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Effect of *Bacillus circulans* bacteria on availability of potassium from different sources on the productivity and quality of pepper under saline soil conditions

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ABSTRACT

A field experiment was carried out at the two successive seasons of 2016 and 2017 in privet farm at El-Rowad village belong to Sahl El-Hussinia, El-Sharkia Governorate, to study the impact of potassium fertilizers combined with or without *Bacillus circulans* bacteria on productivity and quality of pepper plants (*Capsicum annuum* L.) grown under saline soil conditions. A split plot design was used with six replicates for each treatment. After four weeks transplanting plants in filed experiment were divided into two divisions. In the first one the plants were treated with *Bacillus circulans* strain as potasssium solubilizing bacteria (KSB) to increase the availibily of potassium from different sources and the second part was without bio-fertilizer (*Bacillus circulans)* treatment. The potassium fertilizer sources were used as; potassium silicate, potassium sulphate and potassium humate at different rates namely 0, 2 and 4 ml/L.

The results showed that the foliar application of potassium of different sources and rates improved plants growth as indicated by plant length, number of branch, diameter and yield of fruit especially plants sprayed with potassium humate combined with or without *B. circulans*. Pepper plants quality i.e total chlorophyll, proline and vitamin C contents showed also the same positive responses as compared to the untreated plants. Also, the concentrations of N, P, K, Fe, Mn and Zn in fruit pepper were increased with increasing the rate of application of different potassium sources combined with *B. circulans* especially plants treated with potassium humate.

The soil treated with different sources and rates of potassium fertilizers individual or combined with KSB led to decrease both soil pH and salinity, meanwhile, avaliable N, P, K, Fe, Mn and Zn in soil solutions were increased.

From our result we highly recommended to use potassium humat in various rates and in combination with *Bacillus circulans* strain to improve the soil properties and hence the plant growth of pepper.

Key words: *Bacillus circulans*, Pepper productivity and quality, Potassium fertilizers and Soil salinity.

Introduction

The salt affected soils in Egypt are about 2.14 million feddan (one feddan = 4200 m^2) and the majority of these soils are located in the northern center part of Nile Delta and on its eastern and western sides. Large area 55% of the cultivated salt affected soils are located in northern Delta are salt affected 20% located in southern Delta and middle Egypt and 25% in Upper Egypt. The southern parts of Sahl El-Hussinia, El-Sharkia Governorate, have soils degraded by the problems of salinity and sodicity, FAO (1995), El-Bordiny and El-Dewiny (2008).

Potassium plays a key role in N uptake and translocation from roots to vegetative growth. The enhancement effect of potassium sulphate on alleviating the adverse effect of salinity on leaf total chlorophyll content may be attributed to the fact that potassium plays an essential role in photosynthesis and osmoregulatory, (Amro *et al*., 2014).

Potassium humate can be used as a non-expensive source for potassium and it could be used as soil dressing, drenching or foliar applications, Potassium humate application led to improving plant growth parameters, yield and quality of sweet pepper plant, El-Bassiony *et al*, 2010) and Mahmoud and Youssif 2015). On the other hand, humic acids are also important because of their ability to

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chelate micronutrients, thus increasing their bio-availability. Humic acids are an effective agents as a complement to synthetic or organic fertilizers, Hussein and Hassan (2011).

Potassium silicate ($K_2O_n.SiO_2 + H_2O$) caused very good results to improve of the growth and yield of plants under saline conditions, Salim (2014). Foliar application of potassium silicate at a rate 8 ml/L increased the N, P and K concentrations in leaf of sapota plant, (Lalithya *et al*., 2014).

As reported by Sindhu *et al*. (2010), potassium soulbilizing bacteria (KSB), when used as bio-fertilizer for agriculture, can reduce the use of application of chemical fertilizer and support ecofriendly crop production. Potassium solubilizing bacteria (KSB) dissolve potassium from insoluble K-bearing minerals such as micas, illite and orthoclase, by excreting organic acids which either directly dissolved rock K or chelated silicon ions to bring K into the solution. Sheng (2005) stated that using KSB led to improve the growth of pepper plants.

Sheng and Huang (2002) suggested that potassium release from minerals fertilizer was affected by pH, dissolved oxygen and bacterial strain used. The concentration of potassium in solution was increased by 84.8 to 127.9% by inoculation of bacteria as compared with the control. Potassium solubilizing bacterial strains resulted in a release of 35.2 mg/L potassium in 7 days at 28°C at pH range from 6.5-8.0.

Pepper (*Capsicum sp.*) represents an important crop in many countries around the world as a precious vegetable with high biological value, Wetwitayaklung and Phaechamud (2011). Sweet pepper (*Capsicum annuum L.*) is one of the most important, popular and favorite vegetable crops cultivated in Egypt for local consumption and exportation, Kamal (2013). Sweet pepper for fresh vegetable marketing as well as for processing has gained significant economic importance in Egypt in recent years. Also, pepper yield can be improved with foliar application of K–fertilizer, Nassar *et al*. (2001).

The aim of this study is to evaluate the effect of potassium sources and rates with or without bio-fertilization on pepper productivity and quality and in reducing the harmful effects of soil salinity.

Material and Methods

A field experiments was carried out in clay soil of El-Rowad village 32º 00/00 to 32º 15/00/ N latitude and 30º 50 / 00// to 31º 15 00// E longitude at Sahl El-Hussinia, El-Sharkia Governorate, during two successive seasons of summer 2016 - 2017 to study the impact of potassium fertilizer sources in different rates with or without *B. circulans* bacteria on some soil properties and pepper plants productivity and quality under saline soil conditions.

Soil samples were collected from surface layer (0- 30 cm), air dried, and sieved through 2 mm sieve. The main physical and chemical properties of studied soils, before sowing, and also some of their macro- and micronutrients concentrations were determined according to the methods described by Page *et al*. (1982) and the results are represented in Table 1**.**

Table 1: Some physical and chemical properties of the soil used before pepper planting.

Sand %	Silt %	Clay %	Texture	O.M %	$CaCO_3$ %
23.49	35.71	43.80	Clay	0.65	12.70

pH (1:2.5)	EC dSm^{-1} in soil past	Soluble Cations meq L^{-1}				Soluble Anions meq meq L^{-1}		
		Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	HCO^{-}_3	Cl^{-}	SO^{-2}_4
8.07	9.52	10.39	17.52	66.4	0.86	8.45	49.6	37.15

Available macronutrients $mgkg^{-1}$			Available micronutrients $mgkg^{-1}$		
N	P	K	Fe	Mn	Zn
38.49	3.25	172	5.40	1.65	0.58

Isolation of *Bacillus circulans* ;

Surface soil samples (0–30cm) were collected from cultivated pepper plants in summer season from Sahl El-Hussina–El-Sharkia Governorate. The soil solution were prepared by suspending 5 g of soil sample in 95 mL of sterile distilled water, then shacked and heated at 75°C for 5 min. Nutrient Agar Medium (Sigma) were used for isolation and purification of *Bacillus* sp. according to Yorukce *et al.* (2017). The soil solutions were serially diluted from 10^{-1} to 10^{-6} in sterile 0.85% NaCl solution and placed on agar plate medium. Plates were incubated at 35°C for 48 h. After incubation different colonies were isolated on yeast extract glucose agar (Maunder, 1970). Identification of the isolated bacteria were made based on morphological, cultural and biochemical according to Bergey's Manual of Systematic Bacteriology (Krieg and Holt, 1984). Potassium solubilization was quantitative assayed according to Parmar and Sindhu (2013). The amount of soluble potassium was measured in the supernatant by atomic absorption spectrometer (AA-700 AAS with flame air C_2H_2) at 766.5 nm wavelength). The colonies were subjected to characterization using VETIC kit (Bio Mèrieux, France).

The area of experiment was divided into two divisions first plots were treated with KSB and second divisions were without bio-fertilizer. KSB was snow seedling in solution of bio-fertilizer (5 litter from bio-fertilizer mixed with 100 L/fed) after 21, 40 and 65 day from seedling planting at a rate by 20 L bio-fertilizer extract mixed with 400 L water/fed. Bio-fertilizer of *Bacillus circulans* strain was availability of potassium.

The used three potassium fertilizers (potassium sulphat, potassium silicate and potassium humate) were ranged randomly as main plot, where the rates of potassium fertilizers (0, 2 and 4 ml/L) were distributed randomly as sub-plot treatments. The area of each experimental unit plot was 5 x 10 m. All farming processes were carried out before planting. Super phosphate (15.5% P_2O_5) was applied at rate 200 kg /fed during tillage soil. Urea (46% N) was applied as 100 kg N on four equal doses after 21, 35, 65 and 85 days from planting.

Sweet pepper seeds *Cv. California wonder* were sown in top star in foam trays filled with mixed peat moss, sand and clay soil (2:1:1) media in the greenhouse at the private farm in Sahl El-Hussinia Sharkia governorate. After 4 weeks the pepper seedling were transplanted to open field in the first week of May in both seasons 2016 and 2017. Sowing seedlings were planted on one side of ridge (75 cm width, 10 m long) and the distance between seedling was about 30 cm. The experiment was carried out in a split plot design with six replicates.

Sweet pepper fruits from each experimental plot at the marketable green ripe stage were taken from the 3rd harvest for determination of fruits quality characteristics, i.e. (plant length (cm), diameter (cm), branch number per plant, fruit length (cm), fruit diameter (cm) and total yield (ton/fed) and were recorded for all fruits. Photosynthetic total chlorophyll were estimated in fresh leaves as described by Witham *et al.* (1971). Vitamin C was determined as mg/100 g fresh weight according to A.O.A. (1990). Proline content was determined by Bates *et al*. (1973).

Plant tissues (fruits) were analyzed for N, P, K, Fe, Mn and Zn concentration. Samples of ten fruit of plants were cut into small parts and dried at 70°C till constant weight, digested using a mixture of concentrated sulfuric (H_2SO_4) and perochloric (HClO) acids (3:1) as described by Chapman and Paratt (1961). Nitrogen was determined by the micro-Kheldahl method. Posphorous was determined Spectro-photmetrcally by using ammonium molybdate /stannus choloride method according to Cottenie *et al*. (1982). Potassium was determined by flam photometer according to Page *et al*. (1982). Fe, Mn and Zn were determined by using Atomic Absorption (model GBC 932).

All date were subjected to statistical analysis according to Snedecor and Cochran (1990). The least significant differences (LSD at 0.05) were used to compare the treatment means.

Results and Discussion

Effect of K-fertilizer sources and KSB on pepper growth parameters:

Data presented in Table (2) show that the plant length, fruit length, total yield (ton/fed) were significantly increased as affected by different potassium fertilizers with or without *B. circulans*, while the number of branch/plant and fruit diameter were not significant influenced by plants untreated with *B. circulans*. Also, the length of plant, number of branch and yield (ton/fed) were significant increased with increasing rate of different potassium fertilization sources combined with or without *B. circulans*, while the fruit length was not significant increased for plant treated with *B. circulans*. As well as, the fruit diameter was not significant affected for plant treated with or without bio-fertilizer combined with different rates of potassium sources. Concerning the interaction between different potassium sources and rates, the branch number and fruit length (cm) for plants treated with or without bio-fertilizer were not significantly affected, while the plant length and fruit yield (ton/plant) were significant increased with increasing potassium sources and rates without bio-fertilizer. All vegetated growth characters was increased with increasing potassium fertilization rates from 2 to 4 ml/L. The highest mean values of plant length 69.66 cm, number of branch 8.39, fruit length 9.22 (cm), fruit diameter 6.81 (cm), total yield 9.38 ton/fed were found for plants treated with potassium humate fertilizer combined with bio-fertilizer as compared with other treatments. These results are in agreement with Salim *et al*. (2014) who indicated that the increase in vegetative growth of potato plants which sprayed with potassium sources may be due to the role of potassium on plant growth, i.e. promotion of enzymes activity and enhancing the translocation of assimilates and protein synthesis. The corresponding relative increase of mean values of plant length (cm), number of branch/plant, fruit length (cm), fruit diameter (cm) and yield fruit (ton/fed) were 7.73; 4.11; 3.33; 0.68 and 1.81% , respectively for plants as affected by potassium silicate mean rate 2 and 4 ml/L combined with bio-fertilizer, while the relative increases of plant length (cm), number of branch /plant, fruit length (cm), fruit diameter (cm) and fruit yield (ton/fed) were 0.06, 2.02, 2.48, 0.39 and 1.64%, respectively as affected by potassium silicate without bio-fertilizer compared with mean without potassium sources.

Table 2: Morphologicall observation of pepper as affected by different K-fertilizer sources and KSB.

Potassium Fertilizers		Plant length cm		Branch number/plant		Fruit length cm		Fruit diameter cm		Total yield ton/fed	
Sources	Rates ml/L	A*	B	A	B	A	B	A	B	A	B
K-silicate	0	55.25	45.98	5.80	4.90	7.55	5.88	4.95	4.50	7.12	6.55
	2	61.44	47.88	6.55	5.12	7.96	6.45	5.25	4.88	7.89	6.75
	4	63.67	48.12	7.22	5.88	8.40	7.20	5.90	5.36	8.65	7.10
Mean		60.12	47.33	6.52	5.30	7.97	6.51	5.37	4.91	7.89	6.80
K-sulphate	0	58.97	48.44	6.70	5.44	7.80	6.90	5.49	4.81	8.45	6.80
	2	63.29	52.51	7.43	6.39	8.66	7.66	6.09	4.98	8.80	7.30
	4	70.73	55.23	8.10	6.90	9.25	7.98	6.79	5.90	9.21	7.94
Mean		64.33	52.06	7.41	6.24	8.57	7.51	7.51	5.23	8.82	7.35
K-humate	0	59.98	49.50	7.34	6.50	8.40	7.20	6.40	5.99	8.80	7.09
	2	73.67	61.00	8.65	6.90	9.27	7.89	6.89	6.35	9.45	8.59
	4	75.33	66.67	9.19	7.33	10.00	8.30	7.15	6.68	9.92	8.90
Mean		69.66	59.06	8.39	6.91	9.22	7.80	6.81	6.34	9.39	8.19
LSD 5% K.source		3.11	1.64	0.31	ns	0.41	0.19	0.99	ns	0.52	0.022
LSD 5 % K. rate		3.79	5.44	0.39	0.83	ns	0.25	ns	ns	0.98	0.028
Interaction		ns	**	ns	ns	ns	ns	**	ns	ns	**

** **A** and **B** pepper plant treated with and without B. circulan respectively.*

These results are in agreement with those reported by Lalithya *et al*. (2014). They stated that the foliar application of potassium silicate at rate 8 ml/L increased photosynthetic activity, and translocation of metabolites that led to increase size of fruit. In addition, the relative increase of mean values were 15.4% for plant length 17.4% for number of branch; 13.1% for fruit length 14.7% fruit diameter and 10.9% for yield fruit as affected by foliar application of potassium sulphate at mean rate 2 and 4 ml/L combined with bio-fertilizer. While, the relative increases of mean values were 12.3% for plant length 18.4% for number of branch; 17.4% for fruit length; 6.7% for fruit length and 11.8% for fruit yield respectively, as affected by potassium sulphate at mean rate 2 and 4 ml/L without bio-fertilizer compared with mean values of without potassium sources. Also, the relative increases of mean values potassium humate at rates 2 and 4 ml/L combined with bio-fertilizer were 28.3% for plant length; 34.9% for number of branch/plant; 21.7% for fruit length; 25.1 % for fruit diameter and 19.2% for fruit yield respectively, while the relative percent increases of mean values foliar application of potassium humat at rate 2 and 4 ml/L without bio-fertilizer were 33.10; 26.8; 21.6 ; 27.8 and 28.4 for the same investigated parameters respectively, than without mean potassium sources. These results are in agreement by El-Bassiony *et al*. (2010) who stated that the foliar application of potassium humate at rate 4 ml/L led to increase in all vegetative growth parameters. Finely, these results may be due to the potassium sources i.e (potassium silicate, potassium humat and potassium sulphate) that play an important role in metabolism, promotion plant growth, physiological and biochemical processes and cell division. Growth of plants enhancement as treated by *Bacillus circulars* may be also associated to its ability to produce hormone, especially IAA (Sheng and Huang, 2002)

Macro and micronutrients concentration in fruit pepper plants:

Data presented in Table (3) show that the foliar application of different potassium sources and rates gave an increase in N, P and K concentrations in fruit pepper compared with zero potassium sources fertilization. Foliar application of potassium humate combined with or without bio-fertilizer led to increase of N, P and K concentrations in fruit pepper than other treatments. Fouda *et al.* (2014) reported that the application of medium and high rates of potassium humate combined with or without bio-fertilizer increased N, P and K uptake in root of tuber than potassium sulphate and potassium silicate. Also, of foliar application of different potassium sources on N and P concentrations in fruit pepper plants were significantly increased with increasing rates alone or combined with bio-fertilizer, while the K concentration in fruit pepper was significantly increased for plant treated with different potassium sources combined with or without bio-fertilizer but the different rates of potassium sources had not significant effect on K concentration in fruit pepper. The interaction between different potassium sources and rates combined with bio-fertilizer significantly increased the N and P concentrations in fruit pepper. While the increase of K concentration in fruit was significant for plant treated with different potassium sources alone. Generally, the high rate of potassium humat and potassium sulphate recorded the highest increase of N, P and K concentrations in fruit pepper than potassium silicate.

Table 3: Macronutrients concentration in fruit pepper plant.

Potassium Fertilizers		N (%)		P (%)		K (%)	
Sources	Rates ml/L	A*	B	A	B	A	B
K-silicate	0	1.97	1.85	0.39	0.30	2.36	2.31
	2	2.55	2.14	0.45	0.37	2.47	2.34
	4	2.66	2.26	0.48	0.42	2.53	2.38
Mean		2.39	2.08	0.44	0.36	2.45	2.34
K-sulphate	0	2.02	1.94	0.41	0.37	2.40	2.36
	2	2.50	2.22	0.49	0.40	2.48	2.42
	4	2.77	2.29	0.53	0.45	2.55	2.44
Mean		2.43	2.15	0.48	0.41	2.48	2.41
K-humate	0	2.05	1.96	0.42	0.33	2.41	2.34
	2	2.66	2.24	0.55	0.42	2.49	2.45
	4	2.82	2.38	0.59	0.48	2.59	2.48
Mean		2.51	2.19	0.52	0.41	2.50	2.42
LSD 5% K.source		0.033	0.012	0.016	0.026	0.024	0.016
LSD 5 % K. rate		0.023	0.027	0.017	0.037	ns	0.017
Interaction		**	**	**	ns	ns	*

****A*** *and* ***B*** *pepper plant treated with and without B. circulan respectively.*

Ali and Ali (2013) reported that the foliar spray of potassium humat on sweet pepper plants significantly increased N, P and K contents and uptake in fruits. Marchand and Bourrie (1999) indicated that the foliar application of potassium sulphate increased N, P and K concentrations in leaves of green pepper plants. Abou-Baker *et al*. (2011) revealed percent increases of N, P and K concentration in plants as affected by foliar application of potassium silicate under saline stress. Han and Supanjani (2006) indicated that soil inoculation with K- solubilizing bacteria significantly increased N, P and K uptake in pepper.

Micronutrients concentration in fruit pepper plant:

Data presented in Table (4) show that the foliar application of potassium sources and rates alone or combined with bio-fertilizer caused markedly increases in the concentrations of Fe, Mn and Zn in fruit pepper plants with more pronounced increases with increasing rate of potassium sources. The foliar spray of potassium sources combined with or without bio-fertilizer caused significant increases of Fe, Mn and Zn concentrations in fruit pepper plants. The different rates of potassium sources alone or with biofertilizer as foliar application gave significant increase with increasing rates of Mn, while Fe concentration in pepper plants treated with different rates of potassium sources was not significant, as well as, the Zn concentrations in fruit pepper plants was significant increases with increasing of potassium rates combined with bio-fertilizers.

Table 4: Micronutrients concentration in fruit pepper plant.

Potassium Fertilizers		Fe (mg kg^{-1})		Mn (mg kg^{-1})		Zn (mg kg^{-1})	
Sources	Rates ml/L	A*	B	A	B	A	B
K-silicate	0	88.52	77.56	28.00	22.47	57.61	49.86
	2	93.14	83.14	29.14	23.95	62.38	52.84
	4	96.74	83.85	29.85	24.16	65.85	55.18
Mean		92.80	81.52	29.00	23.53	61.95	52.63
K-sulphate	0	89.47	77.59	30.14	23.14	58.69	50.22
	2	95.00	85.63	32.48	25.75	63.87	55.95
	4	98.00	92.00	36.85	27.10	67.10	59.88
Mean		94.16	85.07	33.16	25.33	63.22	55.35
K-humate	0	90.00	79.75	30.52	25.66	59.45	51.30
	2	97.00	88.76	34.86	27.40	64.55	59.26
	4	99.00	94.00	39.75	29.69	69.21	63.14
Mean		95.33	87.50	35.04	27.58	64.40	57.90
LSD 5% K.source		3.301	1.84	1.41	1.50	1.08	2.29
LSD 5 % K. rate		ns	3.14	1.99	0.79	1.57	ns
Interaction		ns	*	**	ns	ns	ns

****A* and *B* pepper plant treated with and without B. circulan respectively.*

These results are in agreement with Khordhidi *et al*. (2009) who revealed that the foliar application of potassium humate led to increased of Mn , Zn and Fe and product quality and plant tolerance to salinity. Fouda *et al*. (2014) found that application of potassium combined with biofertilizer increased Fe, Mn and Zn uptake compared with K fertilizers application alone in tuber of potato plants under saline soil. Zakaria and El-Zemrany (2012) reported that application of K fertilizer combined without bio-fertilizer increased Fe, Mn and Zn uptake in wheat.

Quality of pepper plants:

The results in Table (5) show that potassium sources alone or combined with bio-fertilizer had significant effect on Vitamin C and total chlorophyll (µg/g f.w), while the prolien content in pepper plants not effected K- sources fertilization alone. Also, the effect of different rates of potassium sources on Vitamin C was significant increases with increasing rate of potassium sources combined with or without biofertilizer.

Table 5: Effect of –K- sources, rates and KSB on Chlorophyll, Vitamin C and praline content in pepper plant.

Potassium Fertilizers		Vitamin C VC		Total Chlorophyll µg/g f.w.		Proline mg/g f.w.	
Sources	Rates ml/L	A*	B	A	B	A	B
K-silicate	0	75.66	63.85	49.85	35.89	4.85	6.18
	2	79.42	66.89	52.74	39.44	3.29	5.33
	4	83.41	69.24	55.62	42.61	2.94	4.01
Mean		79.50	66.66	52.74	39.31	3.69	5.17
K-sulphate	0	77.90	65.90	49.90	38.52	4.46	5.34
	2	82.10	69.85	56.88	40.22	2.88	4.75
	4	85.66	72.41	59.27	43.90	2.30	3.89
Mean		81.89	69.39	55.53	40.88	3.21	4.66
K-humate	0	79.52	68.55	51.43	40.29	4.29	5.88
	2	85.74	73.14	59.47	42.17	2.64	4.17
	4	90.24	78.52	62.17	44.31	1.98	3.27
Mean		85.17	73.40	57.69	42.26	2.97	4.44
LSD 5% K.source		1.23	1.23	1.28	1.64	2.89	1.10
LSD 5 % K. rate		1.90	1.90	1.16	1.51	ns	ns
Interaction		ns	ns	ns	ns	ns	ns

**A and B pepper plant treated with and without B. circulan respectively.*

The interaction between potassium sources rates combined with or without bio-fertilizer were not significant for Vitamin C, total chlorophyll and proline concentrations in pepper. The highest mean values of vitamin C and total chlorophyll concentrations were found in pepper plants treated with humate potassium combined with bio-fertilizer. These results are in agreement with El-Bassiony *et al*. (2010) reported that the increase of potassium fertilization rates increased vitamin C and total chlorophyll content in pepper plants. Supanjani (2006) indicated that the decreases in chlorophyll content under stress conditions could be one of the major factors leading to leaf senescence, which is correlated with increased membrane permeability and with accumulated aminolevulinic acid (ALA), an initial precursor of chlorophyll, at high salt concentrations.

The proline content in pepper plants decreased with increasing rates of potassium fertilization alone or combined with bio-fertilizer. Proline is important components of the adaptation of plants under saline soil. Proline accumulation in salt tolerant pepper was significantly increased than that in salt sensitive one, Kaouther *et al*. (2012). Potassium plays an essential role in activating plant enzymes, enhances photosynthesis, reduces respiration, maintains cell turgor, helps in transport of sugars and starches, facilitates in nitrogen uptake, and is also important for protein synthesis. Proline protect plants against osmotic stresses, not only by adjusting osmotic pressure, but also by stabilizing many functional units such as complex electron transport, membranes and proteins and enzymes, Ashraf and Foolad (2007).

Effect of potassium sources and rates on some soil properties:

Soil pH:

Data presented in Table (6) show that the soil treated with potassium sources at different rate characterized by slightly to moderately alkaline conditions, where the pH value was around 7.89 to 8.05 . However, there was no clear effect for the used potassium sources on the soil pH . The pH tends to slightly decreased for soil treated with high rates of potassium humat alone or combined with bio-fertilizer than other treatments. These results indicate that the potassium sources make promoting and decreased soil pH due to high supplies of Ca^{++}, K^{+} and production of organic acid. These results are in agreement with Sajid and Asghari (2016) who found that decreased soil pH result from production of organic acids due to soil microorganisms activity. Khaled *et al*. (2014) reported that the positive effect of potassium humate on reducing soil pH values with or without bio-fertilizer may be referred to the produced organic acid and activity of microorganisms may accelerate the decomposition process. Zakaria (2012) suggested that the soil pH decreased with increasing the rate of potassium fertilization combined with bio-fertilizer.

Soil salinity:

Data presented in Table (6) show that the potassium fertilization alone or combined with biofertilizer decreased soil salinity. the different rates of potassium sources alone or combined with bio-fertilizer on soil salinity was not significant. Soil salinity decreased with increasing rate of humate potassium combined with bio-fertilizer compared with other treatments.

Table 6: Soil pH, EC and available macronutrients in soil after harvest.

Potassium Fertilizers		pH (1:2.5)		EC dSm^{-1}		N $mgkg^{-1}$		P $mgkg^{-1}$		K $mgkg^{-1}$	
Sources	Rates ml/L	A*	B	A	B	A	B	A	B	A	B
K-silicate	0	8.03	8.05	6.18	7.95	45.19	41.80	3.89	3.50	183.0	176.0
	2	8.01	8.03	5.23	7.46	46.23	43.16	4.29	3.89	189.0	183.0
	4	7.98	8.01	4.85	6.75	47.96	44.00	4.78	3.98	194.0	188.0
Mean				5.42	7.39	46.46	42.99	4.32	3.79	188.7	182.3
K-sulphate	0	8.01	8.03	6.05	7.19	45.33	42.09	3.93	3.52	188.0	178.0
	2	7.97	8.01	5.19	6.88	47.19	43.98	4.44	3.88	197.0	190.0
	4	7.89	8.00	4.10	5.10	48.00	44.87	4.69	4.35	208.0	195.0
Mean				5.11	6.39	46.84	43.65	4.35	3.92	197.7	187.6
K-humate	0	8.02	8.04	5.98	6.71	45.52	42.19	3.95	3.55	185.0	179.0
	2	7.98	8.02	4.10	5.66	48.52	44.98	4.59	3.94	203.0	193.0
	4	7.92	8.00	3.55	5.23	49.63	45.27	4.83	4.19	213.0	198.0
Mean		---	--	4.54	5.87	47.89	44.15	4.46	3.89	200.3	190.0
LSD 5% K.source		---	---	0.96	0.34	1.45	1.41	ns	0.48	2.21	1.04
LSD 5 % K. rate		---	---	ns	ns	ns	ns	ns	ns	1.37	2.32
Interaction		---	---	ns	**	ns	ns	ns	ns	**	**

****A** and **B** pepper plant treated with and without B. circulan respectively.*

The relative decreased of mean values of soil EC as affected by potassium silicate at rates 2 and 4 ml/L with bio-fertilizer and without bio-fertilizer were 16.97 and 2.45% respectively compared with no potassium silicate. Also, the corresponding relative decreases were 23.48 and 17.76% for soil treated with potassium sulphate with and without biofertilizer compared with untreated soil. As well as, the relative decreased of mean values soil salinity as affected by potassium humat at mean rate 2 and 4 ml/L were 36.99% combined with bio-fertilizer and 25.24 % without bio-fertilizer compared with mean value without potassium sources. These results are in agreement with Khaled *et al*. (2014) who found that the reduction in soil EC could be attributed to the application of potassium humate that reflect on improving soil aggregation, water movement and leaching the excessive soluble salts. The reduction of salinity means reduction the monovalent Na^{+} and this is particularly evident when the replace of the monovalent K+ to the humate (salt) of the humic complex occurred. Thus, by electrostatic repulsion of the high concentration of K^{+} the Na^{+} will be replaced on the humic complex and the previous equation becomes:

2 K^{+} + Na (humus) ----------> (humus) K + Na^{+}.

The effective removal of Na^+ by leaching depends on the amendment-soil contact, soil permeability and the availability of drainage practices(Ouni *et al*., 2014).

It is worthy to mention that the superiority of humat potassium is related to the occurrence of active organic acids that released from the suspended humate. These organic acids provided a substantial modification of soil physical properties especially soil structure as well as soil aggregation and drainable pores movement of leaching water that enhance progressive removal for Na^+ salts.

Availability of macronutrients in soil after harvest:

Data presented in Table (6) show the values of available macronutrients such as N, P and K (mg/Kg) in the studied soil were not positively influenced by different potassium sources alone or combined with KSB for different rates. Soil treated with K-humate alone or combined with bio-fertilizer had higher values of available N, P and K than other treatments. The foliar application of different potassium sources alone or combined with bio-fertilizer led to significant increases for N and K available in soil, while the P was not significant in soil treated with potassium sources combined with bio-fertilizer. The different rate of potassium sources gave significant increase with increasing rate for K available in soil, while the N and P were not significant. The Interaction between different sources of potassium and rates were not significantly for N and P available in soil, while K available in soil was significant increase for soil treated with different potassium sources single or combined with biofertilizer and rates. The increase of N, P and K availability caused with treatments combined with bio-fertilizer was ascribed to its released from the added bio-fertilizer. Bio-fertilizer (KSB) used beneficial microorganisms that can be applied to soil function to mobilize the availability of N, P and K by their biological activity in particular and help build up micro-flora, Khaled *et al.* (2014). The foliar application of K-humat or -sulphate gave greater available N, P and K than K-sulphate. Fouda *et al.* (2014) indicated that the application of different potassium sources combined with biofertilizer increased soil N, P and K concentrations compared individual biofertilizer.(Linjun 2013) stated that applied K-silicate to soil led to increase of available nitrogen, phosphorus and potassium with increasing its rate. Anukriti *et al.* (2016) suggested that the potassium solubilizing bacterial strains resulted in release of 35 mg/L potassium after 7 days at 28ºC at pH ranged from 6.50 to 8.00.

Available micronutrients in soil after harvest:

Data presented in Table (7) show that, Fe, Mn and Zn increased in soils with increasing the different potassium sources and rates. Foliar application of different potassium sources either individually or combined with biofertilization at different rate not affected Fe, while the Zn was significantly increased. The Mn availability in soil was significantly affected with used different potassium sources. The effect of different rates of potassium sources alone or combined with biofertilizer on Mn available concentration in soil was significantly increased with increasing rate, while the Zn was significantly increased with soil treated with different rates of combined with bio-fertilizer.

Also, the interaction between different source of potassium and different rate alone or with bio-fertilizer on Fe and Zn were not significant, while the Mn was significant in soil treated with different potassium sources and rate single. The highest mean values of Fe, Mn and Zn available concentrations in soil treated with K-humat alone or without bio-fertilizer compared with other treatments. Shaban *et al*. (2012) reported that the availability of Fe, Mn and Zn concentrations in soil increased with increasing rates of potassium fertilizer under saline soil conditions. Zakria and El-Zemrany (2012) indicated that the application of K- sources combined with bio-fertilizer gave increase of available Fe, Mn and Zn. In general, the positive effects of the used potassium sources on available Fe, Mn and Zn could be arranged in the following descending order: potassium humate > potassium sulphate > potassium silicate > without potassium.

Table 7: Available micronutrients in in the studied soil after harvest.

Potassium Fertilizers		Fe $mgkg^{-1}$		Mn $mgkg^{-1}$		Zn $mgkg^{-1}$	
Sources	K_2O rates ml/L	A*	B	A	B	A	B
K-silicate	0	6.14	5.60	1.96	1.68	0.68	0.60
	2	6.58	5.88	2.02	1.73	0.73	0.66
	4	6.79	5.92	2.09	1.78	0.79	0.69
Mean		6.50	5.80	2.02	1.73	0.73	0.65
K-sulphate	0	6.18	5.60	1.97	1.74	0.70	0.62
	2	6.95	5.94	2.05	1.82	0.76	0.69
	4	7.04	6.07	2.13	1.89	0.83	0.73
Mean		6.72	5.87	2.05	1.82	0.76	0.68
K-humate	0	6.29	5.63	1.98	1.72	0.73	0.63
	2	7.02	6.33	2.07	1.85	0.79	0.71
	4	7.16	6.40	2.15	1.93	0.86	0.76
Mean		6.82	6.12	2.07	1.83	0.79	0.70
LSD 5% K.source		ns	ns	ns	0.020	0.030	0.034
LSD 5 % K. rate		ns	ns	0.028	0.039	0.023	ns
Interaction		ns	ns	ns	**	ns	ns

**A and B pepper plant treated with and without B. circulan respectively.*

Biological parameters:

Twenty bacterial species were were isolated from 10 soil samples and identified. The results were (13) rod shaped *Bacillus* sp., +ve G, (3) short rod shaped *Pseudomonas* sp. -ve G, (2) cocci shaped *Azotobacter sp*. –ve G , (1) rod shaped *Brevibacterium sp*. +ve G, (1) rod shape *Paenibacillus* sp. +ve G and (1) cocci shaped *Aerococcus* sp. cocci -ve G . Some biochemical tests were applied to *Bacillus* spp and results are given in Table (8). *Bacillus* bacteria were classified in five species including *B. cereus* (3.5%) , *B. cerculans* (76.5%) , *B. subtilis* (9.5%), *B. thuringiensis* (4.5%) and *B. pumilus* (6.0%). *Bacillus circulans* was isolated from Egyptian soils on yeast extract glucose agar medium. The identified *B.circulans* (76.5%) based on morphological, biochemical tests and confirmed by VETIC Kit.

Table 8: Biochemical characteristics of bacteria isolated from different soil sample

Biochemical Characteristics	*B. negaterium*	*B. thuringiensis*	*B. mycoides*	*B. circulans*	*B. cereus*	*B. subtilis*
Catalase	+	+	+	+	+	+
Glucose	+	+	+	+	+	+
Lactose	-	-	V	+	-	-
Sucrose	-	V	V	+	V	+
Starch hydrolysis	+	+	+	+	+	V
Nitrate reduction	+	+	+	V	+	+
Citrate utilization	+	+	V	_	_	-
Voges- Proskauer	+	+	+	_	+	+
K. soluble	5	4	4	20	5	-

V + variable   + = positive result   - = negative result

Data presented in Table (9) showed that the different potassium sources and rates combined with or without *B. circulans* to increased dehydrogenises (TPF/g soil) activity and bacterial count (10^7 cfu /g soil) in both 50 and 90 days. The highest values of dehydrogenises activities and bacterial counts were found in soil treated with potassium humate followed by potassium silicate than potassium sulphate combined with biofertilizer Dehydrogenises activity led to production of H_2 in the rhizosphere of pepper plants and increasing the hydrogen in root zone decreased soil pH. Shaban and Omar (2006) reported that the high activity of dehydrogenase enzyme and the released carbon dioxide in the rhizosphere cause the formation of carbonic acids and the decrease of the pH increased plant growth. Shaban *et al.* (2012) indicated that the enhanced activity of dehydrogenase enzyme and the released carbon dioxide in the rhizosphere cause the formation of carbonic acids and decrease pH at the root zone.

Table 9: Effect of different potassium sources on enzymatic activity in the rhizosphere soil.

Potassium Fertilizers		Dehydrogenises TPF/gm soil				Catalase enzyme (µ mol min^{-1} /mg)				Bacteria Cfu x10 ^{7} /g soil			
Sources	rates (ml/L)	A*		B		A		B		A		B	
		50 day	90 day	50 day	90 day	50 day	90 day	50 day	90 day	50 day	90 day	50 day	90 day
K-silicate	0	13.60	6.50	49.74	29.71	199.9	242.1	166.1	182.1	28.00	16.33	95.00	34.00
	2	24.12	17.00	66.16	48.18	190.1	233.9	152.2	174.0	44.00	22.22	113.0	54.00
	4	30.17	19.00	78.16	53.12	181.2	225.2	136.2	166.9	48.00	32.11	121.0	67.00
Mean		22.63	14.17	64.69	43.67	190.4	233.7	151.5	174.3	40.00	23.55	109. 7	51.67
K-sulphate	0	12.90	9. 40	45.43	30.43	225.6	265.3	198.4	220.0	18.00	12.00	55.00	23.00
	2	21.11	15.20	67.29	43.29	217.2	241.1	182.4	200.0	39.00	27.00	62.00	41.00
	4	23.16	18.33	88.14	45.14	201.2	222.8	163.6	178.1	54.00	36.00	98.00	72.00
Mean		19.06	16.77	66.95	39.62	214.7	243.1	181.5	199.4	37.00	25.00	71.67	45.33
K- humate	0	25.80	20.43	89.22	59.89	178.9	211.1	148.1	178.9	38.00	19.00	100.0	49.00
	2	32.16	28.11	93.11	63.60	165.2	199.2	135.7	165.2	60.00	23.00	119.0	68.00
	4	39.11	31.42	100.1	76.10	154.0	185.9	124.3	154.0	71.00	41.00	138.0	89.00
Mean		32.36	26.65	91.17	66.53	166.0	198.7	136.0	166.0	56.33	27.67	119.0	68.67

****A* and *B* pepper plant treated with and without B. circulan respectively.*

Also, Data in Table (9) show that catalase activity in root zoon of pepper plants increased for soil treated without bio-fertilizer and decreased potassium sources rate. Catalase activity increased with growth period.

Conclusion

From results of presented in studied suggested that the foliar application of different sources of potassium in various rates individual or combined with KSB were improvement of saline soil. Also, improve pepper growth yield and quality as affected potassium humate combined with bio-fertilizer. On the other hand, the foliar application of all treatments led to increase of macro- and micronutrients content in fruit pepper plants and increased availability of macronutrients in soil especially soil treated with K-humate alone or combined with KSB compared with other treatments under soil salinity conditions. Increasing the number of this bacteria in root zone decreased soil pH and salinity. From previous results we can recommended to use co-inoculation of PGPR with different beneficial properties should be the future trends of bio-fertilizer application and reduced from mineral fertilizers for sustainable crop production.

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