Zagazig J. Agric. Res., Vol. 46 No. (4) 2019 1089-1102

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

# EFFECT OF POTASSIUM SOURCES AND SOIL AMENDMENTS WITH SILICATE DISSOLVING BACTERIA ON AVAILABILITY OF POTASSIUM IN CLAYEY SOIL CULTIVATED WITH WHEAT PLANTS

**Basem H.A. El-Nahas*, S.M.M. Dahdouh, M.S.D. Abu-Hashim and A.M.A. Merwad**

Soils Sci. Dept., Fac. Agric., Zagazig Univ., Egypt

**Received: 16/06/2019; Accepted: 08/07/2019**

**ABSTRACT:** A pot experiment was conducted under greenhouse condition at the Experimental Farm, Faculty of Agriculture, Zagazig University, Egypt. The experiment aimed to study the effect of different potassium sources (potassium sulphate and potassium feldspar) at the recommended rate (40 mg K kg$^{-1}$) either single or in combination with soil amendments *i.e.,* farmyard manure (FYM) and sulfur (S) with or without silicate dissolving bacteria (SDB) on yield and nutrients uptake by wheat through the investigated clayey soil. Soil were taken from the surface layers (0-30 cm) from Hehia District, Sharkia Governorate, Egypt. Application of K-sulphate or K-feldspar as individual application or combined with different soil amendments under SDB gave increase in straw and grain yield, potassium uptake, biological yield, 1000 grain weight and protein content of wheat plants compared to untreated soil. The highest value for each of yield, K-uptake and available K was found in clayey soil treated with K-sulphate combined with FYM plus S in the presences of SDB, while the lowest ones were obtained with untreated soils in absence of soil amendments and SDB. Application of K-sulphate showed greater value in each of yield, protein content, K-uptake by wheat plants and soil available potassium than K-feldspar. Application of SDB to K-sulphate or K-feldspar increased yield, protein content, K-uptake of wheat and available potassium compared to the untreated ones.

**Key words:** K-sulphate, K-feldspar, silicate dissolving bacteria, soil amendments, wheat.

## INTRODUCTION

Potassium is one of the essential nutrients for plant growth. Potassium in a given soil is a reflection of the parent material of the soil. To increase the efficiency of fertilizers used in crop production, it is important to understand the relationships between soil nutrient reserves, soil texture and root growth. As a major constituent within all living cells, potassium is an essential nutrient and is required in large amounts by plants as its content in plant biomass is the second after nitrogen (**Römheld and Kirkby, 2010)**. Soil potassium content is a limiting factor for wheat growth, as it is one of the most important major elements for plant growth. Optimizing the use of K fertilization using natural amendments is growing up in parallel with accelerating increase in fertilizer prices. Feldspars are main source for K and are in many sedimentary rocks (**Wahba and Darwish, 2008; Hemasheenee *et al.,* 2017)**. Organic amendments are soil improving agents which can be applied to improve sandy soil and to obtain favorable structure and increase nutrients in soil (**Setiawati and Mutmainnah, 2016; Voelkner *et al.,* 2017**). Rock K materials are cheap sources of K, although, most are released slowly (**Sheng and Huang, 2002; Zapata and Roy, 2004).**

Silicat solubilizing bacteria are an aerobic which play a significant role in maintaining soil fertility by solubilizing in soluble K (**Setiawati and Mutmainnah, 2016**). They solubilize rock K, such as micas, illite and orthoclases (feldspar). **Bader *et al.* (2006)** found that the dry matter of sorghum plants inoculated with silicate dissolving bacteria and supplied with (feldspars) increased by 48%, 65% and 58% for clay, sandy and calcareous soil, respectively. Application of

***Corresponding author: Tel. :** +201062122315
**E-mail address:** basemelnahas@yahoo.com

K-feldspars combined with chicken manure in the presence of SDB gave the highest value for each of dry matter yield, nutrient uptake of wheat, biological yield, protein content and available potassium in sandy soil **(Merwad, 2017). Singh *et al.* (2019)** reported that the application of farmyard manure (FYM) combined with K fertilizers gave the highest value in each of stover and grains and nutrient uptake of maize plants as application of 50% K-sulphate + 50% K-feldspar **(Merwad, 2016)**. Application of 15 Mg ha.$^{-1}$ of FYM to soil increased straw and grain yield, biological yield, 1000 grain weight and K uptake of wheat (**Kavinder *et al.*, 2019**). **Holík *et al.* (2018)** found that FYM plus K-sulphate gave the highest yield, protein and K-uptake of wheat. **Merwad (2019)** showed that the application of K-feldapare combined with vermicompost with SDB gave the highest yield, protein content and nutrient of wheat plants.

The present work aims at evaluating the efficiency of potassium fertilizers (potassium sulphate and K-feldspar) with and without silicate dissolving bacteria (*Bacillus circullans*) on availability potassium, yield and potassium uptake of wheat plants grown on clayey soil condition.

## MATERIALS AND METHODS

A pot experiment was conducted under greenhouse condition at the Experimental Farm, Faculty of Agriculture, Zagazig University, Egypt. The experiment aimed to study the effect of different potassium sources (potassium sulphate and potassium feldspar) applied at the recommended rate (40 mg K kg$^{-1}$) individually or in combination with soil amendments *i.e.*, farmyard manure (FYM) and sulfur (S) with or without silicate dissolving bacteria (SDB) on yield and K-uptake by wheat (*Triticum aestivum* L., cv. Sakha 93) and soil available potassium.

Soil material for the experiment was collected from the surface layers (0-30 cm) of a field in Hehia District, Sharkia Governorate, Egypt. The soil was air dried for 5-6 days, crushed, sieved to passed through 2 mm plastic screen, thoroughly mixed and stored in plastic bags, for analysis and experimental work. Table 1 shows physical and chemical properties of the soils as determined according to **Piper (1950), Black *et al.* (1965) and Jackson (1973)**. Air dried soil equivalent 8 kg of dry soil was placed in plastic pots of internal dimentions 20 x 25 cm. The experiment was conducted in a randomized complete block factorial in the greenhouse of the Faculty of Agriculture, Zagazig University, Egypt. Three replicates of treated soil were performed.

The experiment involved 2 factors: factor 1: sources of K *i.e.* (1) none, (2) K-sulphat and (3) K-feldspar, (2) Amendments *i.e.* (FYM (3) S and (4) FYM+S. Thus the total treatment combinations are 12 (3 k source x 4 amendments).

Before planting, the treatments of potassium fertilizers as potassium sulphate (400 g K kg$^{-1}$) and potassium feldspar (94 g K kg$^{-1}$) were thoroughly mixed with the soil samples at a rate of 40 mg K kg$^{-1}$. Treatments of farmyard manure were mixed with the soil at a rate of 20 g kg.$^{-1}$. Elemental sulphur was added at a rate of 0.5 g kg$^{-1}$. Some characteristics of farmyard manure are shown in Table 2.

The silicate dissolving bacteria, (SDB), (*Bacillus circullans*) was obtained from the Microbiology Department, National Research Centre, Cairo, Egypt. The SDB was seed inoculated in a concentration of ($1\times10^{10}$ CFU ml$^{-1}$) at rate of 20 ml kg$^{-1}$ potassium sulphate or K-feldspar to mix with soil before planting and irrigated **(Badr *et al.*, 2006)**.

Twenty seeds of wheat (*Triticum aestivum* L, cv. Sakha 93) were seeded per pot. The pots were daily weighed and the soil moisture content was adjusted nearly the field capacity. After germination, plants were thinned to ten plants.

Mineral nitrogen was added as ammonium sulphate (205 g N kg$^{-1}$) at the rate of 100 mg N kg$^{-1}$ soil at three equal splits. The first dose was applied after planting (15 days) and the second and third doses were added at tillering (45 day) and booting (75 day) stages, respectively. The recommended dose of phosphorus was added as ordinary super phosphate (67.6 g P kg$^{-1}$) at the rate of 13 mg P kg$^{-1}$ soil before sowing. After germination, plants were thinned to ten plants/ pot. At harvest, Plant samples were dried at 70˚C for 72 hours, weighed, ground and analyzed

**Table 1. Some physical and chemical properties of the investigated soil**

| Soil characteristic | Value |
|---|---|
| **Soil particles distribution** | |
| Sand (%) | 20.56 |
| Silt (%) | 32.62 |
| Clay (%) | 46.82 |
| Textural class | clayey |
| Field capacity (FC) (%) | 23.2 |
| Organic matter,(g $kg^{-1}$) | 9.82 |
| pH (1:2.5) * | 7.92 |
| EC,( $dSm^{-1}$) ** | 0.72 |
| **Soluble ions, (mmolc $L^{-1}$)**** | |
| $Ca^{++}$ | 2.90 |
| $Mg^{++}$ | 1.73 |
| $Na^{+}$ | 1.20 |
| $K^{+}$ | 1.37 |
| $CO_3^{=}$ | - |
| $HCO_3^{-}$ | 3.52 |
| $Cl^{-}$ | 2.50 |
| $SO_4^{=}$ | 1.18 |
| **Available N, P and K (mg $kg^{-1}$soil )** | |
| Available N | 42.78 |
| Available P | 12.32 |
| Available K | 109 |

* * Suspension of 1:2.5 soil : water ** Soil paste extract

**Table 2. Characteristics of FYM**

| Characteristic | Value |
|---|---|
| **EC**, $dSm^{-1}$** | 2.02 |
| **pH*** | 7.06 |
| **organic matter (g $kg^{-1}$)** | 460 |
| **Total N (g $kg^{-1}$)** | 15.20 |
| **Total P (g $kg^{-1}$)** | 5.40 |
| **Total K (g $kg^{-1}$)** | 10.60 |
| **C/N ratio** | 11.11 |
| **Water holding capacity (WHC) (%)** | 150 |

*FYM-water suspension 1: 5 **FYM water extract 1: 10

for total potassium. Plants were separated into straw and grains. Yield and yield components were recorded. Protein percent "yield quality" in grains was calculated by multiplying N(%) × 5.70 (**Bishni and Hughes, 1979)**. Soil samples were taken after harvest where available potassium was determined. Available K: was extracted with ammonium acetate (pH, 7) and determined using flame photometer instrument using the method described by **Jackson (1973)**. The obtained data of plant parameters and soil were statistically analyzed (LSD at 0.05) according to the method described by **Russell (1991)**.

## RESULTS AND DISCUSSION

### Straw and Grain Dry Weight of Wheat Plants (g plant$^{-1}$) as Affected by Potassium Source, Soil Amendments and Silicate Dissolving Bacteria

The results given in Table 3 show the effect of applied potassium source, soil amendments and silicate dissolving bacteria on straw and grain dry weight of wheat plants (g plant$^{-1}$) grown on clayey soil. Application of various potassium fertilizers *i.e.,* potassium sulphate and potassium feldspar combined with soil amendments *i.e.* farmed manure (FYM) or sulphur (S) in the presences of silicate dissolving bacteria (SDB) gave increases in straw and grain dry weight of wheat plants compared to untreated. These results are similar to those reported by **Guo *et al.* (2019) and Mohamed *et al.* (2019)**. The highest straw and grain dry weight of wheat were obtained under application of K-sulphate combined with sulphur in the presences of SDB, while the lowest ones were obtained with untreated soils in absence of soil amendments and SDB. Combination of the farmyard manure with K-sulphate was to most effective to achieve high grain yields with good quality and leads to sustainable food production (**Holík *et al.*, 2018). Swetha *et al.* (2017)** showed that application of potassium at a rate of 60 kg ha$^{-1}$ combined with sulphur significantly increased the dry weight of leaves, shoot, root and seed yield of maize plants.

Regarding the impact of K-source addition, results indicated that the application of individual K-sulphate or combination with soil amendments and SDB gave higher values of straw and grain dry weight than K-feldspaar application. Similar results were obtained by **Merwad (2019). Singh *et al.* (2019)** reported that the application of FYM combined with potassium fertilizers gave the highest values of straw and grain yields of wheat plants in alluvial soil.

As for the average effect of soil amendments addition, the results showed that using FYM+ sulphur combined with different potassium fertilizers in the presences of SDB gave higher values than FYM or S application. This finding stands in well agreement with those of **Swetha *et al.* (2017)**. Sulfur is an essential element for all organisms since it is present in many molecules (amino acids, oligo peptides, vitamins and many secondary metabolites) and it is involved in several biochemical processes. Plants absorb S as sulfate ion ($SO_4^{2-}$) from soil solution and use it in key steps of their metabolism (**Rossini *et al.*, 2018)**. Under sulfur application, the fresh and dry weights of wheat significantly increased relative to the control treatment in alluvial soil (**Mohamed *et al.*, 2019)**. The application of 15 ton ha.$^{-1}$ of FYM to soil increased straw and grain yield of wheat plants (**Kavinder *et al.*, 2019)**.

Results showed that the addition of SDB increased grain yield compared to the untreated ones. These increases represent 9, 10, 7 and 5% in the case of different potassium fertilizers for untreated, FYM, S and FYM+S, respectively. These results are in agreement with those of **Bader (2006)** who found that the application of biofertilization as SDB on plants increased growth parameters and yield. Application of K-feldspar combined with chicken manure in the presence of SDB gave the highest values of dry matter yield of wheat (**Merwad, 2017)**. Potassium solubilizing bacteria is an aerobic bacteria which plays a significant role in maintaining soil structure by their contribution in the formation and stabilization of water-stable soil aggregates **(Khan *et al.*, 2018; Voelkner *et al.*, 2017; Etesami *et al.*, 2017; Guo *et al.*, 2019)**.

**Table 3. Dry weight of wheat plants (g plant$^{-1}$) as affected by potassium source, soil amendments and silicate dissolving bacteria in clayey soil**

| K-Source (A) | Soil amendment (B) | Straw | | | Grains | | |
|---|---|---|---|---|---|---|---|
| | | Silicate dissolving bacteria (C) | | | | | |
| | | Without | With | Mean | Without | With | Mean |
| **Effect of the interaction (A×B×C)** | | | | | | | |
| **Untreated** | Without | 2.09 | 2.33 | 2.21 | 1.52 | 1.82 | 1.97 |
| | FYM | 2.44 | 2.54 | 2.49 | 1.90 | 2.05 | 2.37 |
| | S | 2.62 | 2.70 | 2.66 | 2.27 | 2.47 | 2.59 |
| | FYM+S | 2.76 | 2.87 | 2.81 | 2.57 | 2.61 | 2.15 |
| | **Mean** | 2.48 | 2.61 | 2.54 | 2.07 | 2.24 | 2.24 |
| **K- Sulpahte** | Without | 2.42 | 2.58 | 2.50 | 2.20 | 2.28 | 2.56 |
| | FYM | 2.69 | 2.81 | 2.75 | 2.36 | 2.76 | 2.58 |
| | S | 2.98 | 3.26 | 3.12 | 2.50 | 2.66 | 2.97 |
| | FYM+S | 3.40 | 3.81 | 3.61 | 2.82 | 3.13 | 2.59 |
| | **Mean** | 2.87 | 3.11 | 2.99 | 2.47 | 2.71 | 2.09 |
| **K- Feldspar** | Without | 2.29 | 2.51 | 2.40 | 2.02 | 2.16 | 2.30 |
| | FYM | 2.62 | 2.73 | 2.67 | 2.25 | 2.35 | 2.54 |
| | S | 2.81 | 2.92 | 2.86 | 2.48 | 2.61 | 2.68 |
| | FYM+S | 3.22 | 3.49 | 3.35 | 2.65 | 2.72 | 1.97 |
| | **Mean** | 2.74 | 2.91 | 2.21 | 2.35 | 2.46 | 2.37 |
| **Effect B×C** | | | | | | | |
| Without | | 2.26 | 2.47 | 2.36 | 1.91 | 2.09 | 2.00 |
| FYM | | 2.59 | 2.69 | 2.64 | 2.17 | 2.39 | 2.28 |
| S | | 2.80 | 2.96 | 2.88 | 2.42 | 2.58 | 2.50 |
| FYM+S | | 3.13 | 3.39 | 3.26 | 2.68 | 2.82 | 2.75 |
| **Effect of SDB (C)** | | 2.70 | 2.88 | 2.58 | 2.30 | 2.47 | 2.23 |
| **LSD 0.05** | A | 0.037 | | | 0.079 | | |
| | B | 0.043 | | | 0.091 | | |
| | AB | 0.074 | | | 0.15 | | |
| | C | 0.030 | | | 0.15 | | |
| | AC | 0.053 | | | NS | | |
| | BC | 0.061 | | | 0.12 | | |
| | ABC | 0.105 | | | NS | | |

FYM: Farmyard manure ; S: Sulfur ; SDB: Silicate Dissolving Bacteria

## Potassium Uptake of Wheat Plants as Affected by Potassium Source, Soil Amendments and Silicate Dissolving Bacteria in Clayey Soil

The results given in Table 4 show the effect of applied potassium source, soil amendments and Silicate Dissolving Bacteria on potassium uptake of wheat plants (mg plant$^{-1}$) grown on alluvial soil. Application of various potassium fertilizers *i.e.* potassium sulphate and potassium feldspar combined with soil amendments *i.e.* farmyard manure (FYM) or sulphur (S) in the presences of Silicate Dissolving Bacteria (SDB) gave increases in K-uptake by straw and grain of wheat plants compared to untreated control. Similar results were obtained by **Merwad (2019)**. **Ortas (2018)** reported that the addition of K-fertilizer increased straw and grain K- uptake of maize plants.

The highest straw and grain K-uptake of wheat were obtained under application of K-sulphate combined with FYM plus sulphur in the presences of SDB, while the lowest ones were obtained with untreated soils in absence of soil amendments and SDB (**Rossini *et al.*, 2018; Kavinder *et al.*, 2019).** The application of FYM the soil helps in increasing the fertility of the soil as physical condition including its water holding capacity. Organic manures, which were perhaps the main sources of plant nutrients in traditional agriculture, receive less emphasis with the advent of high analysis chemical fertilizers (**Singh *et al.*, 2019).** The highest straw and grains K-uptake were obtained with K-feldspar plus Vermicompost in the presence of SDB **(Merwad, 2019). Holík *et al.* (2018)** found that the application of FYM plus K-sulphate gave the highest values of K-uptake of wheat plants.

Regarding the impact of K-source addition, results indicated that the application of individual K-sulphate or combination with soil amendments and SDB gave higher values of straw and grain K-uptake than K-feldspar application. Similar results were obtained by **Singh *et al.* (2019)** who found the nutrient contents as N, P and K in grain and straw of wheat enhanced significantly with the application of FYM at a rate of 10 ton ha$^{-1}$ and K-sulphate. From these result it may be referred that the beneficial effect of FYM is due to its contribution in supplying additional plant nutrients, improvement of soil physical, chemical and biological process in soil. Metabolites root activities increased resulting absorption of moisture and other nutrients enhanced resulting into higher production (**Kavinder *et al.*, 2019)**

Regarding the impact of K-source addition, the results showed that using K-sulphate with SDB under different soil amendments gave higher values than those under K-feldspar. Treatments under K sulphate gave higher values of straw and grain K-uptake than those under K-feldspar. These increases represent 28, 35, 33 and 20% of straw for the treatments of without, FYM, S and FM+S, respectively while the increases represent 24, 35, 28 and 35% of grain for the same treatments, respectively. Similar results were obtained by **El-Akhdar *et al.* (2018), Jamal and Fawad (2018) and Ortas (2018)**. Application of K-feldspar combined with chicken manure in the presence of SDB gave the highest K-uptake of wheat (**Merwad, 2017)**.

As for the average effect of soil amendments addition, the results showed that using FYM+ sulphur combined with different potassium fertilizers in the presences of SDB gave higher values of K-uptake than FYM or S application. This finding stands in well agreement with those of **Abdel-Salam and Shams (2012), Swetha *et al.* (2017) and Singh *et al.* (2019). Abdallah *et al.* (2013)** indicated that sulphur application to calcareous soil significantly increased of straw and grain K-uptake by wheat under different irrigation periods.

Results showed that the application of SDB to K-sulphate or K-feldspar increased straw and grain K-uptake of wheat compared to the untreated ones under application different soil amendments. These increases represent 17, 15 and 17% of straw for the treatments of untreated, K-sulphate and K-feldspar, respectively and 15, 16 and 14% of grain for the same treatments, respectively. These results are in agreement with those of **Sheng and Huang (2002) and Merwad (2019)**. This increasing was due to the fact that SDB releases organic acids which solubilize the insoluble rock K materials (**Abou El-Seoud and Abdel-Megeed, 2012)**. Similarly reported that the activity of Silicate Dissolving Bacteria

**Table 4. Potassium uptake of wheat plants (mg plant$^{-1}$) as affected by potassium source, soil amendments and Silicate Dissolving Bacteria in clayey soil**

| K-Source (A) | Soil amendment (B) | Straw | | | Grains | | |
|---|---|---|---|---|---|---|---|
| | | Silicate Dissolving Bacteria (C) | | | | | |
| | | Without | With | Mean | Without | With | Mean |
| **Effect of the interaction (A×B×C)** | | | | | | | |
| **Untreated** | Without | 13.31 | 17.32 | 15.31 | 13.26 | 17.48 | 15.37 |
| | FYM | 21.09 | 23.56 | 22.32 | 19.91 | 23.18 | 21.54 |
| | S | 27.94 | 34.38 | 31.16 | 29.25 | 33.68 | 31.46 |
| | FYM+S | 39.14 | 43.38 | 41.26 | 37.05 | 40.23 | 38.64 |
| | **Mean** | 25.37 | 29.66 | 27.51 | 24.87 | 28.64 | 26.75 |
| **K- Sulpahte** | Without | 30.92 | 36.54 | 33.73 | 28.94 | 32.12 | 30.53 |
| | FYM | 42.94 | 49.31 | 46.12 | 35.43 | 44.73 | 40.08 |
| | S | 54.86 | 60.76 | 57.81 | 48.00 | 53.20 | 50.60 |
| | FYM+S | 65.56 | 76.17 | 70.86 | 60.52 | 70.17 | 65.34 |
| | **Mean** | 48.57 | 55.70 | 52.13 | 43.22 | 36.76 | 39.99 |
| **K- Feldspar** | Without | 23.63 | 29.24 | 26.43 | 22.93 | 26.32 | 24.62 |
| | FYM | 32.09 | 36.39 | 34.24 | 28.77 | 30.67 | 29.72 |
| | S | 40.61 | 46.18 | 43.39 | 36.62 | 42.20 | 39.41 |
| | FYM+S | 54.44 | 63.92 | 59.18 | 44.61 | 52.52 | 48.56 |
| | **Mean** | 37.69 | 43.93 | 40.81 | 33.23 | 37.93 | 35.58 |
| **Effect B×C** | | | | | | | |
| Without | | 22.62 | 27.70 | 25.16 | 21.71 | 25.31 | 23.51 |
| FYM | | 32.04 | 36.42 | 34.23 | 28.04 | 32.86 | 30.45 |
| S | | 41.14 | 47.11 | 44.12 | 37.95 | 25.29 | 31.62 |
| FYM+S | | 53.05 | 61.16 | 57.10 | 47.39 | 54.31 | 50.85 |
| **Effect of SDB (C)** | | | | | | | |
| | | 37.21 | 43.10 | 40.15 | 33.77 | 34.44 | 34.10 |
| **LSD 0.05** | A | | 0.96 | | | 1.30 | |
| | B | | 1.11 | | | 1.50 | |
| | AB | | 1.93 | | | 2.60 | |
| | C | | 0.79 | | | 1.06 | |
| | A | | 1.36 | | | 1.84 | |
| | B | | 1.57 | | | NS | |
| | ABC | | NS | | | NS | |

FYM: Farmyard manure ; S: Sulfur ; SDB: Silicate Dissolving Bacteria played a pronounced role in the release of K from Feldspar. **Badr *et al.* (2006)** found that potassium uptake improved markedly with inoculation of bacteria in the tested soils compared to corresponding controls. Silicate Dissolving Bacteria play an important role in the formation of humus in the soil, the cycling of other minerals tied up in organic matter (**Dawwam *et al.*, 2013; Magare *et al.*, 2018).** The application of 50% K-sulphate + 50% K-feldspar combined with SDB gave the greatest values of K-uptake by stover and seeds of maize plants **(Merwad, 2016). Abd El-Hakeem and Fekry (2014)** found that the application of potassium sulphate plus K- feldspar with SDB increased K-uptake of tuber potato. **Badr *et al.* (2006)** found that K-uptake of sorghum plants inoculated with Silicate Dissolving Bacteria and supplied with minerals (feldspar and rock phosphate) increased by 48%, 65% and 58% for clay, sandy and calcareous soil, respectively, compared to the plants supplied with minerals alone. **Hellal *et al.* (2009)** reported that the application of organic amendments with feldspar gave the highest values of K-uptake by faba bean plants. Application of K-sulphate plus K-feldspar with SDB increased quality potato tubers, total yield and NPK uptake in tubers and shoots by potato plants (**Labib *et al.*, 2012**). Potassium solubilizing bacteria is an aerobic bacteria which plays a significant role in maintaining soil structure by their contribution in the formation and stabilization of water-stable soil aggregates **(Voelkner *et al.*, 2017; Etesami *et al.*, 2017)**.

## Biological Yield, 1000-Grain Weight and Protein Content of Wheat Plants as Affected By Potassium Source, Soil Amendments and Silicate Dissolving Bacteria in Alluvial Soil

The results of Tables 5 and 6 show that the effect of application of potassium source, soil amendments and Silicate Dissolving Bacteria on biological yield, 1000-grain weight and protein content of wheat plants grown on alluvial soil.

Results of the potassium uptake as shown in Tables 5 and 6 indicate that the application of various potassium source *i.e.* K-sulphate and K-feldspar individual application or combined with different soil amendments in the presences of SDB gave increase in biological yield, 1000 grain weight and protein content of wheat plants grown on alluvial soil compared to control. **Merwad (2017)** found that the application of K-sulphate or K-feldspar combined with chicken manure and SDB gave the highest value for each of biological yield, 1000-grain weight and protein content of wheat. **Singh *et al.* (2019)** reported that the application of FYM combined with potassium fertilizers gave the highest value for each of biological yield, 1000 grain weight and protein content of wheat plants in alluvial soil.

The highest biological yield, 1000-grain weight and protein content of wheat were found in pots treated with K-sulphate combined with FYM+S in the presences of SDB, while the lowest ones were obtained with untreated soils in absence of soil amendments and SDB. These results agree with those obtained by **Abdallah *et al.* (2013) and Tian *et al.* (2017).**

Results showed that the application of SDB to K-sulphate or K-feldspar increased 1000-grain weight and protein content of wheat compared to the untreated ones under application of different soil amendments. These increases represent 4, 3 and 4% of 1000 grain weight for the treatments of untreated, K-sulphate and K-feldspar, respectively and 7, 5 and 4% of protein content for the same treatments, respectively. These results are in agreement with those of **El-Akhdar *et al.* (2018)**.

The promotive effect of different soil amendments on biological yield, 1000-grain weight and protein content of wheat plants grown on alluvial soil may follow the order: FYM + S> S > FYM > without under the application of K- sulphate and K-feldspar in the presences or absence of SDB. The favourable effect of soil amendments on nutrient content is mainly due to the positive effect of this material on increasing the available moisture content and hence increasing the availability of nutrients in the soil solution (**Setiawati and Mutmainnah, 2016**). **Kavinder *et al.* (2019)** found that the application of 15 ton $ha.^{-1}$ of FYM to soil increased biological yield, 1000-grain weight and protein content of wheat plants. Soil amendments are soil improving agents. The application of such amendments could improve the retentive capacity of sandy soil for water and fertilization nutrients and also may help in improving the unfavorable structure and in increasing nutrients availability in soil (**Voelkner *et al.*, 2017; Singh *et al.*, 2019)**.

**Table 5. Biological yield and 1000-grain weight of wheat plants (g plant$^{-1}$) as affected by potassium source, soil amendments and Silicate Dissolving Bacteria in clayey soil**

| K-Source (A) | Soil amendment (B) | Biological yield (g) | | | 1000 Grain weight (g) | | |
|---|---|---|---|---|---|---|---|
| | | Silicate dissolving bacteria (C) | | | | | |
| | | Without | With | Mean | Without | With | Mean |
| **Effect of the interaction (A×B×C)** | | | | | | | |
| **Untreated** | Without | 3.60 | 4.14 | 3.87 | 35.75 | 38.78 | 37.26 |
| | FYM | 4.34 | 4.59 | 4.465 | 40.75 | 41.73 | 41.24 |
| | S | 4.89 | 5.17 | 5.03 | 42.43 | 42.93 | 42.68 |
| | FYM+S | 5.34 | 5.47 | 5.41 | 43.67 | 44.68 | 44.17 |
| | **Mean** | 4.54 | 4.84 | 4.69 | 40.65 | 42.03 | 41.34 |
| **K- Sulpahte** | Without | 4.62 | 4.86 | 4.74 | 40.32 | 40.87 | 40.59 |
| | FYM | 5.05 | 5.57 | 5.31 | 42.21 | 43.65 | 42.93 |
| | S | 5.48 | 5.92 | 5.70 | 45.17 | 47.33 | 46.25 |
| | FYM+S | 6.22 | 6.94 | 6.58 | 49.32 | 50.72 | 50.02 |
| | **Mean** | 5.34 | 5.82 | 5.58 | 44.25 | 45.64 | 44.95 |
| **K- Feldspar** | Without | 4.31 | 4.68 | 4.49 | 38.14 | 38.51 | 38.33 |
| | FYM | 4.88 | 5.08 | 4.98 | 39.62 | 40.43 | 40.03 |
| | S | 5.29 | 5.53 | 5.41 | 41.58 | 43.94 | 42.76 |
| | FYM+S | 5.87 | 6.21 | 6.04 | 45.13 | 48.10 | 46.62 |
| | **Mean** | 5.09 | 5.37 | 5.23 | 41.12 | 42.75 | 41.93 |
| **Effect B×C** | | | | | | | |
| Without | | 4.54 | 4.84 | 4.69 | 38.07 | 39.39 | 38.73 |
| FYM | | 5.34 | 5.82 | 5.58 | 40.86 | 41.94 | 41.4 |
| S | | 5.09 | 5.37 | 5.23 | 43.06 | 44.73 | 43.89 |
| FYM+S | | 4.54 | 4.84 | 4.69 | 46.04 | 47.83 | 46.94 |
| **Effect of SDB (C)** | | 4.99 | 5.35 | 5.16 | 42.00 | 43.47 | 42.74 |
| **LSD 0.05** | A | 0.097 | | | 0.256 | | |
| | B | 0.113 | | | 0.295 | | |
| | AB | 0.195 | | | 0.511 | | |
| | C | 0.079 | | | 0.209 | | |
| | AC | 0.138 | | | NS | | |
| | BC | 0.159 | | | 0.417 | | |
| | ABC | NS | | | NS | | |

**Table 6. Protein content (g kg$^{-1}$ grains) of wheat plants as affected by potassium source, soil amendments and Silicate Dissolving Bacteria in clayey soil**

| K-Source (A) | Soil amendment (B) | Silicate dissolving bacteria (C) | | |
|---|---|---|---|---|
| | | Without | With | Mean |
| **Effect of the interaction (A×B×C)** | | | | |
| Untreated | Without | 65.68 | 75.24 | 70.46 |
| | FYM | 87.97 | 94.05 | 91.01 |
| | S | 98.80 | 103.9 | 101.4 |
| | FYM+S | 108.6 | 111.3 | 110.0 |
| | **Mean** | 90.28 | 96.14 | 93.21 |
| **K- Sulpahte** | Without | 92.53 | 97.28 | 94.91 |
| | FYM | 100.5 | 105.9 | 103.2 |
| | S | 112.6 | 121.7 | 117.2 |
| | FYM+S | 133.5 | 137.2 | 135.4 |
| | **Mean** | 109.8 | 115.5 | 112.6 |
| **K- Feldspar** | Without | 81.99 | 85.31 | 83.65 |
| | FYM | 90.25 | 93.48 | 91.87 |
| | S | 99.75 | 107.3 | 103.5 |
| | FYM+S | 113.1 | 122.9 | 117.9 |
| | **Mean** | 96.26 | 102.3 | 99.26 |
| **Effect B*C** | | | | |
| Without | | 80.07 | 85.94 | 83.00 |
| FYM | | 92.91 | 97.82 | 95.36 |
| S | | 103.7 | 111.0 | 107.3 |
| FYM+S | | 118.4 | 123.8 | 121.1 |
| **Effect of SDB (C)** | | 98.79 | 104.6 | 101.7 |
| LSD 0.05 | A | | 0.79 | |
| | B | | 0.91 | |
| | AB | | 1.58 | |
| | C | | 0.64 | |
| | AC | | 1.12 | |
| | BC | | 1.29 | |
| | ABC | | 2.24 | |

Sulphur is a building block of protein and a key ingredient in the formation of chlorophyll. Without adequate sulphur, crops cannot possibly reach their full potential in terms of yield or protein content. Nor can they make efficient use of nitrogen, phosphorus and other vital elements **(Barczak *et al.*, 2019)**.

## Available Potassium (mg kg$^{-1}$) as Affected by Potassium Source, Soil Amendments and Silicate Dissolving Bacteria in Clayey Soil

Under investigation, the values of available potassium (mg kg$^{-1}$) as affected by the application of potassium sources (K-sulphate and K-feldspar) and soil amendments (FYM and S) in inoculated with Silicate Dissolving Bacteria are illustrated in Fig. 1. The treatments of K-sulphate or K-feldspar combined with FYM+ S with inoculation SDB gave the highest values of available potassium (198 and 184 mg ka$^{-1}$, respectively), while the lowest ones (107 mg kg$^{-1}$) was found with untreated soil. These results are in agreement with those obtained by **Merwad (2017), Merwad and Khalil (2018)**. The highest values of available potassium occurred with K-sulphate treatments followed by K-feldspar and without application of potassium fertilizers. **Wahba and Darwish (2008)** found that the addition of both compost and feldspar individually or together increased available potassium in sandy and calcareous soils compared to control. Taking the mean effect of K-source addition into consideration, the results showed show that using K-sulphate with SDB under different soil amendments gave higher values than those under K-feldspar. These results are in agreement with those obtained by **Merwad (2016 and 2017)**.

Results showed that the application of SDB with K-sulphate or K-feldspar increased available potassium in alluvial soil compared to the untreated ones under application different soil amendments. These increases represent 8% for the treatments of K-sulphate and 3% for K-feldspar treatments. These results are in agreement with those of **El-Akhdar *et al.* (2018)**.

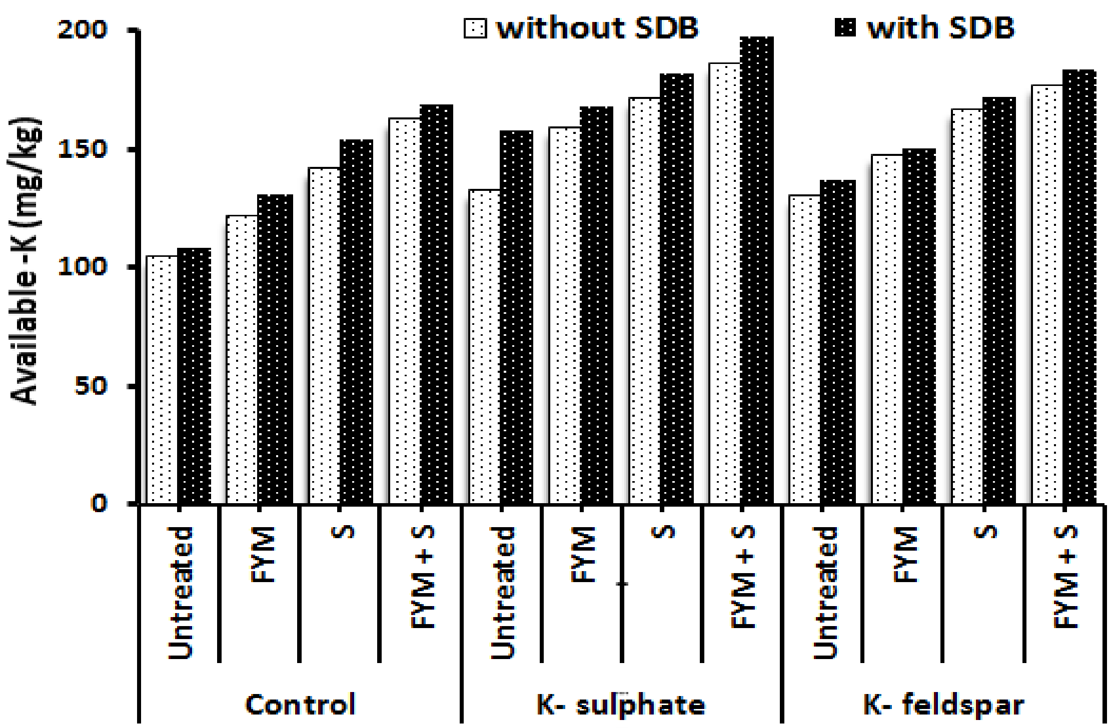


**Fig. 1. Available potassium (mg kg$^{-1}$) as affected by potassium source, soil amendments and Silicate Dissolving Bacteria in clayey soil**

As a general result, the available potassium was clearly increased after harvest at all treatments of any potassium sources application and organic amendments with potassium dissolving bacteria. These increases may be due the microbial activity which has the ability to affect soil reaction in the soil microenvironment leading to solubilizing mineral potassium (**Setiawati and Mutmainnah, 2016**). This finding is in agreement with that obtained by **Hellal *et al.* (2009) and Badr *et al.* (2006**) who found that the available potassium was remarkably increased after 150 days at harvest stage. The increased in the available potassium level after harvest may be due to the mineralization of organic amendments and solubilizing action of certain organic acids produced during manure decomposition as well as the significant effect of microbial activities and role of SDB. Similar results were obtained by **Badr (2006)** who found that the highest values of potassium release was consistent up the end of composting process (feldspar + compost + SDB) after 90 days of incubation.

## REFERENCES

Abd El-Hakeem, S.S. and W.A. Fekry (2014). Effect of K-feldspar, potassium sulphate and silicate dissolving bacteria on growth, yield and quality of sweet potato plants. Zagazig J Agric. Res., 41 (3): 467-477.

Abdallah, A.A., A.I. Mohamed, E.M. El-Sikhry and O.M. Ali (2013). Effect of sulphur application on wheat production in calcareous soil under saline irrigation water conditions. J. Soil and Water Sci., Suez Canal Univ., 1: 7-11.

Abdel-Salam, M.A. and A.S. Shams (2012). Feldspar- K fertilization of potato (*Solanum tuberosm* L.) augmented by biofertilizer. Ame.-Euras J. Agric Environ. Sci., 12 (6): 694- 699.

Abou El-Seoud, B. and A. Abdel-Megeed (2012). Impact of rock materials and biofertilizations on P and K availability for maize (*Zea Maize*) under calcareous soil conditions. Saudi J. Biol. Sci., 19 (1): 55–63.

Bader, M.A., A.M. Shafei and S.H. Sharaf (2006). The dissolution of K and P-bearing minerals by silicate dissolving bacteria and their effect on sorghum growth. Res. J. Agric. Biol Sci., 2 (1):5–11.

Bader, M.A. (2006). Efficiency of K-feldspar combined with organic materials and silicate-dissolving bacteria on tomato yield. J. Appl. Sci. Res., 2: 1191-1198

Barczak, B., M. Jastrzębska and M.K. Kostrzewska (2019). Biofortification of spring barley grain with microelements through sulfur fertilization. J. Chem., 1-7. https://doi.org/10.1155/2019/8214298.

Bishni, U.R. and I.L. Hughes (1979). Agronomic performance and protein content of fall-planted tritica, wheat and rye. Agron. J., 71: 359-360.

Black, C.A., D.D. Evans, J.L. White, L.E. Ensminger and F.E. Chark (1965). Methods of Soil Analysis'. Part. Z. Agron. Ame. Soc. Agron. Inc. Modison Wisc.

Dawwam, G.E., A. Elbetagy, H.M. Emara, I.H. Abbas and M.M. Hassan (2013). Beneficial effect of plant growth promoting bacteria isolated from the roots of potato plant. Ann. Agric. Sci., 58 (2): 195-201.

El-Akhdar, I., A.E. Omara and M.A. Abdel-Rahman (2018). Intergradation of different fertilizers for sustainable agriculture enhanced growth and yield of wheat (*Triticum aestivum* L.). Env. Biodiv. Soil Security, 2: 11- 24.

Etesami, H., S. Emami and H.A. Alikhani (2017). Potassium solubilizing bacteria (KSB): Mechanisms, promotion of plant growth, and future prospects- a review. J. Soil Sci. and Plant Nutr., 17 (4): 897-911.

Guo, J., Y. Jia, H. Chen, L. Zhang, J. Yang, J. Zhang, X. Hu, X. Ye, Y. Li and Y. Zhou (2019). Growth, photosynthesis, and nutrient uptake in wheat are affected by differences in nitrogen levels and forms and potassium supply. Scientific Reports, 9:124. https:// doi. org/ 10.1038/s41598-018-37838-3

Hellal, F.A., M. Abd El-Hady and A.A.M. Ragab (2009). Influence of organic amendments on nutrient availability and uptake by faba bean plants fertilized by rocl phosphate and feldspar. Ame.-Euasian J. Agric. Environ. Sci., 6 (3): 271-279.

Hemasheenee, S., D. Goburdhun, A. Ruggo and H. Neetoo (2017). Understanding the management practices of animal manure adopted by livestock breeders and crop growers of Mauritius. Agric. Res. Tech. Open Access J., 4 (1): 1-8.

Holík, L., L. Hlisnikovský and E. Kunzová (2018). The effect of mineral fertilizers and farmyard manure on winter wheat grain yield and grain quality. Plant Soil Environ., 64: 491–497.

Jackson, M.L. (1973). Soil Chemical Analysis. Prentice Hall, Ic., Englewood Califfs, New Jersy.

Jamal, A. and M. Fawad (2018). Application of different organic manures in optimizing optimum yield for wheat in calcareous soil. WNOFNS, 20: 23-30.

Kavinder, V.S.H., Y.P. Malik, D. Harender and Kavita (2019). Effect of farmyard manure and nitrogen application on growth and productivity of wheat under long term experimental conditions. Current J. Appl. Sci. and Technol., 35 (4): 1-7. https://doi.org/10.9734/cjast/2019/v35i430189.

Khan, I., Z. Shah, W. Ahmad, F. Khan and M. Sharif (2018). Wheat yield and post-harvest fertility status of calcareous soil using shallow and deep tillage and integrated nutrient management (INM). Sarhad J. Agric., 34 (2): 459-470. http://dx.doi.org/10.17582/journal.sja/2018/34.2.459.470

Labib, B.F., K. Ghabour, I.S. Rahim and M.M. Wahba (2012). Effect of potassium bearing rock on the growth and quality of potato crop (*Solanum tuberosum*). J. Agric. Biotech. Sustainable Dev., 4 (1): 7 -15.

Magare, P.N., S.D. Jadhao, B.K. Farkade and D.V. Mali (2018). Effect of levels of potassium on yield, nutrient uptake, fertility status and economics of cotton grown in vertisol. Int. J. Curr. Microbiol. Appl. Sci., 7 (04): 1292-1300. doi:https://doi.org/10.20546/ ijcmas. 2018. 704.144.

Merwad, A.M.A. (2016). Efficiency of K-sulphate and K-feldspar combined with silicate dissolving bacteria on yield and nutrient uptake by maize Plants. Egypt. J. Soil Sci., 56 (2): 249- 259.

Merwad, A.M.A. (2017). Wheat response to potassium fertilization in sandy soil as affected by organic amendments and silicate dissolving bacteria. Egypt. J. Soil Sci., 57 (4): 371- 383.

Merwad, A.M.A. (2019). Management of potassium and silicon in soils for organic crop production using rock potassium. in: the handbook of environmental chemistry, agro-environmental sustainability in MENA. Springer, Berlin, Heidelberg (in press).

Merwad, A.M.A. and M.M.N. Khalil (2018). Effect of moringa residues on nutrients availability and wheat production in sandy and calcareous soils J. Soil Sci. and Agric Eng. Mansoura Univ., 9 (1): 55- 62.

Mohamed, A.I., A.O. Mohamed and O.M. Ali (2019). Effect of sulphur application and water salinity on soil and plant properties. J. Soil Sci. and Environ. Manag., 10 (2): 29-38. http://www.academicjournals.org/JSSEM

Ortas, I. (2018). Influence of potassium and magnesium fertilizer application on the yield and nutrient accumulation of maize genotypes under field conditions. J. Plant Nutr., 41 (3): 330-339.

Piper, C.S. (1950). Soil and Plant Anaylsis. Interscince Publishers Inc. New York.

Römheld, V. and E.A. Kirkby (2010). Research on potassium in agriculture: Needs and prospects. Plant and Soil, 335: 155–180.

Rossini, F., M.E. Provenzano, F. Sestili and R. Ruggeri (2018). Synergistic effect of sulfur and nitrogen in the organic and mineral fertilization of durum wheat: Grain yield and quality traits in the Mediterranean Environ. Agron., 8 (189): 1-16.

Russell, D.F. (1991). MSTAT C, Director of crop and soil science dept. Michigan State Univ. USA Version 2.10.

Setiawati, T.C. and L. Mutmainnah (2016). Solubilization of potassium containing mineral by microorganisms from sugarcane rhizosphere. Agric. and Agric. Sci. Procedia, 9: 108 – 117.

Sheng, X.F. and W.Y. Huang (2002). Mechanism of potassium release from feldspar affected by the strain NBT of silicate bacterium. Acta Pedol. Sin., 39 : 863–871.

Singh, P., V.K. Agrawal and Y.V. Singh (2019): Effect of potassium and FYM on growth parameters, yield and mineral composition of wheat (*Triticum aestivum* L.) in alluvial soil. J. Pharmacognosy and Phytochem., 8 (3): 24-27.

Swetha, P., D. Solanki, S. Kumari and S.G. Savalia (2017). Effect of potassium and sulphur levels on yield and yield attributes of popcorn (*Zea mays* Var. Everta). Int. J. Curr. Microbiol. Appl. Sci., 6(8): 646-655.

Tian, X., C. Li, M. Zhang, Y. Lu, Y. Guo and L. Liu (2017). Effects of controlled-release potassium fertilizer on available potassium, photosynthetic performance, and yield of cotton. J. Plant Nutr. Soil Sci., 180: 505–515.

Voelkner, A., C. Diercks and R. Horn (2017). Compared impact of compost and digestate on priming effect and hydrophobicity of soils depending on textural composition. Soil Discuss., doi:10.5194/soil-2016-62.

Wahba, M.M. and K.M. Darwish (2008). Improving the availability of potassium from feldspar in sandy and calcareous soils. Egypt. J. Soil. Sci., 48 (3): 393 – 398.

Zapata, F. and R.N Roy (2004). Use of Phosphate Rock for Sustainable Agriculture. FAO and IAEA, Rome, Italy.

## تأثير مصادر البوتاسيوم المختلفة ومصلحات التربة والبكتريا المذيبة للسليكات على تيسر البوتاسيوم فى الأراضى الطينية المزروعة بنباتات القمح

**باسم هداية عبدالعزيز النحاس- صلاح محمود محمـــد دحدوح**
**محمد سعيد دسوقي أبو هاشم - عبد الرحمن محمد أمين مرواد**

قسم علوم الأراضي – كلية الزراعة – جامعة الزقازيق – مصر

أجريت تجربة أصص تحت ظروف محكمه في صوبة كلية الزراعة، جامعة الزقازيق لدراسة تأثير إضافة نوعين من الأسمدة البوتاسية (سلفات البوتاسيوم والفلسبار البوتاسى) بالمعدل الموصى به (٤٠ مجم بوكجم$^{-١}$) منفرداً أو مخلوطاً مع مصلحات التربة (سماد المزرعة والكبريت الزراعى) مع إضافة أو عدم إضافة البكتريا المذيبة للسليكات على محصول القمح والبوتاسيوم الممتص وكذلك البوتاسيوم الميسر فى الأرض الطينية، تم أخذ عينات من الطبقات السطحية للتربة (صفر - ٣٠ سم) من مركز ههيا، محافظة الشرقية، مصر، وأظهرت النتائج أن مختلف مصادر أسمدة البوتاسيوم المستخدمة كسلفات البوتاسيوم أو الفلسبار البوتاسى المضافة منفردة أو مخلوطة مع مصلحات التربة المختلفة والبكتريا المذيبة للسليكات أعطت زيادة في محصول القش والحبوب للقمح، المحصول البيولوجى، وزن ١٠٠٠ حبه، محتوى البروتين والبوتاسيوم الممتص بواسطة النبات مقارنة بالتربة غير المعاملة، كانت أعلى قيم لكل من المحصول والبوتاسيوم الممتص بواسطة النبات وكذلك الميسر في التربة الطينية المعاملة بسلفات البوتاسيوم مخلوطا بسماد المزرعة والكبريت الزراعى فى وجود البكتيريا المذيبة للسليكات بينما كانت أقل قيم مع التربة غير المعالجة فى غياب كلا من مصلحات التربة والبكتريا المذيبة للسليكات، أعطى سماد سلفات البوتاسيوم أعلى قيم لكل من المحصول ونسبة البروتين والبوتاسيوم الممتص بواسطة النبات وكذلك الميسر فى التربة تحت الدراسة مقارنة بالمعاملة بالفلسبار البوتاسى، أدت إضافة البكتريا المذيبة للسليكات لكلا من سلفات البوتاسيوم أو الفلسبار البوتاسى لزيادة المحصول ونسبة البروتين والبوتاسيوم الممتص بالنبات وكذلك الميسر فى التربة مقارنة بعدم الإضافة.

**المحكمـــــون:**
**١- أ.د. علـي أحمـد عبدالسـلام** أستاذ الأراضي المتفرغ – كلية الزراعة بمشتهر – جامعة بنها.
**٢- أ.د. السيد عوض محمد عوض** أستاذ الأراضي المتفرغ – كلية الزراعة – جامعة الزقازيق.