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BENEFICIAL EFFECT OF POTASSIUM FERTILIZATION AND YEAST STRAINS ON MAIZE PLANTS GROWN ON SALT AFFECTED SOIL.

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ABSTRACT

The use of yeast as a bio-fertilizer in agriculture has taken a considerable attention because of their bioactivity and safety for human and the environment. The current study aimed to evaluate the effect of potassium fertilization and two yeast strains on maize productivity grown on salt affected soil in Dakahlia Governorate to find out their beneficial effect as biofertilizer. Two years field experiment were conducted to investigate the effect of potassium application levels (0, 30. 40 and 50 kg K/fed.) combined with or without *Saccharomyces cerevisiae* or *Rhodotorula mucilaginosa* on the maize yields, potassium use efficiency, NPK uptake and soil fertility after harvest. In addition, total microbial and yeast counts as well as dehydrogenase activity after 50 and 80 days from planting were studied. The results showed that application of potassium with yeast significantly increased maize grain and stalks yield, 1000-grain weight and weight of ear/plant. The application of potassium enhanced K % in maize stalk and grain and decreased Na %, as well as markedly raised the maize salt tolerance via increasing the K/Na ratio, especially with the highest rate of potassium fertilization. Potassium use efficiency and potassium uptake were markedly increased with the application of potassium combined with yeast. The highest K- utilization rate 84.93 % was recorded with the treatment consists of 30 kg K/fed + *Rhodotorula mucilaginosa.* Potassium fertilization positively affects the nitrogen and phosphorus uptake in both studied seasons. Soil salinity and fertility were slightly increased with the application of potassium fertilizers. The highest values of total microbial and yeast counts as well as the dehydrogenase activity were observed with the low levels of K fertilizer associated with *Rhodotorula mucilaginosa.* So it could be recommended to apply the low levels of potassium together with the yeast strains as a biofertilizer to overcome the salt stress of maize plants.
Keywords: Salt affected soil, K fertilization, *Saccharomyces, Rhodotorula,* maize.

INTRODUCTION

Soil salinity is a major factor limiting plant development, reducing crop yield and considered one of the major obstacles to increase crop productivity. Some of the most severe problems in soil salinity occur in arid and semiarid regions of the world, (El-Dardiry, 2007). Approximately, 7% of the world's land area, 20% of the world's cultivated land, and nearly half of the irrigated lands are affected with high salt contents (Zhu, 2001). In view of another projection, 2.1% of the global dry land agriculture is affected by salinity (FAO, 2003). Salinity in the Nile-Delta progressively increased from less than 4 dSm^{-1} in the southern part to about 16 dSm^{-1} in the northern coastal area in soil paste extract, which is suffering from intrusion of sea water, water shortage and poor water quality in the ends of irrigation canals.

Soil salinity is adversely affecting physiological and metabolic processes, finally diminishing growth and yield (Ashraf and Harris, 2004). Excessive salts injure plants by disturbing the uptake of water into roots and interfering with the uptake of competitive nutrients. The inhibitory effect of salinity on plant growth and yield has been ascribed to osmotic effect on water availability, ion toxicity, nutritional imbalance, and reduction in enzymatic, photosynthetic efficiency and other physiological disorders (David, 2007).

The increasing in the problems associated with salinity in irrigated areas frequently result in the consecutive occurrence of drought and salinity on cultivated land. Currently, 50% of all irrigation schemes are affected by salinity. Nutrient disturbances under salinity reduce plant growth by affecting the availability, transport, and partitioning of nutrients. However, salinity can differentially affect the mineral nutrition of plants. Salinity may cause nutrient deficiencies or imbalances, due to the competition of Na^+ and Cl^- with nutrients such as K^+, Ca^{2+}, and NO_3^-. Despite contradictory reports on the effects of nutrient supply on plant growth under saline conditions, it is generally accepted that an increased nutrient supply will not improve plant growth when the nutrient is already present in sufficient amounts in the soil and when the salt stress is severe. A better understanding of the role of mineral nutrients in plant resistance to salinity will contribute to an improved fertilizer management in arid and semi-arid areas.

Plants have developed a wide range of adaptive/resistance mechanisms to maintain productivity and ensure plant survival under salt stress. Increasing evidence suggests that mineral nutrient status of plants plays a crucial role in increasing plant resistance to environmental stresses including salinity. Among various mineral nutrients is K which has been known for their particular role in enhancing salt tolerance of various crops, (Mengle and Kirkby, 1987 and Liang et al., 2007). Numerous studies have shown that K mitigates the adverse effects of salinity on plant growth. Marschner (1995) and Sanjakara *et al*. (2001) showed that application of K reduces the adverse effects of salinity through its role in stomatal regulation, osmo regulation, energy status, charge balance, protein synthesis and homeostasis. Also, addition of K to saline soils cultivated with rice plants avoids Na toxicity by maintaining a high level of K uptake against Na, (Zayed, 2002 and El-Kohly *et al*., 2003). Cox (2001) showed that potassium consumption distinguished that corn roots developed well and it was powerful enough to absorb water from soil. Therefore, potassium increased resistance capacity against drought that increased growth of corn plant.

Potassium plays a vital role as a macronutrient in plant growth and sustainable crop production. Potassium is essential for protein synthesis, glycolytic enzymes and photosynthesis. It maintains turgor pressure of cell, which is essential for cell expansion. Wiebold, and Scharf (2006) showed that potassium regulate stoma closure and prevent water wasting and regulation osmosis, increase water use efficiency and improved growth condition in corn. In addition, Tabatabaii, et al., (2011) found that application of potassium sulphate fertilizer under drought stress condition increased grain yield and

1000 grain weight up to 200 kg K/ha. Moreover, Ahmad et al., (2012) found that application of K levels (0, 40, 60, 80 and 100 kg K/fed) to maize hybrids (pioneer 3012, pioneer-3062, pioneer-30D55) increased potassium use efficiency (KUE) significantly at all levels over control. The highest KUE was 2.77 kg yield/kg K at K-level 80 kg/fed.

Nowadays, a great attention has been focused on the possibility of using natural and safe agents for promoting growth and crop yields under saline stress. The use of microbial systems for nutrients mobilization, or as biofertilizers is getting popular in recent years and being introduced to cater for different cropping systems.

The yeast *(Saccharomyces cerevisiae)* is rich in amino acid, proteins, carbohydrates, minerals, vitamins, hormones and other growth regulating substances (Omran, 2000). The role played by accumulated amino acids in plants subjected to stress varies from acting as osmolytes, regulation of ion transport, modulating stomatal opening, and detoxification of heavy metals. Amino acids also affect synthesis and activity of some enzymes and gene expression (Rai, 2002). Several studies indicate that plant root growth may be directly or indirectly enhanced by yeasts in the rhizosphere (El-Tarabily and Sivasithamparam, 2006 and Cloete et al., 2009). A wide diversity of soil yeasts have been researched for their potential as bio-fertilizers (Gomaa and Mohamed, 2007 and Abd El-Monem et al., 2008). Representatives of *Rhodotorula* and *Saccharomyces* are able to nitrify ammonium to nitrate via nitrite *in vitro* (Al-Falih, 2006). Whereas the *Saccharomyces* were able to oxidize elemental sulfur *invitro* to produce phosphate, tetrathionate, and sulfate (Al- Falih and Wainwright, 1995). Biofertilization with *Rhodotorula glutinis* alleviated the adverse effects of high levels of salinity. In the majority of cases biofertilized maize seedlings accumulated more polyamines than non biofertilized ones, especially at high salinity levels. Biofertilization improved K-content, in leaves while fluctuant results were observed for Na-content.

The present study was planned to study the effect of potassium and yeast application on the salt tolerance of maize grown on salt affected soils.

MATERIALS AND METHODS

Field trials

This work was conducted at private farm, close to Batra village, Talkha district, Dakahlia Governorate, Egypt, during the two successive summer seasons of 2011 and 2012, to study the effect of potassium fertilization at different levels (0, 30, 40 and 50 kg/fed) with and without yeast strains (*Saccharomyces cerevisiae* or *Rhodotorula mucilaginosa*) on growth and yield of maize plant under salt affected soil conditions.

The soil texture class was clay loam; Table (1) shows some initial soil properties of the experimental soil from surface layer 0 – 30 cm, according to Page, (1982).

Table 1: Some physical and chemical properties of the experimental field before sowing.

Characteristics		Growing Season 2011	Growing Season 2012	Characteristics		Growing Season 2011	Growing Season 2012
Mechanical analysis	Sand %	37.56	37.7	*PH		8.1	8.1
	Silt %	23.27	22.9	**EC dS m^{-1}		5.6	4.8
	Clay %	39.17	39.4	Soluble cations (meq/L)	Ca^{2+}	15.9	12.8
Texture class		Clay loam	Clay loam		Mg^{2+}	10.8	8.6
SP%		57.3	58.2		Na^{+}	25.6	21.5
O.M. (%)		1.2	1.3		K^{+}	5.7	5.4
CaCO3 (%)		2.9	2.8	Soluble anions (meq/L)	$CO_3^{=}$	--	--
Available N ppm		25	30		HCO_3^{-}	8.4	7.4
Available P ppm		11	12		Cl^{-}	28.9	22.6
Available K ppm		445	390		$SO_4^{=}$	20.7	18.3

***pH in 1:2.5 soil : water suspension, ** EC in soil paste extract.**

Inoculum preparation

Yeast strains (*Rhodotorula mucilaginosa* and *Saccharomyces cerevisiae*) were obtained from the microbiology department, Soils, Water and Environment Research Institute, Agric. Res. Center, Giza, Egypt.

The two yeast strains were grown on glucose peptone yeast (GPY) liquid medium contains 2% glucose, 5% peptone 3% yeast extract (Difco, 1985). This medium was autoclaved at 121°C for 20 min then each strain inoculated with loop full and incubated at 30°C for 48 h on rotary shaker at 150 rpm. The inocula of yeast strains ($1x10^7$ CFU/ml) were added with the irrigation water at a rate of 15 L/fed in three times after 15, 30 and 45 days from sowing.

The experimental treatments were arranged in a completely randomized block design with three replicates as following:

1. Control (without potassium fertilization or yeast)
2. 30 kg K/fed
3. 30 kg K/fed + *R. mucilaginosa*
4. 30 kg K/fed + *S. cerevisiae*
5. 40 kg K/fed
6. 40 kg K/fed + *R. mucilaginosa*
7. 40 kg K/fed + *S. cerevisiae*
8. 50 kg K/fed
9. 50 kg K/fed + *R. mucilaginosa*
10. 50 kg K/fed+ *S. cerevisiae*

Each experimental plot consisted of 5 lines with 3.5 m in length and 3 m width whereas; the plot area was 10.5 m^2. Maize Seeds (hybrid pioneer 30-K-8) were sown at April 23rd, 2011 in first season, and at April 28th, 2012 in second season.

Fertilization:

Nitrogen fertilizer was added at the rate of 120 kg N/fed as ammonium nitrate (33.5% N) divided in two equal doses with the second and third irrigations. Phosphorus fertilizer was applied in the form of calcium super phosphate (15.5% P_2O_5 (6.75% P)) at the rate of 13 kg P/fed before sowing. Whereas, potassium fertilizer treatments were added as potassium sulphate (48% K_2O (40% K)) at two equal doses with the first and second irrigation.

Sampling and determinations:

Rhizosphere plant samples were taken after 50 and 80 days from sowing to determine the bacterial total counts and total yeast counts (CFU/g rhizosphere) according to Bunt and Rovira (1955) and GPYA media (Difco, 1985), respectively. At the same time, the dehydrogenase activity was estimated µg TPF/g dry soil / day according to Skujins, (1976).

At harvest, plant samples were taken to determine grain and stalks yield, 1000-grain weight and weight of ear/plant. Nitrogen, phosphorus, potassium and sodium concentration were determined in flag leaf and grain according to Jackson, (1967). Nitrogen, phosphorous and potassium uptake by maize yield were calculated. Potassium use efficiency(KUE**)** was calculated according to Barber (1976) which is defined as the amount of increase in yield of crop per unit of K fertilizer nutrient applied (kg grain /kg K), as follows:

$$KUE = \frac{\text{Grain yield of treatment – grain yield of control (Kg/fed)}}{\text{Total K applied (kg/fed)}}$$

Potassium utilization rate % (KUR): was calculated according to Fink, (1982) as follows,

$$KUR\ \% = \frac{\text{Total uptake by treatment - total uptake by control (kg/fed)}}{\text{Total K applied (kg/fed)}} X100$$

Soil samples were taken after harvest from surface soil layer (0-20cm) to determine EC in soil past extract and available NPK according to Jackson (1967).

The statistical analysis was estimated according to Gomez and Gomez (1984) and treatment means values were compared against the least significant differences test (LSD) at 5% level.

RESULTS AND DISCUSSION

Data presented in Table (2) show the effect of different applied potassium rates either with and/or without yeast strains applications. In general, the increase in potassium application rates markedly increased the plant growth parameters *i.e.* grain and stalk yields, 1000-grain weight and the weight of ear per plant comparing with those of the control treatment. The increases in K dose up to K level 40 kg K/fed gave significant increases in grain yield and weight of ear per plant, whereas the increases in stalks yield and 1000-grain weight were significant up to level 30 kg K /fed. These results may be attributed to the vital role of K in plant, especially under salt affected soil. K has being known for its particular role in enhancing salt tolerance, (Mengle and Kirkby, 1987), Marschner (1995) and Sanjakara *et al*. (2001) showed that application of K reduces the adverse effects of salinity through its role in stomatal regulation, osmo regulation, energy status, charge balance, protein synthesis and homeostasis. Also, these results agree with Tabatabaii, et al., (2011) who found that application of potassium sulphate fertilizer under drought stress condition increased grain yield and 1000-grain weight.

Table 2: Effect of different potassium levels and yeast strains on stalks and grain yield, 1000-grain weight and weight of ear of maize grown on salt affected soil

Treatments	Stalks yield (ton/fed)		Grain yield (ton/fed)		1000-grain weight (g)		Weight of ear (g/plant)	
	1St season	2nd season	1St season	2nd season	1St season	2nd season	1St season	2nd season
Control	3.530	3.539	3.068	3.296	372	373	328	329
30 kg K/fed	3.915	3.913	3.623	3.675	385	386	356	379
30 kg K/fed + *R mucilaginosa*	3.994	3.967	3.687	3.809	398	398	397	409
30 kg K/fed +*S. cerevisiae*	3.944	3.882	3.634	3.774	387	388	362	396
40 kg K/fed	3.887	3.897	3.693	3.803	385	386	377	397
40 kg K/fed + *R. mucilaginosa*	3.905	3.916	3.716	3.827	388	389	378	401
40 kg K/fed +*S. cerevisiae*	3.917	3.871	3.675	3.815	387	388	372	398
50 kg K/fed	3.871	3.880	3.733	3.821	389	390	367	399
50 kg K/fed + *R. mucilaginosa*	3.929	3.921	3.751	3.821	391	392	402	414
50 kg K/fed +*S. cerevisiae*	3.845	3.870	3.728	3.821	390	390	371	402
LSD at 5%	0.088	0.090	0.066	0.078	5.84	5.63	10.52	14.77

Regarding the effect of yeast strains on the studied parameters, *R. mucilaginosa* combined with the different potassium application rates is highly effective on increasing the plant growth parameters comparing with both of *S. cerevisiae* plus potassium and the treated plants with potassium only. The statistical analysis of the effect of *R. mucilaginosa* combined with K rates showed no significant on the grain yield. This means that the use of *R. mucilaginosa* can save about 10 kg for the recommended doses of potassium fertilizers (40 kg K/fed).

The enhancing effect of yeast on plants might be due to the secretion of cytokinins, which enhancing the accumulation of soluble metabolites, increasing the levels of endogenous hormones in treated plants, which could be interpreted by cell division and cell elongation, increasing the metabolic processes rate and levels of hormones (indol acetic acid IAA and gibberellins GA3) in addition to the physiological roles of vitamins and amino acids in the yeast strains. The effective growth regulator activates plant defence mechanisms in response to salinity stresses (Ibrahim *et al*., 2012).

K and Na concentration and K/Na ratio in maize plants:

Data presented in Table (3) reveal the effect of different potassium levels and yeast applications on K and Na concentration as well as the K/Na ratio in both of stalks and grain of maize plants grown on salt affected soils. The obtained results show that the increase in potassium application rates, irrespective with the application of two applied yeast strains, followed by a slight increase in K% in both of maize stalks and grains. Application of K levels significantly increased K % up to level 50 kg in both seasons.

Table 3: Effect of different potassium levels and yeast strains on potassium, sodium and the ratio of potassium/sodium of maize grown on salt affected soil

Treatments	K (%)				Na (%)				K/Na ratio			
	1st season		2nd season		1st season		2nd season		1st season		2nd season	
	Stalk	Grain	Stalk	Grain	Stalk	Grain	Stalk	Grain	Stalk	Grain	Stalk	Grain
Control	2.60	1.39	2.67	1.40	1.52	0.64	1.49	0.58	1.71	2.16	1.79	2.41
30 kg K/fed	2.67	1.41	2.73	1.44	1.38	0.55	1.33	0.47	1.94	2.57	2.06	3.09
30 kg K/fed + *R. mucilaginosa*	2.70	1.42	2.74	1.46	1.29	0.46	1.27	0.40	2.10	3.10	2.16	3.71
30 kg K/fed + *S. cerevisiae*	2.72	1.43	2.78	1.48	1.28	0.47	1.27	0.41	2.12	3.05	2.19	3.63
40 kg K/fed	2.78	1.44	2.84	1.48	1.24	0.51	1.26	0.45	2.25	2.82	2.25	3.32
40 kg K/fed + *R. mucilaginosa*	2.82	1.44	2.87	1.53	1.26	0.49	1.23	0.42	2.24	2.98	2.34	3.64
40 kg K/fed + *S. cerevisiae*	2.84	1.46	2.90	1.52	1.17	0.50	1.23	0.44	2.43	2.90	2.37	3.47
50 kg K/fed	2.86	1.49	3.00	1.56	1.11	0.50	1.10	0.43	2.58	2.96	2.74	3.64
50 kg K/fed + *R. mucilaginosa*	2.94	1.51	3.03	1.58	1.07	0.48	1.08	0.41	2.75	3.13	2.83	3.86
50 kg K/fed + *S. cerevisiae*	2.95	1.50	3.06	1.59	1.12	0.49	1.13	0.42	2.65	3.04	2.72	3.79
LSD at 5%	0.062	0.067	0.049	0.065	0.064	0.045	0.073	0.045	0.144	0.276	0.180	0.349

Concerning the effect of the applied two yeast strains on K % in the two maize parts, it is found that K % was gradually increased in plants treated with yeast comparing with that untreated and the control. *Saccharomyce*s sp. is more effective to enhance K content rather than *R. mucilaginosa,* but this superiority was not significant*.* The promoting effect of yeast applied strains on K content in maize stalks and grain may be due to the biologically active substances produced by these biofertilizers such as auxins, gibberellins, cytokinins, amino acids and vitamins. These findings are in agreement with that reported by Afifi et al., (2003) who pointed out that inoculation of maize with yeast species combined with the half dose of recommended NPK induced growth parameters to match those of the recommended doses of NPK.

An adverse effect of potassium application rates and yeast strains was pronounced on decreasing of Na % in both of maize stalks and grain. This positive effect could be attributed to the tendency of plants to absorb potassium ions rather than sodium ones. This uptake called luxury and entertaining uptake and K plays a vital role in the photosynthesis process.

Recent progress in molecular genetics and plant electrophysiology suggests that the ability of a plant to maintain a high cytosolic K^+/Na^+ ratio appears to be critical to plant salt tolerance. So far, the major efforts of plant breeders have been aimed at improving this ratio by minimizing Na^+ uptake and transport to shoot. The results shown in Table (3) are expected and reflected on the K/Na ratio in both of maize stalks and grain. This popular effect was markedly increased with the increase of potassium application rates with a special reference to that combined with yeast applications. Comparing with the control treatment, the increase percentages of K/Na ratio in maize stalks and grains were 15, 20 and 22% and 28, 53 and 50%, respectively for the treatments 30 kg K/fed and 30 kg K/fed either with *R. mucilaginosa* or *S. cerevisiae*, respectively. By increasing K application rate to 40 kg K/fed also for stalks and grain, either alone or combined with the two yeast strains the K/Na ratio values were 25, 30 and 32% and 37, 51 and 43%, respectively. The corresponding values of K/Na ratio values in maize stalks and grain for the K application rate 50 kg K/fed either with *R. mucilaginosa* or *S. cerevisiae* achieved to 53, 58 and 51% and 51, 60 and 57%, respectively. This finding is in harmony with that postulated by Rajpar et al., (2011) who stated that better K/Na ratio in flag leaf of three maize genotypes ranged from 2.78 to 3.49 under normal condition, but decreased to be between 1.33 and 1.51 by the irrigation with saline water. Also, Akram et al., (2007) pointed out that plants which had a higher K^+/Na^+ ratio were more salt tolerance than those with low K^+/Na^+ ratio.

K –uptake and K use efficiency:

Data in Table (4) reveal that K-uptake by maize stalk's and grain yields increased significantly with increasing potassium application rates either with or without yeast treatments in the both successive seasons. The highest total K-uptake (stalks+ grain yield) was 172.1 kg/fed in the 1st season and 179.2 kg/fed in the 2nd one under the treatment of 50 kg K/fed + *R. mucilaginosa* treatment. The K-uptake by maize plants was obviously increased with increasing K fertilizer application in both studied seasons.These results may be due to the luxuriantly consumption of K by plants (Roy *et al.,* 2006). The effects of K fertilization are in accordance with El-Kohly et al., (2003).

Maximum increase in K^+ uptake at highest level of potassium application rate was noted in plants inoculated with *R. mucilaginosa*. The highest Potassium contents at maize plants inoculated with *R. mucilaginosa* had resulted in higher K^+/Na^+ ratio showing better performance under saline conditions.

Table 4: Effect of different potassium levels and yeast strains on potassium uptake by stalks and grain yield, K efficiency and K utilization rate of maize grown on salt affected soil

Treatments	K uptake (kg/fed.)				KUE (kg grain/kg K)		KUR (%)	
	1st season		2nd season		1st season	2nd season	1st season	2nd season
	Stalk	Grain	Stalk	Grain				
Control	91.8	42.7	94.4	46.0	0.00	0.00	0.00	0.00
30 kgK/fed	104.4	51.2	106.7	52.9	18.472	12.639	70.41	63.74
30 kg K/fed +*R. mucilaginosa*	107.7	52.2	108.8	55.6	20.611	17.111	84.93	79.88
30 kg K/fed +*S. cerevisiae*	107.1	52.1	107.9	55.7	18.861	15.944	82.60	77.29
40 kgK/fed	108.0	53.0	110.7	56.3	15.604	12.688	66.58	66.30
40 kg K/fed +*R. mucilaginosa*	110.0	53.6	112.5	58.4	16.188	13.271	72.91	76.23
40 kg K/fed +*S. cerevisiae*	111.4	53.5	112.4	58.1	15.167	12.979	76.13	75.06
50 kgK/fed	110.6	55.6	116.4	59.6	13.300	10.500	63.54	71.11
50 kg K/fed +*R. mucilaginosa*	115.5	56.6	118.8	60.4	13.650	10.500	75.29	77.53
50 kg K/fed +*S. cerevisiae*	113.5	55.8	118.4	60.6	13.183	10.500	69.76	77.23
LSD at 5%	3.782	2.669	2.439	2.878	--	--	--	--

Respecting the K use efficiency (KUE), the obtained results in Table (4) show that KUE values were markedly increased in the lowest application rate of potassium fertilizer (30 kg K/fed.) combined with *Rhodotorula* strain in both studied seasons. The highest KUE values reached 20.611 and 17.111 kg grain/kg K in both 1st and 2nd growth seasons, respectively. An increasing K supply corresponded with higher K^+ accumulation in plant tissue, which reduced the Na^+ concentration and resulted in a higher K^+/Na^+ ratio

In general, KUR % took the same trend of KUE. The obtained data shown in Table (4) illustrate that percentage of KUR increased up to 84.93 and 79.88 % in the 1st and 2nd seasons, respectively, at a rate of 30 kg K/fed in the presence of *R. mucilaginosa*. In the contrary, it slightly decreased at the higher K application rates.

The ability of plants to satisfy their metabolic requirements for K^+ in the presence of salinity by using higher K^+ fluxes and lower Na^+ fluxes that result in a higher K^+/Na^+ selectivity ratio is essential for salt tolerance. The addition of K^+ to a saline culture solution has been found to increase K^+ concentrations in plant tissue that corresponds with a decrease in Na^+ content, with a further increase in plant growth and salt tolerance.

N and P uptake:

The effect of different potassium levels and yeast strains on nitrogen and phosphorus uptake by maize plants grown on salt affected soil is presented in Table (5). In general, the increase in K application rate was succeeded by an increase in the N uptake by the total maize plant (stalks and grain) as compared with the control treatment. The application of K combined with yeast clearly increased N uptake by maize plants from 199.7 up to 268.3 kg/fed with 34.35% increase in the plants treated with 50 kg K+ *R.*

mucilaginosa in the 1st season. In the 2nd season, N uptake in maize plants increased from 199.2 up to 264.2 kg N/fed with 32.63% increase.

Table 5: Effect of different potassium levels and yeast strains on nitrogen and phosphorus uptake by maize grown on salt affected soil

Treatments	N-uptake (kg/fed)				P-uptake (kg/fed)			
	1st season		2nd season		1st season		2nd season	
	Stalk	Grain	Stalk	Grain	Stalk	Grain	Stalk	Grain
Control	126.5	73.2	122.2	77.0	11.65	9.51	12.74	9.12
30 kg K/fed	155.3	91.1	156.0	90.6	14.36	13.16	17.08	11.88
30 kg K/fed +*R. mucilaginosa*	163.8	92.8	163.5	94.6	13.98	12.90	16.66	11.81
30 kg K/fed +*S. cerevisiae*	159.1	93.3	152.2	94.0	14.07	12.84	16.95	11.83
40 kg K/fed	155.5	94.2	152.8	94.7	15.55	15.39	17.54	14.34
40 kg K/fed +*R. mucilaginosa*	164.0	96.6	157.4	97.6	14.97	14.86	18.15	13.78
40 kg K/fed +*S. cerevisiae*	158.7	96.2	152.4	94.9	15.80	14.95	18.71	14.00
50 kg K/fed	165.8	98.3	161.2	96.9	16.39	16.80	19.52	15.67
50 kg K/fed +*R. mucilaginosa*	168.3	100.0	163.5	100.7	17.02	17.01	20.13	15.79
50 kg K/fed +*S. cerevisiae*	167.9	95.7	165.3	98.1	16.80	16.15	19.61	15.79
LSD at 5%	4.475	3.755	5.649	3.765	1.081	1.253	0.985	1.360

Concerning the effect on P-uptake, data in Table (5) reveal that an increase in P uptake was significantly resulted due to the application of K and/or yeast strains during the two growth seasons compared to control. The highest P uptake was 34.03 and 35.92 kg P/fed in the plants treated with 50 kg K/fed combined with *R. mucilaginosa* in both growth seasons, respectively. These results are in a good harmony with that obtained by Al-Falih, *et al*., (2006) who indicated that plant root growth may be directly or indirectly enhanced by yeast in the rhizosphere, which are responsible for absorbing more nutrients. In addition, Abd El-Monem et al., (2008) stated that representative of *Candida, Geotrichum, Rhodotorula, Saccharomyces* and *Willopsis* are able to nitrify ammonium to nitrate via nitrite in vitro. Whereas, Cloete et al., (2009) reported that *Saccharomyces* was able to oxidize elemental sulphur in vitro to produce phosphate, tetrathionate and sulphate.

Salinity and soil fertility:

Data presented in Table (6) show the effect of different potassium application rates and the applications of yeast strains on soil salinity expressed in dSm^{-1} and the available nitrogen, phosphorus and potassium concentrations expressed in part per million during the two growth seasons. In general, the cultivation of such soil decreased soil salinity comparing with that in the initial case, due to the application the proper amounts of irrigation water including the leaching requirements under good drainage conditions. The obtained results (Table 6) show that the increase of K application rates significantly enhanced soil salinity irrespective of yeast application. These increases are higher in the 1st season compared with the 2nd one. This increase may be due to the application of salts in the form of mineral fertilizer (K_2SO_4) and/or poor soil drainage. No significant effects of yeast strains were recorded on soil salinity. In this respect, Gomaa et al., (2005) studied the effect of salt stress on four Egyptian maize varieties (Giza 2, One Way Cross 10, One Way Cross 129 and Three Way Cross 352) grown under different salinity levels in relation to bio-fertilization with yeast (*Rhodotorula glutinis*). The results showed that bio-fertilization alleviated adverse effects of high levels of salinity and plants accumulated more polyamines than those, which didn't receive bio-fertilizer, especially at high salinity levels. In addition, data reveal that the application of K levels had a significant effect on available N, P and K in both seasons. Available N increased significantly up to the level of 40 kg K/fed, whereas, the increases in available P were irregular with potassium fertilization. The values of available of K significantly increased with continuous added of K levels up to 50 kg K/fed in both seasons.

Table 6: Effect of different potassium levels and yeast strains on soil salinity and macroelement availability under maize growing on salt affected soil

Treatments	EC (dSm^{-1})		Available N (ppm)		Available p (ppm)		Available K (ppm)	
	1^{St} season	2^{nd} season	1^{St} season	2^{nd} season	1^{St} season	2^{nd} season	1^{St} season	2^{nd} season
Control	3.70	3.48	47	42	6.5	8.2	410	367
30 kg K/fed	4.07	3.91	63	57	9.8	11.5	512	469
30 kg K/fed + *R. mucilaginosa*	4.34	3.95	54	49	7.9	9.6	525	482
30 kg K/fed + *S. cerevisiae*	4.12	3.96	54	49	4.8	6.5	528	485
40 kg K/fed	4.18	4.02	66	60	5.8	7.5	609	566
40 kg K/fed + *R. mucilaginosa*	4.41	4.09	58	52	8.5	10.2	623	580
40 kg K/fed + *S. cerevisiae*	4.17	4.01	57	51	7.7	9.4	615	572
50 kg K/fed	4.27	4.11	65	60	9.0	10.7	662	619
50 kg K/fed + *R. mucilaginosa*	4.42	4.00	56	51	7.0	8.7	645	602
50 kg K/fed + *S. cerevisiae*	4.34	3.98	57	52	7.0	8.7	662	619
LSD at 5%	0.125	0.098	3.49	3.50	0.56	0.56	19.12	19.19

Microbial and yeast count:

The dynamics of total microbial count populations and total yeast count in maize rhizospheric roots increased during the two studied seasons after 50 and 80 days from planting compared to the control (Table, 7). Furthermore, data showed an increase in both of total microbial and yeast count population especially after 80 days of planting, during the two growth seasons in comparison with that after 50 days of planting. The highest total microbial count in the maize rhizosphere treated with 40 kg K/fed + *R. mucilaginosa,* ranged between 45.3 and 60.41x10^6 CFU/g soil after 50 and 80 days of planting, respectively in the 1^{st} growing season. While, the total microbial count reached 60.25 and 78.53 x10^6 CFU/g soil after 50 and 80 days of planting, respectively in the second season.

The yeast total counts took the same trend of the total microbial counts during the two growth seasons. The yeast total count varied from 3.91 and 6.2 x 10^4 CFU/g soil after 50 and 80 days of planting, respectively.

Moreover, the yeast total count was increased and ranged between 5.28 and 8.37 x10^4 CFU/g soil after 50 and 80 days of planting in the second growing season, respectively. *Rhodotorula* and *Saccharomyces* are able to secrete some plant growth regulator or promoting substances such as vitamins, hormones, organic acids which accelerate certain microbial process to increase the availability of some nutrients in a form easily taken by plants (khalil and Ismael, 2010). Ibrahim *et al.* (2012) found that the addition of yeast had a beneficial return to increase the population of microorganisms in plant rhizosphere that produce growth-regulating substances.

Table 7: Effect of different potassium levels and yeast strains on total microbial and yeast count in rhizospheric maize plants grown on salt affected soil

Treatments	Total count CFUx10^6/g rhizosphere				Yeast count CFUx10^4/g rhizosphere			
	1st season		2nd season		1st season		2nd season	
	50 day	80 day	50 day	80 day	50 day	80 day	50 day	80 day
Control	18.20	24.50	23.66	32.40	1.50	1.80	1.95	2.34
30 kgK/fed	22.17	30.16	28.80	40.42	2.10	2.95	2.73	3.84
30 kg K/fed +*R. mucilaginosa*	38.32	52.10	49.82	68.82	3.45	5.60	4.49	7.28
30 kg K/fed +*S. cerevisiae*	33.64	46.11	43.70	61.79	3.16	4.32	4.11	5.62
40 kgK/fed	29.00	41.65	38.70	54.25	2.50	3.10	3.38	4.19
40 kg K/fed +*R. mucilaginosa*	45.30	60.41	60.25	78.53	3.91	6.20	5.28	8.37
40 kg K/fed +*S. cerevisiae*	39.50	51.60	52.54	67.10	2.86	4.85	3.81	6.55
50 kgK/fed	26.46	35.52	34.10	45.47	2.65	3.94	3.39	5.04
50 kg K/fed +*R. mucilaginosa*	40.00	56.33	60.26	72.10	3.66	7.45	4.69	7.45
50 kg K/fed +*S. cerevisiae*	31.18	48.11	53.45	61.58	3.15	3.88	4.03	4.97

Enzyme activity:

Dehydrogenase is an oxidoreductase, which is only present in viable cells. This enzyme has been considered as a sensitive indicator of soil quality and it has been proposed as a valid biomarker to indicate changes in total microbial activity due to changes in soil management (Roldán *et al*., 2004).

Data in Table (8) show that the application of different potassium levels either supported with/or without yeast strains i.e. *R. mucilaginosa* or *S. cerevisiae* significantly increased the activity of dehydrogenase enzyme in most of the treated rhizospheric soil planted with maize crop after 50 and 80 days of planting during the 1st and 2nd seasons compared with the control. Moreover, the treatment of 40 kg K/fed + *S. cerevisiae* exhibited the highest activity (37.15 and 50.15 µg TPF/g soil/day) after 50 days whereas 40 kg K/fed + *R. mucilaginosa* exhibited the highest activity after 80 days (82.63 and 111.56 µg TPF/g soil/day) during the two studied seasons, respectively. This beneficial return was pronounced due to the increase in microorganism populations in the maize rhizosphere, which responsible for producing growth regulating substances (Ibrahim et al., 2012).

Table 8: Effect of different potassium levels and yeast strains on dehydrogenase activity in rhizospheric maize plants grown on salt affected soil

Treatments	Dehydrogenase activity µg TPF/g dry soil/day			
	1st season		2nd season	
	50 d	80 d	50 d	80 d
Control	16.84	28.13	21.89	36.57
30 kg K/fed	17.73	39.51	22.60	51.36
30 kg K/fed +*R. mucilaginosa*	24.32	54.16	31.62	70.41
30 kg K/fed +*S. cerevisiae*	27.37	49.20	35.58	63.96
40 kg K/fed	25.89	61.35	34.95	82.73
40 kg K/fed +*R. mucilaginosa*	31.12	82.63	42.01	111.56
40 kg K/fed +*S. cerevisiae*	37.15	75.33	50.15	101.69
50 kg K/fed	22.63	33.50	28.97	56.96
50 kg K/fed +*R. mucilaginosa*	30.41	66.39	38.92	84.98
50 kg K/fed +*S. cerevisiae*	31.18	53.40	39.91	68.35
LSD at 5%	0.009	0.012	0.417	0.011

CONCLUSION

It can be concluded that under salt affected soil conditions; the most effective treatment was potassium fertilization at 30 kg K/fed with inoculation by yeast *(R. mucilaginosa*). This treatment recorded grain yield 3.687 and 3.809 t/fed in both seasons, respectively. So this study confirms the importance of inoculation by yeast combined with potassium fertilization to increase maize grain and stalks yield, NPK uptake, K/Na ratio and K use efficiency under salt affected soil.

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التأثير الإيجابي للتسميد البوتاسى وسلالات الخميرة على نباتات الذرة النامية تحت ظروف الأراضي المتأثرة بالأملاح

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يرجع الاهتمام الكبير لاستخدام الخمائرفى الزراعة كسماد حيوى الى نشاطها وامانها الحيوى على الانسان والبيئه. ولذلك تهدف الدراسة الحالية إلى تقييم كفاءة التسميد البوتاسى منفردا أو متداخلا مع أحد سلالاتين من الخمائر على كفاءة نمو الذرة فى الاراضى المتأثرة بالاملاح بمحافظة الدقهلية وذلك لأثبات تأثيرها المفيد كسماد حيوى. وقد أجريت تجربة حقلية لمدة عامان لدراسة تأثير إضافة مستويات مختلفة من البوتاسيوم (صفر و٣٠ و ٤٠ و ٥٠ كجم بوتاسيوم/للفدان) فى وجود وعدم وجود *Saccharomyces cerevisiae* أو *Rhodotorula mucilaginosa* وتأثير ذلك على إنتاجية الذرة وكفاءة استخدام البوتاسيوم و امتصاص العناصر الكبرى وخصوبة التربة بعد الحصاد. وأظهرت النتائج إن استخدام البوتاسيوم مع الخمائر ادى الى زيادة معنوية فى محصول السيقان و الحبوب ووزن ال-١٠٠٠ حبة ووزن الكوز لكل نبات. وكذلك أدى استخدام البوتاسيوم مع الخمائر إلى ارتفاع ملحوظ فى تحمل نباتات الذرة للملوحه ممثلة فى زيادة نسبة البوتاسيوم للصوديوم وخاصة مع زيادة نسبة التسميد البوتاسى. كما أيضا أدى استخدام البوتاسيوم مع الخميرة إلى زيادة كفاءة استخدام البوتاسيوم وأمتصاصة داخل النبات. وقد سجلت المعاملة ٣٠ كجم بوتاسيوم للفدان مع خميرة *Rhodotorula mucilaginosa* أعلى معدل استفادة من البوتاسيوم وصلت إلى ٨٤,٩٣ %. وقد كان للتسميد البوتاسى تأثير إيجابي لامتصاص الفوسفور والنتروجين فى كلا الموسمين. وعلى الجانب الأخر فقد كانت هناك زيادة معنوية لملوحة وخصوبة التربة مع زيادة التسميد البوتاسى. وسجلت أعلى قيم للعدد الكلى للميكروبات والخمائر وكذلك نشاط إنزيم الديهيدروجينيز فى وجود مستوى منخفض من التسميد البوتاسى مع *Rhodotorula mucilaginosa*. ولذلك يمكن التوصية باستخدام مستويات منخفضة من البوتاسيوم مع سلالات الخمائر كسماد حيوى للتغلب على الإجهاد الملحي لنباتات الذرة.

قام بتحكيم البحث

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