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Mitigation Effect of K-Humate on N, P and K Phytoavailability in Three Different Egyptian Soils under Salinity Stress

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SOIL salinity has several adverse effects on phytoavailability of nutrients and plant growth in arid and semi-arid regions. This study investigated the mitigation effect of K-Humate application on the phytoavailability of N, P and K nutrients in three different Egyptian soils; from Kafr El-Sheikh, West Nubaria and South Al-Tahrir under salinity stress condition using Amberlite IRN-150 resin capsules. Representative surface soil samples (0-15 cm) were artificially salinized through equilibrium with four electrolytic solutions having four salinity levels (0, 5, 20 and 40 me/l, SAR= 7) prepared using mixtures of Na_2SO_4 and $CaCl_2$ salts (S1, S2, S3 and S4, respectively). Soils were then treated with 0, 1, 2 and 3g K-Humate/kg soil under each salinity level. Pots were subjected to drying/rewetting cycles for a period of 60 days then resin capsules were inserted into the soil, incubated for 14 days at soil water FC and phytoavailability of N, P and K were measured (RAQ, g/cm^2). Results showed that increasing soil salinity had significantly adverse effects on N-RAQs and P-RAQs. Application of K-Humate significantly increased N-RAQs and P-RAQs up to the rate of 2 g K-Humate/kg soil under each salinity level in the three tested soils. The highest percent increase in N-RAQs and P-AQs were found to be at the highest salinity level S4. While K-RAQs was not significantly affected by increasing soil salinity, it was significantly increased by increasing K-Humate application rate. Further field research is required in diverse plant environments to assess economical feasibility of K-Humate and comparison with other manures and organic fertilizers.

Keywords: N/P/K phytoavailability, K-Humate, Soil salinity, Resin capsules, Egyptian soils.

Salinity is a major abiotic stress, reducing the yield of wide variety of crops all over the world (Tester & Davenport, 2003 and Ashraf & Foolad, 2007). Plants growing in saline media come across generally with major drawbacks. The first is the increase in the osmotic stress due to high salt concentration of soil solution that decreases water potential of soil. The second is the increase in concentration of sodium (Na^+) and chloride (Cl^-) ions, exhibiting tissue accumulation of these ions and inhibition of mineral nutrients uptake (Marschner, 1995 and Aşik *et al*., 2009). For overcoming the negative effect of salinity, the addition of supplemental organic matter (Walker and Bernal, 2008) to growth media as an ameliorative agent could be necessary.

Humic acid (HA) is a commercial product which is proposed to improve soil fertility and increase the availability of nutrient elements. It consequently affects plant growth and yield and ameliorates the deleterious effects of salt stress. Kulikova *et al*. (2005) indicated that humic substances might show anti-stress effects under abiotic stress conditions such as unfavorable temperature, salinity, pH, etc. Humic substances are well known as stimulators of plant germination and growth (Dell'Amico *et al*., 1994 and Masciandaro *et al.*, 2002). HA appeared to be highly effective as a soil conditioner in vegetable growth, to improve crop tolerance and plant uptake of nutrients under saline conditions (Aydil *et al*., 2012 and Daur & Bakhashwain, 2013). Although the effect of interaction between salts and soil humus application was found statistically significant, the interaction effect between salt and HA foliar treatment was not found significant. Mesut Çimrin *et al.* (2010) concluded that HA application significantly increased N, P, K, Ca, Mg, S, Mn and Cu contents of shoot of pepper seedling. Also, N, P, K, Ca, S, Fe, Mn, Zn and Cu contents of root were increased with HA application. Na contents of both shoot and root of pepper decreased with increased HA doses. HA may also affect the rate and form in which P precipitates in calcareous soils. HA was found to inhibit the precipitation of hydroxyapatite (HAP) (Inskeep and Silverthooth, 1988) and to favor the formation of dicalcium phosphate dihydrate (DCPD) over other, more thermodynamically stable and less soluble phosphates and hence increases the efficiency of applied P fertilizer (Havlin & Westfall, 1984; Grossl & Inskeep, 1991 and Delgado *et al*., 2002).

Use of a resin sink to simulate nutrient movement to plant roots is a more realistic and sensitive test of nutrient availability than chemical-extraction procedures. Resin-accumulated nutrients were also significantly correlated with plant nutrient uptake under a variety of conditions (Sherif, 1996; Carlyle & Malcolm, 1986 and van Raij *et al*., 1986). Furthermore, the use of a mixed- bed ion exchange resin sink allows adsorption of all ionic forms of nutrients that would be present at the root surface. In both living root systems and resin-adsorption systems, nutrient ions continuously diffuse to the sink in response to gradients established by dynamic equilibrium. The mechanism is similar to the soil-root system, in which roots absorb nutrients from soil solution by releasing counter ions such as H^+, OH^- and HCO_3^-. Mixed-bed ion-exchange resin capsules (Yang *et al.*, 1991) can be inserted into disturbed and undisturbed soil samples or directly installed under field conditions to obtain resin adsorption quantities per unit surface area, (RAQ, g/cm^2 or µmol/cm^2). Examples of their use include studies of N and P availability under field conditions, monitoring of nitrate dynamics (Wander *et al*., 1995), monitoring the availability and movement of nutrients in Egyptians soils (Sherif and Hedia, 2001), assessment of labile soil P using resin membrane (Cooperland and Logan, 1994), characterization of K release kinetics from soils and minerals (Wimaladasa & Sinclair, 1988), monitoring the movements of elements in a forest soil (Haibara *et al*., 1990). Indeed, the results obtained by Hedia and Sherif (2004) provide strong evidence that the resin capsule is sensitive to salinity known to influence nutrient availability in soils.

The objective of this study was to investigate the mitigation effect of K-Humate application on the phytoavailability of N, P and K nutrients in three different Egyptian soils under salinity stress condition using resin capsules.

Material and Methods

Soils

Three different soil samples were collected from Kafr El-Sheikh (Motobas), West Nubaria and South Al-Tahrir representing alluvial, calcareous and sandy soils, respectively. Three simple surface soil samples (0-15 cm) were randomly collected from each location and mixed together to form a composite representative sample. Soil samples were air dried, sieved at 2 mm and analyzed for their main characteristics according to the procedures outlined by Page *et al*. (1982) as shown in Table 1.

TABLE 1. Main characteristics of the studied soils.

Criteria	**Soils**		
	Kafr El-Sheikh	**West Nubaria**	**South Al-Tahrir**
Bulk Density, kg/m^3	1.28	1.46	1.69
Particle Size Distrib. %			
Sand	69.3	71.3	92.3
Silt	17.2	23.4	6.3
Clay	13.5	5.3	1.4
Texture Class	CL	SCL	S
EC, dS/m	1.18	1.89	2.11
pH	8.12	8.32	7.82
SAR	8.97	9.41	9.98
Total $CaCO_3$, %	7.12	35.67	6.13
Organic Matter, %	2.43	1.49	0.57
CEC, $cmol_c$/kg	19.64	11.61	5.47
Availability, mg/kg			
N	42.2	34.6	14.7
P	21.3	12.3	10.4
K	54.1	19.1	6.4

Humic substances

A commercial K-Humate powder from Germany was used in treating the studied soils. The main characteristics of the product were determined according to Page *et al*. (1982). It was found that this product contains 58.12% OC, 0.41 % N, 0.09% P and 1.45% K with a CEC of 214.11 $cmol_c$/kg.

Treatments

Four electrolytic solutions were prepared with different salinity levels of 0, 5, 20 and 40 meq/L (S1, S2, S3 and S4, respectively) using a mixture of Na_2SO_4 and $CaCl_2$ salts. The SAR of all solutions was kept at 7 to avoid sodicity interferences. Four portions of 3.5 kg of each soil were packed in suitable plastic pots and continuously leached with these electrolytes until the EC of the leachates were equilibrated. Treated soils were then air-dried, crushed and sieved at 2 mm. The four portions of each soil were fertilized with ammonium sulfate and triple superphosphate at rates of 150 kg N/fed. and 100 kg P/fed, respectively. Potassium fertilizer was not applied based on K- Humate used as a source for humate and K. Each portion for each soil was then divided into four sub-portions which were treated with 0, 1.0, 2.0 and 3.0 g K-Humate/kg soil (H1, H2, H3 and H4, respectively). The treated soils were then packed in 330 ml plastic pots. The pots were brought to their water holding capacity using distilled water. Pots were subjected to drying and rewetting cycles with distilled water at room temperature along a period of 60 days.

Resin capsules

The Amberlite IRN-150 resin capsules were used for measuring the phytoavailability soil test (PST) of N, P and K in the treated soils according to Skogley (1992) and Sherif & Hedia (2001). These capsules provide a system that simulates ion movement to plant roots, where ions of all types are accumulated simultaneously and independently (Skogley, 1992 and 1994). They have a constant, uniform surface area, a feature that is critical to precision and comparison of values among and between samples. When placed in soil, water, or other media, cations and anions will be accumulated simultaneously creating universal system.

At the end of wetting and drying cycles, the soils were brought to their field capacity and one Amberlite resin capsule was inserted in each treated soil pot. The pots were sealed with plastic covers to prevent water evaporation. After incubation for 14 days at room temperature (Skogley, 1994), resin capsules were taken out of the soil and rinsed with distilled water and then leached with 50 ml of 2.0*M* HCl and the leachate was received in a 50-ml measuring flask. The amount of attained nutrients is quantitatively measured in terms of resin absorption quantity (RAQ, µg/cm^2).

Measurements

The quantities of N, P and K were determined in the leachates of the resin capsules which represent the resin adsorption quantities (N, P and K-RAQ, µg/cm^2, respectively) of these nutrients. Nitrogen was measured using Buchi distillation unit (Model K-350) according to the Kjeldahl method (Keeney and Nelson, 1982). Phosphorus was determined colorimetrically according to Page *et al.* (1982) using Shimadzu spectrophotometer (Model UV 1208). Potassium was determined using the Corning flame photometer (Model 400). All measurements were done in duplicates.

Statistical analysis

The data collected were analyzed statistically according to the procedures given by Steel and Torrie (1980) to test the significance of the differences between means of the applied treatments using the CoStat software package (Costat, 2004). All measurements were in triplicates. The percent change in measured N-RAQs, P-RAQs and K-RAQs relative to the control ($\%RAQ_{change}$) due to the applied K-Humate and salinity treatments was also calculated as follows:

$$\%\ RAQ_{change} = \frac{(RAQ_T - RAQ_c)}{RAQ_c} \times 100$$

where RAQ_T and RAQ_C are the measured RAQ values under any treatment and the control, respectively.

Results and Discussion

Results of the effect of K-Humate application on mineral N-RAQ values (Fig. 1) showed that Kafr El-Sheikh soil had generally higher N-RAQs (63.95 µg/cm^2) compared to West Nubaria (52.01 µg/cm^2) and South Al-Tahrir (55.36 µg/cm^2) soils. This may be due to the higher initial available mineral nitrogen and soil organic matter content of Kafr El-Seikh soil (Table 1). N-RAQs generally increased with increasing the K-Humate application rate (1, 2 and 3 g/kg soil) in the three tested soils under each salinity level. However, increasing the salinity level in the three soils from S1 through S4 had an adverse effect on the N-RAQs under each K-Humate application rate. The lowest N-RAQs were obtained at the highest salinity level (S4) in the three soils. Statistical analysis of the obtained results (Tables 2 and 3) revealed that application of K-Humate at 1 and 2 g/kg had significant positive effects on N-RAQs under the three salinity levels in the three soils (Table 2). However, increasing the K-Humate application rate of K-Humate to 3 g/kg did not significantly increase N-RAQs in the three soils. The mitigation effect of K-Humate on mineral soil nitrogen availability is probably due to the modification of the soil conditions that favors nitrogen mineralization (Khaled & Fawy, 2011 and Mesut Çimrin *et al.*, 2010). The calculated percent increases in N-RAQs at 2 g/kg of K-Humate, relative to the control, under different salinity levels in Kafr El-Sheikh soil were 62.11, 54.70, 45.47 and 10.59 %, in West Nubaria soil were 33.94, 30.54, 20.38 and 103.39 % and in South Al-Tahrir were 23.57, 21.30, 61.54 and 122.42 % at S1, S2, S3 and S4, respectively (Table 4). Increasing salinity level from S1 to S2 did not have significant effect on N-RAQs in the three soils (Table 3). However, increasing salinity to S3 and S4 had significantly negative effects on the measured N-RAQs in the three soils at each K-Humate application rate. This negative effect may be due to the unfavorable effect of increasing soil salinity on nitrogen mineralization process (Keeney and Nelson, 1982).

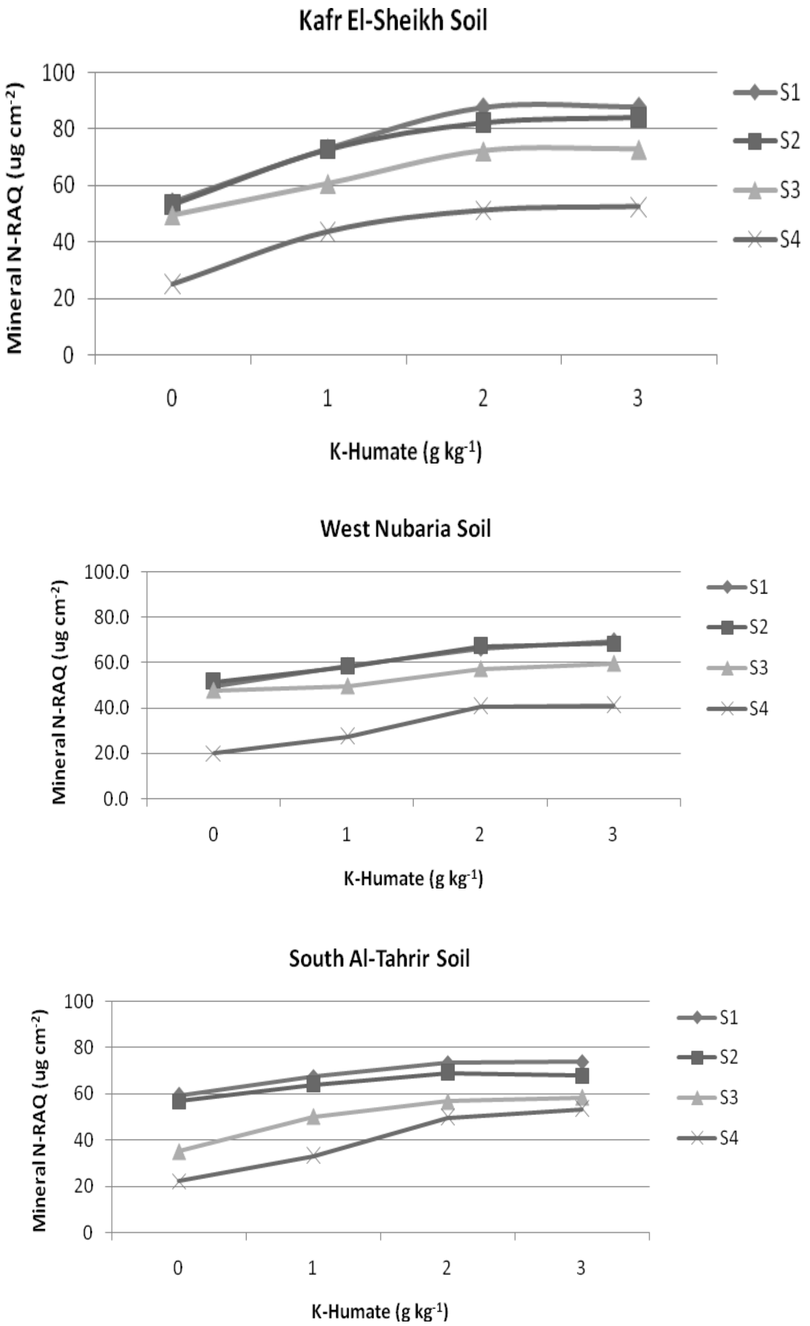

Fig. 1. Mineral N-RAQ values as affected by K-Humate application at different salinity levels in the three tested soils.

TABLE 2. Means of RAQ values (µg/cm^2) for K-Humate treatments and their significance at $LSD_{0.05}$ values.

Soils	$LSD_{.05}$*	K-Humate Treatments (g kg^{-1})			
		0	1	2	3
	Mineral N-RAQ				
Kafr El-Sheikh	3.62	45.53a	62.58b	73.35c	74.35c
West Nubaria	4.87	42.11a	48.43b	57.83c	59.62c
South Al-Tahrir	6.76	43.40a	53.65b	62.15c	63.38c
	P-RAQ values				
Kafr El-Sheikh	4.05	30.10a	34.08a	38.18b	40.18b
West Nubaria	3.19	22.46a	25.19a	27.86a	31.16b
South Al-Tahrir	3.39	25.45a	28.81a	32.28b	33.70b
	K-RAQ values				
Kafr El-Sheikh	3.15	115.10a	120.25b	129.43c	133.35d
West Nubaria	2.71	98.33a	105.65b	111.81c	115.00d
South Al-Tahrir	2.65	84.50a	87.75b	92.03c	92.68c

* For n= 12, values followed by the same letter are not significantly different.

TABLE 3. Means of RAQ values (µg/cm^2) for salinity treatments and their significance at $LSD_{.05}$ values.

Soils	$LSD_{.05}$*	Salinity Treatments (g kg^{-1})			
		S1	S2	S3	S4
			Mineral N-RAQ		
Kafr El-Sheikh	3.11	75.70a	73.13a	63.93b	43.05c
West Nubaria	2.67	61.00a	61.23a	53.50b	32.27c
South Al-Tahrir	4.25	68.53a	64.38a	50.08b	39.60c
	P-RAQ values				
Kafr El-Sheikh	2.98	41.95a	39.78a	36.45b	24.35c
West Nubaria	2.14	31.45a	30.17a	25.18b	18.36c
South Al-Tahrir	2.35	35.03a	33.85a	31.35b	20.01c
	K-RAQ values				
Kafr El-Sheikh	2.79	124.03a	123.43a	124.28a	126.40a
West Nubaria	3.14	109.00a	106.96a	107.65a	107.18a
South Al-Tahrir	2.87	89.15a	89.33a	89.08a	88.40a

* For n= 12, values followed by the same letter are not significantly different.

TABLE 4. Increase percent in mineral N-RAQ values relative to the control.

Soils	Salinity Treatments	K-Humate Treatments (g kg^{-1})		
		1	2	3
Kafr El-Sheikh	S1	35.12	62.11	62.48
	S2	36.84	54.70	58.27
	S3	22.33	45.47	46.68
	S4	73.71	103.59	108.76
West Nubaria	S1	18.38	33.94	40.61
	S2	13.04	30.54	32.88
	S3	4.23	20.38	24.97
	S4	37.31	103.69	105.97
South Al-Tahrir	S1	12.27	21.21	21.82
	S2	11.25	19.17	17.59
	S3	38.46	55.38	59.74
	S4	43.59	110.18	125.52

Measured P-RAQ values (Fig. 2) showed that Kafr El-Sheikh soil had generally the highest P-RAQs (35.63 µg/cm^2) and West Nubaria soil had the lowest values (26.29 µg/cm^2). The higher $CaCO_3$ content of West Nubaria soil may be a limiting factor for the lowest P solubility compared to the other two soils (Table 1). P-RAQs generally increased with increasing the K-Humate application rate in the three soils under each salinity level. However, increasing the salinity level in the three soils also had an adverse effect on the P-RAQs where the lowest P-RAQs were obtained at the highest salinity level (S4). Statistically, the application of 1 g/kg K-Humate had no significant effect on P-RAQs in the three soils (Table 2). However, increasing the K-Humate application rate to 2 g/kg of K-Humate significantly increased P-RAQs in Kafer El-Sheikh and South Al-Tahrir soils only. Increasing the application rate of K-Humate to 3 g/kg significantly increased P-RAQs in West Nubaria soil only.

The increase percent in P-RAQs at 2 g/kg of K-Humate under different salinity levels in Kafr El-Sheikh soil were 28.09, 28.91, 21.73 and 29.08 % and in South Al-Tahrir were 25.28, 26.02, 19.55 and 26.17 % and at 3 g/kg of K-Humate in West Nubaria soil 26.31, 29.89, 29.41 and 50.08% at S1, S2, S3 and S4, respectively (Table 5). The mitigation of phosphorus availability in soils amended with humic substances is attributed to the formation of organo-phosphorus soluble complexes between humate and phosphorus ions in the soil solution (Grossl & Inskeep, 1991; Delgado *et al*., 2002 and Andrews *et al.*, 2004). Similar to the response of N-RAQs to salinity levels, increasing salinity level in the soil from S1 to S2 did not have significant effect on P-RAQs in the three soils (Table 3). However, the increase of salinity to S3 and S4 had significantly negative effect on P-RAQs in the three soils at each K-Humate application rate. It was reported that increasing soil salinity led to the increase of soluble Ca^{2+} concentration which precipitates soluble phosphorus from soil solution in the form of calcium phosphate (Andrews *et al.*, 2004).

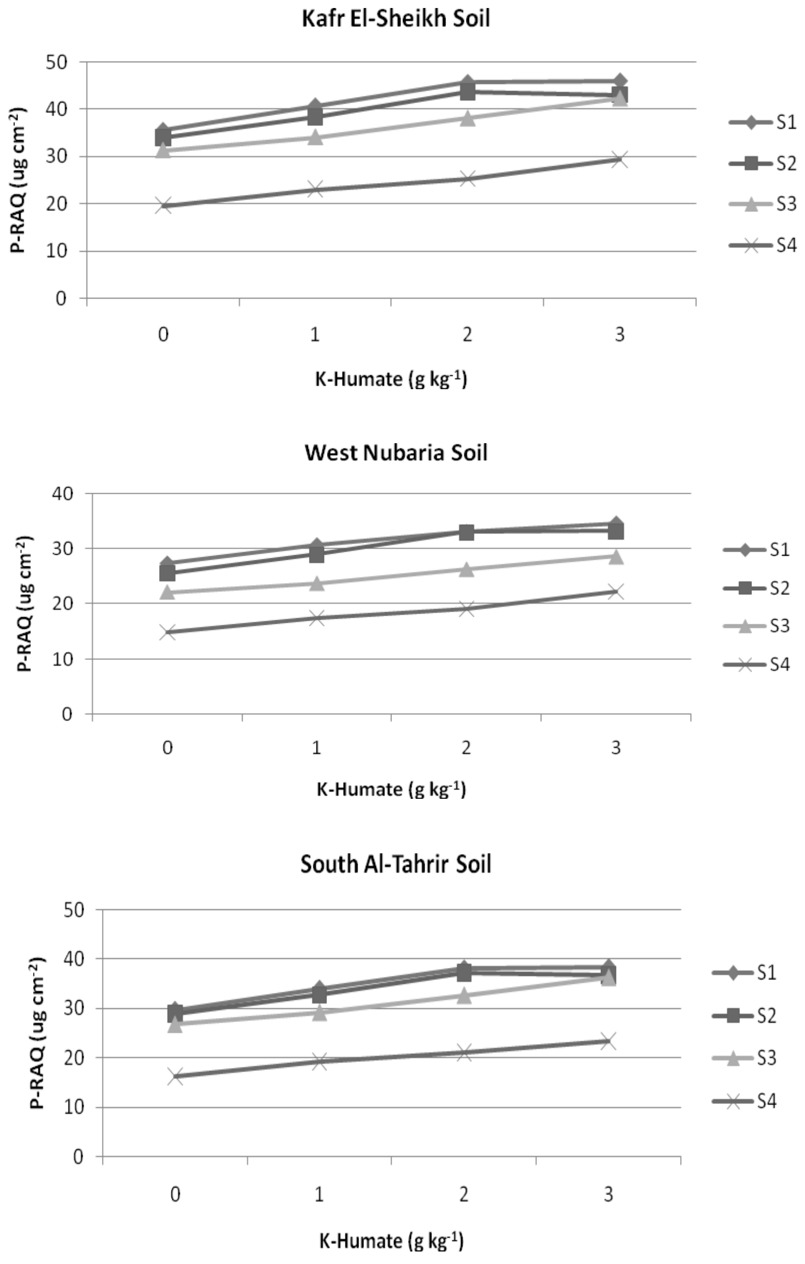

Fig. 2. P-RAQ values as affected by K-Humate application at different salinity levels in the three tested soils.

TABLE 5. Percent increase in P-RAQ values relative to the control.

Soils	Salinity Treatments	K-Humate Treatments (g kg^{-1})		
		1	2	3
Kafr El-Sheikh	S1	14.33	28.09	28.93
	S2	13.27	28.91	27.14
	S3	8.95	21.73	35.14
	S4	17.86	29.08	50.00
West Nubaria	S1	12.00	20.80	26.31
	S2	13.27	28.91	29.89
	S3	7.24	19.00	29.41
	S4	17.36	29.18	50.08
South Al-Tahrir	S1	12.89	25.28	26.04
	S2	11.95	26.02	24.42
	S3	8.05	19.55	31.63
	S4	16.07	26.17	38.99

Average K-RAQ values measured in the three soils (Fig. 3) showed the order: Kafr El-Sheikh> West Nubaria> South Al-Tahrir (124.53, 107.50 and 89.24 µg/cm^2, respectively). This trend may correspond to the differences in the CEC and initial available K of these soils (Table 1). K-RAQs generally increased with increasing the K-Humate application rate in the three soils under each salinity level. This may be due to the release of K from the applied potassium humate material. Increasing the salinity level in the three soils did not affect K-RAQs under each K-Humate application rate. Increasing the application rate of K-Humate from 1 to 3 g/kg had significant effect on K-RAQs except in South Al-Tahrir soil (Table 2). The increases percent in K-RAQs at 3 g/kg of K-Humate under different salinity levels in Kafr El-Sheikh soil were 15.87, 15.36, 16.13 and 16.05 % and in West Nubaria were 19.26, 16.43, 13.10 and 19.12 % and at 2 g/kg of K-Humate in South Al-Tahrir soil were 7.99, 9.25, 8.38 and 10.01 % at S1, S2, S3 and S4, respectively (Table 6). On contrast with N-RAQs and P-RAQs, increasing salinity level from S1 through S4 did not have any significant effects on K-RAQs at each K-Humate application rate in the three soils (Table 3). Since ions of all types in from the soil solution are accumulated simultaneously and independently on the exchange sites of resin capsules (Skogley, 1992, 1994), increasing salinity did not affect K-RAQs in the three soils.

It is also noticeable that the mitigation effect of K-Humate was pronounced mostly at the highest salinity level in the three soils. This was evidenced by the highest percent increases in calculated N-RAQs, P-RAQs and K-RAQs values (Tables 4 - 6).

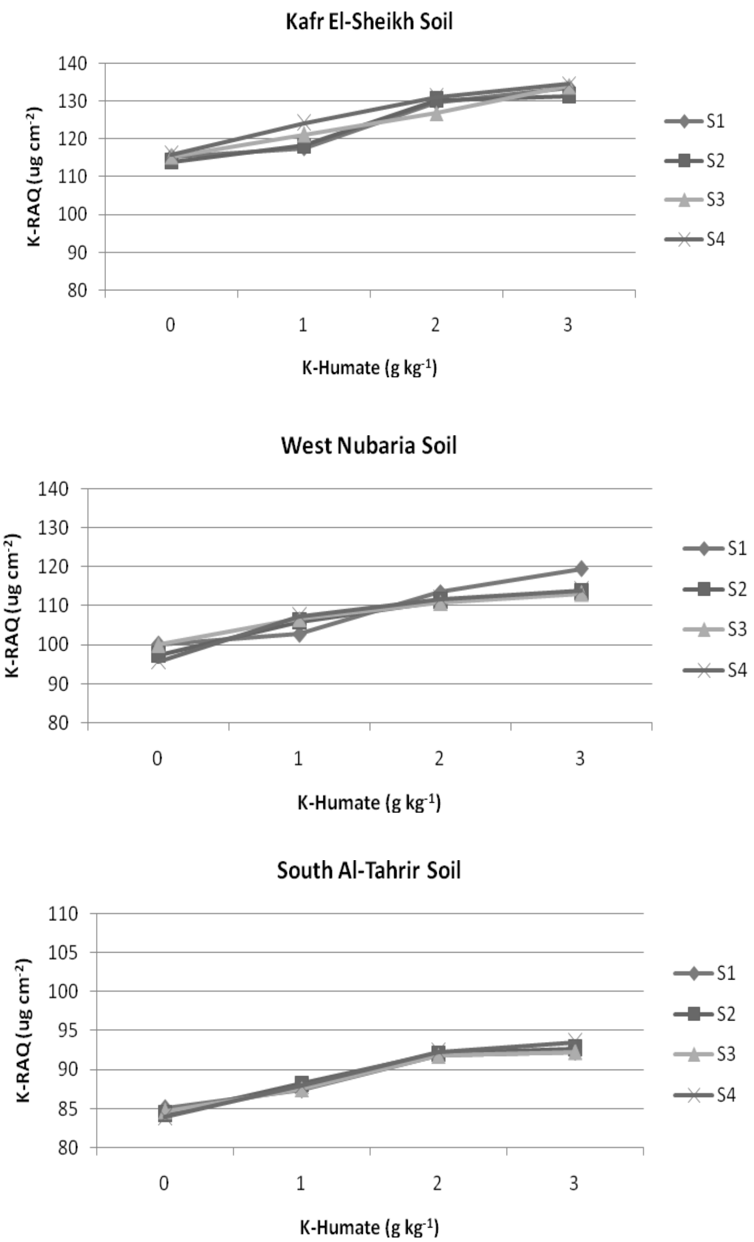

Fig. 3. K-RAQ values as affected by K-Humate application at different salinity levels in the three tested soils.

TABLE 6. Increase percentage in K-RAQ values relative to the control.

Soils	Salinity Treatments	K-Humate Treatments (g kg^{-1})		
		1	2	3
Kafr El-Sheikh	S1	1.99	12.40	15.87
	S2	3.78	14.31	15.36
	S3	5.03	9.97	16.13
	S4	7.08	13.11	16.05
West Nubaria	S1	2.50	13.37	19.26
	S2	8.73	14.12	16.43
	S3	6.70	10.80	13.10
	S4	12.12	16.72	19.12
South Al-Tahrir	S1	2.70	7.99	8.34
	S2	4.63	9.25	9.96
	S3	3.31	8.38	8.97
	S4	4.77	10.01	11.44

Conclusion

Soil application of K-Humate significantly alleviated the adverse effects of soil salinity on N, P and K phytoavailability in the studied soils. Humic substances are thought to improve the soil structure and improve physical properties of soil by increasing the exchange capacity and buffering capacities, promoting the chelation of many elements and making them available to plants. Humic substances may be used in cases where negative effects of salts would inhibit nutrients uptake and plant growth. Under the conditions of our study, the application rates of K-Humate should not exceed 2.0 g K-Humate/kg soil. Economical feasibility in different plant environments under field conditions requires further research studies.

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التأثير المحسن لهيومات البوتاسيوم على إتاحية النيتروجين والفوسفور والبوتاسيوم للنبات في ثلاثة أنواع من الأراضي المصرية تحت ظروف إجهاد الملوحة

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تؤدي زيادة ملوحة التربة إلى العديد من التأثيرات السلبية على إتاحية العناصر الغذائية Phytoavailability ونمو النبات في المناطق الجافة وشبه الجافة. وفي هذه الدراسة تم بحث تأثير إضافة مسحوق هيومات البوتاسيوم K-Humate على إتاحية عناصر N، P ، K في ثلاثة أنواع مختلفة من التربة المصرية، من مناطق كفر الشيخ ، غرب النوبارية وجنوب التحرير تحت ظروف الإجهاد الملحى باستخدام كبسولات الراتنجات Amberlite-IRN150 . حيث تم تمليح عينات من التربة السطحية (صفر-15 سم) من خلال التوازن مع أربعة محاليل إلكتروليتية بمستويات (0، 5، 20 ، 40 مليمكافئ/لتر) أعدت باستخدام مزيج من أملاح - $CaCl_2$ Na_2SO_4 وهذه تمثل S1 ، S2، S3، S4 - على التوالي، مع الحفاظ على مستوى موحد من الصودية (SAR = 7). بعد ذلك، عملت التربة بأربعة معدلات من مسحوق هيومات البوتاسيوم (0, 1, 2, 3 g/kg soil) تحت كل مستوى من مستويات الملوحة الأربعة. وتعرضت المعاملات لعدة لدورات التجفيف والإبتلال لمدة 60 يوما، ثم تم إدراج كبسولات الراتنج في التربة، وتم التحضين عند درجة حرارة المعمل لمدة 14 يوما مع الحفاظ على المحتوى الرطوبي للتربة عند السعة الحقلية وذلك للوصول إلى الاتزان مع المحلول الأرضي للترب المعاملة. وفى نهاية هذه الفترة تم استخلاص وقياس العناصر المدروسة لحساب Phytoavailability لعناصر النيتروجين والفوسفور والبوتاسيوم ($RAQ, \mu g/cm^2$). وأظهرت النتائج أن زيادة مستوى ملوحة التربة كان له تأثيرات سلبية معنويا على قيم N- RAQs وP-RAQs. ووجد أن إضافة K-Humate حتى معدل 2 g/kg للترب الثلاثة أدى إلى زيادة معنوية لقيم كل من N-RAQs و P-RAQs تحت كل مستويات الملوحة في الثلاثة أنواع من التربة التي تم اختبارها. كما وجد أن أعلى استجابة لإضافة هيومات البوتاسيوم في النسبة المئوية للزيادة في قيم N-RAQs و P-AQS تم الحصول عليها عند أعلى مستوى من ملوحة التربة S4 في الأنواع الثلاثة من التربة. في حين لم تؤثر زيادة مستوى ملوحة التربة على قيم K-RAQs بشكل معنوي، لكنها زادت معنويا بصورة مضطردة بزيادة معدل إضافة إضافة K-Humate. ويحتاج هذا المجال لمزيد من البحوث الحقلية تحت البيئات النباتية المتنوعة لتقييم الجدوى الاقتصادية لإضافة K-Humate ومقارنتها مع غيرها من الأسمدة البلدية والأسمدة العضوية الأخرى.