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Effect of Salicylic Acid Foliar Spray and NPK Fertilization on Wheat Productivity

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Abstract

A field experiment was carried out at the Experimental Farm, Agriculture Faculty, South Valley University at Qena Governorate, Egypt, during 2013/2014 and 2014/2015 seasons to study the effect of salicylic acid and NPK fertilization on wheat productivity. The experiment was laid out in a randomized complete block design (RCBD) using strip plot arrangement with three replications. The first variable was salicylic acid concentrations which occupied horizontally. While the second one was NPK rates which allocated vertically. The obtained results showed that all studied traits in both seasons were affected significantly by salicylic acid concentrations in favour of 150 ppm concentration as well as by NPK fertilization rates in favour of high rate(125, 45 and 48 kg fed^{-1} of N, P and K, respectively). Furthermore, wheat plants sprayed by high salicylic acid concentration and subjected to high NPK fertilization rate produced the highest mean values of grain yield (2600 and 2520 kg fed^{-1} in the first and second seasons, respectively). While, wheat plants sprayed by high salicylic acid concentration and subjected to low NPK fertilization rate gave the maximum mean values of use efficiency for nitrogen, phosphorus and potassium in both seasons.

Keywords: *Salicylic acid, NPK fertilization, wheat.*

Introduction

Wheat (*Triticumspp.* L.) crop consider is one of the most important cereal crops in the world with regard to cultivated area and total production. The cultivated area of wheat in Egypt during 2016 season was about 3.0 million fed. with the total yield production of 8.1million metric tonswhile the total consumption reached about 19.7 million metric tons (USDA,2017). So, increasing wheat production in order to reduce the gap between production and consumption are the strategic aim. As land and water resources are limited in Egypt, increasing the productivity of wheat from the unit area is an important part in increasing the total production. Such target will be achieved by increasing the cultivated area, cultivating high yield varieties, and adoption of improved cultural practices.

Salicylic acid (SA), a naturally occurring plant hormone, acts as an endogenous signal molecule responsible for inducing a biotic stress tolerance in plants (Raskin, 1992 and Gunes *et al*., 2007) Exogenous application of SA may participate in the regulation of physiological processes in plants, such as stomata closure, ion uptake and transport membrane permeability and photosynthesis and growth. Salicylic acid treatment affected the nutrient balances in the plant as reported by Borsani *et al.* (2001) who emphasized that exogenous application of SA resulted in a significant increase in plant growth both in saline and non-saline conditions. Also, Al-Hakimi and Hamada (2001) shown that salicylic acid (SA) plays a role in the response of plants to salt and osmotic stresses. Generally, deficiency or very high levels of SA increases the plant susceptibility to abiotic stress. Egypt is considered to be a heavy user of chemical fertilizers, especially N fertilizers then P and K fertilizers. Soil fertility continues to decline because of combined effects of increasing pressure for land use for crop production, inadequate compensation of nutrients exported and lack of nutrients management. The combined application of N, P and K has proved to be more effective in increasing yield of wheat as compared to sole application of either N or P or K (Petkov, 1983). Different NPK levels significantly affected wheat plant height, Number offertile tillers, 1000-grain weight, grain yield and grain protein content of wheat (Hussain *et al.*, 2002; Rehman *et al.*, 2008 and Leghari *et al.*, 2016.

Therefore, this work designed to investigate the response of wheat plants to exogenous application of different concentrations of salicylic acid and NPK fertilization.

Materials and Methods

Experimental site description:

A field experiment was carried out at the Experimental Farm, Agriculture Faculty, South Valley University at Qena Governorate, Egypt, during 2013/2014 and 2014/2015 seasons to study the effect of salicylic acid and NPK fertilization on wheat productivity. The farm is located at an altitude of 79 m above sea level and is intersected by 26°10′ N latitude and 32°43′ E longitude. The soil of the experimental site is sandy-loam throughout its profile (74.4 % sand, 15.8 % silt and 9.8 % clay), with a pH value of 7.77, 2.62 EC (dSm^{-1}), 0.42% organic matter content, 0.34% total N, 7.98, 186 ppm available P and K, respectively.

Experimental treatments and design:

The experiment was carried out in a randomized complete block design (RCBD) using strip plot arrangement with three replications. The first variable was salicylic acid (SA) concentrations (0, 50, 100 1nd 150 ppm) which occupied horizontally. While the second variable was NPK rates which allocated vertically. Three rates of NPK were studied as follows:

1- Low rate of NPK fertilizers (75,15 and 24 kg fed^{-1} of N. P and K, respectively).

2- Recommended rate of NPK fertilizers (100, 30and 36 kg fed^{-1} of N, P and K, respectively).

3- High rate of NPK fertilizers (125, 45 and 48kg fed^{-1} of N, P and K, respectively).

Cultural practices:

Bread wheat (Giza 168 cv.) was sown on the 25th of November in both seasons. Sprayings of SA were done 45 days after sowing. The NPK fertilizerswas applied in the form of Ammonium nitrate (33.5% N), Calcium super phosphate (15.5% P_2O_5) and potassium sulphate (48%K_2O) as a source of nitrogen, phosphorus and potassium, respectively.Calcium super phosphate (15.5% P_2O_5) was added during soil preparation.While, nitrogen fertilizer was applied in three equal doses before the first, second and third irrigation, respectively. Potassium sulphate (48%K_2O) was added before third irrigation. The experimental soil site was fallow in the summer season. All other cultural practices were carried out as recommended for wheat crop.

Measured traits:

At harvest ten guarded stems for each experimental unit were taken and plant height (cm), spike length (cm), number of kernels spike^{-1} and kernels weight spike^{-1} were determined. 1000-kernel weight, biological, grain and straw yields were determined in plot basis. The use efficiency of N, P and K applied to wheat was judged by the quantity of grain yield produced per kg N, P and K applied (Kg Kg^{-1}) according Ali (2010).

Statistical analysis:

All collected data were analyzed with analysis of variance (ANOVA) Procedures using the SAS Statistical Software Package (v.9.2, 2008). Differences between means were compared by LSD at 5% level of significant (Gomez and Gomez, 1984).

Results and Discussions

A- Vegetative traits:

Plant height (cm)

Data presented in Table 1 show that salicylic acid, NPK fertilization and their interaction had a significant effect on plant height of bread wheat cv Giza 168 in the two growing seasons. All studied salicylic acid concentrations enhancement this trait compared to control (without salicylic acid) in favor of 150 ppm concentration (high concentration) which gained the highest mean values of plant height (86.30 and 80.93 cm in the first and second seasons, respectively).Salicylic acid treatment affected the nutrient balances in the plant as reported by Borsani *et al.* (2001) who emphasized that exogenous application of SA resulted in a significant increase in plant growth under different conditions. The same trend was obtained by Raskin (1992) and Gunes *et al*. (2007). Furthermore, the high NPK fertilization rate produced the highest mean values of plant height which were 87.06 and 78.60 cm in the first and second seasons, respectively. This may be due to the role of NPK nutrients in cell elongation and division as well as increases in photosynthesis process. These findings are in a good line with those obtained by Hussain *et al.* (2002), Rehman *et al.* (2008) and Leghari *et al.* (2016). Moreover, the interaction between salicylic acid and NPK fertilization had a significant influence on plant height in both seasons. Thus, the highest mean values of plant height (94.77 and 85.40 cm in the first and second seasons, respectively) were obtained from wheat plants sprayed with 150 ppm salicylic acid and fertilized with 125, 45 and 48 kg fed^{-1} of N, P and K, respectively.

Table 1. Effect of salicylic acid, NPK fertilizations and their interaction on Plant height(cm)

Seasons	2013-2014					2014-2015				
Salicylic acid NPK	0	50	100	150	Mean	0	50	100	150	Mean
Low	70.05	73.50	77.12	80.00	75.17	68.85	69.80	75.00	77.50	72.79
Recommended	71.35	75.90	87.25	84.12	79.66	69.10	71.00	77.00	79.90	74.25
High	75.30	88.15	90.00	94.77	87.06	73.80	75.00	80.20	85.40	78.60
Mean	72.23	79.18	84.79	86.30	-----	70.58	71.93	77.40	80.93	-----
F test and $LSD_{0.05}$value	F test		LSD			F test		LSD		
SA	*		2.05			*		0.93		
NPK	*		1.162			*		1.1		
SA*NPK	*		2.20			*		1.90		

Where, *mean significant at 5% level of significant
Low= 75, 15 and 24 kg fed^{-1} of N, P and K, respectively
Recommended= 100, 30and 36 kg fed^{-1} of N, P and K, respectively
High= 125, 45 and 48 kg fed^{-1} of N, P and K, respectively

Spike length (cm)

Data presented in Table 2 focus that salicylic acid, NPK fertilization and their interaction had a significant effect on spike length of bread wheat cv Giza 168 in the two growing seasons. All studied salicylic acid concentrations enhancement this trait compared to control (without salicylic acid) in favor of 150 ppm concentration (high concentration) which gained the highest mean values of spike length (10.77 and 10.30 cm in the first and second seasons, respectively). Salicylic acid treatment affected the nutrient balances in the plant as reported by Borsani *et al.* (2001) who emphasized that exogenous application of SA resulted in a significant increase in plant growth both in saline and non-saline conditions. The same trend was obtained by Raskin (1992) and Gunes *et al.* (2007). Furthermore, the high NPK fertilization rate produced the highest mean values of spike length which were 11.04 in the first seasons, and 10.30 in the second one. This may be due to the role of NPK nutrients in cell elongation and division as well as increases in photosynthesis process. These findings are in a good line with those obtained by Hussain *et al.* (2002), Rehman *et al.* (2008) and Leghari *et al.* (2016). Moreover, the interaction between salicylic acid and NPK fertilization had a significant influence on spike length in both seasons. Thus, the highest mean values of spike length (11.80 and 11.00 cm in the first and second seasons, respectively) were obtained from wheat plants sprayed by 150 ppm salicylic acid and fertilized with 125, 45 and 48 kg fed^{-1} of N, P and K, respectively.

Table 2. Effect of salicylic acid, NPK fertilizations and their interaction onspike length (cm)

Seasons	2013-2014					2014-2015				
Salicylic acid NPK	0	50	100	150	Mean	0	50	100	150	Mean
Low	9.10	9.35	9.50	10.00	9.49	8.76	9.55	9.85	9.90	9.52
Recommended	10.00	9.50	10.00	10.50	10.00	9.25	9.75	9.95	10.00	9.74
High	10.55	10.80	11.00	11.80	11.04	9.70	10.00	10.50	11.00	10.30
Mean	9.88	9.88	10.17	10.77	------	9.24	9.77	10.10	10.30	-----
F test and $LSD_{0.05}$value	F test			LSD		F test			LSD	
SA	*			0.13		*			0.10	
NPK	*			0.22		*			0.19	
SA*NPK	*			0.25		*			0.23	

Where, *mean significant at 5% level of significant
Low= 75, 15 and 24 kg fed^{-1} of N, P and K, respectively
Recommended= 100, 30 and 36 kg fed^{-1} of N, P and K, respectively
High= 125, 45 and 48 kg fed^{-1} of N, P and K, respectively

B-Yield components:

Number of kernels $spike^{-1}$

Illustrated data in Table 3 reveal that salicylic acid, NPK fertilization and their interaction had a significant effect on the number of kernels $spike^{-1}$ in both seasons. Increasing salicylic acid concentration from 50 to 150 ppm increased significantly number of kernels $spike^{-1}$ by 17.14 and 20.30% in the first and second seasons, respectively. This is to be logic since the same trend was observed with regard to spike length. These results are in harmony with that obtained by Ibrahim *et al.* (2014). Also, the high rate of NPK fertilization produced the highest mean values of kernels number $spike^{-1}$ (53.50 and 51.25 kernel $spike^{-1}$ in the first and second seasons, respectively). This is may be due to the longest spikes produced by the same NPK fertilizer rates which led to an increase in spikelets number and consequently increased number of kernels $spike^{-1}$. Similar trend was observed by Rehman *et al.* (2008) and Ibrahim *et al* (2014). Here too, the highest mean values of kernel number $spike^{-1}$ were recorded from 150 ppm salicylic acid with high NPK fertilization rate in both seasons which gained 60.00 and 58.00 kernel $spike^{-1}$ in the first and second seasons, respectively.

Table 3. Effect of salicylic acid, NPK fertilizations and their interaction onnumber of kernel $spike^{-1}$

Seasons	2013-2014					2014-2015				
Salicylic acid NPK	0	50	100	150	Mean	0	50	100	150	Mean
Low	37.00	41.00	49.00	50.00	44.25	35.00	39.00	46.00	50.00	42.50
Recommended	39.00	45.00	50.00	54.00	47.00	38.00	44.00	49.00	52.00	45.75
High	43.00	54.00	57.00	60.00	53.50	42.00	50.00	55.00	58.00	51.25
Mean	39.67	46.67	52.00	54.67	----	38.33	44.33	50.00	53.33	-----
F test and $LSD_{0.05}$value	F test			LSD 0.05		F test			LSD 0.05	
SA	**			2.50		**			1.60	
NPK	**			2.16		**			1.30	
SA*NPK	**			2.80		**			1.80	

Where, ** mean significant at 1% level of significant
Low= 75, 15 and 24 kg fed^{-1} of N, P and K, respectively
Recommended= 100, 30 and 36 kg fed^{-1} of N, P and K, respectively
High= 125, 45 and 48 kg fed^{-1} of N, P and K, respectively

1000 kernel weight (g)

Exhibited data in Table 4 denote that salicylic acid, NPK fertilization and their interaction had a significant effect on 1000 kernel weight in the two growing seasons. All tested salicylic acid concentrations surpassed control treatment in this respect in favor of 150 ppm concentration which produced the heaviest kernels (39.83 and 35.90 g in the first and second seasons, respectively). This is may be due to the exogenous application of SA may participate in the regulation of physiological processes in plants, such as stomata closure, ion uptake and transport membrane permeability and photosynthesis and growth (Raskin, 1992 and Gunes *et al*., 2007). Also, the heaviest kernels were obtained from wheat plants fertilized by high NPK fertilization rate while the lightest kernels (34.48 and 32.38 g in the first and second seasons, respectively) were obtained from low NPK fertilization rate. These findings are in a good line with those obtained by Hussain *et al.* (2002), Rehman *et al.* (2008) and Leghari *et al.* (2016). Moreover, the highest mean values of 1000 kernel weight (42.50 and 36.70 g in the first and second seasons, respectively) were recorded from bread wheat plants sprayed by 150 ppm salicylic acid and fertilized by high NPK fertilization rate.

Table 4. Effect of salicylic acid, NPK fertilizations and their interaction on 1000 kernel weight (g)

Seasons	2013-2014					2014-2015				
Salicylic acid NPK	0	50	100	150	Mean	0	50	100	150	Mean
Low	30.00	34.40	35.50	38.00	34.48	29.00	32.00	33.50	35.00	32.38
Recommended	35.00	35.00	39.50	39.00	37.13	33.00	34.00	34.90	36.00	34.48
High	35.50	39.00	41.00	42.50	39.50	34.00	34.60	35.00	36.70	35.08
Mean	33.50	36.13	38.67	39.83	------	32.00	33.53	34.47	35.90	-----
F test and $LSD_{0.05}$value	F test			LSD		F test			LSD	
SA	*			1.20		**			0.80	
NPK	**			0.91		**			0.71	
SA*NPK	*			1.50		*			1.20	

Where, *, ** mean significant at 5 and 1% level of significant, respectively
Low= 75, 15 and 24 kg fed^{-1} of N, P and K, respectively
Recommended= 100, 30 and 36 kg fed^{-1} of N, P and K, respectively
High= 125, 45 and 48 kg fed^{-1} of N, P and K, respectively

Kernels weight $spike^{-1}$(g)

The kernels weight $spike^{-1}$ trait affected significantly by tested variables and their interaction in the two growing seasons (Table 5). Wheat plants sprayed by salicylic acid gained significant kernels weight $spike^{-1}$ as compared to control treatment (without salicylic). Thus, high salicylic acid concentration (150 ppm) recorded the highest mean values in this respect (2.67 and 2.53 g in the first and second seasons, respectively). This is to be logic since the same salicylic acid concentration give the highest mean values with regard to number of kernels $spike^{-1}$ and 1000 kernel weight and consequently produced the highest mean values of kernels weight $spike^{-1}$. These results are in harmony with that obtained by Ibrahim *et al.* (2014). Furthermore, the high NPK fertilization rate registered the maximum mean values of kernels weight spike^{-1} (2.60 and 2.38g in the first and second seasons, respectively). This is to be expected since the same NPK fertilization rate gained the highest mean values with regard to number of kernel spike^{-1} and 1000 kernels weight and consequently give the maximum mean values of kernels weight spike^{-1}. Similar trend was observed by Rehman *et al.* (2008) and Ibrahim *et al* (2014). Here too, the highest mean values of kernels weight spike^{-1} (3.00 and 2.70g in the first and second seasons, respectively) were registered from wheat plants sprayed by 150 ppm salicylic acidand fertilized by high NPK fertilization rate.

Table 5. Effect of salicylic acid, NPK fertilizations and their interaction on kernels weight spike^{-1}

Seasons	2013-2014					2014-2015				
Salicylic acid NPK	0	50	100	150	Mean	0	50	100	150	Mean
Low	1.95	2.04	2.19	2.40	2.15	1.65	1.70	2.10	2.40	1.96
Recommended	2.00	2.33	2.43	2.60	2.34	1.75	1.90	2.30	2.50	2.11
High	2.28	2.50	2.60	3.00	2.60	2.00	2.30	2.50	2.70	2.38
Mean	2.08	2.29	2.41	2.67	----	1.80	1.97	2.30	2.53	-----
F test and $LSD_{0.05}$value	F test		LSD			F test		LSD		
SA	*		0.21			**		0.15		
NPK	*		0.25			*		0.22		
SA*NPK	*		0.30			*		0.27		

Where, *, ** mean significant at 5 and 1% level of significant, respectively
Low= 75, 15 and 24 kg fed^{-1} of N, P and K, respectively
Recommended= 100, 30 and 36 kg fed^{-1} of N, P and K, respectively
High= 125, 45 and 48 kg fed^{-1} of N, P and K, respectively

C-Biological, grain and straw yields (kg fed^{-1}):

Biological yield

Data presented in Table 6 reveal that salicylic acid, NPK fertilization rate and their interaction had a significant influence on biological yield in both seasons. Thus, sprayed wheat plants by salicylic acid increased significantly biological yield as compared to control treatment in favor to high salicylic acid concentration (150 ppm) which increasedbiological yieldin the first seasonby the rate of 31.07, 12.13 and 7.45% from 0.00 (control), 50 and 100 ppm salicylic acid concentrations, respectively, being 28.36, 11.02 and 6.83 in the second season in the same order. These findings can be explained by the superiority of high salicylic acid concentration (150 ppm) with regard to plant height and kernels weight spike^{-1} traits which considered the main consist of biological yield. These results are in a good line with those reported by Raskin (1992) and Gunes *et al*. (2007). Also, wheat plants fertilized by high NPK fertilization rate produced the maximum biological yield (5600 and 5035 kg fed^{-1} in the first and second seasons, respectively). This is to be logic since the same NPK fertilization rate give the highest mean values with regard to plant height and kernels weight spike^{-1}. These findings are harmony with those obtained by Rehman *et al.* (2008) and Ibrahim *et al* (2014). Moreover, sprayed wheat plants by 150 ppm salicylic acid with high NPK fertilization rate produced the maximum biological yield (6300 and 5614 kg fed^{-1} in the first and second seasons, respectively).

Table 6. Effect of salicylic acid, NPK fertilizations and their interaction on biological yield (kg fed.$^{-1}$)

Seasons	2013-2014					2014-2015				
Salicylic acid NPK	0	50	100	150	Mean	0	50	100	150	Mean
Low	3800	4950	5000	5300	4763	3398	4449	4500	4608	4239
Recommended	4400	5080	5400	5700	5145	4096	4566	4850	5217	4682
High	5000	5400	5700	6300	5600	4533	4891	5100	5614	5035
Mean	4400	5143	5367	5767	-----	4009	4635	4817	5146	----
F test and $LSD_{0.05}$ value	F test			LSD		F test			LSD	
SA	*			150.00		**			120.20	
NPK	*			110.00		**			101.2	
SA*NPK	**			175.20		**			130.0	

Where, *, ** mean significant at 5 and 1% level of significant, respectively
Low= 75, 15 and 24 kg fed^{-1} of N, P and K, respectively
Recommended= 100, 30and 36 kg fed^{-1} of N, P and K, respectively
High= 125, 45 and 48 kg fed^{-1} of N, P and K, respectively

Grain yield

Exhibited data in Table 7 show that salicylic acid, NPK fertilizationand their interaction had a significant effect on grain yield in the two growing seasons. Increasing salicylic acid concentration from zero to 150 ppm increased significantly grain yield from 1583 to 2200 kg fed^{-1} in the first season and from 1517to 2153 kg fed^{-1} in the second one. This is to be logic since the same trend was observed with regard to kernel weight spike^{-1}. These results are in a good line with those reported by Raskin (1992) and Gunes *et al*. (2007). Furthermore, wheat plants fertilized by the high rate of NPK fertilization produced the highest mean values of grain yield (2188 and 2114kg fed^{-1} in the first and second seasons, respectively). This is to be expected since the same NPK fertilization rate registered the highest mean values with regard to kernels weight spike and consequently produced the highest mean values of grain yield in both seasons. These results are in harmony with those obtained by Rehman *et al.* (2008) and Ibrahim *et al* (2014). Here too, the highest mean values of grain yield (2600 and 2520 kg fed^{-1} in the first and second seasons, respectively) were recorded from wheat plants sprayed by 150 ppm salicylic acid with high NPK fertilization rate.

Table 7. Effect of salicylic acid, NPK fertilizations and their interaction on grain yield (kg fed.$^{-1}$)

Seasons	2013-2014					2014-2015				
Salicylic acid NPK	0	50	100	150	Mean	0	50	100	150	Mean
Low	1300	1600	1750	1900	1638	1250	1530	1720	1860	1590
Recommended	1600	1800	2040	2100	1885	1520	1760	2010	2080	1843
High	1850	2100	2200	2600	2188	1780	2000	2155	2520	2114
Mean	1583	1833	1997	2200	----	1517	1763	1962	2153	----
F test and $LSD_{0.05}$ value	F test			LSD		F test			LSD	
SA	*			55.77		**			50.90	
NPK	*			45.90		**			43.20	
SA*NPK	**			70.90		**			67.90	

Where, *, ** mean significant at 5 and 1% level of significant, respectively
Low= 75, 15 and 24 kg fed^{-1} of N, P and K, respectively
Recommended= 100, 30and 36 kg fed^{-1} of N, P and K, respectively
High= 125, 45 and 48 kg fed^{-1} of N, P and K, respectively

Straw yield

Straw yield traits was affected significantly by the tested factors and their interaction in both seasons (Table 8). The presented data focus that all tested salicylic acid concentration surpassed the control treatment (without salicylic) in this respect in favor of high salicylic acid concentration (150 ppm) which produced the highest mean values of straw yield (3567 and 2993 kg fed^{-1} in the first and second seasons, respectively). The amount of increment in straw yield reached about 26.62, 7.76 and 5.85% as compared to zero, 50 and 100 ppm of salicylic acid concentrations in the first season, being 20.10, 4.21 and 4.83% in the second season in the same order. This is to be expected since the same trend was obtained regarding biological yield. These results are confirmed with those obtained by Raskin (1992) and Gunes *et al*. (2007). Also, straw yield was increased with increasing NPK fertilization rate in both seasons. This is to be logic since the same trend was observed regarding biological yield. These results are in harmony with those obtained by Rehman *et al.* (2008) and Ibrahim *et al* (2014). Here, too the highest mean values of straw yield (3700 and 3094 kg fed^{-1} in the first and second seasons, respectively) were obtained from wheat plants sprayed by 150 ppm salicylic acid and fertilized by high NPK rate.

Table 8. Effect of salicylic acid, NPK fertilizations and their interaction on straw yield (kg fed.$^{-1}$)

Seasons	2013-2014					2014-2015				
Salicylic acid NPK	0	50	100	150	Mean	0	50	100	150	Mean
Low	2500	3350	3250	3400	3125	2148	2919	2780	2748	2649
Recommended	2800	3280	3360	3600	3260	2576	2806	2840	3137	2839
High	3150	3300	3500	3700	3412	2753	2891	2945	3094	2921
Mean	2817	3310	3370	3567	-----	2492	2872	2855	2993	----
F test and $LSD_{0.05}$	F test			LSD		F test			LSD	
SA	*			60.60		**			57.90	
NPK	*			56.90		**			53.30	
SA*NPK	**			78.80		**			77.70	

Where, *, ** mean significant at 5 and 1% level of significant, respectively
Low= 75, 15 and 24 kg fed^{-1} of N, P and K, respectively
Recommended= 100, 30and 36 kg fed^{-1} of N, P and K, respectively
High= 125, 45 and 48 kg fed^{-1} of N, P and K, respectively

Nitrogen, Phosphorus and Potassium use efficiency (Kg/Kg)

Nitrogen use efficiency (NUE)

Data exhibited in Table 9 reveal that salicylic acid, NPK fertilization and their interaction had a significant influence on the NUE in the two growing seasons. Increasing salicylic acid concentration from zero to 150 ppm increased NUE from 16.04 to 22.38 in the first season and from 15.37 to 21.92 in the second one. This is to be logic since the same trend was observed with regard to grain yield. Also, the data state that increasing NPK fertilizer decreased NUE significantly in both seasons although high nitrogen rate generally led to higher yield.Thus, the highest NUE values (21.84 and 21.20 kg grain/kg N applied in the first and second seasons, respectively) were obtained when nitrogen fertilizer was applied by low amount while, the lowest NUE values (17.50 and 16.91kg grain/kg N applied in the first and second seasons, respectively) were recorded from high nitrogen fertilizer rate. The result is consistent with that of Dhugga and Waines (1989), Ortiz-Monasterio *et al*. (1997) Roberts (2008) and Haile *et a*l. (2012) who found significant decreases in NUE with increasing rates of N application. Here too, wheat plants sprayed by high salicylic acid concentration (150 ppm) and subjected to low NPK fertilization rate produced the maximum mean values of NUE which reached 25.33 and 24.80 kg grain/kg N applied in the first and second seasons, respectively. This is logic since the same interaction produced the highest mean values with regard to grain yield and consequently produced the highest mean values of NUE.

Table 9. Effect of salicylic acid, NPK fertilizations and their interaction on nitrogen use efficiency (NUE)

Seasons	**2013-2014**					**2014-2015**				
Salicylic acid NPK	0	50	100	150	Mean	0	50	100	150	Mean
Low	17.33	21.33	23.33	25.33	21.84	16.67	20.40	22.93	24.80	21.20
Recommended	16.00	18.00	20.40	21.00	18.85	15.20	17.60	20.10	20.80	18.43
High	14.80	16.80	17.60	20.80	17.50	14.24	16.00	17.24	20.16	16.91
Mean	16.04	18.71	20.44	22.38	-----	15.37	18.00	20.09	21.92	----
F test and $LSD_{0.05}$ value	F test		LSD			F test		LSD		
SA	*		2.13			*		1.70		
NPK	*		2.06			*		1.65		
SA*NPK	*		2.66			*		1.90		

Where, *mean significant at 5% level of significant
Low= 75, 15 and 24 kg fed^{-1} of N, P and K, respectively
Recommended= 100, 30and 36 kg fed^{-1} of N, P and K, respectively
High= 125, 45 and 48 kg fed^{-1} of N, P and K, respectively

Phosphorus use efficiency (PUE)

Presented data in Table 10 reveal that salicylic acid, NPK fertilization and their interaction had a significant effect on PUE in the two growing seasons. Salicylic acid enhancement PUE as compared to control treatment (without salicylic acid) in favor of 150 ppm concentration which gained the maximum PUE (84.81 and 83.11 kg grain/ kg P applied in the first and second seasons, respectively). This is to be logic since the same salicylic acid concentration give the highest mean values regarding grain yield fed^{-1} trait and consequently produced the highest PUE mean values. Furthermore, increasing NPK fertilizer rate consider the major reason for decreasing PUE although, the same NPK rate gained the highest mean values of grain yield. Thus, the maximum PUE mean values (109.20 and 106.00 kg grain/ kg P applied in the first and second seasons, respectively) were registered when NPK fertilizers were applied at the low rate. This is may be due to the leaching accord when the high fertilizers rate was applied led to decreasing in PUE. Moreover, the wheat plants sprayed by high salicylic acid concentration (150 ppm) and subjected to low NPK fertilization rate gained the maximum mean values of PUE (126.67 and 124.00 kg grain/ kg P applied in the first and second seasons, respectively). The previous findings could be explained by the high grain yield produced under the same interaction which led to high PUE.

Table 10. Effect of salicylic acid, NPK fertilizations and their interaction on phosphorus use efficiency(PUE)

Seasons	2013-2014					2014-2015				
Salicylic acid NPK	0	50	100	150	Mean	0	50	100	150	Mean
Low	86.67	106.67	116.67	126.67	109.20	83.33	102.00	114.67	124.00	106.00
Recommended	53.33	60.00	68.00	70.00	62.83	50.67	58.67	67.00	69.33	61.43
High	41.11	46.67	48.89	57.78	48.62	39.56	44.44	47.89	56.00	46.98
Mean	60.37	71.11	77.85	84.81	-----	57.85	68.37	76.52	83.11	-----
F test and LSD $_{0.05}$ value	F test		LSD			F test		LSD		
SA	*		3.30			*		3.25		
NPK	*		3.00			*		2.87		
SA*NPK	*		6.15			*		5.56		

Where, *mean significant at 5% level of significant
Low= 75, 15 and 24 kg fed^{-1} of N, P and K, respectively
Recommended= 100, 30and 36 kg fed^{-1} of N, P and K, respectively
High= 125, 45 and 48 kg fed^{-1} of N, P and K, respectively

Potassium use efficiency (KUE)

Potassium use efficiency (KUE) trait was affected significantly by salicylic acid, NPK fertilization and their interaction in both seasons (Table 11). All tested salicylic acid concentrations surpassed control treatment in this respect. Furthermore, the tested salicylic acid concentrations varied significantly in favor of high salicylic acid concentration (150 ppm) which gained the maximum mean values of KUE (63.89 and 62.59 kg grain/kg K applied in the first and second seasons, respectively). This is to be expected since the same salicylic acid concentration produced the highest mean values of grain yield and consequently gained the maximum mean values of KUE. Also. The data show that increasing NPK fertilization rate resulted in decreasing in KUE in both seasons. Here too, the wheat plants sprayed by 150 ppm salicylic acid and fertilized by low rate of NPK fertilizers gained the highest mean values of KUE (79.17 and 77.50 kg grain/kg K applied in the first and second seasons, respectively).

Table 11. Effect of salicylic acid, NPK fertilizations and their interaction on potassium use efficiency(KUE)

Seasons	2013-2014					2014-2015				
Salicylic acid NPK	0	50	100	150	Mean	0	50	100	150	Mean
Low	54.17	66.67	72.92	79.17	68.25	52.08	63.75	71.67	77.50	66.25
Recommended	44.44	50.00	56.67	58.33	52.36	42.22	48.89	55.83	57.78	51.19
High	38.54	43.75	45.83	54.17	45.58	37.08	41.67	44.90	52.50	44.04
Mean	45.72	53.47	58.47	63.89	-----	43.80	51.44	57.47	62.59	-----
F test and LSD$_{0.05}$ value	F test		LSD			F test		LSD		
SA	*		2.80			*		2.75		
NPK	*		2.55			*		2.35		
SA*NPK	*		5.40			*		5.00		

Where, *mean significant at 5% level of significant
Low= 75, 15 and 24 kg fed^{-1} of N, P and K, respectively
Recommended= 100, 30and 36 kg fed^{-1} of N, P and K, respectively
High= 125, 45 and 48 kg fed^{-1} of N, P and K, respectively

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تأثير الرش الورقي بحامض الساليسيليك والتسميد بالنيتروجين والفسفور والبوتاسيوم على إنتاجية محصول القمح

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الملخص:

أجريت تجربة حقلية بمزرعة كلية الزراعة جامعة جنوب الوادي بمحافظة قنا – مصر خلال موسمي ٢٠١٣-٢٠١٤ و٢٠١٤-٢٠١٥ لدراسة تأثير الرش الورقي بحامض الساليسيليك والتسميد بالنيتروجين والفسفور والبوتاسيوم على إنتاجية محصول القمح. صممت التجربة بتصميم القطاعات كاملة العشوائية بترتيب الشرائح المنشقة في ثلاث مكررات. حيث تم وضع تركيزات حامض الساليسيليك افقيا والتسميد الازوتي والفوسفوري والبوتاسي راسيا وكانت اهم النتائج ان جميع الصفات محل الدراسة تأثرت معنويا بحامض الساليسيليك والتسميد الأزوتي والفسفوري والبوتاسي لصالح التركيز العالي من الساليسيليك (١٥٠ جزء في المليون) والمعدل المرتفع من التسميد (١٢٥ و٤٥ و٤٨ كجم من الازوت والفسفور والبوتاسيوم على التوالي) لكلا موسمي الدراسة. أعطت نباتات القمح التي رشت بالتركيز العالي من حامض الساليسيليك والمعدل المرتفع من التسميد الازوتي والبوتاسي والفسفوري والبوتاسي اعلي محصول للحبوب والذي بلغ ٢٦٠٠ و٢٥٢٠ كجم للفدان للموسم الأول والثاني على التوالي بينما تم الحصول علي اعلي قيم من كفاءة استخدام الازوت والفسفور والبوتاسيوم من نباتات القمح التي رشت بالتركيز المرتفع من حامض الساليسيليك والمعدل المنخفض من التسميد الازوتي والفسفوري والبوتاسي لكلا موسمي الدراسة.