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The Impact of Potassium Sources and Bio Fertilizer on Corn Plant and Potassium Availability in Calcareous Soil

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Two field experiments were conducted in a calcareous soil during summer seasons of 2019 and 2020 at the experimental in a private farm Mallawi, El- Minia Governorate, Egypt to evaluate application of K fertilization at different rates of K_2SO_4 and non-classic products, *i.e.* K feldspar, mixture with or without inoculation with the K dissolving bacteria (*Bacillus circulans*.) soil chemical properties, plant growth, yield and nutritional value of corn (*Zea-maize* hybrid third 310). Our results proved that inoculation of maize seeds with *Bacillus circulans* at rate of 36% K2O improved soil pH, EC, soil organic matter content and enhanced the soil available N, P and K concentrations. Also, the growth parameters, yield and nutritional status of the plants were significantly increased by using non-traditional potassium fertilizers particularly in the case of seed inoculated with potassium dissolving bacteria (*Bacillus circulans*).

Keywords: Soil; k-sources; bacillus circulans and corn.

1. INTRODUCTION

Potassium is an essential plant nutrient taken up from soil in large quantity. Potassium dynamics on soils is concerning to the magnitude of balance among various K forms and mainly governed by the composition of soils and their chemical and physical properties [1,2].

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Feldspars, which form the mineral series $KAlSi_3O_8$ (Orthoclase) – $NaAlSi_3O_8$ (albite) – $CaAl_2Si_2O_8$ (anorthite), constitute nearly one half of the earth's crust *Crundwell*, [3]. Their alteration, which includes the physicochemical processes of feldspar dissolution, transfer of dissolved solutes, and concomitant secondary mineral precipitation, occurs ubiquitously from shallow to deep buried rocks [4].

K- Bearing Minerals K- feldspar can be positively contributed in covering a great portion of K- plant need after potassium released. Applying bio-fertilizers and dissolving were influenced by the soil conditions such as organic carbon, temperature, moisture, electrical conductivity and other chemicals as well as by the number and types of plants found in soils Etesami et al. [5]. The inoculation with potassium solubilizing bacteria been reported to exert beneficial effects on growth plants [6,7,8,9]. In the same respect, Badr [8,9] found that inoculation with silicate dissolving bacteria into the composition mass appears to enhance the percentage of available K in the mature compost. Similarly, the response of tomato plants was dramatically enhanced in sandy soil of low K content and its effect was higher than potassium sulphate. K-feldspar may be valuable as a slow releasing fertilizer and cheaper source of K Labib et al. [10]. The use of potassium solubilizing bacteria as bio fertilizer; i.e. silicate dissolving bacteria was suggested as a sustainable solution to improve plant growth, nutrition, root growth, plant competitiveness and responses to external stress factors Dawwam et al. [11]. Moreover, application of K- feldspar in combination with SDB mixed with K-sulphate at a ratio of 1:1 (50% potassium sulphate + 50% K-feldspar) led to positive effects of in production of maize yield and uptake of NPK. The treatment of (50% potassium sulphate + 50% K-feldspar) gave the highest values of available potassium in soil compared to other treatments. Using the naturally deposited materials of K-feldspar combined with SDB would be beneficial for farmers and save high costs of chemical fertilizers. Merwad [12]. Rajawat et al. [13] showed that potassium solubilizing bacteria (KSB) solubilize K-bearing minerals and change over the insoluble K to dissolvable types of K that plants can get to. Also, *Bacillus circulans* have ability to solubilize K minerals like biotite, muscovite, feldspar, mica, iolite, and orthoclase. KSB are normally present in every one of the soil, in spite of the fact that their number, assorted variety, and capacity for K solubilization differ which rely on the soil and climatic conditions. Despite that, KSB are the most essential microscopic organisms for solubilizing K minerals which demonstrate viable association amongst soil and plant frameworks.

Maize (*Zea mays* L.) is considered as one of the most important cereal crops used in human consumption, in addition animal feeding and other industry. Abou-el-Seoud and Abdel-Megeed [14] found that inoculation of PSB and KSB in conjunction with direct the application of rock P and K materials into the soil increased P and K availability and uptake, and the plant growth of maize plants grown on P and K limited soils. Abo–Baker Basha and Hassan [15] regarded that the potassium solubilizing bacteria (KSB) are able to solubilize K minerals through the production and excretion of organic acids. Humic acid also plays an important role in improving soil properties and enhancing the microbial activity. Potassium dissolving bacteria as well as humic substances as an organic form to the sandy loam soil improve the estimated parameters including phosphorus and potassium availability in the soil and different growth parameters of canola plants and give a significantly positive effect than the control. Madar et al. [16]. Found that potassium feldspar combined with solubilizing bacteria are considered as promising alternative sustainable fertilizers. the combined application of inorganic K fertilizer (50% RDK) and seed inoculation of KSB biofertilizer under zero-till maize–wheat system has been found to potentially mobilize native soil K pools (non-exchangeable and total K) through redistribution and might help in improved growth, yield, and K-assimilation by maize and wheat. Upon addition of residue (4 and 6 Mg ha^{-1}), inorganic fertilizer (50% to150% RDK), and KSB biofertilizer resulting in positive soil K balance through an increased actual change of K over control. Therefore, recycling of K rich cereal residue by returning into the soil (6 Mg ha^{-1}) and combined application of inorganic K fertilizer (50% RDK) with seed inoculation of KSB biofertilizer might be helped to reduce 50% of inorganic K fertilizer requirement. This assumes significance as residue and KSB biofertilizer under zero tillage maize–wheat system supplements inorganic K fertilize. Ali et al. [17] studies applying of bio-fertilizer with *Bacillus cereus* significantly increased the total yield of potato by 21% above the untreated plants. The application of K-feldspar (12% total K_2O) at a rate of 240 kg K_2O ha^{-1} to potato inoculated with Bacillus cereus gave a total tuber yield of 40 ton $ha\text{-}^{1}$.

2. MATERIALS AND METHODS

2.1 Experimental Design

A field experiment was conducted on calcareous soil in a private farm Mallawi, Minia Governorate, Egypt, cultivated with maize [hybrid third 310 was produce by Department of Maize Research, Field Crops Research Institute, Agricultural Research Center (ARC). Giza, Egypt] during the summer seasons of 2019 and 2020(Maize seeds were planted in 27 and 25 June in 2019 and 2020), to study the evaluation of two potassium sources combined with or without bio-fertilizer on physical and chemical soil properties, phyto available of potassium as well as on the yield of maize. The experimental was completely randomized, three replicates.

The studied treatments were carried out on plots of 3.5 × 3 m (10.5 m^2). The main plots treatments were the two K Sources Natural K (K-feldspar, 10% K_2O) and mineral K sulphate (48% K_2O), the inoculants treatments seeds mixture with or without inoculation with the K dissolving bacteria (KDB) (*Bacillus circulans*) in our experimental we used four K rates 0, 12, 24, and 36% K_2O fed^{-1}. The main soil properties of experimental field were determined according to methods described by Page et al. [18], as shown in Table 1.

2.2 Preparation Inoculated Seeds

Preparation of bacteria was kindly supplied by the Department of microbiology, Soil, water and Environment Research Institute, ARC, Giza, Egypt. Maize seeds were inoculated with bacterial at rate of 300 g inoculants per 30 kg seeds before sowing using 16% Arabic gum solution as a sticking agent.

Based on the recommended agricultural practices of growing maize were applied and the nitrogen rate was 0.300 ton. N ha^{-1} (Fed= 0.4 ha) of NH_4NO_3 (33.3% N) which was applied after 31, 55 and 75 days planting. Calcium super-phosphate (15.5% P_2O_5) at rate of 0.250 ton. ha^{-1} was added during soil preparation. Potassium sulfate (48% K_2O) at rate 0.187 ton. ha^{-1} was added after 31 and 55 days after sowing.

2.3 Soil and Plant Samples

Soil samples were taken (0-30 cm depth) after plant harvest, air dried, grounded and passed through 2 mm sieve for analysis. Samples were analyzed for Soil pH and EC were determined according to Jackson [19]. Available nitrogen, phosphorus and potassium was determined according to Chapman and Pratt [20].

Table 1. Some physical and chemical properties of calcareous soil in a private farm Minia soil

Soil characteristics	2019	2020
Particle size distribution%:	**Value**	**Value**
Coarse sand	0.90	1.75
Fin sand	10.72	11.75
Silt	52.74	55.50
Clay	35.64	31.00
Texture	Silt clay loam	Silt clay loam
pH (1:25 soil: water suspension)	8.22	8.27
EC (dS m^{-1})	1.48	1.57
$CaCO_3$ %	12.30	13.22
Organic matter %	0.58	0.55
Bulk density g cm^{-3}	1.32	1.30
Soluble cations (mmolc L^{-1}):		
Ca^{2+}	7.45	9.20
Mg^{2+}	3.13	3.41
Na^{+}	2.10	2.00
K^{+}	2.14	1.20
Soluble anions (mmolc L^{-1}):		
CO_3^{2-}	0.00	0.00
HCO_3^{-}	6.45	7.72
Cl^{-}	4.04	2.23
SO_4^{-2}	4.33	5.85
Available nutrients (mg kg^{-1})		
Available N	46.25	42.38
Available P	4.10	4.25
Available K	152.00	148.12

Plant height, dry weight plant^{-1}, Yield plant^{-1}, and weight of 100 grains were determined at the maturity stage120 days. Yield and its attributes of maize seeds carbohydrate and contents of N, P and K of leaves were determined. The selected seed samples were dried at 70°C ground and wet digested. The digested product was used to determining N with micro-Kjeldahi method Champman and Pratt, [20]. Phosphorus was determined calorimetrically Watanabe and Olson [21] and potassium by using flam-photometer AOAC [22].

2.4 Statistical Analysis

All data were subjected to analysis of variance using Costat6311Win program Made by Central Lab Of Design & Statistical Analysis Research , Agricultural Research Center (ARC). Giza, Egypt, to test significant difference LSD at 0.05 according to Sendecor and Cochran [23].

3. RESULTS AND DISCUSSION

3.1 Some Chemical Properties of Soil

Data in Table 2 obtained that application of potassium sulphate or feldspar without bacteria inoculated at different rates did not reveal any affect trend in pH values at two seasons studied. However, pH values slightly decreased due to the application of seeds inoculated with bacteria for about reaching (7.97 and 7.95) and (8.02 and 8.00%) in case of potassium sulphate and feldspar in comparison with control in the 1st and 2nd seasons, respectively. Those results agreed with Powlson et al. [24] investigated that soil micro-organisms (collectively the soil microbial biomass) are the agents of transformation of soil organic matter, nutrients and of most key soil processes. Their activities are much influenced by soil physico-chemical and ecological interactions. Report that with Sarhan, M. & El-Gayed, S. [25].

On the other hand, EC values in soil at both two seasons results in Table 2 reveal the soil EC decreased due to applied treatments inoculated seeds with bacteria this decreasing in EC values were (6.01and 7.43%) and 3.79 and 4.55%) in compared with other applications and control in the 1st and 2nd seasons, respectively, this may be bake to acids results from bacteria activity Abo–Baker Basha and Hassan [15] and Wang, et al. [26]. Also, the decreased in soil EC was 2.70% by treatments rates of K_2SO_4 application may be due to the acidic effect of potassium sulphate fertilizer. Concerning, the soil organic matter content data in Table 2 showed no increase exists in OM% with potassium sulphate or feldspar treatments application. While, the seeds inoculated bacteria mixed with potassium sulphate or feldspar led to increasing soil OM% the increase in soil organic matter was (11.67 and 13.33%) and (22.58 and 24.19%) in the case using potassium sulphate and feldspar in compared with control in the 1st and 2nd seasons, respectively. This is may be due to increase in bacteria population mass and its production of organic acids, that trend was recorded in the two seasons of experimental, respectively. Bhattarai et at. [27] found that increasing a large number of bacteria in the soil exists, but because of their small size, they have a smaller biomass.

Available N, P and K in calcareous soil.

The results outlined in Table 2 showed that the values of available nitrogen and phosphorus in soil increased slightly by the treatments of potassium sulphate and feldspar. While applying treatments with seeds inoculated bacteria showed increases in available nitrogen in soil and phosphorus that due to bacteria activities affected in soil phosphorus content.

Data showed that potassium sources applied at different rates with inoculated (*Bacillus circulans*) had significant enhancing available macronutrients N, P and K. The increases in soil available macronutrients as affected by potassium sources reached to 8.40 and 9.94% in the first season and 7.96 and 9.98% in second season for available nitrogen, while available phosphors showed increased by 0.80 and 1.13% in first season and 1.31 and 1.96% in second season in case of feldspar and potassium sulphate inoculated by *Bacillus circulans,* respectively, in the first season and second season. On the other hand, potassium content in soil increased by increasing rates of potassium sulphate and feldspar without seeds inoculated bacteria, while the seeds treated and inoculated by bacteria give high increased of potassium available in the soil. This result may be due to enzyme activity production of bacteria which releasing potassium from rock feldspar also maybe the increased potassium was affected positive for bacteria and its growth. The superior values of available nitrogen, phosphorus and potassium were showed by applying feldspar at rate of 36% K_2O + KDB these values were about 78.66 mg.kg^{-1}, 6.36 mg.kg^{-1} and 236.50 mg.kg^{-1} in first season and 81.67 mg.kg^{-1}, 6.31 mg.kg^{-1}

and 200.28 $mg.kg^{-1}$ in second season, respectively, in the two seasons. Finally, this results were agree with Abou-el-Seoud and Abdel-Megeed [14] indicated that the inoculation of phosphorus solving bacteria and potassium solving bacteria in conjunction with direct the application of rock P and K materials into the soil increased P and K availability.

3.2 Growth and Yield Parameters of Maize

3.2.1 Plant highest and dry weight

Potassium fertilizer stimulated growth of maize plants as shown in (Table 3). The highest value of vegetative growth characters plant height and dry weight were recorded by the treatment that received by feldspar at rate 36% kg K_2O fed^{-1} .+ KDB while the least values were observed by NP+ 0%K on all characters of vegetative growth. The increments in plant height and weight of maize plants under the effect was about 6.58, 6.72% and 2.79 and 2.85% than the plants which received 100% mineral K (control) in the 1st and 2nd seasons, respectively. Moreover, plant height and weight of maize plants was increasing affected by inoculation KDB 13.62, 14.02 for plant height and 3.30, 3.81% for plants weight in case of feldspar or Potassium sulphate respectively, in compared with treatments non inoculation KDB, Almost, a similar trend to that previously obtained in the second season of experimental. These results may be due to the role of potassium element in metabolism and many processes needed to sustain and promote plant vegetative growth and development. These results was agree with Priyanka and Sindhu [28] found that inoculation with *Bacillus circulans* bacteria with feldspar increments in growth parameters, which might be attributed to bacteria that can solubilize them and provide faster and continuous supply of K for optimal plant growth, and Abd-El-Hakeem and Fekry [29] indicated that, using 50% potassium sulphate + 50% K-feldspare + SDB recorded maximum values of plant fresh and dry weight, chlorophyll a and total chlorophyll.

3.3 Some Plant Yield Parameters of Maize Plants

3.3.1 Plant yield and 100 seed weight

The data in Table 3 revealed that the application of mineral potassium or feldspar alone without dissolved potassium bacteria induce variation in seeds yield and corn cob weight of maize, whereas feldspar was better than potassium sulphate, this variation in yield components across the treatments may be to structure and chemical composition. Fertilizing plants with different rates of potassium had increased effect on all of yield and corn cob weight in both seasons. However, fertilizing plants with mineral potassium or feldspar with bacteria inoculated seeds gave the high significant increased values of average corn cob weight fed Kg^{-1}, total yield fad^{-1} and weight of 100 seed (g) in both seasons. Concerning the applied as feldspar + KDB 36% K_2O fed, results indicated that the average of corncob weight fed Kg^{-1} were increased by about 4.85 and 3.85% and the total yield weight fad^{-1} be increased by about 8.71 and 9.52%.

Finally, weight of 100 seed (g) as a parameter of seed quality was affected mainly too by receiving 36% K_2O (feldspar) with bacteria for inoculated seeds than plant control, this increase reaches 7.88% and 7.91% in the 1st and 2nd seasons, respectively in comparison with a control that was received a full dose of NPK fertilizers. Qin and Tian [30]; Dawwam et al. [11] found that the use of potassium solubilizing bacteria was suggested as a sustainable solution to improve plant growth, nutrition, root growth, plant competitiveness and responses to external stress factors. Mehnaz et al. [31] showed significant increases in the plants of the two varieties grown in soil collected from a corn field had respective increases in dry weights of root and shoot about 10-30% and 12-35% and 11-19% and 10 - 18%. In sand, a bacterial mixture was highly effective, whereas in soil individual bacteria namely P.

3.4 Nutritional Status of Maize Plants

3.4.1 Nitrogen, phosphorus and potassium contents

The total content of macronutrients (N, P and K) of leaves and seeds maize plants, respectively, are shown data presented in the Table 4 reveal that the treatments application has increased effects on the concentration of most studied nutrients (N, P and K) in the leaves and grains of maize plants with differences sources of potassium and its rates compared to untreated one.

Table 2. Effect of treatments applied on average values of some chemical properties in soil after the maize plant harvest for two seasons

Treatments	First season						Second season					
	pH	**EC(dS m^{-1})**	**OM(%)**	**N (mg.kg^{-1})**	**P (mg.kg^{-1})**	**K (mg.kg^{-1})**	**pH**	**EC(dS m^{-1})**	**OM(%)**	**N (mg.kg^{-1})**	**P (mg.kg^{-1})**	**K (mg.kg^{-1})**
NPK% (control)	8.15	1.48	0.60	65.60	6.22	208.12	8.18	1.32	0.62	67.86	6.12	173.38
Without bacteria for inoculated seeds												
NP+ 0% K_2O	8.13	1.46	0.60	60.72	6.18	156.5	8.20	1.32	0.62	59.36	6.11	151.63
NP+ 12% K_2O	8.10	1.45	0.60	62.93	6.18	165.0	8.10	1.32	0.62	61.66	6.11	155.58
NP+ 24% K_2O	8.08	1.44	0.61	63.33	6.20	182.32	8.09	1.30	0.62	62.88	6.14	159.00
NP+ 36% K_2O	8.08	1.44	0.62	64.76	6.21	196.0	8.08	1.30	0.63	64.36	6.20	158.5
Mean	8.09	1.45	0.60	62.94	6.19	174.95	8.12	1.31	0.62	62.07	6.14	156.18
NP+ 0% K_2O	8.13	1.46	0.60	60.72	6.18	156.5	8.20	1.32	0.62	59.36	6.11	151.63
NP Felspar 12% K_2O	8.11	1.44	0.60	62.97	6.19	169.5	8.09	1.30	0.62	62.52	6.13	157.50
NP Felspar 24% K_2O	8.10	1.44	0.61	63.94	6.22	194.32	8.08	1.29	0.63	64.86	6.16	160.00
NP Felspar 36% K_2O	8.10	1.43	0.62	65.26	6.24	206.8	8.08	1.29	0.63	65.75	6.19	161.22
Mean	8.11	1.44	0.60	63.22	6.21	181.78	8.11	1.3	0.62	63.12	6.15	157.59
With bacteria for inoculated seeds												
NP+ 0% K_2O	8.03	1.42	0.65	65.67	6.24	176.5	8.06	1.27	0.71	68.36	6.15	158.98
NP+ 12 K_2O	8.00	1.40	0.65	69.33	6.24	205.43	8.04	1.28	0.75	70.15	6.18	163.83
NP+ 24 K_2O	7.96	1.38	0.69	73.11	6.28	225.18	8.00	1.28	0.77	74.58	6.21	182.77
NP+ 36 K_2O	7.90	1.35	0.72	76.33	6.33	232.06	7.96	1.26	0.81	79.96	6.25	197.83
Mean	7.97	1.39	0.67	71.11	6.27	209.79	8.02	1.27	0.76	73.26	6.20	175.85
NP+ 0% K_2O	8.03	1.42	0.65	65.67	6.24	179.5	8.05	1.27	0.71	68.36	6.15	158.98
NP Felspar 12% K_2O	7.98	1.37	0.66	70.73	6.26	210.43	8.01	1.27	0.76	71.65	6.20	165.40
NP Felspar 24% K_2O	7.91	1.35	0.69	73.42	6.30	227.82	7.97	1.26	0.79	76.82	6.28	183.18
NP Felspar 36% K2O	7.87	1.33	0.73	78,66	6.36	236.50	7.94	1.24	0.83	81.67	6.31	200.28
Mean	7.95	1.37	0.68	72.12	6.29	213.56	8.00	1.26	0.77	74.63	6.24	176.96
L.S.D. at 0.05												
K rate (A)	0.03	0.06	0.02	1.22	0.70	7.50	0.04	0.06	0.06	6.00	0.33	5.07
K source (B)	0.07	0.54	0.01	1.98	0.64	10.00	0.09	0.05	0.11	4.56	0.21	6.20
With bacteria (C)	0.05	0.65	0.02	0.95	0.82	9.40	0.08	0.04	0.07	3.70	0.12	3.41
A*B	0.10	0.7	0.05	3.60	0.59	12.00	0.17	0.08	0.15	8.00	0.6	7.10
A*C	0.12	0.18	0.04	6.30	0.90	18.00	0.21	0.07	0.20	6.60	0.80	2.56
B*C	0.16	0.39	0.03	14.88	1.02	22.00	0.26	0.04	0.24	4.33	0.47	6.02
A*B*C	0.22	0.33	0.02	11.00	1.19	25.00	0.30	0.06	0.29	5.50	0.96	5.31

fertilizer rate ="K rate; fertilizer type = "K source; bacteria inoculation = "with bacteria

Table 3. Effect of treatments applied on average values of plant height (m), Plants (fed^{-1} Kg), Cobs (fed^{-1} Kg), Seed yield (fed^{-1} Kg) and 100 seed (g) on two seasons

Treatments	2019					2020				
	Plant height (m)	Plants (fed^{-1} Kg)	Cobs (fed^{-1}Kg)	Seed yield (fed^{-1} Kg)	100 seed weight (g)	Plant height (m)	Plants (fed^{-1} Kg)	Cobs (fed^{-1}Kg)	Seed yield (fed^{-1} Kg)	100 seed weight (g)
NPK%	2.43	19126.5	4804.95	3298.16	31.22	2.38	23821.3	19593	4851.8	30.10
Without bacteria for inoculated seeds										
NP+ 0% K_2O	2.08	17727	3825.3	2423.12	23.00	2.00	1799.7	17727	3918.5	20.30
NP+ 12% K_2O	2.10	18193.5	3918.6	2761.68	25.80	2.02	1892.3	17885	4105.2	23.98
NP+ 24% K_2O	2.13	18306.6	4198.5	2892.31	26.64	2.10	1937.61	18150	4245.1	25.67
NP+ 36% K_2O	2.19	18544	4245.15	2990.26	29.97	2.16	2032.25	18921	4478.0	29.07
Mean	2.13	18192.7	4046.88	2766.843	26.352	2.07	1915.46	18170.75	4186.7	24.755
NP+ 0% K_2O	2.08	17727	3825.3	2423.12	23.00	2.00	1799.7	17727	3918.5	20.30
NP Felspar 12% K_2O	2.12	17962	4105.2	2924.95	26.00	2.05	1920.29	1825.5	4198.5	24.80
NP Felspar 24% K_2O	2.15	18488	4151.85	3053.54	28.52	2.11	1957.61	18600	4291.8	27.22
NP Felspar 36% K_2O	2.20	18660	4291.8	3088.23	30.80	2.18	2125.55	19020	4520.0	29.51
Mean	2.14	18209.2	4093.53	2872.46	27.08	2.09	1950.78	14293.13	4232.2	25.457
With bacteria for inoculated seeds										
NP+ 0% K_2O	2.25	18232	4011.9	2598.33	23.42	2.20	1994.93	18193.6	4011.9	21.84
NP+ 12% K_2O	2.33	18572	4478.4	3022.92	29.16	2.30	2132.25	18990.7	4666.0	28.26
NP+ 24% K_2O	2.52	19093	4758.3	3284.16	31.24	2.42	2254.78	19126.5	4804.1	30.00
NP+ 36% K_2O	2.56	19276	4944.9	3480.09	31.98	2.50	2406.10	20526	4944.6	30.99
Mean	2.42	18793.3	4548.38	3096.375	28.95	2.36	2197.02	19209.2	4606.65	27.773
NP+ 0% K_2O	2.25	18232	4011.9	2598.33	23.42	2.20	1994.93	18193.0	4011.90	21.84
NP Felspar 12% K_2O	2.38	18603.8	4665.4	3153.54	30.57	3.34	2284.16	19465.0	4758.00	28.77
NP Felspar 24% K_2O	2.55	19109.5	4851.6	3349.47	32.69	2.47	2363.44	20059.0	4899.40	30.89
NP Felspar 36% K_2O	2.59	19659.8	5038.2	3585.40	33.68	2.54	2450.9	21459.0	5038.50	32.48
Mean	2.44	18901.3	4641.77	3171.69	30.09	2.39	2273.36	19794.0	4676.95	28.50
L.S.D. at 0.05										
K rate (A)	0.06	93.0	157.7	115	3.20	0.10	135	90.0	160.0	0.16
K source (B)	0.56	80.00	165.0	182	1.55	0.10	182	83.0	150.0	0.50
With bacteria (C)	0.70	73.00	180.8	127	4.00	0.30	147	76.0	141.0	0.41
A*B	0.06	101.2	100.0	160	2.77	0.40	90	101.6	172.0	0.72
A*C	0.19	106.5	120.5	211	3.55	0.20	121	106.3	186.0	0.86
B*C	0.42	119.57	200.0	190	5.00	0.50	150	120.0	168.0	0.68
A*B*C	0.36	130.22	119.0	200	3.21	0.40	170	131.0	100.0	1.00

fertilizer rate ="K rate; fertilizer type = "K source; bacteria inoculation = "with bacteria

The results also, in Table 4 showed that there are significant differences between N, P and K concentration leaves and grains of plants grown in soil with potassium + KDB treatments in both seasons. The highest mean value of N concentration and the maximum mean values of P and K concentration were observed with feldspar at a rate 36% K_2O fed^{-1}+ KDB while the lowest mean values of P and K concentration were obtained with NP application alone in both seasons. Moreover, the impact of KDB on leaves and seed nitrogen content in case of feldspar at rate 36% K_2O fed^{-1}. were reaches 3.85 and 5.10% in leaves 6.96 and 3.86% for seeds. While, the phosphorus content in leaves and seeds recoded increasing arrived at 7.69 and 7.41% in leaves 8.57 and 9.10% for seeds in the 1st and 2nd seasons, respectively; compared with control.

Potassium concentration (%) in plant leaves and seed followed similar the above mention trend, but a significant linear relationship between increase in K_2O rate and increase in potassium percentage was detected amount of 5.88 and 9.33% in leaves and 7.58 and 6.12% in seed compared to control in the 1st and 2nd seasons, respectively. The content of nutrients from soil by plants depends upon the amount of nutrient available and the movement of the ion in the soil solution. Rawat et al. [32] showed that the potassium-solubilizing microorganisms, the component of soil microbial community, play an important role in K solubilization to provide available form to plants. K solubilization benefits crop growth and improves soil fertility in an eco-friendly manner. Potassium-solubilizing strains are able to colonize the rhizosphere, promote crop yield and enhance plant stress response during stress conditions and K uptake.

Table 4. Effect of treatments on average values of N, P and K content in leave and seed maize in two seasons

Treatments	2019						2020					
	N%	P%	K%	N%	P%	K%	N%	P%	K%	N%	P%	K%
	Leaves			Seed			Leaves			Seed		
NPK%	2.60	0.26	0.85	2.73	0.35	2.77	2.55	0.27	0.75	2.59	0.33	2.78
Without bacteria for inoculated seeds												
NP+ 0% K_2O	2.10	0.13	0.42	1.40	0.16	1.85	1.15	0.10	0.35	1.54	0.15	2.02
NP+ 12 K_2O	2.15	0.14	0.46	1.52	0.18	1.95	1.92	0.13	0.41	1.62	0.18	2.15
NP+ 24 K_2O	2.22	0.15	0.55	1.61	0.20	2.30	2.18	0.15	0.51	1.74	0.24	2.72
NP+ 36 K_2O	2.35	0.19	0.65	1.66	0.25	2.60	0.85	0.06	0.19	1.99	0.08	0.88
Mean	2.21	0.15	0.52	1.55	0.20	2.18	1.53	0.11	0.37	1.72	0.16	1.94
NP+ 0% K_2O	2.10	0.13	0.42	1.40	0.16	1.85	0.85	0.06	0.19	1.54	0.08	0.88
NP Felspar 12% K_2O	2.26	0.16	0.48	1.55	0.19	1.95	1.45	0.12	0.39	1.65	0.17	2.05
NP Felspar 24% K_2O	2.35	0.17	0.58	1.63	0.23	2.43	2.00	0.14	0.44	1.77	0.20	2.17
NP Felspar 36% K_2O	2.55	0.21	0.70	1.68	0.27	2.65	2.23	0.16	0.58	2.05	0.27	2.75
Mean	2.32	0.17	0.55	1.57	0.21	2.22	1.64	0.12	0.4	1.75	0.18	1.96
With bacteria for inoculated seeds												
NP+ 0% K_2O	2.24	0.15	0.51	1.65	0.18	2.10	1.15	0.16	0.25	1.99	0.18	2.22
NP+ 12 K_2O	2.45	0.18	0.60	2.18	0.22	2.43	2.24	0.20	0.43	2.23	0.22	2.38
NP+ 24 K_2O	2.58	0.22	0.75	2.60	0.29	2.66	2.38	0.24	0.71	2.52	0.27	2.71
NP+ 36 K_2O	2.65	0.27	0.86	2.85	0.37	2.87	2.65	0.27	0.79	2.67	0.35	2.86
Mean	2.48	0.21	0.68	2.32	0.27	2.52	2.11	0.22	0.55	2.35	0.28	2.54
NP+ 0% K_2O	2.26	0.15	0.51	1.65	0.18	2.10	1.15	0.18	0.25	1.99	0.18	2.22
NP Felspar 12% K_2O	2.54	0.19	0.62	2.25	0.23	2.45	2.28	0.21	0.55	2.26	0.24	2.41
NP Felspar 24% K_2O	2.62	0.24	0.78	2.78	0.31	2.72	2.59	0.26	0.74	2.58	0.31	2.77
NP Felspar 36% K_2O	2.70	0.28	0.90	2.92	0.38	2.98	2.68	0.29	0.82	2.69	0.36	2.95
Mean	2.53	0.22	0.70	2.40	0.28	2.56	2.18	0.24	0.59	2.38	0.27	2.59
L.S.D. at 0.05												
K rate (A)	0.07	0.03	0.01	0.11	0.02	0.20	0.05	0.01	0.07	0.10	0.01	0.12
K source (B)	0.15	0.05	0.02	0.20	0.01	0.24	0.10	0.07	0.06	0.11	0.01	0.09
With bacteria (C)	0.12	0.06	0.01	0.09	0.02	0.18	0.08	0.09	0.08	0.16	0.03	0.16
A*B	0.25	0.08	0.03	0.17	0.05	0.27	0.19	0.02	0.06	0.23	0.04	0.14
A*C	0.19	0.09	0.07	0.13	0.04	0.30	0.21	0.02	0.09	0.20	0.02	0.24
B*C	0.05	0.07	0.10	0.20	0.03	0.20	0.27	0.02	0.10	0.25	0.05	0.29
A*B*C	0.18	0.10	0.09	0.17	0.02	0.33	0.31	0.03	0.12	0.30	0.04	0.33

fertilizer rate =“K rate; fertilizer type = “K source; bacteria inoculation = “with bacteria

Table 5. Average values of Total carbohydrates and curd protein of the seed in both seasons

	2019		2020	
Treatments	**Carbohydrates %**	**Crude protein (%)**	**Carbohydrates %**	**Crude protein (%)**
	Seed		**Seed**	
NPK%	64.78	12.33	63.85	11.86
Without bacteria for inoculated seeds				
NP+ 0% K_2O	50.10	7.35	49.86	8.09
NP+ 12 K_2O	51.90	7.98	51.09	8.51
NP+ 24 K_2O	53.80	8.45	52.18	9.14
NP+ 36 K_2O	55.06	8.72	53.96	10.45
Mean	52.72	8.13	51.77	9.05
NP+ 0% K_2O	50.10	7.35	49.86	8.09
NP Felspar 12% K_2O	52.70	8.14	51.85	8.66
NP Felspar 24% K_2O	55.26	8.56	54.33	9.29
NP Felspar 36% K_2O	55.80	8.82	55.22	10.76
Mean	53.47	8.22	52.82	9.20
With bacteria for inoculated seeds				
NP+ 0% K_2O	59.20	9.66	58.94	10.87
NP+ 12 K_2O	65.50	12.45	61.35	12.18
NP+ 24 K_2O	69.10	13.65	66.91	13.73
NP+ 36 K_2O	71.10	15.96	70.10	14.18
Mean	66.23	12.93	64.33	12.74
NP+ 0% K_2O	59.20	9.66	58.20	10.87
NP Felspar 12% K_2O	65.66	12.92	62.86	12.85
NP Felspar 24% K_2O	70.24	14.60	68.24	13.95
NP Felspar 36% K_2O	73.85	15.33	72.50	14.65
Mean	67.24	13.13	65.45	13.10
L.S.D. at 0.05				
K rate (A)	11.8	0.3	10.00	0.3
K source (B)	20.6	0.5	9.00	0.6
With bacteria (C)	8.90	0.6	7.80	0.6
A*B	17.1	0.8	6.60	0.7
A*C	13.00	0.9	9.50	0.8
B*C	20.00	0.7	11.10	0.8
A*B*C	17.2	1.1	11.80	1.2

fertilizer rate =“K rate; fertilizer type = “K source; bacteria inoculation = “with bacteria

3.5 Nutritional Value of the Seeds

Potassium fertilization sources had a significant effect on total carbohydrates and curd protein of the seed in both seasons Table 5. Generally, the highest values of total carbohydrates and crude protein in seed were recorded by the plants which received feldspar or potassium sulphate at rate 36% K_2O with inoculation *Bacillus circulans* bacteria in the two seasons. Potassium activates several enzymes especially in the metabolism of carbohydrates. The main effect of K_2O on carbohydrate, nitrogen and phosphorus percentages confirm that these percentages were raised as K_2O rate increased. The total carbohydrates content increased by about 7.24 and 8.25%, while crude protein content increased by about 6.89 and 7.24%. The plants which received feldspar + KDB at rate 36% K_2O fed^{-1} increased the total carbohydrates yield fad^{-1} by about 3.45 and 0.20% than control in both seasons under study, respectively. Corn cob formation of maize was positively affected by synthesis and accumulation of starch, since K plays a key role in this regard as it influences cell division and thickening, photosynthesis, formation of carbohydrates, translocations of sugars, mineral nutrients and photosynthetic matter and it also influences enzyme activity George [33].

4. CONCLUSION

Application of K- sources in combination with KDB of 36% of (potassium sulphate or K feldspar) were positive effect on production of maize yield and content of N, P and K. The treatment of (36% K_2O as K feldspar with KDB) gave the highest values of available nitrogen, phosphorus and potassium content in soil compared to other treatments used under study. Using the naturally deposited materials of K-feldspar combined with KDB would be beneficial for farmers and save the high costs of chemical fertilizers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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