b	102.0c	101.3b	341.6a	292.8b
Gemmeiza 10	56.451d	52.827b	103.3c	101.3b	320.3bc	261.0c
F test	**	**	**	**	**	**
Interaction effects						
SK x Cu	NS	NS	NS	**	**	NS

Table 7. Effect of skipping irrigation at different stages of wheat on 1000-grain weight, number of grains/spike and biological yield (ton/fed.) on some wheat cultivars in 2020/21 and 2021/22 growing seasons

Treatments	TGW(g)		No kernels/spike		Biological yield (ton/fed.)	
	2020/21	2021/22	2020/21	2021/22	2020/21	2021/22
Irrigation treatments						
SK 0	41.7a	39.9	53.8a	63.9	8.265a	8.020a
SK 1	40.3bc	39.4	46.4b	62.6	7.105c	6.820c
SK 2	40.7a-c	39.3	49.0b	62.1	6.767d	6.630d
SK 3	39.9c	37.8	47.4b	60.2	7.663b	7.470b
SK 4	41.2ab	37.2	49.0b	64.5	8.069a	7.990a
F test	*	NS	*	NS	**	**
Wheat cultivars						
Misr 1	34.7e	31.8d	46.7b	61.7bcd	7.707b	7.52b
Misr 3	40.5c	40.3b	51.0a	59.8cd	7.252c	7.07c
Sakha 95	41.3b	39.5bc	45.6b	64.0abc	7.909ab	7.71ab
Giza 171	46.7a	43.8a	51.7a	65.3ab	8.044a	7.85a
Gemmeiza9	39.9d	38.4c	50.1a	66.9a	7.356c	7.17c
Gemmeiza 10	41.3b	38.6bc	49.7a	58.3d	7.174c	7.00c
F test	**	**	**	**	**	**
Interaction effects						
SK x Cu	NS	*	NS	Ns	NS	NS

Table 8. Effect of skipping irrigation at different stages of wheat on grain yield (ton/fed.), straw yield and harvest index on some wheat cultivars in 2020/21 and 2021/22 seasons.

treatments	Grain yield (ton/fed.)		Straw yield (ton/fed.)		HI (%)	
	2020/21	2021/22	2020/21	2021/22	2020/21	2021/22
Irrigation treatments						
SK 0	3.208a	3.080a	5.057a	4.940a	38.8a	38.4a
SK 1	2.436d	2.290d	4.669c	4.530c	34.3d	33.6d
SK 2	2.206e	2.140e	4.561c	4.490c	32.6e	32.3e
SK 3	2.780c	2.720c	4.883b	4.750b	36.3c	36.5c
SK 4	3.042b	2.980b	5.027a	5.010a	37.9b	37.3b
F test	**	**	**	**	**	**
Wheat cultivars						
Misr 1	2.578c	2.490c	5.129a	5.020a	33.3c	33.0d
Misr 3	2.810b	2.720b	4.442d	4.360d	38.5a	38.2a
Sakha 95	3.033a	2.930a	4.875b	4.780b	38.2a	37.8a
Giza 171	2.907b	2.810b	5.138a	5.040a	36.1b	35.6b
Gemmeiza9	2.557c	2.470c	4.799bc	4.700bc	34.6bc	34.3c
Gemmeiza 10	2.520c	2.440c	4.653c	4.560c	35.0b	34.8c
F test	**	**	**	**	**	**
Interaction effects						
SK x Cu	NS	NS	NS	NS	NS	NS

C-Interaction effect:-

The interaction effect between skipping and cultivar on heading, maturity date, grain filling period, plant height and TGW was highly significant in 2021/22 while a number of spikes/m^2 was highly significant in 2020/21 (Table 9). In general, Gemmeiza 10 had the lowest number of days to heading (99.3 days) with skipping irrigation at the booting stage in the second season. Regarded for number of days to maturity Gemmeiza 10 recorded the lowest number of days 144.3 days with skipping irrigation at the elongation stage in the 2021/22 season. For the grain filling period Gemmeiza 9 and Gemmeiza 10 were recorded the shortest time of 42.7 and 42.0 days in the 2021/22 season .Misr 3 recorded the shortest plant height 91.67cm under skipping irrigation at the elongation stage in the second stage. Giza 171 had the lowest number of spikes/m^2 240.7 with skipping irrigation at elongation stage in the 2021/22 season. Misr 1 and Giza 171 had the lowest TGW 30.9 and 43.3 g with skipping at the milking and elongation stage, respectively, in the 2021/22 season.

Irrigation water :

Values of applied irrigation (IW) are tabulated in Table (10) and the average data from 2020/21 & 2021/22 is depicted in Figure (1). The mean irrigation water (IW) can be arranged in descending order as follows: 40.5 cm > 36.1 cm > 33.6 cm > 32.2 cm = 32.2 cm for skipping irrigation A, B, D, C, and E, respectively. The data indicates that treatment A, which involves full irrigation at all growth stages, has the highest value of IW. Conversely, treatments involving skipping irrigation have lower values. When compared to the control treatment A with full irrigation, the other treatments exhibit decreased IW values, the decreasing percentage in IW are 10.9, 17.0 and 20.5 for the stated skipped irrigation treatments, respectively. Therefore, skipping irrigation at the tillering stage has the lowest decrease in IW and vice versa with skipping irrigation at either the elongation or flowering stage.

These findings align with those findings by Abdrabbo *et.al*,.(2013), El-Mansoury *et.al.*,(2019), and Meleha *et.al.*,(2020). Additionally, Staricka *et.al.*,(2016) emphasized the crucial role of irrigation management in agriculture and, importance that saved water could be used to irrigate new lands. Moreover, Abdou *et.al.*,(2022) emphasized that irrigation management plays a significant role in the agricultural sector, especially in the context of decreasing water supply and increasing water demand.

Table 9. Interaction effect between skipping irrigation and wheat cultivars on days to heading, days to maturity and grain filling period in 2021/22 , plant height (cm), number of spikes//m² and TGW in 2020/21 .

Skipping Irrigation	Cultivar	No. days to heading	No. days to maturity	Grain filling period	Plant height (cm)	No spikes/m²	TGW
		2021/22	2021/22	2021/22	2021/22	2020/21	2021/22
SK o	Misr 1	103.3d-f	150.3ef	47.0b-f	110ab	328.7b-h	33.2kl
	Misr 3	102fg-i	151cde	49.0a-c	93.67e	373.7a	42.07b-e
	S 95	101.7fg-j	152.7ab	51.0a	113.3a	366.7ab	42.3b-e
	G 171	104c-e	152bcd	48.0a-d	105b-d	360.7a-c	48.6a
	Gem 9	106.7a	153.7a	47.0b-f	103.3b-d	354.3a-d	38.4d-j
	Gem 10	102.7e-h	149fgh	46.3c-g	103.3b-d	321.3c-h	34.7j-l
SK 1	Misr 1	101.3g-j	151cde	49.7a-c	103.3b-d	285.7h	31.87l
	Misr 3	101h-j	147ij	46.0c-g	100.0d	313.3d-h	41.33b-g
	S 95	100.3-jk	147ij	46.7b-f	103.3b-d	301.7f-h	42.13b-e
	G 171	102.7e-h	150.3ef	47.7a-e	103.3b-d	305.3e-h	43.33b
	Gem 9	104.7b-d	148.3g-i	43.7f-h	100.0d	338.3a-f	37.23h-j
	Gem 10	101.3g-j	144.7l	43.3f-h	101.7cd	340a-f	40.2b-h
SK 2	Misr 1	104c-e	150.7de	46.7b-f	103.3b-d	294gh	31.73l
	Misr 3	102.7e-h	146.7jk	44.0e-h	91.67e	291gh	41.8b-f
	S 95	102.7e-h	146.7jk	44.0e-h	108.3a-c	339a-f	40.43b-h
	G 171	102.3e-h	150ef	47.7a-e	101.7cd	240.7i	42.33b-d
	Gem 9	105.3a-c	148hij	42.7gh	100.0d	327.7b-h	39.07c-i
	Gem 10	102.3e-h	144.3l	42.0h	100.0d	292gh	40.5 b-h
SK 3	Misr 1	102f-i	152.3a-c	50.3ab	110ab	311.7d-h	31.17l
	Misr 3	101h-ij	147.3ij	46.3c-g	101.7cd	341.7a-f	38.87c-i
	S 95	100jk	148h-j	48.0a-d	110.0ab	345a-f	36.67h-k
	G 171	100jk	151c-e	51.0a	110.0ab	341.7a-f	42b-e
	Gem 9	105.7ab	150.3ef	44.7d-h	103.3b-d	341.7a-f	39.17c-i
	Gem 10	99.3k	145.3kl	46.0c-g	108.3a-c	330a-g	39.07c-i
SK 4	Misr 1	103e-g	149.7efg	46.-f	110.0ab	313.3d-h	30.9l
	Misr 3	101.7fg-j	151cde	49.3a-c	91.67e	350a-d	37.6g-j
	S 95	101.3g-j	152.7ab	51.3a	110.0ab	359a-c	36i-k
	G 171	104c-e	152b-d	48.0a-d	103.3b-d	350.3a-d	42.67bc
	Gem 9	105.7ab	152.7ab	47.0b-f	103.3b-d	346a-e	37.97f-j
	Gem 10	102.7e-h	149f-h	46.3c-g	103.3b-d	318.3c-h	38.33e-j

Table 10. Seasonal irrigation water ($m^3 fed^{-1}$ and cm) for wheat as affected by different irrigation treatments in 2020/21 and 2021/22.

treatment	2020/21		2021/22		Average	
	m^3	cm	m^3	Cm	m^3/fed.	Cm
A	1620.4	38.6	1782.4	42.4	1761.4	40.5
B	1467.4	34.9	1562.9	37.2	1515.2	36.1
C	1310.8	31.2	1389.5	33.1	1350.3	32.2
D	1361.8	32.4	1463.8	34.9	1412.7	33.6
E	1301.7	31.0	1405.7	33.5	1353.7	32.2

A: irrigation at all growth stages (control). B= (Sk1), C= (Sk2). D= (Sk3), E= (Sk4).

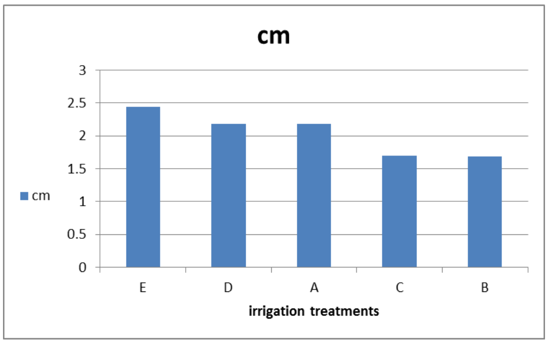


Fig. 1. average seasonal irrigation water (cm) for different irrigation treatments

Consumptive use (CU)

The mean values of seasonal consumptive use along with their rates are presented in Table 11. The seasonal values of CU have almost the same trend as IW. Full irrigation treatment A with no skipping watering at any growth stage has the highest average value of seasonal CU with its rate of 34.3 cm and 2.1mmdayy^{-1}, respectively. The average mean seasonal consumptive use (CU) can be arranged in descending order as follows: 34.3 cm > 33.1 cm > 30.6 cm > 30.1 cm > 29.3 cm for treatments A, B, C, D, and E, respectively. The reduction of skipping irrigation treatments compared with the control treatment A is 3.5, 10.8, 12.2 and 14.6 % for skipping irrigation treatments B, C, D and E, respectively.

The found results are in the same line as that obtained with Samiha Ouda *et.al.*,(2021). They revealed that when wheat with 50% Etc is at booting stage, a yield reduction of 6% could be attained. Moreover, a yield reduction of 4 or 6% at 90 or 95% is applied as irrigation water.

Table 11. Mean seasonal consumptive use (CU, cm) and its rate(mmday^{-1}) for wheat cultivars as affected by skipping irrigation in 2020/21 and 2021/22.

treatments	1st season		2nd season		Average	
	Seasonal (cu , cm)	Rate mm day^{-1}	Seasonal (cu ,cm)	Rate mm day^{-1}	Seasonal (cu , cm)	Rate mm day^{-1}
A	34.1	2.1	34.0	2.1	34.3	2.1
B	33.1	2.1	33.1	2.1	33.1	2.1
C	30.6	1.9	30.5	1.9	30.6	1.9
D	30.5	1.9	29.8	1.8	30.1	1.9
E	29.0	1.8	29.5	1.8	29.3	1.8

Crop-water functions

Values of both parameters of production of irrigation water (PIW) and water productivity (WP) are presented in Tab le (12). Regarding PIW, the values can be arranged in descending order as follows: 2.22 kg/m³ > 1.95 kg/m³ > 1.78 kg/m³ > 1.61 kg/m³ > 1.56 kg/m³ of applied water for treatments E, D, A, C, and B, respectively. For WP, it is clear that its values can be arranged in descending order as 2.44>2.18=2.18>1.70>1.69 kgm-3 consumed water for treatments E, A, D, B and C, respectively.

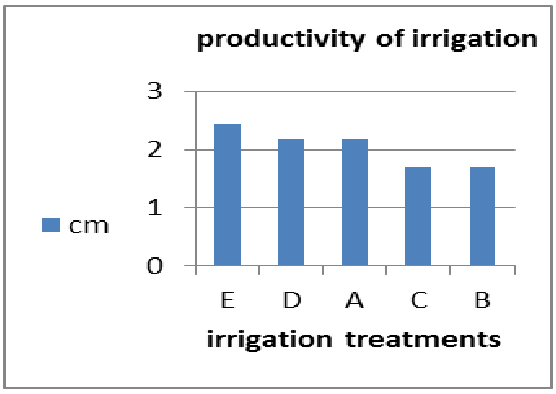
It should be noted that PIW and WP depend upon marketable yield as the nominator and either applied irrigation water and/or crop consumed water as dominator. In other words, parameters are due to its lowest values of IW and Cu. Meaningfully, we should keep in our attention that we must take both yield and water when we determine PIW and WP. Therefore, with abundant of water supply, it is advisable to follow the control non-skipping irrigation treatment, otherwise under water shortage follow skipping irrigation at the booting and/or milking growth stage.

These results are consistent with those found by Karrou *et.al.*,(2012), who found that a 15% reduction in wheat yield occurred when irrigation was applied at 78% of full irrigation. Additionally, Meleha *et.al.*,(2020) demonstrated that the highest mean water productivity (WP) was achieved using the bed broadcast planting method.

Figures (2 and 3) represent crop-water functions of both PIW and WP for different irrigation treatments. Therefore, with abundant of water supply, it is advisable for watering wheat to follow the control non-skipping irrigation, otherwise under water shortage, follow skipping irrigation at the booting and/or milking stage due to its high crop yield.

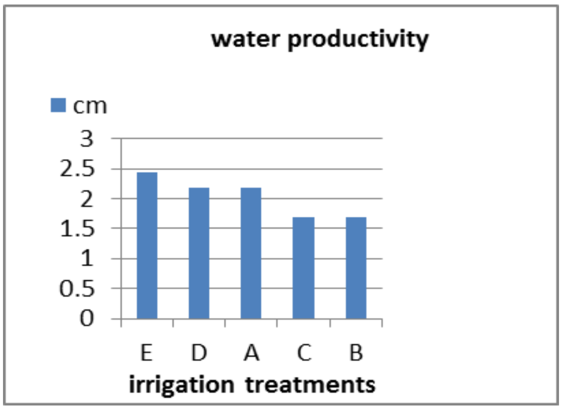
Table 12. Productivity of irrigation water (PIw, kg m^{-3}water applied) and water productivity (WP, kgm^{-3}water consumed) as affected by irrigation treatments and wheat cultivars in 2020/21 and 2021/22.

Treatments	Gain yield kg/fed.	Irrigation water m^3/fed.	Consumptive use, m^3/fed.	Crop water functions	
				PIW, kgm^{-3}	WP, kgm^{-3}
A	3144.0	1761.4	1440.6	1.78	2.18
B	2363.0	1515.2	1390.2	1.56	1.70
C	2173.0	1350.3	1289.4	1.61	1.69
D	2750.0	1412.7	1264.2	1.95	2.18
E	3011.0	1353.7	1234.8	2.22	2.44



D,1.95 kg/m3 A,1.70 kg/m3
C,1.61 kg/m3 E,2.22 kg/m3
B,1.56 kg/m3
1 m3 applied irrigation water produces

Fig. 2. productivity of irrigation water (PW, kg m^{-3} water applied) as affected by different irrigation treatments of wheat.



E,2.44 1 m3 D,2.18 1 m3
A,2.18 1 m3n C,1.70 1 m3
B,1.69 1 m3
1 m3 consumed water produced

Fig. 3. Water productivity (WP, kg m-3 consumed water as affected by different irrigation treatments of wheat.

CONCLUSION

Suitable wheat cultivars that should be cultivated in the middle north of the Nile Delta area are Sakha 95, Giza 171 and Gemmeiza 9. In case of abundant irrigation water, it is advisable to provide wheat with full irrigation at all growth stages. In case of water shortage, the milking stage is the less stage which affected by such a situation. On the other hand, tillering , elongation, and booting stages are the most critical ones i.e. irrigation should be done at those stages. Productivity should be taken into consideration both crop yield and water. Skipping one irrigation saved a pronounced amount of irrigation water to cultivate a new land.

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تأثير حرمان ري بعض أصناف القمح عند أطوار النمو المختلفة على الانتاجية المائية بمنطقة شمال دلتا النيل

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[٣] قسم المقننات المائيه- معهد بحوث الاراضى والمياه- مصر

الملخص

اقيمت تجربة حقلية خلال موسمى الزراعة ٢٠٢٠/٢١ و٢٠٢١/٢٢ بالمزرعة البحثية بمحطة البحوث الزراعية بسخا- وسط شمال دلتا النيل، وذلك لدراسة اثر الحرمان من الري عند الأطوار الفسيولوجية لبعض اصناف القمح على المحصول ومكوناته، بالاضافة الى بعض العلاقات المائية وكذلك العائد المحصولى من وحدة المياة سواء المضافة او المستهلكة. وقد اجريت الدراسة على ستة اصناف من القمح مصر ١، مصر ٣ ، سخا٩٥ ، جيزة ١٧١ و جميزة ٩ وجميزة ١٠. بينما كانت معاملات الرى هي بدون حرمان (المقارنة)- حرمان عند مرحله التفريع- حرمان عندالاستطالة- حرمان عند مرحلة الحبلان – حرمان فى مرحلة الطور اللبني. وقد اظهرت النتائج ما يلى: معاملة المقارنه (بدون حرمان) اعطت اعلى قيمة للمحصول ومكوناته واعلى قيمة فى المياه المضافة الاستهلاك المائى- وكذا قيمه متوسط للعائد المحصولى كوحدة المياه سواء المضافة او المستهلكة. يالنسبه لمعاملات الحرمان فقد اظهرت النتائج ان منع الرى عند الطور اللبنى يؤدى لنقص طفيف فى المحصول الناتج. بالرغم من ان بعض معاملات الحرمان قد اعطت قيم أعلى في العائد المحصولى لوحدة المياه سواء المضافة او المستهلكة مقارنة بتلك التى يدون حرمان الا انة يجب الاخذ فى الاعتبار ان تلك الصفات تتوقف على المحصول وعلى وحدة المياه.وعلية: توصى الدراسة بأن الصنف سخا ٩٥ يليه جيزة ١٧١ وجميزة ٩هم الاكثر ملائمه لمنطقة شمال دلتا مصر. عند وفره مياه الرى نوصى بعدم منع الرى عند اى مرحله من مراحل النمو. فى حاله نقص مياة الرى يمكن منع الرى فى الطور اللبنى حيث نقص المحصول يكون طفيف جدا.