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(Original Article)

Response of Some Bread Wheat Cultivars to Foliar Applications Time of Salicylic Acid Concentrations Under the New Valley Conditions

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Abstract

A field experiment was carried out during 2021/2022 and 2022/2023 seasons in Almawhoub, Aldakhla, New valley Governorate, Egypt. This investigation aimed to study the effect of spraying three wheat cultivars with different concentrations of salicylic acid (SA) on the growth and yield traits. Randomized complete block design (RCBD) using split plots in strips arrangement with three replications was used.

The cultivars Sakha 95, Giza 171, and Gemmiza 11 were assigned in vertical strips while spraying with three concentrations of salicylic acid (0, 45, 60, and 75 ppm) were allocated in horizontal strips. In addition, three SA application times, i.e., 30, 45 and 60 days after planting were allocated in the sub- units. The experimental unit area was 10.50 m^2.

The results proved that mean effect of spraying wheat plants by salicylic acid at 75 ppm in both seasons gave the highest mean values of plant height (116.5 and 121.8 cm), maximum number of spike/ m^2 (344.4 and 358.2 spike / m^2), the highest 1000 grain weight (49.5 and 51.66 g), and the maximum grain yield (19.37 and 20.18 ardab/ fed)in the first and second seasons respectively. Foliar application at 60 days from planting registered the maximum average values of all studied traits under investigation. Spike length was insignificantly affected. Here too, the obtained results showed that Sakha 95 cultivar surpassed the other studied cultivars in grain yield (ardab/ fed), No. of spike/m^2, and 1000 grain/weight. Gemmiza 11 was better than the other cultivars in plant height and spike length. Most of interactions revealed that spraying wheat plants by 75 ppm salicylic acid after 60 days from planting registered the highest values of studied traits.

Keywords: *Foliar application, Salicylic acid, Wheat, Grain yield and its components*

Introduction

Wheat plays a vital and increasing role in agricultural strategies every year in Egypt because of the annual steady increase in its population. This led to an increase in the gap between wheat production and consumption. The cultivated area reached 1,411 million hectares, producing more than 9 million tons (FAO STAT, 2021). However, Egypt imports more than 9 million tons annually. This

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gap drives agricultural policy. For this reason, there are active scientific efforts undertaken by the government to work to increase production including horizontal and vertical expansion to increase wheat productivity to cover the increasing demand for wheat.

It is known that wheat cultivars varied in their yield potential especially under newly reclaimed soil in horizontal expansion where its yield varies from an average of 3.4 tons/ha (Elkot 2023); to 6.6 to 8.4 tons/ha (Kamal *et al*. 2011), or 3.2 to 5.7 tons/ha (Kandil *et al.* 2016). Furthermore, in vertical expansion, there are many attempts to maximize the productivity of existing cultivars through some agricultural practices such as fertilizing with microelements and using growth regulators. Thus, selection and cultivation of the high yield cultivar either in old or newly reclaimed soils are very important for wheat production.

Salicylic acid (SA) is a natural plant hormone responsible for inducing abiotic stress tolerance in plants (Gunes *et al*., 2007). Foliar application of SA may participate in regulating physiological processes in plants, such as stomata closure, ion uptake and transport, membrane permeability, photosynthesis, and growth. Salicylic acid treatment affected the nutrient balances in the plant as reported by Borsani *et al*. (2001) who emphasized that foliar application of SA resulted in a significant increase in plant growth both in normal and saline soils. Al-Hakimi and Hamada (2001) showed that salicylic acid (SA) plays a role in the response of plants to salt and osmotic stresses.

Shalaby *et al*. (2017) indicated that all studied traits in both seasons were affected significantly by salicylic acid concentrations in favor of sprayings SA at 150 ppm 45 days after sowing. Dias *et al*. (2021) recorded that the application of SA increased the values of all components of grain yield compared to the control treatment SA. The application of SA promoted a greater increase in the variables analyzed when applied in stage 10 of wheat plants (which marks the end of the vegetative phase and represents the periods from germination to the double-ring stage floral initiation). Jatana *et al.* (2021) indicated that salicylic acid foliar application at 75 and 100 mg l^{-1} increased grain-filling period, improved the normalized difference vegetative index (NDVI), pollen viability, number of grains $spike^{-1}$, proline content, 1000- grain weight, and grain yield.

Abd El-Aziz, and Anter (2023) showed that there were considerable variations among wheat cultivars for the 24 investigated traits. Gemmiza12 wheat cultivar had the maximum grain production over three seasons when 150 mg L^{-1} salicylic acid was applied (3,628 kg/ha in the first season, 3,770 kg/ha in the second season, and 3,911 kg/ha in the third season). moreover, they concluded that Gemmiza12 treated with 150 mg L^{-1} salicylic acid in El-Tur region, South Sinai, Egypt, might be the most economically viable cultivar for wheat grain and straw yields in such area.

Dias *et al.,* (2021), in their attempt to identify the most appropriate time to apply SA to the wheat crop, found that application of SA at stage 10 of vegetative growth of wheat plants increases the grain yield components of the wheat crop.

This current investigation aimed to: (1) evaluate the performance of three wheat cultivars, (2) study the effects of SA concentration foliar applications on some agronomic traits, yield, and its components of wheat cultivars under investigation, and (3) find out suitable time of foliar application of SA.

Materials and Methods

Afield experiment was carried out during (2021/2022 and 2022/2023) seasons in Almawhoub, Aldakhla, New valley governorate, Egypt. This investigation aimed to study the effect of spraying three wheat cultivars (Sakha 95 Giza 171 and Gemmiza 11) with different concentrations of salicylic acid (0, 45, 60 and 75 ppm) at the three application times; (30, 45 and 60 days after sowing) on the growth, yield, and yield components of wheat. Randomized complete block design (RCBD) was used in split plot with strip arrangement with three replications. The three wheat cultivars were assigned in vertical strips, spraying with four concentrations of salicylic acid were allocated in horizontal strips while the three application times were assigned to the sub- units.

Table 1 represents some chemical and physical analyses for the field of experiment prior to conducting the experiment. The soil of experiments was plowed, leveled, and divided into units each with a total area of 10.5 m^2. Seeds were sown on 29th November and 30th November in the two successive seasons (2021/2022 and 2022/2023) respectively.

Table 1. Some physical and chemical properties of the soil in both seasons.

Season	Sand %	Silt %	Clay %	Texture	pH 1:1	ECe dS/m	Total $CaCO_3$ %
2021/2022 (S1)	19.30	31.00	49.70	Clay	7.50	1.42	3.13
2022/2023 (S2)	21	29.40	49	Clay	7.65	1.33	3.25

Season	Total N %	Available nutrients ppm				
		P	K	Fe	Mn	Zn
2021/2022 (S1)	1.50	12.70	364	8.70	8.30	1.00
2022/2023(S2)	1.18	10.20	325	8.60	8.00	0.90

All cultural processes (fertilization, irrigation, and weeding operations) were followed as recommended. Spraying was carried out after dissolving each concentration used in the spray solution 400 liters of water per feddan. Salicylic acid concentrations were sprayed after 30, 45 and 60 days from sowing. Spraying was conducted using mediated sprinkler dorsal spraying in the morning or evening to avoid high temperatures. A detergent solution was added to the solution to reduce the surface tension of the water and to ensure complete wetness of the leaves to increase the efficiency of the spray solution. Other cultural practices were carried out during the growing season.

Five plants were randomly taken from each plot at harvest to determine the following characters:

1-Plant height (cm).

2-Spike length (cm).

3-Number of spikes/ m^2.

4- Thousand grain weight (g).

5-Grain yield (ard /fed.).

Statistical Analysis

All obtained data were subjected to analysis of variance and treatment means were compared for significant differences using the LSD at p = 0.05. The MSTAT-C computer program was used to perform all the analysis of variance with the procedure outlined by Steel and Torrie (1982).

Table 2. Means of plant height (cm) as affected by wheat cultivars, foliar application of salicylic acid concentrations at different time and their interactions in 2021/2022 season

Cultivars (C)	Salicylic Acid concentrations (S, ppm)	Time of application (T)			Mean
		30 days	45 days	60 days	
Sakha 95	Control	103.00	103.00	103.00	103.00
	45	107.70	108.70	109.30	108.60
	60	110.00	112.00	112.00	111.30
	75	111.00	113.00	114.00	112.70
	Mean	107.90	109.20	109.60	108.90
Giza 171	Control	109.00	109.00	109.00	109.00
	45	108.30	109.70	112.00	110.00
	60	111.60	112.80	113.70	112.70
	75	111.70	114.30	115.30	113.80
	Mean	110.20	111.50	112.50	111.40
Gemmiza 11	Control	117.00	117.00	117.00	117.00
	45	118.30	119.30	120.00	119.20
	60	120.00	120.30	121.00	120.40
	75	122.70	123.30	123.30	123.10
	Mean	119.50	120.00	120.30	119.90
S × T	Control	109.70	109.70	109.70	109.70
	45	111.40	112.60	113.80	112.60
	60	113.90	115.00	115.60	114.80
	75	115.10	116.90	117.50	116.50
	Mean	112.00	113.10	113.70	

F test and LSD 0.05	F test	LSD 0.05
C	*	1.104
S	**	0.465
C × S	**	0.805
T	**	0.268
T × C	n.s	-
T × S	**	0.335
C × S × T	n.s	-

Where ns, * and ** mean non- significant and significant at 5 and 1 % level of probability, respectively

Results and Discussion

1-Plant height (cm)

Results in Tables 2 and 3 showed that there were significant differences in plant height between the three studied wheat cultivars. Gemmiza 11 var. recorded the tallest plants (119.2 and 120.4 cm) while the shortest plants (108.9 and 114.3 cm) were obtained by sakha 95 in 1st and 2nd seasons, respectively. The increase percentages of plant height of Gemmiza 11 for both Sakha 95 and Giza 171 in the 1st and 2nd season, by (10.10 and 7.63%) and (8.83 and 7.24%), respectively. This increment might be due to the different response between cultivars which are related to the genetic background of the studied cultivars. These results are consistent with the results obtained by Ahmed (2013).

Regarding SA application, plant height showed marked differences among SA concentrations. Spraying wheat plants by salicylic acid at 75 ppm gave the tallest plant (116.5 and 121.8 cm) in the 1st and 2nd seasons respectively.

Table 3. Means of plant height (cm) as affected by wheat cultivars, foliar application of salicylic acid concentrations at different time and their interactions in 2022/2023 season.

Cultivar (C)	Salicylic Acid concentrations (S, ppm)	Time of application (T)			Mean
		30 days	45 days	60 days	
Sakha 95	Control	109.00	109.00	109.00	109.00
	45	112.40	113.30	113.70	113.10
	60	115.40	117.30	117.20	116.60
	75	117.00	118.50	120.20	118.60
	Mean	113.50	114.50	115.00	114.30
Giza 171	Control	113.20	113.20	113.20	113.20
	45	113.80	114.30	116.80	115.00
	60	115.40	117.00	118.10	116.80
	75	116.50	119.40	120.60	118.80
	Mean	114.70	116.00	117.20	116.00
Gemmiza 11	Control	120.60	120.60	120.60	120.60
	45	122.50	123.80	124.60	123.60
	60	124.10	125.00	126.20	125.10
	75	126.90	128.50	128.90	128.10
	Mean	123.50	124.50	125.10	124.40
S × T	Control	114.30	114.30	114.30	114.30
	45	116.20	117.10	118.40	117.20
	60	118.30	119.80	120.50	119.50
	75	120.10	122.10	123.20	121.80
	Mean	116.80	117.90	118.70	

F test and LSD 0.05	F test	LSD 0.05
C	*	0.986
S	**	0.422
C × S	**	0.768
T	**	0.288
T × C	n.s	-
T × S	**	0.335
C × S × T	n.s	-

Where ns, * and ** mean non- significant and significant at 5 and 1 % level of probability, respectively

The concentration of 75 ppm of SA showed increase in plant height by (6.19 and 6.56 %) as compared with the control treatment in 1st and 2nd seasons, respectively.

These results are consistent with the results obtained by He (2005) who found that application of salicylic acid enhanced photosynthesis and also increased photosynthetic products. Similar findings have been reported by Sakhabutdinova *el al.* (2003), Yildirim *et al*. (2008), and EL-Nasharty *et al*. (2019).

In relation to foliar application time, results indicated that foliar application after 60 days from sowing produced the tallest plants (113.7 and 123.2 cm) in comparison to the control treatment (112.0 and 116.8 cm) in 1st and 2nd seasons, respectively. In this respect, the highly efficient spraying of SA at 60 days from sowing might be due to suitability time of application which met the periods from germination to the double-ring stage (floral initiation) of wheat plants as indicated by Dias *et al.* (2021).

Concerning the interaction between wheat cultivars and salicylic acid, all studied salicylic acid concentrations increased plant height with increasing SA concentrations compared to control (without salicylic acid) in favor of 75 ppm concentration on Gemmiza 11 which produced the highest mean values of plant height (123.1 and 128.1 cm) in the 1st and 2nd seasons, respectively. This enhancement in plant height might be due to the relation to the genetic type of Gemmiza 11 or might be due to the role of SA in raising the efficiency of the nutrient balances in the plant as reported by Borsani *et al*. (2001) who proved that exogenous application of SA induced a significant increase in plant growth under different conditions. The same trend was stated by Gunes *et al*. (2007).

The interaction between SA and time of application had a highly significant influence on plant height in both seasons. The highest mean values of plant height (117.5 and 123.2 cm) in the first and second seasons, respectively, were obtained from wheat plants sprayed with 75 ppm salicylic acid at 60 days from sowing in 1st and 2nd seasons. These findings are in good line with those obtained by Shalaby *et al*. (2017) who indicated that all studied traits in 1st and 2nd seasons were affected significantly by salicylic acid concentrations in favor of 150 ppm concentration when spraying was done 45 days after sowing.

Insignificant interaction effects were noticed for C × T and the (C × S × T) on plant height. These interactions recorded the highest values of plant height (120.3 and 125.1 cm) for Gemmiza11 cultivar with application at 60 days and (123.3 and 128.9cm), for Gemmiza11 with 75 SA and application at 60 days in the 1st and 2nd seasons respectively.

2-Spike length (cm)

Data in Tables 4 and 5 indicated that cultivars had a highly significant response on spike length in the two growing seasons. Gemmiza 11 had the longest spike (13.45 and 14.96 cm), while Sakh 95 recorded the lowest spike length (10.84 and 12.41 cm) in1st and 2nd seasons, respectively. These results are due to the genetic variation under this study. Abd El-Hameed (2012) found that wheat

cultivar Sids 13 followed by Sids12 and Misr 1 recorded the highest values for spike length (cm). Nourel-Din *et al*. (2013) recorded significant differences among the tested wheat cultivars in the two seasons in a spike length.

All studied salicylic acid concentrations recorded the higher values of this trait despite the insignificant effect compared to control (without salicylic acid) in favor of 75 ppm concentration (high concentration) which gained the highest mean values of spike length (12.38 and 13.99 cm) in the first and second seasons, respectively.

Table 4. Means of spike length (cm) as affected by wheat cultivars, foliar application of salicylic acid concentrations at different time and their interactions in 2021/2022 season.

Cultivar (C)	Salicylic Acid concentrations (S, ppm)	Time of application (T)			Mean
		30 days	45 days	60 days	
Sakha 95	Control	10.51	10.51	10.51	10.51
	45	10.53	10.62	10.62	10.59
	60	10.53	11.12	11.13	10.93
	75	10.82	11.61	11.61	11.35
Mean		10.60	10.97	10.97	10.84
Giza 171	Control	11.23	11.23	11.23	11.23
	45	11.32	11.32	11.32	11.32
	60	11.33	11.63	11.64	11.53
	75	11.33	12.33	12.33	12.00
Mean		11.30	11.63	11.63	11.52
Gemmiza 11	Control	13.12	13.12	13.12	13.12
	45	13.22	13.31	13.31	13.28
	60	13.42	13.67	13.67	13.59
	75	13.42	14	14	13.81
Mean		13.30	13.53	13.53	13.45
S × T	Control	11.62	11.62	11.62	11.62
	45	11.69	11.75	11.75	11.73
	60	11.76	12.14	12.15	12.02
	75	11.86	12.65	12.65	12.38
General Mean		11.62	11.93	11.93	
F test and LSD 0.05		F test		LSD 0.05	
C		**		0.76	
S		n.s		-	
C × S		*		0.82	
T		n.s		-	
T × C		n.s		-	
T × S		n.s		-	
C × S × T		n.s		-	

Where ns, * and ** mean non- significant and significant at 5 and 1 % level of probability, respectively

With respect to the spike length, the data obtained in Tables 4 and 5 indicated that all tested cultivars were similar in their response to SA rates in both seasons. The increase of SA rate resulted in a significant increase of spike length of all tested cultivars in both seasons. Gemmiza 11 sprayed with 75 ppm recorded the highest spike length (13.81 and 15.30 cm) in 1st and 2nd seasons, respectively. The response of wheat cultivars to levels of SA levels varies. This is mostly reflected in many of the yield components, especially spike length. In this regard Abd El-

Aziz, and Anter (2023) found that the Gemmiza12 wheat cultivar had the maximum spike length over three seasons when sprayed with 150 mg L^{-1} salicylic acid. Shalaby *et al.* (2017) indicated that all studied traits in both seasons were affected significantly by salicylic acid concentrations in favor of 150 ppm concentration for cultivars in the 1st and 2nd seasons, respectively.

Moreover, the other interactions; (T × C), (T × S) and (C × S × T) had insignificant effect on spike length of bread wheat in both seasons.

Table 5. Means of spike length (cm) as affected by wheat cultivars, foliar application of salicylic acid concentrations at different time and their interactions in 2022/2023 season.

Cultivar (C)	Salicylic Acid concentrations (S, ppm)	Time of application (T)			Mean
		30 days	45 days	60 days	
Sakha 95	Control	11.50	11.51	11.51	11.51
	45	12.30	12.22	12.32	12.28
	60	12.10	12.82	12.93	12.62
	75	12.60	13.51	13.61	13.24
Mean		12.13	12.52	12.59	12.41
Giza 171	Control	12.00	12.03	12.03	12.02
	45	12.60	12.42	12.52	12.51
	60	12.60	13.03	13.24	12.96
	75	12.40	13.83	14.03	13.42
Mean		12.40	12.83	12.96	12.73
Gemmiza 11	Control	14.60	14.72	14.82	14.71
	45	14.80	14.71	14.91	14.81
	60	14.70	15.07	15.27	15.01
	75	15.20	15.30	15.40	15.30
Mean		14.83	14.95	15.10	14.96
S × T	Control	12.70	12.75	12.79	12.75
	45	13.23	13.12	13.25	13.20
	60	13.13	13.64	13.81	13.53
	75	13.40	14.21	14.35	13.99
General Mean		12.99	13.32	13.44	
F test and LSD 0.05		F test		LSD 0.05	
C		**		0.71	
S		n.s		-	
C × S		*		0.79	
T		n.s		-	
T × C		n.s		-	
T × S		n.s		-	
C × S × T		n.s		-	

Where ns, * and ** mean non- significant and significant at 5 and 1 % level of probability, respectively

3-Number of spikes/ m^2

The data in Tables 6 and 7 exhibited that cultivars had a highly significant influence on the number of spikes/ m^2 in both seasons, the variety Sakha 95 (337.1 and 356.3) better performed than Giza171 (296.6 and 312.3) and Gemmiza 11 (249.0 and 263.4) in 1st and 2nd seasons, respectively. The variable response of cultivars to the number of spike/ m^2 is analogous to the findings of Gupta *et al*. (2015) who explained that the difference might be owing to its longer panicles, as seen in WH-1105.

Table 6. Means of spikes number /m^2 as affected by wheat cultivars, foliar application of salicylic acid concentrations at different time and their interactions in 2021/2022 season.

Cultivar (C)	Salicylic Acid concentrations (S, ppm)	Time of application (T)			Mean
		30 days	45 days	60 days	
Sakha 95	Control	282.00	282.00	282.00	282.00
	45	296.40	317.30	353.20	322.30
	60	332.60	367.20	378.20	359.30
	75	347.30	396.10	410.40	384.60
Mean		314.60	340.70	356.00	337.10
Giza 171	Control	248.00	248.00	248.00	248.00
	45	261.10	276.30	297.40	278.30
	60	283.50	327.10	339.20	316.60
	75	312.40	353.20	365.10	343.60
Mean		276.30	301.20	312.40	296.60
Gemmiza 11	Control	196.10	196.10	196.10	196.10
	45	211.40	236.50	241.30	229.70
	60	224.10	275.60	296.40	265.40
	75	257.10	319.20	338.40	304.90
Mean		222.00	256.90	268.10	249.00
S × T	Control	242.00	242.00	242.00	242.00
	45	256.30	276.70	297.30	276.80
	60	280.10	323.30	337.90	313.80
	75	305.60	356.20	371.30	344.40
General Mean		274.50	302.60	315.30	

F test and LSD 0.05	F test	LSD 0.05
C	**	7.17
S	**	9.82
C × S	**	10.24
T	**	8.67
T × C	**	9.87
T × S	**	10.65
C × S × T	**	12.45

Where ** means significant at 1 % level of probability

All SA foliar concentrations produced significantly higher number of spikes/ m^2 in both seasons. The maximum number of spikes/ m^2 was (344.4 and 358.2) because of spraying SA at 75 ppm, in both seasons than the control.

Using SA resulted in enhanced assimilation, nutrient uptake, nitrate reduction, and photosynthesis which improved nutrient absorption, translocation, cytoplasmic streaming, and increased cell protection, which led to increased yield components for wheat as well as ameliorating the negative impacts of drought stress (Munsif *et al*., 2022).

Additionally, all time of application significantly affected number of spikes/ m^2 in both seasons. The maximum number of spikes/ m^2 was recorded for the application 60 days after sowing.

Number of spikes/ m2 were highly significantly affected by all first order interactions; (T × C), (C × S) and (T × S) which recorded the highest value of number of spikes/ m2, namely, (384.6 and 356.4) for Sakha 95 sprayed by 75 ppm SA, (344.4 and 358.2) for Sakha 95 sprayed after 60 days from sowing and (315.3

and 331.3 spikes/m2) for the mean of all wheat cultivars when sprayed by 75 ppm SA after 60 days from sowing in 1st and 2nd seasons, respectively.

Regarding the 2nd order interactions, (C × T × S), it had highly significant effects on number of spikes/ m^2 in 1st and 2nd seasons. The highest values of number of spikes/ m^2 were recorded for Sakha 95 sprayed with 75 ppm SA after 60 days from sowing.

Table 7. Means of spikes number /m2 as affected by wheat cultivars, foliar application of salicylic acid concentrations at different time and their interactions in 2022/2023 season.

Cultivar (C)	Salicylic Acid concentrations (S, ppm)	Time of application (T)			Mean
		30 days	45 days	60 days	
Sakha 95	Control	305.10	305.10	305.10	305.10
	45	327.10	351.20	367.40	348.60
	60	341.20	386.10	397.50	374.90
	75	362.10	403.40	423.70	396.40
Mean		333.90	361.50	373.40	356.30
Giza 171	Control	263.40	263.40	263.40	263.40
	45	276.30	291.40	313.50	293.70
	60	301.40	342.70	357.40	333.80
	75	328.40	368.70	378.10	358.40
Mean		292.40	316.60	328.10	312.30
Gemmiza 11	Control	209.40	209.40	209.40	209.40
	45	222.40	251.20	255.40	243.00
	60	239.70	291.10	313.40	281.40
	75	271.80	334.50	352.70	319.70
Mean		235.80	271.60	282.70	263.40
S × T	Control	259.30	259.30	259.30	259.30
	45	275.30	297.90	312.10	295.10
	60	294.10	340.00	356.10	330.10
	75	320.80	368.90	384.80	358.20
General Mean		291.00	319.70	331.30	
F test and LSD 0.05		F test		LSD 0.05	
C		**		6.88	
S		**		9.42	
C × S		**		9.81	
T		**		8.27	
T × C		**		9.87	
T × S		**		10.47	
C × S × T		**		11.98	

Where ** means significant at 1 % level of probability

4- Thousand grain weight (g)

Results in Tables 8 and 9 showed highly significant differences in 1000 grain weight among the three studied wheat cultivars. Sakha 95 recorded the maximum mean values of 1000 grain weight than both Giza 171 and Gemmiza 11 in both seasons, respectively. Also, the increase percentages of 1000 grain weight of Sakha 95 surpassed both Giza 171 and Gemmiza11 in the 1st and 2nd season, by (4.6 and 12.34%) and (5.4 and 13.44%), respectively. This increment might be due to the different response between cultivars which are related to the genetic background

of the studied cultivars. These results are consistent with the results obtained by Ahmed (2013) and El-Nasharty *et al.* (2017).

Table 8. Means of 1000 grain weight (g) as affected by wheat cultivars, foliar application of salicylic acid concentrations at different times and their interactions in 2021/2022 season.

Cultivar (C)	Salicylic Acid concentrations (S, ppm)	Time of application (T)			Mean
		30 days	45 days	60 days	
Sakha 95	Control	44.48	44.48	44.48	44.48
	45	45.36	47.62	48.32	47.10
	60	46.23	51.61	52.51	50.12
	75	49.62	53.24	54.33	52.40
Mean		46.42	49.24	49.91	48.52
Giza 171	Control	43.44	43.44	43.44	43.44
	45	44.03	45.12	45.32	44.82
	60	44.22	48.96	49.32	47.50
	75	46.62	50.86	51.63	49.70
Mean		44.58	47.10	47.43	46.37
Gemmiza 11	Control	39.81	39.81	39.81	39.81
	45	41.23	42.72	43.63	42.53
	60	41.63	45.12	45.36	44.04
	75	44.34	47.21	47.63	46.39
Mean		41.75	43.72	44.11	43.19
S × T	Control	42.58	42.58	42.58	42.58
	45	43.54	45.15	45.76	44.82
	60	44.03	48.56	49.06	47.22
	75	46.86	50.44	51.20	49.50
General Mean		44.43	46.89	47.37	
F test and LSD 0.05		F test		LSD 0.05	
C		**		1.13	
S		**		1.31	
C × S		**		1.43	
T		**		1.57	
T × C		*		1.62	
T × S		**		1.76	
C × S × T		**		1.83	

Where * and ** mean significant at 5 and 1 % level of probability, respectively.

Regarding SA application, 1000 grain weight showed marked differences among SA concentrations. Spraying wheat plants by salicylic acid at 75 ppm recorded the highest 1000 grain weight (49.5 and 51.66) in both seasons, respectively. The concentration of 75 ppm of SA showed an increase in 1000 grain weight as compared with the control treatment (16.3 and 5.1 %) in 1st and 2nd seasons, respectively.

These results are coincided with the results obtained by He (2005) whom found that application of salicylic acid enhanced photosynthesis and also increased photosynthetic products. Similar findings were reported by Sakhabutdinova *el al*. (2003), Yildirim *et al.* (2008), and Al-Badrawi and Alabdulla (2021) who showed that spray salicylic acid at a concentration of 120 mg L^{-1} attained the highest weight of 1000 grain (37.10 g) and grain yield (6.12 µg ha^{-1})

Table 9. Means of 1000 grain weight (g) as affected by wheat cultivars, foliar application of salicylic acid concentrations at different time and their interactions in 2022/2023 season.

Cultivar (C)	Salicylic Acid concentrations (S, ppm)	Time of application (T)			Mean
		30 days	45 days	60 days	
Sakha 95	Control	46.82	46.82	46.82	46.82
	45	47.16	49.45	50.08	48.90
	60	48.38	53.95	54.84	52.39
	75	52.22	55.76	56.73	54.91
Mean		48.65	51.50	52.12	50.76
Giza 171	Control	44.95	44.95	44.95	44.95
	45	46.13	46.86	47.16	46.72
	60	45.58	50.65	51.12	49.12
	75	48.51	53.07	53.97	51.85
Mean		46.30	48.89	49.30	48.16
Gemmiza 11	Control	40.97	40.97	40.97	40.97
	45	42.67	44.34	45.32	44.11
	60	43.12	46.95	47.39	45.82
	75	45.83	49.12	49.70	48.22
Mean		43.15	45.35	45.85	44.78
S × T	Control	44.25	44.25	44.25	44.25
	45	45.32	46.89	47.52	46.58
	60	45.70	50.52	51.12	49.11
	75	48.86	52.65	53.47	51.66
General Mean		46.24	48.81	49.32	

F test and LSD 0.05	F test	LSD 0.05
C	**	1.04
S	**	1.26
C × S	**	1.37
T	**	1.43
T × C	*	1.56
T × S	**	1.64
C × S × T	**	1.71

Where * and ** mean significant at 5 and 1% level of probability, respectively.

In relation to time of foliar application, results indicated that foliar application at 60 days from planting registered the maximum mean values of 1000 grain weight with values (47.37 and 49.32 g) while the minimum ones resulted from spraying at 60 days (44.43 and 46.24 g) in 1st and 2nd seasons, respectively. In this respect, the highly efficiently of spraying SA time at 60 days from sowing might be due to suitability time of application which met the periods of the double-ring stage (floral initiation of wheat plants) as mentioned by Dias *et al*. (2021). Moreover, Shalaby *et al*. (2017) indicated that all studied traits in both seasons were affected significantly by salicylic acid concentrations in favor of 150 ppm concentration.

Concerning the first order interaction between cultivars and salicylic acid (C × T), All studied salicylic acid concentrations increased 1000 grain weight with increasing SA concentrations compared to control (without salicylic acid) in favor of 75 ppm concentration with Sakha 95 which gained the highest mean values of 1000 grain weight (52.40 and 50.76 g) in the 1st and 2nd seasons, respectively. This

enhancement in 1000 grain weight is due to the relation to the genetic type of Gemmiza 11 or might be due to the role of SA in raising the efficiency of the nutrient balances in the plant as reported by Borsani *et al.* (2001) who proved that exogenous application of SA registered in a significant increase in plant growth under different conditions. The same trend was obtained by Gunes *et al*. (2007).

Concerning significant first order interaction (C × S.), obtained results revealed that spraying Sakha 95 var after 60 days from sowing gave the maximum value of 1000 grain weight (49.91 and 52.12 g) in the first and second seasons, respectively

Moreover, the interaction between SA and time of application (T × S.) had a highly significant influence on 1000 grain weight in both seasons. Thus, the highest mean values of 1000 grain weight (51.20 and 53.47 g) in the first and second seasons, respectively) were obtained from wheat plants sprayed with 75 ppm salicylic acid at 60 days from sowing in both seasons. These findings are in good line with those obtained by Shalaby *et al*. (2017).

Concerning the significant second order interaction (C × T × S) on 1000 grain weight, the interaction recorded the highest values of (54.33 and 56.73 g), for sakha 95 under 75ppm SA applied 60 days after sowing in 1st and 2nd seasons, respectively.

5-Grain yield (ard. /fed.)

The results in Tables 10 and 11 indicated that there are significant differences for cultivars, SA concentrations, and application time of SA of this trait in both seasons.

The cultivars were significantly affected in terms of grain yield. Sakha 95 cultivar produced the highest values (20.74 and 21.14 ardab/fed), while Gemmiza 11 cultivar recorded the lowest values (16.85 and 17.24 ardab/fed), The superiority of Sakha 95 cultivar than the other cultivars might be due to its high values of number of spikes/ m^2 and 1000 grain weight (Tables 6, 7, 8, and 9). This might be because Sakha 95 cultivar had the longest grain filling stage duration, which led to more absorption and transition of nutrients to the grains. The result agrees with Farooq *et al*. (2014). Varietal differences in yield were reported by several researchers. Ali *et al.* (2022) stated that the highest value of grain yield of wheat was attained by the Shandaweel-1 cultivar compared to other cultivars. Moustafa and Hussein (2020) indicated superiority and the suitability of Misr 3 and Misr 2 under the newly reclaimed lands at El-Minia governorate. The cultivars' differences in grain yield may be attributed to genetical factors and environment conditions which affected yield attributes and the highest number of spikes m^2 produced by Misr 3. These results agree with those reported by Thanaa and El-Hussin (2013).

The SA concentrations had a highly significant effect on the grain yield in both seasons. Spraying wheat plants with salicylic acid at 75 ppm recorded the maximum values of grain yield (19.37 and 20.18 ard/fed.). Also, increasing salicylic acid concentration from zero to 75 ppm increased significantly grain yield

from (16.96 to 19.73 ardab/fed) in the first season and from (17.42 to 20.18 ardab/fed) in the second one. These results are in good line with those reported by Gunes *et al*. (2007).

Table 10. Means of grain yield (ard/fed) as affected by wheat cultivars, foliar application of salicylic acid concentrations at different times and their interactions in 2021/2022 season.

Cultivar (C)	Salicylic Acid concentrations (S, ppm)	Time of application (T)			Mean
		30 days	45 days	60 days	
Sakha 95	Control	19.04	19.04	19.04	19.04
	45	20.33	21.14	21.41	20.96
	60	20.63	21.55	21.69	21.29
	75	21.28	21.79	21.93	21.67
Mean		20.32	20.88	21.02	20.74
Giza 171	Control	16.12	16.12	16.12	16.12
	45	16.78	17.13	18.63	17.51
	60	17.55	19.37	19.55	18.82
	75	18.44	20.13	20.38	19.65
Mean		17.22	18.19	18.67	18.03
Gemmiza 11	Control	15.71	15.71	15.71	15.71
	45	16.07	16.36	16.97	16.47
	60	16.81	17.47	17.76	17.35
	75	17.13	18.11	18.42	17.89
Mean		16.43	16.91	17.22	16.85
S × T	Control	16.96	16.96	16.96	16.96
	45	17.73	18.21	19.00	18.31
	60	18.33	19.46	19.67	19.15
	75	18.95	20.01	20.24	19.73
General Mean		18.10	18.78	19.09	
F test and LSD 0.05		F test		LSD 0.05	
C		**		0.76	
N		**		0.84	
C × S		**		0.91	
T		*		0.65	
T × C		**		0.73	
T × S		**		0.79	
C × S × T		**		0.84	

Where * and ** mean significant at 5 and 1 % level of probability, respectively

Concerning the application time, the results showed that the highest significant values (19.09 and 19.54 ardab/fed) were obtained from the application after 60 days from sowing in 1st and 2nd seasons, respectively.

The increase in grain yield and the components already presented is due to the application of Sa as it is related to the structure and levels of chlorophyll in plants in addition to improving the activity of enzymes such as rubisco, carbonic anhydrase, and nitrate reductase (Vicente and Plasencia, 2011). It also positively influences the transport of electrons in photosystem II (Janda *et al.,* 2012), which are directly related to photosynthesis.

The results obtained in Tables 10 and 11 showed that the 1st order interactions' (C × T), (C × S) and (T × S) had significant impacts on grain yield in

both seasons. These interactions recorded (21.67 and 22.12 ardab/fed) for spraying Sakha 95 by 75 ppm SA, (21.02 and 21.42 ardab/fed) for spraying Sakha 95 by SA after 60 days from sowing and (20.24 and 20.68 ardab/fed) for spraying SA after 60 days from sowing in 1st and 2nd seasons, respectively.

Regarding the 2nd order interactions, data demonstrated that sprayed Sakha 95 reached the maximum grain yield productivity (21.93 and 22.42 ardab/fed) because of spraying with 75 ppm SA after 60 days from sowing in 1st and 2nd seasons.

Table 11. Means of grain yield (ard/fed) as affected by wheat cultivars, foliar application of salicylic acid concentrations at different times and their interactions in 2022/2023 season.

Cultivar (C)	Salicylic Acid concentrations (S, ppm)	Time of application (T)			Mean
		30 days	45 days	60 days	
Sakha 95	Control	19.37	19.37	19.37	19.37
	45	20.67	21.57	21.76	21.33
	60	21.07	21.96	22.11	21.71
	75	21.78	22.17	22.42	22.12
Mean		20.72	21.27	21.42	21.14
Giza 171	Control	16.71	16.71	16.71	16.71
	45	17.11	17.67	19.06	17.95
	60	17.81	19.91	20.22	19.31
	75	18.9	20.67	20.91	20.16
Mean		17.63	18.74	19.23	18.53
Gemmiza 11	Control	16.17	16.17	16.17	16.17
	45	16.43	16.76	17.38	16.86
	60	17.12	17.87	18.11	17.70
	75	17.56	18.46	18.71	18.24
Mean		16.82	17.32	17.59	17.24
S × T	Control	17.42	17.42	17.42	17.42
	45	18.07	18.67	19.40	18.71
	60	18.67	19.91	20.15	19.58
	75	19.41	20.43	20.68	20.18
General Mean		18.50	19.24	19.54	
F test and LSD 0.05		F test		LSD 0.05	
C		**		0.71	
S		**		0.79	
C × S		**		0.87	
T		*		0.61	
T × C		**		0.68	
T × S		**		0.75	
C × S × T		**		0.79	

Where * and ** mean significant at 5 and 1 % level of probability, respectively

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استجابة بعض أصناف قمح الخبز لوقت الرش الورقي بتركيزات مختلفة من حامض السالسيليك تحت ظروف الوادي الجديد

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الملخص

نفذت تجربة حقلية خلال الموسمين الزراعيين المتتاليين 2022/2021، 2023/2022 في قرية الموهوب مركز الداخلة محافظة الوادي الجديد، مصر. بهدف دراسة تأثير رش ثلاثة أصناف من القمح بتراكيز مختلفة من حامض السالسيليك على نمو ومحصول القمح. وكان تصميم القطاعات الكاملة العشوائية (RCBD) باستخدام القطع المنشقة في شرائح لثلاث مكررات هو المستخدم في التجربة.

وأصناف القمح (سخا 95، جيزة 171، جميزة 11) وضعت رأسيا. أما الرش بثلاثة تراكيز من حامض السالسيليك (0، 45، 60، 75 جزء في المليون) وضعت أفقيا، بينما اوقات الرش؛ بعد 30، 45 أو 60 يوما من الزراعة كان في القطع المنشقة. وكانت مساحة القطعة 10.5 م^2 (الطول = 3.5 م × العرض 3.0 م).

أثبتت النتائج أن متوسط تأثير رش نباتات القمح بحامض السالسيليك بتركيز 75 جزء بالمليون أعطى أعلى ارتفاع للنبات (116.5 و121.8 سم) وأقصى عدد سنابل/م^2 (344.4 و358.2 سنبلة / م^2) وأعلى وزن 1000 حبة (49.5 و51.66) واعلا القيم لإنتاج الحبوب (19.37 و20.18) أردب/فدان في كلا الموسمين.

سجل الرش الورقي بعد 60 يوما من الزراعة أعلى القيم المتوسطة لجميع الصفات تحت الدراسة حيث: -

سجل طول السنبلة استجابات ضئيلة.

1- تفوق الصنف سخا 95 على الأصناف الأخرى في إنتاجية الحبوب (أردب/فدان) وعدد السنابل /م^2 ووزن 1000 حبة

2- حقق صنف جميزة 11 أفضل قيم مقارنة بالأصناف الأخرى في ارتفاع النبات وطول السنبلة

3- أظهرت معظم التفاعلات أن رش نباتات القمح بحمض السالسيليك بتركيز 75 جزء في المليون بعد 60 يوماً من الزراعة سجل أعلى قيم للصفات.

الكلمات المفتاحية: *حامض السالسيليك، الرش الورقي، القمح، محصول الحبوب ومكوناته*