

The effect of potassium from different sources applied as foliar spray and soil drenching on the nutrients' status of the saline calcareous soil, yield, and quality of carrot (*Daucus carota* L.)

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ABSTRACT

Aims: A field study aims to study the effect of potassium (K) fertilization applied as foliar spray and soil drenching on some soil properties and on the yield and quality of carrot (*Daucus carota* L.) grown in a saline calcareous soil.

Study design: a split plot design.

Place and Duration of Study: The field experiment was carried out during the two successive winter seasons of 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: Foliar application and soil drenching was carried out by individual treatments and combined with or without the compost. The treatments included the K-humate (K-H), K- nitrate (KNO_3), and K-sulphate (K_2SO_4) as different K sources at two rates 1 and 2. Sowings were performed and foliar application was carried out 21, 45, and 65 days after sowing.

Results: The applied compost significantly intensified the soil available N and K but no significant effect observed on the available P. Foliar application of the different sources of K combined with the compost realized a significant increment in the soil available K in a descending order $\text{K-H} > \text{K}_2\text{SO}_4 > \text{KNO}_3$. Soil available Zn was significantly affected by K-sources with a more pronounced effect of the K-H. The carrot root length (cm), fresh weight (g), and yield as well as the K use efficiency (KUE) were significantly increased compared to the control by applying the K-H with the compost. Minimum values were achieved by adding the KNO_3 without compost. An increase in the root diameter, the ascorbic acid and the total sugar content of the carrot roots was non-significant for most of the treatments.

Conclusion: The complex composition of the compost that may limit the physiological role

Keywords: Calcareous soil; Carrot; Foliar spray; Humate; Potassium sources; Saline soil

1. INTRODUCTION

Water scarcity and the recurrent droughts are becoming a serious problem especially in the context of climate change predictions. The crop production under salinity stress is expanding. Salinity is a major abiotic stress inhibits the plant growth and development 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 the 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 plant. For the storage root yield, the NaCl salinity was more toxic than the Na₂SO₄ salinity [4,5]. Chloride (Cl) and Na⁺ are absorbed by the roots and transported to the leaves where they accumulate leading to the burn and necrosis of the leaves. High Na may cause the deterioration of the soil structure, reducing the water infiltration and soil aeration. The problems are greater in the fine textured soils such as clays and loams than the sandy soils [6]. It reduces the Ca²⁺ availability, transport, and mobility to the growing regions of the plant affecting the crop quality. The uptake of the Na⁺ reduces the K⁺ uptake while the Cl⁻ reduces the NO₃⁻ 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 Ca²⁺ 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 the 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 the interest for the ecology-oriented agricultural practices such as the foliar spray fertilization in the form of macro- and micronutrients as well as the different bio stimulators [9]. Farmers are minimizing the chemical K fertilizer dose in Egypt due to economic aspects. The foliar spray fertilization method is usually is sometimes more economic and efficient than the soil fertilization. Very small amounts of the fertilizers can be applied per hectare. It reduces the applicant passage, reduces the soil compactness problem and thereby the ground water pollution. Potassium in an organic chelated form (K-borate citrate and NPK Humate) was an economic K source could be used as foliar spray application. Carrot is a K-demanding plant and the foliar application of the K has increased the plant yield [8,10].

Carrot (*Daucus carota* L.) is one of the most economically valuable, short duration root vegetable 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 different categories of food products. It is also a major source of sesquiterpene alcohol carotol, as the main constituent in the seed essential oils [13]. Carotenoids in the carrot are important secondary metabolites involved in the plant photosynthesis, vegetable nutritional quality and in metabolic prevention in the human health. 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]. The quality standards require the application of a balanced fertilization [16]. Carrot is considered susceptible to salinity relatively [17,18]. Salts affect both the soil structure and crop yield. Salinity in the root zone increases the osmotic pressure of the soil solution and reduces both the soil water availability and the rate of water absorption by the carrot [6,19].

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

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The aim of the present study is to study, determine or evaluate the effect of foliar spray application of the K from three different sources of K fertilizers on the carrot roots yield and quality under the calcareous saline soil conditions. Different K fertilizers in a liquid form of the K-humate, K- nitrate, and K-sulphate solution at two different rates were applied as individual and combined with the compost treatments during the cultivation season. After harvesting, the yield, quality, and nutrient use efficiency parameters were estimated.

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2. MATERIAL AND METHODS

A field experiment was carried out during the two successive winter seasons of 2015/2016 and 2016/2017 at the El-Road village, Sahl El-Hussinia, El-Sharkia Governorate (32° 15' 00" N 30° 50' 00" E), Egypt. The aim was to evaluate the effect of different sources and rates of potassium fertilization on some soil properties and on the yield and quality of carrot (*Daucus carota* L.) grown in a saline calcareous soil (Typic CalciTorrepts; Vertisol (FDC) [22]. Some of the physical and chemical properties of the experiment soil were estimated before planting [23,24] and presented in Table 1.

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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	
OM (%)						0.60	
pH (1:2.5 soil : water suspension)						8.22	
EC (dS/m) (1:5 soil : water extract)						13.20	
Anions (meq/l)			Cations (meq/l)				
HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	Ca ⁺⁺	Mg ⁺⁺	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.	W.P.	A.W.	B.D. (g/cm ³)		T.P. (%)		
32.55	14.85	13.30	1.34		45.00		

2.1. PLANTING

In both seasons, each experiment was carried out in a split plot design with four replicates. The experimental area was one fed (fed = 0.42 ha = 4200 m²) divided in two divisions. The first division was without compost and the second division was treated by the compost at a 5-ton application rate before 15 days from planting. Each experimental unit plot was 5 m width × 10 m long divided into rows 65 cm apart.

Before planting, the soil was fertilized by the super phosphate (15.5% P₂O₅, 200 kg application rate during the soil tillage. Sowing was performed on the 25th of September 2016 and/or 2017. The carrot seeds (*Daucus carota* L.), cv. Chantenay were hand sown 3 seeds/hill 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 after 21 and 45 days from planting according to the Ministry of Agriculture recommendation.

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Foliar spray application and soil drench using the different K sources in liquid form (476.2 L/ha); K-humate (K-H), K-nitrate (KNO₃) and K-sulphate (K₂SO₄), at different rates were carried out three times 21, 45, and 65 days after sowing as follows:

- 1- Control (0 – K₂O), foliar application of fresh water
- 2- K – Humate; K-H (rate 1: 500 ppm K₂O, rate 2: 1000 ppm K₂O)
- 3- K – Nitrate; KNO₃ (rate 1: 1250 ppm K₂O, rate 2: 2500 ppm K₂O)
- 4- K – Sulphate; K₂SO₄ (rate 1: 1250 ppm K₂O, rate 2: 2500 ppm K₂O)

At the harvesting, 130 days from planting, the roots yield (ton/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 (%) was determined according to the method described by [25].

2.2. ANALYSIS OF PLANT AND SOIL SAMPLES

Carrot roots were dried at 70 °C for 72 h and ground. A half gram of ground roots was wet digested using the acid mixture (1:1 H₂SO₄/HClO₄) [26]. After harvesting, the soil pH and EC were measured. The soil available N, P, K were extracted by 1% K₂SO₄, 0.5 N NaHCO₃, and 1 N NH₄OAc (pH 7.0), respectively. The total percentage of N, P, and K in digested plant samples and the available in the soil extracts were measured 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. Spectrophotometer using SnCl₂ indicator and K by flame photometer, respectively [27,28]. The total content of Fe, Mn and Zn in roots' and the soil available were measured by Inductively Coupled Plasma Spectrometry (ICP-Ultima 2 JY Plasma).

2.2. Potassium Use Efficiency Indices:

The Nutrient Use Efficiency Indices can be calculated according to Craswell and Godwin (1984) and Roozbeh *et al.* (2011) [29,30]. Potassium use efficiency (KUE) also can be expressed as Apparent K recovery (AKR):

$$1. \text{ K Use Efficiency (KUE/AKR)} = \frac{(P_{nf} - P_0)}{\text{Fertilizer rate (kg of K applied)}} \times 100$$

Where: P_n = root potassium (K) content

P_{nf} = root K in fertilized plots f = fertilized plots

P₀ = root K in non-fertilized

plots 0 = non-fertilized plots

$$2. \text{ Agronomic Efficiency (AE)} = \frac{Y_f - Y_0}{\text{Fertilizer rate (kg of K applied)}} \times 100$$

Y = root yield

$$3. \text{ Physiological Efficiency (PE)} = \frac{P_f - P_0}{P_{nf} - P_0} \times 100$$

2.3. 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 of the treatment effects at a significance level LSD of 0.05 [31].

3. RESULTS AND DISCUSSION

3.1. The effect of the studied K-sources on some of the soil properties

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

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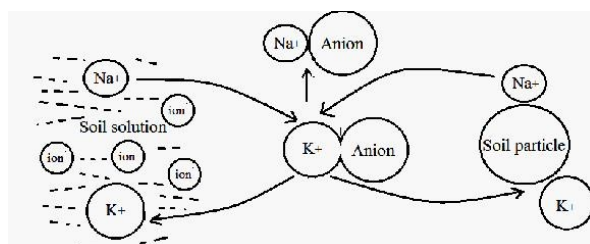
3.1.1. Soil pH

The studied K-sources decreased the soil pH in the order $K-H > K_2SO_4 > KNO_3$. Combined treatments with compost were more effective than the individual without compost. According to the L.S.D. 0.05 values in Table 2, the K-H and $K-SO_4^{2-}$ with and without compost at both rates 1 and 2 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 1000 ppm rate of application.

Table 2. Soil pH, EC and Available macronutrient in soil after harvest

Sources	K ₂ O rates	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
K-Humate	0	8.07	8.12	9.20	9.75	42.85	40.88	4.79	4.60	142.00	140.00
	1	8.02	8.07	6.10	7.89	45.33	42.70	4.97	4.85	149.00	146.00
	2	7.98	8.03	5.00	7.55	49.11	45.78	5.08	4.98	155.00	151.00
L.S.D. 5%		0.04	0.05	0.42	0.64	1.64	1.45	0.97	0.97	1.08	1.88
K-Nitrate	0	8.09	8.15	9.85	10.97	41.25	39.22	4.65	4.44	138.00	136.00
	1	8.05	8.13	7.34	9.54	43.46	39.87	4.72	4.69	143.00	140.00
	2	8.03	8.10	6.40	8.10	45.80	41.30	4.89	4.73	144.00	141.00
L.S.D. 5%		0.05	0.04	0.42	0.69	2.18	1.90	0.87	0.87	1.15	3.41
K-Sulphate	0	8.08	8.13	9.44	9.89	42.00	40.15	4.70	4.54	140.00	138.00
	1	8.03	8.09	6.49	8.30	44.87	41.87	4.98	4.75	145.00	142.00
	2	8.00	8.06	5.20	7.88	47.00	43.90	5.03	4.88	153.00	147.00
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	ns	**	*	ns	*	ns	ns	***	*
Rates		**	**	***	***	***	***	ns	ns	***	***
Rates*Treatments		Ns	ns	ns	ns	ns	ns	ns	ns	***	ns

The decrease in the soil pH may be due to the conjugate ion effect of the K-salts used. The acid radical; humate (H^-), nitrate (NO_3^-) or sulphate (SO_4^{2-}), behaves as if it was a base in the soil solution. The anions attract the cations either soluble in solution or exchangeable on soil particles. Attraction forces between the Na^+ ions and the different anions is often stronger than K^+ because the Na^+ is a hard acid due to its' smaller ionic size and greater ionic potential than K^+ . i.e. the Na^+ ion replaces the K^+ in the salt and the K^+ is liberated in the soil solution and becomes more 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 solubility product (SP) of the salt and the soil solution conditions. The Na^+ effect on the soil pH is decreased as it is captured by the conjugate base (the acid radical of the added K- salt). The OH^- resulted from the water (HOH) ionization is minimized and consequently the pH of 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 (NO_3^-) or sulphate (SO_4^{2-}) anion.



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

Among the effective amelioration methods is 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 the 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 $\text{K-H} > \text{K}_2\text{SO}_4 > \text{KNO}_3$ with the compost. The most significant decrease was observed for the K-H at the 1000 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 conjugate ion effect 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 2 indicates that the nutritional status of the studied saline calcareous soil was significantly affected by the applied treatments. Amending the soil with the compost has enriched the soil available N and K. This is often attributed to the decomposition and mineralization of compost releasing the macronutrients [32].

Additionally, the available N and K in the studied soil were significantly increased by drenching soil with the K-sources used in the same mentioned order $\text{K-H} > \text{K}_2\text{SO}_4 > \text{KNO}_3$ at all rates as individual and combined with the 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 the soil. The increase in the available P was non-significant for all treatments with and without the compost. The humic substances promote the conversion of a number of mineral elements into forms available to plants as stated previously [21].

Concerning the foliar application of the K-sources, the maximum values of the soil available K resulted by applying the K-H could be caused by the release of the fixed K by the humate [33]. The trend of the K availability increases as the applied rate increases from rate 1 to rate 2. 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 3 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 the Zn without compost. This non-significant increase reveals that the toxicity by heavy metals as one of the severe salinity effects could be controlled the K-salts applied. The exception of the Zn may be attributed to the difference in its ionic properties related to its position in the periodic table compared to the 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 the compost buffering effect. The increase in the soil available Fe, Mn and Zn with compost was greater than without compost.

Table 3 Micronutrients available in soil after harvest

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Sources	K ₂ O rates	Fe (mg/kg)		Mn (mg/kg)		Zn (mg/kg)	
		Compost		Compost		Compost	
		With	Without	With	Without	With	Without
K- Humate	0	7.04	6.80	3.05	2.95	0.72	0.66
	1	7.18	7.04	3.75	3.22	0.84	0.73
	2	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
K - Nitrate	0	6.98	6.60	2.98	2.93	0.65	0.58
	1	7.04	6.84	3.05	2.98	0.73	0.62
	2	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
K-Sulphate	0	7.02	6.78	3.02	2.90	0.68	0.62
	1	7.15	6.99	3.25	3.12	0.78	0.69
	2	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

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 rate of the treatments increased. 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. Data in Table 4 indicate that the carrot root length (cm), fresh weight (g) and yield (ton/ha) significantly increased by all studied K-sources compared with the control with and without compost at both rates except for the 2500 ppm rate of K₂SO₄ (root length). 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.

Table 4 Yield and yield component of root

Sources	K ₂ O rates	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
	1	17.55	15.88	2.32	2.18	67.53	58.20	6.89	4.88	46.55	37.76
	2	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
	1	15.84	13.00	1.96	1.85	57.80	49.60	5.66	3.97	37.48	24.76
	2	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
	1	16.30	13.95	2.08	1.96	64.75	52.76	6.77	4.13	41.67	32.79
	2	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	***	**	**

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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 the 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 is may be due to the biocompatibility and additional nutritive content of the humate anion for the plant compared to the SO_4^{2-} and NO_3^- anions and the increased NPK content in the carrot roots. The interaction between the treatments and rates was significant for the carrot root length (cm) with the compost, and both the roots fresh weight (g), and yield (ton/ha) with and without the compost.

It had been well established that the humate anions as HS enhance the nutrient availability and absorption by plant under salinity condition ns. Salinity affects the plant growth due to the increase in the concentration of salt in the root zone because water is removed from the soil profile by evapo-transpiration. The 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 influence positively the metabolic and signalling pathways involved in the plant development, by acting directly the specific physiological targets and the expression of specific genes at the molecular level [21]. The HS application improved the growth of shoots and roots fresh and dry weight of pepper plant [35].

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3.3. The NPK content of the carrot roots

It can be observed from Table 5 that the NPK content of the 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 is 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.

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Table 5 Macronutrients concentration in root of Carrot

Sources	K ₂ O rates	N (%)		P (%)		K(%)	
		Compost		Compost		Compost	
		With	Without	With	Without	With	Without
K-Humate	0	1.38	1.33	0.43	0.35	2.22	1.93
	1	1.77	1.69	0.48	0.43	2.39	2.13
	2	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
K-Nitrate	0	1.35	1.27	0.35	0.29	2.15	1.85
	1	1.60	1.49	0.39	0.32	2.20	1.95
	2	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
K-Sulphate	0	1.32	1.29	0.38	0.31	2.19	1.88
	1	1.53	1.50	0.44	0.38	2.35	2.06
	2	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

The significant increase in the N, P and K due to the K-H with the compost was by 34.06, 27.91, and 12.61%, while by the KNO₃ it was by 29.63, 34.29 and 9.59%, then by the K₂SO₄ 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 the compost as shown in Table 5.

3.4. The micronutrient concentration in the carrot roots

Table 6 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 K₂SO₄ (by 15.36%) and the KNO₃ (13.85%) with the compost. Similarly, the Mn (mg/kg) significantly increased by 14.62%, 14.97% and 4.55% due to the K-H, K₂SO₄ and the KNO₃, respectively. The K-H with and without compost showed the most significant increase in the Zn concentration (mg/kg) in the carrot roots by 24.25 and 27.07%, respectively.

Table 6 Micronutrients concentration in root of Carrot

Sources	K ₂ O rates (ml/L)	Fe (mg/kg)		Mn (mg/kg)		Zn (mg/kg)	
		Compost		Compost		Compost	
		With	Without	With	Without	With	Without
K - Humate	0	76.00	72.10	49.52	41.10	24.00	21.94
	4	85.30	78.95	53.20	47.33	26.34	23.75
	8	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
K - Nitrate	0	73.96	67.40	46.82	39.55	23.80	19.68
	4	77.40	69.88	48.29	41.49	24.29	20.66
	8	84.20	73.90	48.95	41.00	24.78	22.30
L.S.D. 5%		1.75	1.90	1.31	0.87	2.65	0.87
K - Sulphate	0	76.80	69.55	47.23	40.44	23.95	20.17
	4	84.00	75.95	50.44	43.98	25.18	22.90
	8	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

3.4. The effect of applying compost and potassium sources on the ascorbic acid and the total sugar content

Table 7 shows the ascorbic acid (mg/100 g f.w.) and the total sugar content (%) of the carrot roots in the present study. The ascorbic acid has increased by the different treatments compared to the control but the significant increase was recorded for the rate 2 of all K sources used in the study except for the KNO₃ without the compost. Application of the K sources combined with the compost enhanced the ascorbic acid content in the order K-H (by 17.43%) > KNO₃ (by 14.88%) > K₂SO₄ (14.63%).

Table 7 Ascorbic acid, total sugar content in carrot roots (mean two seasons)

Sources	K ₂ O rates	Ascorbic acid (mg/100g f.w.)		Total sugar content (%)	
		Compost		Compost	
		With	Without	With	Without
K - Humate	0	6.77	5.84	15.46	14.22
	1	7.50	6.23	16.20	14.69
	2	7.95	6.87	16.80	15.02
L.S.D. 5%		0.97	0.97	0.69	1.19
K - Nitrate	0	5.98	4.88	15.28	14.10
	1	6.30	5.23	15.58	14.32
	2	6.87	5.77	15.63	14.39
L.S.D. 5%		0.87	1.51	0.85	1.49
K - Sulphate	0	6.22	4.97	15.39	14.15
	1	6.88	5.86	15.75	14.33
	2	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

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

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

3.5. Potassium (K) use efficiency indices

The K use efficiency indices listed in Table 8 were calculated for the different K sources: K-H, KNO₃, and K₂SO₄ at the maximum application rate (1000 and 2500 ppm). The numerical values of the KUE/AKR and the AE indices for all the K sources studied with the compost fertilizer were greater than without the compost in the order: K-H > K₂SO₄ > KNO₃. A highly significant interaction between the compost and the K sources in the mentioned order was observed (Tables 2 and 4). 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 K₂SO₄ and KNO₃ treatments. Apparently, the conjugate ion effect for the humate anion was much more efficient in K utilization by the plant than the sulphate (SO₄²⁻) followed by the nitrate (NO₃²⁻).

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 KNO₃ without the compost showed the minimum AE value as indicated by Table 8.

Combination with the compost enhanced the K use and agronomic efficiency because of the biocompatibility of the organic substrates compared to the mineral nitrate (NO₃²⁻) and sulphate (SO₄²⁻) 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 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 [36,37].

However, the physiological efficiency (PE) of the K-H and KNO₃ with the compost was smaller than without compost while the PE for the K₂SO₄ with the compost was greater than without it [38]. This may be due to the complex composition of the compost that may limit the physiological role of the K in the form of humate or nitrate (NO₃²⁻). Potassium is considered as a major osmotically active cation of plant cell. Bulky moieties may be formed between some of the compost components and the humate and/or the NO₃²⁻ 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 SO₄²⁻ form. The KNO₃, at the 1000 - 2000 ppm rates stimulated the growth, increased the yield, and enhanced some biochemical constituents of the potato plant (*Solanum tuberosum* L.) [39]. Application of K₂SO₄ has increased the biomass

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production and increased the uptake of the essential nutrients like K, Ca, Mg and P in saline soils [40].

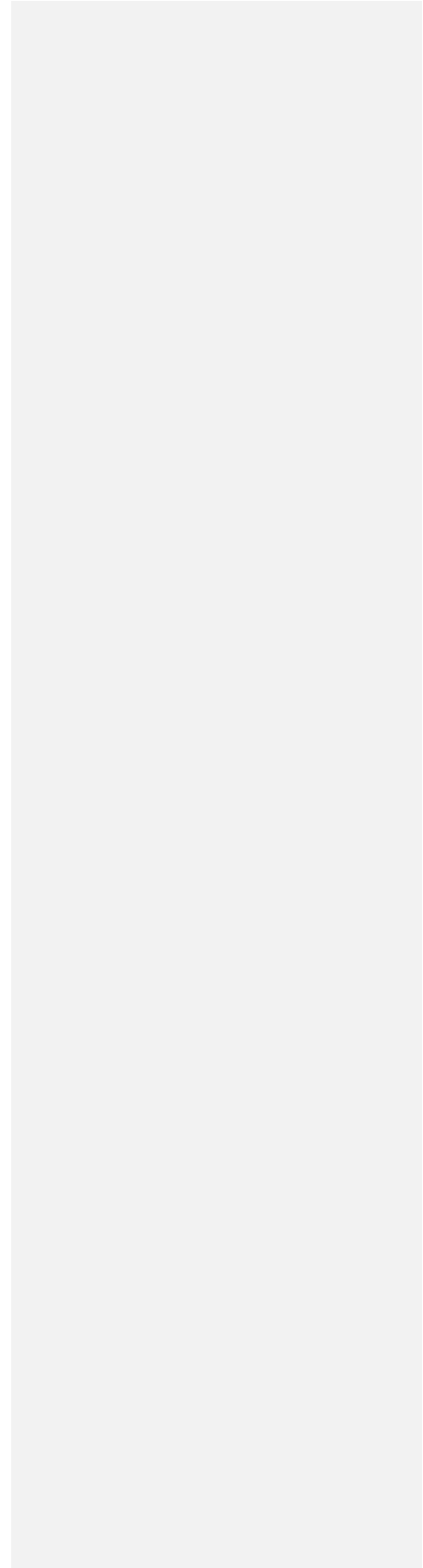


Table 8. Potassium (K) Use Efficiency Indices

K-Source	Applied K rate 2 (kg K ₂ O)/ha	Root K Content (%)		(KUE/AKR) (%)		Yield of root (ton/ha)		AE (%)		PE (%)	
		Compost				Compost					
		With	Without	With	Without	With	Without	With	Without	With	Without
K - Humate	0.50	2.22	1.93	56.54	52.50	32.81	25.93	3412.50	3394.33	60.36	64.65
		2.50	2.19			49.71	42.74				
K - Nitrate	1.22	2.15	1.85	10.66	10.66	29.76	23.52	681.68	388.83	8.18	36.46
		2.28	1.98			38.07	28.26				
K - Sulphate	1.22	2.19	1.88	18.38	18.38	30.95	25.36	1250.38	885.50	68.05	48.19
		2.40	2.09			45.24	35.48				

4. Conclusion

A field study was carried out to study the effect of different sources of the potassium (K) fertilization on some properties of a saline calcareous soil and on the yield and quality of carrot (*Daucus carota* L.). The studied K-sources decreased the soil pH in the order K-H > K₂SO₄ > KNO₃. 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, the ascorbic acid and the total sugar content of the carrot roots was non-significant for most of the treatments. The potassium (K) use efficiency indices were calculated. The physiological efficiency (PE) of the K-H and KNO₃ with the compost was smaller than without compost while the PE for the K₂SO₄ 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 form of humate or nitrate (NO₃⁻²).

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