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POTASSIUM FERTILIZATION, COMPOST AND BIO-FERTILIZER FOR IMPROVING POTATO PRODUCTIVITY, ITS QUALITY AND PROFITABILITY IN SANDY SOIL

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ABSTRACT: *Nutrient management become more important to be discussed to obtain optimum yield with maximum profitability, So, two field experiments were conducted in spilt plot design at El-Sharawy village in EL-Bostan area – Noubaria Region, Elbehera governorate (Latitude 30° 43' 22.01" N, Longitude 30° 16' 44.50" E) during the winter growing seasons of 2014 and 2015 on potato (c.v. spunta), to evaluate the effect of organic manure at two rates (10 and 20 m^3 compost fed^{-1}) with or without seed potato inoculation with potassium release bacteria (KRB) "Bacillus circulans" (Org_1, Org_1+Bio, Org_2 and Org_2+Bio), four K treatments (K1: 96 kg K_2O fed^{-1} as K-sulfate (SOP), K2: 48 kg K_2O fed^{-1} as SOP+ 1% K_2O foliar as SOP, K3: 48 kg K_2O fed^{-1} as feldspar (FDS) + 1% K_2O foliar and K4: 24 kg K_2O fed^{-1} as FDS+ 1% K_2O foliar) and their interactions on potato yield and quality. Results reveal that addition of different K-treatments as SOP or FDS with foliar spray of 1% K_2O significantly affected shoot fresh and dry weights, tuber yield and its quality parameters (specific gravity, starch and carbohydrate %) and NPK-uptake in favor of SOP. Also, the values of plant growth parameters, tuber yield, tuber quality parameters and NPK-uptake were increased with increasing compost rate from 10 to 20 m^3 fed^{-1} along with KRB inoculation. Interaction between Org_2+Bio and K2 produced the highest values of tuber yield (16.697 t fed^{-1}) and NPK-uptake, whereas, higher values of tuber quality parameters were recorded under interactions of (Org_1+Bio*K2 or K3) and (Org_2+Bio*K2 or K3). For economic evaluation, results showed that K2 and K3 treatments along with 10 m^3 compost fed^{-1}+Bio were superior for net return (NR) and investment factor (IF), since the highest values of NR and IF were 11247 L.E fed^{-1} and 1.93 with interaction Org_1+Bio*K3.*

Key words: *potassium, feldspar, compost, K-releases bacteria, sandy soil, potato yield and its quality, NPK-uptake and economic evaluation.*

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important vegetable crops in Egypt, that requires high amounts of potassium fertilizer for optimum growth, production and tuber quality (Al-Moshileh and Errebi 2004). Potassium is one of essential nutrients for plant that plays a vital role in photosynthesis, carbohydrate transport, protein formation, control of ionic balance, regulation of plant stomata and water use activation of plant enzyme and many other processes (Munson *et al.,* 1985).

For economic and environmental reasons, nutrients management becomes more important to be discussed to obtain optimum yield with maximum profitability, especially for potassium fertilization. In this frame, change of the potato fertilization by potassium from traditional system (application of all K-requirements as K-sulfate fertilizer) to an integrated one consists of soil and foliar potassium applied from mineral *fertilizers* and natural sources such as feldspar and application of organic fertilizers with inoculation by bacteria dissolving potassium (*Bacillus circulans*) may be needed.

In this concern, El-Sawy *et al.,* (2000) found that tuber yield, dry shoot weight, chemical composition of potato and specific gravity of tubers significantly increased with increasing K-foliar concentration (0, 1, 2 and 3% K_2O as K_2SO_4), while tuber yield was significantly increased by increasing soil application of K-rate up to 48 kg K_2O fed^{-1}. Also, Gommaa (2007) showed that foliar K application at four concentrations 0, 0.5, 1.0 and 1.5 % K_2O (as K_2SO_4) significantly increased potato tuber yield, and the highest tuber yield was at 1 % K_2O. Dkhil *et al.,* (2011) indicated that foliar of 2 g KNO_3/L was effective in increasing average tuber diameter, mean tuber weight of potato that grown on loamy-sandy soil. In another study, Singh and Lal (2012) showed that increasing K levels application up to 150 kg K_2O ha^{-1} (63 kg fed^{-1}) increased tuber yield, tuber size and N and K uptake by potato, which recorded maximum yield (39.83 t ha^{-1} = 16.7 t fed^{-1}) on sandy loam soil.

In Egypt, there is a great need to optimize the use of the natural resources of nutrients to continue the development and sustainability of agriculture and reduce the cost of production and increase the net return. In this frame, Labib *et al.,* (2012) showed that addition of K recommended for potato as 50 % K-sulfate + 50 % K-feldspar resulted in the highest content of starch, mono-sucrose and protein of potatoes, total yield and weight of vegetative plants as well as tubers comparing with using K-sulfate only at field study on sandy soil. Also, Shehata *et al.,* (2014) found that application of 11.8 t compost/fed+ 77kg rock phosphate+ 252kg feldspar+ inoculation with mixture bacteria dissolving P and K (*B. megaterium* and *B. circulans*) had the highest potato tubers weight per plant, total yield, NPK concentrations at tubers, dry matter and carbohydrate % of potato tubers on sandy soil.

Regarding the use of organic fertilizers, Makaraviciute (2003) found that farmyard manure application increased dry matter and starch content in the tuber, where potato tuber yield increased by 20 %. Also, El-Sayed *et al.,* (2014) showed that treatment received 50 % mineral fertilizers + 23.8 t. ha^{-1} compost (10 t. fed^{-1}) with bio-fertilizer had the highest weight of marketable tubers/plant on field study on sandy soil. Also, they indicated that organic production of potato using 23.8 t. ha^{-1} compost+ bio-fertilizer+ rock phosphate+ feldspar could be an alternative to conventional production without significant reduction in yield and quality on sandy soil under sprinkler irrigation.

So, the present study aims to increase the return of applied potassium, through the methods of K-fertilization (soil and foliar), sources of K (K-sulfate and feldspar) and compost application with inoculation by K-release bacteria (*Bacillus circulans*) to obtain the optimum yield of potato with high quality and maximum economic return under sandy soil conditions.

MATERIALS AND METHODS

Two field experiments were conducted during the winter growing seasons 2014 and 2015 at El-Sharawy village in EL-Bostan area – Noubaria Region, Elbeheira governorate (Latitude 30° 43' 22.01" N, Longitude 30° 16' 44.50" E) to evaluate the effect of organic manure (compost) with or without inoculation by potassium release bacteria (bio-fertilizer), K fertilization and their interactions on potato yield (*Solanum tuberosum*, *L.* – c.v. Spunta), its quality and economic return under the conditions of sandy soil. Samples of the experimental soil and compost were analyzed before planting according to Hesse (1971) as shown in Tables 1 and 2.

Table 1: Physical and chemical properties of the experimental soil before planting (mean of two seasons).

Properties	Particles size distribution				OM %	$CaCO_3$ %	pH	EC dSm^{-1}
	Sand %	Silt %	Clay %	Texture class				
Values	91.5	5.4	3.1	Sandy	0.14	3.5	8.1	0.41

Properties	Cations and anions in the soil paste extract, (meq 100 g^{-1})								Available NPK (mg kg^{-1})		
	Cations				Anions				N	P	K
	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}			
Values	1.61	1.28	1.02	0.18	--	1.53	1.92	0.64	13	6	80

pH was measured in 1: 2.5 suspension; EC was measured in soil paste extract.

Table 2: Some properties of the applied compost (mean of two seasons):

Properties	pH	EC dSm^{-1}	Moisture %	Weight of m^3 (kg)	OM %	Total C %	Total N %	C:N ratio	Total P %	Total K %
Values	7.57	5.66	26	650	34.53	20.0	1.25	16:1	0.87	0.93

pH was measured in 1: 10 suspension; EC was measured in 1: 10 water extract.

The two experiments were designed in a split plot with three replicates; the plot area was 10.5 m^2. The main plots received four treatment of compost without or with seed potato inoculation by bio-fertilizer that contains strains of K-release bacteria (KRB) "*Bacillus circulans*" (provided from the unit of bio-fertilizers at Soil, Water and Environment Research Institute, Agric. Res. Center, Giza, Egypt); as follows

1- Org_1: 10 m^3 (6.5 t fed^{-1}) compost fed^{-1}.
2- Org_1+Bio: 10 m^3compost fed^{-1} + inoculation with bio-fertilizer.
3- Org_2: 20 m^3 (13 t fed^{-1}) compost fed^{-1}.
4- Org_2+Bio: 20 m^3compost fed^{-1} + inoculation with bio-fertilizer.

The sub plots received four treatments of K a soil and foliar application from two sources; K-sulfate (SOP) "48% K_2O" or feldspar (FDS) "10 % K_2O" as follows:

1- K1: 96 kg K_2O fed^{-1} as SOP (control).
2- K2: 48 kg K_2O fed^{-1} as SOP + 1% K_2O foliar as SOP.
3- K3: 48 kg K_2O fed^{-1} as FDS + 1% K_2O foliar as SOP.
4- K4: 24 kg K_2O fed^{-1} as FDS + 1% K_2O foliar as SOP.

Application of fertilizers:

The organic manure (compost) was applied before the last tillage, and then soil was irrigated 3 times before planting. Seed potato tubers were inoculated with effective bacteria just before planting.

Feldspar which is a natural rock of potassium contains about 10 % K_2O (as total) and was added to the soil with organic manure before planting. The rates of SOP was added to the soil in three equal doses, during preparation practices for cultivation and before fourth and eighth irrigation, while foliar treatment of 1% K_2O (SOP) was applied at 3 times; after complete emergency then at 15 days intervals (spraying solution volume was 400 L fed^{-1}).

All plots received the recommended rates of N and P fertilizers. Nitrogen fertilizer was applied at 150 kg N fed^{-1} as ammonium nitrate (33.5% N) in eight equal doses weekly starting from the first irrigation after emergency. Phosphorus fertilizer was added during soil preparation before planting at the rate of 75 kg P_2O_5 fed^{-1} as Ca-superphosphate (15 % P_2O_5).

Drip irrigation system was used where irrigation laterals were 16 mm in diameter and 30 meter length have in line emitters (drippers) spaced 0.3 m apart with 3.6 L h^{-1} flow rate at pressure of 100 kpa.

Planting and harvest:

Seed potato tubers were planted on 1st December 2013 in 1st season and harvested on 2nd April 2014, while in 2nd season seed potato tuber were planted on 3rd December 2014 and harvested on 4th April 2015. At 90 days from planting plant height (cm) and shoot fresh weight (g $plant^{-1}$) were recorded. At harvest, the following parameters were recorded: (1) shoot dry yield (t fed^{-1}), tuber yield/Plant (kg $plant^{-1}$), average tuber weight (g) and total tuber yield (t fed^{-1}). (2) Tuber quality parameters: dry matter %, specific gravity, starch %, protein %, carbohydrate % and reducing sugar % (A.O.A.C., 1990). (3) N, P and K % were determined in tuber dry matter according to A.O.A.C. (1990); and NPK uptake in tuber was then calculated (kg fed^{-1}).

Specific gravity = (tuber weight in the air) / (tuber weight in the air - tuber weight in the water), (Smith, 1975).

Starch %= 17.457+ (0.89 × (dry matter % - 24), (Burton, 1948).

Protein %= N % in tuber × 6.25, (Ranganna, 1977).

(4) Profitability was calculated as net return and investment factor as follows.

Gross return (GR), L.E = yield price (tuber yield t fed^{-1} × price t^{-1}).

Net return (NR), L.E = (gross return- total cost).

Investment factor (IF) = gross return (L.E.)/total cost (L.E.).

The statistical analysis of the obtained data was done according to the methods described by Gomez and Gomez (1984) using LSD to compare the means of treatments values at 5%.

RESULTS AND DISCUSSION

1- Growth, Yield and Its Components.

Plant growth parameters:

Data in Table 3 show that shoot fresh weight/plant after 90 days and shoot dry weight (t. fed^{-1}) at harvest significantly increased with addition of K-treatments at 48 kg K_2O fed^{-1} as SOP or FDS with foliar 1% K_2O compared to K-recommended (RK) rate (96 kg K_2O fed^{-1}) in favor of FDS showing that 50 % of RK could be saved by foliar 1 % K_2O. These effects may be attributed to the uniform distribution of nutrients in foliar sprays and less likelihood that the nutrients will be washed off before absorption occurs on the other hand the promotive effect of K may be due to the role of K in translocation of metabolized materials from shoot to tubers (storage parts) and correlation between the amount of K-applied and the rate of translocation from shoot to tubers. These results agreed with El-Sawy *et al.,* (2000).

Also, data in the same table reveal that increasing compost level from 10 to 20 m^3 fed^{-1} with or without K-release bacteria (KRB) significantly increased plant height, shoot fresh weight $plant^{-1}$ and shoot dry weight fed^{-1}, and the highest values were 48.5 cm, 331 g $plant^{-1}$ and 1.656 t fed^{-1} with treatment 20 m^3 compost with bio-inoculation (Org_2+Bio) for pervious parameters, respectively.

Table 3: Effect of compost, K-release bacteria, K-treatments as SOP or feldspar with foliar K and their interactions on potato growth, yield and its components (Average of two growing seasons).

Characteristics / Treatments		Shoot fresh weight (g $plant^{-1}$)	Plant height (cm)	Shoot dry weight (t fed^{-1})	Tuber yield (kg $plant^{-1}$)	Average weight of tuber (g)	Tuber yield (t fed^{-1})
		At 90 days		At harvest			
Organic ± Bio-fertilizer treatments							
Org_1		297^{c}	42.17^{c}	1.485^{c}	0.880^{b}	179^{c}	15.376^{b}
Org_1+Bio		301^{c}	46.17^{b}	1.505^{c}	0.915^{ab}	193^{b}	15.622^{b}
Org_2		325^{b}	47.75^{a}	1.627^{b}	0.925^{a}	198^{ab}	16.179^{a}
Org_2+Bio		331^{a}	48.50^{a}	1.656^{a}	0.938^{a}	207^{a}	16.404^{a}
LSD at 5%		4.8	1.12	0.024	0.008	9.14	0.288
K-treatments							
K1		289^{c}	47.33^{b}	1.446^{c}	0.932^{a}	196^{a}	16.150^{a}
K2		314^{b}	49.75^{a}	1.570^{b}	0.933^{a}	198^{a}	16.169^{a}
K3		323^{a}	44.25^{c}	1.617^{a}	0.918^{a}	198^{a}	15.825^{b}
K4		328^{a}	43.25^{c}	1.640^{a}	0.874^{c}	184^{b}	15.437^{c}
LSD at 5%		6.7	1.05	0.034	0.009	9.78	0.244
Interaction effects							
Org_1	K1	284	42.67	1.422	0.923	185	15.710
	K2	299	45.33	1.497	0.920	184	15.693
	K3	303	40.33	1.515	0.902	180	15.243
	K4	301	40.33	1.507	0.773	168	14.857
Org_1 + Bio	K1	285	47.00	1.423	0.925	196	15.803
	K2	295	48.67	1.477	0.927	199	15.890
	K3	300	45.00	1.500	0.913	198	15.577
	K4	324	44.00	1.620	0.893	179	15.217
Org_2	K1	290	49.33	1.448	0.933	201	16.403
	K2	326	52.00	1.630	0.936	201	16.397
	K3	346	45.33	1.730	0.920	203	16.160
	K4	340	44.33	1.698	0.910	189	15.757
Org_2 + Bio	K1	298	50.33	1.490	0.947	205	16.683
	K2	335	53.00	1.675	0.950	210	16.697
	K3	344	46.33	1.722	0.937	213	16.320
	K4	347	44.33	1.737	0.920	201	15.917
LSD at 5%		13.5	ns	0.068	0.019	Ns	ns

Org_1= 10 m^3 compost fed^{-1}; Org_2= 20 m^3 compost fed^{-1}; Bio= inoculation by K-release bacteria;
K1= 96 kg K_2O fed^{-1}; K2= 48 kg K_2O fed^{-1} + 1 % K_2O foliar; K3= 48 kg K_2O fed^{-1} as feldspar + 1% K_2O foliar; K4= 24 kg K_2O fed^{-1} as feldspar + 1% K_2O foliar.

Concerning the effect of interaction between compost levels with or without KRB and different K treatments, data show that interactions have significant effects on shoot fresh weight per plant and shoot dry weight per fed., and insignificant effect on plant height. The values of plant height, shoot fresh and dry weight were higher under interaction Org_2+Bio*K than other interactions. These results are in accordance with El-Sayed *et al.,* (2014).

Potato yield and its components:

Data in Table 3 indicated that addition of K-treatments have a significant effect on tuber yield/plant, average tuber weight and total tuber yield (t. fed^{-1}). However, no significant differences in average tuber weight, tuber yield $plant^{-1}$ or tuber yield fed^{-1} were detected between the RK and K2 (48 kg K_2O as SOP + foliar 1% K_2O), while these parameters were significantly reduced by using FDS instead of SOP compared with RK with 2% and 4.4 % reduction in tuber yield fed^{-1} due to K3 and K4 respectively. Also, applying of 24 kg K_2O fed^{-1} as FDS+ foliar 1% K_2O recorded significant reduction in average tuber weight by about 6 % compared with RK. This effect may be attributed to the slow released K from FDS with insufficient available K for potato growth. These results are in accordance with those of Gomaa (2007), El-Dissoky (2008) and Singh and Lal (2012) who found that tuber yield responded significantly to foliar spray of 1%K_2O with soil application of 24, 36 and 48kg K_2O fed^{-1}.

Also, data show that increasing compost level application from 10 to 20 m^3 fed^{-1} significantly increased tuber yield per feddan by about 5 % with or without inoculation, and average tuber weight by 10.6 % and 7.2 % with and without bio-fertilization, respectively, and tuber yield per plant by 5.1 % and 2.5 % with and without bio-fertilization, respectively with no significant effect for the bio-fertilizer on tuber yield. The highest value of tuber yield per feddans was 16.404 t. fed^{-1} at treatment Org_2+Bio. These results may be due to the positive effects of compost as organic fertilizer on physical and chemical properties of the sandy soil that considers poor in organic matter (as shown in Table 1), in addition to the role of K-release bacteria and its effect on biological properties of sandy soil under study which reflected on the tuber yield. These results are in harmony with those of El-Sayed *et al.,* (2014).

Data also reveal that the effect of interaction among the studied treatments was significant for plant tuber yield only, and insignificant for average tuber weight and total tuber yield. The highest values were recorded with the inoculated composted plots (20 m^3 fed^{-1}) combined with soil application of half recommended K-rate as SOP along with foliar spray of 1 % K_2O. The highest tuber yield was 16.697 t. fed^{-1} with interaction Org_2+Bio*K2 and was on bar with that of the RK (K1) showing that 50% of RK could be saved by using this interaction. These results are agreeable with those obtained by Gomaa (2007), Abo El-Khair *et al.,* (2009) and Shehata *et al.,* (2014).

2- Tubers Quality:

As shown in Table 4, data illustrate that foliar addition of 1 % K_2O with 50 % soil addition of recommended K as SOP or feldspar have significant effects on the studied parameters of tuber quality except reducing sugar % which was insignificantly affected. It is obvious that values of tuber quality parameters were superior under K2 (50 % of Rd-K as SOP+ 1 % K_2O foliar) and K3 (50 % of Rd-K as feldspar+ 1 % K_2O foliar) compared with control with no significant difference between the two treatments. Since the values of tuber quality that recorded under K2 and K3 were 19.0 and 19.08 % for dry matter % (DM), 1.086 and 1.091 for specific gravity (SG) and 12.93 and 13.0 % for starch % (St), respectively. Generally, tuber quality improved with increasing DM%, SG, St% and carbohydrate %, and decreased with increasing reducing sugar %. The positive effect of addition K-rates on tuber quality is in accordance with Labib *et al.,* (2012).

Table 4: Effect of compost, K-release bacteria, K-treatments as SOP or feldspar with foliar K and their interactions on tuber quality parameters (Average of two growing seasons).

Treatments		Dry matter %	Specific gravity	Starch %	Carbohydrate %	Reducing sugar %	Protein %
Organic ± Bio-fertilizer treatments							
Org_1		17.89[b]	1.079[b]	11.94[b]	77.13[ab]	2.76[a]	14.73[b]
Org_1 + Bio		19.38[a]	1.089[a]	13.27[a]	77.99[a]	2.78[a]	14.32[c]
Org_2		18.97[a]	1.090[a]	12.90[a]	76.18[c]	2.66[a]	14.95[ab]
Org_2 + Bio		19.18[a]	1.091[a]	13.09[a]	76.76[bc]	2.77[a]	15.29[a]
LSD at 5%		0.66	0.006	0.59	0.94	ns	0.35
K-treatments							
K1		18.42[b]	1.084[c]	12.41[b]	76.83[b]	2.75[a]	14.62[b]
K2		19.00[a]	1.086[bc]	12.93[a]	78.14[a]	2.80[a]	15.40[a]
K3		19.08[a]	1.091[a]	13.00[a]	76.88[b]	2.68[a]	14.86[b]
K4		18.92[a]	1.088[ab]	12.86[a]	76.21[b]	2.74[a]	14.41[b]
LSD at 5%		0.39	0.004	0.35	0.81	ns	0.52
Interaction effects							
Org_1	K1	16.95	1.066	11.10	76.47	2.81	14.96
	K2	18.71	1.074	12.67	78.03	2.99	16.07
	K3	17.36	1.089	11.47	76.87	2.47	14.11
	K4	18.52	1.086	12.51	77.17	2.78	13.79
Org_1 + Bio	K1	19.31	1.087	13.21	77.93	2.84	14.54
	K2	19.88	1.087	13.72	80.13	2.78	14.28
	K3	19.22	1.092	13.13	77.07	2.71	14.30
	K4	19.11	1.088	13.03	76.83	2.79	14.14
Org_2	K1	18.99	1.092	12.92	76.57	2.68	13.77
	K2	17.84	1.092	11.90	77.90	2.65	15.68
	K3	19.87	1.092	13.71	75.83	2.66	16.15
	K4	19.17	1.086	13.09	74.40	2.67	14.21
Org_2 + Bio	K1	18.42	1.090	12.41	76.33	2.68	15.21
	K2	19.56	1.092	13.43	76.50	2.78	15.59
	K3	19.87	1.090	13.71	77.77	2.87	14.88
	K4	18.87	1.092	12.82	76.43	2.73	15.49
LSD at 5%		0.79	0.008	0.70	1.62	Ns	1.04

Org_1= 10 m^3 compost fed^{-1}; Org_2= 20 m^3 compost fed^{-1}; Bio= inoculation by K-release bacteria; K1= 96 kg K_2O fed^{-1}; K2= 48 kg K_2O fed^{-1} + 1 % K_2O foliar; K3= 48 kg K_2O fed^{-1} as feldspar + 1% K_2O foliar; K4= 24 kg K_2O fed^{-1} as feldspar + 1% K_2O foliar.

Concerning the effect of compost along with Bio-inoculation by K release bacteria, it is obvious from the results in Table 4 that these treatments have significant effects on tuber quality parameters, except reducing sugar % which was insignificantly affected. Inoculation with K-release bacteria with addition of compost levels (Org_1 or Org_2) was more effective on DM, SG, St, carbohydrate % and protein %. This positive effect may be attributed to the effect of compost and Bio-inoculation on soil properties and plant growth, yield and consequently on tubers quality. These results are in agreement with Makaraviciute (2003) and El-Sayed *et al.,* (2014).

Also, data in the same table indicate that the effect of interaction among Org ± Bio and K-treatments was significant on DM, SG, St%, Ch% and protein %, but insignificant on reducing sugar %. The interactions of Org_1+Bio*K2, Org_2+Bio*K2 and Org_2+Bio*K3 were superior in its effects on mostly of tuber quality parameters. This effect may be attributed to the integration effect that happened through organic manure (compost) effect, beneficial effect of K-release bacteria and the important role of K in plant growth. Similar observations were obtained by Ali (2006) and Abo El-Khair *et al.,* (2009) who found that inoculation with *B. circulans* in the presence of K-sources (K-sulfate and feldspar) increased potato tuber content of carbohydrate and soluble sugars.

3- N, P and K uptake in tubers:

Data in Table 5 show that application of 50 % RDK as SOP or feldspar with foliar spray of 1 % K_2O have significant effect on N and K-uptake and insignificant effect on P-uptake. The highest values of N, P and K uptake were recorded under K2 (50 % of RK as SOP + 1 % K_2O foliar) and K3 (50 % of RK as feldspar + 1 % K_2O foliar). The significant effect of soil combined with foliar K application as K-sulfate or feldspar on K-uptake may be related to the important role of K in plant especially in tubers where K is a high consumption element for potato (AL-Moshileh and Errebi, 2004). These results are in accordance with those obtained by Ali (2006), Gomaa (2007).

Also, data in the same table reveal that increasing level of compost from 10 to 20 m^3 fed^{-1} with or without Bio-fertilizer have significant effects on N, P and K-uptake in tuber, where the highest values of N, P and K-uptake were 91.7, 8.19 and 81.2 kg fed^{-1} respectively with Org_2+ Bio (20 m^3 compost fed^{-1}+ Bio). This significant effect of compost and bio-fertilizer may be return to the integration effect of organic manure (compost) and bio-fertilizer that reflected on availability of N, P and K in soil and its content of these nutrients especially K, which reflected consequently on its uptake by plants (Abo El-Khair *et al.,* 2009 and El-Sayed 2014). In addition to this, it is well known that many organic compounds produced by microorganisms, such as acetate, citrate and oxalate which can increase mineral dissolution rate (Welch and Ullman, 1993), also microorganisms produced growth promoting substance, which increase plant growth, then tuber yield, nutrient uptake and quality of tuber (Abou Hussein *et al.,* 2002).

Regarding the effect of interaction on N, P and K-uptake, Data presented in Table 5 illustrate that N and K-uptake were significantly affected by interaction between compost with or without K-release bacteria and different treatments of K application, while P-uptake was insignificantly affected. It is obvious from those results that all values of N, P and K-uptake in tubers were higher under interactions among Org_2+Bio and K-treatments (K1, K2, K3 and K4), since the superiority was for interactions Org_2+Bio*K2 and Org_2+Bio*K3. These results may be due to integration effect between compost and K-release bacteria (*B. circulans*) and K-sources (K-sulfate and feldspar) on soil, which reflected on soil physical, chemical and biological properties and availability of

N, P and K, and consequently on plant growth and its uptake of NPK and other nutrients, also it is related with the effect of Bio-inoculation in increasing release of K on soil (Abo El-Khair *et al.,* 2009 and Shehata *et al.,* 2014).

Table 5: Effect of compost, K-release bacteria, K-treatments as SOP or feldspar with foliar K and their interactions on N, P and K uptake in tuber yield (Average of two growing seasons).

Treatments		N-uptake (kg fed^{-1})	P-uptake (kg fed^{-1})	K-uptake (kg fed^{-1})
Organic ± Bio-fertilizer treatments				
Org_1		77.3^{c}	6.67^{b}	65.1^{c}
Org_1+Bio		82.6^{bc}	7.78^{a}	75.9^{b}
Org_2		87.4^{ab}	7.73^{a}	78.4^{ab}
Org_2+Bio		91.7^{a}	8.19^{a}	81.2^{a}
LSD at 5%		5.9	0.49	3.95
K-treatments				
K1		82.8^{bc}	7.59^{ab}	74.4^{b}
K2		90.1^{a}	7.93^{a}	77.2^{a}
K3		85.9^{ab}	7.71^{ab}	77.2^{a}
K4		80.3^{c}	7.15^{b}	72.0^{c}
LSD at 5%		4.36	ns	2.22
Interaction effects				
Org_1	K1	75.9	6.77	63.4
	K2	89.8	7.42	69.6
	K3	71.1	6.34	62.4
	K4	72.3	6.15	65.1
Org_1 + Bio	K1	84.7	7.72	74.7
	K2	85.9	8.49	81.5
	K3	81.6	7.60	75.5
	K4	78.3	7.31	72.0
Org_2	K1	81.7	8.00	80.1
	K2	87.4	7.29	73.6
	K3	98.9	8.39	84.4
	K4	81.8	7.23	75.5
Org_2 + Bio	K1	89.0	7.86	79.3
	K2	97.1	8.50	84.0
	K3	91.9	8.49	86.4
	K4	88.6	7.92	75.2
LSD at 5%		8.72	ns	4.44

Org_1= 10 m^3 compost fed^{-1}; Org_2= 20 m^3 compost fed^{-1}; Bio= inoculation by K-release bacteria;
K1= 96 kg K_2O fed^{-1}; K2= 48 kg K_2O fed^{-1} + 1 % K_2O foliar; K3= 48 kg K_2O fed^{-1} as feldspar + 1% K_2O foliar; K4= 24 kg K_2O fed^{-1} as feldspar + 1% K_2O foliar.

4- Economic Evaluation:

Data in Table 6 show total costs (TC), gross return (GR), net return (NR) and investment factor (IF) for potato tuber yield at different treatments. In this study, it would be pointed out to inputs and outputs as follows:

1- The inputs were as follows:
   - L.E. 5600 for ton of SOP (280 L.E/50 kg).
   - L.E. 350 for ton of feldspar.
   - L.E. 160 for m^3 of compost.
   - L.E. 50 for labor/day.
   - L.E. 320 for K-foliar (3 times).
   - L.E.10000 Constant costs (the costs of seeds, super phosphate fertilizer, ammonium nitrate fertilizer and any other practices).

2- The outputs were: L.E. 1500, for ton of potato.

Data in Table 6 and Fig. 1 illustrate the effect of K-treatments on NR and IF. Results show that values of NR and total tubers yield were the highest under K2, while K3 recorded the highest IF. As for NR, the descending order of K treatments effect was as follows K2 > K3 > K1 > K4, and for IF K3 > K2 = K4 > K1, but the arrangement for total tubers yield was K2 > K1 > K3 > K4. Soil application of 50 % of K-recommended as K-sulfate or feldspar with foliar spray (3 times) with 1% K_2O (K2 and K3) recorded the highest values of NR (10859 and 10835 L.E) and of IF (1.81 and 1.84), respectively.

Table 6: Economic evaluation of different treatments on total potato tuber yield (Average of two growing seasons).

Treatments		Potato yield (t fed^{-1})	Org-Cost	Bio-Cost	K-foliar Cost	K-applied Cost	Lab-ors Cost	Cons-tant costs	TC (L.E)	GR (L.E)	NR (L.E)	IF
Org_1	K1	15.71	1600	0	0	1120	100	10000	12820	23565	10745	1.84
	K2	15.69	1600	0	320	560	100	10000	12580	23540	10960	1.87
	K3	15.24	1600	0	320	168	0	10000	12088	22865	10777	1.89
	K4	14.86	1600	0	320	84	0	10000	12004	22285	10281	1.86
Org_1 + Bio	K1	15.80	1600	30	0	1120	100	10000	12850	23705	10855	1.84
	K2	15.89	1600	30	320	560	100	10000	12610	23835	11225	1.89
	K3	15.58	1600	30	320	168	0	10000	12118	23365	11247	1.93
	K4	15.22	1600	30	320	84	0	10000	12034	22825	10791	1.90
rg_2	K1	16.40	3200	0	0	1120	100	10000	14420	24605	10185	1.71
	K2	16.40	3200	0	320	560	100	10000	14180	24595	10415	1.73
	K3	16.16	3200	0	320	168	0	10000	13688	24240	10552	1.77
	K4	15.76	3200	0	320	84	0	10000	13604	23635	10031	1.74
Org_2 + Bio	K1	16.68	3200	30	0	1120	100	10000	14450	25025	10575	1.73
	K2	16.70	3200	30	320	560	100	10000	14210	25045	10835	1.76
	K3	16.32	3200	30	320	168	0	10000	13718	24480	10762	1.78
	K4	15.92	3200	30	320	84	0	10000	13634	23875	10241	1.75

Means	Mean of Org ± Bio treaments				Mean of K-treatments			
	Org_1	Org_1 + Bio	Org_2	Org_2 + Bio	K1	K2	K3	K4
NR	10691	11030	10296	10603	10590	10859	10835	10336
IF	1.86	1.89	1.74	1.76	1.78	1.81	1.84	1.81

Org_1= 10 m^3 compost fed^{-1}; Org_2= 20 m^3 compost fed^{-1}; Bio = inoculation by K-release bacteria;
K1= 96 kg K_2O fed^{-1}; K2= 48 kg K_2O fed^{-1} + 1 % K_2O foliar; K3= 48 kg K_2O fed^{-1} as feldspar + 1% K_2O foliar; K4= 24 kg K_2O fed^{-1} as feldspar + 1% K_2O foliar.

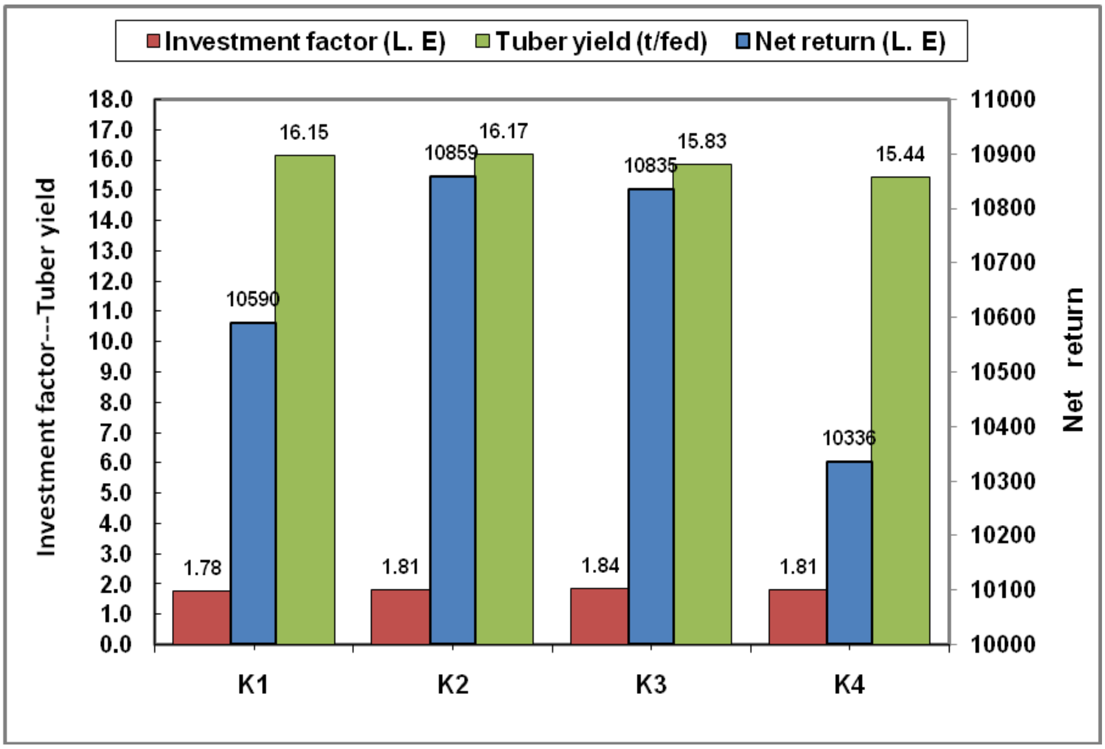

Fig. 1: Influence of K-treatments on tuber yield, net return and investment factor.

As for the effect of organic fertilization data in Table 6 and Fig. 2 reveal that NR and IF values were affected positively by addition of compost levels with or without inoculation with K-release bacteria. As treatments order for NR and IF, they were Org_1+Bio > Org_1 > Org_2+Bio > Org_2, while for total tubers yield, it was Org_2+Bio > Org_2 > Org_1+Bio > Org_1. The highest value of NR and IF was 11030 L.E and 1.89 with application of compost level 10 m^3 (6.5 t fed^{-1}) with inoculation by K-release bacteria (Org_1+Bio).

Regarding the interactions effect (as shown in Fig. 3), it is clear that the effect of interaction among compost levels with or without inoculation by K-release bacteria and K-treatments on NR and IF was positive, where their values were higher under interaction Org_1*K than Org_2*K, and under interaction Org_1+Bio*K than Org_2+Bio*K. The superiority was for interaction of Org_1+Bio*K-treatments. The highest values of NR was 11225 and 11247 L.E fed^{-1} with interactions Org_1+Bio*K2 and Org_1+Bio*K3 with IF 1.89 and 1.93 (the highest IF), respectively. Generally, all treatments fulfilled reasonable profitability where IF values were more than 1, so it could be considered that the superiority was for interaction of Org_1+Bio with K2 or K3 treatment. These results are accordance with those obtained by El-Sirafy *et al.,* (2008).

Finally from the previous results, it can be noticed that application of 50 % of recommended K (48 kg K_2O fed^{-1}) as SOP or as feldspar with foliar spray of 1 % K_2O (K2 and K3) was superior on the most of plant growth parameters, total yield and its components, parameters of tuber quality, NPK-uptake and economic evaluation (NR and IF), as well as compost levels with inoculation with K-release bacteria comparing with traditional K-fertilization (K1: 96 kg K_2O fed^{-1}). These may be attributed to that K-treatments K2 (50% of Rd-K as SOP+ 1% K_2O foliar) and K3 (50% of Rd-K as feldspar+ 1% K_2O foliar) were more efficient on supplying plants at the period of growth until harvest with the highest K-utilization efficiency and with the lowest losses of K-applied through leaching (El-Sirafy *et al.,* 2008, Singh and Lal, 2012 and Labib *et al.,* 2012). Application of K-treatments K2 and K3 gave the longest period for plants to uptake its requirements' of K that agree with every stage of plant growth comparing with traditional K-fertilization K1 (addition of K-recommended doses as soil application, which is more likelihood to be lost through leaching with irrigation water). Application of K as feldspar increase continuous supply of K in sandy soil without risk of undesired increase in the soil solution concentration or losses due to leaching, and increase sustainability soil fertility of K (Shehata, *et al.,* 2014). Also, K-treatments K2 and K3 can save about 50 % of K-recommended. In addition to this, the economic return of K2 and K3 comparing with K1 were high, where K-sulfate fertilizer as export fertilizer is high expensive (arrange from 5600-6000 L.E/t) compare with natural sources as feldspar, which needs an activator to release K, that by addition compost and inoculation with bio-fertilizer that contains K-release bacteria "*Bacillus circulans*". Application of compost and K-release bacteria also affected chemical, physical and biological properties of experimental sandy soil, which reflected on plants growth, tuber yield and its quality and the uptake of NPK (Abo El-Khair *et al.,* 2009, El-Sayed *et al.,* 2014 and Shehata *et al.,* 2014). It is well known that microbes can enhance mineral dissolution rate by products that interact with the mineral surface such as carbonic acid, acetate, citrate and oxalate in addition to growth promoting substances (Welch and Ullman, 1993).

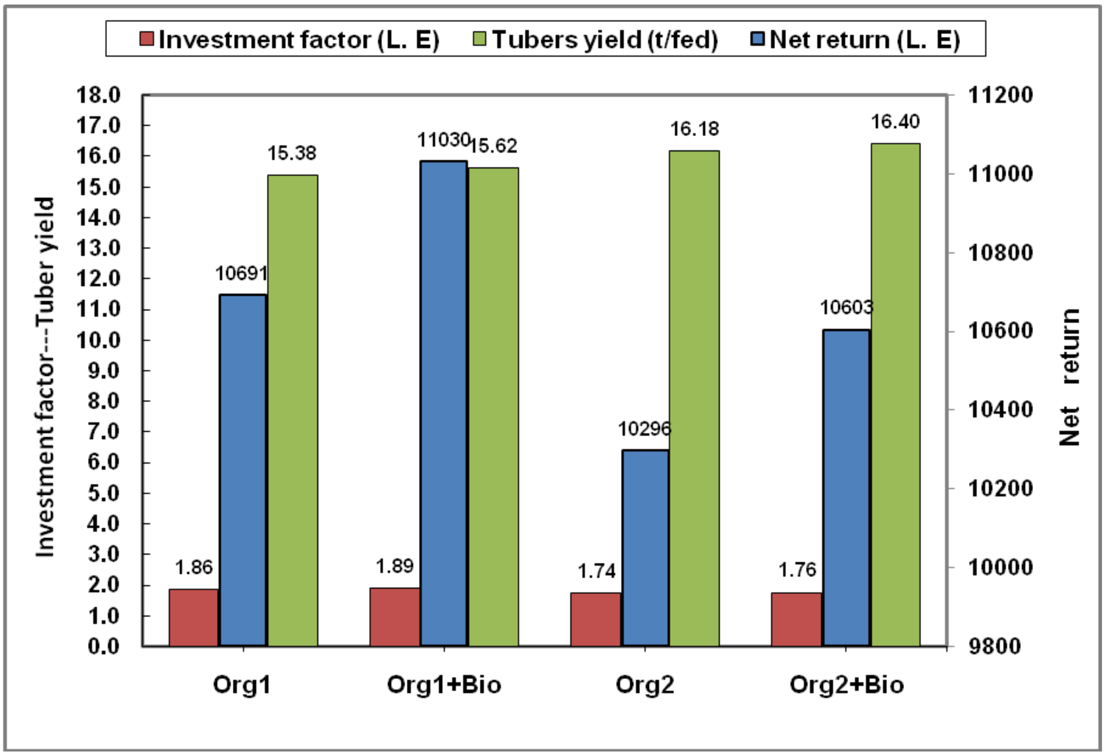

Fig. 2: Influence of compost levels ± Bio-fertilizer on tuber yield, net return and investment factor.

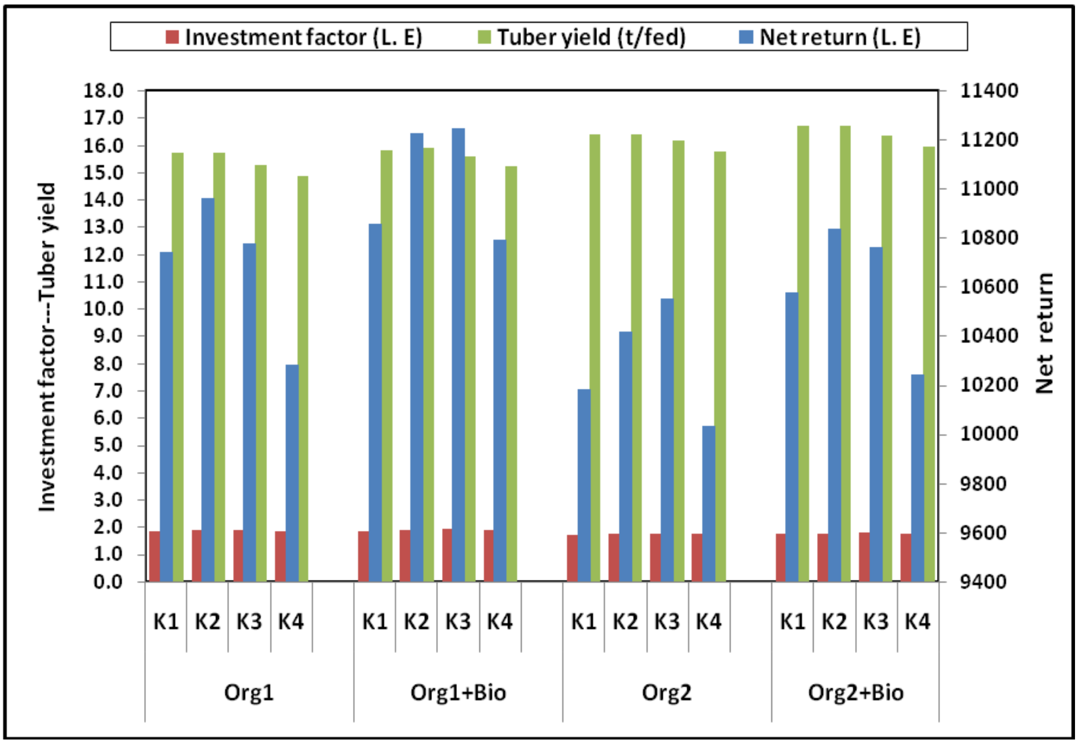

Fig. 3: Influence of interactions on tuber yield, net return and investment factor.

In conclusion; The present study recommends applying 10 m^3 compost fed^{-1} with inoculation with bio-fertilizer that contains strains of K-release bacteria (*Bacillus circulans*) + soil addition of 48 kg K_2O fed^{-1} as K-sulfate or feldspar + foliar spray of 1 % K_2O (3 times) in addition to the recommended doses of N (150 kg N fed^{-1}) and P (75 kg P_2O_5 fed^{-1}) are necessary to reach optimum yield of potato with high quality and maximum profitability under the same conditions of the studied sandy soil.

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تأثير التسميد البوتاسي والكمبوست والتلقيح الحيوي علي تحسين إنتاجية وجودة وربحية محصول البطاطس النامي في الأرض الرملية

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الملخص العربى

أصبحت إدارة المغذيات من الأهمية بمكان للحصول على المحصول الأمثل ذو الربحية العظمي، لذا أجريت تجربتان حقليتان كقطع منشقة بأرض رملية بقرية الشعراوي بمنطقة البستان – النوبارية – محافظة البحيرة – مصر (الواقعة بين خط عرض 30° – 43´ – 22.01" شمالاً وخط طول 30° – 13´ – 44.50 " شرقاً) خلال موسمي النمو الشتويين لعامي 2014 و 2015علي محصول البطاطس– صنف اسبونتا وذلك لتقييم تأثير التسميد العضوي عند معدلين 10 و 20 م3 كمبوست للفدان مع أو بدون التلقيح الحيوي بالبكتريا الميسرة للبوتاسيوم "*Bacillus circulans*" والتسميد البوتاسي عند أربع معاملات مختلفة (K1: 96 كجم K_2O للفدان ؛ K2: 48 كجم K_2O كسلفات بوتاسيوم للفدان + رش 1% K_2O ؛ K3: 48 كجم K_2O كفلدسبار للفدان + رش 1% K_2O ؛ K4: 24 كجم K_2O كفلدسبار للفدان + رش 1% K_2O) والتفاعل بينهما علي محصول البطاطس ومكوناته وجودته والممتص من النتروجين والفوسفور والبوتاسيوم بواسطة محصول الدرنات والعائد الاقتصادي لكل معاملة.

- أشارت النتائج إلي أن إضافة معاملات التسميد البوتاسيوم المختلفة سواء في صورة سلفات بوتاسيوم أو فلدسبار مع الرش الورقي بي 1% K_2O أثر معنويا على كل من الوزن الطازج والجاف للعرش ومحصول الدرنات الكلي والوزن النوعي للدرنة ونسب كل من النشا والكربوهيدرات في الدرنة وكذلك الممتص من النتروجين والبوتاسيوم.
- زادت قيم كل من قياسات النمو، محصول البطاطس الكلي، ونسب المادة الجافة والنشا والكربوهيدرات في الدرنة والوزن النوعي للدرنة والممتص من النتروجين والفوسفور والبوتاسيوم مع زيادة معدل إضافة الكمبوست إلي 20 متر مكعب للفدان و التلقيح بالبكتريا الميسرة للبوتاسيوم.
- حقق التفاعل بين مستوي الكمبوست 20 متر مكعب للفدان + البكتريا الميسرة للبوتاسيوم والتسميد البوتاسي عند K2 (48 كجم K_2O كسلفات بوتاسيوم للفدان + رش 1% K_2O) أعلي القيم لكل من محصول الدرنات الكلي (16,697 طن/فدان) والممتص من النتروجين والفوسفور والبوتاسيوم، في حين حقق التفاعل بين كلا من مستويي الكمبوست +البكتريا الميسرة للبوتاسيوم ومعاملا التسميد البوتاسي K2 و K3 (48 كجم K_2O كفلدسبار + رش 1% K_2O) أعلي القيم لقياسات الجودة.
- بالنسبة للتقييم الاقتصادي المعاملات على المحصول، أشارت النتائج أن كلا من معاملات التسميد البوتاسي K2 و K3 كانتا الأكثر تفوقا بالنسبة للعائد الاقتصادي ومعامل الربحية، هذا وقد حقق التفاعل بين مستوى الكمبوست 10 متر مكعب للفدان مع التلقيح بالبكتريا الميسرة للبوتاسيوم ومستويي التسميد البوتاسي K3 أعلي عائد اقتصادي (11247 جنية مصري) وأعلي معامل ربحي (1,93).

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