Asian Jr. of Microbiol. Biotech. Env. Sc. Vol. 23, No. (3) : 2021 : 372-380

ISSN-0972-3005

EFFECT OF POTASSIUM INOCULANTS AND BLACK MICA ON RHIZOSPHERIC SOIL PROPERTIES OF MAIZE (*ZEA MAYS* L.)

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(Received 3 April, 2021; Accepted 24 May, 2021)

Key words : *Potassium, KMB, Biotite, Soil properties, Maize*

Abstract – A field experiment was conducted at Agricultural Research farm, BHU during the *Kharif* season of the year 2017 to evaluate the performance of Potassium Solubilizing Bacteria and doses of inorganic K as well as mineral K (Biotite) on the soil physic-chemical properties of the rhizospheric soil of maize at different stages (30, 45, 60 and at harvest). The Treatments comprises two KMB isolates with separate combinations of RDK and biotite. The result showed that treatment combination with full dose of RDK through inorganic and mineral source of K along with KSB gave higher EC compared to other treatment which is clear through treatments T9, T10, T13 and T14. This implies KSB inoculation help in increasing soil EC. Data revealed that T6 i.e. 100% RDK gave better organic carbon than T5 i.e. 75% RDK & T4 i.e. 50% RDK and even better than T7 i.e. 50% RDK + 50% RDK through Biotite and T8 i.e. 75% RDK + 25% RDK through Biotite.

INTRODUCTION

Potassium (K) is the third major nutrient essential for crop production after nitrogen and phosphorus. It is a major constituent of several soil minerals. It plays an essential role for enzyme activation, protein synthesis, photosynthesis and quality of produce (Romheld and Kirkby, 2010). The potassium content of Indian soils has traditionally been considered as adequate, but in the recent years, the importance of K and the need for its continued optimal availability for the better crop production has been observed as deficient due to the hidden hunger and luxury consumptions of K (Leaungvutiviroj *et al.*, 2010; Zhang and Kong, 2014). It is one of the seven most common elements in the earth's crust and on an average the surface layer (lithosphere) contains ~ 2.6% potassium. The present conceptual understanding of soil potassium availability is the existence of four distinct K pools differing in accessibility to plant roots with the reversible transfer of K between the pools. The K content of Indian soils varies from less than 0.5 to 3.0%. The average total K content of these soils is ~ 1.52% (Mengel and Kirkby, 1987). Soil solution K plays a vital role in providing the pathway for K uptake from the soil by plant roots (Oborn *et al.*, 2005). According to McLean and Watson (1985) this pool is very low in K content, representing only 0.1-0.2% of the total soil K (~ 5% of total crop demand). It is immediately available and replenished by both the exchangeable K (EK, readily plant available K) and the slow or non-exchangeable K (SEK, slowly plant available K) pools. These two pools, EK and SEK make up about 1-2% and 1-10% of the total K, respectively and are the main contributors to K uptake by plants. The exchangeable fraction i.e. the K held on negatively charged sites of clay mineral.

Maize (*Zea mays* L.) is one of the most important cereal crops in the world that maintain the world agricultural economy. It belongs to *Poaceae* family and is the only species of the genus *Zea* (2n=20). The outstanding features of maize have been well documented all over the world. This crop is being considered as a "*Queen of Cereals*". Maize is being consumed in many ways, such as human food, fodder for animals and in industry for production of milk and oil. It ranks below wheat and sorghum, but considerably above rice as far as the nutritive value is concerned. Maize grains contain 10% protein, 4% oil, 70% carbohydrate, 2.3% crude fibre, 10.4% albuminoids and 1.4% ash. Maize grains have a significant amount of vitamin A, nicotinic acid, riboflavin and vitamin E. It is photo insensitive thus grow throughout the year. Kharif (monsoon) season is the main growing season in northern India. In the south, however, maize may be sown any time from April to October, as the climate is warm even in the winter. Maize requires considerable moisture and warmth from germination to flowering. The most suitable temperature for germination is 21 °C and for growth is 32 °C. Extremely high temperature and low humidity during flowering damage the foliage desiccate the pollen and interfere with proper pollination, resulting in poor grain filling. Maize is an exhaustive crop and utilizes more nutrients from the soil for growth and development. Though the production of maize has increased after green revolution but scarcity of nutrient in soil has greatly affected its yield and quality.

Solubilization of insoluble minerals by bacteria helps uptake and utilization of nutrient from the soil (Muentz, 1890) showed the first evidence of microbial involvement in solubilization of rock potassium Microorganisms like *Aspergillus niger*, *Bacillus extroquens* and *Clostridium pasteurianum* were found to grow on muscovite, biotite, orthoclase microclase and mica in vitro (Archana, 2013). Different bacterial species like silicate bacteria were found to dissolve potassium, silicates and aluminium from insoluble minerals (Aleksandrov *et al*., 1967). Soil organic matter is in rapid equilibrium with soil solution K and is considered to be readily available to plants. Remaining pool or major pool of K which holds the bulk ~ 90-98% of the total soil K, is held in the structure of the primary K bearing mineral soils, K occurs in the form of silicate minerals viz., muscovite, orthoclase, biotite, feldspar, illite, mica (ruby mica, mica powder, mica scrap, mica stone, mica flakes), vermiculite, smectite. The total pool of soil K is extremely complex and this can be solubilized by KSMs through the production of acids and it will be available to plants (Basak and Biswas, 2012). The rhizospheric bacteria help in soil processes such as exudation of soluble compounds, storage and release of nutrients, mobilization and mineralization of nutrients, soil organic matter decomposition and solubilization of K (Zeng *et al*., 2012; Meena *et al*., 2014b), phosphate solubilization, nitrogen fixation, nitrification, denitrification and sulphur reduction (Khan *et al*., 2009; Diep and Hieu, 2013). Those bacteria possessing potassium solubilizing ability are called potassium solubilizing bacteria (KSB) and they can convert the insoluble or mineral structural potassium compounds into soluble forms in soil and make them available to the plants (Zeng *et al*., 2012).

MATERIALS AND METHODS

Physiographic situation of Experiment field

Varanasi is located between $25^0$18′ North latitude and $80^0$36′ East longitude. The area falls in a semi-arid to sub-humid climate with moisture deficit index in between 20 to 40. The normal period for the onset of monsoon in this region is the 3rd week of June which lasts up to end to September or sometimes extends up to the first week of October. Showers of rain are experienced during winter season. The annual rainfall of this region is ~ 1100 mm. Generally the maximum and minimum temperature ranges between 20-42 ^{0}C and 9-28 ^{0}C, respectively. May and June are the hottest month with a mean maximum temperature ranging from 39 to 42 ^{0}C. The 4 cold period lies in between November to January with minimum temperature varying in between 9-10 ^{0}C. The mean relative humidity is about 68% which rise to 82% during wet season and goes down to 30% during dry season. Initial soil properties of experimental field also analyzed. Soil was near to neutral (pH 6.7), EC (0.33 dSm^{-1}) low in organic carbon (0.37%), available N (188.12 kg ha^{-1}), available P (14.92 kg ha^{-1}) and available K (244.48 kg ha^{-1}).

Experimental design and treatment details

An experiment with Potassium Solubilizing Bacteria and doses of inorganic K as well as mineral K (Biotite) was being carried out at Agricultural Research farm, BHU during the *Kharif* season of the year 2017 taking Maize (*Zea mays* L. variety- K-99) as a test crop.

Before starting the experiment, the physico-chemical properties of the soil were determined using applicable methods. Two months prior to the starting of the field trial, the compost was prepared using eco-friendly organic waste materials. In the field experiment, 14 treatments were replicated 3 times in a random block design (RBD), for which a total of 42 plots were prepared in 3 parallel blocks. The 14 treatments were marked by T_1 through T_{14} as follows: T_1 = control, T_2 = OVPS 05 (*Flavobacter* *iumanhuiense* strain OPVS 05, Gene bank accession number- KJ410663, Primary numbering- 55,), T_3 = OVPS 07 (*Agrobacterium tumefaciens* strain OPVS 07, Gene bank accession number- KJ410665, Primary numbering- 61), T_4 = 50% RDK, T_5 = 75% RDK, and T_6 = 100% RDK, T_7 =50% RDK + 50% RDK through Biotite, T_8 =75% RDK + 25% RDK through Biotite, T_9 =50% RDK + 50% RDK through Biotite + OVPS 05, T_{10} = 50% RDK + 50% RDK through Biotite + OVPS 07, T_{11} = 50% RDK + 25% RDK through Biotite + OVPS 05, T_{12} =50% RDK + 25% RDK through Biotite + OVPS 07, T_{13} =75% RDK + 25% RDK through Biotite + OVPS 05 and T_{14} =75% RDK + 25% RDK through Biotite + OVPS 07.

Soil sampling and analysis

For determining the properties of the initial soil samples, a composite soil sample was prepared by mixing soil samples collected from three different sites of the experimental area. For the post-harvest analysis of soil , another composite soil sample was prepared by collecting soil samples from five plots per treatment. In both cases, soil samples were obtained from a depth of 0–15 cm.The soil samples was first dried in open air, then grounded, and finally passed through a sieve having pores 2 mm in size. Soil properties were analyzed by following standard methods.

Soil pH

A soil-water suspension was prepared in the ratio of 1:2.5 (10g soil with 25 mL of distilled water) and the pH was measured with a digital pH meter using reference (KCl) and glass electrode standardized with pH 4.0 and pH 9.2 reference buffers before and after pH determination (Chopra and Kanwar, 1982).

Electrical Conductivity (EC)

Electrical conductivity was determined to know total concentration of soluble salts present in soil. The soil water suspension prepared for determination of pH was used to estimate the electrical conductivity of soil. Soil suspension was allowed to settle till supernatant become clear. The EC was measured with conductivity meter.

Organic Carbon

Soil organic carbon was determined by following the procedure as given by Walkely and Black (1934). One gram air dried soil sample was taken in 500 ml of Erlenmeyer flask, added 10 ml of 1 N potassium di-chromate solution and then 20 ml conc. H_2SO_4 was added, shaken gently to mix and left for 30 minutes then 200 ml of distilled water, 10 ml orthophosphoric acid and 1 ml of diphenylamine indicator was added and titrated with 0.5 N ferrous ammonium sulphate. At end point colour changed from violet to blue to bright green. A blank titration was also carried out.

$$\% \text{ Organic 'C' in soil} = \frac{(B\text{-}T) \times 0.003 \times 10 \times 1 \times 100}{B \times \text{wt. of soil}}$$

Where,

Strength of $K_2Cr_2O_7$ used = 1 *N*

Volume of $K_2Cr_2O_7$ taken = 10

B = Volume of 0.5 *N* FAS solution used for blank titration

T = Volume of 0.5 *N* FAS solution used for sample titration

Available nitrogen

Available Nitrogen content in soil was determined using Kjeltec Semi-Auto Nitrogen Analyser by alkaline Potassium permanganate method as proposed by Subbiah and Asija (1956). The method has been widely adopted to get a reliable index of nitrogen availability in soil due to its rapidity and reproducibility.

Procedure: Five g of soil sample was weighed and transferred in a distillation tube. The sample was moistened with 5 ml distilled water, washing down the soil adhering to the neck of flask. Twenty five ml 0.32% $KMnO_4$ was added to it and the distillation tube was set to the instrument. In a 250 ml conical flask, 20 ml of 2% boric acid mixed indicator was taken and placed under the receiver tube. Tap water was run continuously in the condenser. 25 ml of 2.5% NaOH was sucked and added to the distillation tube. Then it was put on distillation for 9 min. During this process the N released in the form of ammonia is trapped in the boric acid, which develops green colour. The flask containing the distillate was removed. The distillate was then titrated against 0.02 *N* H_2SO_4 until pink colour developed.

Calculation

$$\text{Mineralizable N (kg/ha)} = \frac{(S\text{-}V) \times 0.02 \times 14 \times 10^6 \times 2.24}{1000 \times 5}$$

$$\text{Mineralizable N (kg/ha)} = (S\text{-}V) \times 125.44$$

Where

S = Sample titration reading

V = Blank titration reading

Available phosphorus

Available phosphorus content of soil was determined by Olsen's method (Olsen *et al*., 1954). Firstly reagent A was prepared by using ammonium molybdate, antimony potassium tartrate and H_2SO_4. Then reagent B was prepared with the help of reagent A. 2.5 g of soil was taken in a 150 ml conical flask, a pinch of Darco G-60 and 50 ml of Olsen's reagent (0.5 *M* $NaHCO_3$) was added to it. It was then shaken for 30 minute on mechanical shaker and the suspension was filtered through Whatman No. 1 filter paper. 5 ml of filtrate was transferred in a 25 ml volumetric flask and was acidified with 2.5 *M* H_2SO_4 to pH 5.0 and 20 ml distilled water was added followed by 4 ml of reagent B. After waiting for 10 min the intensity of blue colour was measured on spectrophotometer at 882 nm. Simultaneously a blank was also run. First standard reading was taken followed by sample reading.

Calculation

2.5 g of soil sample is diluted in 50 ml of 0.5N $NaHCO_3$ solution.

Hence, dilution factor = $\frac{50}{2.5}$ = 20 times

5 mL of aliquot is taken in 25 ml volumetric flask.

Hence, dilution factor = $\frac{25}{5}$ = 5 times

Therefore, total dilution factor (DF) =20 x 5 = 100 times

$$\text{Hence, Concentration of Phosphorus (mg kg}^{-1}\text{)} = \frac{\text{y (absorbance from standard curve)}}{\text{m (slope of the standard curve)}} \times 100$$

Available Phosphorus (kg ha^{-1}) = Concentration of Phosphorus (mg kg^{-1}) x 2.24

Available potassium

Available potassium content of soil was determined by Flame Photometer (1 *N* ammonium acetate extract) method (Hanway and Heidel, 1952). Five gram soil was transferred in a 100 ml conical flask and 25 ml of 1 N ammonium acetate solution was added and it was shaken for 5 minutes. The suspension was then filtered through Whatman No. 1 filter paper and potassium concentration in the filtrate was measured using flame photometer. First standard reading was taken followed by sample reading.

Calculation

Dilution factor = 25 / 5 = 5 times

Concentration of K in the sample from standard curve against the reading R = C

Available K (kg ha^{-1}) = C x dilution factor x 2.24

= C x 5 x 2.24

= C x 11.2

Statistical analysis and interpretation of data

The raw data generated during the whole experiment were subjected to statistical analysis by following the Randomized Block Design (RBD) with the appropriate ANOVA table. Overall significance of treatments was tested by F-test and further comparisons were made with the critical difference (CD) at 5% degree of significance to draw the valid differences among the treatments Gomez and Gomez (1984).

RESULTS

Available nitrogen at 30 DAS, treatment T13, i.e. 75% RDK + 25% RDK through Biotite + OVPS 05 followed by T12, i.e. 50% RDK + 25% RDK through Biotite + OVPS 07 resulted higher available N as compared to other treatments (Table 1). At 45 DAS, treatment T13, i.e. 75% RDK + 25% RDK through Biotite + OVPS 05 showed higher available N followed by T5, i.e. 75% RDK as compared to other treatments. At 60 DAS, treatment T13, i.e. 75% RDK + 25% RDK through Biotite + OVPS 05 followed by T14, i.e. 75% RDK + 25% RDK through Biotite + OVPS 07 gave better results as compared to other treatments. At harvest, treatment T13, i.e. 75% RDK + 25% RDK through Biotite + OVPS 05 followed by T9, i.e. 50% RDK + 50% RDK through Biotite + OVPS 07 resulted higher available N as compared to other treatments. Treatment T13 found to be superior among all the treatment at different growing periods of maize crop. At 30 DAS, T13, i.e. 75% RDK + 25% RDK through Biotite + OVPS 05 showed higher available P followed by T14, i.e. 75% RDK + 25% RDK through Biotite + OVPS 07 as compared to control (Table 1). At 45 DAS, T13, i.e. 75% RDK + 25% RDK through Biotite + OVPS 05 followed by T9, i.e. 50% RDK + 50% RDK through Biotite + OVPS 05 gave higher available P as compared to control. At 60 DAS, T13, i.e. 75% RDK + 25% RDK through Biotite + OVPS 05 resulted higher available P followed by T9, i.e. 50% RDK + 50% RDK through Biotite + OVPS 05 as compared to control. At harvest, T13, i.e. 75% RDK + 25% RDK through Biotite + OVPS 05 followed by T14, i.e. 75% RDK + 25% RDK through Biotite + OVPS 07 found to have higher available P as compared to control.

Treatments T13 was found to be superior overall treatment at different growing periods of maize crop.

At 30 DAS, treatments T6, T8, T9, T10, T11, T13 and T14 had significantly higher amount of available K as compared to control (Table 2). Among the treatments T13, i.e. 75% RDK + 25% RDK through Biotite + OVPS 05 showed best result followed by T14, i.e. 75% RDK + 25% RDK through Biotite + OVPS 07 as compared to other treatments and control. At 45 DAS, all the treatments except T3 gave significant outcome as compared to control. Among the treatments T13, i.e. 75% RDK + 25% RDK through Biotite + OVPS 05 resulted more available K followed by T14, i.e. 75% RDK + 25% RDK through Biotite + OVPS 07 as compared to other treatments. At 60 DAS, all treatments yielded higher available K as compared to control and T13 i.e. 75% RDK + 25% RDK through Biotite + OVPS 05 followed by T14, i.e. 75% RDK + 25% RDK through Biotite + OVPS 07 gave best result. At harvest, all the treatments showed higher available K as compared to control but none of them reached to the level of significance. Here treatments T13, i.e. 75% RDK + 25% RDK through Biotite + OVPS 05 gave higher available K followed by treatments T14, i.e. 75% RDK + 25% RDK through Biotite + OVPS 07. All the treatments had lower pH as compared to control but none of them reached to the level of significance. Lowest pH was found in treatment T9, i.e. 50% RDK + 50% RDK through Biotite + OVPS 05 followed by T10, i.e. 50% RDK + 50% RDK through Biotite + OVPS 07 as compared to control. The reason can be due to more amount of mineral form of K i.e. biotite where KSB can act upon it (Table 2).

At 30, 45 and 60 DAS the electrical conductivity (EC) of soil, none of the treatments were able to reach the level of significance (Table 3). At 30 DAS, T9, i.e. 50% RDK + 50% RDK through Biotite + OVPS 05 followed by T10, i.e. 50% RDK + 50% RDK through Biotite + OVPS 07 gave higher soil EC as compared to other treatments and control. At 45 and 60 DAS, T10, i.e. 50% RDK + 50% RDK through Biotite + OVPS 07 showed higher EC followed by T9, i.e. 50% RDK + 50% RDK through Biotite + OVPS 07 as compared to other treatments and

Table 1. Effect of KSB isolates and mineral K on available nitrogen and phosphorus at different growth periods of maize

Tr. No.	Treatments	Available N (kg ha^{-1})				Available P (kg ha^{-1})			
		30 DAS	45 DAS	60 DAS	At harvest	30 DAS	45 DAS	60 DAS	At harvest
T1	Control	143.8	148.72	131.12	135.43	19.46	19.78	19.59	16.94
T2	OVPS 05	157.95	166.04	140.21	137.88	20.08	20.69	20.44	17.79
T3	OVPS 07	146.18	162.06	137.19	137.31	19.92	20.55	20.36	17.71
T4	50% RDK	158.74	170.00	141.04	138.2	20.19	21.70	20.77	18.12
T5	75% RDK	168.91	173.49	142.09	138.34	20.73	21.91	20.89	18.84
T6	100% RDK	236.61	202.24	153.56	145.71	21.89	23.12	22.40	19.75
T7	50% RDK + 50% RDK through Biotite	172.76	174.92	143.12	139.09	20.73	21.96	21.11	18.46
T8	75% RDK + 25% RDK through Biotite	236.55	191.28	152.89	144.99	21.69	23.06	22.18	19.53
T9	50% RDK + 50% RDK through Biotite + OVPS 05	252.94	205.57	157.44	147.64	23.79	25.80	23.38	19.78
T10	50% RDK + 50% RDK through Biotite + OVPS 07	241.55	203.94	154.19	145.72	23.31	23.47	22.40	19.75
T11	50% RDK + 25% RDK through Biotite +OVPS 05	210.12	181.38	151.97	143.53	21.13	22.27	22.05	19.40
T12	50% RDK + 25% RDK through Biotite+ OVPS 07	182.24	184.75	143.92	142.83	21.06	22.17	21.81	19.16
T13	75% RDK + 25% RDK through Biotite + OVPS 05	286.46	249.23	167.11	148.14	26.31	26.49	25.14	22.49
T14	75% RDK + 25% RDK through Biotite + OVPS 07	265.01	226.88	164.84	147.83	24.87	24.34	22.43	20.73
	SEm±	23.92	15.19	6.00	5.10	1.60	1.44	1.17	1.17
	CD (p=0.05)	69.52	44.16	17.44	NS	NS	NS	NS	NS
	CV (%)	11.27	11.90	6.99	6.20	12.52	11.00	9.29	10.58

control. At harvest, all treatments gave significantly higher EC than control. Among them T13, i.e. 75% RDK + 25% RDK through Biotite + OVPS 05 followed by T10, i.e. 50% RDK + 50% RDK through Biotite + OVPS 07 gave higher soil EC as compared to other treatments and control. It was observed that all treatments resulted higher organic carbon (Table 3) than control but none of them reached to the level of significance in all the given growing periods of maize crop. Treatment T10, i.e. 50% RDK + 50% RDK through Biotite + OVPS 07 followed by T9, i.e. 50% RDK + 50% RDK through Biotite + OVPS 05 showed higher organic carbon in different growing stages of maize crop.

DISCUSSION

It shows that available N increased from 30 DAS to 45 DAS and then decreased at 60 DAS. The reason for such increment can be due to top dressing of nitrogenous fertilizer and the decrement can be due to the plant uptake. It can be inferred that available P decreased with increase in growing periods, the reason behind it can be related to the plant uptake which decreased the available P in the soil. Data also indicate that T6, i.e. 100% RDK had higher K content in soil than T5, i.e. 75% RDK and T4, i.e. 50% RDK. It was also found that same treatment combination when used with KSB yielded higher availability of P in soil. It can be extracted that KSB helps in increasing the P availability. Similar observations were reported by Sugumaran and Janarthanam (2007) where available P and K were increased from 6.24 to 9.28 mg/kg in soil due to inoculation of *B. mucilaginosus* (KSB) as compared to uninoculated control in groundnut plant. Similar trend was also observed by Patiram and Mali (2004), Sakarvadia*et al.* (2012); Veeresha and Pradeep (2014); Chaudhary *et al.* (2017) and Hussain *et al.* (2019) in maize.

It was found that similar treatment combination when mixed with KSB yielded higher available K. Furthermore, there is a decreasing pattern of available K with increasing the growing period were recorded and this can be due to plant uptake. It was also revealed that T13 was best treatment among all other treatments. Isolates OVPS 05 was superior to

Table 2. Effect of KSB isolates and mineral K on available K and soil reaction (pH) at different growth periods of maize crop

Tr. No.	Treatments	Available K (kg ha^{-1})				Soil pH			
		30 DAS	45 DAS	60 DAS	At harvest	30 DAS	45 DAS	60 DAS	At harvest
T1	Control	202.06	220.83	150.56	164.25	7.27	7.24	7.20	7.16
T2	OVPS 05	238.29	274.50	213.04	176.08	7.16	7.13	7.08	7.03
T3	OVPS 07	262.19	301.25	195.52	191.71	7.20	7.16	7.11	7.06
T4	50% RDK	287.51	354.48	161.82	207.83	7.24	7.21	7.15	7.10
T5	75% RDK	293.40	412.49	183.50	178.28	7.33	7.31	7.25	7.14
T6	100% RDK	325.17	351.45	201.48	222.52	7.27	7.23	7.18	7.12
T7	50% RDK + 50% RDK through Biotite	264.40	393.43	225.26	223.15	7.20	7.17	7.13	7.07
T8	75% RDK + 25% RDK through Biotite	243.47	401.80	159.40	209.46	7.22	7.19	7.15	7.09
T9	50% RDK + 50% RDK through Biotite + OVPS 05	340.30	407.77	174.36	226.39	6.86	6.81	6.77	6.68
T10	50% RDK + 50% RDK through Biotite + OVPS 07	333.31	350.52	206.16	220.77	7.18	7.14	7.01	6.86
T11	50% RDK + 25% RDK through Biotite +OVPS 05	355.01	312.63	166.79	203.94	7.18	7.12	7.08	7.01
T12	50% RDK + 25% RDK through Biotite+ OVPS 07	363.14	325.77	212.98	191.92	7.15	7.13	7.08	7.03
T13	75% RDK + 25% RDK through Biotite + OVPS 05	387.26	423.41	235.38	226.41	7.08	7.02	6.99	6.91
T14	75% RDK + 25% RDK through Biotite + OVPS 07	340.20	257.35	227.65	206.91	7.13	7.09	7.05	7.00
	SEm±	1.11	5.62	1.42	3.15	0.13	0.13	0.12	0.12
	CD (p=0.05)	3.23	16.34	4.14	9.17	NS	NS	NS	NS
	CV (%)	0.63	2.84	1.27	2.68	3.12	3.12	2.97	3.01

OVPS 07. It can also be extracted that combination of fertilizer and mineral form of K along with KSB resulted higher available K as compared to 100% RDK. The reason can be the solubilization of mineral K that resulted sustain available K for plant growth. Increasing in available K through KSB was also reported by Park *et al.* (2003); Sheng *et al.* (2003), and Sugumaran and Janarthanam (2007). There was decreasing trend on the value of pH with respect to increase in growing periods of maize crop. This decreasing trend may be due to the activity of KSB. KSB on solubilization releases various organic acids that in turn decrease the pH. The release of these organic acids can be one of the reasons of solubilization of mineral form of K and hence releases K which is available for plant uptake. There are also various heterotrophic microorganisms which help in excretion of organic acids which causes decrease in pH of soil but in general there was no much variation. Application of potassium mobilizing bacteria (KMB) which leads to solubilization of native source of potassium like illite and feldspar by different bacteria species (Sheng and He, 2006). These findings are in agreement with those of Parmar (2016).

From the data, it is reflected that those treatment combination with full dose of RDK through inorganic and mineral source of K along with KSB gave higher EC compared to other treatment which is clear through treatments T9, T10, T13 and T14. This implies KSB inoculation help in increasing soil EC. Data revealed that T6 i.e. 100% RDK gave better organic carbon than T5 i.e. 75% RDK & T4 i.e. 50% RDK and even better than T7 i.e. 50% RDK + 50% RDK through Biotite and T8 i.e. 75% RDK + 25% RDK through Biotite. The reason can be the combination of those treatments which KSB which not only helped solubilization of mineral K but also helped in increasing organic carbon content on soil. These results also collaborated with the results found by Veereshaand Pradeep (2014).

CONCLUSION

Application of KSB and mineral K(black mica i.e. biotite) positive influenced soil properties along

Table 3. Effect of KSB isolates and mineral K on electrical conductivity and organic carbon at different growth periods of maize crop

Tr. No.	Treatments	EC (dSm^{-1})				Organic carbon (%)			
		30 DAS	45 DAS	60 DAS	At harvest	30 DAS	45 DAS	60 DAS	At harvest
T1	Control	0.22	0.28	0.24	0.21	0.38	0.42	0.42	0.30
T2	OVPS 05	0.23	0.30	0.26	0.24	0.43	0.44	0.45	0.37
T3	OVPS 07	0.23	0.30	0.26	0.23	0.43	0.45	0.47	0.39
T4	50% RDK	0.25	0.31	0.27	0.26	0.43	0.45	0.48	0.40
T5	75% RDK	0.25	0.31	0.27	0.26	0.44	0.46	0.48	0.40
T6	100% RDK	0.26	0.32	0.27	0.28	0.48	0.48	0.51	0.50
T7	50% RDK + 50% RDK through Biotite	0.27	0.33	0.28	0.31	0.45	0.46	0.48	0.40
T8	75% RDK + 25% RDK through Biotite	0.27	0.33	0.29	0.32	0.45	0.47	0.49	0.44
T9	50% RDK + 50% RDK through Biotite + OVPS 05	0.36	0.36	0.34	0.39	0.49	0.49	0.53	0.54
T10	50% RDK + 50% RDK through Biotite + OVPS 07	0.34	0.37	0.35	0.41	0.50	0.50	0.57	0.59
T11	50% RDK + 25% RDK through Biotite +OVPS 05	0.29	0.34	0.30	0.33	0.46	0.47	0.49	0.46
T12	50% RDK + 25% RDK through Biotite+ OVPS 07	0.28	0.33	0.29	0.32	0.46	0.47	0.49	0.49
T13	75% RDK + 25% RDK through Biotite + OVPS 05	0.33	0.35	0.33	0.42	0.49	0.48	0.51	0.51
T14	75% RDK + 25% RDK through Biotite + OVPS 07	0.31	0.34	0.32	0.35	0.49	0.48	0.52	0.53
	SEm±	0.01	0.04	0.03	0.01	0.02	0.02	0.04	0.05
	CD (P=0.05)	0.04	NS	NS	0.02	0.07	NS	NS	NS
	CV (%)	8.59	19.34	17.79	3.72	6.99	5.77	11.84	10.79

with nutrient availability. Considering the efficiency of K solubilizer isolates towards soil properties and nutrient availability in soil at different growth stages. OPVS 05 appeared to be more effective than OPVS 07. Use of these efficient KSB isolates under favorable conditions certainly will enhance supply of K to crop. However, authentications through multilocation field trails are necessary prior to the recommendation of these KSB isolates as apotassic inoculants.

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