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Wheat Productivity and Grains Quality as Affected by Foliar Fertilizations and Irrigation Treatments

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ABSTRACT

In order to investigate the impact of foliar fertilization treatments (NPK fertilizer, nano-fertilizer, salicylic acid (SA) and proline acid and its mixture) on productivity and grain quality of wheat cultivar (Sids-14), two field experiments were conducted at a private farm in Ezab El-Arab Village, Aga District, Dakahlia Governorate, Egypt, during the 2020–2021 and 2021–2022 seasons. Under three irrigation treatments, the plants were given four irrigations (control), three irrigations were given while the second irrigation was skipped, and three irrigations were given while the final irrigation was withheld. The trials utilized a strip-plot design with three replications. The yield, its components, and the grain quality characteristics of wheat were drastically reduced throughout the course of the two growing seasons by missing the second irrigation or withholding the final irrigation. When spraying with a combination of NPK fertilizer + nano-fertilizer + SA + proline acid in both seasons, the greatest values of yield, its components, and grains quality characteristics of wheat were noted. Withholding the last irrigation (plants received 3 irrigations) and spraying a mixture of NPK fertilizer at the rate of 5 g/liter + nano-fertilizer at the rate of 0.75 ml/liter water + 200 ppm of salicylic acid at the rate of + proline acid at the rate of 200 ppm in each spraying under the environmental conditions of Dakahlia Governorate could be recommended in order to keep grain quality and high production, while simultaneously reducing water requirements.

Keywords: Wheat, water stress, foliar fertilization treatments, productivity, grains quality

INTRODUCTION

In Egypt and around the world, wheat, "*Triticum aestivum* L." is one of the most crucial cereal crops for human nutrition and serves as a significant source of energy. It is simple to transform wheat into a variety of foods, including bread, pasta, biscuits, and desserts. It's also important to note that wheat straw may be used as animal feed. In Egypt, there were around 3.319 million feddan of wheat planted in the 2021 growing season, and there were more than 9.0 million tons produced, with 18.08 ardab/fed (FAO, 2023). Egypt's domestic use of wheat is insufficient. To fulfil the ongoing demand and close the gap between wheat production and consumption, all parties involved must pay closer attention and enhance output. In order to acquire the highest output of various wheat types with the best quality features, tremendous efforts have been made to develop appropriate agronomic practices.

The main concern with climate change is drought. Most of the wheat is grown in condensates in such a semiarid zone, where 61% of nations worldwide receive less than 500 mm of rainfall each year. In these areas, the amount of irrigation water that plants can use to grow becomes a limiting element, and plants' capacity to increase their drought resistance is a key aspect when environmental conditions are unfavorable. In the foreseeable future, it is anticipated that Egypt's agriculture will have more limited access to water. For the wheat crop to reach its peak production, it needs enough water at all phases of its physiological development. However, similar to other cereal crops, there are key growth periods in which a lack of soil moisture significantly reduces grain output. Wheat plants are exposed to several adverse situations during grain filling, including poor winter rainfall, a lack of irrigation water, the necessity to suspend irrigation in order to conserve water, and early land evacuation in order to cultivate the subsequent crop (Shehab El-Din & Ismail, 1997). According to Chowdhury *et al.* (2021), drought significantly decreased the quantity, weight, and yield of grains. According to Havrlentova *et al.* (2021), one of the most significant variables that affects plant morphology, biochemistry, and physiology and ultimately results in a loss in crop output and seed quality is drought. According to Islam *et al.* (2021), drought stress significantly reduced grain output by 11–34% and grain filling time by 15–24%. Additionally, drought-induced early leaf senescence and decreased total dry matter and yield outputs. According to research by Seadh *et al.* (2021), the last one or two irrigations considerably reduced wheat production, its components, and grain quality features. The maximum yield values, as well as its component and grain quality attributes, were obtained when plants received regular watering (five irrigations). Regarding its impact on yield, its components, and the qualitative characteristics of the grains, delaying the last irrigation (providing plants four irrigations) was the second-best water stress treatment. Water stress is one of the main factors limiting wheat output, according to Sharma *et al.* (2022), and it is getting worse in many of the world's wheat-growing countries. Wheat crop growth and production are significantly reduced as a result. The plant's yields of grain and straw are significantly reduced by water stress during the tillering, grain filling, and blooming phases. Wheat is susceptible to several effects from drought stress, including

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morphological, physiological, biochemical, and molecular changes. Abd El-Rady and Koubisy (2023) showed that the plant height, yields and its components traits significantly decreased under water deficit stress (two irrigations at 21 and 45 days after the planting irrigation). Ebeed *et al.* (2023) revealed that drought negatively affected the growth, morphological characteristics, and some metabolic activities of wheat by decreasing most of the measured parameters compared to their control values.

Foliar fertilization is a method of feeding plants that involves slathering liquid fertilizers on onto their leaves. Both the leaf's stomata and the epidermis are used for the absorption. Although the stomata facilitate quicker elemental movement, the epidermis may also absorb large amounts of material. By way of their bark, plants may also take in nutrients. Foliar fertilization has received a lot of attention lately, and its effectiveness may vary depending on the environment, the plant's physiological state of growth, and its nutritional status (UR Rahman *et al.*, 2014).

Foliar fertilization has received a lot of interest since it may be used to apply just tiny amounts of NPK nutrients at specific times of the year (Narang *et al.*, 1997). According to Seadh *et al.* (2017), the most productive and high-quality wheat grains came from twice-foliar spraying the plant with a combination of commercial NPK components, amino acids, and yeast extract. Solanki *et al.* (2020) announced that foliar spraying with 1% of (18:18:18 NPK) beside the recommended doses on minerals NPK fertilizers at flowering recorded maximum yield, higher net return with benefit cost ratio.

Nanotechnology has established itself in the agricultural sector and other sectors. Plants receive nutrients from Nano-fertilizers. Due to their large surface area and ability to retain a large number of ions while gently releasing them in time to meet crop need, they have nano-dimensions between 30 and 40 nm. There are phosphatic and nitrogenous fertilizers that are slow-release and highly sorbent (Lal, 2008). Unique characteristics of Nano-fertilizers include an increase in production, extremely high absorption, an increase in photosynthesis, and a notable rise in the surface area of the leaves (INIC, 2014). El-Ramady *et al.* (2021) stated that although the use of nano-nutrients in nano-biofortification is a promising method for producing biofortified edible plants, more research is still needed to address unresolved issues such as the appropriate crops and recommended doses. Beiranvand *et al.* (2022) determined that the foliar application of nano fertilizer increased the amount of grain protein (3.3%) by increasing the amount of nitrogen (76%) in the shoot and the amount of grain nitrogen (16%). Gangwar *et al.* (2022) indicated that foliar application of nano-fertilizers significantly increased plant height, grains number/spike, grain & straw yields in comparison to control treatment.

According to Ashraf *et al.* (2010), A hormone-like substance called (SA) is essential for controlling several physiological functions, such the closing of stomata, the absorption and transport of ions, and membrane permeability, transpiration, nitrate metabolism, photosynthesis and growth, flowering, inhibition of ethylene biosynthesis, and stress tolerance. Salinity, drought, and heat are just a few of the biotic and abiotic stressors that application of SA promoted plant tolerance to (Khan *et al.* 2010). Shalaby *et al.* (2017) demonstrated that salicylic acid concentrations significantly influenced all examined features in favor of 150 ppm concentration. Additionally, wheat plants treated with high concentrations of salicylic acid yielded the maximum amounts of grain. According to Jatana *et al.* (2022), administration of salicylic acid to the leaves at doses of 75 and 100 mg-1 lengthened the period during which grains fill up, increased the number of grains per spike, and enhanced grain production. El-Hawary *et al.* (2023) shown that foliar spraying 100 ppm of SA might be a potential therapy for promoting beneficial wheat growth and production in soils impacted by salinity.

Plant cells may adjust to salinity by using proline amino acid to raise the concentration of culture osmotic components and balance the cytoplasm's osmotic potential (Wated *et al.*, 1983). Proline accumulates when the amount of free amino acids in plant tissues increases with salt because higher salinity slows down protein synthesis (El-Leboudi *et al.*, 1997). Farhad *et al.* (2015), exogenous application of proline significantly boosted wheat growth, yield components including grain and straw yields, and these effects were positively correlated with higher percentages and absorption of N, P, K, and S. According to Desoky *et al.* (2017), wheat's growth and production were improved by applying proline to the leaves at a rate of 0.2%, reducing the harmful impacts of drought stress.

To ascertain the impact of foliar fertilization treatments on the productivity and grain quality of wheat cultivar (Sids-14) under water stress circumstances in the ecological context of Dakahlia Governorate, Egypt, this inquiry was recognized.

MATERIALS AND METHODS

A field study was carried out throughout the growth seasons of 2020–2021 and 2021–2022 at a private farm in Egypt's Ezab El-Arab Village, Aga District, and Dakahlia Governorate. This study's main goal was to examine how wheat (Sids-14 cultivar) under water stress responded to foliar fertilization treatments in terms of production and grain quality. The trials utilized a strip-plot design with 3 replicates. The vertical plots received one of three irrigation treatments, consisting of four irrigations (control treatment), three irrigations with the second irrigation skipped, and three irrigations with the final irrigation withheld. To stop water from leaking into neighboring plots, the vertical plots were divided by deeper canals.

The horizontal plots were allocated to ten foliar fertilization; control treatment "without", using irrigation water, trading NPK fertilizer "5 g/liter of Gold Fertic", commercial nano fertilizer "0.75 ml/liter of Amino Lex Star", 200 ppm of SA, 200 ppm of proline acid, the combination of 5 g/liter of trading NPK fertilizer + 0.75 ml/liter of nano fertilizer, the combination of 5 g/liter trading NPK fertilizer + 200 ppm of SA, the combination of 5 g/liter trading NPK fertilizer + 200 ppm of proline acid and the combination of 5 g/liter trading NPK fertilizer + 0.75 ml/liter of nano fertilizer + 200 ppm of SA + 200 ppm of proline acid.

The commercial NPK fertilizer, Gold Fertic, which contains of NPK as a ratio of 19:19:19 was produced from International Company for Agricultural Crops, Fertilizers Factory in Minya. The commercial nano fertilizer, Amino

Lex Star, which was a distinct complex fertilizer, manufactured using nanotechnology, containing free amino acids (plant source) of type (L) by 25%, in addition to, marine algae extracts, macro-and microelements produced from El-Shorouk for Fertilizers. El-Gomhouria Company for Chemical & Medical produces salicylic & proline acids. Foliar solution amount was 200 liters/fed, and the experimental plots were sprayed three times, up to saturation point, after 30, 45, and 60 days from planting. In order to moisten the material, 0.02% of Tween-20 was utilized.

Each experimental unit measured 3 x 3.5 m and had a 10.5 m2 area (i.e., 1/400 feddan). The crop planted in both seasons prior to the summer harvest was rice. Before soil preparation, random soil samples were obtained at a depth of 0 to 30 cm from the units of experimental soil surface to test the physical & chemical soil parameters as defined by Page (1982), which are presented in Table 1. In Table 2, monthly weather information for the Aga district over the two growth seasons of 2020–2021 and 2021–2022 is shown together with relative humidity percentage.

Table 1.The experimental field's physical and chemical soil characteristics over the 2020/2021 and 2021/2022 seasons.

Soil analyses		2020/2021 season	2021/2022 season
A: Mechanical analysis:			
Percentage of coarse sand		2.77	2.72
Percentage of fine sand		23.14	24.09
Percentage of silt		45.74	44.68
Percentage of clay		28.35	28.51
Soil texture		Clay loam	Clay loam
B: Chemical analysis:			
EC (dSm^{-1})		1.25	1.13
pH		7.99	7.89
Percentage of organic matter		1.65	1.75
Percentage of S.P.		62.20	62.40
Percentage of total $CaCO_3$		4.13	4.05
Available (mg/kg)	N	48.58	52.60
	P	5.92	6.12
	K	170.50	189.50
Extractable DTPA (ppm)	Zn	0.85	0.96
	Fe	3.21	3.35
	Mn	1.38	1.49

Table 2. Maximum and lowest monthly temperatures (°C) & relative humidity (%) at the experimental location for the two growth seasons.

Month	Temperature (°C)				Relative humidity (%)			
	2020/2021		2021/2022		2020/2021		2021/2022	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
November	29.4	21.1	26.2	18.6	84.8	37.0	84.9	44.6
December	24.9	15.9	25.9	17.9	77.7	41.5	81.6	48.0
January	19.4	10.5	19.5	10.4	81.6	39.2	85.9	44.9
February	20.5	11.4	20.3	12.5	84.8	39.2	85.4	37.0
March	25.9	14.2	26.6	16.9	85.5	39.7	85.0	31.0
April	30.9	19.4	29.6	18.8	85.6	35.5	85.0	29.0
May	33.2	23.6	32.8	22.7	83.9	36.1	84.0	44.1

Two ploughings, and division into the experimental units with the aforementioned dimensions, the experimental field was thoroughly prepared. 150 kg/fed of calcium super phosphate (15.5% P2O5) was used to prepare the soil. In the first and second seasons, the cultivation took place on November 20 and 23, respectively. The Afir method of spread sowing was used to plant wheat seeds at a rate of 75 kg/fed. Plants were treated for water stress as shown in the treatments after the first irrigation was applied 25 days after seeding.

Ammonium nitrate, a 33.5% N nitrogen fertilizer, was broadcasted at a rate of 80 kg N/fed in two equal doses before the first and second irrigations. Prior to the initial irrigation, potassium fertilizer was broadcasted at a rate of 50 kg/fed in the form of potassium sulphate (48% K2O). The Ministry of Agriculture's guidelines for standard agricultural practices for cultivating of wheat were adhered to, except for the factors under studied.

The following characteristics were estimated after harvest: plant height (cm), spikes number/m2, length of spike (cm), grains number/spike, weight of grains/spike (g), and 1000-grain weight (g). Grain yield per feddan; was measured by taking complete plants from each plot, air drying them, then threshing the grains, weighing them in kilograms, and converting them to ardab per feddan (1 ardab equal 150 kg). Weighted in kg/plot, the straw from the preceding sample was then converted to heml per feddan (1 heml = 250 kg). Total nitrogen was calculated using the modified improved Kjeldahl method, as described in A.O.A.C. (2019), in the Soil Fertility Tests and Fertilizer Quality Assessment Laboratory of the Faculty of Agriculture at Mansoura University in Egypt. The total nitrogen content of wheat flour was multiplied by 5.75 to determine the crude protein percentage. According to Peterburgski (1968), the Soil Fertile. Tests and Fertilizer Quality Assessment Lab. Fac. of Agric. Mans. Univ., Egypt, measured the percentage of potassium in grains (%) using a flame photometer. Using the anthrone approach as reported by Sadasivam and Manickam (1996), the total proportion of carbohydrates in grains was determined.

Using the "MSTAT-C" computer software program, all data were statistically analyzed in accordance with (ANOVA) as described by Gomez and Gomez (1984). The differences between means of treatments were assessed at the 5% level of probability using the least significant difference (LSD) technique, as described by Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

1. Effect of water stress treatments:

Concerning the impact of irrigation treatments *i.e.* giving plants four irrigations (control treatment), skipping the second irrigation (giving plants three irrigations) and withholding the last one irrigation (giving plants three irrigations) on yield and its components (plant height, number of spikes/m2, spike length, number of grains /spike, grains weight/spike, 1000-grain weight, grain & straw yields/fed), crude protein, potassium and total carbohydrates percentages in grains, The findings of this investigation suggested that yield, yield components and quality of grains were significantly affected by water stress treatments in the 1st & 2nd seasons as shown in Tables 3 & 4. Noteworthy, by skipping the second irrigation or withholding the last one irrigation, yield and its components and grains quality characters of wheat were significantly decreased in the two seasons of this study. In view of the fact that the highest values of most of yield, yield components and grains quality of wheat were produced by without water stress (giving plants four irrigations *i.e.,* control treatment) in both seasons as shown in Tables 3 and 4. It was followed by withholding the last one irrigation (giving plants three irrigations) in both seasons. While, the lowest values of plant height, spikes number/m2, length of spike, grains number/spike, weight of grains/spike, 1000-grain weight, grain & straw yields/fed, crude protein, potassium and total carbohydrates percentages in grains of wheat were produced from skipping the second irrigation (giving plants three irrigations) in both seasons. The decline percentages in grain yield/fed of wheat by skipping the second irrigation or withholding the last one irrigation reached about 4.71 and 1.54 % compared without water stress treatment (giving plants 4 irrigations *i.e.,* control treatment) over both seasons of this study.

These improvements in grain quality and production are attributable to wheat plants receiving less watering stress. Four irrigations may be required to consistently supply moisture to wheat plants, allowing for greater development that improves vegetative growth characteristics and results in taller plants. On the other hand, drought reduced plant height owing to hormonal imbalance (cytokinin and abscisic acid), owing to alterations in cell wall extensibility, which in turn inhibited development (Zhao *et al.,* 2006). These results are in good accordance with those obtained by Chowdhury *et al.* (2021), Havrlentova *et al.* (2021), Islam *et al.* (2021), Seadh *et al.* (2021), Sharma *et al.* (2022), Abd El-Rady and Koubisy (2023) and Ebeed *et al.* (2023).

Table 3. Plant height, number of spikes/m^2, spike length, number of grains/spike, grains weight/spike and 1000-grain weight of wheat as affected by water stress and foliar fertilization treatments as well as their interaction during 2020/2021 and 2021/2022 seasons.

Characters / Treatments	Plant height (cm)		Number of spikes/m^2		Spike length (cm)		Number of grains/spike		Grains weight/spike (g)		1000 – grain weight (g)	
	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022
A- Water stress treatments:												
Without water stress	108.9 a	110.9 a	404.1 a	411.5 a	18.23 a	18.80 a	84.56 a	86.10 a	5.416 a	5.515 a	62.51 a	63.65 a
Skipping the second irrigation	104.6 b	106.1 b	388.1 c	393.7 b	17.64 c	17.89 b	80.80 b	81.97 b	4.733 c	4.802 b	57.10 c	57.92 b
Withholding the last one irrigation	104.7 b	108.8 ab	393.4 b	409.5 ab	18.07 b	18.56 ab	81.63 b	84.94 ab	4.983 b	5.185 a	59.48 b	61.90 a
F. test	*	*	*	*	*	*	*	*	*	*	*	*
B- Foliar fertilization treatments:												
Without spraying	98.8 b	101.3 b	376.0 e	385.3 d	16.58 d	16.99 d	72.11 d	73.85 d	4.377 e	4.485 e	54.30 f	55.60 f
Spraying water	99.3 b	101.7 b	382.2 de	391.5 cd	16.64 d	17.05 d	73.22 d	75.01 d	4.411 de	4.516 de	54.32 f	55.63 f
Spraying NPK fertilizer	106.3 ab	108.9 ab	398.2 c	407.9 b	18.37 b	18.83 b	81.66 b	83.68 b	4.977 c	5.099 c	60.82 bc	62.30 bc
Spraying nano fertilizer	101.3 b	103.0 b	386.6 d	396.1 c	17.07 c	17.49 c	76.55 c	78.41 c	4.633 d	4.746 d	57.34 de	58.74 de
Spraying salicylic acid	101.4 b	103.7 b	396.0 c	405.8 b	18.35 b	18.80 b	81.22 b	83.20 b	4.911 c	5.031 c	59.25 cd	60.72 cd
Spraying proline acid	100.6 b	103.1 b	382.6 de	392.1 cd	17.03 c	17.44 c	76.00 c	77.82 c	4.500 de	4.609 de	56.22 ef	57.61 ef
Spraying NPK fertilizer + nano fertilizer	113.8 a	116.7 a	402.2 bc	411.9 b	18.87 a	19.33 a	90.22 a	92.45 a	5.444 b	5.574 b	61.94 b	63.44 b
Spraying NPK fertilizer + salicylic acid	115.2 a	118.0 a	411.1 ab	421.2 a	18.94 a	19.41 a	90.44 a	92.64 a	5.888 a	6.033 a	65.08 a	66.70 a
Spraying NPK fertilizer + proline acid	107.7 ab	110.4 ab	400.4 c	410.2 b	18.85 a	19.32 a	90.11 a	92.33 a	5.366 b	5.500 b	61.49 bc	62.99 bc
Spraying NPK fertilizer + nano fertilizer + salicylic acid + proline acid	116.4 a	119.3 a	416.8 a	427.1 a	19.06 a	19.53 a	91.77 a	94.02 a	5.933 a	6.080 a	66.22 a	67.85 a
F. test	*	*	*	*	*	*	*	*	*	*	*	*
C- Interaction (F. test):												
A × B	*	*	*	*	*	*	*	*	*	*	*	*

Table 4.Grain and straw yields/fed, crude protein, potassium and total carbohydrates percentages in wheat grains as affected by water stress and foliar fertilization treatments as well as their interaction during 2020/2021 and 2021/2022 seasons.

Characters / Treatments	Grain yield (ardab/fed)		Straw yield (heml/fed)		Protein (%)		Potassium (%)		Carbohydrates (%)	
	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022
A- Water stress treatments:										
Without water stress	20.74 a	21.45 a	14.79 a	15.06 a	11.63 a	12.12 a	2.72 a	2.84 a	62.79 a	65.49 a
Skipping the second irrigation	20.15 c	20.44 b	13.86 c	14.06 b	10.17 c	10.36 c	1.77 c	1.80 c	40.76 c	41.54 c
Withholding the last one irrigation	20.61 b	21.12 ab	14.06 b	14.64 ab	10.97 b	11.14 b	2.31 b	2.35 b	53.25 b	54.05 b
F. test	*	*	*	*	*	*	*	*	*	*
B- Foliar fertilization treatments:										
Without spraying	17.22 f	17.64 d	10.13 g	10.37 f	10.37 j	10.44 h	1.98 f	1.99 f	45.64 f	45.98 f
Spraying water	17.27 ef	17.69 d	10.63 f	10.89 e	10.46 i	10.53 gh	2.05 ef	2.07 ef	47.30 ef	47.66 ef
Spraying NPK fertilizer	21.51 c	22.05 b	13.17 c	13.49 c	10.66 e	10.90 e	2.23 c	2.30 cd	51.36 c	52.84 cd
Spraying nano fertilizer	17.41 e	17.83 d	10.78 e	11.04 d	10.55 g	10.71 f	2.14 cde	2.17 de	49.37 cde	50.10 de
Spraying salicylic acid	21.28 d	21.81 c	13.04 d	13.37 c	10.60 f	10.80 ef	2.20 cd	2.24 cd	50.72 cd	51.68 cd
Spraying proline acid	17.38 ef	17.81 d	10.71 ef	10.97 de	10.52 h	10.60 g	2.10 def	2.11 ef	48.35 def	48.71 ef
Spraying NPK fertilizer + nano fertilizer	23.25 ab	23.83 a	18.49 a	18.95 ab	11.91 b	12.26 b	2.47 b	2.55 b	57.00 b	58.69 b
Spraying NPK fertilizer + salicylic acid	23.26 ab	23.84 a	18.50 a	18.96 ab	10.96 c	11.49 c	2.62 a	2.75 a	60.38 a	63.39 a
Spraying NPK fertilizer + proline acid	23.09 b	23.66 a	18.39 b	18.84 b	10.70 d	11.19 d	2.25 c	2.35 c	51.87 c	54.05 c
Spraying NPK fertilizer + nano fertilizer + salicylic acid + proline acid	23.32 a	23.89 a	18.53 a	18.99 a	12.51 a	13.12 a	2.63 a	2.77 a	60.67 a	63.85 a
F. test	*	*	*	*	*	*	*	*	*	*
C- Interaction (F. test):										
A × B	*	*	*	*	*	*	*	*	*	*

2. Effect of foliar fertilization treatments:

Foliar fertilization treatments *i.e.* control treatment “without”, water spraying, 5 g/liter of NPK fertilizer “Gold Fertic”, 0.75 ml/liter of nano fertilizer “Amino Lex Star”, 200 ppm of SA, 200 ppm of proline acid, the combination of 5 g/ liter of NPK fertilizer and nano fertilizer at the rate of 0.75 ml/liter water, the combination of NPK fertilizer at the rate of 5 g/ liter + salicylic acid at the rate of 200 ppm, the combination of 5 g/ liter of NPK fertilizer + 200 ppm of proline acid and the combination of 5 g/liter of NPK fertilizer + 0.75 ml/liter of nano fertilizer + 200 ppm of SA + 200 ppm of proline acid on yield and its components the achieved results of this investigation showed that yield, its components and grains quality were significantly affected due to studied foliar fertilization treatments in both seasons as shown in Tables 3 and 4. The highest values of plant height, number of spikes/m2, spike length, number of grains/spike, weight of grains/spike, weight of 1000-grain, grain, straw yields/fed, crude protein, potassium and total carbohydrates percentages in grains of wheat of wheat were recorded when spraying wheat plants with the application of NPK fertilizer at the rate of 5 g/ liter besides nano fertilizer at the rate of 0.75 ml/liter water beside 200 ppm of beside 200 ppm of proline acid in each spraying in both seasons as shown in Tables 3 and 4. The second best foliar fertilization treatments was spraying with the mixture of NPK fertilizer at the rate of 5 g/ liter + salicylic acid at the rate of 200 ppm in each spraying, followed by spraying with the mixture of NPK fertilizer at the rate of 5 g/ liter + nano fertilizer at the rate of 0.75 ml/liter water in each spraying, then the mixture of NPK fertilizer at the rate of 5 g/ liter + nano fertilizer at the rate of 0.75 ml/liter water in each spraying, the mixture of NPK fertilizer at the rate of 5 g/ liter + proline acid at the rate of 200 ppm in each spraying, commercial NPK fertilizer, Gold Fertic, at the rate of 5 g/ liter water in each spraying, salicylic acid at the rate of 200 ppm in each spraying, commercial nano fertilizer, Amino Lex Star, at the rate of 0.75 ml/liter water in each spraying, proline acid at the rate of 200 ppm in each spraying and irrigation water in both seasons. Whilst, the lowest values of plant height, spikes number/m2, length of spike, grains number/spike, weight of grains/spike, 1000-grain weight, grain & straw yields/fed, crude protein, potassium and total carbohydrates percentages in grains of wheat were achieved from the treatment of control in both seasons.

The improvement in grain yield/fed of wheat by spraying with the mixture of NPK fertilizer + nano fertilizer + salicylic acid + proline acid, the mixture of NPK fertilizer + salicylic acid, the mixture of NPK fertilizer + nano fertilizer, the mixture of NPK fertilizer + proline acid, commercial NPK fertilizer, salicylic acid, commercial nano fertilizer, proline acid and irrigation water reached about 35.43, 35.11, 35.05, 34.11, 24.96, 23.61, 1.09, 0.95 and 0.29 % compared control treatment (without foliar application) over both seasons of this study. This improvement in yield, its constituent parts, and the characteristics of the grains produced by the combination of NPK fertilizer, nano-fertilizer, salicylic acid, and proline acid may be attributable to combining the beneficial effects of these fertilizers. When the root system is still developing in the early stages of development, foliar fertilization may boost N, P, and K supplies (Mallarino *et al.*, 2001). Moreover, nano-fertilizers are a brand-new category of synthetic fertilizers that include a range of easily accessed nutrients at the nanoscale. Because they are more effective and environmentally friendly than conventional chemical fertilizers, nano-fertilizers are advised (Janmohammadi *et al.*, 2016). Salicylic acid is also thought to function similarly to a hormone, playing a significant role in membrane permeability, controlling stomata closure, ion uptake & transport, production of ethylene, transpiration, photosynthesis and growth, nitrate metabolism, flowering, and stress tolerance (Ashraf *et al.*, 2010). Under abiotic stressors, proline acid is an essential osmo-protectant that regulates osmotic pressure, quenches ROS, and maintains redox equilibrium (Matysik *et al.*, 2002). These results are in good accordance compatible with those recorded by Farhad *et al.* (2015), Desoky *et al.* (2017), Seadh *et al.* (2017), Solanki *et al.* (2020), El-Ramady *et al.* (2021), Beiranvand *et al.* (2022), Gangwar *et al.* (2022), Jatana *et al.* (2022) and El-Hawary *et al.* (2023).

3. Effect of interaction:

As demonstrated in Tables 3 & 4, the obtained data showed that there was a considerable impact caused by the interaction between the two examined factors (water stress and foliar fertilization treatments) on most of studied characteristics in both seasons. We only discuss the interactions that are statistically significant for both seasons' grain output and crude protein % in wheat grains. The highest grain yield/fed and percentage of crude protein in grains of wheat were resulted from plots that giving plants four irrigations *i.e.*, control treatment (without water stress) and foliar spraying three times with the combination 5 g/ liter of NPK fertilizer + 0.75 ml/liter of nano fertilizer + 200 ppm of SA + proline acid at the rate of 200 ppm in each spraying in both seasons (Figs. 1 & 2).

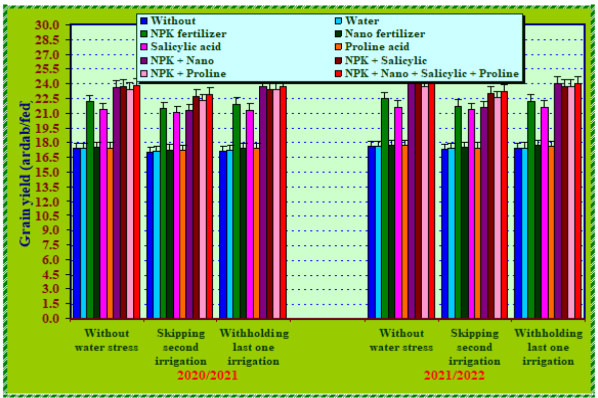

Fig. 1. Grain yield (ardab/fed) of wheat as affected by the interaction between water stress and foliar fertilization treatments during 2020/2021 and 2021/2022 seasons.

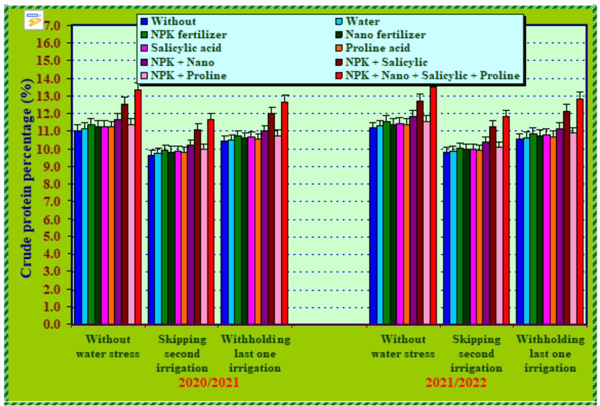

Fig. 2.Crude protein percentage (%) in wheat grains of wheat as affected by the interaction between water stress and foliar fertilization treatments during 2020/2021 and 2021/2022 seasons

Wheat plants withholding the last one irrigation (giving plants three irrigations) and sprayed with the combination of NPK fertilizer at the rate of 5 g/liter + nano fertilizer at the rate of 0.75 ml/liter water + 200 ppm of salicylic acid + 200 ppm of proline acid in each spraying considered as the second-best interaction treatment regarding its effect on grain yield/fed and crude protein percentage in grains of wheat in both seasons. Whereas, the third best interaction treatment was normal irrigated plants (giving 4 irrigations) and sprayed with the combination of 5 g/ liter or NPK fertilizer + 200 ppm of salicylic acid in each spraying in both seasons. It was important to note that plants received 3 irrigations and foliar sprayed three times with any foliar fertilization treatment significantly exceeded grain yield/fed and crude protein percentage in grains of wheat as compared with giving plants 4 irrigations besides without foliar application in both seasons. Conversely, the lowest levels of grain yield/fed & crude protein percentage in grains of wheat were resulted from skipping the second irrigation (giving plants three irrigations) without foliar spraying over the two growth seasons.

CONCLUSION

Our results suggested that, under conditions of environmental of Dakahlia Governorate, Egypt, it could be giving plants 3 irrigations "withholding the last irrigation" and spraying wheat plant with a combination of NPK fertilizer at the rate of 5 g/liter + 0.75 ml/liter water of nano-fertilizer + 200 ppm of salicylic acid + 200 ppm of proline acid in each spraying will save water consumption while maintaining good production and grain quality of.

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تأثير معاملات التسميد الورقي على إنتاجية وجودة حبوب القمح تحت ظروف الإجهاد المائي

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الملخص

أقيمت تجربتان حقليتان فى حقل خاص بقرية عزب العرب، مركز أجا، محافظة الدقهلية، مصر، خلال موسمى 2021/2020 و2022/2021 م بهدف دراسة تأثير معاملات التسميد الورقي (سماد مركب NPK، سماد نانوى، حمض السالسيلك، حمض البرولين والخليط بينهم) على إنتاجية وجودة حبوب القمح تحت ظروف الإجهاد المائي (الري العادي؛ إعطاء النباتات 4 ريات، اسقاط الرية الثانية ومنع الرية الأخيرة؛ أى إعطاء النباتات 3 ريات). نفذت كل تجربة فى تصميم الشرائح المتعامدة فى ثلاث مكررات. أدت معاملات الإجهاد المائى تحت الدراسة إلى انخفاض معنوي فى صفات المحصول ومكوناته وجودة حبوب القمح في كلا الموسمين. كما تشير النتائج المتحصل عليها أن أعلى القيم من صفات المحصول ومكوناته وجودة حبوب القمح نتجت من الرش الورقي بخليط سماد NPK + السماد النانوى + حمض الساليسيليك + حمض البرولين في كلا الموسمين. من نتائج هذه الدراسة يمكن التوصية بالري العادي لنباتات القمح والرش الورقي بخليط سماد NPK بمعدل 5 جم / لتر + السماد النانوى بمعدل 0.75 مل / لتر + حمض الساليسيليك بمعدل 200 جزء في المليون + حمض البرولين بمعدل 200 جزء في المليون في كل رشة لتعظيم إنتاجية وجودة حبوب القمح صنف سدس-14. بينما للحفاظ على الإنتاجية العالية وجودة الحبوب وفي نفس الوقت تقليل الاحتياجات المائية، يمكن التوصية بمنع الرية الأخيرة (إعطاء النباتات ثلاث ريات) ورشها بخليط سماد NPK بمعدل 5 جم / لتر + السماد النانوى بمعدل 75.0 مل / لتر ماء + حمض الساليسيليك بمعدل 200 جزء في المليون + حمض البرولين بمعدل 200 جزء في المليون في كل رشة تحت الظروف البيئية لمنطقة أجا، محافظة الدقهلية، مصر.