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Impact of *Enterobacter cloacae* and Different Potassium Sources on Growth, Productivity and Tuberous Roots Quality of Cassava under Reclaimed Sandy Soils Conditions

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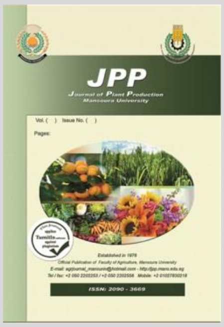

ABSTRACT

Chemical potassium fertilizers used to increase plant yield; nevertheless, overuse of these fertilizers is costly and pollutes the environment. So, many farmers have turned to cheaper alternative sources of potassium, such as foliar spraying potassium silicate or natural substitutes like feldspar with high potassium content. In this context, two field experiments through the two following seasons of 2022/2023 and 2023/2024 were carried out in a private farm on reclaimed sandy soils in EL-Minia City's western district, El-Minia Governorate, Egypt, to study the effect of different potassium sources (without addition, potassium sulfate, feldspar, and potassium silicate) with or without inoculation by *Enterobacter cloacae* (*E. cloacae*) were arranged in a split plot design with three replicates on vegetative growth, yield, and tuberous roots quality of cassava plants "cv. American" as well as soil remaining nutrients. The soil fertilized with potassium sulfate or feldspar, either alone or in combination with bacteria enhanced vegetative growth parameters compared to those of un-fertilized soil. But feldspar exhibited a positive effect on remaining nutrients in soil, tuberous roots yield, and quality of tuberous root, i.e., starch, total carbohydrate, and total soluble sugar content. Moreover, the inoculation with *E. cloacae* significantly increase in all vegetative growth parameters, yield, and tuberous root quality of cassava; therefore, our findings suggest that the application of feldspar mineral combined with *E. cloacae* could be considered as an alternative for chemical potassium fertilizers for cassava production in reclaimed sandy soils.

Keywords: Cassava; *E. cloacae*; potassium sulfate; feldspar; potassium silicate; tuberous root quality.

INTRODUCTION

Cassava (*Manihot esculenta Crantz)* is a perennial plant in the *Euphorbiaceae* family. It is a crucial crop for food security due to its drought tolerance and predicted high resistance to climate change, making it suitable for cultivation in tropical and subtropical regions (Duque and Setter, 2019). Cassava ranks second after rice in the least developed countries and is the fifth most significant staple crop globally, following maize, rice, wheat and potatoes (Bechoff *et al*., 2018). In 2018, global cassava production reached 279 million metric tons (MMTs), with Africa contributing 60% of this total (FAO, 2020). By 2025, it is expected that sub-Saharan Africa will contribute about 61% of the global cassava production, reflecting a notable increase compared to previous years, as projected by FAO (2020). The economic significance of cassava plants primarily stems from their tuberous roots; variations in yield are ascribed to the interplay between the roots and the physicochemical properties of the soil (Nassef *et al*., 2024). Since the leaves of cassava are higher in protein, various vitamins, lipids, essential minerals and fiber than the roots, which are higher in carbohydrates, cassava leaves are consumed in large amounts (Wasonga *et al*., 2020). Moreover, cassava could be utilized as processed food, animal feed, or starch for pharmaceuticals (Marzouk *et al*., 2020). Cassava wastes can also be utilized to produce bioethanol for use in vehicles and various industries (de Carvalho *et al*., 2018). In underdeveloped countries, cassava has huge economic potential to lessen poverty, particularly in regions with low soil fertility and dry climate (Yan *et al*., 2021).

Potassium considers a vital macro-nutrient necessary for the proper plant growth and development; potassium element represents about 2.60% of weight of the Earth's crust is composed from potassium elements, which are essential macronutrients for the healthy growth and development of plants (El-Egami *et al*., 2024). K^+ is essential for a number of physiological and biochemical processes, including osmotic regulation, enzyme activation, charge neutralization, and maintenance of plant cell membrane (Luo *et al*., 2024). K^+ also controls the synthesis of starch, photosynthesis, the following transport and metabolism of carbohydrates, the activation of enzymes, and plants growth and improvement (El-Egami *et al*., 2024 and Nassef *et al*., 2024). The absence or low availability of potassium in the soil cannot be compensated by any other nutrient. Potassium deficiency significantly impacts plant growth and development.

Potassium sulfate is suitable for all crops, adaptable to a wide range of soils, enhances plant resistance, is water-soluble, and releases K^+ ions that are readily absorbed by the soil (Pahalvi *et al*., 2021). On the other hand, chemical potassium fertilizers need to be applied in large quantities to boost crop yields per unit area and compensate for declining soil potassium levels. However, their high cost increases

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production expenses and contributes to environmental contamination.

Natural potassium fertilizers consider a low-cost source of K; can be used as a fertilizer for different crops (Ciceri *et al*., 2019). Feldspar constitutes approximately 50% of the Earth's crust by mass and about 64% by volume (Zhang *et al.*, 2023). K-feldspar is an insoluble potassium resource that has the largest and greatest reserves. It has high potassium content (Chen *et al*., 2024). Feldspar can supply potassium to the soil for agricultural uses (Wang *et al.*, 2022). Varieties of potassium fertilizer made from feldspar can be designed to fit different types of soil, giving farmers a flexible choice (Mohammed *et al*., 2024).

Potassium silicate (K_2SiO_3) serves as a dual source of potassium and high soluble silicon. Silicon is considered one of the best crucial elements in plant development, particularly for mitigating the adverse effects of abiotic stress (Hafez *et al.*, 2021), which is low-cost and has a significant impact on plant productivity (Mousa *et al*., 2023).

Bio-fertilizers are environmentally friendly, cost-effective, non-toxic, and serve as bio-control agents. Therefore, their use holds considerable potential to enhance plant yield, reduce reliance on chemical fertilizers, and promote sustainable agricultural practices (Ashrafi-Saiedlou *et al*., 2024), in this context, using rock materials with bio-fertilizers for improving soil fertility and productivity (El-Saied *et al*., 2021 and Mohammed *et al*., 2024). The application of microbial inoculants can help reduce the use of conventional inorganic fertilizers (El-Saied and Rashwan, 2021). Co-inoculation with K-dissolving bacteria could dissolve potassium from K-feldspar by generating different organic acids such as tartaric, citric, and oxalic acid, accelerating the mineral's K release (Wang *et al.,* 2022). Among plant growth promoting rhizobacteria (PGPR), *Enterobacter* sp is known to secrete plant growth hormones and can be found in a variety of varied habitats. Not only has *E. cloacae* been demonstrated to fix nitrogen (Wang *et al*., 2023), but also have the ability to solubilize phosphate and potassium (El-Saied *et al*., 2020) by releasing organic acids including fumaric, citric, ketoglutaric, malic, and oxalic acids (Zuluaga *et al*., 2023).

Therefore, using environmentally friendly bio-fertilizers and alternative sources of potassium to reduce the usage of chemical fertilizers for increasing cassava growth, productivity and tuberous root quality. This was achieved by investigating the effect of applying *Enterobacter cloacae* strain LC07192 as potassium-solubilizing microorganisms in combination with different potassium sources on cassava under reclaimed sandy soils and estimating various vegetative and biochemical parameters of cassava.

MATERIALS AND METHODS

1. Experimental Site and Tested Treatments

At a private farm in the western district of El-Minia city, El-Minia Governorate, Egypt, two field experiments were conducted on reclaimed sandy soils (28°14'N Latitude, 30° 15' E Longitude) during the two successive seasons of 2022/2023 and 2023/2024 to study the effect of different potassium sources with or without inoculation on vegetative growth, yield and tuberous root quality of cassava plants "cv. American" as well as soil remaining nutrients.

Before planting, soil samples were taken at a depth of 0.0 to 30.0 cm and they were then thoroughly homogenized to study the physical and chemical features (Jackson, 2005). An examination of the experimental lactation's soil is illustrated in Table (1).

Table 1. Physical and chemical properties of soil sample from experimental site through two successive seasons of 2022/2023 and 2023/2024.

Properties	Values	
	2022/2023	2023/2024
I- Physical properties		
Sand %	88.50	88.20
Clay %	3.70	3.80
Silt %	7.80	8.00
Soil texture	Sandy	
(Wilting point) (%)	2.88	2.91
Available water (%)	5.50	5.60
Saturation percent	31.50	32.20
Bulk density (g cm^{-3})	1.83	1.86
(Field capacity) (%)	8.22	8.25
(Max Water hold capacity) (%)	19.2	19.5
II- Chemical properties		
pH soil–water suspension ratio (1:2.5)	8.13	8.12
EC (ds m^{-1}) soil:water extract (1:5)	1.04	1.01
$CaCO_3$ (g kg^{-1})	91.80	91.20
Cation Exchange capacity ($cmol_c$ kg^{-1})	4.60	4.90
Available N (mg kg^{-1})	17.20	17.35
Available K (mg kg^{-1})	181	183
Available P (mg kg^{-1})	6.41	6.53
Organic matter (g kg^{-1})	1.02	1.04
Organic Carbon (g kg^{-1})	1.06	1.07

2. Experimental Desgin

This experiment which includes eight treatments was organized in a split plot in a randomized complete block design with three replicates. The treatments were arranged as follows:

A. Main plots (bio-fertilizer).

1. Un-inoculation.
2. Inoculation.

B- Sub-plots (some potassium fertilization sources).

1. without potassium fertilizer addition.
2. 476 kg ha^{-1} of potassium fertilizer in the form of potassium sulphate (48% K_2O) was added, and the total amounts were divided into four doses.
3. 2155.5 kg ha^{-1} of potassium fertilizer as a feldspar rock (10.6% K_2O). The total amount of feldspar was added during the preparation of soil.
4. Spraying cassava plants with potassium silicate (22% SiO_3 and 11% K_2O) with a concentration of 1000 ppm six times, starting at 45 days from planting dates in both seasons, and repeated five times with an interval of 15 days. In addition, control plants were sprayed with distilled water at the same times.

3. Agricultural Practices

Stem cuttings (stakes) of cassava plants were planted in the fourth week of April in both seasons. Stakes were obtained from the Horticultural Research Institute, Potato and Vegetatively Propagated Vegetable Crops Department, Ministry of Agriculture, El-Dokki, Giza, Egypt. The experimental plot area was 30 m^2, and it had 5 rows, each 6 m in length and 100 cm in width (between rows). Cassava stakes were planted by hand in hills on one side of the row at a distance of 100 cm between plants. Similar-thickness cassava stalks measuring about 2.5-3.0 cm in diameter were chopped into 20-25 cm long stalk cuttings. These were then planted vertically with two thirds of the cuttings burrowed into the soil and the remaining third above ground. A drip irrigation system was then used to irrigate immediately after planting.

Feldspar (10.6% K_2O) was obtained from Al-Ahram for Mining Co., Ltd., Egypt, and the chemical composition of feldspar that using in the experiment through the two seasons of 2022/2023 and 2023/2024 is shown in Table (2). In addition, potassium silicate (Smart Care Silica) contained 22% SiO_3 and 11% K_2O was obtained from Technogene Group, Soliman Gohar Square, Dokki, Giza, Egypt; potassium sulfate (48% K_2O) was purchased from Evergrow Co., Egypt.

Table 2. Some chemical constitution of feldspar used in the experiment through two seasons of 2022/2023 and 2023/2024.

Components					
SiO_2	**64.37%**	**Fe_2O_2**	**0.08%**	**Cl**	**0.03%**
K_2O	10.60%	P_2O_2	0.05%	MnO_2	0.02%
MgO 7.03%	7.03%	$CaCO_3$	0.42%	CaO	0.36%
Al_2O_2	15.12%	TiO_2 0.01%	0.01%	Na_2O	1.91%
pH	8.21	EC (dS m^{-1})	0.55		

Using Aleksandrov medium as a selective medium for potassium solubilization, *Enterobacter cloaceae* strain LC07192 shown great efficiency in phosphate and potassium solubilizing capability based on a prior study (El-Saied *et al.*, 2020). Healthy and homogenous cassava stalks were immersed in a solution of bacterial strains using a liquid culture of *E. cloacae.* The biofertilizer, applied in liquid form, was administered three times, the first one with planting and with a two-month interval with irrigation water.

Prior planting, 47.6 $m^3$of chicken manure per hectare was broadcasted and carefully mixed with the soil surface (0-25 cm); the chemical analysis of the manure were 4.66%, 0.22%, 0.65%, 0.13%, 41%, 384.3 mg kg^{-1}, 315.5 mg kg^{-1} and 110 mg kg^{-1} for N, P, K, F, organic matter, Mn, Zn, and Cu, respectively. 1190 kg ha^{-1} of calcium super phosphate (15.5% P_2O_5) was also applied during soil preparation.

The recommended dose for cassava included 595 kg of nitrogen ha^{-1} which was added in the form of ammonium sulphate (20.6% N). The total amount of nitrogen was divided into four doses. Nitrogen fertilization started a month after planting, and then other amounts were applied monthly. All cultural practices such as irrigation, weed and pest control were carried out for the production of cassava, according to the Ministry of Agriculture, Egypt.

3. Data recorded

Vegetative growth parameters: At 200 days after planting, representative random samples of five plants were labeled in each plot and the following parameters were estimated:

a. Plant height (cm), leaves number/plant, number of main stems and number of lateral branches/plant, and leaf area (cm^2), which was determined as the fifth leaf number (fully expanded leaf) from the plant top for five plants, according to the formula of (Almeida, 2013).

b. Total chlorophyll content (mg $10g^{-1}$ FW) was measured in accordance with (Lichtenthaler and Buschmann, 2001**)**.

Yield and its components: After ten months from the planting date in both seasons, the tuberous roots of each plot were harvested and collected then cleaned of suspended soil to calculate the yield per hectare (ton). After that, these parameters, i.e., number of tuberous roots per plant and tuberous root fresh weight (g), tuberous roots/shoot ratio, length and diameter of tuberous root (cm), and dry matter percentage in tuberous root were determined for each plot.

Chemical composition of tuberous root: At harvesting time, samples of five tuberous roots were taken from each experimental unit to estimate starch (%) as mentioned by (Smith and Zeeman, 2006). Total carbohydrate (%) was determined according to (James *et al*., 1996) and total soluble sugar (g $100g^{-1}$) was determined according to Sadasivam and Manickam (1996). The total fiber percentage of the tuberous root was determined as cited by A.O.A.C. (1990). Nitrogen was determined in cassava tubers according to method of Horneck and Miller (1998). Phosphorus was assessed colorimetrically, and potassium was determined by using a flame photometer according to the method of (Munson, 1998).

Available remaining nutrients and pH: Chemical properties (N, P, K and pH) of cassava soil post-harvest determined according to the procedures outlined by Jackson, 2005.

4. Statistical Analysis

Data were subject to the statistical analysis of ANOVA, and the entries means were compared according to the least significant differences (LSD) at 5% levels, as reported by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

1. Vegetative growth characters and total chlorophyll

Effect of bio-fertilizer

There are significant differences between inoculated and un-inoculation cassava plants regarding plant growth and total chlorophyll in leaves in both seasons (Tables 3 and 4). Inoculated cassava plants with *E. cloacae* significantly increased plant height (3.74%), leaves number/plant (5.93%), number of main stems (32.84%), leaf area (7.47%), lateral branches per plant (4.88%) and total chlorophyll by (6.32%) average of the two seasons as compared to un-inoculated plants. *E. cloacae* has an aptitude to produce hormones, chiefly IAA (Yue *et al*., 2023), fixing nitrogen and siderophore synthesis (Wang *et al*., 2023), phosphate solubilizing properties, and potassium solubilizing capability (El-Saied *et al*., 2020), which had an effect on the parameters of vegetative growth acceleration. It is well recognized that phosphorus and nitrogen are crucial for the molecular structure of DNA and RNA. This leads to enhanced protoplasm production and protein synthesis, which in turn promotes vegetative development. This is explained by the development of favorable conditions that allow bacteria in the root systems to take up and transfer nutrients and water to the green portions of the plant, as well as by stimulating photosynthetic processes that lead to denser vegetative growth (Feng *et al*., 2022). Bacterial inoculation increases the synthesis of chlorophyll by producing pyridoxal enzymes, which are necessary for the synthesis of α-amino levulinic acid synthetase, a key component in chlorophyll synthesis or the stimulation of cytokinins (Kahil *et al*., 2017 and Al-Sayed *et al*., 2022). Via bacterial inoculation, which accelerates the metabolic rates required for the synthesis of these components and enhances the absorption and translocation of significant metal ions (Costa-Santos *et al*., 2021). These results agreed with (Hasan and Marzouk, 2020; El-Saied *et al*., 2021; Yousef *et al*., 2023 and El-Egami *et al*., 2024). The results demonstrated that comparing with un-inoculated plants; inoculated plants exhibited improving for plant growth and total chlorophyll.

Effect of potassium fertilization sources

Results in Tables (3 and 4) display the effect of potassium fertilizer sources on plant vegetative growth and total chlorophyll of cassava plants grown in reclaimed soils in both seasons. It was clear that vegetative growth and total chlorophyll content were significantly increased by the application of different potassium fertilizer sources (potassium sulphate, feldspar and potassium silicate) as compared to unfertilized plants. The best results for all plant growth parameters and total chlorophyll in leaves were obtained with potassium sulphate with no significant differences between feldspar rock in most cases of plant growth and total chlorophyll in both seasons. The plants that received potassium sulphate had the maximum plant height (6.13%), leaves number per plant (12.57%), number of main stems per plant, (22.51%), number of lateral branches per plant (11.15%), leaf area (10.67%) and total chlorophyll content in leaves (16.00%) average of the two seasons compared with unfertilized plants that showed the lowest values. This means that fertilizing cassava plants grown in reclaimed soil with potassium sulphate at 476 kg ha^{-1} or Feldspar at 2155.5 kg ha^{-1} gave the highest values of all plant growth parameters and total chlorophyll, with no significant differences between them in both seasons. Cassava plant growth primarily affects soil fertility; potassium can be essential to many cultivated plant physiological and biochemical processes; and K may be engaged in N-metabolism, support the growth of more leaves, and enhances crop production (Fernandes *et al*., 2017). Application of potassium sulphate resulted in notable growth; this is because nutrients available to the plant through chemical fertilizers are soluble. Therefore, its impact is immediate and direct, and it affects on plant growth (Pahalvi *et al*., 2021). Chlorophyll units are the factories where plants create their metabolites. Potassium, acting as a cofactor, regulates the formation of total chlorophyll and the photosynthesis process (Hou *et al*., 2018). In this study, the total chlorophyll increased with K addition, it is essential for photosynthetic processes among storage roots and stimulating enzymes (Wasonga *et al*., 2020). Similar results were reported by Abdel-Salam and Shams (2012) on potato, Abd-El-Hakeem and Fekry (2014) on sweet potato, Abou El-Khair and Mohsen (2016) on Jerusalem artichoke and Hassan *et al*. (2020) on cassava. Data showed plants fertilized with mineral K or feldspar-K gave the highest plant growth and total chlorophyll as compared to unfertilized plants.

Effect of interaction between bio-fertilizer and potassium fertilization sources

An interaction among *E. cloacae* and potassium fertilization source has a significant effect on plant growth and total chlorophyll in the leaves of cassava grown in reclaimed soil during two seasons. Data presented in Tables (3 and 4) showed that inoculated cassava plants and fertilized by potassium sulfate gave the highest value of vegetative growth and total chlorophyll content in leaves. Also, no significant differences per the interaction among the same inoculated plants and fertilized with feldspar rock in most cases of plant growth and total chlorophyll in both seasons. On the other hand, the lowest values of all the above-mentioned parameters were recorded by un-inoculated cassava which was unfertilized by potassium in both seasons. The utilization of feldspar especially in combination with *E. cloacae*, might be considered as an alternative source of potassium fertilizers and a beneficial, cheap source of K-fertilization for agriculture in sandy soils. Because of the metabolites' transfer from cassava leaves to roots, there is a notable impact on vegetative development (Natarajan *et al*., 2019).

Table 3. Effect of bio-fertilizer (*Enterobacter cloacae*), potassium fertilization sources and their interactions on plant height, number of leaves and main stems per cassava plant in 2022/2023 and 2023/2024 seasons.

Treatments		**Plant height (cm)**		**Number of leaves/plant**		**Number of main stems/plant**	
		2022/2023 season	**2023/2024 season**	**2022/2023 season**	**2023/2024 season**	**2022/2023 season**	**2023/2024 season**
Effect of biofertilizer (*Enterobacter cloacae*)							
Un-inoculation with *E. cloacae*		166.23	166.02	149.15	151.61	3.54	3.31
Inoculation with *E. cloacae*		172.43	172.25	158.80	159.80	4.60	4.50
F-test		*	**	**	**	**	**
Effect of potassium fertilization sources							
Without addition K		163.70	163.20	143.78	144.13	3.55	3.45
KS		172.90	174.05	159.93	164.18	4.30	4.25
FS		172.30	171.45	157.60	159.63	4.30	4.05
KSil		170.80	167.85	154.60	154.90	4.13	3.88
LS.D at 0.05 level		4.64	2.35	4.14	5.30	0.29	0.24
Effect of the interaction							
Un-inoculation with *E. cloacae*	Without K	162.10	161.50	140.25	143.00	3.25	3.15
	KS	169.50	170.20	154.67	159.75	3.75	3.50
	FS	167.00	166.80	151.50	153.90	3.65	3.35
	KSil	166.30	165.50	150.20	149.80	3.50	3.25
Inoculation with *E. cloacae*	Without K	165.20	164.90	147.30	145.25	3.85	3.75
	KS	175.90	177.80	165.20	168.60	4.85	5.00
	FS	175.30	176.10	163.7	165.35	4.95	4.75
	KSil	173.30	170.30	159.00	160.00	4.75	4.50
LS.D at 0.05 level		6.56	3.32	5.86	7.49	0.40	0.35

Ns, * and ** means that non-significant, significant at 5 % and 1 % levels of probability, respectively.

***Enterobacter cloacae* (*E. cloacae*). KS = potassium sulphate, FS = feldspar and KSil = potassium silicate.**

Table 4. Effect of bio-fertilizer (*Enterobacter cloacae*), potassium fertilization sources and their interactions on the number of lateral branches, leaf area and total chlorophyll in the leaves of cassava plant in 2022/2023 and 2023/2024 seasons.

Treatments		Number of lateral branches/plant		Leaf area (cm^2)		Total chlorophyll (mg 10g^{-1} FW)	
		2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
Effect of biofertilizer (*Enterobacter cloacae*)							
Un-inoculation with *E. cloacae*		155.88	152.56	152.35	155.06	39.55	42.63
Inoculation with *E. cloacae*		166.63	164.88	160.89	161.53	42.02	45.36
F-test		*	**	**	**	**	*
Effect of potassium fertilization sources							
Without addition K		150.50	146.88	145.32	147.83	37.35	39.87
KS		166.25	164.25	161.85	162.58	43.17	46.42
FS		166.00	163.25	161.45	163.58	42.25	45.40
KSil		162.25	160.50	157.85	159.20	40.35	44.30
LS.D at 0.05 level		2.21	3.45	3.48	3.82	0.97	0.92
Effect of the interaction							
Un-inoculation with *E. cloacae*	Without K	150.00	144.75	141.30	145.50	36.50	39.74
	KS	160.50	158.00	158.20	158.40	41.88	44.90
	FS	158.00	154.50	156.40	159.75	40.60	43.10
	KSil	155.00	153.00	153.50	156.60	39.20	42.80
Inoculation with *E. cloacae*	Without K	151.00	149.00	149.35	150.15	38.20	40.00
	KS	172.00	170.50	165.50	166.75	44.47	47.93
	FS	174.00	172.00	166.50	167.40	43.90	47.70
	KSil	169.50	168.00	162.20	161.80	41.50	45.80
LS.D at 0.05 level		3.13	4.87	4.92	5.40	1.37	1.30

Ns, * and ** means that non-significant, significant at 5 % and 1 % levels of probability, respectively.

***Enterobacter cloacae* (*E. cloacae*). KS = potassium sulphate, FS = feldspar and KSil = potassium silicate.**

2. Yield and its components

Effect of bio-fertilizer

The yield and its components of cassava plants were affected by *E. cloacae* inoculation in both seasons (Tables 5 and 6). Inoculated plants had a significant effect on tuberous roots yield and tuberous root parameters and scored the highest values of number of tuberous roots per plant (15.93%), the tuberous root fresh weight (3.99%), the tuberous roots/shoot ratio (19.94%), and the total yield (20.74%) as the average of the two seasons over un-inoculated plants. As for tuberous root length, tuberous root diameter, and dry matter content in tuberous root, the data indicated that inculcated plants showed the same trend with yield and its components in both seasons. The plants inculcated with *E. cloacae* recorded percentages of 8.17, 15.01, and 5.87 for the tuberous root length, the tuberous root diameter, and the dry matter content in tuberous root, respectively, as the average of the two seasons over un-inculcated plants. These results are in agreement with those stated by Zhongyong *et al.* (2006), Luo *et al.* (2008), Shafeek *et al.* (2012), and Hassan *et al.* (2020). They exhibited that inoculated cassava plants with bio-fertilizers recorded a high yield and its components comparing with un-inoculated plants.

Effect of potassium fertilization sources

The data in Tables (5 and 6) shows that the parameters varied widely under different potassium fertilization sources and registered significantly higher yield and its components as compared to un-fertilized plants. Fertilizing cassava plants with feldspar rock gave the best values for yield and its components, such as the number of tuberous roots/plant,the tuberous root fresh weight, the tuberous roots/shoot ratio, and the total yield, as shown in Table (5), as well as tuberous root length, tuberous root diameter, and the dry matter content in tuberous root, as shown in Table (6), with no significant differences with potassium sulphate treatment in most cases in both seasons. The relative increases in total yield were about 28.57% for feldspar rock and 25.18% for potassium sulphate over the un-fertilized one, as an average of the two seasons. This means that fertilizing cassava plants grown in newly reclaimed soil with feldspar as a source of potassium was better than fertilizing with potassium sulphate; an increase in yield and its components were recorded compared to fertilization with potassium sulfate. Generally, the application of potassium enhances crop yield by activating enzymes and promoting photosynthesis, which leads to increased biomass production. The reason for the increase in tuber size may be related to potassium's ability to promote cell division and enhance the effectiveness of the photosynthesis process (Torabian *et al.*, 2021). These results are consistent with the findings of numerous other researchers in this field, including (El-Mageed *et al.*, 2022). Because feldspar is released slowly and their use as fertilizers often gives a significant yield later (El-Saied *et al.*, 2021), cassava is harvested after ten months from planting, so it has an optimistic result on tuberous roots yield and yield parameters. These results agree with those reported by Ezui *et al.* (2017), Munyahali *et al.* (2017), Omondi *et al.* (2019) and Hassan *et al.* (2020) on cassava. Results indicated that fertilizing cassava plants with different potassium treatments gave the best productivity as compared to unfertilized plants.

Effect of interaction between bio-fertilizer and potassium fertilization sources

The components of cassava yield were significantly affected by the interaction between *Enterobacter cloacae* as a bio-fertilizer and potassium application in both growing seasons (Tables 5 and 6). The results indicated that fertilizing with feldspar was the greatest effective in enhancing tuber roots yield and its parameters when inoculated with *E. cloacae* as compared to other treatments in both seasons. The highest yield parameters, i.e., number of tuberous roots per plant (14.57), average tuberous root weight (339.85 g), tuberous roots/shoot ratio (2.23), tuberous roots yield (47.15 ton ha^{-1}.), tuberous root length (42.29 cm), tuberous root diameter (4.84 cm), and dry matter in tuberous root (38.54%) average of the two seasons were recorded with the interaction between inoculated plants and feldspar, followed by the interaction inoculated plants and potassium sulphate. Whereas, the lowest yield parameters were obtained by un-inoculated cassava, which didn't receive potassium. Samantray *et al.* (2022) reported that two distinct mechanisms are involved in the microbial inoculation used to extract potassium from K-feldspar through the biological interactions of microorganisms. First, when bacteria dissolve K-feldspar, the K-feldspar lattice deforms or disintegrates, allowing K^+ ions to seep out. Second, bacteria produce glucose, various organic acids, and exopolysaccharides, all of which aid in the release of K^+ ions (Chen *et al*., 2024).

Table 5. Effect of bio-fertilizer (*Enterobacter cloacae*), potassium fertilization sources and their interactions on tuberous roots number, tuberous root fresh weight, tuberous roots/shoot ratio and total yield of cassava plant in 2022/2023 and 2023/2024 seasons.

Treatments		**Tuberous roots number/plant**		**Tuberous root fresh weight (g)**		**Tuberous roots/ shoot ratio**		**Total yield (ton ha $^{-1}$)**	
		2022/2023 season	**2023/2024 season**	**2022/2023 season**	**2023/2024 season**	**2022/2023 season**	**2023/2024 season**	**2022/2023 season**	**2023/2024 season**
					Effect of biofertilizer (*Enterobacter cloacae*)				
Un-inoculation with *E. cloacae*		11.74	11.98	311.81	313.58	1.74	1.72	34.93	35.79
Inoculation with *E. cloacae*		13.70	13.80	324.49	326.06	2.09	2.06	42.45	42.94
F-test		**	**	**	*	**	**	**	**
					Effect of potassium fertilization sources				
Without addition K		11.63	12.08	292.00	295.50	1.79	1.76	32.35	34.00
KS		13.32	13.27	326.38	328.62	2.00	1.97	41.43	41.58
FS		13.33	13.45	333.35	334.65	2.02	1.99	42.36	42.91
KSil		12.63	12.75	320.94	320.50	1.85	1.83	38.62	38.96
LS.D at 0.05 level		1.03	0.63	6.24	5.72	0.07	0.08	2.53	2.32
					Effect of the interaction				
Un-inoculation with *E. cloacae*	Without K	11.00	11.50	285.00	291.00	1.69	1.67	29.82	31.86
	KS	12.33	12.15	320.50	322.00	1.76	1.73	37.63	37.25
	FS	12.15	12.25	327.00	329.30	1.78	1.76	37.82	38.40
	KSil	11.50	12.00	314.73	312.00	1.72	1.70	34.45	35.63
Inoculation with *E. cloacae*	Without K	12.25	12.65	299.00	300.00	1.88	1.85	34.88	36.14
	KS	14.30	14.38	332.27	335.24	2.23	2.20	45.23	45.91
	FS	14.50	14.65	339.70	340.00	2.25	2.22	46.89	47.41
	KSil	13.75	13.50	327.00	329.30	1.98	1.95	42.79	42.28
LS.D at 0.05 level		1.45	0.89	8.82	8.09	0.10	0.11	3.58	3.28

Ns, * and ** means that non-significant, significant at 5 % and 1 % levels of probability, respectively.
***Enterobacter cloacae* (*E. cloacae*). KS = potassium sulphate, FS = feldspar and KSil = potassium silicate.**

Table 6. Effect of bio-fertilizer (*Enterobacter cloacae*), potassium fertilization sources and their interactions on tuberous root length, tuberous root diameter and dry matter in tuberous root of cassava plant in 2022/2023 and 2023/2024 seasons.

Treatments		**Tuberous root length (cm)**		**Tuberous root diameter (cm)**		**Dry matter in tuberous root (%)**	
		2022/2023 season	**2023/2024 season**	**2022/2023 season**	**2023/2024 season**	**2022/2023 season**	**2023/2024 season**
				Effect of biofertilizer (*Enterobacter cloacae*)			
Un-inoculation with *E. cloacae*		36.64	34.95	3.78	3.88	34.28	33.68
Inoculation with *E. cloacae*		39.42	37.91	4.37	4.44	36.11	35.84
F-test		**	*	**	*	*	*
				Effect of potassium fertilization sources			
Without addition K		34.40	32.52	3.52	3.62	32.17	31.46
KS		38.85	37.46	4.37	4.40	36.32	36.06
FS		40.71	40.02	4.41	4.49	37.50	37.27
KSil		38.16	35.73	4.02	4.14	34.79	34.25
LS.D at 0.05 level		1.05	1.63	0.30	0.10	2.63	2.19
				Effect of the interaction			
Un-inoculation with *E. cloacae*	Without K	33.53	31.62	3.32	3.44	31.12	30.41
	KS	36.88	35.91	3.98	4.01	35.42	34.66
	FS	38.92	37.95	4.01	4.09	36.56	35.88
	KSil	37.22	34.31	3.82	3.99	34.02	33.75
Inoculation with *E. cloacae*	Without K	35.26	33.41	3.71	3.79	33.22	32.50
	KS	40.82	39.00	4.75	4.79	37.21	37.45
	FS	42.50	42.09	4.81	4.88	38.44	38.65
	KSil	39.10	37.16	4.21	4.29	35.55	34.75
LS.D at 0.05 level		1.49	2.30	0.43	0.64	3.72	3.10

Ns, * and ** means that non-significant, significant at 5 % and 1 % levels of probability, respectively.
***Enterobacter cloacae* (*E. cloacae*). KS = potassium sulphate, FS = feldspar and KSil = potassium silicate.**

3. Tuberous root quality

Effect of bio-fertilizer

Tuberous root quality of cassava i.e., starch, total carbohydrates, total fibers, and total soluble sugar, was significantly affected by bacterial inoculation in both seasons, as shown in Table (7). The highest values of tuberous root quality were associated with *E. cloacae* inoculation, except for total fibers, in the two growing seasons. The percentages of starch, total carbohydrates, and total soluble sugar increased by 7.36%, 8.19%, and 33.33% for the average of the two seasons over untreated plants. While the total fibers percentage was decreasing by 9.24% compared to un-inoculated plants as an average of the two seasons. Increase in nutritional quality as a result of inoculation with *Enterobacter cloacae* that have not only been shown to fix nitrogen (Wang *et al*., 2023) but also have phosphate and potassium solubilizing ability (El-Saied *et al*., 2020). These results agree with those reported by Hassan *et al.* (2020). They found that starch and total carbohydrates in cassava tubers were the best when inoculated cassava plants with bio-fertilizer as compared to un-inoculated plants.

Effect of potassium fertilization sources

Tuberous roots quality of cassava was increased by the application of different potassium sources, except for total fibers, in both seasons (Table 7). Application of natural alternative feldspar was the most noticeable treatment, which caused a significant increase in tuberous roots quality. Whereas the plants that were fertilized with feldspar increased by 13.22% for starch, 12.59% for total carbohydrates, and 82.97% for total soluble sugar. On the other side, total fibers decreased by 16.89% as average of the two seasons compared to un-fertilized plants. On the other side, fertilizing with potassium sulphate came in second rank. While the lowest values of all tuberous root quality were recorded with the unfertilized plants, except total fibers recorded the highest values in both seasons. The results clearly demonstrate that potassium fertilizers have a significant impact on tuberous root quality. Potassium plays a crucial role in transporting carbohydrates to tuberous roots and aids in the conversion of carbohydrates into a starch, protein, and various of vitamins by activating enzymes (El-Egami *et al.*, 2024) as emphasized by (Hasanuzzaman *et al.*, 2018 and Johnson *et al.*, 2022). Potassium is necessary for starch synthesis in storage organs and transfer through the phloem (Sardans and Peñuelas, 2021). According to Arnao *et al.* (2021) there is an optimistic correlation between leaf pigments and carbohydrates. Consequently, the percentage of carbohydrates in tuberous roots was higher, suggesting that the production of photosynthetic pigments in leaves may be an induced factor for the synthesis of carbohydrates. These results agree with those reported by George *et al.* (2002) and Abd El-Baky *et al.* (2010) on sweet potato, Abou El-Khair and Mohsen (2016) on Jerusalem artichoke and Omondi *et al.* (2019) on cassava. They showed that fertilization plants with different potassium sulphate or feldspar recorded the best results for tuber root quality as compared to unfertilized plants.

Effect of interaction between bio-fertilizer and potassium fertilization sources

Data tabulated in Table (7) indicate that tuberous roots quality was influenced by the interaction between *E. cloacae* and different potassium sources in both seasons. Inoculated cassava plants with *E. cloacae* and fertilized with feldspar have an increase in tuberous roots quality, except for total fibers content (49.40%, 65.65%, and 0.98g 100g^{-1}) for starch, carbohydrates, and total soluble sugar content as an average of two seasons, respectively. While the lowest values of tuberous roots quality except for total fibers was obtained by un-inoculated cassava and any potassium addition, which recorded the highest value of total fibers (2.72%) average two seasons. There was a beneficial link between the increase in the total soluble sugar content and potassium application with bacterial inoculation in both seasons (El-Egami *et al.*, 2024 and Mutmainnah *et al.*, 2024).

Table 7. Effect of bio-fertilizer (*Enterobacter cloacae*), potassium fertilization sources and their interactions on the tuberous roots quality of cassava plants in 2022/2023 and 2023/2024 seasons.

Treatments		**Starch (%)**		**Total carbohydrates (%)**		**Total soluble sugar (g 100g^{-1})**		**Total fibers (%)**	
		2022/2023 season	**2023/2024 season**	**2022/2023 season**	**2023/2024 season**	**2022/2023 season**	**2023/2024 season**	**2022/2023 season**	**2023/2024 season**
		Effect of biofertilizer (*Enterobacter cloacae*)							
Un-inoculation with *E. cloacae*		43.77	43.59	56.70	57.76	0.63	0.63	2.45	2.49
Inoculation with *E. cloacae*		46.91	46.88	61.83	62.00	0.84	0.84	2.19	2.21
F-test		**	**	**	**	*	*	**	*
		Effect of potassium fertilization sources							
Without addition K		41.95	42.35	54.85	56.15	0.50	0.44	2.57	2.58
KS		45.85	45.79	60.50	61.63	0.81	0.83	2.20	2.27
FS		48.20	47.25	62.35	62.63	0.85	0.87	2.12	2.17
KSil		45.36	45.55	59.35	59.13	0.78	0.80	2.40	2.37
LS.D at 0.05 level		0.86	0.60	1.21	1.30	0.055	0.060	0.09	0.18
		Effect of the interaction							
Un-inoculation with *E. cloacae*	Without K	41.20	41.80	54.20	55.40	0.44	0.37	2.73	2.72
	KS	43.50	44.15	57.50	58.90	0.69	0.70	2.31	2.43
	FS	46.90	45.20	58.90	59.75	0.71	0.75	2.22	2.29
	KSil	43.47	43.20	56.20	57.00	0.65	0.68	2.55	2.51
Inoculation with *E. cloacae*	Without K	42.70	42.90	55.50	56.90	0.56	0.52	2.41	2.44
	KS	48.20	47.43	63.50	64.35	0.92	0.95	2.09	2.11
	FS	49.50	49.30	65.80	65.50	0.97	0.98	2.01	2.05
	KSil	47.25	47.90	62.50	61.25	0.90	0.92	2.25	2.23
LS.D at 0.05 level		1.22	0.84	1.72	1.84	0.063	0.085	0.13	0.26

Ns, * and ** means that non-significant, significant at 5 % and 1 % levels of probability, respectively.

***Enterobacter cloacae* (*E. cloacae*). KS = potassium sulphate, FS = feldspar and KSil = potassium silicate.**

4. Mineral contents of tuberous roots

Effect of bio-fertilizer

Mineral contents of the tuberous roots of cassava were significantly affected by inoculation with *E. cloacae* in both seasons (Table 8). The relative increases of N, P, and K were about 8.76%, 28.30%, and 16.57% (average of the two seasons), respectively, due to the plants that were inoculated with *E. cloacae* than un-inoculated plants. Increased nutrient concentration as a result of bio-fertilizer application may be due to the inoculation with *E. cloacae* that have not only been shown to fix nitrogen (Wang *et al.*, 2023) but also have phosphate and potassium solubilizing abilities (El-Saied *et al.*, 2020), furthermore release certain chemicals that improve the availability of additional nutrients for plants (Pahalvi *et al.*, 2021). Moreover, *E. cloacae* secrete various organic acids, which improve potassium and phosphate solubility (Zuluaga *et al.*, 2023). The same results coincide with Hassan *et al.* (2020) where the results reached that treated cassava plants with bio-fertilizer recorded the highest N, P, and K contents in tuber roots as compared to un-inoculated plants.

Effect of potassium fertilization sources

The presented data in Table (8) revealed that the mineral contents were significantly affected due to the application of different potassium sources as compared to unfertilized plants in both seasons. It is worth mentioning that both applications of feldspar or potassium sulfate had significant effects on the contents of N, P, and K in tuberous roots as compared to treated plants with potassium silicate in both seasons. However, fertilizing plants with 2155.5 kg ha^{-1} of feldspar recorded the maximum relative increases in N, P, and K (10.99%, 32.69%, and 27.97%), respectively, as the average of the two seasons over the plants that were unfertilized. On the other side, there were no significant differences between potassium sulphate and feldspar treatments as for N, P, and K in most cases. While treated plants with potassium silicate came in third rank in this respect. Because potassium is a component of numerous physiological, biochemical, regulatory, and metabolic processes in plants, it may have a supporting role in the mineral contents of cassava tuberous roots (Kafkafi *et al*., 2001 and Zörb *et al*., 2014). Additionally, it improved ionic equilibrium and nutritional absorption, leading to higher nutrient content (Horst, 1995 and Kubar *et al*., 2019).The current results are parallel to those stated by (Abdel-Salam and Shams, 2012 and Labib *et al*., 2012) on potato and Hassan *et al.* (2020) on cassava where the application of potassium sulphate or K-feldspar obtained high N, P, and K contents in tubers.

Effect of interaction between bio-fertilizer and potassium fertilization sources

The interaction between inoculated cassava plants with *E. cloacae* and fertilizing with different potassium sources had a significant effect on the N. P. K. contents in tuberous roots in both seasons (Table 8). The data showed that cassava plants that were inoculated with *E. cloacae* and fertilized with feldspar as a K source exhibited an increase in mineral contents and scored relative increases of about 21.19%, 73.33%, and 43.90% for N, P, and K, respectively, for the average of the two seasons over the plants that were un-inculcated and unfertilized, which recorded the lowest contents of N, P, and K in tuberous roots in two seasons. On the other side, there were no significant differences amongst fertilizing with potassium sulphate or feldspar and treating with *E. cloacae* in most cases in both seasons. These results match with (Hasan and Marzouk, 2020) on cassava.

Table 8. Effect of bio-fertilizer (*Enterobacter cloacae*), potassium fertilization sources and their interactions on N, P, and K contents in tuberous roots of cassava plants in 2022/2023 and 2023/2024 seasons.

Treatments		**N (%)**		**P (%)**		**K (%)**	
		2022/2023 season	**2023/2024 season**	**2022/2023 season**	**2023/2024 season**	**2022/2023 season**	**2023/2024 season**
Effect of biofertilizer (*Enterobacter cloacae*)							
Un-inoculation with *E. cloacae*		0.96	0.98	0.26	0.27	0.91	0.90
Inoculation with *E. cloacae*		1.05	1.07	0.33	0.35	1.05	1.06
F-test		**	*	**	*	**	**
Effect of potassium fertilization sources							
Without addition K		0.96	0.97	0.26	0.28	0.85	0.83
KS		1.03	1.04	0.31	0.31	1.01	1.01
FS		1.05	1.08	0.34	0.35	1.08	1.07
KSil		0.98	1.01	0.29	0.29	0.98	1.00
LS.D at 0.05 level		0.048	0.054	0.024	0.045	0.085	0.036
Effect of the interaction							
Un-inoculation with *E. cloacae*	Without K	0.93	0.91	0.22	0.23	0.84	0.80
	KS	0.97	0.99	0.28	0.27	0.92	0.90
	FS	0.99	1.02	0.29	0.30	0.97	0.96
	KSil	0.95	0.98	0.26	0.26	0.90	0.92
Inoculation with *E. cloacae*	Without K	0.99	1.03	0.30	0.32	0.87	0.86
	KS	1.08	1.08	0.33	0.35	1.10	1.11
	FS	1.10	1.13	0.39	0.39	1.19	1.17
	KSil	1.01	1.03	0.31	0.32	1.05	1.08
LS.D at 0.05 level		0.068	0.076	0.033	0.064	0.067	0.051

Ns, * and ** means that non-significant, significant at 5 % and 1 % levels of probability, respectively.

***Enterobacter cloacae* (*E. cloacae*). KS = potassium sulphate, FS = feldspar and KSil = potassium silicate.**

5. Available remaining nutrients and pH

Effect of bio-fertilizer

Table (9) showed that remaining nutrients were significantly affected by *E. cloacae* inoculation in both seasons. It was illustrated that inoculation by the bacterial strain had a positive effect on remaining nutrients compared with un-inoculated, with available N increasing by 8.48 and 7.34%, P by 6.47 and 3.84%, and K by 4.22 and 4.15% in the 1st and 2nd seasons, respectively. While pH decreased by 0.86 and 0.74% through two seasons, respectively. The pH of the soil slightly decreased after adding biofertilizer. This slight pH change may be due to the soil's higher buffering capacity, which protects it from pH changes caused on by the addition of bio-fertilizer (Ali *et al*., 2022). K-solubilizing bacteria reflected effective natural decomposing agents that increase nutrient availability in soils (El-Egami *et al*., 2024). This results matched with (El-Saied and Rashwan, 2021) where *E. cloacae* inoculation had positive effect on available nutrient post-harvest when compared to un-inoculated plants.

Effect of potassium fertilization sources

Application of potassium sources has significantly enhanced available macronutrients N, P, and K (mg kg^{-1}). The most pronounced treatment was alternative natural feldspar, which increased the availability of nitrogen by 4.93, 3.69%, phosphorous by 5.46, 4.63%, and potassium by 23.84, 20.86%, through two seasons, respectively. On the other hand, pH values slightly increased due to mineral feldspar by 0.75 and 0.50% in comparison with unfertilized K soil in both seasons, respectively (Table 9). Because these rocks solubilize slowly, a synergistic effect could result from applying K rocks directly on one side and co-inoculating bacteria on the other as shown in Table (2), Functional groups associated with active soil reactions, such as hydroxyl (OH) and carboxyl (COOH) groups, and exchangeable basic cations are involved in feldspar amendment (Al-Sayed *et al*., 2022).

Effect of interaction between biofertilizer and potassium fertilization sources

For an interaction between bio-fertilizer and different sources of potassium fertilizers, the data showed that inoculation with *E. cloacae* and soil receiving feldspar as K fertilizer exhibited an increase in remaining nutrients (19.20, 19.23; 6.84, 6.79; and 235.50, 233.00 mg kg^{-1}) for N, P, and K through the two following seasons, respectively (Table 9). Further, it can solubilize rock K as feldspar through bio-fertilizers by means of plant production, the excretion of various soil organic acids or chelated silicon, and releasing of additional nutrients, enabling plants to absorb them with easily. The improved soil properties might have enabled the release of more available nutrients, so enhancing plant development and growth (Ali *et al.*, 2021 and Yousef *et al.*, 2023). Because these rocks solubilize slowly, a synergistic effect could result from applying K rocks directly on one side and co-inoculating bacteria on the other (Doaa and Ashmawi, 2022). Our results in accordance with (El-Saied *et al.*, 2021) where *E. cloacae* inoculation combined with natural alternative fertilizers had positive effect on available nutrient post-harvest.

Table 9. Effect of bio-fertilizer (*Enterobacter cloacae*), potassium fertilization sources and their interactions on the chemical properties (N, P, K, and pH) of cassava soil post-harvest in 2022/2023 and 2023/2024 seasons.

Treatments		**N (mg kg^{-1})**		**P (mg kg^{-1})**		**K (mg kg^{-1})**		**pH**	
		2022/2023 season	**2023/2024 season**	**2022/2023 season**	**2023/2024 season**	**2022/2023 season**	**2023/2024 season**	**2022/2023 season**	**2023/2024 season**
Effect of biofertilizer (*Enterobacter cloacae*)									
Un-inoculation with *E. cloacae*		17.34	17.57	6.18	6.25	203.49	203.80	8.11	8.10
Inoculation with *E. cloacae*		18.81	18.86	6.58	6.49	212.08	212.25	8.04	8.04
F-test		**	**	**	**	*	**	**	**
Effect of potassium fertilization sources									
Without addition K		17.66	17.91	6.23	6.26	187.85	189.78	8.05	8.05
KS		18.15	18.30	6.43	6.38	215.04	217.77	8.08	8.08
FS		18.53	18.57	6.57	6.55	232.64	229.39	8.11	8.09
KSil		17.95	18.09	6.29	6.30	195.61	195.16	8.06	8.05
LS.D at 0.05 level		0.089	0.137	0.068	0.108	2.036	2.31	0.018	0.020
Effect of the interaction									
Un-inoculation with *E. cloacae*	Without K	17.00	17.35	6.06	6.19	181.00	184.55	8.09	8.07
	KS	17.40	17.60	6.24	6.27	209.65	212.54	8.10	8.11
	FS	17.87	17.90	6.29	6.31	229.77	225.77	8.14	8.13
	KSil	17.10	17.44	6.11	6.24	193.54	192.32	8.09	8.08
Inoculation with *E. cloacae*	Without K	18.33	18.47	6.39	6.33	194.70	195.00	8.01	8.03
	KS	18.90	18.99	6.62	6.49	220.43	223.00	8.06	8.05
	FS	19.20	19.23	6.84	6.79	235.50	233.00	8.08	8.05
	KSil	18.80	18.73	6.47	6.35	197.68	198.00	8.03	8.02
LS.D at 0.05 level		0.126	0.194	0.097	0.152	2.88	3.27	0.026	0.029

Ns, * and ** means that non-significant, significant at 5 % and 1 % levels of probability, respectively.
***Enterobacter cloacae* (*E. cloacae*). KS = potassium sulphate, FS = feldspar and KSil = potassium silicate.**

CONCLUSION

It could be concluded that under same conditions, fertilizing cassava plants with feldspar (10.6% K_2O) at 2155.5 kg ha^{-1} as a natural alternative potassium source and inoculating plants with *E. cloacae* as potassium solubilizing bacteria achieved most pronounced vegetative growth parameters, yield, tuberous roots quality, as well as remaining nutrients in soil. So, utilization of feldspar in combination with *E. cloacae* might be considered as an alternative source of potassium fertilizers and a beneficial, cheap source of K-fertilization for agriculture in sandy reclaimed soils.

REFERENCES

A.O.A.C. (1990). Official methods of analysis of the Association of Official Analytical Chemists (Vol. 1). The Association.

Abd-El-Hakeem, S.S. and Fekry, W.A. (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.

Abdel-Salam, M.A. and Shams, A.S. (2012). Feldspar-K fertilization of potato (*Solanum tuberosum* L.) augmented by biofertilizer. American-Eurasian J. Agric. and Environ. Sci., 12(6): 694-699. DOI: 10.5829/idosi.aejaes.2012.12.06.1802

Abd El-Baky, M.M.H., Ahmed, A.A., El-Nemr, M.A. and Zaki, M.F. (2010). Effect of potassium fertilizer and foliar zinc application on yield and quality of sweet potato. Res. J. Agric. Biological Sci., 6(4): 386-394.

Abou El-Khair, E.E. and Mohsen, A.A.M. (2016). Effect of potassium fertilization sources on yield and active ingredient of Jerusalem artichoke under sandy soil conditions. Egypt . J. of Appl. Sci., 31(1): 1-22.

Al-Sayed, H.M., Ali, A.M., Mohamed, M.A., and Ibrahim, M.F. (2022). Combined effect of prickly pear waste biochar and Azolla on soil fertility, growth, and yield of Roselle (*Hibiscus sabdariffa* L.) plants. J. of Soil Sci. and Plant Nut., 22(3): 3541-3552. https://doi.org/ 10.1007/ s42729-022-00908-7

Ali, A.M., Hegab, S.A., Abd El Gawad, A.M., and Awad, M. (2022). Integrated effect of filter mud cake combined with chemical and biofertilizers to enhance potato growth and its yield. J. of Soil Sci. and Plant Nut., 1-10. https://doi.org/10.1007/s42729-021-00661-3

Ali, M.M., Anwar, R., Shafique, M.W., Yousef, A.F., and Chen, F. (2021). Exogenous application of Mg, Zn and B influences phyto-nutritional composition of leaves and fruits of loquat (*Eriobotrya japonica* Lindl.). Agronomy, 11(2), 224. https://doi.org/ 10.3390/ agronomy11020224

Almeida, R.A. (2013). Aspectos germinativos de duas cultivares de melancia em diferentes doses de composto orgânico. Catolé do Rocha: Universidade Estadual da Paraíba. 23p.

Arnao, M.B., Hernández-Ruiz, J., Cano, A., and Reiter, R.J. (2021). Melatonin and carbohydrate metabolism in plant cells. Plants, 10(9), 1917. https://doi.org/ 10.3390/plants10091917

Ashrafi-Saiedlou, S., Rasouli-Sadaghiani, M., Samadi, A., Barin, M., and Sepehr, E. (2024). *Aspergillus niger* as an eco-friendly agent for potassium release from K-bearing minerals: Isolation, screening and culture medium optimization using Plackett-Burman design and response surface methodology. Heliyon, 10(7). https://doi.org/10.1016/j.heliyon.2024.e29117

Bechoff, A., Tomlins, K., Fliedel, G., Becerra Lopez-Lavalle, L.A., Westby, A., Hershey, C., and Dufour, D. (2018). Cassava traits and end-user preference: Relating traits to consumer liking, sensory perception, and genetics. Critical Reviews in Food Sci. and Nut., 58(4): 547-567. https://doi.org/10.1080/10408398.2016.1202888

Chen, M., Zhao, L., Huang, Y., Fu, L., Ma, L., Chen, K., and Gu, Z. (2024). Review on K-Feldspar Mineral Processing for Extracting Metallic Potassium as a Fertilizer Resource. Minerals, 14(2), 168. https://doi.org/10.3390/min14020168

Ciceri, D., Close, T.C., Barker, A.V, and Allanore, A. (2019). Fertilizing properties of potassium feldspar altered hydrothermally. Communications in Soil Science and Plant Analysis, 50(4): 482-491. https://doi.org/10.1080/00103624.2019.1566922

Costa-Santos, M., Mariz-Ponte, N., Dias, M.C., Moura, L., Marques, G., and Santos, C. (2021). Effect of Bacillus spp. and Brevibacillus sp. on the Photosynthesis and Redox Status of Solanum lycopersicum. Horticulturae, 7(2), 24. https://doi.org/10.3390/horticulturae7020024

de Carvalho, J.C., Borghetti, I.A., Cartas, L.C., Woiciechowski, A.L., Soccol, V.T., and Soccol, C.R. (2018). Biorefinery integration of microalgae production into cassava processing industry: Potential and perspectives. Bioresource Technology, 247: 1165-1172. https://doi.org/10.1016/j.biortech.2017.09.213

Doaa, M. and Ashmawi, A.E. (2022). Effect of Feldspar, Compost and Biochar on Cultivating Cowpea (*Vigna unguiculata* ssp. unguiculata) Plant and Soil Sandy Clay Loam Properties. Asian Soil Res. J., 6: 42-57. https://doi.org/10.9734/asrj/2022/v6i130123

Duque, L.O. and Setter, T.L. (2019). Partitioning index and non-structural carbohydrate dynamics among contrasting cassava genotypes under early terminal water stress. Environmental and Experimental Botany, 163: 24-35. https://doi.org/10.1016/j.envexpbot.2019.03.023

El-Egami, H.M., Hegab, R.H., Montaser, H., El-Hawary, M.M., and Hasanuzzaman, M. (2024). Impact of Potassium-Solubilizing Microorganisms with Potassium Sources on the Growth, Physiology, and Productivity of Wheat Crop under Salt-Affected Soil Conditions. Agronomy, 14(3), 423. https://doi.org/10.3390/agronomy14030423

El-Mageed, T.A.A., Mekdad, A.A.A., Rady, M.O.A., Abdelbaky, A.S., Saudy, H.S. and Shaaban, A. (2022). Physio-biochemical and Agronomic Changes of Two Sugar Beet Cultivars Grown in Saline Soil as Influenced by Potassium Fertilizer. J. Soil Sci. Plant Nutr., 22: 3636-3654. https://doi.org/10.1007/s42729-022-00916-7

El-Saied, R.M., Abd Elhamed, R.S., and Hassanein, W.A. (2020). Possibility of decreasing consumption of chemical fertilizers with using phosphorous and potassium solubilizing bacteria inoculation on fennel. Plant Archives, 20: 3159-3169.

El-Saied, R.M., Rashad, E.M., and AlBakry, A.F. (2021). Integration Effect of Enterobacter cloacae and Paenibacillus polymyxa with Mineral Fertilizers on Nutrients Uptake, Productivity and Soil Borne Pathogens of Maize and Wheat Plants. Middle East J. of Agriculture Science, 10(3): 996-1013. DOI: 10.36632/mejar/2021.10.3.65

El-Saied, R.M. and Rashwan, B.R.A. (2021). Combined application of various sources of organic fertilizers with biofertilizers for improvement potato productivity and soil fertility status. Environment, Biodiversity and Soil Security, 5: 155-170. DOI: 10.21608/jenvbs.2021.78349.1138

Ezui, K.S, Franke, A.C., Leffelaar, P.A., Mando, A., van Heerwaarden, J., Sanabria, J., Sogbedji, J. and Giller, K.E. (2017). Water and radiation use efficiencies explain the effect of potassium on the productivity of cassava. European Journal of Agronomy, 83: 28-39. doi:10.1016/j.eja.2016.11.005

Feng, Z., Li, X., Fan, B., Zhu, C., and Chen, Z. (2022). Maximizing the production of recombinant proteins in plants: from transcription to protein stability. International Journal of Molecular Sciences, 23(21), 13516. https://doi.org/10.3390/ijms232113516

Fernandes, A.M., Gazola, B., Nunes, J.G.da S., Garcia, E.L., and Leonel, M. (2017). Yield and nutritional requirements of cassava in response to potassium fertilizer in the second cycle. Journal of Plant Nut., 40(20): 2785-2796. https://doi.org/10.1080/01904167.2017.1382520

FAO. (2020). FAOSTAT Statistical Databases [WWW Document]. Food Agric. Organ, United Nations. http://www.fao.org/faostat/en/#data/FBS

George, M.S., Guoquan, L. and Weijun, Z. (2002). Genotypic variation for potassium uptake and utilization efficiency in sweet potato *(Ipomoea batatas* L.). Filed Crops Res., 77: 7-15.

Gomez, K.A. and Gomez, A.A. (1984). Statistical procedure for Agric. Res. 2nd ed. John Wiley and Sons Inc. New York, 680 p.

Hasan, S.H. and Marzouk, N.M. (2020). Response of Cassava Crop Cultivated In Sandy Soil To Different Sources of Potassium Fertilizers. Annals of Agric. Sci., Moshtohor, 58(3): 633-640. https://journals.ekb.eg/article_127288.html

Hassan, N.M.K., Marzouk, N.M., Fawzy, Z.F. and Saleh, S.A. (2020). Effect of bio-stimulants foliar application on growth, yield and product quality of two Cassava cultivars. Bulletin of the National Res. Centre, 44(59): 1-9. DOIhttps://doi.org/10.1186/ s42269-020-00317-9

Hafez, E.M., Osman, H.S., El-Razek, U.A.A., Elbagory, M., Omara, A.E.D., Eid, M.A., and Gowayed, S.M. (2021). Foliar-applied potassium silicate coupled with plant growth-promoting rhizobacteria improves growth, physiology, nutrient uptake and productivity of faba bean (*Vicia faba* L.) irrigated with saline water in salt-affected soil. Plants, 10(5), 894. https://doi.org/10.3390/plants10050894

Hasanuzzaman, M., Bhuyan, M.B., Nahar, K., Hossain, M.S., Mahmud, J. A., Hossen, M.S., Masud, A.A.C., Moumita and Fujita, M. (2018). Potassium: a vital regulator of plant responses and tolerance to abiotic stresses. Agronomy, 8(3), 31. https://doi.org/ 10.3390/ agronomy8030031

Horneck, D.A. and Miller, R.O. (1998) Determination of total nitrogen in plant tissue. In: Kalra YP (ed) Handbook of references methods for plant analysis. CRC Press, Boca Raton, pp 75-83

Horst, M. (1995). Mineral nutrition of higher plants. Acta Physiologiae Plantarum, 17, 393.

Hou, W., Yan, J., Jákli, B., Lu, J., Ren, T., Cong, R., and Li, X. (2018). Synergistic effects of nitrogen and potassium on quantitative limitations to photosynthesis in rice (*Oryza sativa* L.). J. of Agric. and Food Chem., 66(20): 5125-5132. https://doi.org/10.1021/acs.jafc.8b01135

Jackson, M.L. (2005). Soil chemical analysis: advanced course: a manual of methods useful for instruction and research in soil chemistry, physical chemistry of soils, soil fertility, and soil genesis. UW-Madison Libraries parallel press.

James, D.W., Kotuby-Amacher, J., Anderson, G.L., and Huber, D.A. (1996). Phosphorus mobility in calcareous soils under heavy manuring. American Soc. of Agron., Crop Sci., Society of America, and Soil Sci. Soci. of America, (25):4, 770-775.

Johnson, R., Vishwakarma, K., Hossen, M.S., Kumar, V., Shackira, A.M., Puthur, J.T., Abdi, G., Sarraf, M., and Hasanuzzaman, M. (2022). Potassium in plants: Growth regulation, signaling, and environmental stress tolerance. Plant Phys. and Biochem., 172: 56-69. https://doi.org/10.1016/j.plaphy.2022.01.001

Kafkafi, U., Xu, G., Imas, P., Magen, H., Tarchitzky, J., Johnston, A.E., and others. (2001). Potassium and chloride in crops and soils: the role of potassium chloride fertilizer in crop nutrition. IPI Research Topics, No. 22

Kahil, A.A., Hassan, F.A.S., and Ali, E.F. (2017). Influence of bio-fertilizers on growth, yield and anthocyanin content of Hibiscus sabdariffa L. plant under Taif region conditions. Annual Research & Review in Biology, 17(1) :1-15. https://doi: 10.9734/ARRB/ 2017/ 36099

Kubar, G.M., Talpur, K.H., Kandhro, M.N., Khashkhali, S., Nizamani, M.M., Kubar, M.S., Kubar, K.A., and Kubar, A.A. (2019). 27. Effect of potassium (K^+) on growth, yield components and macronutrient accumulation in Wheat crop. Pure and Applied Biology (PAB), 8(1): 248-255. http://dx.doi.org/ 10.19045/ bspab.2018.700183

Labib, B.F., Ghabour, T.K., Rahim, I.S. and Wahba, M.M. (2012). Effect of potassium bearing rock on the growth and quality of potato crop (*Solanum tubersoum*). J. Agric. Biotech. and Sustain. Dev., 4(1): 7-15. DOI: 10.5897/JABSD11.033

Lichtenthaler, H.K. and Buschmann, C. (2001). Extraction of phtosynthetic tissues: chlorophylls and carotenoids. Curr. Protocols in Food Analy. Chem., 1(1): F4-2.

Luo, M., Chu, J., Wang, Y., Chang, J., Zhou, Y., and Jiang, X. (2024). A high-affinity potassium transporter (MeHKT1) from cassava (*Manihot esculenta*) negatively regulates the response of transgenic Arabidopsis to salt stress. BMC Plant Biology, 24(1), 372. https://doi.org/10.1186/s12870-024-05084-7

Luo, X.l., Zhong, C., H-xia, X., Ying, P.A., Cheng, L., Fang, S.Z. and Chen, H.L. (2008). Effects of Bio-Organic Fertilizer on the Growth of Cassava and the Physical and Chemical Biological Character of Soil. Acta Agriculturae Boreali-Occidentalis Sinica, 01: 65-71.

Marzouk, N., Hassan, N., Fawzy, Z., and El-Ramady, H. (2020). Cassava cultivars response to different levels of potassium fertilization under drip irrigation and sandy soil conditions. Egy. J. of Soil Sci., 60(3): 317-334. https://dx.doi.org/10.21608/ejss.2020.34054.1367

Mohammed, K.A.S., Eid, M.S.M., and Usman, A.R.A. (2024). Enhancing the Agronomic Performance of Potassium Fertilizer and Potassium-Bearing Minerals in Sandy Loam Soil by Adding Humic Acids and Mycorrhiza. Assiut J. of Agric. Sci., 55(1): 236-254. https://dx.doi.org/10.21608/ ajas. 2023.243994.1303

Mousa, T.A.E., Bardisi, S.A., Esmail, H.E.M., and Zayd, G.A. (2023). Plant growth, yield, and tuber quality of some potato cultivars as affected by potassium sources as foliar application under sandy soil conditions. Zagazig J. of Agric. Res., 50(6) :863-880. https://doi.org/10.21608/zjar.2023.339935

Munson, R.D. (1998). Principles of plant analysis. Methods for Plant Analysis, 1.

Munyahali, W., Pypers, P., Swennen, R., Walangululu, J. and Merckx, R. (2017). Responses of cassava growth and yield to leaf harvesting frequency and NPK fertilizer in South Kivu, Democratic Republic of Congo. Field Crops Res., 214: 194-201. http:// dx.doi.org/10.1016/j.fcr. 2017.09.018

Mutmainnah, M., Sudiarso, S., and Wicaksono, K. (2024). Response of Potassium Fertilizer Application to Production and Sugar Content of Several Varieties of Sweet Corn (*Zea mays saccharata* Sturt.). Proceedings of the 3rd International Conference on Education, Humanities, Health and Agriculture, ICEHHA 2023, 15-16 December 2023, Ruteng, Flores, Indonesia. https://doi. org/https://dx.doi. org/10.4108/eai.15-12-2023.2345655

Nassef, D.M.T., Metwaly, A.K., and Mahdy, A.S. (2024). Response of Cassava Tubers Yield and its Components to Different Agricultural Treatments. Assiut J. of Agric. Sci., 55(2): 276-289. https://dx. doi.org/10.21608/ajas.2024.277501.1347

Natarajan, B., Kondhare, K.R., Hannapel, D.J., and Banerjee, A.K. (2019). Mobile RNAs and proteins: prospects in storage organ development of tuber and root crops. Plant Science, 284, 73-81. https://doi.org/10.1016/j.plantsci.2019.03.019

Omondi, J.O., Naftali, L., Shimon, R., Kukew, T., Uri, Y. and Yasuor, H. (2019). Potassium and storage root development: focusing on photosynthesis, metabolites and soluble carbohydrates in cassava. Physiologia Plantarum, 169(2): 169-178. doi: 10.1111/ppl.13060

Pahalvi, H.N., Rafiya, L., Rashid, S., Nisar, B., and Kamili, A.N. (2021). Chemical fertilizers and their impact on soil health. Microbiota and Biofertilizers, Vol 2: Ecofriendly Tools for Reclamation of Degraded Soil Environs, 1-20. https://doi.org/10.1007/978-3-030-61010-4_1

Samantray, J., Anand, A., Dash, B., Ghosh, M.K., and Behera, A.K. (2022). Silicate minerals-Potential source of potash-A review. Minerals Engineering, 179, 107463. https://doi.org/10.1016/j.mineng. 2022. 107463

Sadasivam, S. and Manickam A. (1996). Biochemical Methods, 2nd Ed. New Age international (P) Limitid Publishers, New Delhi P. 42-43.

Sardans, J. and Peñuelas, J. (2021). Potassium control of plant functions: Ecological and agricultural implications. Plants, 10(2), 419. https://doi.org/ 10.3390/ plants10020419

Shafeek, M.R, Omar, N.M., Mahmad, R.A. and Abd El-Baky, M.M.H. (2012). Effect of Bio-organic fertilization on growth and yield of cassava plants in newly cultivated land. Middle East J. of Agric. Res., 1(1): 40-46.

Smith, A.M. and Zeeman, S.C. (2006). Quantification of starch in plant tissues. Nature Protocols, 1(3): 1342-1345. https://doi.org/10.1038/nprot.2006.23

Torabian, S., Farhangi-Abriz, S., Qin, R., Noulas, C., Sathuvalli, V., Charlton, B., and Loka, D. A. (2021). Potassium: A vital macronutrient in potato production—A review. Agronomy, 11(3), 543. https://doi.org/10.3390/agronomy11030543

Wang, J., Ding, Z., Al-Huqail, A.A., Hui, Y., He, Y., Reichman, S.M., Ghoneim, A.M., Eissa, M.A., and Abou-Zaid, E.A.A. (2022). Potassium source and biofertilizer influence K release and fruit yield of Mango (*Mangifera indica* L.): A three-year field study in sandy soils. Sustainability, 14(15), 9766. https://doi.org/10.3390/su14159766

Wang, X., Wu, Z., Xiang, H., He, Y., Zhu, S., Zhang, Z., Li, X., and Wang, J. (2023). Whole genome analysis of Enterobacter cloacae Rs-2 and screening of genes related to plant-growth promotion. Env. Sci. and Pollution Res., 30(8), 21548-21564. https://doi.org/ 10.1007/s11356-022-23564-x

Wasonga, D.O., Kleemola, J., Alakukku, L., and Mäkelä, P.S.A. (2020). Growth response of cassava to deficit irrigation and potassium fertigation during the early growth phase. Agronomy, 10(3), 321. https://doi. org/10.3390/agronomy10030321

Yan, Y., He, M., Guo, J., Zeng, H., Wei, Y., Liu, G., Hu, W., and Shi, H. (2021). The CBL1/9-CIPK23-AKT1 complex is essential for low potassium response in cassava. Plant Physiology and Biochemistry, 167: 430-437. https://doi.org/10.1016/j.plaphy. 2021.08. 026

Yousef, A.F., Ali, A.M., Azab, M.A., Lamlom, S.F., and Al-Sayed, H.M. (2023). Improved plant yield of potato through exogenously applied potassium fertilizer sources and biofertilizer. AMB Express, 13(1), 124. https://doi.org/10.1186/s13568-023-01627-7

Yue, H., Sun, S., Wang, R., Ma, X., Shen, S., Luo, Y., Ma, X., Wu, T., Li, S., Yang, Z., and others. (2023). Study on the mechanism of salt relief and growth promotion of *Enterobacter cloacae* on cotton. BMC Plant Biology, 23(1), 656. https://doi.org/ 10.1186/ s12870-023-04641-w

Zhang, X., He, Z., Jia, W., Meng, F., Zhang, W., Lu, C., Hao, X., Gai, G., Huang, Z., Xu, M., and others. (2023). Mechanism of Potassium Release from Feldspar by Mechanical Activation in Presence of Additives at Ordinary Temperatures. Materials, 17(1), 144. https://doi.org/10.3390/ma17010144

Zhongyong, C., Xinglu, L., Jiang, S., Hexia, X., Minqing, C., Yuanlan, H. and Yinghua, Y.P. (2006). The Effects of Bio-organic Fertilizer on Plants Growth and Root Tubers Yield of Cassava. Chainais Agricultural Sci. Bulletin., 22(11): 202-206.

Zörb, C., Senbayram, M. and Peiter, E. (2014). Potassium in agriculture--status and perspectives. J. of Plant Phys., 171(9) :656-669. https://doi.org/10.1016/j.jplph. 2013. 08.008

Zuluaga, M.Y.A., de Oliveira, A.L.M., Valentinuzzi, F., Jayme, N.S., Monterisi, S., Fattorini, R., Cesco, S., and Pii, Y. (2023). An insight into the role of the organic acids produced by *Enterobacter* sp. strain 15S in solubilizing tricalcium phosphate: in situ study on cucumber. BMC Microbiology, 23(1), 184. https://doi.org/10.1186/s12866-023-02918-6

تأثير بكتيريا *Enterobacter cloacae* وبعض مصادر التسميد البوتاسي المختلفة على نمو وإنتاجية وجودة الجذور الدرنية في الكاسافا تحت ظروف الأراضي الرملية المستصلحة

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الملخص

تستخدم الأسمدة الكيماوية البوتاسية لزيادة إنتاجية النبات؛ ومع ذلك فإن الإفراط في استخدام هذه الأسمدة مكلف ويلوث البيئة. لذلك، إتجه العديد من المزارعين إلى مصادر بديلة ورخيصة للبوتاسيوم، مثل الرش الورقي بسيليكات البوتاسيوم أو البدائل الطبيعية مثل الفلسبار الذي يحتوي على نسبة عالية من البوتاسيوم. في هذا السياق تم إجراء تجربتين حقليتين خلال الموسمين المتتاليين 2023/2022 و 2024/2023م في مزرعة خاصة ذات تربة رملية مستصلحة بمنطقة غرب المنيا بمحافظة المنيا بمصر لدراسة تأثير بعض معاملات التسميد البوتاسي (بدون إضافة، كبريتات البوتاسيوم، الفلسبار، وسيليكات البوتاسيوم) مع أو بدون التلقيح ببكتيريا *Enterobacter cloacae* (*E. cloaca*)، رتبت في تصميم القطع المنشقة بثلاث مكررات وتاثير ذلك على النمو الخضري والمحصول وجودة الجذور الدرنية لنباتات الكاسافا (الصنف الأمريكي)، وكذلك حالة خصوبة التربة. تم تسميد التربة بكبريتات البوتاسيوم أو الفلسبار، إما بمفردها أو مع البكتيريا، مما أدى إلى تعزيز معايير النمو الخضري مقارنة بالتربة غير المعاملة. لكن أظهر الفلسبار تأثيراً إيجابياً على العناصر الغذائية المتبقية في التربة، وإنتاجية الجذور الدرنية، وجودة الجذر الدرني متمثلا في المحتوى من النشا والكربوهيدرات الكلية والسكر القابل للذوبان. علاوة على ذلك، أدى التلقيح ببكتيريا *E. cloacae* إلى زيادة معنوية في معايير النمو الخضري والمحصول وجودة الجذر الدرني للكاسافا؛ لذلك، تشير النتائج التي توصلنا إليها إلى أن استخدام معدن الفلسبار مع بكتيريا *E. cloacae* يمكن اعتباره بديلاً للأسمدة البوتاسية الكيماوية لإنتاج الكاسافا في التربة الرملية المستصلحة.

الكلمات المفتاحية: الكاسافا، بكتيريا *Enterobacter cloacae*، كبريتات البوتاسيوم، الفلسبار، سليكات البوتاسيوم، جودة الجذور الدرنية.