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Promoting effect of potassium solubilizing bacteria (*Bacillus cereus*) on nutrients availability and yield of potato

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Abstract

A field experiment was carried out during 2017/18 – 2018/19 seasons at the agricultural experimental farm, Faculty of agricultural, Al-Azhar University, Assiut, Egypt, in a randomized complete block design (RCBD) with three replicates. This study aims to assess the performance of bio-fertilization (*Bacillus cereus*) as potassium solubilizing bacteria (KSB) on the growth of potato tuber and availability of N, P and K as well as soil peering potassium additives. The results showed that the application of bio fertilizer significantly increased plant height (PH), branches number (BN), tuber weight and potato yield by about 14, 27, and 11%, respectively, compared to the untreated one. The N, P, and K uptake were significantly increased in the plants inoculated with Bacillus cereus compared to the un-inoculated plants. Nitrogen, phosphorus and potassium use efficiency values increased by 50 % over the untreated plants to for all tested nutrients. An increasing in the graded weights of potato for large (17.71%), medium (3.62%) and small size (19.95%) of tubers and the total yield (11.19%) increment compared to the untreated plots. Also, Nitrogen, phosphorus and potassium use efficiency values increased by 50 % over the untreated plants to for all tested nutrients.

Keywords: bio-fertilizer, potato yield, nutrient availability, uptake.

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1. Introduction

Potato (*Solanum tuber sum* L.) is one of the world's major staple crops after rice, wheat and maize due to its nifty yield potential and high nutritious value (Kumar *et al*., 2012). It is contain 70-82% water,17-29% dry matter, 11-23% carbohydrate, 0.8-3% protein, 0.1% fat, and 1.1% minerals as well as it has rich source of starch, vitamin C, and B which leads to being the food of future (Khurana and Naik, 2003; Myers, 2011). Also, it occupied about 9 million ha and its production is about 365 million tons (FAO, 2014). In Egypt, the cultivated area of potato crop in 2010 was about 335 thousand feddans (feddan = 0.420 hectares = 1.037 acres) (Abdallah *et al*., 2015). In last decades, bio-fertilizers have been used in increasing crop production to supply it with nutrients; stimulate plant growth through the production of plant hormones; inhibit the activity of plant pathogens; improve soil structure; bioaccumulation or microbial leaching of inorganics (Brierley, 1985; Davison, 1988; Ehrlich, 1990). *Pseudomonas* and *Bacillus* which known as potassium solubilizing bacteria (KSB) in silicate form play an important role in case of potassium (Nurali *et al*., 2005) and its application is useful at growth of different plants (Xiao *et al*., 2017).It is suggested as a solution for improve plant nutritive; enzyme activation, maintaining cell turgor; transportation of sugars and starches; improving crop quality; increasing resistance against stress condition such as pests and diseases, reduce nitrate and nitrite contents of potato tubers (Abou-Hussein *et al*., 2002; Meena *et al*., 2014). Moreover, KSB plays an essential role in improving soil fertility; production, and reduce the amount of chemical fertilizers (Zhang *et al*., 2013). Bio-fertilizers are applied to the soil or plant in order to reduce the uses of chemical fertilizers (Bojórquez *et al*., 2010). However, continuous and excessive use of chemical fertilizers cause health and environmental hazards, deterioration in soil properties and consequently crop shortages. Therefore, using different microbial strains as bio fertilizers has led to a decrease in the use of chemical fertilizers and has provided high quality goods free of agrochemicals harmful and safety for human consumption (El Naim *et al*., 2017). An increase in some growth parameters such as plant weight, number of large tubers, and total tubers was recorded as a result of the addition of bio-fertilizers individually or in combination with organic and inorganic amendments (Singh *et al*., 2017). Furthermore, the application of bio-fertilizer supports the conditions of root growth, increase the growth, and finally improve the biological functions of the plant (El-Azab and Camilia, 2018). There is a lack of information on the use of bio-fertilizers such as potassium solubilizing bacteria in potato production as substitute for the use of chemical fertilization to be free of chemicals. So, the current study aims to investigate the effect of bio-fertilization on the growth and potato yield as well as soil bearing potassium.

2. Materials and methods

2.1 Field experiment

The present study was carried out during the seasons of 2017/18 (30 September) and 2018/19 (1^{st} October) at the agricultural experimental farm, Faculty of agricultural, Al-Azhar university, Assiut, Egypt, which is located at 27^{o} 12^{-} $16.67^{=}$ N latitude and 31^{o} 09^{-} $36.86^{=}$ E longitude. The tested bio-fertilizer **(***Bacillus cereus* as potassium solubilizing bacteria) was obtained from the National Research Center, Giza, Egypt. These bacteria were added after the emergence of potato plants and once again after one week to guarantee their function. The experimental plot has an area of $10.5m^2$ (3m width ×3.5m length). According to the Egyptian Ministry of Agriculture and Land Reclamation, super-phosphate (15.5% P_2O_5) was added at a rate of 75 Kg P/ fed during land preparation. Nitrogen fertilizer (urea, 46% N) at a rate of 120 kg N/ fed was divided into three equal doses and was added at 30, 60 and 90 days after planting. Each plot received a mixture sources of feldspar, filter mud cake and potassium sulfate at the time of nitrogen fertilization (each source was about 24 kg K/ fed).Plant samples were collected at harvest stage (30^{th} January 2018 and 1^{st}February 2019) and the growth parameters (plant height, branches number, fresh weight and yield weight) were recorded. The collected samples were cleaned, washed with tap and distilled water, air dried, and then oven dried at 70˚C until constant weight, ground and stored for chemical analysis. Some physiochemical properties of the cultivated soil were listed in Table (1).

Table (1): Some physical and chemical properties of cultivated soil

Properties	Units	Value
Sand	(g kg^{-1})	535
Silt	(g kg^{-1})	223
Clay	(g kg^{-1})	242
Texture	-----	Sandy clay loam
CaCO3	(g kg^{-1})	14
pH (1:2.5)	------	8.04
EC (1:1)	(dS m^{-1})	1.4
Organic matter	(g kg^{-1})	13.8
Total N	(mg kg^{-1})	300
Total P	(mg kg^{-1})	297
Total K	(mg kg^{-1})	394
Available N	(mg kg^{-1})	53
Available P (Olsen)	(mg kg^{-1})	8.5
Available K	(mg kg^{-1})	92.6

Each value represents a mean of three replicates.

2.2 Soil and plant analysis

Particle-size distribution was carried out by using the pipette method according to (Jackson, 1973). The soil pH was measured in 1:2.5 (Soil: water) suspension and the electrical conductivity (EC) was measured in 1:1 extract (Jackson, 1973). Soil organic matter was determined by wet oxidation method by $K_2Cr_2O_7$ 1N and H_2SO_4 (Baruah and Barthakur, 1997). Total and Available nitrogen was measured according to Jackson (1973). The available phosphorus was measured according to Olsen *et al*. (1954). The available potassium was measured by flame photometer (Jackson, 1973). Total phosphorus was measured in the soil samples by digestion using 20 ml of a mixture of 7:3 ratio of sulfuric to perchloric acids. Total calcium carbonate was determined by Collin's calcimeter according to Nelson (1982). Dried grounded plant material of 0.2 g was digested using 10 mL of a mixture of 7: 3 ratio of sulfuric to perchloric acids (Jackson, 1973). Total nitrogen, phosphorus and potassium were measured according to Jackson (1973). Use efficiency of applied nitrogen (UEN), phosphorus (UEP) and potassium (UEK) were calculated using the following equation: tubers yield of the treatments (kg/fed) – tubers yield of the control (kg/fed)/ N, P and K applied level (kg/fed.

3. Results and Discussion

3.1 Growth and potato tubers yield

Data in Figure (1) show some growth parameters of potato plants at full blooming stage. The bio-fertilization significantly (P<0.05) increased the plant high (PH) and branches number (BN). The increases were 14.00and 26.86 % for the PH and BN, respectively above the control. These results are in agreement with those of many investigators who reported that the bio-fertilization increased potato growth (Abdel-Salam and Shams, 2012; Anjanadevi *et al*., 2016). These increases in vegetative growth might be due to the increases in the soil microbial flora that could solubilize potassium from the feldspar with continues supply of k which lead to enhance plant grow this a result of bio-fertilization (Parmar and Sindhu, 2013; Zaki *et al*., 2012). However, the results suggested that the inoculation with *Bacillus cereus* resulted in increases in the dry weight content by about 24.21 % above the control. This might be due to early growth which facilitates the plant to attain maximum dry weight content (Kabir, 2014). This result was similar with that reported by Mahamud *et al*. (2015). Moreover, the results recorded a total yield of 16.67 ton/fed with 11.19 % increment compared to the untreated plots. Similar results were pointed out by Abdel-Salam and Shams (2012) and Labib *et al*. (2012) on potato, Abd-El-Hakeem and Fekry (2014) on sweet potato. The increases in the total yield of potato crop may be due to the promotion of nutrients uptake and enhancement of plant growth through its ability to produce plant hormones as a result of inoculation with *Bacillus circulars* (Youssef *et al*., 2010).

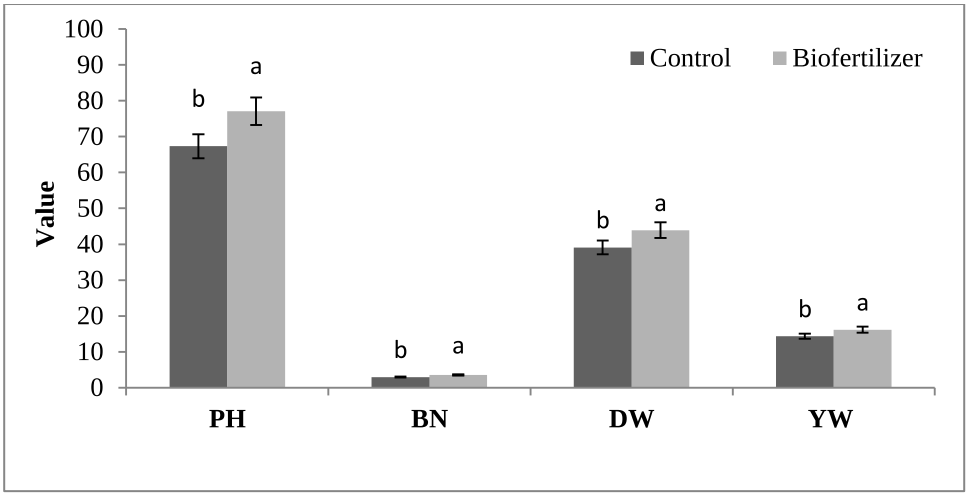

Figure (1): Effect of bio fertilizer on the growth parameter of potato plants as average of both seasons. PH= plant high (cm), BN= branches number /plant, DW=dray weight (g tuber^{-1}), YW= yield weight (ton/fed).Means denoted by different letters are significantly difference according to Duncan's test at P<0.05.

3.2 Nitrogen, phosphorus, and potassium concentration and their uptake by potato plants

The effect of bio-fertilization on the uptake of nitrogen (N), phosphorus (P) and potassium (K) are shown in Figure (2). The uptake of N, P, and K in potato plants were significantly (P<0.05) affected by bio-fertilizer application. The obtained results demonstrated that N, P, and K uptake increased by 34.28, 32.37 and 63.58 %, respectively, compared to untreated plots. Improving the availability of these nutrients may be through the production of organic acids and other chemicals, which stimulates plant growth and uptake of nutrients. Similar results were reported by Abdel-Salam and Shams (2012) and Labib *et al*. (2012) who found that the inoculation with *Bacillus circulans* on potato plants increased the uptake of N, P and K. Also, combined effect of potassium dissolving bacteria with K and P-bearing minerals on sorghum enhanced phosphorus uptake by 71 %, 110 % and 116 %, and K uptake by 41 %, 93 %, and 79 % in clay, sandy and calcareous soils, respectively (Badr *et al*. 2006). Inoculation with bio fertilizer (*Bacillus circulans*) could improve P and K and micro nutrients availability by producing organic acids and other chemicals, which stimulate growth and nutrients plant uptake (El kholy *et al*., 2012). The impact of bio-fertilization on the concentration of N, P, and K was investigated at harvest stage (Figure 3). The results demonstrated that the concentration of N, P, and K in potato plants significantly (P<0.05) increased by 7.39, 6.08 and 30.91%, respectively, as a result of using bio fertilizers. Similar results were reported by Prajapati *et al*. (2013) and Shehata *et al*. (2014) who found that the N, P, and K concentrations were high in okra plants due to using bio-fertilizer. These increases might be due to the high activity of potassium dissolving bacteria which shows their ability to live zone rhizosphere at high number in the presence of the feldspar rock and/or converting of the unavailable forms of mineral nutrient to available forms (Hassan *et al*., 2006; Kandeel and Sharaf, 2003).

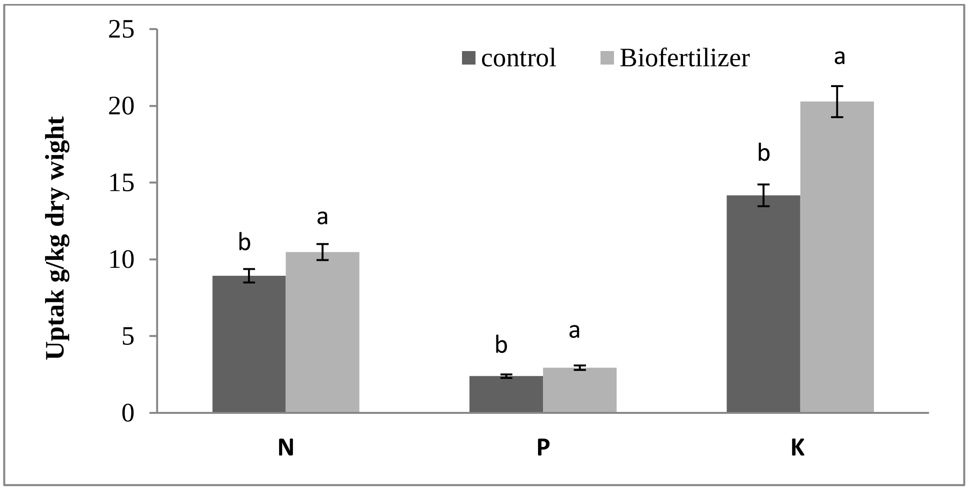

Figure (2): Effect of bio fertilizer on N, P and K uptake by potato plants as average of both seasons. Means denoted by different letters are significantly difference according to Duncan's test at P<0.05.

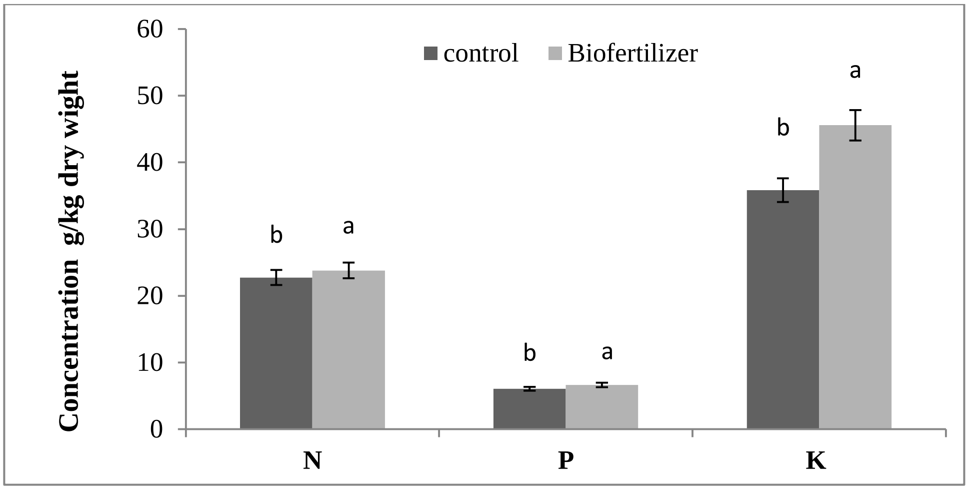

Figure (3): Effect of bio fertilizer on the concentration of N, P and K of potato tubers as average of both seasons. Means denoted by different letters are significantly difference according to Duncan's test at P<0.05.

3.3 Potato tubers graded

The graded weight of large, medium and small size tubers of potato plants were significantly (P<0.05) affected by bio-fertilizer application compared to the untreated one (Figure 4). The results clearly indicated that the graded weights of potato were increased by 17.71, 3.62 and 18.95 % for large, medium and small size of tubers, respectively as a result of applying bio-fertilizer. The increase in total yield and the graded weight of tubers may be due to the increase in the number of stems, the role of potassium on photosynthesis, translocation through phloem, and production of large molecular weight substances (such as starch) within storage organs, which contribute in the rapid size of the potato tubers (Abd El Gawad, 2009; Sharma and Sud, 2001).

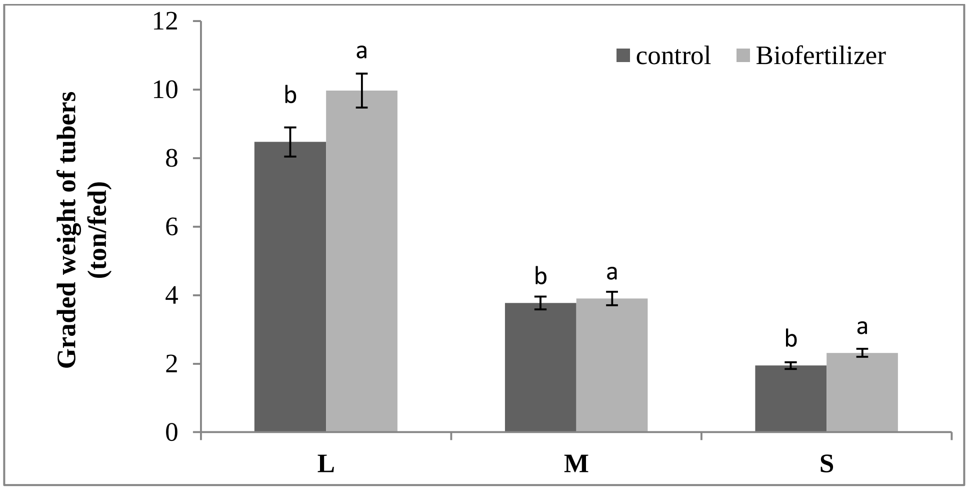

Figure (4): Effect of bio fertilizer on the graded weight of potato tubers as average of both seasons. L=Large Size (ton/fed), M= Medium Size (ton/fed), S= Small Size (ton/fed). Means denoted by different letters are significantly difference according to Duncan's test at $P<0.05$.

3.4 Soil properties

Some soil properties in relation to bio-fertilization are shown in Table (2). Inoculation with bio-fertilizers (*Bacillus cereus*) resulted in an increase in the soil reaction and organic matter by 1.97 and 6.10 %, respectively over the un-inculcated one. Similar results were reported by Lima *et al*. (2010) and Niewia domska (2013) who observed that potential of free-living bacteria to increase organic matter of soil due to increase the produce numerous bioactive substances in soil. Available of N, P and K was significantly ($P<0.05$) increased due to bio fertilizers treatments to reach 2.55, 2.96 and 40.11 %, respectively, compared to the untreated one. Similar results were obtained by Abou-el-Seoud and Abdel-Megeed (2012). The increasing of K availability may be due the K solubilization from feldspar and increased microbial activity in the rhizosphere of plants (Abou-el-Seoud and Abdel-Megeed, 2012). So, the partial break down of feldspar by AM-mycrrhizal fungi and *B. circulars* bacteria promote the release of nutrients (Massoud *et al*., 2009).

Table (2): Effect of bio fertilizer on some soil chemical properties (average of two seasons).

Variable	Control	Bio-fertilizer
pH (1:2.5)	8.00 b	8.16 a
EC (1:1) (dsm^{-1})	1.47 a	1.48 a
Organic matter (%)	1.52 b	1.62 a
Available N (mg kg^{-1})	77.92 b	79.91 a
Available P (mg kg^{-1})	8.55 b	8.80a
Available K (mg kg^{-1})	200.91 b	281.50 a

Means in the same row denoted by different letters are significantly difference according to Duncan's test at $P<0.05$.

3.5 Nutrients use efficiency

Nutrient use efficiency is a highly important concept for evaluating crop production systems. Nutrients use efficiency are considered as a function of the soil capacity to supply sufficient amount of nutrients and the ability of plants to uptake them (Baligar *et al*., 2001). Effect of bio-fertilizer application on nutrients use efficiency is shown in (Figure 5).

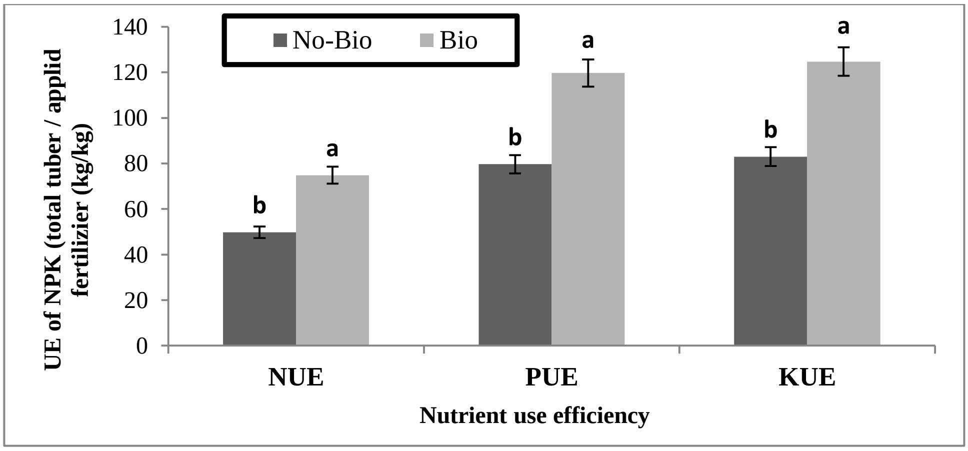

Figure (5). Effect of bio-fertilizers application on nutrients use efficiency. NUE= Nitrogen use efficiency, PUE= Phosphorus use efficiency and KUE= Potassium use efficiency.

Nitrogen, phosphorus and potassium use efficiency values increased by 50 % over the untreated plants to for all tested nutrients. The increases in the nutrient use efficiencies may be due to release these nutrients gradually by solubilizing bacteria and produced organic acids as a result of bio fertilizers application. This result in compatible with those obtained by Dawwam *et al*. (2013) who indicated that the use of potassium solubilizing bacteria as bio fertilizer was a sustainable solution to improve plant growth, nutrition, root growth, plant competitiveness due its role in solubilize rock–K mineral powder through production and excretion of organic acids or chelate silicon ions to bring K into solution which lead to increasing nutrient use efficiency.

4. Conclusions

The use of bio fertilization to reduce mineral fertilization and to obtain clean food has become a vital issue. The potassium solubilizing bacteria improved the growth parameters of potato plant than the untreated plants. Inoculation with Bacillus cereus bacteria resulted in a significant increase in the plant height and dry biomass as well as it increased the availability and NPK uptake. Moreover, the bio fertilizers increased the total yield and enhanced the graded weight of potato tubers. Nitrogen, phosphorus and potassium use efficiency values increased by 50 % over the untreated plants to for all tested nutrients. Therefore, we recommend using bio fertilization for potato plants to increase its production in an organic farming that enhance its opportunity for exporting.

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