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(Original Article)

Effect of Irrigation Intervals and Foliar Spray with Salicylic Acid on the Production of Two Bread Wheat Cultivars in Newly Reclaimed Land

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Abstract

In the present study, we estimated the yield and its attributes as well as water use efficiency of two bread wheat cultivars, i.e., Shandaweel-1 and Giza-171 under three irrigation intervals, i.e., irrigation every 6, 9 and 12 days, and three concentrations of salicylic acid, i.e., 0.0, 150, and 300 ppm which was done at a private farm in the village of Al-Ghuraira, Esna center, Luxor governorate upper Egypt during 2018/2019 and 2019/2020 seasons. This study was laid out in a strip-split plot arrangement was based on a randomized complete block design (RCBD) with three replications. The results indicated that increasing irrigation intervals (I) from 6 up to 9 or 12 days significantly decreased vegetative traits, yield and yield attributes traits, i.e., plant height, flag leaf area, spike length., number of kernels spike^{-1}, kernels weight spike^{-1}, 1000-grain weight as well as grain yield fed.$^{-1}$, but significantly increased grain protein content (%), water use efficiency (WUE) and water saving% in both seasons. The Foliar application of 300 ppm of salicylic acid (SA_3) had significantly increased all the yield and its attributes traits compared to the control treatment (SA_1) As well as improving WUE under the conditions of irrigation periods every 9 and 12 days. Shandaweel-1 cultivar outperformed Giza-171 cultivar in plant height, spike length, grain yield and WUE in both seasons, and number of kernels spike^{-1} in the 1st season. Likewise, Giza-171 surpassed Shandaweel-1 in flag leaf area, kernels weight spike^{-1}, 1000-grain weight and protein% in both seasons, and number of kernels spike^{-1} in 2nd season. Furthermore, the second order interaction $I_6 \times SA_3 \times WC_2$ gave the highest value for 1000-grain weight (78.0 g) in the 1st season only.

Keywords: *Bread wheat cultivars, Irrigation Intervals, Salicylic acid, Yield, Water saving.*

Introduction

Wheat (*Triticum* sp. L.) consider the most important cereal crop in the world regarding its cultivated area and production. In Egypt, cultivated area of wheat was about 3.4 million fed with a production of 8.9 million tons with an

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average of 2.6 tons fed^{-1}, and imports 10 million tons of wheat to fill the gap (FAOSTAT, 2020). The upper Egypt region is located in the southern part of the country, the region is distinguished by high temperatures, and it grows wheat by about 17% (Mohiy and Salous, 2022). Currently, the government has taken procedures to increase the production of wheat and backup producers by encouraging farmers to cultivate and buy wheat from the farmers at a high price (Abdelmageed *et al*., 2019). Wheat is grown in widely varied climatic, and under both rain-fed and irrigated cultivation due to its high level of adaptation, hence, slightly dry, temperate climatic conditions are most suitable for wheat cultivation (Shalaby *et al*., 2020), to overcome water deficiency and save the irrigated area by means the development of high yield cultivars with stabilized performance under limited water environments (Shehab-Eldeen and Farhat, 2020). Hamada *et al*. (2022) reported that the commercial wheat cultivars in the Egyptian agricultural system vary in their yield production, quality, and response to biotic and abiotic stresses thus should redistribute cultivars and cultivate them under appropriate conditions to obtain maximum productivity.

The challenges of water-saving for surface irrigation systems are particularly important because the most used in the world and allow a greater margin for saving water. Therefore, improving the irrigation performance requires a variety of practices, which provide for reducing the water use, increasing land and water productivity, enabling a higher farmer income, and protecting water resources (Gonçalves *et al*., 2021). Drought stress severely impacts plants physiology and production, hence the deficiency of food security, and economic losses. Shah *et al*. (2016) indicated that plots irrigated with 470 mm water produced the maximum grains $spike^{-1}$ (64), leaf area index (4.24), 1000-grains weight (43.19 g), and grain yield (3130 kg ha^{-1}) compared to other irrigation levels *i.e*., 120, 230, and 360 mm water. Wheat plants irrigated with 4 irrigations increase significantly leaf area index, plant height, spike length, number of spikelets $spike^{-1}$, and grain yield as compared to plots irrigated with 2 or 3 irrigations (Kanwal *et al*., 2020). Kotb *et al*., (2021) cleared that irrigation 6 times significantly resulted in increased spikes number m^{-2}, 1000-grain weight, and grain yields of wheat compared with the plots irrigated 4 times. The maximum values for plant height, number of spikes m^{-2}, number of grains $spike^{-1}$ 1000-grain weight, flag leaf area, and grain yield were obtained from wheat plants that received four irrigations compared to plants irrigated twice across the growing seasons (El-Nagar and EL-Gohary, 2022). Improving WUE in the crop production sector includes improving land cultivation, developing drought-tolerant genotypes, and applying special agriculture practices (El-Hendawy, 2016).

Salicylic acid (2-hydroxybenzoic acid) is considered as of the phenolic compounds widely distributed in plant species it's a natural plant endogenous hormone it has a physiological effect on the growth and flowering of plants and the absorption of ions it gives plants systemic immunity against pathogens and helps plants to resist stresses resulting from temperature, drought, and salinity (EL-Nasharty *et al*., 2019). Sofy (2015) pointed out that drought stress at the grain filling stage significantly decreased plant height, spike length, number of grains spike^{-1}, 1000-grain weight in wheat plants, and mitigation of the adverse effects of drought via the application of salicylic acid. Erdal *et al.* (2011) and Munsif *et al.* (2022) pointed out that salicylic acid may enhance stress tolerance in plants by interactive impacts on some physiological processes (transpiration rate, photosynthesis, stomata regulation, ion uptake, and plant growth.

The objective of this study was to determine the best irrigation intervals and foliar salicylic acid application on the yield and its attributes of two bread wheat cultivars in newly reclaimed soils under Luxor Governorate climatic conditions.

Materials and Methods

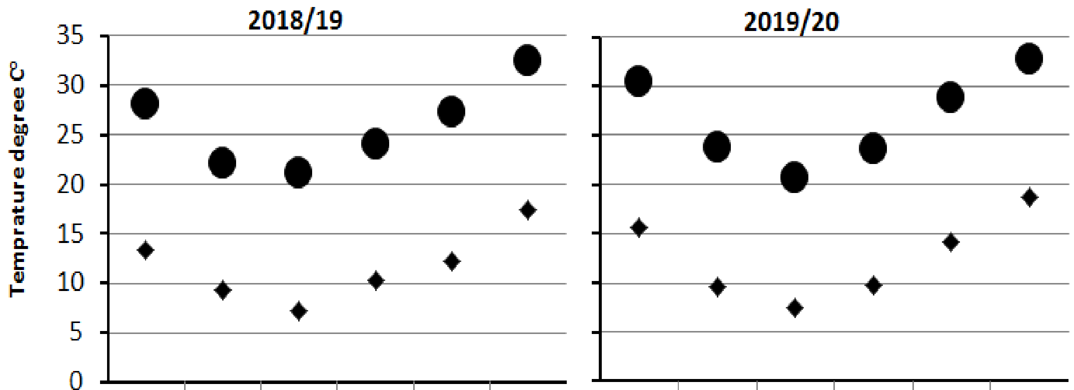
The objective of this study was to determine the response of two bread wheat cultivars to foliar spray with salicylic acid under different irrigation intervals in the newly reclaimed soil during 2018/2019 and 2019/2020 seasons.

Location

The experiment was conducted at a private farm in the village of Al-Ghuraira, Esna Center, Luxor Governorate Upper Egypt, which is located at a 25° 18/ latitude and 32° 34/ longitude. Its altitude is about 82 m above sea level.

Prevalent temperatures

Temperatures for Al-Ghuraira village, Esna Center, Luxor Governorate Upper Egypt during the growing seasons of 2018-19 and 2019-20 as shown in Fig. 1.



	2018/19 NOV	DEC	JAN	FEB	MAR	APR	2019/20 NOV	DEC	JAN	FEB	MAR	APR
● MAX TEM.	28.07	22.19	21.06	24.07	27.23	32.53	30.5	23.74	20.61	23.62	28.87	32.67
◆ MIN TEM.	13.3	9.23	7.13	10.29	12.26	17.4	15.63	9.61	7.52	9.69	14.13	18.73

Figure 1. Air temperature °C during the growth periods of wheat in two growing seasons.

Soil properties of the experimental site

The soil samples were taken from the experimental site at (0-30 cm) to determine some soil's physical and chemical properties according to Page (1982) as shown in Table 1.

Table 1. Physical and Chemical properties of the soil of the experimental field

Physical properties		Chemical properties			
Practical size distribution (%)		Soluble cations (meq L^{-1})		Soluble anions (meq L^{-1})	
Properties	**Value**	**Properties**	**Value**	**Properties**	**Value**
Sand	87.70	Na^+	1.61	HCO_3^-	0.70
Silt	9.90	K^+	0.41	Cl^-	1.65
Clay	5.40	Ca^{++}	0.65	SO_4^{--}	0.77
Texture grade	Sandy	Mg^{++}	0.45	CO_3^{--}	-
Saturation percent (S.P.) %	23.00	**Organic matter (O.M) %**			0.11
pH (1: 2.5, soil: water)	8.00	**EC (ds m^{-1} at 25 ºC) "1: 5, soil: water"**			0.31

The biological experiment

The experiment included three factors were arranged in a strip-split plot arrangement under randomize complete blocks design (RCBD) with three replications. The first factor is the irrigation intervals represented by 6, 9, and 12 days, which were placed in horizontal plots, while the second factor was salicylic acid concentrations (0.0, 150, and 300 ppm), which was placed in the vertical plots, and the third factor was two bread wheat cultivars i.e., Shandaweel-1 and Giza- 171 which were placed in sub-plots. The area of each experimental unit was 10.5 m^2 (3 ×3.5m) = 1/400 fed, isolated by a buffer zone of 1.5 m width to avoid the horizontal water seepage. The planting was 24th and 26th of November in 2018 and 2019 respectively. The concentrations of salicylic acid were sprinkled on the total vegetative of wheat two times, after 30 and 60 days from sowing (DFS). All other cultural practices were done according to standard recommendations for planting wheat in newly reclaimed soils of Upper Egypt.

The studied traits are as follows

Vegetative growth traits

Ten readings were taken randomly on the plants from heading date to maturity date of each sub-plot to estimate the following growth traits:

- Flag leaf area (cm^2): were measured according to Hunt (1982) where it was measured as follows flag leaf area = ¾ (leaf length × maximum leaf width).
- Plant height (cm): the plant was measured from the level of the soil surface to the tip of the spike excluding awns.
- Spike length (cm): It was estimated from ten main spikes were randomly chosen from each plot.

The yield and its component

At harvest, ten spikes were taken from each sub-plot at random to determine the following traits: grain weight $spike^{-1}$ (g), number of grains $spike^{-1}$, and 1000-grain weight (g).

Grain yield (ton fed^{-1}) was calculated on the basis of the weight of the grain yield $plot^{-1}$ then converted into grain yield ton fed^{-1}.

Protein content % in grain: N content in grains was determined using micro-kjeldahl and protein percentage was calculated by multiplying N content by factor 5.75 according to A.O.A.C. (1990).

Irrigation requirement computation and water supply

The experiment was irrigated according to surface irrigation (traditional) method and divided into three sections, irrigated after 6 days, 9 days and 12 days.

Table 3 shows the quantity of water applied was measured in the studied area by using a rectangular sharp-crested weir. The discharge was calculated using the following formula of (Masoud, 1967).

$$Q = CLH^{3/2}$$

Where, Q: The discharge in cubic meters per second.

L: The length of the crest in meters.

H: The head in meters.

C: An empirical coefficient that must be determined from the discharge measurements.

Table 2. The amount of water added for each irrigation period (every 6, 9, and 12 days) during the two growing seasons.

Irrigation intervals	Water quantity	
	1st season	2nd season
I_6 = 6 days	5493.7	5127.4
I_9 = 9 days	4394.9	4136.4
I_{12} = 12 days	3877.9	3684.0

Water Use Efficiency (WUE) was calculated according to Molden and Sakthivadivel (1999) as the following equation:

WUE (kg m^{-3}) = grain yield (kg fed^{-1})/Water applied (m^3 fed^{-1}).

Statistical analysis

The collected data were analyzed using analysis of variance (ANOVA) as published by Gomez and Gomez (1984). Mean values were compared to each other using the Least Significant Differences (LSD) at the probability level of 0.05, and simple correlation coefficients between all pairs of the studied traits were calculated as suggested by Snedecor and Cochran (1989).

Results and Discussions

Effect of irrigation intervals

The data of studied traits (Table 3), *i.e.*, flag leaf area, plant height, and spike length, No. of kernels spike, kernels weight spike^{-1}, 1000-kernel weight, grain yield and WUE of bread wheat. The presented data show that all the studied traits were significantly affected by the tested irrigation intervals in both seasons. Thus, irrigation intervals every 6 days (I_6) increased flag leaf area by 11.36 and 17.84%, plant height by 3.97 and 8.49%, spike length by 3.67 and 10.78%, No. of kernels spike^{-1} by 11.11 and 15.99%, kernels weight spike^{-1} by

18.42 and 32.35%, 1000-kernel weight by 8.20 and 14.33% and grain yield by 8.0 and 17.39%, but decreased WUE by 10.71 and 15.25% in 2018-19 season, and by 10.45 and 20.99% for flag leaf area, by 1.06 and 5.33% for plant height, by 1.80 and 6.60% for spike length, by 7.84 and 10.82%, for number of kernels spike^{-1}, by 9.46 and 32.35% for kernels weight spike^{-1}, by 2.21 and 13.91% for 1000-kernel weight, and by 11.54 and 16.00% for grain yield, but decreased WUE by 10.94 and 14.93%, in 2019-20 season, compared to irrigation intervals every 9 days (I_9) and 12 days (I_{12}), respectively.

Short irrigation interval (every 6 days) led to an adequate water supply in the root zone, especially at plant critical stages might have increased the capacity of the wheat plant in photosynthesis, help the plants to rapid cell division and its elongation and thus increased yield components and relative water content that have an indirect contribution in carbohydrates transfer from vegetative tissue to grain. The best irrigation period was every 6 days, which gave (2.7and 2.9 tons fed^{-1}) in the first and second season respectively. The increase in the grain yield per feddan from the irrigation treatment every 6 days is expected because these treatments led to an increase in all the characteristics of the components of the crop and its various contributions, thus increasing the grain yield per feddan. Also, in this regard, the decrease in the efficiency of water use for the irrigation treatment every 6 days was due to the increase in the irrigation water for this treatment than the rest of the treatments, which led to a decrease in the return from uniting the water. Dry matter turns into grains, which leads to a decrease in water use efficiency under this treatment.

Table 3. Means of yield and its attributes traits as well as WUE and protein content of two bread wheat cultivars as affected by irrigation intervals during 2018-19 and 2019-20 seasons

Irrigation intervals (I)	Flag leaf area (cm^2)		Plant height (cm)		Spike length (cm)	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
I_6 (6 days)	58.8	63.4	102.2	104.7	11.3	11.3
I_9 (9 days)	52.8	57.4	98.3	103.6	10.9	11.1
I_{12} (12 days)	49.9	52.4	94.2	99.4	10.2	10.6
F value	*	*	*	*	*	*
LSD 0.05	0.27	0.24	1.22	0.14	0.21	0.13
Irrigation intervals (I)	**Number of kernels spike^{-1}**		**kernels weigh spike^{-1} (g)**		**1000-kernel weight (g)**	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
I_6 (6 days)	66.0	68.8	4.5	4.5	68.6	64.7
I_9 (9 days)	59.4	63.8	3.8	4.1	63.4	63.3
I_{12} (12 days)	56.9	59.4	3.4	3.4	60.0	56.8
F value	*	*	*	*	*	*
LSD 0.05	0.40	1.39	0.05	0.19	0.63	1.87
Irrigation intervals (I)	**Grain yield (ton fed^{-1})**		**Water use efficiency (kg m^{-3})**		**Protein content %**	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
I_6 (6 days)	2.7	2.9	0.50	0.57	10.5	10.2
I_9 (9 days)	2.5	2.6	0.56	0.64	11.3	10.6
I_{12} (12 days)	2.3	2.5	0.59	0.67	12.2	11.6
F value	*	*	*	*	*	*
LSD 0.05	0.04	0.04	0.01	0.01	0.05	0.22

* Mean significant at 5 % level of probability

Furthermore, enough irrigation water may help the plant to absorb its need for water and nutrients as well as increased the grain-filling period (El-Hendawy, 2016). Drought stress leads to decreased fresh and dry matter production (Gora *et al*., 2022), total chlorophyll, and photosynthesis (Shalaby *et al*., 2020), and thus reduced the spike length (Kanwal *et al*., 2020), flag leaf area (El-Sarag and Ismaeil, 2013), grains weight spike^{-1} and 1000-grain weight (Al-Zahy *et al*., 2020 and Kotb *et al*., 2021), grain yield (El-Nagar and EL-Gohary, 2022), and increased WUE (Taha *et al*., 2017). Xu *et al*. (2016) cleared that the increase in WUE was produced from 60 mm water applied at elongation, attaining a relatively high grain yield, whereas enough irrigation with180 mm water applied increased grain yield but decreased WUE. The grain yield increase was related to the improvement of most agronomic traits that correlated with grain yield, in response to short irrigation intervals (Aissaoui and Fenni, 2021). Many researchers reported that shorter irrigation intervals improved the growth and yield traits of wheat crops (Shah *et al*., 2016; Ragheb *et al*., 2017; Ahmed and Mustafa, 2018; Walsh *et al*., 2020; Munsif *et al*., 2022). Increasing irrigation period was followed by a significant decrease in all studied traits except for protein under sandy soils conditions, which leads to rapid loss of water and nutrients, and exposes plants to drought stress, thus an increase in protein content of wheat plants (El-Saadony *et al*., 2021). Moreover, Awad *et al*. (2015) illustrated that drought stress led to number of grains spike^{-1} by 28.58 and 28.74%, grain weight plant^{-1} by 17.97 and 39.60%, 1000-grain weight by 36.97 and 7.95%, and grain yield by 35.56 and 39.38%, in comparison to full irrigation treatment in both seasons, respectively.

Table 4. The amount of seasonal applied water for wheat as affected by irrigation intervals during the two seasons

Irrigation intervals (I)	Water applied		Water saved %				The over mean values of the two seasons	
	2018-19	2019-20	2018-19		2019-20			
	(m^3 fed^{-1})		m^3 fed^{-1}	%	m^3 fed^{-1}	%	m^3 fed^{-1}	%
I_6 (6 days)	5493.7	5127.4	-	-	-	-	-	-
I_9 (9 days)	4394.9	4136.4	1098.8	20.0	991.0	19.3	1044.9	19.6
I_{12} (12 days)	3877.9	3684.0	1615.8	29.4	1443.4	28.2	1529.6	28.8

Regarding WUE and water saving in Tables 3 and 4, the data showed that the irrigation every 12 days (I_{12}) led to an increase in WUE by 18.0 and 17.5 % and water save% by 29.4 and 28.2% compared to the I_6 in the 2019 and 2020 seasons, respectively. Irrigation every 12 days gave the highest value of WUE 0.59 and 0.67 kg m^{-3} in both seasons, respectively. Economically in relation to the quantities of water used for each irrigation period during the two seasons, the average irrigation period every 6 days consumes the largest amount of water, while the average irrigation period every 12 days consumes the least amount of water by a difference of (1529.6 m^3) water, and therefore this amount can be used to cultivate an area of about (1699 m^2) producing about (971 kg) of grain. Therefore, scheduling water every 12 days is best. Supported our results Bakry *et al*. (2013) found that the water irrigation requirement of (80% IR) produced a high grain yield fed^{-1} and insignificantly out yielded the water irrigation requirements of (100 and 60% IR), this means that we can save 20% of irrigation water by using 80% IR to irrigate the new lands under the conditions of this trail.

Effect of salicylic acid

Data in Table 5 shows that foliar application of salicylic acid caused a significant increase in all studied traits in both seasons, except 1000-grain weight trait which was not affected significantly by the tested salicylic acid concentrations in the 2nd season. Spraying wheat plants with 300 ppm of salicylic acid resulted in the greatest mean values of flag leaf area (60.0 and 63.1 cm^2), plant height (101.4 and 105.8 cm), spike length (11.6 and 11.6 cm), number of kernels $spike^{-1}$ (64.6 and 68.4 kernel $spike^{-1}$), kernels weigh $spike^{-1}$ (4.3 and 4.4 g), 1000-grain weight (67.3 and 64.1 g), grain yield (2.8 and 2.9 ton fed^{-1}), WUE (0.63 and 0.68 kg m^{-3}) and protein% (11.5 and 11.0%) in the 1st and 2nd seasons, respectively. These results are due to salicylic acid participating in the regulation of many physiological processes in plants such as photosynthesis, the uptake of nutrients, and bearing different stresses to which plants are exposed, that improved growth traits, and in turn, increased yield and its components of wheat.

Table 5. Means of yield and its attributes traits as well as WUE and protein content of two bread wheat cultivars as affected by salicylic acid application during 2018-19 and 2019-20 seasons

Salicylic acid (SA)	Flag leaf area (cm^2)		Plant height (cm)		Spike length (cm)	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
SA_1 (Control)	47.8	51.8	95.0	99.7	10.0	10.4
SA_2 (150 ppm)	53.7	58.3	98.3	102.2	10.7	10.9
SA_3 (300 ppm)	60.0	63.1	101.4	105.8	11.6	11.6
F value	*	*	*	*	*	*
$LSD_{0.05}$	**0.40**	**1.42**	**0.56**	**0.91**	**0.19**	**0.09**
Salicylic acid (SA)	**Number of kernels $spike^{-1}$**		**kernels weigh $spike^{-1}$ (g)**		**1000-kernel weight (g)**	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
SA_1 (Control)	55.9	58.9	3.4	3.5	61.1	59.2
SA_2 (150 ppm)	61.7	64.7	3.9	4.0	63.7	61.5
SA_3 (300 ppm)	64.6	68.4	4.3	4.4	67.3	64.1
F value	*	*	*	*	*	NS
$LSD_{0.05}$	0.19	1.17	0.04	0.15	0.91	--
Salicylic acid (SA)	**Grain yield (ton fed^{-1})**		**Water use efficiency (kg m^{-3})**		**Protein content %**	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
SA_1 (Control)	2.2	2.4	0.48	0.57	11.2	10.6
SA_2 (150 ppm)	2.5	2.7	0.54	0.63	11.3	10.8
SA_3 (300 ppm)	2.8	2.9	0.63	0.68	11.5	11.0
F value	*	*	*	*	*	*
$LSD_{0.05}$	0.02	0.03	0.01	0.01	0.05	0.09

Where NS and * mean non-significant and significant at a 5 % level of probability, respectively

The application of salicylic acid enhanced the 1000-grain weight, yield and its components, rate and duration of grain filling compared to the control treatment in three wheat cultivars (Khamseh *et al*., 2013). Al-Badrawi and Alabdulla (2021) showed that spray salicylic acid at a concentration of 120 mg L^{-1} attained the highest number of grains $spike^{-1}$ (44.82 grain $spike^{-1}$), weight of 1000 grain (37.10 g), grain yield (6.12 μg ha^{-1}), chlorophyll content in the Flag leaf (475.00 mg m^{-2}), grain protein (14.31%), and proved to have a great possibility in enhancing the grain yield of wheat in drought-expose regions (Maghsoudi *et al*., 2019). Sofy (2015) evident that wheat treated with SA achieved highly significantly increased in plant height, number of grains plant^{-1}, the weight of 1000-grains, and a beneficial regulatory role in plants sown under drought stress conditions. Using SA resulted in enhanced assimilation, nutrient uptake, nitrate reduction, and photosynthesis, improved flow absorption translocation, cytoplasmic streaming, and increased cell safety, which led to increased yield and its components for wheat as well as ameliorating the negative impacts of drought stress (Karim and Khursheed, 2011 and Munsif *et al*., 2022).

Table 6. Means of yield and its attributes as well as, WUE and protein content of two bread wheat cultivars during 2018-19 and 2019-20 seasons

Wheat cultivars (WC)	Flag leaf area (cm^2)		Plant height (cm)		Spike length (cm)	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
WC1 Shandaweel-1	47.3	51.0	99.1	105.0	11.0	11.1
WC2 Giza -171	60.3	64.5	97.4	100.2	10.6	10.9
F value	*	*	*	*	NS	NS
Wheat cultivars (WC)	**Number of kernels spike^{-1}**		**kernels weigh spike^{-1} (g)**		**1000-kernel weight (g)**	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
WC1 Shandaweel-1	61.9	63.5	3.5	3.7	57.0	57.2
WC2 Giza -171	59.7	64.5	4.3	4.3	71.1	66.0
F value	*	NS	*	*	*	*
Wheat cultivars (WC)	**Grain yield (ton fed^{-1})**		**Water use efficiency (kg m^{-3})**		**Protein content %**	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
WC1 Shandaweel-1	2.6	2.8	0.57	0.66	11.1	10.6
WC2 Giza -171	2.4	2.5	0.52	0.59	11.6	11.0
F value	*	*	*	*	*	*

Where NS and * mean non-significant and significant at a 5 % level of probability, respectively

Wheat cultivars performance

The bread wheat cultivars significantly influenced most of the studied traits in both seasons, except spike length in both seasons and number of kernels spike^{-1} in the 2nd season (Table 6). Giza-171 cultivar superiority to Shandaweel-1 and produced the greatest mean values of flag leaf area (60.3 and 64.5 cm^2), kernels weigh spike^{-1} (4.3 and 4.3 g), 1000-kernel weight (71.1 and 66 g) and protein% (11.6 and 11.0%) in the two respective seasons. Likewise, Shandaweel-1 gets the maximum mean values of plant height (99.1 and 105 cm), spike length (11 and 11.1 cm), grain yield (2.6 and 2.8 ton fed^{-1}) and WUE (0.57 and 0.66 kg m^{-3}), respective, in both seasons, and number of kernels spike^{-1} (61.9) in 2018-19 season than Giza-171. Shandaweel-1 cultivar more yielded grain and water use efficiency than the Giza-171 cultivar by (8.33 and 12.00%) and (9.62 and 11.86%) in the 2018-19 and 2019-20 seasons, respectively. These variations in grain yield may be attributed to the remarkable degree of genetic variation and their genetic background for them which may contribute the most to adaptation and flexibility to diverse environmental conditions that may be more favorable for Shandaweel-1 than Giza-171. The highest value of grain yield of wheat was attained by the Shandaweel-1 cultivar compared to other cultivars (Elattar and Moustafa, 2021 and Elmoselhy *et al*., 2022).

Hamada *et al.* (2022) pointed out that cultivars differ from each other in their ability to tolerate varied environmental conditions there by cultivating the appropriate cultivar in its best conditions to maximize its yield due to continual climate change as well redistribution of cultivars is one of the amendments that increase yield. Finally, the Shandawel-1 cultivar scored the highest yield of 5.22 ton ha^{-1} compared to other cultivars *i.e.*, Giza-171, Misr-1, and Sakha-94 (Gad *et al*., 2020). Similar results were reported by Said and Abd El-Moneem (2016); Makarem *et al.* (2019); Al-Zahy *et al.* (2020); Mohammed *et al.* (2021); Mohamed *et al.* (2022) and Upadhyaya and Bhandari, (2022) who reported that superiority any cultivar may be due to the reacting among genetic-make up and their environmental conditions.

Table 7. Means of flag leaf area, kernels weight spike^{-1}, 1000-grain weight and water use efficiency of wheat as affected by interaction between irrigation intervals × salicylic acid during 2018-19 and 2020 seasons

Irrigation Intervals (I)	Salicylic Acid (SA)	Flag leaf area (cm^2) 2019-20	kernels weigh Spike^{-1} (g) 2018-19	1000-kernel weight (g) 2018-19	Water use efficiency (kg m^3) 2019-20
I_6	SA_1	56.6	4.0	65.3	0.53
	SA_2	64.2	4.7	70.2	0.56
	SA_3	69.5	4.9	70.5	0.61
I_9	SA_1	51.0	3.4	61.2	0.58
	SA_2	59.0	3.7	62.2	0.64
	SA_3	62.2	4.3	66.8	0.69
I_{12}	SA_1	47.7	2.9	56.7	0.60
	SA_2	51.9	3.4	58.9	0.68
	SA_3	57.7	3.9	64.5	0.73
F value		*	*	*	*
$LSD_{0.05}$		0.75	0.07	1.04	0.01

Interaction effect

Data illustrated in Table 7 indicate that the interaction between irrigation intervals and foliar spray with salicylic acid was significant for flag leaf area and WUE in the 2nd season, kernels weight spike^{-1}, and 1000-grain weight in the 1st season. Wheat plants which were irrigated every 6 days and sprayed with 300 ppm salicylic acid gained the highest mean values of flag leaf area (69.5 cm^2) in the 2nd season, kernels weight spike^{-1} (4.9 g), and 1000-grain weight (70.5 g) in the 1st season., while the interaction between I_{12}×SA_1 recorded the lowest value for these traits, and the highest value for WUE (0.73 kg m^3) was attained from (I_{12}×SA_3) in the 2nd season. Our results are in harmony with those acquired by Sofy (2015), El-Saadony *et al.* (2021) and Munsif *et al.* (2022).

Moreover, the first order interaction between irrigation intervals and wheat cultivars had a significant effect on flag leaf area, kernels weight spike^{-1} and 1000-grain weight in seasons, plant height and grain yield in the 2nd season (Table 8). Giza-171 cultivar which was irrigated every 6 days achieved the highest mean values of flag leaf area (67.8 and 72.1 cm^2), kernels weight spike^{-1} (5.0 and 4.9 g) and 1000-grain weight (76.4 and 70.8 g) respective, in both seasons. Likewise, the tallest plants (106.1 cm) and heaviest grain yield (3.0 ton fed^{-1}) were acquired when irrigated shandaweel-1 cultivar every 6 days during the 2nd season. El-Saadony *et al.* (2021) found that the interaction between water stress and cultivars was significant and recorded the maximum values for flag leaf area, No. of grains spike^{-1}, and grain yield. Our results are in agreement with those obtained by Said and Abd El-Moneem (2016); Shalaby *et al.* (2020) and Aissaoui and Fenni (2021) who reported that the cultivation of wheat cultivars under drought stress was significantly and scored the higher grain yield.

Table 8. Means of flag leaf area, plant height, kernels weight spike^{-1}, 1000-grain weight and grain yield of wheat as affected by interaction between irrigation intervals × two bread wheat cultivars

Irrigation Intervals (I)	Wheat cultivars (WC)	Flag leaf area (cm^2)		Plant height (cm)	kernels weight Spike^{-1} (g)		1000-grain weight (g)		Grain yield (ton fed^{-1})
		2018-19	2019-20	2019-20	2018-19	2019-20	2018-19	2019-20	2019-20
I_6	WC_1	49.8	54.8	106.1	4.1	4.1	60.9	58.6	3.0
	WC_2	67.8	72.1	103.3	5.0	4.9	76.4	70.8	2.8
I_9	WC_1	48.6	52.3	106.1	3.4	3.6	56.6	57.0	2.8
	WC_2	57.0	62.5	101.1	4.1	4.5	70.1	69.7	2.4
I_{12}	WC_1	43.6	45.9	102.8	3.1	3.3	53.5	56.1	2.6
	WC_2	56.2	59.0	96.1	3.7	3.5	66.6	57.4	2.3
F value		*	*	*	*	*	*	*	*
$LSD_{0.05}$		0.56	1.31	0.95	0.07	0.11	0.64	1.18	0.05

Furthermore, the first order interaction between SA concentrations and wheat cultivars had a significant effect on flag leaf area, and grain yield fed.$^{-1}$ in both seasons and first seasons, respectively (Table 9). Spraying Giza-171 cultivar with 300 ppm of salicylic acid scored the highest average values of flag leaf area (69.4 and 68.2 cm^2 in the two seasons, respective) but treated Shandaweel-1 cultivar with 300 ppm of salicylic acid gained the highest average value of grain yield (2.9 ton fed^{-1} in the 1st season). El-Saadony *et al.* (2021) agreed with our results.

Table 9. Means of flag leaf area and grain yield of wheat as affected by the interaction between salicylic acid × two bread wheat cultivars

Wheat cultivars (WC)	Salicylic Acid (SA)	Flag leaf area (cm^2)		Grain yield (ton fed^{-1})
		2018-19	2019-20	2018-19
WC_1	SA_1	42.7	42.9	2.2
	SA_2	48.7	51.9	2.7
	SA_3	50.5	58.1	2.9
WC_2	SA_1	52.9	60.7	2.1
	SA_2	58.7	64.7	2.3
	SA_3	69.4	68.2	2.8
F value		*	*	*
$LSD_{0.05}$		0.56	1.31	0.06

Figure 2 illustrated that foliar application of salicylic acid promoted the 1000-grain weight of wheat cultivars under different irrigation intervals (I×SA×WC). In the 1st season, cleared that spraying the Giza-171 cultivar with salicylic acid at 300ppm and irrigation every 6 days ($I_6 \times SA_3 \times WC_2$) achieved the highest value for 1000-grain weight (78.0 g), while the lowest value (51.9 g) was recorded from interaction among ($I_{12} \times SA_1 \times WC_1$). Said and Abd El-Moneem (2016) supported our results.

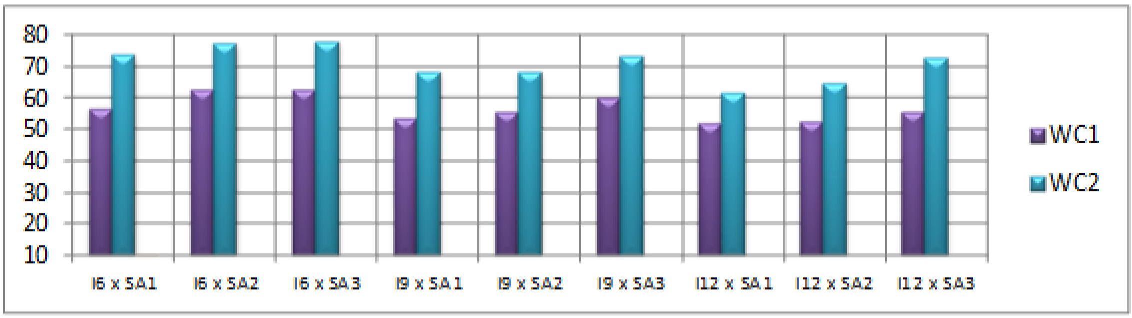


Figure 2. 1000-grain weight of wheat as affected by interaction among I×SA×WC in 2018-19 season.

Table 10. Correlation coefficients among flag leaf area, plant height, spike length, number of kernels spike^{-1}, kernel weight spike^{-1}, 1000-kernel weight, grain yield, water productivity and protein content% in the 1st season (above diagonal) and in the 2nd season (below diagonal)

Traits	FL	PH	SL	NK	KWS	TKW	GY	WUE	PC%
Flag leaf area (FL)	1	0.477*	0.414^{ns}	0.487*	0.911**	0.923**	0.420^{ns}	-0.042^{ns}	-0.098^{ns}
Plant height (PH)	0.135^{ns}	1	0.891**	0.942**	0.705**	0.349^{ns}	0.906**	-0.273^{ns}	-0.658**
Spike length (SL)	0.540*	0.749**	1	0.880**	0.046^{ns}	0.255^{ns}	0.917**	-0.240^{ns}	-0.887**
Number of kernels spike^{-1} (NK)	0.706**	0.663**	0.887**	1	0.722**	0.327^{ns}	0.910**	-0.232^{ns}	-0.587**
Kernels weight spike^{-1} (KWS)	0.885**	0.410^{ns}	0.646**	0.844**	1	0.887**	0.590**	-0.277^{ns}	-0.385^{ns}
1000-kernel weight (TKW)	0.841**	0.144^{ns}	0.357^{ns}	0.569**	0.919**	1	0.220^{ns}	-0.088^{ns}	-0.116^{ns}
Grain yield (GY)	0.276^{ns}	0.897**	0.778**	0.802**	0.520*	0.210^{ns}	1	-0.124^{ns}	-0.404^{ns}
Water use efficiency (WUE)	-0.356^{ns}	-0.328^{ns}	-0.356^{ns}	-0.455^{ns}	-0.437^{ns}	-0.309^{ns}	-0.355^{ns}	1	0.437^{ns}
Protein content% (PC%)	-0.062^{ns}	-0.492*	-0.228^{ns}	-0.352^{ns}	-0.351^{ns}	-0.274^{ns}	-0.494*	0.399^{ns}	1

* and ** mean significance at 0.05 and 0.01, respectively

Simple Correlation analysis

The correlation coefficients among 9 traits of wheat are shown in Table 10, showing that most of each other of the studied traits were positive, and had a significant correlation. In both seasons, positive correlation shown by a significant (r) value for GY observed with PH (r=0.906** and 0.897**), SL (r=0.917** and 0.778**), NK (r=0.910** and 0.802**) and KWS (r=0.590** and 0.520*) respectively, and negatively correlated with PC (r=-0.494*) in the 2nd season only whereas, GY was uncorrelated with FL and TKW in both seasons. This indicates that these traits had the greatest effect on GY. Similar results of a positive association of grain yield with plant height, No. of grain spike^{-1} and spike length were observed by El-Saadany *et al*. (2021). In the 1st season, FL had a significant and positive correlation with PH, NK, and TKW. A significant and positive correlation was detected between PH with SL, NK, KWS, GY, and PC%. SL showed a significant and positive correlation with NK, GY, and PC%.

A positive and significant correlation was gained between NK with KWS, GY, and PC%. KWS had a positive and significant correlation with TKW and GY.

In the 2nd season a significant and positive correlation of FL with SL, NK, KWS, and TKW. PH showed a significant and positive correlation with SL, NK, GY, and a negative correlation with PC%. SL had a positive and significant correlation with NK, KWS, GY, and a negative correlation with PC%. A positive and significant correlation was obtained between NK with KWS, TKW, and GY. KWS had a significant and positive correlation with TKW, and GY. WUE had a non-significant and negative correlation with all studied traits in both seasons.

Conclusion

Finally, it is preferable to plant the cultivar Shandaweel-1 for it realized the highest productivity and spraying with 300 ppm of SA resulted in a significant increase in the yield and its attributes, plus improved WUE under the conditions of late irrigation periods. Irrigation every 12 days gave the highest WUE and saved an amount of water about 28.8% can be used to cultivate new areas in newly reclaimed lands under the conditions of the Luxor Governorate.

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تأثير فترات الري والرش الورقي بحمض السالسيليك على إنتاج صنفين من قمح الخبز في الأرض المستصلحة حديثًا

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الملخص

في التجربة الحالية تم تقدير المحصول ومكوناته وكذلك كفاءة استخدام الماء لصنفين من قمح الخبز (شندويل 1 وجيزة 171) تحت ثلاث فترات ري مختلفة (الري كل 6 و 9 و 12 يوماً) مع ثلاث تركيزات لحمض السالسيليك (معاملة كنترول، 150 و 300 جزء في المليون) يرش علي الاوراق، حيث نفذت التجربة بمزرعة خاصة بقرية الغريرة، مركز أسنا، محافظة الأقصر بجنوب مصر بالأراضي المستصلحة حديثاً خلال موسمي 2019/2018 و2020/2019. تم أستخدم تصميم القطاعات الكاملة العشوائية بترتيب الشرائح المنشقة في ثلاث مكررات.

أشارت النتائج ان زيادة فترات الري من 6 إلى 9 و12 يوماً أدت إلى نقص معنوي لصفات ارتفاع النبات، مساحة ورقة العلم، طول السنبلة، عدد الحبوب بالسنبلة، وزن حبوب السنبلة، وزن 1000 حبة، محصول الحبوب في الموسمين، بينما ازداد محتوي البروتين بالحبة وكفاءة استخدام المياه معنوياً بزيادة فترات الري خلال الموسمين.

أدي الرش الورقي بـ 300 جزء بالمليون من حمض السالسيليك إلى زيادة معنوية في المحصول وصفاته مقارنة بمعاملة المقارنة بعدم الرش وكذلك تحسين كفاءة استخدام المياه تحت ظروف فترات الري كل 9 و12 يوماً.

تفوق الصنف شندويل 1 على الصنف جيزة 171 في صفات: ارتفاع النبات، طول السنبلة ومحصول الحبوب وكفاءة استخدام المياه خلال الموسمين وعدد الحبوب في السنبلة بالموسم الاول. كما تفوق الصنف جيزة 171 على الصنف شندويل 1 في صفات: مساحة ورقة العلم، وزن حبوب السنبلة، وزن 1000 حبة والنسبة المئوية للبروتين خلال موسمي الدراسة، وعدد حبوب السنبلة بالموسم الثاني.

أعطي التفاعل من الدرجة الثانية بين العوامل الثلاثة (الري كل 6 أيام × الرش بحمض سالسيليك بتركيز 300 جزء بالمليون × الصنف شندويل 1) قيم عالية لوزن 1000 حبة خلال الموسم الاول فقط.

ومن نتائج البحث فانه يوصي بزراعة الصنف شندويل 1 تحت ظروف الاراضي المستصلحة حديثاً، وكذلك الرش بتركيز 300 جزء في المليون من حامض السالسليك، في حالة ندرة المياه فانه يوصى بالري كل 12 يوم لإعطائها أعلى كفاءة في استخدام المياه مع توفير حوالي 1529,6 م^3 من مياه الري بنسبة 28,8٪ بالمقارنة بالري كل 6 أيام تحت ظروف محافظة الأقصر.