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Assessing the Implications of K and Ascorbic Acid Application on Wheat (*Triticum aestivum*) Growth, Yield and NPK Uptake

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ABSTRACT

A 2-factor field experiment was conducted on wheat (*Triticum aestivum* cv. Giza 168), 2016/2017, grown on a *Torripsamment* sand soil in Ismailia, North of Egypt to assess K and ascorbic acid (AA) application. K treatments were K_0 none, K_1 through the soil at 200 kg K ha^{-1}, K_2 foliar spray with1000 mg K L^{-1} solution and K_3 through soil + foliar. Ascorbic acid (AA) spray treatments were A_0 none, A_1 spray with 100 g $L^{-1}$and A_2 200 g L^{-1}. Fertilization showed the positive response for yields (grains and straw) and NPK uptake in plant reaching highest by treatment of K_3A_2. Grains in the non-fertilized yielded 2.26 Mg ha^{-1} increasing to 13.7% by K_0A_1 and 119% by K_3A_2. Same two respective treatments showed grains uptake of 24.5 and 219% for N; 8.6 and 34.6 % for P and 18.2 and 367% for K.

Keywords: K fertilization, Ascorbic acid, straw and grain yield, N, P, and K uptake.

INTRODUCTION

Cereals are the most essential crops in Egypt. Wheat, the most strategic is the main source of energy in the Egyptian diet. Due to the high Egyptian population which consumes more than the local production, the country must import grains to satisfy the demand. In 2015 the production of 8.7 million Mg (mega-grams, i.e. metric tons) was augmented by a 10 million Mg to fill the gap; bearing in mind that cultivated wheat area was 41 % to 47 % of the total winter crop area (FAO, 2015). Wheat grows in different soils and climates (Malik *et al*., 2015) and is affected by different stresses including salinity, drought, cold and heat (Gill *et al*., 2003; Ahmed and Ahmed, 2005 and Shao *et al*., 2009). Drought increases rhizosphere solutes around plant roots causing reverse osmosis (Waraich *et al.*, 2011) and negatively affecting physiological, biochemical and metabolic processes (Waraich *et al.*, 2011 and Malik *et al*., 2015). It causes negative changes in respiration, nutrient translocation, nutrient uptake, morphology (Lawlor, 2002; Jaleel, *et al*., 2008 and Farooq *et al*., 2008). It is causes degradation of chlorophyll (Moaveni, 2011; Waraich *et al.*, 2011 and Malik and Ashraf, 2012). It produces reactive oxygen species (ROS) such as H_2O_2, superoxide and others in plant all of which deteriorate cell membrane stability (Tartoura, 2010 and Waraich *et al.*, 2011) and interact negatively with DNA, proteins, lipids and pigments leading to damaged cells (Ashraf, 2009; Ashraf, 2010 and Tartoura, 2010). Therefore adverse effects of drought decrease yield of wheat as well as growth parameters including plant height, spikes weight, and number of tillers, blades and spikes per plant, flag leaf area (Ahmed and Ahmed, 2005; Ibrahim, 2012 and Hussein and Khursheed, 2014). Carbohydrates, proteins, soluble sugars, N, P and K in plant decrease by drought (Hussein and Khursheed, 2014 and Raza *et al.*, 2015).

Potassium is essential for many processes as photosynthesis, enzyme activation, metabolism, starch translocation, nitrogen metabolism, proteins synthesis, regulation of stomatal movement and water relations (Marschner, 1995; Mengel and Kirkby, 2001; Simonsson *et al.*, 2007; Waraich *et al*., 2011 and Min *et al.*, 2013). Satisfactory K in plants makes it resistant to drought stress (Soleimanzadeh *et al*., 2010). Its foliar spray can cause plant tolerance to drought and regulates the functions of stomata (Kant and Kafkafi, 2002 and Wang *et al*., 2013); and enhance photosynthesis, growth and yield (Egilla *et al*., 2001 and Grzebisz *et al*., 2005) and enhance cell expansion, maintain turgor and protects chloroplasts from oxidative damage (Kant and Kafkafi, 2002 and Waraich *et al.*, 2011). Foliar spray of K leads to resistance of cellular membrane to rupture (Wei *et al*., 2013) and increases NPK uptake (Raza *et al*., 2015).

Ascorbic acid (AA) which is an anti-oxidant, enables plant to resist adverse effects (Dolatabadian *et al.*, 2010; Malik and Ashraf, 2012; Hussein and Khursheed, 2014 and Malik *et al*., 2015). It has in important function in plant metabolism protecting it against ROS (Shao *et al*., 2008 and Zaefyzadeh *et al.*, 2009). Foliar spray of wheat using 50 or 100 mg AA L^{-1} protected the photosynthetic function from the damaging effects of high salinity (Abo-Marzoka *et al*., 2016 and Khan *et al*., 2006). It enhances plant growth and augments cell division, cell wall expansion, photosynthesis transpiration and stomatal conductance (Pignochi and Foyer, 2003; Ishikawa *et al.*, 2006 and Malik and Ashraf, 2012). Its application may be foliar spray, through rooting medium or by soaking of seeds (Malik and Ashraf, 2012 and Malik *et al*., 2015). Its Foliar spray increases wheat growth (Malik and Ashraf, 2012) plant height, number of tillers and spikes, flag leaf area, blades area, spike length and grain yield (Amin *et al.*, 2008). Foliar application of AA corrects nutritional disorders, increases NPK content, photosynthesis and carbohydrates (Amin *et al.*, 2008 and Hussein and Khursheed, 2014).

The aim of this study is to assess the effect of K (foliar and soil addition) and ascorbic acid (foliar) singly or combined on wheat (growth, yield, and nutrient uptake), grown on a sandy soil under drip irrigation.

MATERIALS AND METHODS

An experiment was conducted on wheat (*Triticum aestivum* c.v. Giza 168), 2016/2017, grown on a Torripsamment sand soil (Table 1) in Ismailia Governorate, North of Egypt, irrigated with well water (Table 2) through a sprinkler system. The experiment aimed at assessing no K-fertilization (K_0) or with K fertilization through the soil at 200 kg K ha^{-1} (K_1) or through foliar spray (K_2) using K solution of 1000 mg K L^{-1} or both K fertilizations combined (K_3). Such treatments were used without ascorbic acid (AA) foliar spray (A_0) or with its foliar spray using solutions of 100 g L^{-1} (A_1) or 200 g L^{-1} (A_2). The experimental design was a factorial randomized complete block. Factor 1 was K fertilization (K_0, K_1, K_2, and K_3) and Factor 2 was ascorbic acid spray (A_0, A_1 and A_2). Treatments were in 4 replicates; and a plot size of 10.5 m^2. The K fertilizer was potassium sulphate (410 g K kg^{-1}) and the ascorbic acid was an analytical grade chemical. Spraying was done in 3 occasions for K: 15, 35 and 55 days after seeding, and 3 others for ascorbic acid: 20, 40, and 60 days after seeding. Spray rate for each material and each occasion was 1200 L ha^{-1}. The soil was sand with very low N, P, and K for satisfactory wheat growth (Abdelsalam and Abdelhaleem 1994), thus all plots were given organic manure (compost, 70 Mg ha^{-1}) as well as mineral N and P. The manure (Table 3) was given along with P (20 kg P ha^{-1} as calcium super-phosphate "68 g P kg^{-1}") during soil preparation (2 weeks before seeding) while N was given at a rate of 250 kg ha^{-1}, as ammonium sulphate (206 g N kg^{-1}), added in two times 30 and 45 days after cultivation. Crop was sown on 15/11/ 2016 and harvested on 15/4/2017. All laboratory analyses were conducted according to Chapman and Pratt, (1961); Page *et al*., (1982) and Klute, (1986).

Table 1. Soil properties of the experiment site

Property	value
Particle size distribution (%)	
Coarse sand	35.40
Fine sand	57.31
Silt	3.22
Clay	4.07
Soil texture*	***sand***
$CaCO_3$ (g kg^{-1})	10.1
Organic matter (g kg^{-1})	0. 2
pH (1:2.5, w:v soil: water suspension.)	7.98
EC dSm^{-1} (soil paste extract)	0.97
Soluble ions ($mmol_c$ L^{-1})	
Ca^{2+}	4.82
Mg^{2+}	2.23
Na^+	2.87
K^+	0.21
CO_3^{2-}	0.00
SO_4^{2-}	3.09
HCO_3^-	2.94
Cl^-	4.10
Available NPK (mg kg^{-1}) **	
N	9.3
P	0.7
K	11.1

***According to the International Soil Texture Triangle (Moeys, 2016).**
****Extracts are:- KCl (N); Na-bicarbonate (P) and ammonium acetate (K)**

Table 2. Analysis of irrigation water

EC (dSm^{-1})	pH	Soluble Ions ($mmol^c$ L^{-1})								SAR
		Na^+	Mg^{2+}	Ca^{2+}	K^+	Cl^{-1}	HCO^-_3	CO_3^{2-}	SO_4^{2-}	
1.48	8.13	7.14	4.56	3.28	0.12	10.88	1.45	0.10	3.10	3.61

Table 3. Analysis of compost

pH (1:2.5)	EC dSm^{-1} (1:5)	Organic matter	ash	Total NPK (g kg^{-1})		
		(g kg^{-1})		N	P	K
8.10	3.2	443	347	4.3	2.3	6.3

RESULTS AND DISCUSSION

Grains and straw yields (Table 4):

The non-treated plants gave a very low grain yield of 2.26 Mg grains ha^{-1} (Table 4). Application of K or ascorbic acid (AA) singly or combined increased yield by a range of 13.7% due to K_0A_1 up to as high as 107.5% due to K_3A_2 indicating a very high positive response to both K application (through soil + foliar) and ascorbic acid (AA). Straw yield followed a pattern or response very similar to that of the grain yield. The non-treated crop gave a low straw yield of 3.22 Mg ha^{-1}, which increased by 16.5 % due to K_0A_1 up to as high as 141% due to K_3A_2. The total grains+ straw yield followed a pattern of response resembling that of the grain or the straw yield. The low grains+ straw yield of 5.48 Mg ha^{-1} given by the non-treated crop increased by 15.3 % due to K_0A_1 up to as high as 127% due to K_3A_2. The additive (cumulative) effect of K fertilization + AA spray was evident as the treatments of K and AA gave a high positive effect when combined together. The main effect of K treatments in the current study was as follows $K_3 > K_2 > K_1 > K_0$ except in grain yield it was as follows $K_3 > K_1 > K_2 > K_0$ while, for the AA treatments was as follows $A_2 > A_1 > A_0$, i.e. a positive progressive effect of each of K and AA factors . Such pattern occurred with no interaction caused by K application to AA spray. The positive effect of ascorbic acid was particularly marked in presence of K_3 (soil and foliar K + foliar ascorbic acid). The increased yields due to K application reflects a non-satisfactory contents of available K in soil despite application of manure. The 11 mg available K in the sandy soil of the study was far below the 75 mg K considered as satisfactory for wheat (Abdelsalam and Abdelhaleem 1994). Potassium positive effect in enhancing many activities in plants was reported by researchers else where (Marschner, 1995, Mengel and Kirkby, 2001, Waraich *et al*., 2011 and Min *et al*., 2013). Research on application of 190 kg K ha^{-1} to wheat grown on a sandy loam soil caused a substantial increase of 101% in grain yield (Ranjhi *et al.,* 2002) .; and application of 60 kg K ha^{-1} soil- combined with a foliar spray of 5000 mg K L^{-1} solution increased wheat grain yield of up to 170% (Arabi *et al.,* 2002). Ascorbic acid is an anti-oxidant agent enhancing many plant growth and enzymes activity (Pignochi and Foyer, 2003); enhancing photosynthesis *(*Malik and Ashraf, 2012) and alleviating environmental stress (Dolatabadian *et al.,* 2010). An increase of 26% in maize grain yield was obtained by Abo-Marzoka *et al.,* (2016) upon foliar spraying with a solution of 100 mg ascorbic acid L^{-1} .

Table 4. Wheat grain and straw Yields as affected by K application (soil and foliar) and ascorbic acid(foliar).

K fertilization (K)	Ascorbic Acid Foliar Spray (A)											
	A_0	A_1	A_2	mean	A_0	A_1	A_2	mean	A_0	A_1	A_2	mean
	Grain Yield (Mg ha^{-1})				Straw Yield (Mg ha^{-1})				Grains +Straw Yield (Mg ha^{-1})			
K_0	2.26	2.57	2.64	2.49	3.22	3.75	4.28	3.75	5.48	6.32	6.91	6.24
K_1	3.33	3.43	3.53	3.43	4.99	5.36	6.32	5.56	8.32	8.79	9.85	8.98
K_2	3.99	4.17	4.32	4.16	5.80	6.02	6.97	6.26	9.78	10.19	11.29	10.42
K_3	4.27	4.49	4.69	4.48	6.51	6.70	7.76	6.99	10.78	11.19	12.44	11.47
mean	3.46	3.66	3.79		5.13	5.46	6.33		8.59	9.12	10.12	
LSD 5%	K:0.07 A:0.07 KA: ns				K:0.10 A:0.09 KA: ns				K:0.15 A:0.13 KA: ns			

Notes: K_0, K_1, K_2 and K_3 are none, K soil-applied 200 kg K ha^{-1}, K-foliar 1000 mg K L^{-1} spray solution and K-Soil + K-foliar combined respectively. A_0, A_1, and A_2 are no spray, spray with 100 and with 200 g L^{-1} ascorbic acid solution respectively. ns: not significant.

N uptake (Table 5) :

The pattern of N uptake followed a trend rather similar to that of the yields (Table 5). All treatments receiving K or AA or both showed increased uptake in grains or straw or grains + straw. Increases ranged from 24.5% by K_0A_1 to as high as 219% by K_3A_2 for grains. Respective increases for straw were 30.1 and 316% for the same mentioned treatments; those for grains + straw were 26.6 and 256% for the same mentioned treatments. The positive response shown by N uptake due to application of K and or ascorbic acid is mainly an outcome of the increased yields in grains and straw of wheat. The uptake of N by grains + straw followed a same pattern as the of N uptake in grains and that by straw. The ratio of N uptake by grains to that by straw averaged 1.65:1 for the non-fertilized and 1.34:1 for the fertilized. Average positive responses occurred to application of K and also to application of ascorbic acid. The pattern of response to K was: K3 > K_2> K_1> K_0 and that for the ascorbic acid was : A_2> A_1> A_0 . The additive (cumulative) effect of K fertilization + AA spray was evident as the treatments of K + AA gave a high increase in N uptake. There was no interaction caused by any of the two factors of K or ascorbic acid interfering with the effect of each other, except in straw N- uptake when response to K was most prominent under the high dose of ascorbic acid.

Table 5. N uptake (kg ha^{-1}) by wheat as affected by K application (soil and foliar) and ascorbic acid(foliar)

K fertilization (K)	Ascorbic Acid Foliar Spray (A)											
	A_0	A_1	A_2	mean	A_0	A_1	A_2	mean	A_0	A_1	A_2	mean
	N uptake by grains				N uptake by straw				N uptake by grains+ straw			
K_0	24.1	30.0	34.3	29.5	14.6	19.0	24.8	19.5	38.7	49.0	59.1	48.9
K_1	43.6	47.8	50.4	47.3	31.3	37.4	46.0	38.2	74.9	85.2	96.3	85.5
K_2	56.8	60.3	65.8	61.0	39.1	41.8	51.2	44.0	95.9	102.1	117.0	105.0
K_3	63.9	69.5	76.9	70.1	46.5	50.5	60.8	52.6	110.4	120.0	137.7	122.7
mean	47.1	51.9	56.9		14.6	19.0	24.8		80.0	89.1	102.5	
LSD 5%	K:2.8 A:2.5 KA: ns				K:0.9 A:0.8 KA:1.5				K:3.1 A:2.7 KA: ns			

***See footnotes of Table 4 for treatment designations**

P uptake (Table 6) :

The uptake of P was much lower than that of N. Unfertilized treatments showed the lowest P uptake while the fertilized ones showed increases in P uptake (Table 6). The increase in uptake by grains ranged from 8.6 % by K_0A_1 to as high as 346% by K_3A_2. Respective increases caused by same respective treatments were 68.3 to 1343% in straw and 29.5 and 673% for grains + straw. Uptake of P was considerably greater in straw than in grains. The ratio in grains to that by straw was 2.13: 1.00 where no fertilizers were applied, and averaged 1.00:1.19 over all treatments. Average positive response to K application showed a pattern of K_3 > K_2> K_1> K_0 and that for the ascorbic acid was A_2> A_1> A_0 . The additive (cumulative) effect due to combining K with ascorbic acid was evident and they gave a high increase in P uptake. There was interaction caused by K to the response to ascorbic acid when in some cases the high and low doses of AA were of similar effect in presence of foliar K.

Table 6. P uptake (kg ha^{-1}) by wheat as affected by K application (soil and foliar) and ascorbic acid(foliar)

K fertilization (K)	Ascorbic Acid Foliar Spray (A)											
	A_0	A_1	A_2	mean	A_0	A_1	A_2	mean	A_0	A_1	A_2	mean
	P uptake by grains				P uptake by straw				P uptake by grains+ straw			
K_0	3.02	3.28	4.15	3.48	1.42	2.39	3.60	2.47	4.4	5.7	7.8	6.0
K_1	5.13	6.78	7.43	6.45	4.20	5.55	7.20	5.65	9.3	12.3	14.6	12.1
K_2	8.13	9.20	10.83	9.39	10.68	11.71	16.35	12.91	18.8	20.9	27.2	22.3
K_3	10.40	11.10	13.47	11.66	12.41	15.00	20.49	15.97	22.8	26.1	34.0	27.6
mean	6.67	7.59	8.97		7.18	8.66	11.91		13.8	16.3	20.9	
LSD 5%	K:0.46 A:0.39 KA:0.79				K:1.24 A:1.07 KA:2.14				K:1.4 A:1.2 KA:2.40			

***See footnotes of Table 4 for treatment designations**

K uptake (Table 7) :

K uptake followed a rather similar pattern as that of N, much lower than that of N (Table 5). The lowest uptake was by the non-fertilized treatment. All fertilized ones had greater K uptake. The lowest increase was by $K_0A_1$and the highest was by K_3A_2 of which the increases were 18.2 and 367% respectively for grains uptake, 31.3 and 380 % respectively for straw uptake and 29.1 and 378% for grains+straw respectively. The uptake in straw exceeded that of the grains by several folds. The ratio of K uptake in grains to that in straw was 1.00: 4.95 where no fertilizers were applied, and averaged 1.00: 5.09 for the fertilized treatments. Average positive response to K and that to ascorbic acid spray followed a pattern very much similar to that of N as well as P application; $K_3 > K_2 > K_1 > K_0$ and $A_2 > A_1 > A_0$. The additive effect of K in combination with ascorbic acid spray was prominent giving the highest K uptake. There was an interaction caused by K to the response to ascorbic acid when in some cases of straw and grains+straw the high and low doses of AA were not significantly different under foliar K.

Table 7. K uptake (kg ha^{-1}) by wheat) as affected by K application (soil and foliar) and ascorbic acid(foliar)

K fertilization (K)	Ascorbic Acid Foliar Spray (A)											
	A_0	A_1	A_2	mean	A_0	A_1	A_2	mean	A_0	A_1	A_2	mean
	K uptake by grains tf5rv				K uptake by straw				K uptake by grains+ straw			
K_0	5.5	6.5	7.4	6.5	27.2	35.7	49.4	37.4	32.7	42.2	56.8	43.9
K_1	13.0	14.1	15.5	14.2	52.4	69.3	88.1	69.9	65.5	83.4	103.6	84.2
K_2	16.5	18.1	19.8	18.1	84.3	89.4	104.8	92.8	100.8	107.5	124.6	111.0
K_3	20.6	22.8	25.7	23.0	103.2	108.8	130.6	114.2	123.8	131.5	156.2	137.2
mean	13.9	15.4	17.1		6.8	75.8	93.2		80.7	91.1	110.3	
LSD 5%	K:0.6	A:0.5	KA: ns		K:2.8	A:2.4	KA:4.9		K:2.8	A:2.4	KA:4.8	

***See footnotes of Table 4 for treatment designations**

Assessment of treatments impact on uptake of N, P and K:

The increased N, P and K uptake due to K application reflects non-satisfactory contents of available K in soil despite application of manure to all plots of the experiment. Increased yield amounting to 26% in maize grains was obtained by Abo-Marzoka et al. (2016) upon spraying plants with ascorbic acid solution. Gul et al. (2011) sprayed wheat with a solution of 5000 mg K L^{-1} and obtained considerable increase in growth and other important traits including number of spikes per plant.The increase in plant growth and biomass yield was associated with increased N , P and K uptake due to applying K. Application of K cause increased yields in plants grown on soils with non-sufficient contents of available K. (Ranjhi *et al.,* 2002; Arabi *et al.,* 2002 and Min *et al.*, 2013). Foliar spray of ascorbic acid increases N, P and K uptake by plant (Pignochi and Foyer, 2003; Amin *et al.*, 2008 and Hussein and Khursheed, 2014).

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تقييم اثار إضافة البوتاسيوم و حمض الاسكوربيك على نمو و محصول و امتصاص عناصر النيتروجين و الفوسفور و البوتاسيوم في القمح (*Triticum aestivum*).

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تم اجراء تجربة حقلية عاملية (عاملان) على نبات القمح (*Triticum aestivum cv. Giza 168*) الذى زرع في ٢٠١٧/٢٠١٦ في ارض رملية (*Torripsamment*) بمحافظة الاسماعلية ، شمال مصر لتقييم اثر المعاملة بالتسميد البوتاسى و حمض الاسكوربيك. معاملات التسميد البوتاسى كانت K_0 لم يتم إضافة بوتاسيوم بها، K_1 إضافة السماد البوتاسى إضافة أرضية بمعدل ٢٠٠ كجم/هكتار، K_2 إضافة السماد البوتاسى ورقيا بالرش بمحلول تركيز البوتاسيوم بة ١٠٠٠ ملليجرام/لتر، K_3 إضافة سماد بوتاسى إضافة أرضية بعدل ٢٠٠ كجم/هكتار و ورش بمحلول تركيز البوتاسيوم بة ١٠٠٠ ملليجرام/لتر. بالنسبة لحمض الاسكوربيك كانت المعاملات كالتالى A_0 لم يتم الرش بحمض الاسكوربيك ، A_1 تم الرش بحمض الاسكوربيك بمعدل ١٠٠ جم/لتر، A_2 الرش الرش بحمض الاسكوربيك بمعدل ٢٠٠ جم/لتر. أظهرت النتائج تاثير ايجابى على المحصول (حبوب او قش) و أيضا على امتصاص العناصر(NPK) معطية افضل نتائج عند تداخل K_3A_2. محصول الحبوب اعطى ٢.٢٦ طن مترى/هكتار عند عدم إضافة سماد (سواء بوتاسى او حمض اسكوربيك) وزاد بنسبة ١٣.٧% عند تداخل K_0A_1 ووصل الى ١١٩% عند تداخل K_3A_2. و نفس هذان التداخلان اعطيا زيادة في امتصاص الحبوب للعناصر على نفس الترتيب ٢٤.٥ و ٢١٩% لعنصر النيتروجين ٨.٦ و ٣٤.٦% لعنصر الفوسفور، ٢٨.٢ و ٣٦٧% لعنصر البوتاسيوم.