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Impact of Bio and Mineral Fertilizers on Potato (*Solanum tuberosum* L.) Productivity and Quality

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ABSTRACT

A field experiment was implemented in 2017/2018 winter season in privet farm at Nabarouh city, El-Dakahlia Governorate under open field conditions (31°06′52.3″ N 31°17′43.8″E) to study the effect of biological and mineral fertilizers on the productivity and quality of potato (Solanum tuberosum L, cv. Spunta). The experimental design was split-plot design with three replicates. The main treatments were without bio-fertilizer(B_0) and with bio-fertilizer(B_1) while the sub-main treatment was mineral fertilization at rates of (control = without KP-mineral fertilizer(KP_0), 33%(KP_1), 66%(KP_2) and 100%(KP_3) of potassium and phosphorus fertilizer recommendation dose for potato. The obtained results were: Biological fertilization (B_1) gave the highest mean yield of fresh and dry weight, 15.72 and 2.86 ton.fed^{-1}, respectively compared with B_0. Whereas 100% PK-mineral fertilization (KP_3) gave the highest mean yield of fresh and dry weight which was 16.02 and 3.13 ton.fed^{-1}, respectively. In addition, the interaction treatment B_1KP_2 gave the highest mean yield of fresh and dry weight (17.15 and 3.43 ton.fed^{-1}). Also, KP_3 led to the highest percentage of N, P and K (%), they were 0.79, 0.276 and 1.89%, respectively. The interaction treatment of bio with 66% of mineral fertilizers (B_1KP_2) gave the highest significant increase of N, P and K% in potato tubers hence it may saving 34% of mineral fertilization. With regard to the quality parameters for potato, it was found that bio-fertilization (B_1) was the best treatment for the quality characteristics as well as 66% of the recommended fertilizers dose and there were insignificant differences between B_1KP_2 and B_1KP_3.

Keywords: Biofertilizers (phosphorin and Microbin), Mineral fertilization, Potato plant and Quality paramrter.

INTRODUCTION

Potato (*Solanum tuberosum L.*) is one of the most important vegetable crops in the world. It ranks fourth globally after wheat, corn and rice in terms of nutritional importance (Muthoni and Nyamango, 2009). Egypt ranks first in the Arab World and Africa in terms of potato production, with a cultivated area of 381,000 feddans with a production of 4113,000 tons (A.O.D.A., 2018). Potato is one of the most reliable commodities for solving the food problem. It is characterized by the relative abundance of feddan yields when compared to cereal crops. In addition, potatoes are grown in more than once a year.

Potatoes are a stressful crop of soils, as they require large quantities of nutrients (Abdel Salam and Shams, 2012), therefore the use of bio fertilizers which considered environmentally safe and no harmful fertilizers for humans and animals is a supportive technology for plant growth as well as vital stimuli that stimulate plant growth as well as the ability to improve plants absorption of nutrients and improve plant growth It also contributes to increasing plant production and improving its quality, as some of them increase the plants tolerance to extreme weather conditions.

The conventional use of mineral fertilizer can increase the tubers yield but inordinate use of nitrogen has a negative effect on tubers quality, environment pollution, public health and economical losses. So, the intense use of mineral fertilizers may reduce starch, dry matter and sugar contents in tubers and potatoes go bad more rapidly during the storage (Balemi, 2012).

The random use of fertilizers results in several fertilizer problems. Once the fertilizer is added, some problems start to appear, such as the loss of fertilizers in various ways, such as volatilization, washing and stabilization according to the prevailing cations and different soil properties. The high price of these fertilizers increases the cost of producing agricultural crops and thus the use of organic and bio fertilizers reduce these problems (Zaghloul, 2002).

Inoculation of potatoes with Plant Growth Promoting Rhizobacteria (PGPR) improves the qualities of growth, dry matter, carbohydrate content and thus potato productivity. These organisms also increase the availability of macronutrients in soil, improvement of the biological activity of the soil, increasing the binding of free nitrogen from the air, reducing the erosion and loss of nutrients. (Mayer *et al.*, 2008; and Mayer *et al.*, 2010).

It is well known that the application of potassium solubilizing bacteria (KSB) can be a promising technique to solubilize the K reserves from soil and make it available to the plants, resulting in promotion of plant growth and minimizing the application of K-fertilizers. K solubilization is carried out by a large number of bacteria such as B. *mucilaginosus*, B. *edaphicus*, B. circulans, *Pseudomonas*, *Burkholderia*, *Acidithiobacillus ferrooxidans*, and *Paenibacillus* spp. Previous researches well showed that KSB were able to dissolve K from different insoluble K bearing minerals by excreting organic acids. Among action mechanisms of KSB in making K available to plant,

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production of organic acids is major mechanism, which can either directly increase dissolution either by a proton- or ligand-mediated mechanism or they can also indirectly increase dissolution by the formation of complexes in solution with reaction products. Therefore, application of KSB as bio fertilizer not only enhance plant growth and yield but also can lessen the use of agrochemicals and support eco-friendly crop production. These technologies are becoming vital in modern day agricultural practices. The changing scenario of agricultural practices and environmental hazards associated with chemical fertilizers demands more significant role of bio fertilizers in coming years (Etesami *et al.,* 2017).

The use of phosphate solubilizing bacteria (PSB) as inoculants in soil increases the phosphorous uptake by the plants and also the crop yield. The ability of phosphate solubilizing bacteria to convert insoluble form of phosphorous into soluble one is an important trait in sustainable farming for increasing crops yield. Also, PSB play an important role in enhancing phosphorous availability to plants by lowering soil pH and by microbial production of organic acids and mineralization of organic P by acid phosphatases. These organisms besides providing P also facilitate the growth of plants by improving the uptake of nutrients and stimulating the production of some phytohormones. PSB have high potential as bio-fertilizers especially in P-deficient soils to enhance the growth and yield performance of crops (Awasthi *et al.,* 2011).

Several studies confirmed that bio-fertilizer increased the production of some vegetable crops, reduced the use of mineral fertilizer to 25-50%, and increased the yield of potato tubers by about 17%. The addition of organic fertilizers led to an increase in the crop, especially when adding quantities that meet the requirements of plants for nutrients, mainly the nitrogen component. Through the integrated fertilization between chemical, organic and biological species, it is possible to maintain soil productivity and ensure sustainable crop productivity (Datta *et al.,* 2009)

Biological fertilization contributed to the increase in the growth of plants, the amount of nitrogen in the leaves, the formation of root nodules, and the increase in the amount of nitrogen in the soil. The bacteria also contribute to increase the concentration of plant hormones in plants, which improve the growth of the root system, and thus increase their absorption of mineral elements and their accumulation in plants. The use of biological fertilization as a substitute for mineral fertilization also contributed to increase soil fertility and to improve the rate of plant growth and productivity, moreover raising its content of mineral elements NPK as well as its contribution to improving other soil properties (Wu *et al.,* 2005)

When adding bio fertilizers to the potato plant, they gave taller plants and tubers of greater average weight (Mbouobda *et al.,* 2014) and contributed to increasing plant height and plant biomass as well as improving root growth (Javaid and Mahmood 2010 and javaid, 2011)

Due to the fact that potato plants need large quantities of nutrients (Abdel Salam and Shams, 2012), and because of the high prices of mineral fertilizers and their transportation costs, the focus in recent years has been towards the use of biological fertilizers as they are inexpensive nutrients sources, as they work to fix nitrogen by using soil inoculation with bacterial strains as well as they working as a stimulant for plant growth, which constitutes a positive role in increasing the rate of growth and quantity of production and improving the quality of tubers. So, the main objective of this research is initiated to test the effect of organic and bio-fertilizer on potato plant productivity. Furthermore, it was hoped that the results may lead to reduce the use of chemical fertilizers under field condition.

MATERIALS AND METHODS

A field experiment was carried out at privet farm at Nabarouh city, El-Dakahlia Governorate under open field conditions (31°06′52.3″ N 31°17′43.8″ E) during winter season at November, 2017 to investigate the effect of bio and mineral fertilizers on potato plant (Solanum tuberosum L, cv. Spunta). Before planting, the main physical and chemical properties of the experimental soil were determined in the surface (0-30 cm) samples collected from the experimental soil using the methods described by Kim, (1996); Page *et al.*, (1982) and Jackson (1973). The obtained data are illustrated in Table 1. The experiment area was divided into 8 sectors and each sector was divided into 3 experimental units. Cultivation was carried out at 1st November 2017 on rows with 2.90 m length and 0.70 m wide as well as leaving a distance of 30 cm between the experimental units and sectors for the purpose of preventing the transfer of fertilizers. Also, 0.25 m distance was leaving between each plant. Each experimental unit consists of five rows.

Table 1. Some characteristics of the experimental soil

pH in 1:2.5 soil paste	EC. dS.m^{-1} In 1:5 extract	Soluble anions meq.L^{-1}				Soluble cations, meq.L^{-1}				Particle size distribution %				Soil texture	OM. %	Available nutrients mg.kg^{-1}		
		Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	C.sand	F.sand	Silt	Clay			N	P	K
7.56	2.196	9.13	3.38	1.17	8.28	0.00	5.68	6.27	10.02	7.14	20.28	20.95	51.63	Clay	1.4	43.69	7.66	349.36

The experimental treatments include two factors. The first factor represents treatments of biological fertilizer, without bio (B_0) and with bio-fertilizer (B_1). The second factor represents the used mineral fertilizer, which was added in four rates (100%, 66%, 33% of PK fertilizer recommendation dose and control "without PK mineral fertilizer"). So, the experiment had 8 treatments which arranged within the experimental units in a split-plot design in three replicates. The area of each experimental unit was 15.95 m^2.

The used biological fertilizer was prepared in Microbiology Section, Soils, Water and Environment Research Institute, Agricultural Research Center, Giza, Egypt, which contain phosphorin and Microbin. The phosphorin inoculants contain *Bacillus megatherium* var. phosphaticum, and Microbin contains four bacterial species- *Azospirillum brasilienses, Azotobacter vienlandi*, *Bacillus megatherium* var. *phosphaticum* and *Pseudomonas aurantiaca*. The bio- fertilizer was added in one dose; Bio fertilizers were applied by dipping potato seed tubers in a suspension culture of bio fertilizers for about 60 min before sowing time. The seed tubers were planted in the field immediately after the incubation treatment.

Organic fertilizer (farmyard manure was obtained from the Experimental Research Farm of the Faculty of Agriculture, Mansoura University) was added before planting by two weeks, at a rate of 20 ton.fed^{-1}, (feddan=4200 m^2), where it was spread on the soil surface and mixed in the soil at depth of 20 cm. Organic fertilizer analysis were carried out according the methods described by Page *et al.,* (1982) and Black (1983). The obtained data are illustrated in Table 2. The NPK fertilizers recommended dose was 180 units N, 75 unit $P_2O_5$and 96 units K_2O. The source of phosphorus fertilizer was ordinary super phosphate (15.5% P_2O_5) which was applied before planting with adding organic fertilizer. The nitrogen fertilizer was added in three equal doses, 1st and 2nd was added as ammonium sulfate (20.5% N) after 3 and 6 weeks of planting, respectively, while the 3rd dose was applied after 60 days of planting in a form of ammonium nitrate (33.5% N),. The source of potassium fertilizer was potassium sulphate (48% K_2O) which added in two equal doses, 1st dose was added after 6 weeks of planting, while the 2nd dose was applied after 60 days of planting. The treatments of both P and K fertilization at their application times were carried out at the three rates of their recommendation under the ordinary cultivation practices such as irrigation, weed management etc., and were done according to the commercial potato production, recommended by Agriculture Ministry of Egypt.

Table 2. Some characteristics of organic fertilizer (FYM)

pH	EC dS.m^{-1}	Total nutrients %			OC	OM	C:N
in 1:10 suspension	In 1:10 extract	N	P	K	%	%	Ratio
6.1	4.90	2.2	0.86	2.1	44	35.4	20:1

At harvesting time (106 days after planting), tubers of each plot were collected at 14th of February, 2018. Fresh tuber yield for each plot was weighted and converted to kg.m^{-2} and kg.fed^{-1}. Tuber samples of each plot were taken to the laboratory to make some analysis such as, tuber quality dry matter content in tubers (%), the content (%) of crude protein, starch (%) and dry matter content. These samples were taken from each experimental plot and washed with tap water followed with distilled water and cut into slices; 100 grams were taken and dried in an electric oven at 70 ° C for 48 hours until a constant weight. The weight was calculated and the percentage of dry matter was calculated by dividing (the dry weight/the fresh weight) x100 (Haase, 2003). Crude protein content (%) was calculated as "multiplying total nitrogen percentage by 5.7 ". Starch (%) was calculated using the method described in Mane and Kadhim (2014) on dry matter basis as Starch %= 17.55+ (0.891 * (24.182-dry weight %)). Also, other determinations such as tubers content (%) of N, P and K which determined in the powder of tuber which digested with sulfuric and berchloric acids (Peterburgski, 1968), then were also measured using standard methods. Nitrogen was determined by Kildahl method mentioned by Black (1965), Phosphorous was determined spectro photometrically by the methods described by Cooper (1977) using ammonium molybdate and ascorbic acid. Potassium was determined by Jenway Flame photometer (Peterburgski, 1968). Nutrients uptake in tuber were calculated in kg.fed^{-1} by multiplying nutrients percentage by dry weight of tuber. Determination of total soluble solids (TSS, °brix) was measured by digital pocket refractometer in potato juice according to A.O.A.C. (1990)

The obtained data were subjected to analysis of variance (ANOVA) based to co-state software computer system program for statistics. LSD test value had been used to test differences between treatment means with 0.05 using Duncan's multiples range test for presentation of results as typically mentioned by Steel and Torrie (1984)

RESULTS AND DISCUSSION

Tuber yield

Data in Table 3 illustrated that total fresh yield of potato tuber was increased with addition of bio and mineral fertilizers. Bio fertilizers which contain phosphorin and Microbin (B_1) gave the highest mean fresh yield of potato's tuber (15.72 ton.fed^{-1}).

Table 3. Tuber fresh weight of potato (ton.fed^{-1}) as affected by additions of mineral and bio fertilizers.

Bio fertilizer treatments (B)	Minerals fertilizers rates				Means of bio fertilizer	LSD at 5% of bio-fertilizers treatments
	Control KP_0	33% KP KP_1	66% KP KP_2	100% KP KP_3		
Without bio B_0	12.41	13.42	14.65	15.19	13.93 b	**
With bio B_1	13.66	15.24	17.15	16.84	15.72 a	0.1847
Means of mineral fertilizer	13.05 d	14.33 c	15.90 b	16.02 a		
F test		**				
LSD at 5% in mineral fertilizers treatments		0.0589				
LSD at 5% for interaction between B*KP		**0.0417				

Also, it was obvious that, the applications of bio-fertilizers (B_1) resulted in a significant increase of tuber fresh weight by a percent of 11.39% over the control (B_0). This increase in fresh tuber yield may return to, the effect of bio-fertilizer which may improve the physical, chemical and biological properties of the soil. As well as to the role of inoculated microorganisms and phosphate-decomposing bacteria, as these organisms secrete growth stimulants such as auxins, gibberellins and cytokines, these growth regulators play an important role in stimulating plant growth and microbial activity, which is reflected in improving rhizo-sphere. These results are in harmony with those obtained by Ahmed *et al.,* (2009) and Mirdad (2010).

Also, increasing mineral fertilizer increased fresh tuber yield of potato, the treatment of 100% of PK mineral fertilization (KP_3) gave the highest significant increase in fresh tuber yield (16.02 ton.fed^{-1}) which increased by percentage of 22.76% over the control, whereas KP_2 increased by a percentage of 21.84%.

Concerning the interaction effect of bio and mineral fertilizers, it was significant in increasing tuber fresh weight of potato. The interaction between bio-fertilizer (B_1) in

combination with KP_2 gave the highest fresh tuber yield (17.15 ton.fed^{-1}) compared with other treatments, with an increase percent of 38.20% over the control treatment (without bio and KP-fertilizer). The increase in fresh tuber yield as a result of the addition of bio and mineral fertilization may be due to the availability of nutrients in the soil solution, and the ability of organic and bio fertilizers to secrete some hormones in addition to enzymes and vitamins, and this may explain the increase in tuber weight, this is what many researchers have found as Mir and Quadri, (2009) and El-Zehery (2019).

Data in Table 4 show that tuber dry weight yield (ton.fed^{-1}) of potato responded high significantly by applications of bio-fertilizers. The highest value was 2.863 ton.fed^{-1} which obtained with treatment of B_1 and gave an increase percent of 26.18% over the control (B_0=without bio fertilizers) treatment. Whereas increasing addition rate of mineral fertilizer (100%, 66%, 33% of PK fertilizer recommendation dose and control=without PK mineral fertilizer) gave significantly increase of potato tuber dry weight. The highest yield of tuber dry weight 3.133 ton.fed^{-1} was found with application of 100% recommended dose by a percent increase of 65.16% over the control (without KP fertilization). Also, combination KP_2 gave an increase percent by 53.51% over the control. KP_3 and KP_2 gave a close increase percent of tuber dry weight as illustrated in Table 4.

Table4. Tuber dry weight of potato (ton.fed^{-1}) as affected by additions of mineral and bio fertilizers.

Bio fertilizer treatments (B)	Minerals fertilizers rates				Means of bio fertilizer	LSD at 5% of bio-fertilizers treatments
	Control KP_0	33% KP KP_1	66% KP KP_2	100% KP KP_3		
Without bio B_0	1.753	2.047	2.397	2.879	2.269 b	**
With bio B_1	2.041	2.594	3.430	3.387	2.863 a	0.0197
Means of mineral fertilizer	1.897 d	2.320 c	2.913 b	3.133 a		
F test		**				
LSD at 5% in mineral fertilizers treatments		0.0263				
LSD at 5% for interaction between B*KP			**0.0456			

The interaction effect between bio and 66% mineral fertilizers (B_1KP_2) had a significant effect, the highest value of tuber dry weight was (3.430 ton.fed^{-1}) with an increase percent of 95.66 % over the control. This increase may be due to the fact that different fertilizers provided good conditions for plant growth and absorption of water and nutrients resulted from improving soil characteristics and increase their fertility and increase the nutrients availability and their absorption by plant roots and thus this reflects on increasing the average dry weight of tuber and increasing the yield. These results are consistent with those obtained with Zelalem *et al.* (2009); Najm *et al.* (2013); Shaheen *et al.* (2014) and El-Zehery (2019).

Nutrients content

Data in Table 5 show that application of bio-fertilizers (B_1) recorded a highly significant increase of N, P and K content (%) in potato tubers, where the increase percentage of these nutrient were by 5.88, 19.63 and 23.03%, respectively over the control (B_0) treatment. This may be due to the role of bio-fertilizer on the increase of the available amount of these nutrients, as well as to the role of organic fertilizers in improving some soil characteristics.

Table 5. Nutrients content (%) in potato's tubers as affected by additions of bio and mineral fertilizers.

Treatments	N %	P %	K %
Without bio B_0	0.68 b	0.214 b	1.52 b
With Bio B_1	0.72 a	0.256 a	1.87 a
F test	**	**	**
LSD at 5%	0.0095	0.0004	0.0251
Control (KP_0)	0.57 c	0.152 d	1.39 d
33% KP (KP_1)	0.63 b	0.239 c	1.64 c
66% KP (KP_2)	0.79 a	0.272 b	1.81 b
100% of KP (KP_3)	0.79 a	0.276 a	1.89 a
F test	**	**	**
LSD at 5%	0.0107	0.0010	0.0148
LSD at 5% for interaction between B*KP	**0.0262	** 0.0022	**0.0361

At the same time, increasing rate of added mineral fertilizers increased significantly the percentage of N, P and K in tubers, where the KP_3 gave increase percentage by 38.60, 81.58 and 35.97% for each nutrient respectively, over the control (without KP-fertilizers). Also, it could be obvious from Table 5 that KP_3 and KP_2 had a close results and effects. It is worthily to note that increasing mineral fertilizers may have led to an improvement in the characteristics of vegetative growth, which reflected in increasing the efficiency of the root system to absorb these nutrients and increase their concentration in the plant. This led to an increase in the efficiency of photosynthesis, which resulted in an increase in the amount of materials manufactured in leafs and their transportation and storage in the tubers as well, and then increasing the absorbed quantities of nitrogen, phosphorus and potassium.

The interaction effect between bio and mineral fertilizers gave significant increases of N, P and K content, the highest values of N% in potato tubers was 0.84% with B_1KP_2 as illustrated in Fig 1 with an increase rate by 50% over the control (without bio and KP fertilization, B_0KP_0). Also, the highest values of P% in potato tubers was 0.292% with B_1KP_2 as illustrated in Fig 2 with an increase rate by 175% over the control (B_0KP_0). Moreover, the highest values of K% in potato tubers was 2.06% with B_1KP_2 as illustrated in Fig 3 with an increase rate by 63% over the control (B_0KP_0). These results indicate that, the mineral fertilizer led to an increase in the absorbed nutrients (NPK) especially with the 75% of recommended dose of mineral fertilizers which can be attributed on the basis that the used mineral fertilizers are directly ready, whereas for the organic and bio fertilizer applications, although it is generally a slow-release fertilizer and also it needs a basic mineral dose to react with, but the quality of the added organic fertilizer decomposition which contains a ratio of carbon to nitrogen is ideal (18:1) as mentioned in Table 2, which resulted in release and availability of the nutrients, especially nitrogen , phosphorus and potassium, which it contains in a good concentration, and as for bio-fertilizer, it is fertilizer that contains nitrogen- fixing and potassium and phosphate-soluble organisms that can have important roles in

increasing the releasing as well as absorption of nutrients by improving root growth and secreting hormones and chelates. Similar results were obtained by Bottini *et al.*, (2004); Najm *et al.*, (2010); Ierna *et al.*, (2011); Eliwa *et al.*, (2012); Shaheen *et al.*, (2014) and El-Zehery (2019).

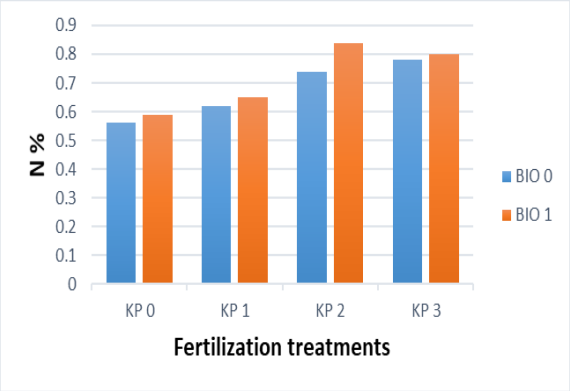

Fig. 1. Nitrogen percentage in tubers yield (%) as affected by additions of mineral and bio fertilizers treatments.

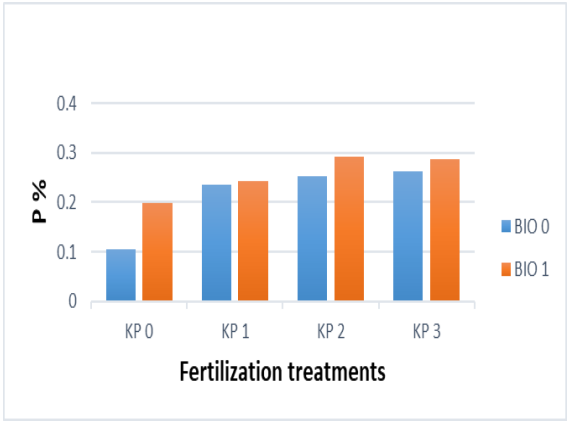

Fig. 2. Phosphorus percentage in tubers yield (%) as affected by additions of mineral and bio fertilizers treatments.

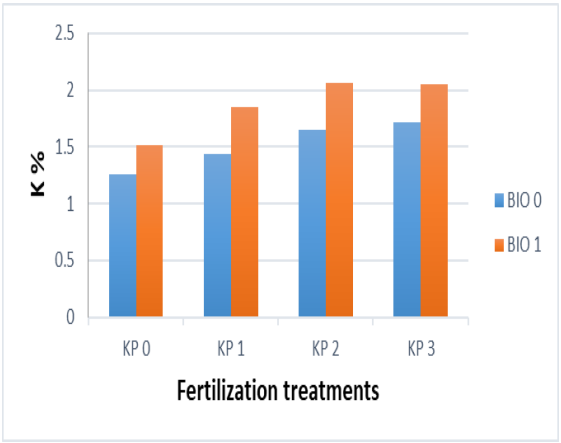

Fig. 3. Potassium percentage in tubers yield (%) as affected by additions of mineral and bio fertilizers treatments.

Nutrients uptake

Data in Table 6 show that there is a significant increase in the nutrients uptake as a result of adding bio and mineral fertilizers. Concerning bio fertilizers, N, P and K uptake were found that with the treatment of B_1 increased its uptake by 35.14%, 48.72 and 55.65% over the control (B_0), respectively.

Table 6. Nutrients uptake (kg.fed^{-1}) as affected by additions of bio and mineral fertilizers.

Treatments	N kg.fed^{-1}	P kg.fed^{-1}	K kg.fed^{-1}
Without bio B_0	15.68 b	5.07 b	35.20 b
With Bio B_1	21.19 a	7.54 a	54.79 a
F test	**	**	**
LSD at 5%	0.4096	0.0474	0.5519
Control (KP_0)	10.90 d	2.95 d	26.62 d
33% KP (KP_1)	14.70 c	5.57 c	38.70 c
66% KP (KP_2)	23.37 b	8.04 b	55.14 b
100% of KP (KP_3)	24.77 a	8.66 a	59.52 a
F test	**	**	**
LSD at 5%	0.2980	0.0698	0.5476
LSD at 5% for interaction between B*KP	**0.2308	**0.1209	**0.2860

With regard to mineral fertilizer rates it was found that with increasing mineral fertilizers nutrients (NPK) uptake of potato tuber increased significantly. The highest values of N, P and K uptake were 24.77, 8.66 and 59.52 kg.fed^{-1} respectively. The KP_3 was a superior treatment which gave an increase rate of 127.25, 193.56 and 123.59% with N, P and K uptake, respectively over the control (KP_0).

The interaction effect between bio and mineral fertilization gave significant increases effect on tubers uptake of N, P and K. The highest values of nitrogen uptake of potato was 28.93 kg N.fed^{-1} with the treatment of B_1KP_2 as illustrated in Fig 4 with an increase rate of 194.60% over the control (B_0KP_0). The highest values of P uptake of potato was 10.03 kg P.fed^{-1} with B_1KP_2 as illustrated in Fig 5 with an increase rate of 442.16% over the control (B_0KP_0). Moreover, the highest values of K uptake of potato tubers was 70.66 kg K.fed-1 with B_1KP_2 as illustrated in Fig 6 with an increase rate of 219.15% over the control (B_0KP_0). These findings reveal that, the interaction between mineral fertilizers and bio-fertilizers resulted in increased nutrient uptake (NPK), particularly under the influence of the interaction of mineral fertilizers with bio-fertilizers (B_1KP_2) at 75% of the recommended fertilizer dose. This effects could be owing to the influence of biological fertilization on increasing the viability and activity of nutrients in the soil, whether mineral fertilizers, available or fixed forms of the elements.

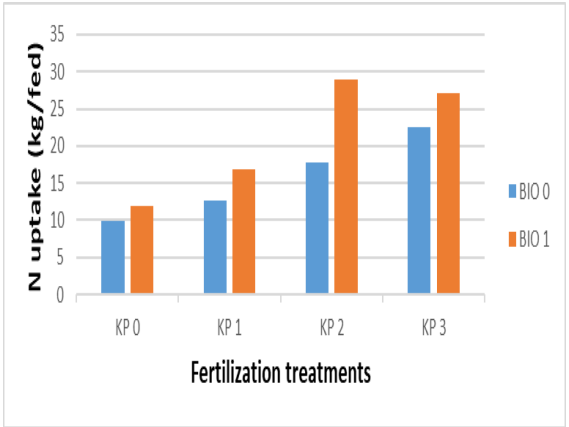

Fig. 4. Nitrogen uptake in tubers yield (kg.fed^{-1}) as affected by additions of mineral and bio fertilizers treatments.

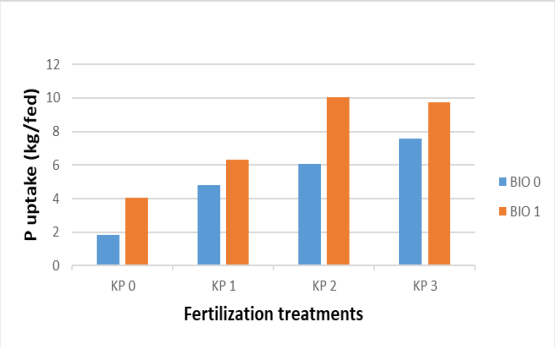

Fig. 5. Phosphorus uptake in tubers yield (kg.fed^{-1}) as affected by additions of mineral and bio fertilizers treatments.

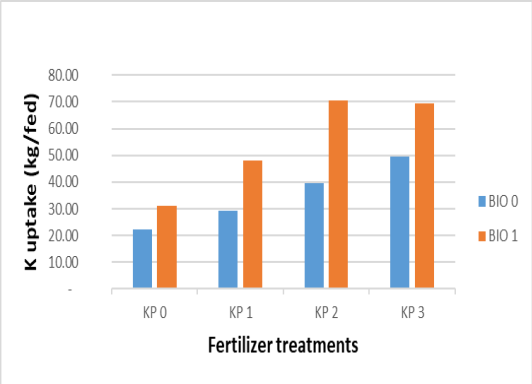

Fig. 6. Potassium uptake in tubers yield (kg.fed^{-1}) as affected by additions of mineral and bio fertilizers treatments.

In addition, bio-fertilizers not only promotes root growth and hormone secretion, but also serves to increase the releasing rate of available nutrients from organic matter added to the soil, which in turn thereby increasing dry matter yield in addition to the high efficiency in absorbing nutrients from the soil, thereby increasing the uptake of these nutrients. These results are consistent with those obtained by Bottini *et al.*, (2004); Najm *et al.* (2010); Ierna *et al.* (2011); Eliwa *et al.* (2012); Shaheen *et al.* (2014) and El-Zehery (2019).

Quality parameters

Quality parameters of potato tubers i.e. (TSS%, crude protein%, starch% and dry matter%) were stated and the found data were recorded in Table 7. These parameters were affected positively by the studied treatments of mineral and bio fertilizers, bio fertilizers (B_1) had a significant effect on the studied qualities of tubers compared to the control (B_0). The highest concentration (%) of total dissolved solids "TSS", crude protein, starch and dry matter in tubers of potato were 5.41, 4.10, 12.07 and 18.02% respectively which found with the treatment of B_1 recorded increases percentage of 11.09, 6.49, 15.95 and 11.51% over the control (B_0). Also, mineral fertilizers as the sub-main factor improved these tuber's qualities especially with applications of 100% of recommended dose PK_3. Recorded contents (%) of TSS, crude protein, starch and dry matter in tubers of potato of 5.70, 4.50, 13.41 and 19.53%, respectively gave an increase percentage of 33.49, 37.61, 49.83 and 34.60% over the control (PK_0). There was insignificant (difference) relation between KP_2 and KP_3 for the means of total dissolved solids (TSS) and protein%, while KP_3 had significant increase comparing with KP_2 for dry matter%, starch% in tuber.

Table 7. Some quality characters in potato's tubers as affected by additions of mineral and bio fertilizers.

Treatments	TSS %	Crude Protein%	Starch %	Dry matter%
Without bio B0	4.87 b	3.85 b	10.41 b	16.16 b
With Bio B1	5.41 a	4.10 a	12.07 a	18.02 a
F test	**	**	**	**
LSD at 5%	0.0949	0.0569	0.0879	0.0990
Control (KP0)	4.27 c	3.27 c	8.95 d	14.51 d
33% KP (KP1)	4.95 b	3.60 b	10.39 c	16.13 c
66% KP (KP2)	5.63 a	4.52 a	12.46 b	18.18 b
100% of KP (KP3)	5.70 a	4.50 a	13.41 a	19.53 a
F test	**	**	**	**
LSD at 5%	0.0938	0.0604	0.1514	0.1678
LSD at 5% for interaction between B*KP	**0.1148	**0.0854	**0.1236	**0.1098

The interaction effect between bio and mineral fertilization gave a significant increases effect on the quality parameters of tubers. The highest values (%) of TSS, protein, starch and dry matter, were 5.8, 4.81, 13.93 and 20.11%, respectively with an increase rate of 53.85, 50.78, 62.73 and 42.73, respectively over the control (B_0KP_0) as illustrated in Figs 7, 8, 9 and 10. Concerning TSS%, starch% and dry matter% there were insignificant differences between both B_1KP_2 and B_1KP_3 and they were very close, whereas with protein% there was significant difference and B_1KP_2 was the superior. There a strong relation between starch% and dry matter%, so the increase in the percentage of dry matter and starch in the tubers may be due to the role of added organic and bio fertilizers which forming a strong vegetative growth that has a role in increasing the carbohydrate and protein stored in the tubers. The increase in dry matter means an increase in total dissolved solids in the tubers. The increase in the amount of starch in the tubers is due to the high content of leaves from the phosphorous and potassium elements that contribute effectively to the starch composition as a reflection of efficiency of photosynthesis process.

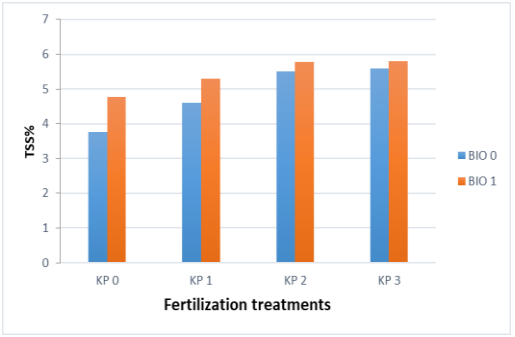

Fig. 7. Total dissolved solids (TSS) in tubers yield (%) as affected by additions of mineral and bio fertilizers treatments

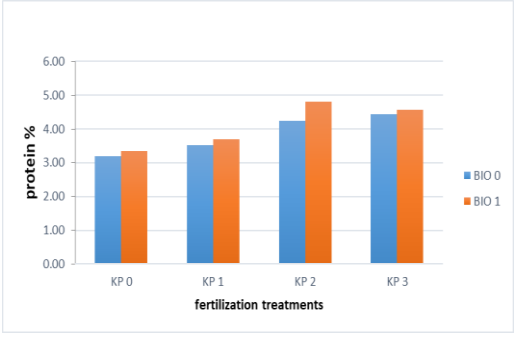

Fig.8. Protein in tubers yield (%) as affected by additions of mineral and bio fertilizers treatments.

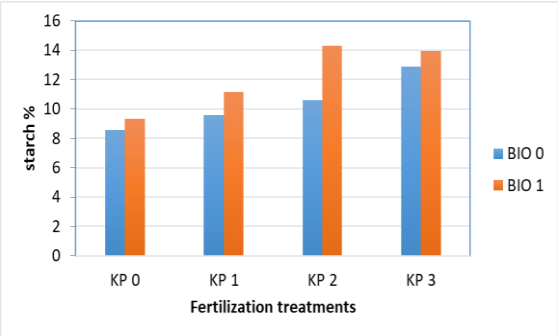

Fig. 9. Starch in tubers yield (%) as affected by additions of mineral and bio fertilizers treatments.

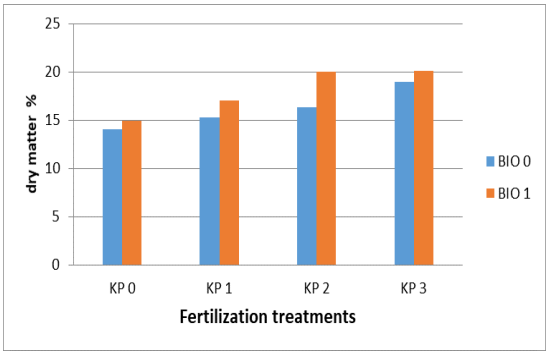

Fig. 10. Dry matter in tubers yield (%) as affected by additions of mineral and bio fertilizers treatments.

Also, the increase in the percentage of protein can be attributed to the availability of nutrients such as NPK and especially nitrogen which come from different sources for example organic and inorganic, nitrogen is directly involved in the synthesis of amino acids, which are the basic compounds for protein synthesis, while phosphorous enters into the synthesis of RNA and DNA, which directly affects protein synthesis, while potassium increases the efficiency of nitrogen absorption and hence increase in protein synthesis. These results are also in line with the findings documented by other investigators such as Erdogan *et al.* (2010); Ahmed *et al.* (2009); Yassen *et al*, (2011); Abdel Salam and Shams (2012); Mirshekari and Alipour (2013); Kim *et al.* (2003); Baddour (2014); Said *et al.* (2016) and El-Zehery (2019).

CONCLUSION

In general, the results indicate the possibility of partial compensation for mineral fertilizers by adopting bio fertilizers. Therefore, from the results of the current study, it is possible to conclude that it can obtain good crop quality and a good productivity of the potato crop by adopting an integrated joint fertilization between biological and mineral substances, and we could save about 30% of mineral fertilization relatively. The best treatment under experiment conditions was adding bio-fertilizer with 66% of the recommended dose of phosphorus and potassium, which led to increasing potato yield and saving about 34% of mineral fertilizers.

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تأثير التسميد الحيوي والمعدني علي انتاجيه وجوده البطاطس

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الملخص

تم تنفيذ تجربه حقليه في الموسم الشتوي٢٠١٧ /٢٠١٨ في مزرعة خاصة مدينة نبروة محافظه الدقهليه، مصر تحت ظروف حقلية مفتوحة , وموقعها الجغرافى ٣١° ٠٦′ ٥٢,٣ ″ شمالا، ٣١° ١٧′ ٤٣,٨ ″ شرقا وذلك لدراسه تأثير الأسمده الحيويه والمعدنيه علي انتاجيه وجوده نبات البطاطس (Solanum tuberosum L, cv. Spunta). وقد تم تصميم التجربه في قطع كامله العشوائيه في ثلاث مكررات حيث كانت المعامله الرئيسيه بدون حيوي B_0 ومع الأسمدة الحيوية B_1 بينما المعامله الشقيه هي التسميد المعدني بمعدلات (كنترول (KP_0) – ٣٣% (KP_1) -٦٦% KP_2 -١٠٠% KP_3 من التوصيه السماديه للفوسفور والبوتاسيوم لنبات البطاطس). وكانت النتائج المتحصل عليها : ادي التسميد الحيوى B_1 للحصول على اعلى متوسط للوزن الطازج والجاف لدرنات البطاطس وكانت القيم المتحصل عليها هي ١٥,٧٢ و٢,٨٦ طن/فدان علي الترتيب. كما ادي التسميد المعدنى ١٠٠% (KP_3) للحصول على اعلى متوسط للوزن الطازج والجاف لدرنات البطاطس وكانت القيم المتحصل عليها هي ١٦,٠٢و ٣,١٣ طن/فدان علي الترتيب. اضافة الى ذلك فإن معاملة التفاعل بين الحيوى والمعدنى B_1KP_2 أعطى أعلى متوسط محصول الوزن الطازج والجاف ١٧,١٥ و ٣,٤٣ طن/فدان علي الترتيب. بينما التسميد المعدني ١٠٠% من التوصيه السماديه ادت الي اعلى زياده في المحتوي من (%) النتروجين والفوسفور والبوتاسيوم في درنات البطاطس فكانت ٠,٧٩و ٠,٢٧٦ و١,٨٩% على الترتيب. كذلك فقد اعطت معاملة التفاعل بين الحيوى والمعدنى B_1KP_2 أعلى زيادة فى % للنيتروجين والفسفور والبوتاسيوم وبالتالي قد يوفر حوالى ٣٤٪ من التسميد المعدنى. و فيما يتعلق بمعايير الجودة لدرنات البطاطس ، وجد أنه كان تأثير التسميد الحيوي (B_1) الافضل بالنسبه لصفات الجوده بينما كان هناك اختلافات ضئيلة بين معاملات التفاعل B_1KP_2 و B_1KP_3 بالنسبه لصفات جوده البطاطس.