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Effect of Potassium Solubilizing Bacteria (KSB) on the Performance of Sweet Corn (*Zea mays* L. *saccharata*) in Potassium Sufficient Soils of Semi-arid Tropic

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted on potassium sufficient sandy loam soil (*Alfisols*) to evaluate the impact of potassium solubilizing bacteria (KSB) on the performance of *rabi* sweet corn. The study consisted of 10 treatments with different doses of potassium with and without KSB treatment [Seed

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treatment (ST) + Soil drenching (SD) at Knee height (KH) stage]. Result of this experiment indicated that sweet corn yield was gradually reduced with reduction of recommended dose of potassium (RDK) irrespective of KSB treatment. Amongst all treatments, application of 100% RDK in 2 equal splits at sowing and KH stage + KSB (ST + SD) (T_{10}) resulted in highest growth, yield (19.7 t ha^{-1}) and yield attributes. However, T_{10} was on par with the result of [100% RDK + KSB (ST) + KSB (SD) at KH stage], (50% RDK at basal + 50% RDK at KH stage), [100% RDK+ KSB (ST) +KSB (SD) at KH stage] and [75% RDK at basal + KSB (ST) +KSB (SD) at KH stage] treatments. Whereas, implication of 25% or 50% reduction of RDK was significantly inferior to 100% RDK. The study revealed that KSB could substitute 25% of RDK supplied to nutrient exhaustive crop like *rabi* sweet corn without compromising the economic yield in potassium rich *alfisols* of semi-arid tropic.

Keywords: Integrated nutrient management; potassic fertilizer; K- split application; Telangana.

ABBREVIATIONS

KH : Knee height stage
RDK : Recommended dose of potassium
KSB : Potassium solubilizing bacteria
ST : Seed treatment
SD : Soil drenching

1. INTRODUCTION

Corn or Maize (*Zea mays* L.) is one of the most important cereal crops in the world with multifarious uses after rice and wheat. In India, total cultivated area under maize was 9.89 M ha with an annual production of 31.6 Mt and average productivity of 3,199 kg ha^{-1} [1]. Sweet corn (*Zea mays* L. saccharata) is a type of corn grown for human consumption as raw or processed food throughout the world.

As far as plant nutrition is concerned, potassium (K^+) is a very important macronutrient which controls plant water status, it regulates ionic balances, activity of stomata cells to prevent unnecessary water loss by transpiration, K plays a significant role in photo-synthesis and in the production and translocation of carbohydrate to areas of meristematic growth, fruit development and storage and also aids in activation of more than 60 enzymes which catalyzes various metabolic process [2].

In India, there is very limited source of K-ore for manufacturing potassic fertilizer, hence, the entire required amount of K-fertilizer is imported from abroad in the form of muriate of potash (KCl) and sulphate of potash (K_2SO_4). The total import of muriate of potash (MOP) during the year 2020 was more than 5.08 Mt [3]. Govt. of India is giving subsidy of Rs. 759 bag^{-1} (50 kg) to keep the domestic MOP price (Rs. 1675 bag^{-1}) within the reach of farmer, when international price of MOP is Rs. 2434.61 bag^{-1} [4]. It imposes huge monetary burden to the Indian government. Keeping in view, in the year 2023, The Indian government planned to introduce a new scheme – PM PRANAM (PM Promotion of Alternate Nutrients for Agriculture Management Yojana) to rely on all natural ways and resources in lieu of chemical fertilizers togrow the crops.

In India, 79% of soils are medium to high in inherent potassium status [5]. Depending on the soil around 98 % of total soil K was found in unavailable form [6]. As the conversion process of unavailable to available K is a very slow process and not sufficient to replenish the dearth of available potassium in crop growing season [5], soil microorganisms (KSB) can play a significant role in solubilization process through acidolysis, production of organic acids, chelation, complexolysis, and ion-exchange reactions [7].

Keeping in view high import of potassic fertilizers to India and its monetary burden on economy, high potassium demand by sweet corn, sufficiency of soil potassium but in unavailable form and considerable potential of KSB in converting un-available soil potassium and making it available to the crop, there was an urgent need to assess and quantify the efficacy of KSB in potassium management vis-à-vis minimizing chemical fertilizers requirement in rabi sweet corn.

2. MATERIALS AND METHODS

A field experiment was conducted during rabi season (November- February) (2022- 23) at College farm of Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, India (17° 19' 18" N latitude, 78° 24' 31" E longitude, with an elevation of 542.6 m above mean sea level) which is under semi-arid tropic region (SAT). The soil (p^H=7.45) was sandy loam in texture, deficient in soil organic carbon (0.39%) and available N (177.2 kg ha^{-1}), and rich in available-P (26.2 kg ha^{-1}) and available-K (188.3 mg kg^{-1}). Soil texture, p^H, organic carbon, available nitrogen, available phosphorus, available potassium were determined by duly following the procedures given by Piper [8], Jackson [9], Walkley and Black [10], Subbaiah and Asija [11], Olsen et al. [12] and Jackson [9], respectively. During the crop growth period, the weekly mean maximum atmospheric temperature ranged from 34.2°C to 28.4°C with an average of 30.4°C and mean minimum atmospheric temperature ranged from 18.2°C to 10.8°C with an average of 14.7°C (Fig. 1). These weather data were taken from Agro Climate Research Centre, Agricultural Research Institute, Rajendranagar, Hyderabad. The experiment, consisted of 10 potassium management practices, was laid out in randomized block design with 3 replications. The 10 treatments were- T_1: 0% RDK (Recommended dose of potassium), T_2: 100% RDK (Basal) (50 kg ha^{-1}), T_3: 50% RDK (Basal) (25 kg ha^{-1}), T_4: 75% RDK (Basal) (37.5 kg ha^{-1}), T_5: 50% RDK (Basal) + 50% RDK [at Knee Height (KH) stage], T_6: T_1 + KSB [Seed Treatment (ST)] + KSB [Soil Drenching (SD)] at KH stage, T_7: T_2 + KSB (ST) + KSB (SD) at KH stage, T_8: T_3 + KSB (ST) + KSB (SD) at KH stage, T_9: T_4 + KSB (ST) + KSB (SD) at KH stage, T_{10}: T_5 + KSB (ST) + KSB (SD) at KH stage. Seeds of variety Madhuri were treated with KSB (Bacillus amyloliquefaciens) (procured from Dept. of Microbiology, PJTSAU) @ 10 ml kg^{-1} seed and for soil drenching 2.5 ml KSB was mixed with 1 L of water. Quantity of water used for KSB soil drenching was 20 ml water $plant^{-1}$ and the recommended dose of fertilizer (RDF) was 200: 60: 50 (N: P_2O_5: K_2O) kg ha^{-1}. Urea, single super phosphate (SSP) and muriate of potash (MOP) were used as sources of N, P and K respectively for soil application. Plant samples were collected from each plot and replication and leaf area was estimated by using leaf area meter and at 60°C plant samples were oven dried until constant weight was gained for recording drymatter production. Leaf area was divided by ground area (allotted for a single plant) to calculate Leaf area index (LAI). The data recorded on various parameters were analyzed statistically duly following the technique of analysis of variance for randomized block design [13].

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Perusal of the data (Table 1) indicated that numerically highest plant height was recorded with T_{10} [50% RDK (Basal) + 50% RDK at KH stage + KSB (ST) + KSB (SD) at KH stage] treatment at different stages. However, at KH stage there was no significant difference in plant height owing to different treatment imposition, except T_1(0% RDK) and T_6 [0% RDK + KSB (ST) +KSB (SD)] treatment. Numerical increment of plant height with increase dose of potassium might be due to proper photosynthesis and cell growth which is in consonance with Swetha et al. [14].

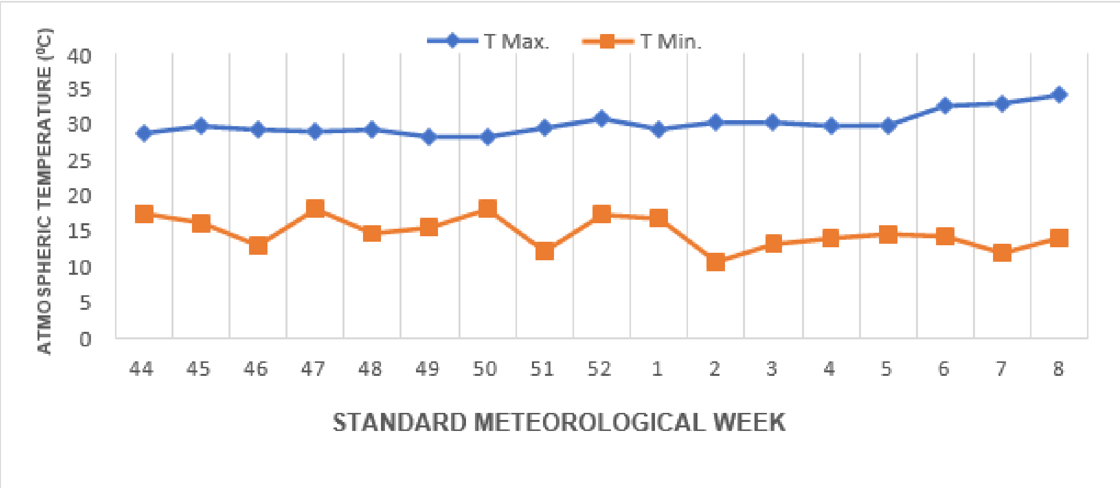

Fig. 1. Weekly maximum and minimum temperatures (℃) during the crop growth period

Table 1. Influence of potassium solubilizing bacteria (KSB) on growth parameters of rabi sweetcorn

Treatments	Plant height (cm)			LAI			Drymatter (kg ha^{-1})		
	Knee height stage	Tasseling stage	Harvesting stage	Knee height stage	Tasseling stage	Harvesting stage	Knee height stage	Tasseling stage	Harvesting stage
T_1: 0% RDK	56.4	149.1	168.2	0.31	3.21	3.19	384	6987	14298
T_2: 100% RDK (Basal) (50 kg ha^{-1})	63.1	180.2	216.4	0.52	4.92	4.81	476	9065	17186
T_3: 50% RDK (Basal) (25 kg ha^{-1})	60.2	174.5	197.3	0.48	3.31	3.28	454	7016	14416
T_4: 75% RDK (Basal) (37.5 kg ha^{-1})	62.1	178.0	202.2	0.51	4.10	4.01	470	8037	15310
T_5: 50% RDK (Basal) + 50% RDK (at KH stage)	60.5	182.2	217.7	0.49	5.00	4.78	455	9185	17210
T_6: T_1 + KSB (ST) + KSB (SD) at KH stage	57.6	150.6	170.3	0.32	3.29	3.23	395	6994	14325
T_7: T_2 + KSB (ST) + KSB (SD) at KH stage	63.8	180.6	218.1	0.53	4.95	4.88	480	9110	17195
T_8: T_3 + KSB (ST) + KSB (SD) at KH stage	61.5	175.4	198.4	0.50	3.89	3.82	465	7990	14913
T_9: T_4 + KSB (ST) + KSB (SD) at KH stage	62.5	179.8	213.6	0.52	4.52	4.48	472	8987	16378
T_{10}: T_5 + KSB (ST) + KSB (SD) at KH stage	61.7	183.5	220.8	0.50	5.20	5.12	467	9200	17244
SEm ±	**2.9**	**7.4**	**8.9**	**0.02**	**0.26**	**0.23**	**19**	**362**	**581**
CD (p= 0.05)	**NS**	**22.1**	**26.5**	**NS**	**0.77**	**0.69**	**58**	**1076**	**1726**

Table 2. Influence of potassium solubilizing bacteria (KSB) on yield attributes of rabi sweetcorn

Treatments	Yield attributes					
	Cobs plant^{-1}	Cob weightplant^{-1} (g)	Cob length(cm)	Cob girth (cm)	Number of kernel rowscob^{-1}	Number of kernels row^{-1}
T_1: 0% RDK	1.8	212.3	15.2	3.3	13.1	20.9
T_2: 100% RDK (Basal) (50 kg ha^{-1})	1.7	295.6	16.3	5.3	13.7	30.5
T_3: 50% RDK (Basal) (25 kg ha^{-1})	1.7	215.2	15.4	3.4	13.2	23.0
T_4: 75% RDK (Basal) (37.5 kg ha^{-1})	1.7	251.2	15.8	4.3	13.5	26.8
T_5: 50% RDK (Basal) + 50% RDK (at KH stage)	1.8	295.4	16.6	5.4	13.6	31.8
T_6: T_1 + KSB (ST) + KSB (SD) at KH stage	1.7	214.6	15.4	3.4	13.1	22.4
T_7: T_2 + KSB (ST) + KSB (SD) at KH stage	1.7	297.6	16.5	5.4	13.8	31.7
T_8: T_3 + KSB (ST) + KSB (SD) at KH stage	1.7	244.5	15.7	4.1	12.9	25.9
T_9: T_4 + KSB (ST) + KSB (SD) at KH stage	1.8	289.5	16.1	4.8	13.3	29.1
T_{10}: T_5 + KSB (ST) + KSB (SD) at KH stage	1.7	298.5	16.8	5.5	13.2	32.1
SEm ±	**0.1**	**11.4**	**0.9**	**0.3**	**0.3**	**1.2**
CD (p=0.05)	**NS**	**33.9**	**NS**	**0.8**	**NS**	**3.5**

On the other hand, after KH stage there was some significant changes in leaf area index (LAI) and drymater due to treatment imposition. At knee height stage significantly lower LAI and drymater were resulted from T_1 and T_6 treatment but remaining treatment were statistically on per. At Tesselling and Harvesting stage numerically highest LAI and drymatter were recorded from T_{10} treatment which was on par with T_5, T_2, T_7 and T_9 treatments. Whereas, further reduction of potassium dose irrespective of KSB treatment resulted in impaired growth in both stages, however, T_4 and T_8 treatment showed insignificant result and those results were superior over T_1, T_3 and T_6 treatments in terms of LAI and drymatter production. These findings are in close agreement with Gnanasundari et al. [15].

Significant improvement of growth parameter due to increment in K-fertilizer or partial substitute of RDK with KSB dose might be attributed to maintenance of cell osmotic pressure [16], improvement in nitrogen assimilation [17] and photosynthetic carbon assimilations [18].

3.2 Yield Attributes

Experimental result (Table 2) revealed that there was some significant positive impact of K and KSB on cob weight plant^{-1}, Cob girth and number of kernel row^{-1} whereas, no. of cob plant^{-1}, cob length, no. of kernel row cob^{-1} were not significantly influenced by different treatment. Cob weight plant^{-1}, cob girth, and no. of kernel row^{-1} were increased by 40.6%, 66.6% and 43.3% respectively due to the T_{10} over T_1 treatment and T_{10} treatment was on per with T_5, T_7, T_2 and T_9 treatments. Furthermore, T_9 i.e., 75% RDK + KSB (ST+SD) resulted into statistically equal impact on change in cob girth, no. of kernels row^{-1} and cob weight plant^{-1} when compared with the highest treatment (T_{10}). This indicated considerable potential of KSB in soil and their potential to solubilize soil mineral K into water soluble and exchangeable fractions. Gradual inferiority of yield attributes owing to reduced K application is also aligned with the findings of Gnanasundari et al. [15] in maize under K rich soil. Increment in yield attributes might be resulted from adequate supply of K which might have helped in proper grain filling [19] and translocation of photosynthates from source to sink [20].

3.3 Yield

Significantly highest cob yield, green fodder yield were obtained from T_{10} treatment which was statistically similar with T_5, T_7, T_2 and T_9 treatments. Eventually harvest index (HI) was also insignificantly influenced by K management practices. It is noteworthy that in between basal and two equal split applications of 100% RDK, letter gave the superior result irrespective of KSB treatment. It supports the findings of [21].

This result also implied that KSB could make 75% RDK (37.5 kg K_2O ha^{-1}) equivalent to 100% RDK (50 kg K_2O ha^{-1}) with its potential to solubilize the unavailable soil-K [22].

These findings are also in accordance with Madar et al. [23] and Gnanasundari et al. [15] where application of K showed significant impact in corn, despite having high inherent soil-K.

Table 3. Influence of potassium solubilizing bacteria (KSB) on yield of rabi sweetcorn

Treatments	Green cob yield (t ha^{-1})	Green fodder yield(t ha^{-1})	Harvest Index (HI)
T_1: 0% RDK	15.1	17.9	45.8
T_2: 100% RDK (Basal) (50 kg ha^{-1})	19.1	22.2	46.3
T_3: 50% RDK (Basal) (25 kg ha^{-1})	15.5	18.3	45.9
T_4: 75% RDK (Basal) (37.5 kg ha^{-1})	16.1	18.8	46.1
T_5: 50% RDK (Basal) + 50% RDK (at KH stage)	19.5	22.6	46.3
T_6: T_1 + KSB (ST) + KSB (SD) at KH stage	15.2	17.9	45.9
T_7: T_2 + KSB (ST) + KSB (SD) at KH stage	19.3	22.4	46.3
T_8: T_3 + KSB (ST) + KSB (SD) at KH stage	15.8	18.5	46.1
T_9: T_4 + KSB (ST) + KSB (SD) at KH stage	18.0	20.9	46.3
T_{10}: T_5 + KSB (ST) + KSB (SD) at KH stage	19.7	22.8	46.4
SEm ±	**0.8**	**0.9**	**0.4**
CD (p= 0.05)	**2.2**	**2.6**	**NS**

4. CONCLUSION

It could be concluded that in spite of having high inherent soil-K, it is imperative to supply 100% RDK (50 kg K_2O ha^{-1}) to get higher yield. However, partial substitution of synthetic K up to the extent of 25% is possible by treating corn seed with KSB followed by soil drenching at Knee height stage without compromising the potential yield in alfisols of semi-arid tropic.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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