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Changes in Morphological, Physiological and Reproductive Characters of Wheat Plants as Affected by Foliar Application with Salicylic Acid and Ascorbic Acid

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Abstract: A field experiment was conducted for the two successive seasons of 2004/2005 and 2005/2006 at the experimental station of the National Research Centre at Shalakan, Qalubia Governorate, Egypt to study the response of wheat plants to foliar application of salicylic acid, ascorbic acid at (0.0, 100, 200 and 400 mg L^{-1}) as well as their interaction on vegetative growth, photosynthetic pigments content, yield and some biochemical constituents of wheat grains. The data indicated that, an enhancement effect of growth characters, yield, total carbohydrate as well as nitrogen, phosphorus and potassium content in wheat grains was obtained by 100 or 200 mg L^{-1} of salicylic acid. Moreover, the same preceding underwent a reverse pattern of change using the higher concentrations of salicylic acid (400 mg L^{-1}). On the other hand, all ascorbic acid treatments tended to induce increases on wheat growth criteria. There was a progressive increase in plant height, number of tiller and spikes, flag leaf area, blades area/plant, spike length, grain index (g), grain and straw yield per plant and per fed by increasing ascorbic acid level up to 400 mg L^{-1}. Photosynthetic pigments in the leaves as well as some biochemical constituents in grains were significantly increased by increasing concentration of ascorbic acid. Generally, foliar application of wheat plants (*Triticum aestivum* L.) cv. Gemmiza 10 with salicylic acid at 100 mg L^{-1} combined with ascorbic acid at 200 or 400 mg L^{-1} were more effective in increasing growth characters, yield and its components in addition to photosynthetic pigments content in the leaves, total carbohydrate percentage, as well as nitrogen, phosphorus and potassium content in wheat grains as compared with other treatments or untreated plants.

Key words: wheat plants (*Triticum aestivum* L.); salicylic acid SA; ascorbic acid AA; growth characteristics; yield; biochemical constituents.

INTRODUCTION

Wheat is considered the first strategic food crop in Egypt. It has maintained its position during that time as the basic staple food in urban areas and mixed with maize in rural areas for bread making. In addition, wheat straw is an important fodder (Gomma, 1999). In Egypt wheat plants are sometimes exposed to drought at different periods of growth. A possible approach to minimize drought that induces crop losses is the foliar application with chemical desiccant on wheat plants (Gaballah & Mandour, 2000; Nicolas & Turner, 1993). Salicylic acid (SA) naturally occurs in plants in very low amounts and participates in the regulation of physiological processes in plant such as stomatal closure, nutrient uptake, chlorophyll synthesis, protein synthesis, inhibition of ethylene biosynthesis, transpiration and photosynthesis (Raskin, 1992; Khan *et al.,* 2003; Shakirova *et al.,* 2003). It has been identified as an important signaling element involved in establishing the local and systemic disease resistance response of plants after pathogen attack (Alvarez, 2000). Salicylic acid (SA), jasmonic acid (JA), and ethylene-dependent signaling pathways regulates plant responses to both abiotic and biotic stress factors (Mulpuri *et al.*, 2000). Moreovere, SA treatments at 0.5 mM strongly or completely suppressed the Cd-induced up-regulation of the antioxidant enzyme activities of barley (Metwally, *et al.*, 2003). SA has a direct physiological effect through the alteration of antioxidant enzyme activities. Certain enzymes were activated by SA treatment, while others, like catalase, were inhibited. Catalase seems to be a key enzyme in salicylic acid-induced stress tolerance, since it was shown to bind SA *in vitro* (Chen *et al.*, 1993) and inhibited by SA in several plant species (Conrath *et al.*, 1995). SA induces flowering, increase flower life, retards senescence and increases cell metabolic rate. The sustained level of salicylic acid may be a prerequisite

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for the synthesis of auxin and/or cytokinin (Metwally *et al*., 2003). On the other hand, Ascorbic acid (AA) is an organic compound required in trace amount to maintain normal growth in higher plants (Podh, 1990). AA influences mitosis and cell growth in plants (Noctor and Foyer, 1998; Smirnoff and Wheeler, 2000), affects phytohormone-mediated signaling processes during the transition from the vegetative to the reproductive phase as well as the final stage of development and senescence (Barth *et al*., 2006). Furthermore, AA affects nutritional cycle's activity in higher plants and plays an important role in the electron transport system (Liu *et al.,* 1997). It is also important as a cofactor for a large number of key enzymes in plants (Belanger *et al.,* 1995; Arrigoni and de Tullio, 2000).

The potent impact of salicylic acid and ascorbic acid on various areas of plant structure and function prompt many investigators to apply them to several crop plants aiming to control pattern of growth and development coupled with enhancement of systemic resistance against various hurtful agents which may appear in the surrounding environments. Salicylic acid promotes some physiological processes and inhibiting others depending on its concentration, plant species, development stages and environmental conditions (Ding and Want, 2003 and Mateo *et al*., 2006). SA increased the number of flowers, pods/plant and seed yield of soybean (Gutierrez-Coronado *et al*., 1998); enhanced wheat growth (Shakirova *et al*., 2003) and maize growth (Shehata *et al.,* 2001; Abdel-Wahed *et al.,* 2006; El-Mergawi and Abdel-Wahed, 2007). On the contrary, salicylic acid at relatively high doses inhibited plant growth and chlorophyll contents of tomato (Kord and Hathout, 1992), lupine (Haroun *et al.,* 1998) and wheat plants (Singh & Usha, 2003; Iqbal & Ashraf, 2006). On the other hand, the beneficial effects of ascorbic acid upon growth and productivity have been reported on lemongrass (Tarraf *et al*., 1999); cotton (Ghourab and Wahdan, 2000); sugar beet (Salem *et al*., 2000); cucumber (El-Greadly, 2002), sweet pepper (Shawky, 2003) wheat (Abdel-Hameed *et al*., 2004).and on sunflower plants (El-Gabas (2006). Thus salicylic acid and ascorbic acid could be expected to influence the growth and yield of wheat plants.

Therefore, the present investigation was undertaken to study the impact of spraying salicylic acid, ascorbic acid, individually or in combination on some morphological criteria, yield as well as some biochemical constituents of wheat (*Triticum aestivum* L.) cv. Gemmiza 10 plants to improve growth, yield, grain quality and nutritional value.

MATERIALS AND METHODS

A field experiment was carried out at the experimental Station of National Research Centre, Shalakan Qalubia Governorate during the two successive seasons of 2004/2005 - 2005/2006 to study the effect of foliar application of Salicylic acid (SA), ascorbic acid (AA) and their interaction on vegetative growth, yield and its component as well as photosynthetic pigments content in the leaves, total carbohydrate content and some macronutrient content of wheat grains.

The experimental design was split plot with four replicates. Salicylic acid treatments occupy the main plots and ascorbic acid treatments were allocated at random in sub-plots. Grains of wheat plants (*Triticum aestivum* L.) cv. Gemmiza 10 were sown on the 15^{th} November in both season in rows 4 meters long, the distance between hills along the row was 25 cm apart, Plot area was 12 m^2 (3.0 m in width and 4.0 m in Length). The recommended agricultural practices of growing wheat were applied and the grain rate was 70 kg/fed. Pre-sowing, 100 kg/fed. of calcium super-phosphate (15.5 % P_2O_5) was applied to the soil. Nitrogen fertilizer, 100 kg N/fed. of ammonium nitrate (33.5 % N) was applied at three equal doses before the first, third and fifth irrigation. Potassium sulfate (48.52 % K_2O) was added at two equal doses of 50 kg/fed. before the first and third irrigations. Irrigation was regularly carried out at intervals according to weather conditions to keep the moisture content of the soil to field capacity.

Wheat plants were foliar sprayed with salicylic acid or ascorbic acid, each at the concentration of 0.0, 100, 200 and 400 mg L^{-1}. Combinations of the different concentrations of the two factors were also applied. In both seasons, foliar application of salicylic acid as well as ascorbic acid was carried out twice; the plants were sprayed firstly with ascorbic acid after 30 and 45 days from sowing and ascorbic acid after 60 days and 75 days from sowing. Control plants were sprayed with distilled water and the volume of the spraying solution was maintained just to cover completely the plant foliage till drip.

At milky stage and soft-dough stage (100 and 120 days after sowing, respectively) growth characters were measured in terms of, plant height, number of tiller and spikes, dry weight/plant (g), flag leaf area and blades area (cm^2/plant) according to (Bremner and Taha, 1966). At harvest stage, the mean values of yield and yield characters, i.e., plant height, number of tiller and spikes/plant, spike length (cm), weight of spikes/plant (g), grain index (100-grain weight (g)), grain and straw yield per plant (g) and per fed. (Ton) were determined. Plant samples were dried in an electric oven with drift fan at 70°C for 48 hr. till constant dry weight.

Total carbohydrate was determined in the dried grains, using phenol sulphuric method (Dubois *et al*., 1956). Phosphorus and potassium were determined after wet digestion according to (Jackson, 1973), total nitrogen was determined using the modified Micro-Kjeldahl method (A.O.A.C, 1988). Photosynthetic pigments of leaves were determined and calculated after 90 and 105 days from sowing of wheat plants according to (Saric *et al*., 1967).

Combined analysis of data for two growing seasons was carried out according to Snedecor and Cochran (1990) and the values of least significant differences (L.S.D. at 5 % level) were calculated to compare the means of different treatments.

RESULTS AND DISCUSSION

Growth Parameters:

Data presented in Table (1) show that foliar application of salicylic at 100 and 200 mg L^{-1} promoted growth criteria of wheat plants (plant height, number of tiller, number of spikes, flag leaf area (cm^2), blades area/plant (cm^2), dry weight/plant (g) compared to corresponding untreated plants at milky and softy-dough stages of growth. In all cases, the increments in growth parameters were often highly significant in comparison with untreated ones. Salicylic acid at 100 mg L^{-1} was the most effective treatment in increasing growth parameters, whereas, growth characters of wheat plants significantly decreased by increasing salicylic concentration up to 400 mg L^{-1} at milky and softy-dough stages. In this respect, many investigators found that low concentrations of salicylic acid enhanced growth of soybean (Gutierrez-Coronda *et al.,* 1998), maize (Shehata *et al.,* 2001; El-Mergawi and Abdel-Wahed, 2007) and wheat plants (Shakirova *et al*., 2003; Iqbal and Ashraf, 2006), whereas high concentrations caused an inhibitory effect on growth of tomato, lupine, wheat and maize plants (Kord and Hathout, 1992; Haroun *et al* ., 1998; Singh and Usha, 2003; Abdel-Wahed *et al.,* 2006). Moreover, El-Bahay (2002) reported that salicylic acid has the potentiality to exert a suppressive or stimulative impact on various growth aspects of lupine seedlings through their direct interference with the enzymatic activities responsible for biosynthesis and/or catabolism of growth promoting and inhibiting substances.

Table 1: Effect of salicylic acid and ascorbic acid on growth characters of wheat plant at milky satge (100 days after sowing) and soft dough stage (120 days after sowing).(Combined analysis of two seasons)

Treatments (mg L^{-1})		After 100 days from sowing						After 120 days from sowing					
Salicylic acid		Plant height (cm)	Number of tillers	Number of spikes	Flag leaf area	Blades area (cm^2) $plant^{-1}$	Dry weight (g)	Plant height (cm)	Number of tillers	Number of spikes	Flag leaf area (cm^2)	Blades area (cm^2) $plant^{-1}$	Dry weight (g) $plant^{-1}$
	0.0	84.82	3.45	3.43	26.48	367.97	10.46	92.90	3.83	3.75	26.91	363.95	13.96
	100	88.13	4.59	4.53	30.49	444.27	11.67	106.60	5.13	5.02	32.92	438.87	15.49
	200	86.19	4.32	4.21	28.77	429.82	11.43	96.31	4.75	4.79	29.09	416.92	14.50
	400	78.24	3.36	3.27	21.01	343.70	10.08	88.39	3.70	3.54	22.50	344.96	12.90
LSD at 5%		1.88	N.S.	N.S.	1.69	12.06	0.47	2.54	0.38	0.42	1.46	22.01	0.16
Ascorbic acid	0.0	82.42	3.60	3.52	23.80	379.07	10.54	91.67	3.82	3.70	24.27	369.15	13.80
	100	86.67	4.39	4.16	26.08	431.59	11.38	96.88	4.84	4.78	27.13	395.15	14.76
	200	89.80	5.19	5.02	29.90	448.35	11.71	109.46	5.34	5.01	31.28	419.08	15.60
	400	91.67	5.27	5.13	32.06	459.25	12.26	112.01	5.59	5.11	33.01	440.13	15.72
L.S.D. at 5%		2.66	0.55	0.39	1.87	32.15	0.59	3.76	0.44	0.56	1.92	24.81	0.73

Furthermore, ascorbic acid at 100, 200 and 400 mg L^{-1} was more effective than salicylic treatments in increasing vegetative growth of wheat plants at milky and softy-dough stages. The increment in growth characters (i.e. plant height, number of tiller, number of spikes/plant, flag leaf area (cm^2), blades area/plant (cm^2) and dry weight/plant (g) reached maximum values at 400 mg L^{-1} of AA compared to control plants at two physiological stages of growth. The increase in the dry weights of wheat plant might be attributed to an increase in number of tiller and spikes as well as leaf area, leading to increased photosynthetic activity. Similar improvement in plant growth of tomato, sunflower, wheat, cucumber and cotton plants were obtained by. Concerning the interaction between salicylic and ascorbic acid on vegetative growth of wheat plants, similar significant increases have been obtained in the same mentioned characteristics of growth using different concentrations of salicylic and ascorbic acid at milky and softy-dough stages of growth. The highest values of growth criteria were obtained by the interaction of salicylic acid at 100 or 200 mg L^{-1} + ascorbic acid at 200 or 400 mg L^{-1} (Table 2).

Table 2: Effect of interaction between salicylic acid (SA) and ascorbic acid (AA) on growth characters at milky stage (100 days after sowing) and soft dough stage (120 days after sowing).(Combined analysis of two seasons).

Treatments (mg L^{-1})		After 100 days from sowing						After 120 days from sowing					
SA	AA	Plant height (cm)	Number of tillers	Number of spikes	Flag leaf area (cm^2)	Blades area (cm^2) $plant^{-1}$	Dry weight (g) $plant^{-1}$	Plant height (cm)	Number of tillers	Number of spikes	Flag leaf area (cm^2)	Blades area (cm^2) $plant^{-1}$	Dry weight (g) $plant^{-1}$
0.0	0.0	81.41	3.51	3.46	23.67	344.23	10.35	91.77	3.89	3.85	26.77	409.97	13.65
	100	88.92	4.41	4.37	29.57	440.70	11.60	106.50	4.96	4.74	29.63	429.17	14.86
	200	93.92	5.18	5.07	33.20	463.01	12.21	110.59	5.59	5.49	33.28	442.80	15.19
	400	96.65	5.28	5.19	37.08	489.13	12.47	114.28	5.71	5.58	35.99	469.53	16.26
100	0.0	84.21	3.94	3.88	24.54	362.73	11.01	95.13	4.94	4.73	25.85	334.93	14.21
	100	87.82	4.19	4.02	26.17	429.33	11.31	102.09	5.11	5.06	30.80	414.60	14.39
	200	90.71	4.36	4.30	30.76	444.73	11.88	105.90	5.26	5.14	31.76	424.27	14.90
	400	91.94	4.43	4.35	33.20	472.47	12.20	108.89	5.41	5.27	33.88	439.27	15.34
200	0.0	78.79	3.43	3.38	21.45	325.20	10.53	90.71	4.21	4.19	25.01	361.09	13.81
	100	82.73	4.30	4.18	24.39	420.37	11.15	95.19	4.69	4.32	26.63	396.50	13.91
	200	86.31	4.31	4.16	26.98	426.17	11.21	98.25	4.87	4.84	27.61	405.90	14.37
	400	89.35	4.35	4.26	29.35	457.60	11.76	100.45	4.92	4.90	29.22	419.10	14.76
400	0.0	75.54	3.36	3.27	21.01	323.70	10.08	85.90	3.80	3.54	22.50	296.97	12.89
	100	81.78	3.92	3.80	22.20	369.80	10.60	92.84	4.32	3.96	23.06	369.47	13.81
	200	82.36	3.69	3.76	25.12	407.50	11.25	94.46	4.65	4.51	25.48	381.37	14.49
	400	83.56	4.27	4.18	27.50	417.80	11.43	96.09	4.91	4.77	26.43	393.60	14.63
L.S.D. at 5%		3.32	N.S.	N.S.	0.74	1.59	0.34	2.30	0.12	0.15	3.76	2.62	0.16

Photosynthetic Pigments:

The effect of foliar spray with salicylic acid, ascorbic acid and their interaction on the photosynthetic pigments in the leaves of wheat plants at milky and softy-dough stages of growth are shown in Table (3). Generally, ascorbic acid was more effective than salicylic acid in increasing the different photosynthetic pigments; as there was a gradual increase in chl. a, chl. b and carotenoids with increasing applied concentration of ascorbic acid up to 400 mg/l over their corresponding control at two stages of growth. Similarly, Shaddad *et al.* (1990) and Abdel-Wahed *et al.* (2006) on maize, Hathout *et al.* (1993) on tomato, Salem *et al.* (2000) on sugar beet, Hanna *et al.* (2001) on wheat and El-Gabas (2006) on sunflower plants found that ascorbic acid increased chlorophyll a, b, total chlorophylls and attributed this to stimulation the biosynthesis of chlorophylls and delay leaf senescence. Moreover, salicylic acid significantly increased chl. a, chl. b and carotenoids recording maximum values at 100 mg/l. On the contrary, the content of such pigments were reversely changed using higher concentration of salicylic acid. These results are in agreement with those obtained by Gharib (2006) who found that in sweet basil and marjoram plants salicylic acid at 10^{-5} M stimulated total chlorophyll synthesis whereas 10^{-3} M has a reverse effect. Stomatal index and stomatal density of pepper seeds were negatively affected by treatment with salicylic (SA) and sulfosalicylic acid (SSA) at 10^{-3} M. On the other hand, SA and SSA at 10^{-4} and 10^{-5} M increased the stomatal index and stomatal density on abaxial side, showing the opposite response in the adaxial side (Mendoza *et al*., 2002). Shakirova *et al.* (2003) and Iqbal *et al.* (2006) on wheat plants and Abdel-Wahed *et al.* (2006) and El-Mergawi & Abdel-Wahed, 2007) on maize plants found that salicylic acid caused significant increased in chlorophyll content.

Interaction treatments of salicylic acid and ascorbic acid show slight increase in chlorophyll a, b and total carotenoids in the leaves of wheat plants compared with their controls at 90 and 150 days after sowing (Table 3). However, the highest recorded values of chl a, chl. b and carotenoid content was obtained in leaves of wheat plants treated with salicylic acid at 100 or 200 mg L^{-1} + ascorbic acid at 200 or 400 mg L^{-1} compared to other treatments and control plants at two stages of growth. The accumulation of photosynthetic pigments as a result of interaction treatments may be due to increase in photosynthetic efficiency as reflected by increasing in both chl a, chl. b and carotenoids content in the leaves of wheat plants.

Yield and its Components:

Data presented in Table (4) show that foliar application of salicylic acid, especially at 100 mg L^{-1} resulted in the highest increase in yield and its components (i.e., plant height, number of tiller, number of spikes, grain index (g), spike length (cm), weight of spikes/plant (g) and grain and straw yield per plant and per fed). On the other hand, SA at 400 mg L^{-1} recorded the lowest values of yield and its components compared to their corresponding controls. In this connection, foliar application of salicylic acid significantly increased yield and its components of maize (Shehata *et al,*. 2001 and Abdel-Wahed *et al.*, 2006) and wheat plants (Shakirova *et al.,* 2003, Iqbal and Ashraf, 2006).

Table 3: Effect of salicylic acid (SA), ascorbic acid (AA) and their interaction on the photosynthetic pigments content in the leaves of wheat plants.(Combined analysis of the two seasons).

Treatments (mg L^{-1})		Chl (a) A	Chl (a) B	Chl (b) A	Chl (b) B	Total carotenoids A	Total carotenoids B
Salicylic acid	0.0	0.54	0.72	0.21	0.24	0.44	0.48
	100	0.74	0.90	0.29	0.31	0.49	0.54
	200	0.67	0.84	0.26	0.29	0.47	0.52
	400	0.64	0.78	0.24	0.28	0.45	0.50
L.S.D. at 5%		0.06	0.04	0.02	0.03	0.01	0.02
Ascorbic acid	0.0	0.55	0.69	0.22	0.25	0.44	0.49
	100	0.67	0.80	0.26	0.29	0.46	0.51
	200	0.69	0.86	0.28	0.30	0.48	0.53
	400	0.76	0.94	0.29	0.32	0.51	0.57
L.S.D. at 5%		0.08	0.07	0.03	0.04	0.02	0.02
Interaction treatments:							
SA	AA						
0.0	0.0	0.56	0.75	0.22	0.25	0.45	0.49
	100	0.67	0.78	0.26	0.28	0.47	0.51
	200	0.69	0.84	0.29	0.31	0.49	0.54
	400	0.75	0.92	0.30	0.33	0.51	0.58
100	0.0	0.54	0.73	0.22	0.23	0.43	0.47
	100	0.66	0.76	0.25	0.27	0.46	0.50
	200	0.68	0.83	0.27	0.30	0.48	0.53
	400	0.73	0.90	0.29	0.31	0.50	0.56
200	0.0	0.52	0.69	0.21	0.22	0.44	0.45
	100	0.62	0.74	0.24	0.26	0.46	0.49
	200	0.65	0.81	0.28	0.29	0.47	0.52
	400	0.70	0.88	0.29	0.31	0.49	0.55
400	0.0	0.51	0.66	0.21	0.22	0.42	0.44
	100	0.60	0.72	0.24	0.25	0.45	0.48
	200	0.62	0.79	0.26	0.28	0.46	0.51
	400	0.69	0.87	0.28	0.30	0.48	0.54
L.S.D. at 5%		0.01	0.02	0.01	0.02	0.02	0.02

A: 90 days after sowing, B: 105 days after sowing

Table 4: Effect of salicylic acid and ascorbic acid on yield and its components of wheat plant. (Combined analysis of two seasons).

Treatments (mg L^{-1})		Plant height (cm)	Number of tillers plant $^{-1}$	Number of spikes plant $^{-1}$	Grain yield (g) plant $^{-1}$	Straw yield (g) plant $^{-1}$	Spike length (cm)	Weight of spikes(g) plant $^{-1}$	Grain index (g)	Grain yield (ton) fed $^{-1}$	Straw yield (ton) fed $^{-1}$
Salicylic acid	0.0	88.09	4.42	4.21	7.46	9.69	14.80	11.38	6.56	2.37	3.68
	100	98.63	5.08	5.01	9.21	11.37	16.60	13.54	7.48	3.40	5.01
	200	93.84	4.72	4.63	8.89	10.48	15.57	12.52	7.39	3.15	4.87
	400	83.73	3.63	3.52	8.09	10.12	15.14	12.21	7.21	2.86	3.90
L.S.D. at 5%		3.10	0.13	0.19	0.34	0.42	0.70	0.29	0.50	0.12	0.45
Ascorbic acid	0.0	87.70	4.33	3.94	7.27	9.47	14.03	10.69	6.83	2.84	3.81
	100	95.19	4.44	4.34	9.09	10.21	15.59	11.78	7.24	3.63	4.86
	200	99.61	5.18	5.07	9.34	11.80	16.33	13.72	7.51	3.87	5.21
	400	105.09	5.30	5.21	10.01	12.23	16.57	14.08	7.80	3.92	5.30
L.S.D. at 5%		3.69	0.10	0.31	0.69	0.54	0.61	0.49	0.29	0.33	0.67

Ascorbic acid significantly increased yield and its components of wheat plants i.e., plant height, number, tiller and spikes of plants, spike length, weight of spikes/plant, grain index and grain and straw yield per plant and per fed. compared to the other treatments (Table 4). The maximum values of yield and its components were obtained as a result of foliar spray with AA at 400 mg L^{-1}. Similarly, Hanafy *et al.* (1995) and Abdel-Hameed (2004) on wheat; El-Greadly (2002) on cucumber and El-Gabas (2006) on sunflower found that spraying ascorbic had favorable effects on growth characters and yield particularly with the higher concentration. Furthermore, yield of wheat plants is far more sensitive to the interaction treatments of salicylic acid at 100 or 200 mg L^{-1} + ascorbic acid at 200 or 400 mg L^{-1} recording the highest increase in plant height, number of tiller and spike, spike length, grain index, weight of spike/plant, grain and straw yield/plant and per fed. (ton) compared to their relative controls and other combinations (Table 5). In this connection, ascorbic acid alone or combined with ethrel increased main stem length and recorded the highest early yield of cucumber plants (El-Greadly, 2002).

Table 5: Effect of interaction between salicylic acid (SA) and ascorbic acid (AA) on yield and its components of wheat plants. (Combined analysis of two seasons).

Treatments (mg L^{-1}) SA	AA	Plant height (cm)	Number of tillers $plant^{-1}$	Number of spikes $plant^{-1}$	Grain yield (g) $plant^{-1}$	Straw yield (g) $plant^{-1}$	Spike length (cm)	Weight of spikes (g) $plant^{-1}$	Grain index (g)	Grain yield (ton) fed^{-1}	Straw yield (ton) fed^{-1}
0.0	0.0	89.14	3.88	3.84	7.53	9.46	14.09	10.38	6.85	2.53	3.82
	100	102.33	4.74	4.69	8.90	10.56	16.53	12.46	7.32	3.35	5.01
	200	104.61	5.46	5.19	9.43	11.61	17.32	14.57	7.71	3.54	5.24
	400	108.28	5.69	5.27	9.88	12.16	17.76	15.07	7.82	3.76	5.40
100	0.0	93.42	4.19	4.31	7.86	9.89	14.86	10.62	6.99	2.46	3.77
	100	95.08	4.69	4.52	8.50	10.30	15.23	12.22	7.04	3.25	4.62
	200	98.24	5.11	4.98	9.21	11.27	16.13	13.46	7.53	3.44	5.12
	400	101.79	5.18	5.02	9.30	11.38	16.31	13.57	7.63	3.50	5.21
200	0.0	86.90	3.92	3.89	7.30	9.23	14.26	10.27	6.46	2.51	3.71
	100	89.72	4.34	4.30	8.42	10.12	15.03	11.52	6.78	2.89	4.48
	200	93.81	4.72	4.52	8.81	11.04	15.86	12.66	7.21	3.18	4.62
	400	96.14	4.79	4.58	8.90	11.11	15.96	12.84	7.31	3.29	5.07
400	0.0	81.97	3.64	3.69	7.19	9.09	13.01	9.81	6.21	2.39	3.63
	100	84.64	4.27	4.14	8.11	10.14	14.77	11.28	6.68	2.81	4.24
	200	86.79	4.58	4.39	8.64	10.33	15.17	12.54	7.17	3.03	4.53
	400	90.90	4.68	4.42	8.78	10.56	15.06	12.63	7.26	3.15	4.72
L.S.D. at 5%		2.23	n.s.	n.s.	0.20	0.11	1.03	0.41	0.18	0.13	0.18

Chemical Constituents:

The data in Fig. (1) show that foliar application of SA significantly increased the total carbohydrate content in wheat grains and accompanied by similar effects on nitrogen, phosphorus and potassium up to 200 mg L^{-1} relative to untreated controls and decreased thereafter. Data revealed that maximum values of total carbohydrates N, P and k content of wheat grains were obtained by 100 mg L^{-1} of salicylic acid. These results are agreement with those obtained by Shakivora *et al.,* (2003) and Rashad (2003). Sarangthem & Singh (2003) found that the level of N, proteins and nitrate reductase activity were increased in *Phaseolus vulgaris* by foliar application of SA at 0.1%. In other study, increased mineral nutrient content seem to be involved in stress-tolerance mechanism and play an important role to enhance the activity of enzymes responsible for drought resistance (Wu *et al.,* 1999; Cherki *et al*., 2002). SA applied at 100 mg L^{-1} increased the uptake of N, P and K element of wheat grains. Similarly, in tomato, significant increase in the uptake of elements was obtained with10^{-4} M and 10^{-5} M salicylaldehyde (Kord and Hathout, 1992). In addition, Haroun *et al.* (1998) found that low dose of salicylic acid (2.5 mM) significantly increased total carbohydrate content in seed lupine. While, higher doses (5 and 10 mM) significantly decreased total carbohydrate content in maize grains (Shehata *et al.*, 2001 and Abdel-Wahed *et al.,* 2006)

In addition, foliar application of ascorbic acid significantly increased total carbohydrates, N, P and K content in wheat grains up to 400 mg L^{-1} relative to their untreated controls (Fig.1). Similarly, the highest values of total carbohydrates and crude protein content of wheat grains was obtained by foliar application of ascorbic acid at 500 ppm compared with plants treated with 1000 ppm ascorbic acid or control (Hanna *et al*., 2001). Also, ascorbic acid significantly increased N, P and K content in leaves and grains of Ber (Rajpal *et al*., 2001), cotton (El-Shazly and El-Masri, 2003), wheat (Abdel-Hameed *et al*., 2004) and sunflower plants (El-Gabas, 2006) compared with their controls. On the other hand, the interaction between salicylic acid and ascorbic acid treatments enhanced the above mentioned biochemical constituents in wheat grains in most cases compared with the individual effect of salicylic acid and untreated plants (Fig.1). In addition, interaction between salicylic acid at 100 mg L^{-1} and ascorbic acid at 200 and 400 mg L^{-1} recorded the highest values of total carbohydrates, N, P and K content in wheat grains.

From the preceding results and discussion, it can be concluded that foliar application of wheat cultivar Gemmiza 10 plants with salicylic acid at 100 mg L^{-1} and ascorbic acid (up to 400 mg L^{-1}), individually or their interaction at elongation stage, stimulate the growth of wheat plants via the enhancement of the biosynthesis of photosynthetic pigments; improved yield by increasing grain yield/plant grains index as well as carbohydrate and macroelement content of wheat grains and thus salicylic acid and/or ascorbic acid treatments improved wheat grain quality and nutritional value.

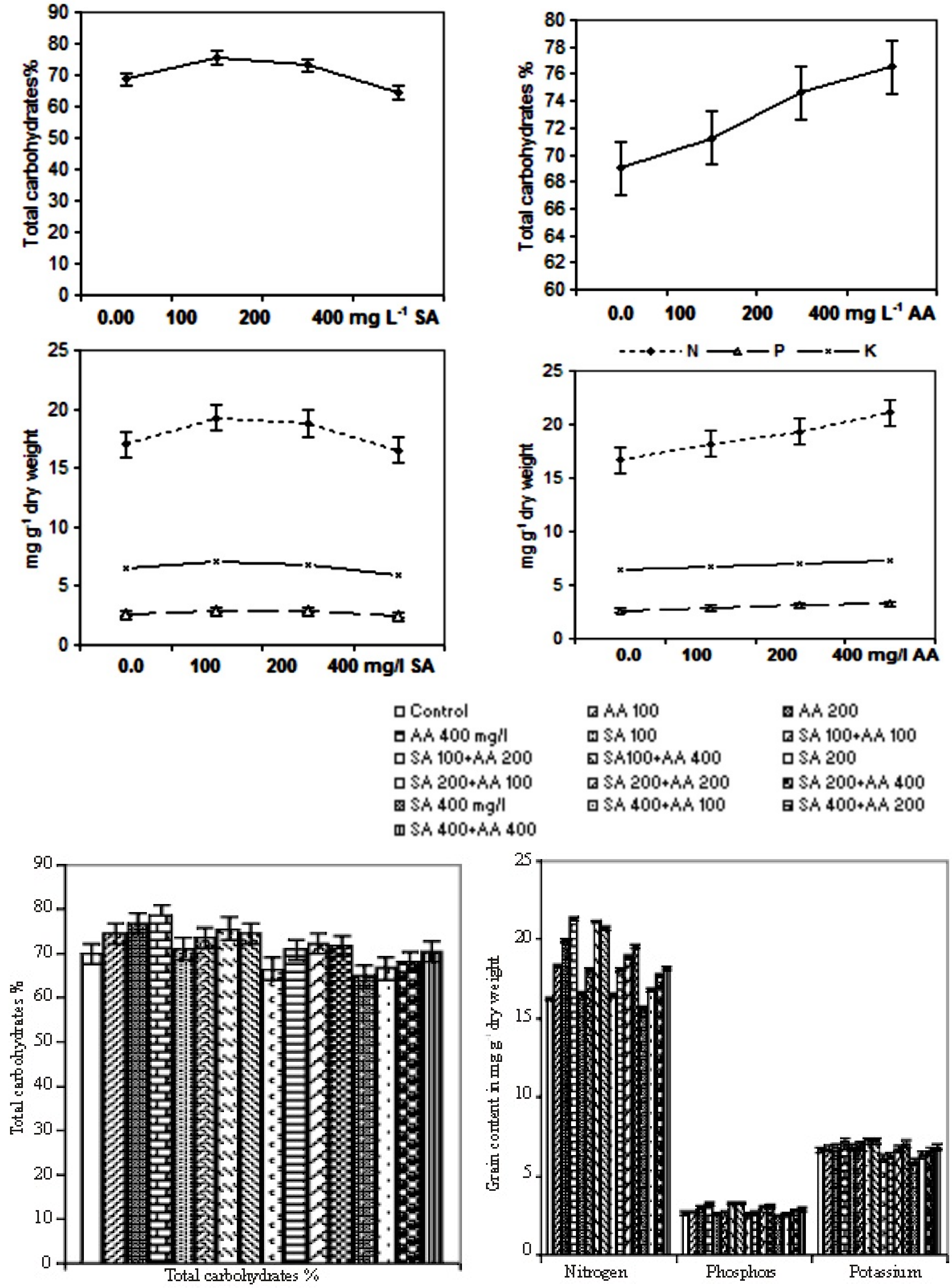

Fig. 1: Effect of salicylic acid (SA), ascorbic acid (AA) and their interaction on chemical constituents of wheat grains (Combined analysis of the two seasons). Vertical bars represent L.S.D at 5%.

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