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Possibility of Reducing the Amount of Mineral Potassium Fertilizers for Flame Seedless Grapevines by Using Rock-Feldspar

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Abstract: This investigation was conducted for three consecutive seasons (2017, 2018 & 2019) in a private vineyard located at 58 km from Cairo on the Cairo-Alexandria desert rode to study the possibility of reducing the amount of mineral potassium fertilizers for Flame Seedless grapevines by using rock-feldspar combined with potassium solubilizing bacteria. The chosen vines were ten years old, grown in a sandy loam soil, spaced 2 X 3 meters apart, irrigated by the drip irrigation system, trained to spur-pruned and trellised by the telephone shape system. Potassium sulphate (48.5% K_2O) as a source of mineral potassium fertilization (control) was added at the rate of 120 units potassium/Feddan and divided into three batches: 25% at the beginning of bud burst till flowering, 50% after fruit set till harvesting and 25% after harvest. Rock-feldspar (10.5% K_2O) was applied to the equivalent of the mineral potassium fertilizer based on its potassium content, once during winter service at the first week of January of each season. A strain of potassium solubilizing bacteria (*Bacillus circulans*) was applied as bio-inoculant at 20cm/vine twice to the soil: the first addition was added during winter service in the first week of January and the other 35 days after the first addition. Five treatments were performed as follows: 100% mineral potassium (control), 75% mineral potassium + 25% rock-feldspar + potassium solubilizing bacteria, 50% mineral potassium + 50% rock-feldspar + potassium solubilizing bacteria, 25% mineral potassium + 75% rock-feldspar + potassium solubilizing bacteria and 100% rock-feldspar + potassium solubilizing bacteria. The study indicated that there is a possibility of using rock-feldspar fertilizer as a partial substitute of mineral potassium fertilizer. The results revealed that the combined application of 50% mineral potassium + 50% rock-feldspar inoculated with potassium solubilizing bacteria (*Bacillus circulans*) was the best management system for ensuring the best vegetative growth characters, enhancing vine nutrition status, increasing yield and improving fruit quality attributes as well as microbial and enzyme activity of the rhizosphere of Flame Seedling grapevines.

Key words: Mineral potassium fertilizer · Rock-feldspar · Potassium solubilizing bacteria · Yield · Grapevines

INTRODUCTION

Potassium is one of the most important elements in plant nutrition. It is the mineral nutrient required in the largest amount by plants especially in fruit quality and productivity. Potassium plays a fundamental role in many biochemical and biophysiological processes for many plant including carbohydrate metabolism enzyme active, uptake, protein synthesis, osmotic potential regulation, photosynthesis and translocation of assimilates [1, 2].

The high expense of overly manufactured fertilizers is one of the key issues that farmers face. In Egypt, mineral potassium fertilizer has become a very expensive fertilizer, besides the excessive uses of chemical fertilizers have resulted in serious problems, *i.e.* soil salinity, pollution of the underground water. As a result, researchers have turned their attention to using other sources of fertilizers that are safe for humans, animals and the environment as partial alternatives to mineral sources. So, alternative indigenous resources such as rock-feldspar are becoming more important in order to reduce reliance on imported or expensive commercial fertilizers [3, 4].

Rock-feldspar is a slow release fertilizer and is not easy to apply directly, where feldspar consists of aluminum silicate with potassium, so the direct contact

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between bio-fertilizer and rock-feldspar may be important in mineral alteration and used the release potassium from rock-feldspar by generating organic and inorganic acids [5, 6].

Bio-fertilizers are microorganisms that considered promising alternative to synthetic agrochemicals for increasing the availability of mineral elements in soil [7]. The beneficial effects of these bio-fertilizers are mainly due to its role in decreasing environmental pollution, enhancing rhizosphere with mineral elements, promoting mineral absorption, as well as stimulating hormones biosynthesis, increasing plant resistance to pathogens and improving soil fertility [8].

The potential of potassium solubilizing bacteria (KSB), such as *Bacillus circulans*, are able to solubilize rock–feldspar and increase potassium availability in soils by the recirculation of minerals bound in K-rock and excretion of organic acid, which dissolve complex elements into solution [9, 10]. Another well-known mechanism for dissolving potassium is extracellular polysaccharides production that has the ability to dissolve potassium-bearing minerals and facilitate the availability of potassium in the soil solution [11].

The ultimate objective of this study was evaluate the possibility of reducing the amount of chemical potassium fertilizers through using natural rock (feldspar) combined with biofertilizer (potassium solubilizing bacteria) for Flame Seedless grapevines.

MATERIALS AND METHODS

This research was conducted in a private vineyard located at 58 km from Cairo on the Cairo-Alexandria desert rode for three consecutive seasons (2017, 2018 & 2019) to investigate the possibility of reducing the amount of chemical potassium fertilizers for Flame Seedless grapevines via using rock-feldspar combined with potassium solubilizing bacteria.

The selected vines were ten years old, grown in sandy loam soil, drip-irrigated, spaced 2 X 3 meters apart, trained to bilateral cordon and trellised by the telephone shape system. The vines were spur-pruned during the first week of January with maintain a load of 40 buds/vine by leaving 10 spurs with 2 buds on each cordon.

Before the experiment started, from the experimental field, typical soil samples were collected. Physical, chemical and microbiological analyses of soil were performed according to Chapman and Pratt [12] in soil, water and environment research institute, as shown in Table (1).

Table 1: Physical, chemical and microbiological analysis of the soil

Sand (%)	73.4
Silt (%)	2.1
Clay (%)	24.5
Texture	Sandy loam
PH	7.21
EC (ds/m)	1.49
Organic matter (%)	0.59
Ca Co_3 (%)	0.63
Available N (mg/kg soil)	25
Available P (mg/kg soil)	9
Available K (mg/kg soil)	88
Total microbial count (cfu/g soil)	46×10^5
Total potassium solubilizing bacteria (cfu/g soil)	1.50×10^5

Based on the weight of the pruning's and the diameter of the vine's trunk, one hundred and twenty standardized vines were selected as indirect estimations of vine vigour. Each six vines represented as a replicate and each four replicates were acted by one of the following treatments:

- 100% mineral potassium (control)
- 75% mineral potassium + 25% rock-feldspar + potassium solubilizing bacteria
- 50% mineral potassium + 50% rock-feldspar + potassium solubilizing bacteria
- 25% mineral potassium + 75% rock-feldspar + potassium solubilizing bacteria
- 100% rock-feldspar + potassium solubilizing bacteria

Potassium sulphate (48.5% K_2O) as a source of mineral potassium fertilization (control) was added at the rate of 120 units potassium/Feddan and divided into three batches: 25% at the beginning of bud burst till flowering, 50% after fruit set till harvesting and 25% after harvest.

Rock-feldspar (10.5% K_2O) was purchased from Al-Ahram Company for Natural Fertilizers, Giza, Egypt. It was applied to the equivalent of the mineral potassium fertilizer based on its potassium content, once during winter service at the first week of January of each season.

Microbial Determinations: For microbial determinations, soil samples were kept at 4°C in plastic bags to stabilize the microbiological activity distributed during soil sampling and handling. Plate count technique was applied using nutrient agar medium [13] to enumerate total bacterial count and potassium soloublizing bacteria in respective order.

Isolation of Potassium Solublizing Bacteria: The isolation and enumeration of potassium solublizing bacteria from rhizosphere soil of grapevine was carried out by serial dilution technique using Aleksandrov's agar medium [14].

The bacterial isolate was selected and identified using morphological, biochemical and physiological method using Bio-log technique. The efficient isolate was identified as *B. circulans*. It was inoculated in 250ml conical flasks that possessed 100ml Aleksandrov's medium for 4 weeks at 28°C and then, enriched on nutrient broth medium [13] for 48 hours at 28°C. Inoculant *B. circulans* (1x 10^8cell/ml) was added twice to the soil at 20cm/vine: the first addition was added during winter service in the first week of January and the other 35 days after the first addition.

The considered treatments were evaluated through the following determinations:

Morphological Characteristics of Vegetative Growth: The following morphological traits were estimated on four fruitful shoots during the first week of June:

The average main shoot length (cm), shoot diameter (cm), number of leaves/shoot and leaf area (cm^2) of the 5th and 6th apical leaves by the CI-203- Laser Area Meter manufactured by CID, Inc., Vancouver, USA.

Chemical Characteristics of Vegetative Growth: Leaf total chlorophyll and macro-elements content: During the second week of June, leaf samples were obtained from the 5th and 6th apical leaves on the main shoot/vine and the following attributes were determined:

Total chlorophyll: it was determined using the Minolta non-destructive chlorophyll meter SPAD 502 according to Wood *et al.* [15].

Macro-elements: Nitrogen (%) was determined according to Pregl [16] using the modified micro-Kjeldahl method. According to Snell and Snell [17], phosphorus (%) was calorimetrically measured and potassium (%) was determined according to Jackson [18] using Flame photometry instrument.

Cane total carbohydrates content: During winter pruning (the fourth week of January), cane samples were estimated by Smith *et al.* [19].

Yield and Physical Characteristics of Bunch: At maturity, when TSS reached about 16-17 percent, representative random samples of 6 bunches/vine were collected according to Tourky *et al*. [20].

Yield/vine (kg) was determined as the average bunch weight (g) X No. of bunches/vine. Average bunch weight (g) and dimensions (cm) were also measured.

Berry Physical Properties: Average berry weight (g), berry size (cm^3) and berry dimensions (length and diameter) (cm) were estimated.

Berry Chemical Properties: Total soluble solids (TSS) using hand refractometer and total titratable acidity as tartaric acid in berry juice were determined [21]. Then the TSS/acid ratio and total anthocyanin of the berry skin (mg/100g fresh weight) according to Husia *et al.* [22] were assessed.

Microbiological Studies

Soil Microbial Properties: Total microbial count (-x10^5 colony forming unit (cfu)/g soil) was determined outlined by Esher and Jensen [23].

Total count of potassium solubilizing bacteria (-x10^5 colony forming unit (cfu)/g soil) was determined outlined by Aleksandrov's agar medium for silicate bacteria [14].

Dehydrogenase activity (µgTPF.g/dry soil/day) was determined according to Salman [24].

Experimental Design and Statistical Analysis: For the experiment, the complete randomized block design was performed. According to Snedecor and Cochran [25], the statistical analysis of the present data was performed. Usage the new LSD values at 5% level, averages were compared [26].

RESULTS AND DISCUSSION

Morphological Characteristics of Vegetative Growth: Data presented in Table (2) indicated that all fertilization treatments greatly affected all vegetative growth traits *i.e.* shoot length, shoot diameter, No. of leaves/shoot and leaf area in the three seasons.

Vines received 50% mineral potassium + 50% rock-feldspar combined with potassium solubilizing bacteria achieved significantly the highest values of these parameters followed by 75% mineral potassium + 25% rock-feldspar combined with potassium solubilizing bacteria. On the other hand, vines received 100% rock-feldspar combined with potassium solubilizing bacteria resulted in the lowest values of these ones in the three seasons.

The beneficial effect of rock – feldspar in improving vegetative growth is mainly due to the nutrients considered as the most important macro-elements needed for many metabolic processes [5].

The increments in growth parameters due to inoculation of *Bacillus circulans* bacteria with rock-feldspar might be attributed to bacteria that can dissolve them and offer a rapid and more consistent supply of potassium to plants for optimal growth [27].

Table 2: Effect of potassium fertilization on vegetative growth characteristics of Flame Seedless grapevines during 2017, 2018 and 2019 seasons

	Average shoot length (cm)			Average shoot diameter (cm)			Average number of leaves/shoot			Average leaf area (cm^2)		
Characteristics Treatments	2017	2018	2019	2017	2018	2019	2017	2018	2019	2017	2018	2019
100% MP (control)	156.3	164.5	168.7	1.43	1.45	1.49	24.8	26.1	26.7	162.4	169.5	176.9
75% MP + 25% RP + KSB	175.0	183.2	187.9	1.48	1.51	1.55	26.8	28.2	28.9	171.9	178.4	184.3
50% MP + 50% RP + KSB	180.4	188.4	193.2	1.53	1.55	1.59	27.4	28.9	29.6	175.2	182.9	187.6
25% MP + 75% RP + KSB	162.1	170.2	174.6	1.46	1.47	1.53	25.4	26.7	27.4	166.1	174.7	179.2
100% RP + KSB	144.2	152.6	156.5	1.38	1.42	1.44	23.3	24.6	25.2	159.7	165.2	171.4
New LSD at 0.05 =	3.8	4.3	4.9	0.04	0.03	0.02	0.3	0.5	0.6	2.3	2.8	3.1

Mineral potassium (MP) Rock feldspar (RF) Potassium solubilizing bacteria (KSB)

Table 3: Effect of potassium fertilization on leaf total chlorophyll and mineral elements content and cane total carbohydrates content of Flame Seedless grapevines during 2017, 2018 and 2019 seasons

	Total chlorophyll (SPAD)			Nitrogen (%)			Phosphorus (%)			Potassium (%)			Total carbohydrates (%)		
Characteristics Treatments	2017	2018	2019	2017	2018	2019	2017	2018	2019	2017	2018	2019	2017	2018	2019
100% MP (control)	32.02	33.00	33.99	1.36	1.42	1.46	0.19	0.21	0.25	0.31	0.33	0.34	25.02	26.24	27.09
75% MP + 25% RP + KSB	34.20	34.47	35.51	1.50	1.57	1.61	0.24	0.27	0.29	0.33	0.35	0.37	29.27	30.45	31.36
50% MP + 50% RP + KSB	34.67	34.98	36.03	1.53	1.59	1.63	0.29	0.31	0.34	0.35	0.38	0.40	31.97	33.41	34.06
25% MP + 75% RP + KSB	34.08	34.07	35.09	1.48	1.55	1.60	0.22	0.24	0.26	0.32	0.34	0.35	27.06	28.46	29.31
100% RP + KSB	30.52	31.52	32.46	1.34	1.38	1.43	0.17	0.18	0.21	0.29	0.32	0.33	24.45	25.08	25.37
New LSD at 0.05 =	0.42	0.47	0.51	0.02	0.02	0.01	0.04	0.02	0.03	0.02	0.01	0.02	1.39	1.43	1.49

Mineral potassium (MP) Rock feldspar (RF) Potassium solubilizing bacteria (KSB)

These results are in accordance with those reported by Mohamed [5] and Shaheen *et al.* [28] on Superior Seedless grapevines and Mekawy and Abd El-Hafeez [29] on Red Globe grapevines, they indicated that vegetative growth parameters was higher in vines fertilized with 50% mineral fertilizers + 50% feldspar + bio-fertilizer than those in the vines fertilized with 100% of the mineral fertilizer.

Chemical Characteristics of Vegetative Growth: As shown in Table (3), leaf total chlorophyll and macro-elements content expressed total nitrogen, phosphorus and potassium as well as cane total carbohydrates content were significantly influenced by all fertilization treatments during the three seasons.

With respect to leaf content of total chlorophyll, the highest values of this estimation was obtained from vines received 50% mineral potassium + 50% rock-feldspar combined with potassium solubilizing bacteria followed by 75% mineral potassium + 25% rock-feldspar combined with potassium solubilizing bacteria. On the other hand, vines received 100% rock-feldspar combined with potassium solubilizing bacteria recorded the lowest values of this one during the three seasons.

Concerning leaf content of and macro-elements *i.e.* total nitrogen, phosphorus and potassium, vines received 50% mineral potassium + 50% rock-feldspar combined with potassium solubilizing bacteria recorded significantly the highest values of these estimations followed by 75% mineral potassium + 25% rock-feldspar combined with potassium solubilizing bacteria. On the other hand, vines received 100% rock-feldspar combined with potassium solubilizing bacteria had the lowest values of these ones during the three seasons.

Regarding cane content of total carbohydrates, the highest values of this estimation was obtained from vines received 50% mineral potassium + 50% rock-feldspar combined with potassium solubilizing bacteria followed by 75% mineral potassium + 25% rock-feldspar combined with potassium solubilizing bacteria, whereas vines received 100% rock-feldspar combined with potassium solubilizing bacteria recorded the lowest values of this one during the three seasons.

The positive effect of rock feldspar on increasing total chlorophyll in the leaves and total carbohydrates in the canes may be attributed to more nutrient uptake such as N, P and K involved in chlorophyll formation which consequently improve the photosynthesis process and carbohydrate content [5, 30].

Increasing the mineral elements uptake in plant due to inoculation with potassium-solubilizing bacteria with feldspar might be attributed to bacteria that can solubilize them by cycling of minerals tied up in K-rock and excretion of organic acid, which dissolve complex elements into solution [9].

Table 4: Effect of potassium fertilization on yield and bunch physical characteristics of Flame Seedless grapevines during 2017, 2018 and 2019 seasons

	Yield/vine (kg)			Average bunch weight (g)			Average bunch length (cm)			Average bunch width (cm)		
Characteristics Treatments	2017	2018	2019	2017	2018	2019	2017	2018	2019	2017	2018	2019
100% MP (control)	12.79	14.41	15.03	475.49	507.26	518.37	25.96	26.27	26.44	15.41	15.59	15.72
75% MP + 25% RP + KSB	14.19	15.90	16.62	523.47	553.84	567.13	26.17	26.49	26.67	15.63	15.88	15.91
50% MP + 50% RP + KSB	14.73	16.40	17.12	539.73	567.61	578.29	26.36	26.65	26.82	15.76	15.97	16.02
25% MP + 75% RP + KSB	13.45	15.20	15.82	498.14	531.53	543.74	26.09	26.38	26.56	15.57	15.73	15.80
100% RP + KSB	12.24	13.77	14.38	456.83	486.41	499.18	25.87	26.16	26.33	15.29	15.52	15.61
New LSD at 0.05 =	0.49	0.43	0.41	14.92	13.54	11.07	0.17	0.14	0.13	0.09	0.07	0.04

Mineral potassium (MP) Rock feldspar (RF) Potassium solubilizing bacteria (KSB)

Table 5: Effect of potassium fertilization on berry physical properties of Flame Seedless grapevines during 2017, 2018 and 2019 seasons

	Average berry weight (g)			Average berry size (cm^3)			Average berry length (cm)			Average berry diameter (cm)		
Characteristics Treatments	2017	2018	2019	2017	2018	2019	2017	2018	2019	2017	2018	2019
100% MP (control)	3.06	3.14	3.17	2.73	2.79	2.88	1.73	1.79	1.84	1.72	1.77	1.83
75% MP + 25% RP + KSB	3.11	3.19	3.23	2.76	2.83	2.93	1.77	1.84	1.89	1.74	1.81	1.87
50% MP + 50% RP + KSB	3.15	3.21	3.26	2.79	2.87	2.96	1.79	1.85	1.91	1.77	1.83	1.90
25% MP + 75% RP + KSB	3.09	3.15	3.21	2.75	2.80	2.91	1.74	1.82	1.86	1.72	1.81	1.83
100% RP + KSB	3.05	3.12	3.16	2.72	2.77	2.87	1.71	1.78	1.83	1.71	1.78	1.83
New LSD at 0.05 =	0.03	0.01	0.02	0.02	0.03	0.02	0.02	0.01	0.02	0.03	0.01	0.02

Mineral potassium (MP) Rock feldspar (RF) Potassium solubilizing bacteria (KSB)

These results are in harmony with those reported by Mohamed [5] and Shaheen *et al.* [28] on Superior Seedless grapevines and Mekawy and Abd El-Hafeez [29] on Red Globe grapevines, they indicated that leaf NPK content was higher in vines fertilized with 50% mineral fertilizers + 50% feldspar + bio-fertilizer than those in the vines fertilized with 100% of the mineral fertilizer.

Yield and Physical Characteristics of Bunch: Data presented in Table (4) indicated that all fertilization treatments significantly affected yield and physical characteristics of bunch expressed average of bunch weight, length and width in the three seasons.

Vines received 50% mineral potassium + 50% rock-feldspar combined with potassium solubilizing bacteria achieved significantly the highest values of these parameters followed by 75% mineral potassium + 25% rock-feldspar combined with potassium solubilizing bacteria. On the other hand, vines received 100% rock-feldspar combined with potassium solubilizing bacteria attained the lowest values of these ones during the three seasons.

The increment in yield by using natural raw potassium (feldspar) may be due to their great abilities for providing with various nutrients for the trees needed to increase yield and improving physical and chemical of soil properties [31].

The positive action of using biofertilizers may be due to their great abilities for providing various nutrients and hormonal biosynthesis, which resulted in improving yield per vine [32].

These results are consistent with those stated by Mohamed [5] and Shaheen *et al.* [28] on Superior Seedless grapevines and Mekawy and Abd El-Hafeez [29] on Red Globe grapevines, they indicated that yield and its components was higher in vines fertilized with 50% mineral fertilizers + 50% feldspar + bio-fertilizer than those in the vines fertilized with 100% of the mineral fertilizer.

Physical Properties of Berries: As shown in Table (5), all physical properties of berries expressed average of berry weight, size and dimensions were significantly affected by all fertilization treatments in the three seasons.

The highest significant values of these parameters was obtained from vines received 50% mineral potassium + 50% rock-feldspar combined with potassium solubilizing bacteria followed by 75% mineral potassium + 25% rock-feldspar combined with potassium solubilizing bacteria, while vines received 100% rock-feldspar combined with potassium solubilizing bacteria recorded the lowest values of these ones during the three seasons.

Chemical Properties of Berries: Data presented in Table (6) indicated that all fertilization treatments greatly affected all chemical properties of berries *i.e.* TSS, acidity, TSS/acid ratio and total anthocyanin during the three seasons.

Table 6: Effect of potassium fertilization on berry chemical properties of Flame Seedless grapevines during 2017, 2018 and 2019 seasons

	TSS (%)			Acidity (%)			TSS/acid ratio			Total anthocyanin (mg/100g F.W.)		
Characteristics Treatments	2017	2018	2019	2017	2018	2019	2017	2018	2019	2017	2018	2019
100% MP (control)	16.08	16.13	16.29	0.64	0.66	0.68	25.13	24.44	23.96	44.57	45.69	46.91
75% MP + 25% RP + KSB	16.55	16.64	16.73	0.61	0.63	0.65	27.13	26.41	25.74	45.38	46.87	48.24
50% MP + 50% RP + KSB	16.78	16.91	17.02	0.57	0.60	0.61	29.44	28.18	27.90	46.54	47.91	49.13
25% MP + 75% RP + KSB	16.25	16.36	16.43	0.63	0.65	0.66	25.79	25.17	24.89	44.99	46.43	47.65
100% RP + KSB	15.96	16.02	16.11	0.67	0.68	0.71	23.82	23.56	22.69	43.34	44.77	46.02
New LSD at 0.05 =	0.24	0.21	0.19	0.03	0.02	0.03	1.53	1.37	1.23	0.97	0.83	0.74

Mineral potassium (MP) Rock feldspar (RF) Potassium solubilizing bacteria (KSB)

Vines received 50% mineral potassium + 50% rock-feldspar combined with potassium solubilizing bacteria recorded significantly the highest values of TSS, TSS/acid ratio and total anthocyanin and the lowest values of acidity followed by 75% mineral potassium + 25% rock-feldspar combined with potassium solubilizing bacteria. On the other hand, vines received 100% rock-feldspar combined with potassium solubilizing bacteria resulted in the lowest values of TSS, TSS/acid ratio and total anthocyanin and the highest values of acidity during the three seasons.

The natural rock encourage the biosynthesis of plant growth promoters and caused the clear improve of berry quality attributes through better absorption of micronutrient from the soil [32].

These results are in agreement with those reported by Mohamed [5] and Shaheen *et al.* [28] on Superior Seedless grapevines and Mekawy and Abd El-Hafeez [29] on Red Globe grapevines, they indicated that berry quality attributes was improved in vines fertilized with 50% mineral fertilizers + 50% feldspar + bio-fertilizer than those in the vines fertilized with 100% of the mineral fertilizer.

Microbiological Studies: The Effect of fertilization treatments on soil microbial and enzyme activity in the rhizosphere of Flame Seedless grapevines were evaluated during 2017, 2018 and 2019 seasons are shown in Table (7) and Figure (1).

Total Microbial Count: The results in Table (7) revealed that the total microbial count of inoculant plants significantly increase in the first and second seasons (2017, 2018). While it was a noticeable decrease in last season (2019). The total microbial count increased in the first and second seasons respectively. The most observed data at (50% feldspaer+50%NPK) which inculcated with K-solubilizing bacteria, the highest value of total microbial count was reached exactly as expected mainly the result of the second season (126 & 147 $\times 10^5$cfu/ g soil). However, in the third year of the experiment 2019, there is a slight decrease in total microbial count compared was observed, This unexpected result may be due to the pH tends to slightly decrease for soil treated with different rates of natural potassium source (feldspar) combined with biofertilizer than other treatments. These results indicate that the potassium sources make promoting and decreased soil pH due to high supplies of K+ and production of organic acid. These results are in agreement with Sajid and Asghari [33] who found that decreased soil pH results from the production of organic acids due to soil microorganism activity. Per contra non-inoculants plant grown with or without feldspar as potassium source give the lowest value of the study (89, 105, 123$\times 10^5$cfu/ g soil) and (113, 112, 119 $\times 10^5$ CFU/ g soil) through three seasons. The results are in agreement with those obtained by Han *et al*. [34] and Etesami *et al*. [35] who explained that the rise in populations of microorganisms in the rhizospheric of most plants are affected by a combination inoculation of microorganism with natural or organic potassium source. In addition, Mehta *et al*. [36] provide a strong foundation for further development of *B. circulans* strain as bio-fertilizer in horticulture to achieve the desired plant growth-promoting activity.

Total Potassium Solubilizing Bacteria Count: The results in Table (7) and Figure (1) indicate that during consecutive seasons (2017, 2018 & 2019), the effect of 50% rock-feldspar inoculated with *B. circulans* gave a noticeable increase in values of K-solubilizing populations where the count of KSB recorded (11.05, 11.97 and 12.12$\times 10^5$ CFU /g soil) during three seasons, whereas all other treatments exhibited fewer counts and the least numbers of *B. circulans* recorded with NPK treatment without inoculation that was (1.50, 1.92&2.09 $\times 10^5$ CFU /g soil) at three seasons respectively. However, all rock-feldspar inoculated with *B. circulans* treatments recorded highly count numbers of *B. circulans* at the end of during three seasons, respectively (9.21, 12.12, 11.79 & 11.16 $\times 10^5$ CFU/g soil) more than control treatment (2.09 $\times 10^5$) CFU /g soil.

Table 7: Effect of KSB and different concentrations of feldspar on microbial and enzyme activity in the rhizosphere of Flame Seedless grapevines during 2017, 2018 and 2019 seasons

	Total count of microbial (10^5CFU/g rhizosphere)			Total count of potassium solubilizing bacteria (10^5CFU/g rhizosphere)			Dehydrogenase activity (µ g TPF g^{-1} dry soil day^{-1})		
Characteristics Treatments	2017	2018	2019	2017	2018	2019	2017	2018	2019
100% MP (control)	89	105	123	1.50	1.92	.09 2	38.70	69.15	78.61
75% MP + 25% RP + KSB	113	128	119	7.83	8.46	9.21	76.42	72.42	67.18
50% MP + 50% RP + KSB	126	147	121	11.05	11.97	12.12	79.18	85.32	59.97
25% MP + 75% RP + KSB	138	142	130	11.31	11.20	11.79	71.21	58.76	62.90
100% RP + KSB	113	112	119	10.56	10.97	11.16	67.96	56.02	39.56
New LSD at 0.05 =	---	---	---	---	---	---	2.83	3.71	4.29

Mineral potassium (MP) Rock feldspar (RF) Potassium solubilizing bacteria (KSB)

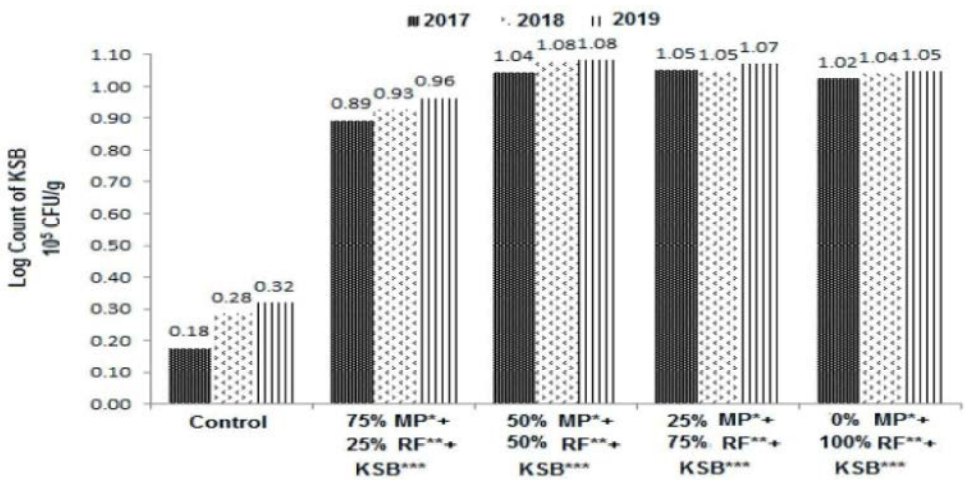

Fig. 1: Effect of KSB and different concentration of feldspar on total count of potassium solubilizing bacteria in the rhizosphere of Flame Seedelss grapevines during 2017, 2018 and 2019 seasons

Potassium influences plant water intake, root growth, turgor maintenance, transpiration and stomatal regulation [37]. It is found in soil as silicate minerals that are inaccessible to plants and it is absorb by plants as potassium ions, which are water insoluble. Microbes as Bacillus sp., *Aspergillus niger etc.* are broad spectrum bio-fertilizers solubilize silicates by creating organic acids, which promote silicate breakdown and aid in metal ion removal [38].

Dehydrogenase Enzyme Activity: Data are shown in Table (7) showed that the presence of dehydrogenase enzyme activity among fertilization potassium treatments due to soil microbial activity inoculated with KSB at different concentrations of feldspar through three seasons.

The influence effect of biofertilizers on dehydrogenase activity in the rhizosphere of vineyards in soil treated with 50% feldspar combined with *B. circulans* recorded the highest values of dehydrogenase enzyme activity compared to control and other treatments.

The significantly increased values recorded were (79.18, 85.32 µg TPF (tri-phenylformasan) at season 2017, 2018. On the antithetical slight decrease in dehydrogenase was observed in Overall transactions during season 2019. As we mentioned above, these unexpected results may be attributed to the limited ph of the soil and increased organic complexes mineralization [39].

These results were in line with other research which stated that several mechanisms of potassium solubilization by biofertilizer as reported by Sindhu *et al*. [40], who found that potassium-soluble bacteria (KSB), when used as a biofertilizer for agriculture, can reduce the use of chemical fertilizers and support eco-friendly crop production by dissolving potassium from insoluble K-bearing minerals such as mica, illite and orthoclase, by Excretion of organic acids by directly dissolving potassium rock or chelating them from silicon ions and facilitating them in the soil solution. In this respect, Khalil *et al*. [41] stated that using KSB led to improve growth of pepper plants. Similarly, Lallawmkima *et al*. [42]

showed that the highest plant performance was achieved when macronutrient requirements were partially met by using mineral fertilizers in combination with biofertilizers. Our results are in agreement with Hasan and Ragab [43] and Ahmed *et al.* [44] found that the rise of potassium magnitude in the soil may partially be attributed to organic acids production by the biofertilizers, which reduced the soil pH, resulting in the conversion of non-available potassium into available form. In addition to, by creating chelating substances, soil microorganisms can also make potassium accessible to plants, resulting in potassium solubilization [30].

CONCLUSIONS

From the foregoing results, it can be concluded that there is a possibility of using rock-feldspar fertilizer as a partial substitute of mineral potassium fertilizer to reduce environmental pollution and alleviate dependence on imported or expensive commercial fertilizers as well as maximizing the utilization of available natural resources.

In general, the combined application of 50% mineral potassium + 50% rock-feldspar inoculated with potassium solubilizing bacteria (*Bacillus circulans*) can be recommended to improve the vegetative growth characters, nutrition status, yield and fruit quality attributes as well as microbial and enzyme activity of the rhizosphere of Flame Seedling grapevines.

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