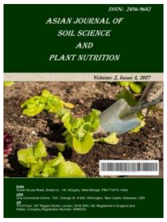

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Effect of Different Sources of Potassium on the Nutrient Status of Saline Calcareous Soil and Carrot (*Daucus carota* L.) Yield and Quality

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Authors' contributions

This work was carried out in collaboration between all authors. Author KAS designed the study, wrote the protocol and followed up the field work, authors MSM and SMAA managed the laboratory analyses of the study. Author RTR managed the literature searches, performed the statistical analysis and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: A field experiment was performed in a saline calcareous soil. Its aim was to evaluate the fertilization effects of potassium (K) from different sources in the form of a liquid solution sprayed on both plant and soil on some soil properties and on the carrot (*Daucus carota* L.) yield and quality. The purpose of the study is to try replacing the traditional soil application of some K fertilizers by spraying application using the liquid solution form.

Study Design: A split plot design with four replicates.

Place and Duration of Study: The experiment was carried out during two successive winter seasons (2016/2017 and 2017/2018) at the El-Road village, Sahl El-Hussinia, El-Sharkia Governorate (32°15' 00" N 30°50' 00" E), Egypt.

Methodology: The K sources used were K-humate (K-H), K-nitrate (KNO_3), and K-sulphate (K_2SO_4)

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in individual treatments with and without the compost in addition to the control. They were applied in a solution form sprayed on plant and soil at two rates: 600 and 1200 g K_2O/ha. Sowing of seeds was performed and K application doses were applied three times at 21, 45, and 65 days after sowing.
Results: The lyotropic order of K mitigates salinity stress on the plant. The compost along with the applied K significantly intensified the soil available nitrogen and K, but no significant effect was observed for available phosphorous. Spraying K from different sources with the compost caused a significant increment in the soil available K in a descending order K-H > K_2SO_4 > KNO_3. Soil available Zinc was significantly affected by K sources with a more pronounced effect by K-H. The carrot root length (cm), fresh weight (g), and yield, as well as the plant K use efficiency (KUE), were significantly increased by applying the K-H with the compost compared to the control alone. Minimum values were obtained for the KNO_3 treatment without the compost.
Conclusion: The complex composition of compost may limit the fertilization effect of sprayed K in the humate form but improves that of sulphate and nitrate.

Keywords: Carrot; spray; humate; potassium sources; saline soil.

1. INTRODUCTION

Water scarcity and the recurrent droughts are becoming a serious problem, especially with the climate change predictions. Crop production under salinity stress is expanding which is a major abiotic stress inhibits the plant growth and reduces the crop production [1,2].

The salinity-mineral nutrition relations are extremely complex. Salinity affects the nutrient availability, competitive uptake, transport, partitioning, or accumulation within the plant. Numerous salinity–nutrient interactions occur simultaneously and affect the crop yield or quality depending on salinity level and the composition of salts, the crop species, the nutrient in question, and a number of environmental factors [3].

High soil salinity levels reduce the water uptake by the plant. For the storage root yield, the NaCl salinity was more toxic than the Na_2SO_4 salinity [4,5]. Chloride (Cl) and Na^+ are absorbed by roots and transported to leaves where they accumulate leading to burning and necrosis of leaves. High Na may cause deterioration of the soil structure, reducing the water infiltration and soil aeration. Greater problems are in the fine textured soils such as clays and loams than sandy soils [6]. It reduces the Ca^{2+} availability, transport, and mobility to the growing regions of plant affecting the crop quality. The uptake of Na^+ reduces the K^+ uptake while the Cl^- reduces the NO^-_3 uptake. Salinity causes a combination of complex interactions that affect the plant metabolism, susceptibility to injury or internal nutrient requirement. Nutrients addition is more successful in improving the crop quality such as the correction of Na-induced Ca^{2+} deficiencies by supplemental Ca [3].

Potassium (K) plays a vital role in the crop production and quality metabolism. It acts on many physiological processes of the plant such as photosynthesis and carbohydrates translocation, the energy status, and maintenance of the tissue water. Increased amounts of the K enhance the ability of plants to resist diseases, insect's attacks, cold and drought stresses, and other adverse conditions. Potassium fertilization was associated with the increase in the carotene concentration in the carrot root. An optimum dose of K is necessary to produce a maximum yield and a good quality. The yield, quality, and shelf life of carrot were increased gradually with K fertilization [7]. The potassium fertilization maintains the soil fertility and there is a necessity for its continuous use for carrot production [8].

The global trends to healthy food production and the environmental protection have increased an interest in ecology-oriented agricultural practices such as foliar spray fertilization of macro-, micronutrients and different bio stimulators [9]. Farmers in Egypt are minimizing the chemical K fertilizer dose due to economic aspects. The foliar spray fertilization method is sometimes more economical and efficient than the soil fertilization. Very small amounts of fertilizers can be applied per hectare. It reduces the applicant passage, reduces soil compactness problem and thereby the groundwater pollution. Potassium in an organic chelated form (K-borate citrate and NPK Humate) was an economic K source could be used for foliar spray application. Carrot is a K-demanding plant and foliar application of K has increased the plant yield [8,10].

Carrot (*Daucus carota* L.) is one of the most economically valuable, root vegetable that grows for the human food in Egypt [11,12]. It contains a health anticancer constituent beta-carotene, rich in Vitamins A, B, C, and K, pantothenic acid, folate, K, Fe, Cu and Mn [7]. Carrot seed essential oil is a fragrance component in cosmetics and perfumes and is a flavor ingredient in some food products. It is also a source of sesquiterpene alcohol carotol [13]. Carotenoids in carrot are important metabolites involved in the plant photosynthesis and vegetable nutritional quality. Carotenoid and sugar contents were highly correlated and correlated to the chlorophyll contents involved in the plant response to pathogen infection [14].

The increase of the carrot production is influenced by the N and K fertilization [7,15]. Quality standards require the application of a balanced fertilization [16]. Carrot is considered susceptible to salinity [17,18]. Salts affect both the soil structure and crop yield. Salinity in root zone increases the osmotic pressure of soil solution and reduces both the soil water availability and rate of water absorption by carrot [6,19].

There is a physiological link between organic farming and the antioxidant molecules accumulation in plants. Also, accumulation of nutritionally valuable molecules is linked with both abiotic and biotic stresses [20]. An increasing interest in using the humic substances (HS) under salinity conditions due to their hormone-like roles. They can be used as a growth regulator to control the hormone level, improve the plant growth, and enhance the stress tolerance [21].

The present study aims to evaluate the fertilization efficiency by different K sources applied in the form of liquid solution sprayed on plant and soil and its effect on some soil properties as well as on carrot yield and quality. Solutions of K-humate, K-nitrate, and K-sulphate were used as individual treatments in the absence and presence of the compost (that was dry mixed with soil before planting for the combined treatments). After harvesting, some parameters were estimated.

2. MATERIALS AND METHODS

A field experiment was carried out during two successive winter seasons (2016/2017 and 2017/2018) at the El-Road village, Sahl El-Hussinia, El-Sharkia Governorate (32°15' 00" N 30°50' 00" E), Egypt. The experimental soil was characterized by high concentration of soluble salts and high $CaCO_3$ percent (Typic CalciTorrerts; Vertisol (FDC) [22]. Some soil physical and chemical properties were estimated before planting [23,24] and presented in Table 1.

2.1 Planting

The experimental area was 0.42 ha in two independent parts. The first one was without compost application while the second part was treated with the compost at a 5-t application rate before planting by 15 days. Some properties of the used compost were presented in Table 2.

Before planting, the soil was fertilized with the super phosphate (15.5% P_2O_5) 476.2 kg/ha as basal dressing in all plots. Each experimental unit was 5 m width × 10 m long divided into rows 65 cm apart. Sowing was performed on the 25th of September 2016 and 2017. The carrot seeds (*Daucus carota* L.), cv. Chantenay were hand sewn using 3 seeds per hill, at a 1.5 cm depth and 15 cm apart.

The plants were thinned to one plant after 25 days of planting. Irrigation was done by the El-Salam canal at 12 days intervals. Nitrogen fertilization (urea, 46% N) was applied as basal and top dressing in all plots after 21 and 45 days from planting, respectively according to the Ministry of Agriculture recommendation.

The K treatments were arranged in a split plot design with four replicates. The main factor was the K-source, with and without compost, and the sub-factor was the rate of application. The K-sources were K-humate (K-H), K-nitrate (KNO_3) and K-sulphate (K_2SO_4) and two rates of application 600 and 1200 g K_2O/ha were used for each source. The desired dose K-salt was dissolved in water to give two concentrations of K: 1250 and 2500 ppm K_2O/L. The K solutions (476.2 L/ha) were sprayed three times after sowing by 21, 45, and 65 days. The control was sprayed with fresh water i.e. not sprayed with any K-source (0 – K).

At harvesting, 130 days from planting, the root yield (t/ha) was calculated. A random sample of 10 plants from each plot was collected to record the growth parameters such as the root length (cm), root diameter (cm), the fresh and dry weight of the root (g). The ascorbic acid (mg/100 g f.w.) and total sugar (%) were determined according to the method described previously [25].

2.2 Analysis of Plant and Soil Samples

Carrot roots were dried at 70ºC for 72 h and ground. A half gram of the ground roots was wet digested using the acid mixture (1:1 H_2SO_4/$HClO_4$) [26]. After harvesting, the soil pH and EC were measured. The soil available N, P and K were extracted by the following solutions: 1% K_2SO_4, 0.5 N $NaHCO_3$, and 1 N NH_4OAc (pH 7.0), respectively. The total percentage of N in digested plant samples and the available in the soil extracts were estimated by distillation using Kjeldahl apparatus. While the P in the digested plant samples as well as soil available P were estimated colorimetrically by UV-Vis. Spectro-photometer (JENWAY UV/Vis. Spectro-photometer 6405, UK) using $SnCl_2$ indicator and the K by the flame photometer (EEL Flame Photometer, EVANS *Electro Selenium*, England), respectively [27,28]. The total contents of iron (Fe), manganese (Mn) and zinc (Zn) in roots and the soil were measured by Inductively Coupled Plasma Spectrometry (ICP-*Ultima 2 JY* Plasma).

2.3 Potassium Use Efficiency Indices

The Nutrient Use Efficiency Indices were calculated as previously mentioned [29,30], Potassium Use Efficiency **(KUE)** can also be expressed as Apparent K Recovery **(AKR)**:

1. Potassium Use Efficiency (KUE or AKR) =

$$\frac{(P_{nf} - P_{n0})}{Fertilizer\ rate\ (kg\ K\ applied)} \times 100 \qquad (1)$$

Where:

***P_{nf}* =** root potassium (K) content in fertilized plots (**f =** fertilized plots)
***P_{n0}* =** root potassium (K) content in non-fertilized plots (**0** = non-fertilized plots)

2. Agronomic Efficiency (AE) =

$$\frac{Y_f - Y_0}{Fertilizer\ rate\ (kg\ K\ applied)} \times 100 \qquad (2)$$

Y = root yield

3. Physiological Efficiency (PE) =

$$\frac{Y_f - Y_0}{P_{nf} - P_{n0}} \times 100 \qquad (3)$$

2.4 Statistical Analysis

The one-way analysis of variance (ANOVA) was carried out using the Co-State software (Ver. 6.311) to determine the statistical significance (LSD) of treatments at a significance level of P = .05 [31].

3. RESULTS AND DISCUSSION

3.1 Effect of K-sources on Some Soil Properties

The pH, EC and the available N, P and K after harvesting for the soil used in the study were significantly affected by the different K-sources used.

3.1.1 <u>Soil pH</u>

The applied K-sources decreased the soil pH in the order K-H > K_2SO_4 > KNO_3. Treatments with compost were more effective than the individual without compost. According to the LSD values in Table 3, the K-H and K_2SO_4 with and without compost at both rates significantly decreased the soil pH compared to the control. The KNO_3 significantly decreased the pH only at the 2500 ppm rate with and without compost by 0.74 and 0.61%, respectively. The most significant decrease in the pH was recorded for the K-H with and without compost by 1.12 and 1.11%, respectively, at the 2500 ppm rate of application.

The decrease in the soil pH may be due to a dual effect of the K-salt ions. According to the order of K^+ in the lyotropic series along with the acid radical (humate, nitrate or sulphate) effects, K^+ exchanges for Na^+ in the root zone. Sodium replaces the K^+ in salt and K^+ is released into soil solution and becomes available (Scheme 1). The formed Na - salt (humate: Na-H, nitrate: $NaNO_3$, sulphate: Na_2SO_4) is either precipitated or leached depending on the soil solution conditions. The Na^+ effect on the soil pH is decreased being captured by the conjugate base (the acid radical of the added K-salt) and consequently, the pH of the solution is decreased. The miscellaneous functional groups in the humate anion may make it the most efficient compared to the unified effect of the sole nitrate or sulphate anion.

Among the effective amelioration, methods are the removal of exchange and soluble Na^+ and changing the ionic composition of the soil with leaching the Na-salts out of the soil profile. Such procedures were reported to reduce pH and osmotic pressure of soil solution, thus promoting good conditions for plant growth. The humic substances (HS) distribution decreased soil Na, EC and pH. High supplies of K minimize adsorption of Na at the cation-exchange sites on soil particles, so enhancing Na leaching losses [21].

3.1.2 Soil EC

All treatments at all rates with and without compost significantly decreased the EC of the saline soil. The efficiency in decreasing the EC was in the order K- H > K_2SO_4 > KNO_3 with the compost. The most significant decrease was observed for the K- H at the 2500 ppm rate by 45.65 and 22.56% with and without compost, respectively.

The salt accumulation refers to an excess of the exchangeable sodium (Na) and the high soil pH. The decrease in the soil EC can be attributed to the effect of the conjugate ion and its order in the lyotropic series mentioned for the soil pH. The ionic composition of the soil solution is changed and the ionic strength is decreased because the excess mono-valent Na^+ ions are neutralized by the conjugate anions. The Na^+ ions are removed from solution either by precipitation or by leaching away from the soil [21].

3.1.3 The soil available N, P and K.

Table 3 indicates that the nutritional status of the saline calcareous soil was significantly affected by the applied treatments. Amending soil with compost has enriched the soil available N and K. This is often attributed to the decomposition and mineralization of compost releasing macronutrients [32].

Additionally, the available N and K in the studied soil were significantly increased by drenching the soil with the K-sources used in the same mentioned order K-H > K_2SO_4 > KNO_3 at all individual rates and with compost. The minimized effect of salinity due to the studied treatments has enhanced the fertilization effect of K. This, in turn, enhanced the nutrients' availability or at least didn't decrease it such as in case of the available P. The soil content of $CaCO_3$ (%) may decrease the availability of the P in soil. The increase in the available P was non-significant for all treatments with and without compost. The humic substances promote the conversion of a number of mineral elements into forms available to plants as stated previously [21].

Concerning the spray application of K-sources, the maximum values of the soil available K resulted by applying K-H could be attributed to the additional input of K as well as the release of the fixed K by humate [33]. The K availability increases as the applied rate increases from rate 1250 ppm to rate 2500 ppm. As a whole, the studied factors, treatments and rates showed a high significance effect on the soil available N and K but the effect on the P was non-significant. Only the soil available K was significantly affected by the interaction between the potassium sources' treatments and rates.

3.1.4 The soil available micronutrients

Table 4 indicates that the variation in the soil available Fe, Mn and Zn with and without compost at all rates of the treatments was non-significant except for Zn without compost. This non-significant increase reveals that the toxicity by heavy metals as one of the severe salinity effects could be controlled by the K-salts applied. The exception of Zn may be due to the difference in its ionic properties compared with Fe and Mn. The Zn ionic potential and charge/size ratio is smaller than that of the Fe and Mn. It is less affected by the conjugate ion of the K-salt applied especially in the absence of compost buffering effect. The increase in the soil available Fe, Mn and Zn with compost was greater than without compost.

In other words, neither the available Fe nor the Mn significantly affected by the applied compost or the K-sources. However, the soil available Zn was significantly increased as the increased rate of treatments. The most pronounced increase was by the K-H and this may be due to the chelation ability of the humate for Zn ions [34].

3.2 Yield and Growth Parameters of the Carrot

The different sources of K used in the present study exhibited an almost significant enhancement in the estimated yield components and growth parameters, especially with the compost. Table 5 refers to a significantly increased carrot root length (cm), fresh weight (g) and yield (ton/ha) by all studied K-sources with and without compost at both rates compared with the control (except for root length by K_2SO_4, 2500 ppm). The increase in the root diameter was non-significant according to the LSD values. Also, the increase in the root dry weight (g) without compost was non-significant for the KNO_3 at both rates and for the K_2SO_4 at the 2500 ppm rate.

The different K-sources can be arranged according to their efficiency in enhancing the estimated yield components and growth parameters in the order K- H > K_2SO_4 > KNO_3. The K-H combined with compost showed the most significant increase in the root length (by 36.52%), fresh weight of roots (by 21.38%), dry weight (by 71.13%) and the yield of roots (by 51.51%). This may be due to the biocompatibility and additional nutritive content of the humate anion for the plant compared to the sulphate and nitrate anions and the increased NPK content in carrot roots. The interaction between treatments and rates was significant for the carrot root length (cm) with compost, and both the roots fresh weight (g), and yield (ton/ha) with and without compost.

It had been well established that the humate anions as HS enhance the nutrient availability and absorption by the plant under salinity conditions. Salinity in the root zone results in water removal from the soil profile by evapo-transpiration. Mechanisms of growth inhibition include disturbance of plant water retention, due to the high osmotic potential of the external medium and adverse effects on the gas exchange, photosynthesis and protein synthesis. The HS seem to positively affect the metabolic and signalling pathways involved in the plant development, by acting directly on specific physiological targets and the expression of specific genes at the molecular level [21]. The HS application improved the growth of fresh and dry weight of shoots and roots for pepper plant [35].

3.3 The NPK Content of the Carrot Roots

It can be observed from Table 6 that the NPK content of carrot roots is significantly increased by all treatments at both rates with and without compost except for the K content without compost. The applied compost significantly enhanced the concentration of the macronutrient in the carrot roots. This could be attributed to the increased availability of the soil macronutrients resulted from the compost decomposition. It had been mentioned that the sufficient supply of K for the carrot improves the plant metabolism and physiological processes. This, in turn, enhances the balanced absorption of nutrients by plant and hence optimizes the nutrient content in the plant.

The significant increase in the N, P and K due to K-H with compost was by 34.06, 27.91, and 12.61%, while by the KNO_3 it was by 29.63, 34.29 and 9.59%, then by the K_2SO_4, it was by 26.52, 36.84 and 9.59%, respectively. The humate salts improve the nutrients availability and absorption by plants as stated. The interaction between the K-sources treatments and rates has significantly increased the N and K concentrations in the carrot roots with compost as shown in Table 6.

3.4 The Micronutrient Concentration in the Carrot Roots

Table 7 shows that the Fe (mg/kg) in the carrot roots is significantly increased with and without compost by all treatments. The most significant increase was by the K-H (by 21.05%), the K_2SO_4 (by 15.36%) and the KNO_3 (13.85%) with compost. Similarly, the Mn (mg/kg) significantly increased by 14.62%, 14.97% and 4.55% due to the K-H, K_2SO_4 and the KNO_3, respectively. The K-H with and without compost showed the most significant increase in Zn concentration (mg/kg) in the carrot roots by 24.25 and 27.07%, respectively.

3.5 The Effect of Different Treatments on the Ascorbic Acid and Total Sugar Content

Table 8 shows the ascorbic acid (mg/100 g f.w.) and total sugar content (%) of carrot roots in the present study. The ascorbic acid has increased by different treatments compared to the control but the significant increase was recorded for the 2500 ppm rate of all K sources used in the study except for the KNO_3 without compost. Application of K sources combined with the compost enhanced the ascorbic acid content in the order K-H (by 17.43%) > KNO_3 (by 14.88%) > K_2SO_4 (14.63%).

The total sugar content (%) in the roots has increased by different K-sources. But, the only significant increase was achieved by the K-H with compost by 4.79%.

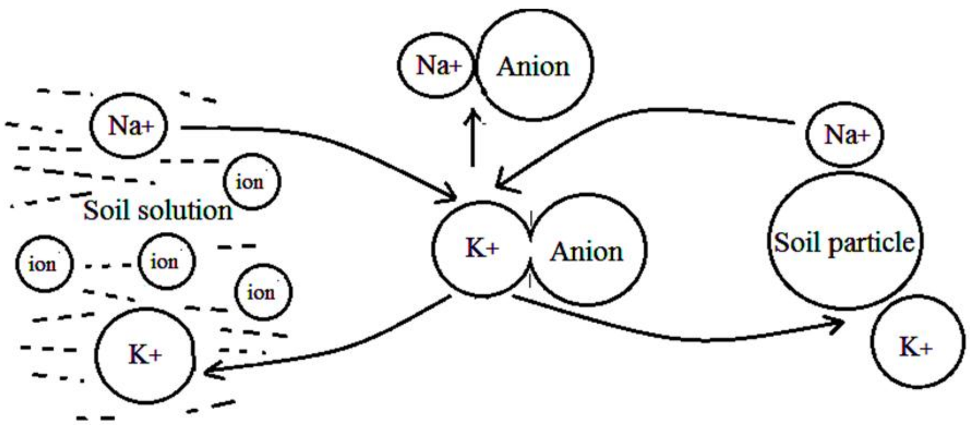
The aforementioned results revealed that the combination between the spray application of the K sources and compost as a soil amendment has enhanced the estimated quality characteristics of the carrot roots.

3.6 Potassium (K) Use Efficiency Indices

The K use efficiency indices listed in Table 9 were calculated for the different K sources: K-H,

KNO_3, and K_2SO_4 at the maximum application rate (1.2 kg K_2O/ha). The numerical values of the KUE/AKR and the AE indices for all the K sources studied with compost fertilizer were greater than without compost in the order: K-H > K_2SO_4 > KNO_3. A highly significant interaction between the compost and the K sources in the mentioned order was observed (Tables 3 and 5). This has maximized the soil K availability for plant roots that enhanced the K content of carrot roots and consequently raised the KUE value, especially for the K-H. The effect of the applied compost on the KUE values was limited for the K_2SO_4 and KNO_3 treatments. Apparently, the conjugate in effect for the humate anion was much more efficient in K utilization by plant than the sulphate followed by the nitrate.

Application of the K-H with the compost has increased the agronomic efficiency (AE) in accordance with the enhanced KUE which in turn represented by the increased productivity of carrot roots. Application of the potassium nitrate (KNO_3) without the compost showed the minimum AE value as indicated by Table 8.



Scheme 1. Suggested mechanism for the effect of the studied K-sources on the soil pH and EC

Table 1. Some characteristics of the experiment soil before cultivation

Particle size distribution (%)						
Coarse sand		**Fine sand**		**Silt**		**Clay**
6.30		25.40		30.91		37.39
Texture class						Clay loam
$CaCO_3$ (%)						13.85
Organic Matter (OM, %)						0.60
pH (1:2.5 soil : water suspension)						8.22
EC[a] (dS/m) (1:5 soil : water extract)						13.20
Anions (meq/l)			**Cations (meq/l)**			
HCO^-_3	**Cl^-**	**SO^{2-}_4**	**Ca^{2+}**	**Mg^{2+}**	**Na^+**	**K^+**
12.10	75.99	43.91	18.55	27.89	84.85	0.71
Available nutrients (mg/kg)						
Macronutrients			**Micronutrients**			
N	**P**	**K**	**Cu**	**Fe**	**Mn**	**Zn**
38.40	4.29	135	1.22	6.39	2.89	0.59
F.C.[b]	**W.P.[c]**	**A.W.[d]**	**B.D.[e] (g/cm^3)**		**T.P.[f] (%)**	
32.55	14.85	13.30	1.34		45.00	

[a] Electrical Conductivity, [b] Field Capacity, [c] Welting Point
[d] Available Water, [e] Bulk Density [f] Total Porosity

Table 2. Chemical properties of the compost used in the study

Moisture content (%)	**pH (1:2.5)**	**EC (dS/m) (1:10)**	**C (%)**	**C/N ratio**	**(%) OM**	**N**	**P**	**K**	**mg/kg Fe**	**Mn**	**Zn**
22	7.74	3.59	28.41	15.36	44.10	1.85	0.58	2.14	285	149	40

Table 3. Soil pH, EC and available macronutrient in soil after harvest

Sources	K_2O rates (ppm)	pH (1:2.5)		EC (dSm^{-1})		N (mg/kg)		P (mg/kg)		K (mg/kg)	
		Compost		Compost		Compost		Compost		Compost	
		With	Without	With	Without	With	Without	With	Without	With	Without
	0	8.07	8.12	9.20	9.75	42.85	40.88	4.79	4.60	142.0	140.0
K-Humate	**1250**	8.02	8.07	6.10	7.89	45.33	42.70	4.97	4.85	149.0	146.0
	2500	7.98	8.03	5.00	7.55	49.11	45.78	5.08	4.98	155.0	151.0
L.S.D. $_{5\%}$		**0.04**	**0.05**	**0.42**	**0.64**	**1.64**	**1.45**	**0.97**	**0.97**	**1.08**	**1.88**
	0	8.09	8.15	9.85	10.97	41.25	39.22	4.65	4.44	138.0	136.0
K-Nitrate	**1250**	8.05	8.13	7.34	9.54	43.46	39.87	4.72	4.69	143.0	140.0
	2500	8.03	8.10	6.40	8.10	45.80	41.30	4.89	4.73	144.0	141.0
L.S.D. $_{5\%}$		**0.05**	**0.04**	**0.42**	**0.69**	**2.18**	**1.90**	**0.87**	**0.87**	**1.15**	**3.41**
	0	8.08	8.13	9.44	9.89	42.00	40.15	4.70	4.54	140.0	138.0
K-Sulphate	**1250**	8.03	8.09	6.49	8.30	44.87	41.87	4.98	4.75	145.0	142.0
	2500	8.00	8.06	5.20	7.88	47.00	43.90	5.03	4.88	153.0	147.0
L.S.D. $_{5\%}$		**0.05**	**0.04**	**0.42**	**0.69**	**2.18**	**1.90**	**0.87**	**0.87**	**1.15**	**3.41**
		Significance of factors									
Treatments		**ns**[a]	**ns**	**	*	**ns**	*	**ns**	**ns**	***	*
Rates		**	**	***	***	***	***	**ns**	**ns**	***	***
Rates*Treatments		**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	***	**ns**

[a] *Non-significant*

Table 4. Micronutrients available in soil after harvest

Sources	K_2O rates (ppm)	Fe (mg/kg)		Mn (mg/kg)		Zn (mg/kg)	
		Compost		Compost		Compost	
		With	Without	With	Without	With	Without
	0	7.04	6.80	3.05	2.95	0.72	0.66
K- Humate	**1250**	7.18	7.04	3.75	3.22	0.84	0.73
	2500	7.27	7.09	3.96	3.51	0.87	0.79
L.S.D. $_{5\%}$		**0.68**	**1.19**	**0.97**	**1.19**	**n.s.**	**0.02**
	0	6.98	6.60	2.98	2.93	0.65	0.58
K - Nitrate	**1250**	7.04	6.84	3.05	2.98	0.73	0.62
	2500	7.13	6.98	3.09	3.04	0.76	0.67
L.S.D. $_{5\%}$		**1.75**	**1.76**	**1.57**	**0.87**	**n.s.**	**0.01**
	0	7.02	6.78	3.02	2.90	0.68	0.62
K-Sulphate	**1250**	7.15	6.99	3.25	3.12	0.78	0.69
	2500	7.25	7.03	3.60	3.22	0.82	0.74
L.S.D. $_{5\%}$		**1.75**	**1.76**	**1.57**	**0.87**	**n.s.**	**0.01**
		Significance of factors					
Treatments		**ns**	***	**ns**	**ns**	***	***
Rates		**ns**	**ns**	**ns**	**ns**	**-**	***
Rates*Treatments		**ns**	**ns**	**ns**	**ns**	**-**	**ns**

The combination with the compost enhanced the K use and agronomic efficiency because of the biocompatibility of the organic substrates compared to the mineral nitrate and sulphate substrates. Results indicate the greater fertilizing role of the organic fertilizer than the mineral one that can play a complementary role when combined with the organic compost. Chemical reactions are possible between the compost organic matter and the highly soluble mineral fertilizer producing biocompatible nutrients like amino acids. The K-Humate contains many

Table 5. Yield and yield component of the root

Sources	K_2O rates (ppm)	Root length (cm)		Root diameter (cm)		Fresh weight of root (g)		Dry weight of root (g)		Yield of root (ton/ha)	
		Compost		Compost		Compost		Compost		Compost	
		With	Without	With	Without	With	Without	With	Without	With	Without
K-Humate	**0**	14.98	13.55	2.06	1.88	58.00	49.00	5.23	4.12	32.81	25.93
	1250	17.55	15.88	2.32	2.18	67.53	58.20	6.89	4.88	46.55	37.76
	2500	20.45	17.10	2.41	2.33	70.40	63.97	8.95	5.54	49.71	42.74
L.S.D. 5%		**0.97**	**0.97**	**0.68**	**0.68**	**1.41**	**1.41**	**0.97**	**0.68**	**1.19**	**1.97**
K-Nitrate	**0**	14.00	10.85	1.88	1.75	53.60	45.89	4.97	3.88	29.76	23.52
	1250	15.84	13.00	1.96	1.85	57.80	49.60	5.66	3.97	37.48	24.76
	2500	15.98	13.85	2.06	1.98	58.38	53.88	6.20	4.08	38.07	28.26
L.S.D. 5%		**1.51**	**1.75**	**0.87**	**0.87**	**3.29**	**1.90**	**0.87**	**0.87**	**2.65**	**0.87**
K-Sulphate	**0**	14.86	13.00	1.98	1.80	56.70	47.22	5.19	3.97	30.95	25.36
	1250	16.30	13.95	2.08	1.96	64.75	52.76	6.77	4.13	41.67	32.79
	2500	17.00	15.77	2.16	2.05	66.40	58.00	8.64	5.33	45.24	35.48
L.S.D. 5%		**1.51**	**1.75**	**0.87**	**0.87**	**3.29**	**1.90**	**0.87**	**0.87**	**2.65**	**0.87**
Significance of Factors											
Treatments		*	*	ns	ns	**	**	*	ns	**	***
Rates		***	***	ns	ns	***	***	***	*	***	***
Rates*Treatments		*	ns	ns	ns	**	**	ns	ns	***	**

Table 6. Macronutrients concentration in root of carrot

Sources	K_2O rates (ppm)	N (%)		P (%)		K(%)	
		Compost		Compost		Compost	
		With	Without	With	Without	With	Without
	0	1.38	1.33	0.43	0.35	2.22	1.93
K-Humate	**1250**	1.77	1.69	0.48	0.43	2.39	2.13
	2500	1.85	1.79	0.55	0.49	2.50	2.19
L.S.D. 5%		**0.03**	**0.06**	**0.01**	**0.02**	**0.01**	**0.97**
	0	1.35	1.27	0.35	0.29	2.15	1.85
K-Nitrate	**1250**	1.60	1.49	0.39	0.32	2.20	1.95
	2500	1.75	1.57	0.47	0.37	2.28	1.98
L.S.D. 5%		**0.05**	**0.08**	**0.03**	**0.02**	**0.01**	**1.51**
	0	1.32	1.29	0.38	0.31	2.19	1.88
K-Sulphate	**1250**	1.53	1.50	0.44	0.38	2.35	2.06
	2500	1.67	1.58	0.52	0.46	2.40	2.09
L.S.D. 5%		**0.05**	**0.08**	**0.03**	**0.02**	**0.01**	**1.51**
Significance of factors							
Treatments		**	**	**	***	***	ns
Rates		***	***	***	***	***	ns
Rates*Treatments		**	ns	ns	*	***	ns

Table 7. Micronutrients concentration in root of Carrot

Sources	K_2O rates (ppm)	Fe (mg/kg)		Mn (mg/kg)		Zn (mg/kg)	
		Compost		Compost		Compost	
		With	Without	With	Without	With	Without
	0	76.00	72.10	49.52	41.10	24.00	21.94
K - Humate	**1250**	85.30	78.95	53.20	47.33	26.34	23.75
	2500	92.00	83.90	56.76	52.00	29.82	27.88
L.S.D. 5%		**2.37**	**1.28**	**1.97**	**1.75**	**0.77**	**0.97**
	0	73.96	67.40	46.82	39.55	23.80	19.68
K - Nitrate	**1250**	77.40	69.88	48.29	41.49	24.29	20.66
	2500	84.20	73.90	48.95	41.00	24.78	22.30

Sources	K_2O rates (ppm)	Fe (mg/kg)		Mn (mg/kg)		Zn (mg/kg)	
		Compost		Compost		Compost	
		With	Without	With	Without	With	Without
L.S.D. $_{5\%}$		**1.75**	**1.90**	**1.31**	**0.87**	**2.65**	**0.87**
	0	76.80	69.55	47.23	40.44	23.95	20.17
K - Sulphate	**1250**	84.00	75.95	50.44	43.98	25.18	22.90
	2500	88.60	79.44	54.30	47.80	26.77	25.38
L.S.D. $_{5\%}$		**1.75**	**1.90**	**1.31**	**0.87**	**2.65**	**0.87**
Significance of Factors							
Treatments		**	***	**	***	ns	***
Rates		***	***	***	***	***	***
Rates*Treatments		ns	*	ns	**	**	ns

Table 8. Ascorbic acid, total sugar content in carrot roots (mean two seasons)

Sources	K_2O rates (ppm)	Ascorbic acid (mg/100g f.w.)		Total sugar content (%)	
		Compost		Compost	
		With	Without	With	Without
	0	6.77	5.84	15.46	14.22
K - Humate	**1250**	7.50	6.23	16.20	14.69
	2500	7.95	6.87	16.80	15.02
L.S.D. $_{5\%}$		**0.97**	**0.97**	**0.69**	**1.19**
	0	5.98	4.88	15.28	14.10
K - Nitrate	**1250**	6.30	5.23	15.58	14.32
	2500	6.87	5.77	15.63	14.39
L.S.D. $_{5\%}$		**0.87**	**1.51**	**0.85**	**1.49**
	0	6.22	4.97	15.39	14.15
K - Sulphate	**1250**	6.88	5.86	15.75	14.33
	2500	7.13	6.64	15.93	14.49
L.S.D. $_{5\%}$		**0.87**	**1.51**	**0.85**	**1.49**
		Significance of factors			
Treatments		**ns**	**ns**	**ns**	**ns**
Rates		**ns**	**ns**	**ns**	***
Rates*treatments		**ns**	**ns**	**ns**	**ns**

nutrients necessary to the development of plant life and the mechanism of possible growth promoting effect. It is usually attributed to a hormone-like impact, that is the photosynthesis activation, cell division acceleration, and increasing the permeability of plant cell membranes and improved nutrient uptake and finally the activation of biomass production. Moreover, humified substances contain a stable fraction of carbon, thus regulating the carbon cycle and releasing the nutrients that improve plant growth [36-38].

However, the physiological efficiency (PE) of the K-H with the compost was smaller than without compost while the PE for the KNO_3 and K_2SO_4 with the compost was greater than without it [39]. This may be due to the complex composition of the compost that may limit the physiological role of K in the form of humate. Potassium is considered as a major osmotically active cation of the plant cell. Bulky moieties may be formed between some of the compost components and the humate forms of the K. Such moieties may restrict the osmotic diffusion of K through the plant cell walls. The opposite may be true for the nitrate and/or sulphate form. In a previous study, application of the KNO_3, at 1000 - 2000 ppm rates had been stimulated the growth, increased the yield, and enhanced some biochemical constituents of the potato plant (*Solanum tuberosum* L.) [40]. Application of K_2SO_4 has increased the biomass production and increased the uptake of the essential nutrients like K, Ca, Mg and P in saline soils [41].

Table 9. Potassium (K) use efficiency indices

K-Source	Applied K rate 2 ($kg\ K_2O$)/ha	Root K Content (%) Compost		(KUE/AKR)[a] (%)		Yield of root (ton/ha) Compost		AE[b] (%)		PE[c] (%)	
		With	Without	With	Without	With	Without	With	Without	With	Without
K - Humate	**1.20**	2.22	1.93	**23.33**	**21.67**	32.81	25.93	**1408.33**	**1400.83**	**60.36**	**64.65**
		2.50	2.19			49.71	42.74				
K - Nitrate	**1.20**	2.15	1.85	**10.83**	**10.83**	29.76	23.52	**692.50**	**395.00**	**63.92**	**36.46**
		2.28	1.98			38.07	28.26				
K - Sulphate	**1.20**	2.19	1.88	**17.50**	**17.50**	30.95	25.36	**1190.83**	**843.33**	**68.05**	**48.19**
		2.40	2.09			45.24	35.48				

[a] Potassium Use Efficiency/Apparent Potassium Recovery, [b] Agronomic Efficiency, [c] Physiological Efficiency

4. CONCLUSION

A field study was carried out to evaluate the fertilization efficiency of potassium (K) from different sources applied on both plant and soil on some properties of a saline calcareous soil and on carrot (*Daucus carota* L.) yield and quality. The lyotropic order of K inhibits the effect of Na and mitigates salinity stress on soil and plant which affected all estimated parameters. The studied K-sources decreased the soil pH in the order K-H > K_2SO_4 > KNO_3. Treatments with the compost were more effective than without compost. The soil available N and K, the carrot root length (cm), fresh weight (g), and yield were significantly increased compared to the control. The increase in the root diameter, ascorbic acid and the total sugar content of the carrot roots was almost non-significant. The potassium (K) use efficiency indices were calculated. The physiological efficiency (PE) of the K-H with the compost was smaller than without compost while the PE for the KNO_3 and K_2SO_4 with the compost was greater than without it. This may be due to the complex composition of the compost that may limit the physiological role of the K in the humate form.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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