Yield and Water Productivity of Bread Wheat Cultivars under Diversified Irrigation Regimes

Y. A. El-Gabry[1] and F. A. Hashem[2]

[1] Department of Agron., Faculty of Agriculture, P.O Box 68. Hadayek Shobra, 11241 Cairo, Egypt.
[2] Central Laboratory for Agricultural Climate, P.O. Box 296 Dokki, 12411 Giza, Egypt.
fadl_hashem@yahoo.com

Abstract: The growth and productivity of bread wheat cultivars is affected by deficit water irrigation. Therefore, field experiment was conducted at Agricultural Experiment and Research Station, Faculty of Agriculture, Shalakan, Kalubia, Egypt, during the winter season of 2015/16-2016/17 to study the effect of irrigation regime (I1: full irrigation 5 irrigations, I2: skipping 2nd irrigation, I3: skipping 3rd irrigation) on yield and water productivity of five wheat cultivars (Sids 13, Gemmeiza 12, Sakha 94 and Misr 2). A spilt-plot in a randomized complete block design with three replications was used. Plant growth parameters and yield parameters in addition to water productivity (WP) were determined. The results showed that skipping irrigation significantly decreased plant growth and yield parameters in both seasons. Wheat plants irrigated five times possessed maximum biomass weight, spikes plant^{-1}, spike length, grain weight spike^{-1}, and grain yield aradab fed^{-1} as compared to skip 2nd irrigation and skip 3rd irrigation. Among wheat cultivars, Masr 2 cultivar gave the highest value from plant growth and yield parameters. Moreover, the lowest value was produced by Sakha 94 cultivar. However, it is concluded that interaction of full irrigations and Masr 2 cultivar proved optimum for obtaining maximum grain yield and skipping 2nd irrigation treatment proved maximum water productivity with wheat cultivars.

[Y.A. El-Gabry and F. A. Hashem. **Yield and Water Productivity of Bread Wheat Cultivars under Diversified Irrigation Regimes.** *Nat Sci* 2018;16(1):143-149]. ISSN 1545-0740 (print); ISSN 2375-7167 (online). http://www.sciencepub.net/nature. doi:10.7537/marsnsj160118.16.

Key words: Wheat cultivars, grain yield, plant height, skipping irrigation, growth, yield and water productivity.

1. Introductions

Wheat (*Triticum aestivum*, L.) is the most important cereal crop in Egypt and covers 3.5 million acres of land with an annual production of 9.6 million ton (**Economic Affairs Sector, 2015**). The statistics indicate that local production of wheat is not sufficient for consumption requirements, thus Egypt imports about 6 million tons to meet the needs of local markets. In this regard, researchers make efforts to increase the productivity per unit area of wheat by devising new cultivars of high productivity and low water consumption.

Egyptian agriculture relies heavily on irrigation, however water resources are limited. The agricultural sector consumes more than 84% of the available water resources (**El-Beltagy and Abo-Hadeed 2008**). In surface irrigation, farmers are commonly seen to over-irrigate their fields, causing greater losses by leaching. Therefore, optimal irrigation application, throughout the growing season, is an important for increasing wheat productivity per unit of water applied without additional costs (**Swelam and Atta 2011**). Due to limitation in water resources, water should be supplied precisely at the peak period of crop growth, which may provide good yield. However, shoot dry weight, number of grains, grain yield and biological yield decreased to a greater extent when water stress was imposed at the anthesis stage while imposition of water stress at booting stage caused a greater reduction in plant height and number of tillers (**Gupta et al., 2001 and Abdrabbo et al., 2016**).

Kandil (2001) studied the response of wheat cultivars (i.e., Giza 164, Sakha 69 and Sids 1) to water stress induced by skipping irrigation either at tillering, heading and milk-ripe stages. The results showed that plant height, spikes/plant, spike length, and grain and biological yields per faddan were markedly reduced by subjecting the plants to water stress. The depressing effects of soil moisture stress were comparatively high at tillering, intermediate at heading and low at milk-ripe stage. Moreover, significant differences were observed among the tested wheat cultivars in grain yield and its attributes, where Giza 164 cultivar was higher in grain yield than the other ones. **Kassab (2004)** studied the effect of irrigation treatments (irrigation every 30 days and skipping irrigation at tilling, heading or milk-ripe stages) on wheat yield and its attributes. The results revealed that skipping irrigation at any of the three studied stages significantly reduced plant height. **Abro (2012)** and **Qabil (2017)** concluded that for obtaining maximum grain yield in wheat, the crop should be supplied with five irrigations since the reduction in grain yield associates the decrease in number of irrigations.

Accordingly, under the conditions of lack of irrigation water, it is necessary to find means of assistance to increase the utilization of water while reducing the losses in the yield. Selection of cultivars that have high ability to tolerate drought and benefit from each unit of water is considered one the most important and costless practice. Herein, different varietal responses in yield and water utilization among wheat cultivars were recorded by **Mohamed (2013)** who found that Sids 12 cultivar was the highest in yield and its components and the most tolerant to drought stress compared with commercial cultivars (Sakha 93, Sakha 94, Gemmeiza 10 and Giza 168) and other tested lines.

Therefore, the objective of this study was to investigate effects of skipping irrigation on growth, yield, yield components and water productivity (WP) of wheat cultivars, and find out the appropriate system of irrigation regimes for enhancing production of wheat and water saving.

2. Materials and Methods

Experimental site description

A field experiment was conducted at the Research and Experimental Station Farm, Faculty of Agriculture (30°19′ N, 31°16′ E), Ain Shams University at Shalakan, Kalubia Governorate, Egypt during 2015/16 and 2016/17 growing seasons. The study area belongs to arid regions. Table 1 illustrates monthly mean weather data, i.e. maximum and minimum air temperature, and relative humidity, for the two studied seasons, gained from automated weather station allocated at the experimental location. As presented in Table 2, physical and chemical properties of the experimental soil were analyzed before cultivation according to **Chapman and Pratt (1961)**. Also, water status in terms of field capacity (FC) and wilting point (WP) were determined according to **Israelsen and Hansen (1962)**. The preceding crop was maize in both seasons.

Table 1. Average air temperature and relative humidity of the experimental site at Shalakan in 2015/16 and 2016/17 seasons.

Month	2015/16			2016/17		
	Air temperature (ºc)		Relative humidity (%)	Air temperature (ºc)		Relative humidity (%)
	Minimum	Maximum		Minimum	Maximum	
Nov	13.45	25.10	58.30	12.65	23.60	95.16
Dec	13.60	23.05	59.22	10.85	22.05	89.25
Jan	10.95	19.85	64.35	10.05	25.05	87.13
Feb	11.85	19.95	55.85	12.01	20.95	75.91
Mar	10.65	20.75	61.09	11.95	18.95	85.62
Apr	12.10	25.65	56.10	12.18	20.45	82.75
May	15.45	28.30	56.95	12.85	23.05	80.56

Table 2. Physical properties and water status of the soil at Shalakan region

Depth	Particle size distribution, %				Texture	Chemical properties		θ_S % on weight basis	
(cm)	Coarse sand	Fine sand	Silt	Clay	class	pH	EC (dS m^{-1})	FC	WP
0-30	11.5	29.5	40.6	18.4	Silt	7.75	0.6	17	8
30-60	9.2	30.9	42.4	17.5	Silt	7.70	0.7	17	7.5

Note: FC, Field capacity, PWP, Permanent wilting point.

Treatments and trail design

The study aimed to evaluate the performance of four wheat cultivars, i.e. Misr 2, Sids 13, Gemmiza 12 and Sakha 94 watered surface with three irrigation treatments (I_1: normal irrigation, 5 irrigation; I_2: skipping the 2nd irrigation; and I_3: skipping the 3rd irrigation). A split plot in a randomized complete blocks design with three replicates was used. Irrigation treatments were randomly arranged in the main plots, while, wheat cultivars occupied the sub plots. Net plot size was 12 m^2 involving fifteen rows, four meters long with 20 cm apart.

Common practices

Seeding rate was 350 seeds m^{-2}, sown by single row hand drill in mid–November in both seasons. Super phosphate (15.5% P_2O_5) was added during soil preparation at a rate of 23 kg P_2O_5 fed^{-1}. Urea (46.5 N %) was applied at a rate of 80 kg fed^{-1} in three portions, 20% with seeds planting, 40% before the first irrigation and 40% with the second irrigation. All other agriculture practices of wheat cultivation were done in accordance with standard recommendations for commercial growers suggested by the Ministry of Agriculture and Land Reclamation, Egypt (**Anonymous, 2008**).

Data recording

Crop parameters

At harvest (on 10th May in each season), one square meter was taken randomly from the middle area of each plot to determine plant growth traits (plant height and biomass weight) and yield parameters (spikes $plant^{-1}$, spike length, grains $spike^{-1}$ and grain weight $spike^{-1}$). Moreover, grain yield fed^{-1} was determined from the whole plot area.

Water productivity

Water productivity (WP) was calculated as a ratio of grain yield to the total quantity of irrigation water applied according to **Karrou et al (2012).**

Regression relationship

Simple regression relationships between wheat grain yield (dependent variable) and each of spikes plant^{-1} spike length, grains spike^{-1} and grain weight spike^{-1} (independent variables) were estimated as described by **Draper and Smith (1998)**.

Data analysis

Data were subjected to analysis of variance (ANOVA) according to **Gomez and Gomez (1984)**, using SAS software program Version 9 for comparing among means, Duncan's multiple range test at 0.05 probability level was used.

3. Results

Available data in Tables 3, 4 and 5 showed the genotypic variation in plant height, biomass weight, spikes plant^{-1}, spike length, grains spike^{-1}, grain weight spike^{-1}, grain yield fed^{-1} and water productivity among wheat cultivars under different irrigation patterns which can be explained as follow:

Plant height and biomass weight

The effects of different irrigation treatments on wheat plant height and biomass weight are presented in Table 3. In this regard, supplying wheat plants with normal irrigation (5 irrigations) significantly increased wheat plant height and biomass weight in both seasons than the other two treatments, except skipping the 2nd irrigation treatment for plant height in the first season.

Plants of Misr 2 cultivar were the tallest and achieved the weightest biomass surpassing the other cultivars with no significant variation in plant height with Sids 13 in 2015/16 season. Sakha 94 was the inferior in this respect (Table 3).

Misr 2 plants irrigated with normal irrigation showed the maximum value of plant height in both seasons. While, Misr 2 x skipping the 2nd irrigation treatment in 2015/16 and Sids 13 x normal irrigation in 2016/17 were the effective combination for producing higher values of biomass weight (Table 3). Contrariwise, in the irrigated plots with skipping the 3rd irrigation, Sakha 94 (for plant height) and Gemmiza 12 (for biomass weight) gave the lowest values.

Table 3. Plant height and biomass weight of wheat cultivars as affected by irrigation treatments.

Variables	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
	Plant height (cm)				Biomass weight (g m^{-2})			
2015/16								
Misr 2	110 a	105 b	98.7 e	**104 A**	403.3 b	429.0 a	254.0 g	**362 A**
Sids 13	105 b	101 d	103 c	**103 A**	355.0 c	303.3 e	224.2 h	**294 B**
Gemmiza 12	97.4 f	94.4 g	95.2 g	**95.7 B**	333.3 d	281.0 f	189.2 i	**268 C**
Sakha 94	85.0 i	92.4 h	84.9 i	**87.4 C**	287.2 ef	270.0 g	196.4 i	**251 C**
Mean	**99.4 A**	**98.1 A**	**95.4 B**		**345 A**	**321 B**	**216 C**	
2016/17								
Misr 2	108 a	100 c	86.6 f	**98.1 A**	329.0 b	303.0 de	296.0 e	**309 A**
Sids 13	103 b	100 c	85.0 g	**96.0 B**	379.0 a	311.0 cd	217.0 h	**302 B**
Gemmiza 12	98.9 c	94.8 d	80.5 h	**91.4 C**	338.0 b	251.0 f	192.0 i	**260 C**
Sakha 94	92.5 e	95.6 d	76.3 i	**88.1 D**	317.0 c	239.0 g	193.0 i	**250 D**
Mean	**101 A**	**97.4 B**	**82.1 C**		**341 A**	**276 B**	**224 C**	

Note: I_1: normal irrigation, 5 irrigations; I_2: skipping 2nd irrigation; and I_3: skipping 3rd irrigation. Different letters in the column indicate significant differences at P<0.05 using Duncan's multiple range test.

Spike traits

Wheat spike traits, i.e. spikes plant^{-1}, spike length, grains spike^{-1} and grain weight spike^{-1} as influenced by irrigation and varietal differences are illustrated in Table 4. As expected, supplying plants with sufficient water amount, i.e. normal irrigation, led to higher improvements in such traits in both growing seasons. However, the differences between normal irrigation treatment and that of skipping the 2nd irrigation did not reach the level of significance for spikes plant^{-1} and spike length in 2015/16 season.

Varietal differences in wheat spike traits appeared well among the tested cultivars as shown in Table 4. Herein, Misr 2 cultivar showed potency and stability in spike traits, i.e. spikes plant^{-1}, spike length, grains spike^{-1} and grain weight spike^{-1} since it recorded the maximum values over the two studied seasons. Also, spike length of Sids 13 was as similar as that of Misr 2 in both seasons.

Remarkable impact of the interaction between irrigation and wheat cultivar on spike traits was obtained (Table 4). By and large, irrigating Misr 2 plants with normal irrigation possessed the maximum values of all spike traits exceeding the other combinations in both seasons, except spikes plant^{-1} (showed the maximum value with Misr 2 x skipping the

2nd irrigation) in the first season. Moreover, Misr 2 x normal irrigation or skipping the 2nd irrigation as well as Sids 13 x normal irrigation were statistically at par for recording spike length in the first season.

Table 4. Spike traits of wheat cultivars as affected by irrigation treatments.

Variables	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
	Spikes plant^{-1}				Spike length (cm)			
2015/16								
Misr 2	15.0 b	16.2 a	14.5 c	**15.2 A**	13.7 a	13.6 ab	12.1 c	**13.1 A**
Sids 13	15.1 b	13.9 d	13.7 d	**14.2 B**	13.6 ab	13.3 b	11.8 d	**12.9 A**
Gemmiza 12	12.0 f	12.9 e	11.3 g	**12.0 C**	10.6 e	10.4 e	9.60 g	**10.2 B**
Sakha 94	12.5 e	12.9 e	10.9 g	**12.1 C**	10.4 e	10.1 f	9.30 h	**9.90 B**
Mean	**13.6 A**	**13.9 A**	**12.6 B**		**12.1 A**	**11.8 A**	**10.7 B**	
2016/17								
Misr 2	16.0 a	14.4 c	13.7 d	**14.7 A**	15.1 a	11.8 c	10.6 e	**12.5 A**
Sids 13	15.3 b	13.4 de	13.0 f	**13.9 B**	14.7 b	11.7 c	10.2 f	**12.2 A**
Gemmiza 12	13.3 ef	11.8 h	9.80 j	**11.6 C**	11.1 d	9.60 f	8.70 h	**9.80 B**
Sakha 94	12.6 g	11.5 h	10.3 i	**11.5 C**	10.5 e	9.30 g	8.60 h	**9.50 B**
Mean	**14.3 A**	**12.7 B**	**11.7 C**		**12.9 A**	**10.6 B**	**9.50 C**	
Variables	Grains spike^{-1}				Grain weight spike^{-1} (g)			
2015/16								
Misr 2	64.1 a	61.9 b	57.1 d	**61.0 A**	4.69 a	3.99 c	3.63 d	**4.10 A**
Sids 13	59.6 c	48.9 f	52.9 e	**53.8 B**	4.20 b	3.36 e	3.14 f	**3.57 B**
Gemmiza 12	53.0 e	39.5 i	44.o g	**45.5 C**	3.15 f	2.98 g	2.62 i	**2.92 C**
Sakha 94	47.6 f	41.7 h	37.9 i	**42.4 D**	3.26 ef	2.57 i	2.78 h	**2.87 C**
Mean	**56.1 A**	**48.0 B**	**47.9 B**		**3.82 A**	**3.22 B**	**3.04 C**	
2016/17								
Misr 2	60.4 a	52.2 c	57.5 b	**56.7 A**	4.67 a	3.56 cd	3.62 c	**3.95 A**
Sids 13	56.7 b	45.2 e	45.9 e	**49.3 B**	3.88 b	3.47 d	2.95 f	**3.43 B**
Gemmiza 12	48.4 d	41.7 f	38.7 g	**43.0 C**	3.23 e	2.68 h	2.75 g	**2.89 C**
Sakha 94	43.4 f	36.8 h	36.5 h	**38.9 D**	2.77 g	2.35 i	2.59 h	**2.57 D**
Mean	**52.2 A**	**44.0 B**	**44.7 B**		**3.64 A**	**3.01 B**	**2.98 B**	

Note: I_1: normal irrigation, 5 irrigations; I_2: skipping 2nd irrigation; and I_3: skipping 3rd irrigation. Different letters in the column indicate significant differences at P<0.05 using Duncan's multiple range test.

Grain yield and water productivity (WP)

Analysis of variance showed the remarkable effects of irrigation and genetic variation and their interaction on wheat grain yield and water productivity (WP) in 2015/16 and 2016/17 seasons (Table 5).

Table 5. Grain yield and water productivity (WP) of wheat cultivars as affected by irrigation treatments.

Variables	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
	Grain yield (aradab fed^{-1})				WP (kg m^{-3})			
2015/16								
Misr 2	18.8 a	16.4 c	16.4 c	**17.2 A**	1.50 b	1.64 a	1.64 a	**1.59 A**
Sids 13	17.1 b	14.2 d	14.1 d	**15.2 B**	1.37 d	1.42 c	1.41 c	**1.40 B**
Gemmiza 12	15.8 d	13.8 f	12.9 g	**14.2 C**	1.26 f	1.38 d	1.29 e	**1.31 C**
Sakha 94	16.0 d	12.9 g	11.7 h	**13.5 C**	1.28 ef	1.29 e	1.17 g	**1.25 C**
Mean	**16.9 A**	**14.3 B**	**13.8 B**		**1.35 B**	**1.43 A**	**1.38 B**	
2016/17								
Misr 2	18.3 a	16.1 b	14.8 c	**16.4 A**	1.46 b	1.61 a	1.48 b	**1.52 A**
Sids 13	16.4 b	13.9 d	13.3 e	**14.5 B**	1.31 d	1.39 c	1.33 d	**1.34 B**
Gemmiza 12	14.6 c	12.7 f	11.9 g	**13.1 C**	1.17 f	1.27 e	1.19 f	**1.21 C**
Sakha 94	13.2 ef	11.3 h	10.5 i	**11.7 D**	1.05 h	1.13 g	1.05 h	**1.08 D**
Mean	**15.6 A**	**13.5 B**	**12.6 B**		**1.25 B**	**1.35 A**	**1.26 B**	

Note: I_1: normal irrigation, 5 irrigations; I_2: skipping 2nd irrigation; and I_3: skipping 3rd irrigation. Different letters in the column indicate significant differences at P<0.05 using Duncan's multiple range test.

Well–watered plants (5 irrigations) produced the maximum grain yield surpassing that of received less water (4 irrigations) in both seasons. In this respect application of normal irrigation caused increases in grain yield ranged from 16.9–23.2 compared to skipping irrigation as an average of the two seasons. While skipping the 2nd irrigation treatment was the potent practice for water utilizations in terms of WP. Such distinctive treatment achieved 6.95 and 5.35% increases than normal irrigation and skipping the 3rd irrigation, respectively, over two years.

Misr 2 cultivar showed the potency and efficiency in possessing grain yield and WP along the two studied seasons (Table 5). Herein, the yield of Misr 2 exceeded the grand mean of all tested cultivars by 14.4 and 17.7% for grain yield and 15.2 and 18.8% for WP in the 1st and 2nd seasons, respectively. Sids 13 came in the second order in this respect.

As shown in Table 5, the interactive impact among irrigation treatments and wheat cultivars indicated high compatibility between Misr 2 with normal irrigation (for grain yield) and with skipping the 2nd irrigation (for WP). Also, skipping the 2nd or the 3rd irrigation with Misr 2 gave the same WP in the 1st season. The inferior interaction in this regard was Sakha 94 x skipping the 3rd irrigation in both seasons (for grain yield and WP), in addition to, skipping the 2nd irrigation treatment in the second one (for WP).

Regression relationship

Simple linear regression relationships between grain yield and each of spikes plant^{-1}, spike length, grains spike^{-1} and grain weight spike^{-1} are illustrated in fig 1. There were direct positive relations between grain yield and all yield components except grain weight spike^{-1}, which was inverse relation. From R^2 values, the most contributing component is grains spike^{-1} followed by spikes plant^{-1}, spike length, and grain weight spike^{-1}.

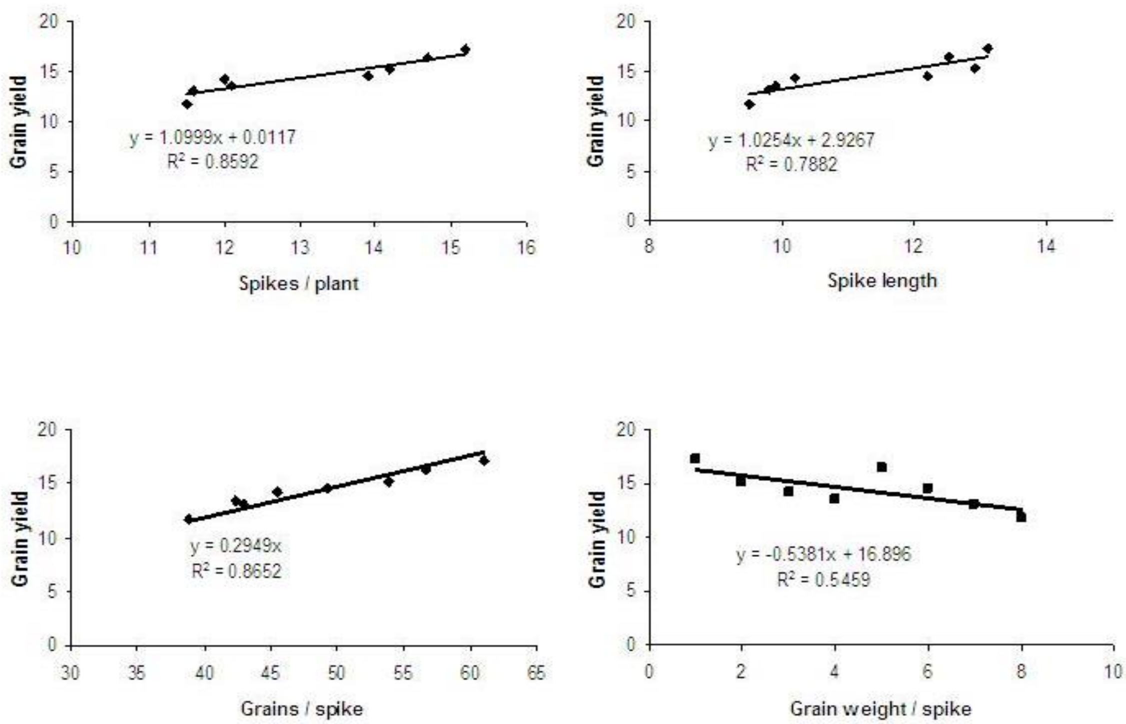

Fig 1. Simple regression relationships between grain yield and each of spikes plant^{-1}, spike length, grains spike^{-1} and grain weight spike^{-1}

4. Discussion

Irrigation

Grain yield in wheat is the end result of a number of contributing and inter-related components via number of grains per spike, number of spikes per unit area and grain weight. The magnitude of each component is determined by processes such as tillering, spike development and grain filling, occurring at different stages of crop development. Moreover, the normal growth and development of wheat mainly depends upon available water. Therein, the exposure to water stress at any growth stage is deleterious as well as there are specific critical stages during which the negative effect is more lucid. Thus, our findings emphasized that supplying wheat plants with normal irrigation (5 irrigations) as well–watered pattern achieved improvements in wheat growth and yield attributes (Tables 4 & 5). It well known that irrigation plays a crucial role in terms of bringing good growth and development of wheat (**Khajanij and Swivedi, 1988 and Elhag, 2017**). Higher grain weight of well-watered plants is associated with longer grain filling duration and faster grain filling rate (**Li et al., 2000 and Ejaz et al., 2007**). **Chauhan et al. (2008)** stated that application of five irrigations to wheat crop resulted in the highest grain yield. On the contrary skipping one irrigation whether the 2nd irrigation, at tillering stage or the 3rd one at booting stage caused reductions in yield and yield attributes as reported in Table 5. Water stress-induced accelerated senescence after anthesis shortens the duration of grain filling by causing premature desiccation of the endosperm and by limiting embryo volume has also been reported **(Westage, 1994)**. However, it should be noted that, comparing to normal irrigation, the depression in the yield associated with applying skipping the 2nd irrigation treatment was less than resulting from skipping the 3rd irrigation one. Farmers may apply such treatment in light of the scarcity of water. Adding water below full crop–water requirements is one of the strategies designed to improve water savings in agriculture (**Bashir and Mohamed, 2014**) and is regarded one of the significant tools to overcome scarce water supplies through lessening irrigation water amounts (**Fereres and Soriano 2007**). **Wajid et al. (2002)** reported that wheat crop produced highest grain yield by applying irrigation at all definable growth stages. Whilst, water deficiency affects plant growth and grain yield **(Hussain et al. 2004; Wajid et al. (2004)**. In this context, **Karim et al. (2000)** investigated the effect of water stress at reproductive stage on grain growth pattern and yield responses of wheat and found that 94% of tillers of irrigated plants produced spikes, compared to 79% of the stressed plants. Grain yield was reduced to 65% in the stressed plants compared to that of irrigated ones **(Karim et al. 2000)**.

Varietal variations

The variations in yield and its attributes and WP among wheat cultivars might be due to the genetic makeup reflecting on grain filling rate and translocation of biochemical assimilates from source to sink. Varietal differences in yield components among wheat cultivars were observed by **Hassan and GabAllah (2000), El-Metwally and Saudy (2009), El-Habbal et al. (2010), Noureldin et al. (2013).**

Regression relationship

From studying regression relationships between grain yield and it components, plant breeders should mainly focus their attention for improving wheat cultivars on the most contributing traits via grains spike^{-1} and spikes plant^{-1}. Similar trend was obtained by **Ngwako and Mashiqa (2013) and Mekkei and El Haggan (2014).**

Conclusion

Although there is a reduction of yield and its components due to skipping the second irrigation, this may be acceptable in areas with water shortage. Especially since such treatment has achieved the highest efficiency of water use, in terms of high water productivity. Also, choosing the appropriate cultivar, as Misr 2, for this purpose is considered important.

References

1. Abdrabbo. M. A. A., F. A. Hashem and A. F. Abou-Hadid. 2016. Irrigation requirements for some bread wheat cultivars in relation to planting dates. Journal of Agricultural Science and Research (JASR) Vol. 3, Issue1.
2. Abro N.A. 2012. Effect of irrigation regimes on grain yield and harvest index of wheat varieties. M. Sc. Thesis, Sindh Agriculture University, Tandojam.
3. Anonymous, 2008. Ministry of Agriculture and Land Reclamation- Extension bulletin of the management of wheat in the old land. Bulettien No. 1119 pp., 24.
4. Bashir, M.A., Mohamed, Y.M. 2014. Evaluation of full and deficit irrigation on two sunflower hybrids under semi–arid environ–ment of Gezira, Sudan. Agri–Food App. Sci. 2, 53–59.
5. Chapman, H.D. and P.F. Pratt. 1961. Methods of Analysis for Soil, Plant, and Water. University of California, Division of Agric Sci.
6. Chauhan, C.P.S., R. Bsingh and S.K. Cupta. 2008. Supplemental irrigation of wheat with saline water. Agricultural water Management 95: 253-258.
7. Draper, N. R., and H. Smith. 1998. Applied Regression Analysis, 3rd Ed. John Wiley & Sons, New York.
8. Ejaz Ahmad Waraich, R. Ahmad, Anser ali and Saif Ullah. 2007. Irrigation and nitrogen effects on grain development and yield in wheat (*Triticum aestivum* L.) Pak. J. Bot., 39(5) 1663-1672.
9. El-Beltagy A.T., Abo-Hadeed A.F. 2008. The main pillars of the National Program for maximizing the water-use efficiency in the old land. The Research and Development Council. MOALR. (in Arabic); p. 30.
10. EI-Habbal, M.S; F. Ashmawy; H.S. Saudy and Iman Kh. Abbas. 2010. Effect of nitrogen fertilizer rates on yield, yield components and grain quality measurements of some wheat

cultivars using SPAD- meter. Egypt. J. Agric. Res., 88 (1): 211-223.
11. Dalia A. A. Elhag. 2017. Effect of irrigations number on yield and yield components of some bread wheat cultivars in north Nile delta of Egypt. Egypt. J. Agron. Vol. 39, No.2 pp.137- 148.
12. El-Metwally, I.M., Saudy, H.S. 2009. Herbicide tank-mixtures efficiency on weeds and wheat productivity. Annals Agric. Sci., Moshtohor 47 (2), 95–109.
13. Fereres, E., Soriano, M.A. 2007. Deficit irrigation for reducing agricultural water use. J. Exp. Bot. 58, 147–159.
14. Gomez KA, Gomez AA. 1984. Statistical procedures for agriculture research. New York (NY): John Wiley & Sons.
15. Gupta, P.K., Gautam, R.C. and Ramesh, C.R. 2001. Effect of water stress on different stages of wheat cultivation. Plant Nutri. Fert. Sci. 7(2): 33-37.
16. Hassan, A.A., GabAllah, A.B. 2000. Response of some wheat cultivars to different levels and sources of nitrogen fertilizers under new reclaimed sandy soil. Zagazig J. Agric. Res. 27, 13–29.
17. Hussain A., Ghaudhry M.R., Wajad A., Ahmed A., Rafiq M., Ibrahim M., Goheer A.R. 2004. Influence of water stress on growth, yield and radiation use efficiency of various wheat cultivars. Int J Agric Biol 6: 1074 -1079.
18. Israelsen, O.W. and V.E. Hansen. 1962. Irrigation Principles and Practices, third edition, John Wiley and Sons, Inc New York, London.
19. Kandil SA, Abo-EI-Kheir MSA and El-Zeiny HA. 2001. Response of some wheat cultivars to water stress imposed at certain growth stages. Egypt. J. Appl. Sci., 16(1): 82-98.
20. Karim A., Hamid A., Lalic A. 2000. Grain growth and yield performance of wheat under subtropical conditions: ii. Effect of water stress at reproductive stage. Cereal Res Commun 1-2:101-108.
21. Karrou, M., T. Oweis, R. Abou El-Enein and M. Sherif. 2012. Yield and water productivity of maize and wheat under deficit and raised bed irrigation practices in Egypt. African Journal of Agricultural Research Vol. 7(11), pp. 1755-1760.
22. Kassab O.M., El-Zeiny H.A. and Ibrahim M.M. 2004. Effect of water deficit and micronutrients foliar application on the productivity of wheat plants. Minufiya J. Agric. Res., 29 (4): 925-932.
23. Khajanij SN, Swivedi RK. 1988. Response of wheat (*Triticum aestivum* L.) to irrigation and fertilizer mixture under late condition. Bhartiya Krishi Anusandhan Patrika 3(1), 37-42.
24. Li, A.G., Y.S. Hou, G.W. Wall, A. Trent, B.A. Kimbal and P.J. Pinter. 2000. Free air carbon dioxide enrichment and drought stress effects on grain filling rate and grain filling duration in spring wheat. Crop Sci., 40: 1263-1270.
25. Mekkei M. E. R and El Haggan Eman A. M. A. 2014. Effect of different irrigation regimes on grain yield and quality of some Egyptian bread wheat cultivars. J. Agri-Food & Appl. Sci., 2 (9): 275-282.
26. Mohamed A.A.E. 2013. Effect of water stress on morphological, physiological and productivity traits of wheat. Ph.D. Thesis, Faculty of Agric., Cairo University.
27. Naglaa Qabil. 2017. Genetic analysis of yield and its attributes in wheat (Triticum aestivum L.) under normal irrigation and drought stress conditions Egypt. J. Agron. Vol.39, No.3, pp. 337 – 356.
28. Ngwako S. and P.K. Mashiqa. 2013. The effect of irrigation on the growth and yield of winter wheat (*Triticum aestivum* L.) cultivars. Intl J Agri Crop Sci. Vol., 5 (9), 976-982, 2013.
29. Noureldin, N.A., H.S. Saudy, F. Ashmawy and H. M. Saed. 2013. Grain yield response index of bread wheat cultivars as influenced by nitrogen levels. Ann. Agric. Sci., Ain Shams Univ., 58 (2):147-152.
30. Swelam A., Atta Y. 2011. New approach of farm management under surface irrigation to improve water saving and productivity. New Horizons in Sci. Technol. 1:76–83.
31. Wajid A., Hussain A., Ahmed A., Rafiq M., Goheer A.R., Ibrahim M. 2004. Effect of sowing date and plant density on growth, light interception and yield of wheat under semi-arid condition. Int. J. Agric. Biol., 6: 1119-1123.
32. Wajid A., Hussain A., Maqsood M., Ahmad A., Awais M. 2002. Influence of sowing date and irrigation levels on growth and grain yield of wheat. Pak. J. Agric. Sci., 39(1): 22-24.
33. Westage, M.E. 1994. Water status and development of maize endosperm and embryo during drought. Crop Sci., 34: 76-83.

1/25/2018