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Impact of potassium solubilizing bacteria (KSB) and sources of potassium on yield attributes of maize (*Zea mays* L)

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Abstract
A field experiment was carried out at Agricultural Research Farm of Banaras Hindu University Varanasi during Kharif 2017 and 2018. Effect of two potassium solubilizing bacterial strains i.e. KSB_1 (KJ410663) and KSB_2 (KJ410665) were assessed in combination with mineral K. Data revealed that combination of inorganic source and mineral source i.e. biotite along with KSB significantly increased number of lines cob^{-1}, number of grains cob^{-1}, cob length, cob weight, grain weight cob^{-1}and 100-seed weight of crop over uninoculated control. Application of 100% RDK through inorganic and mineral source of K with KSB_1 gave maximum yield attributes as compared to control. Maximum grain and stubble yield were found to be higher with treatment 75% RDK + 25% Biotite + KSB_1 compared to control and reference strain. Therefore, KSB_1 strain was superior to be KSB_2.

Keywords: Potassium, maize, yield attribute, KSB, biotite, grain and stubble yield

Introduction

After nitrogen (N) and phosphorus (P), potassium (K) is the most important plant nutrient that has a key role in the growth, metabolism and development of plants. In addition to increasing plant resistance to diseases, pests, and abiotic stresses, K is required to activate over 80 different enzymes responsible for plant and animal processes such as energy metabolism, starch synthesis, nitrate reduction, photosynthesis, and sugar degradation [3, 12, 22, 24]. K is the seventh most abundant element in Earth's crust. Total K content in soils ranges between 0.04 and 3% K. Although K is present as an abundant element in soil, only 1 to 2% of this element is available to plants [21]. The rest are bound with other minerals and therefore are unavailable to plants.

Maize is (*Zea mays* L.) is the third most important cereals next to rice and wheat in the world as well in India, contributing about 20 per cent share of worlds total cereal production. Maize is being consumed both as food and fodder crop and also required by various industries in India. Maize is known as "Queen of cereal" because of its high production potential and wider adoptability. In world, maize occupies an area of 163.9 million ha with the production of 832 million tones and productivity of 5080 kg per ha. In India, maize is grown over an area of 9.86 million ha with the production of 26.26 million tones and productivity is 2664 kg ha^{-1} [4]. Maize is an exhaustive crop and utilizes more nutrients from the soil for growth and development. Solubilization of insoluble minerals by bacteria helps to uptake and utilization of nutrient from the soil.

Microbial soil community is able to influence soil fertility through soil processes viz. decomposition, mineralization, and storage / release of nutrients [18]. Mechanisms of KSB in promotion of plant growth [21]. Reported that some beneficial soil microorganisms, such as a wide range of saprophytic bacteria, fungal strains and actinomycetes, could solubilize the insoluble K from soils by various mechanisms. Some of these mechanisms include the production of inorganic and organic acids, acidolysis, polysaccharides, complexolysis, chelation, polysaccharides, and exchange reactions. K solubilizing bacteria (KSB) have attracted the attention of agriculturists as soil inoculum to promote the plant growth and yield. The KSB are effective in releasing K from inorganic and insoluble pools of total soil K through solubilization [10, 13, 16, 20]. It has been reported that inoculation with KSB produced beneficial effect on growth of different plants [1, 6, 23]. Thus, identification of efficient bacterial strains capable of solubilizing K minerals can quickly conserve our existing resources and avoid environmental pollution hazards caused by heavy application of K-fertilizers.

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Material and Methods

A field experiment was conducted during *kharif* seasons 2017 and 2018 in an inceptisol of Agricultural Research Farm of Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India. An experiment was laid out in randomized block design with three replications and 14 treatments. Treatments consisted of T1=Control; T2= KSB_1 ; T3= KSB_2 ; T4= 50% RDK; T5= 75% RDK; T6= 100% RDK; T7= 50% RDK +50% RDK through Biotite ; T8= 75% RDK+25% RDK through Biotite; T9= 50% RDK+ 50% RDK through Biotite+ KSB_1; T10= 50% RDK + 50% RDK through Biotite + KSB_2; T11=50% RDK +25% Biotite + KSB_1; T12= 50% RDK+25% Biotite + KSB_2; T13= 75% RDK +25% RDK through Biotite + KSB_1; T14=75% RDK + 25% RDK through Biotite + KSB_2. The experimental field was plowed transversely with a disc pulled by a tractor. Dry weeds and stubble were removed. The field was plowed again by the cultivator and finally planking was done to achieve a tilth. Block boundaries, plots and irrigation channels were created manually. The gross plot size is 6m × 2m ($12m^2$) per plots. The experimental plots were leveled before sowing the seeds.Maize variety 'K-99' was selected for sowing. The sowing was done with the help of manual drill using seed rate of 20 kg ha^{-1}. Periodical intercultural operations like irrigation and weeding were carried out and plots were maintain for good crop growth.

At bulk surface (0-15cm) soil sample was collected before sowing and after harvest of crop. As per the treatments specification all the doses of phosphorus (P_2O_5) as DAP and potash (K_2O) as muriate of potash were applied as basal dose during field preparation whereas half dose of nitrogen as urea was applied at the time of sowing and remaining half amount of nitrogen was top dressed in two equal split doses at 30 days and 55 days after sowing (DAS).The yield attributes such as number of lines cob^{-1}, number of grains cob^{-1}, cob length, cob weight, grain weight cob^{-1},100-seed weight and grain and stubble yield were recorded after harvesting of crop. The data pertaining to each character of the maize crop were analyzed statistically by applying the standard technique. Analysis of variance for randomized block design was worked out and the significance was tested to draw valid conclusions [6].

Result and Discussion

Data pertaining to lines per cob are presented in table 1. All treatments showed higher lines per cob than control. Maximum lines per cob was found in T_{13} i.e. 75% RDK + 25% RDK through Biotite + KSB_1 followed by T_{14} i.e. 75% RDK + 25% RDK through Biotite + KSB_2 and treatment T_{13} gave maximum lines per cob as compared to control during both the experimental years.

Cob length (cm)

Data pertaining to cob length are presented in table.1.Cob length greatly influenced by different treatments than control but none of them was able to reach the level of significance. Treatment T_{13} i.e. 75% RDK + 25% RDK through Biotite + KSB_1 followed by T_{14} i.e. 75% RDK + 25% RDK through Biotite + KSB_2 gave maximum cob length and minimum cob length was observed at control (T_1) during both the years. Increase in length of cob might be due to the improvement in soil chemical properties and nutritional status, and increased microbial activity in the root zone because of the integrated effects of KSB strains with K fertilization [7, 2, 25].

Weight of Cob (per cob)

A critical perusal of data presented in table.1 revealed that weight per cob with grain of maize crop significantly influenced by KSB isolates and sources of K in years 2017 and 2018.In first and second year treatment T_{13} i.e. 75% RDK + 25% RDK through Biotite + KSB_1 gave maximum weight of cob with grain followed by T_9, T_{10}, T_{11}, T_{12} and T_{14} and minimum in control.

Table 1: Effect of KSB isolates and sources of K on cob length (cm), lines per cob and weight per cob with grain (g) of maize crop

Year of Experiments						
	2017			2018		
Treatments	Cob length (cm)	Lines cob^{-1}	Weight cob^{-1}(g)	Cob length (cm)	Lines cob^{-1}	Weight cob^{-1}(g)
T1 Control	10.4	11.7	57.2	10.9	10.7	53.6
T2 KSB_1	11.5	12.5	67.5	11.9	12.3	68.2
T3 KSB_2	10.9	12.1	60.8	11.1	11.9	55.7
T4 50% RDK	11.7	12.4	62.5	12.3	12.3	62.0
T5 75% RDK	12.2	13.6	62.9	12.3	12.4	67.2
T6 100% RDK	12.3	13.8	74.2	12.5	13.6	70.8
T7 50% RDK +50% RDK through Biotite	12.4	13.9	74.8	12.8	13.4	77.1
T8 75% RDK+25% RDK through Biotite	12.2	13.9	64.1	12.5	13.3	73.5
T9 50% RDK+ 50% RDK through Biotite+ KSB_1	12.6	14.0	66.1	13.3	13.4	54.8
T10 50% RDK + 50% RDK through Biotite + KSB_2	12.8	14.5	64.1	13.3	12.9	58.3
T11 50% RDK +25% Biotite + KSB_1	13.5	15.6	73.0	14.1	15.6	61.8
T12 50% RDK+25% Biotite + KSB_2	12.8	15.4	61.3	14.0	13.8	72.7
T13 75% RDK +25% RDK through Biotite + KSB_1	15.2	16.0	77.5	15.7	16.4	78.5
T14 75% RDK + 25% RDK through Biotite + KSB	14.4	15.8	75.6	14.7	15.7	78.1
SEm±	0.72	0.83	4.64	0.50	0.73	4.10
CD(p=0.05)	2.10	2.42	NS	1.47	2.11	11.91

Grains per cob

Data pertaining on effect of KSB isolates and sources K fertilization grains per cob of maize crop presented in table.2 revealed that grains per cob of maize crop was significantly enhanced by the application of KSB isolates and K fertilizers. All the isolates showed significant superiority over control. In first year; T_{13} gave higher grains per cob as compared to un-inoculated control. In second year, T_{13} gave maximum number of grains per cob followed by T_9 as compared to control T_1.During both the years T_{13} gave maximum number of grains per cob as compared to other treatments.

Grain weight per cob

Data pertaining to grain weight per cob of maize crop presented in table.2. influenced significantly by KSB isolates and sources of K. In first and second year, maximum grain weight per cob was recorded with 75% RDK +25% RDK through Biotite + KSB_1 followed by treatment $T_{14}>T_{11}>T_{12}>T_9>T_7>T_6$ and minimum grain weight per cob in control.

100- Seed weight

Data pertaining to 100-grains weight of maize presented in table.2 clearly indicate that it was significantly influenced with KSB isolates and K sources treatments. However, the rate of increase in 100-grain weight differed with the potassium solubilizing bacterial (KSB) isolates. In first year, Treatment T_{14} i.e. 75% RDK + 25% RDK through Biotite + KSB_2 gave significantly higher 100-grain weight of maize crop compared to T_{13} i.e. 75% RDK + 25% RDK through Biotite + KSB_1 and they showed significant superiority over rest of the treatments. But in second year, Treatment T_{13} i.e. 75% RDK + 25% RDK through Biotite + KSB_1 gave significantly higher 100-grain weight of maize crop compared to T_{14} i.e. 75% RDK + 25% RDK through Biotite + KSB_2 and they showed significant superiority over rest of the treatments. The data reflect that similar treatment when combined with inorganic source and mineral source along with KSB gave higher yield attribute. The reason can be due to solubilization of Biotite by KSB that releases more K into the solution where plant could uptake more K therefore yield get enhanced. Similar result regard to yield attributes were reported by [17, 11, 5, 8, 14, 19, 15].

Table 2: Effect of KSB isolates and sources of K on grains per cob, per cob grain weight (g) and 100 grain weight (g) of maize crop

Year of Experiments						
	2017			2018		
Treatments	Grains cob $^{-1}$	Per cob grain weight (g)	100 grain weight (g)	Grains cob $^{-1}$	Per cob grain weight (g)	100 grain weight (g)
T1 Control	175.7	26.0	17.9	177.1	23.9	18.5
T2 KSB_1	196.0	27.0	21.2	270.5	30.3	24.7
T3 KSB_2	190.5	26.3	19.1	186.6	31.3	18.7
T4 50% RDK	224.1	28.1	19.9	263.6	31.9	20.8
T5 75% RDK	223.4	29.4	20.8	264.8	28.0	21.0
T6 100% RDK	234.4	30.9	22.0	352.2	29.9	21.3
T7 50% RDK +50% RDK through Biotite	245.1	32.9	22.2	274.4	29.1	22.8
T8 75% RDK+25% RDK through Biotite	257.8	32.3	19.8	352.3	27.7	21.1
T9 50% RDK+ 50% RDK through Biotite+ KSB_1	254.8	33.8	23.7	403.3	30.4	21.1
T10 50% RDK + 50% RDK through Biotite + KSB_2	275.7	29.8	24.4	333.0	28.3	21.2
T11 50% RDK +25% Biotite + KSB_1	286.5	35.9	24.7	283.3	32.7	23.6
T12 50% RDK+25% Biotite + KSB_2	286.2	34.6	24.8	391.4	31.6	21.6
T13 75% RDK +25% RDK through Biotite + KSB_1	303.2	38.0	25.3	413.6	36.6	25.2
T14 75% RDK + 25% RDK through Biotite + KSB	302.7	36.7	25.9	402.2	33.3	24.5
SEm±	1.52	2.14	1.29	1.83	1.75	1.41
CD(p=0.05)	4.41	6.22	3.75	5.32	5.10	4.10

Grain and stubble Yield (qha^{-1})

The data revealed that maize grain and stubble yield significantly increased due to application of potassium solubilizing bacteria and sources of potassium presented in Table. 3. Maximum grain and straw yield was recorded in treatment T_{13} followed by treatment T_{14} while minimum in treatment T_1 (control).First year grain yield is lesser than from second year but in stubble yield, first year stubble yield is higher than second year. Grain yield (54.30qha^{-1} and 56.20qha^{-1}) was significantly higher with75% RDK +25% RDK through Biotite + KSB_1 as compared to control (24.40 qha^{-1}and 23.60 qha^{-1}) at both the two years. Stubble yield (98.66 qha^{-1} and 95.38 q ha^{-1}) was also significantly superior with75% RDK +25% RDK through Biotite + KSB_1 as compared to control (47.78 qha^{-1}and 47.73 qha^{-1}) from both years of research. This implies that maize plant needs full dose of recommended K to yield optimum grain weight and stubble yield. It is also evident that various combinations yielded better when mixed with KSB. The reason to may be solubilization of mineral form of K i.e. Biotite by KSB that release more K. Similar outcomes were reported by [8, 14, 19, 15].

Table 3: Effect of KSB isolates and sources of K on grain and stubble yield (qha^{-1}) of maize crop

Year of Experiments				
	2017	2018	2017	2018
Treatments	Grain yield (qha^{-1})	Grain yield (qha^{-1})	Stubble yield (qha^{-1})	Stubble yield (qha^{-1})
T1 Control	24.44	23.63	47.48	47.73
T2 KSB_1	27.07	27.76	52.87	55.53
T3 KSB_2	24.49	24.37	51.59	52.68
T4 50% RDK	25.61	26.34	54.56	54.71
T5 75% RDK	25.80	28.54	54.65	48.27
T6 100% RDK	38.47	38.35	62.16	66.01
T7 50% RDK +50% RDK through Biotite	31.08	35.51	76.94	71.01
T8 75% RDK+25% RDK through Biotite	27.12	30.01	54.24	57.07
T9 50% RDK+ 50% RDK through Biotite+ KSB_1	42.10	44.49	93.11	88.97
T10 50% RDK + 50% RDK through Biotite + KSB_2	41.76	41.48	83.52	82.96
T11 50% RDK +25% Biotite + KSB_1	36.48	40.48	72.96	75.31

T12 50% RDK+25% Biotite + KSB_2	34.68	37.66	82.69	77.62
T13 75% RDK +25% RDK through Biotite + KSB_1	54.33	56.19	98.66	95.38
T14 75% RDK + 25% RDK through Biotite + KSB	46.56	47.48	94.21	94.95
SEm±	2.21	2.49	2.95	3.71
CD(p=0.05)	6.42	7.23	8.58	10.79

Conclusion

It is concluded that the application of KSB and sources of K significantly influenced the yield attributes and yield of maize crop as compared to uninoculated control. The number of lines cob^{-1}, number of grains cob^{-1}, cob length, cob weight, grain weight cob^{-1},100-seed weight, grain and stubble yield of maize was significantly superior with treatment T_{13} (75% RDK +25% RDK through Biotite + KSB_1) as compared to other treatments. Therefore, application of 100% RDK through inorganic and mineral K with KSB gave better result over the 50% application and uninoculated control.

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