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Effect of Potassium Solubilizing Bacteria and Phosphorus Solubilizing Bacteria on Growth and Yield of Maize (*Zea mays* L.)

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A field experiment was conducted at department of agricultural microbiology at UAS Dharwad to test the two potassium solubilizing bacteria and one phosphorus solubilizing bacteria on growth and yield maize in comparison with the 75 per cent and 100 per cent fertilizer level as absolute control. The maize seeds were treated with KSB 11, KSB 27 and PSB 98 (2). From this research results showed that there were increased in plant height, leaf area, and increased yield as compare to control among all the treatments dual inoculation of KSB and PSB with 75 per cent N and P was recorded maximum growth and yield parameters of maize crop. This result concluded that dual inoculation of KSB and PSB have more effective as compare to individual application to the Maize.

Key words: Phosphorus solubilizing bacteria (PSB), Potassium solubilizing bacteria (KSB), Maize, KSB 11, KSB 27 and PSB 98 (2).

Phosphorus is a major plant nutrient next to nitrogen in plant metabolic activity which ultimately reflects on the crop yields. Phosphorus is a constituent of nucleic acids, phytins, phospholipids, ATP *etc.*, Phosphorus plays an important role in virtually all major metabolic processes in plant growth and development. Phosphorus taken up by the cell in the form of HPO_4^{2-} or $H_2PO_4^-$ (Beever and Burns, 1981). is Wider distribution of Phosphorus in nature is seen, both in organic and inorganic forms in a bound state which is not easily available for absorption by plants. The insoluble phosphate which is not directly available to plants usually comprises around 95 to 99 per cent of the total soil phosphorus (Molla *et al.*, 1984).

Solubilization of insoluble P by microorganisms was evidentially reported by Pikovskaya (1948). Nutrient recycling in soils is a major role by microorganisms which helps to maintaining of good soil conditions. A group of microorganisms have the capacity to release the soluble form of phosphorus *viz.*, HPO_4^{2-} and $H_2PO_4^-$, from the in soluble inorganic P sources and make it available to plants. This bioconversion of in soluble inorganic phosphates into soluble available form has been referred to as mineral phosphate solubilization (MPS) (Goldstein, 1994). Microbial production of organic acid appears to be the main mechanism for solubilization of in soluble inorganic phosphate compounds.

The third most important essential macronutrient is Potassium (K) after phosphorus for growth of crop plants. As large amounts are absorbed from the root zone in the production of most of the crop plants. The total K content of soils frequently exceeds 20, 000 ppm (parts per million). Nearly all of this is in the structural component of soil minerals and is not available for plant growth. Because of large differences in soil

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parent materials and the effect of weathering of these materials the amount of K supplied by soils varies. Potassium was available in three different forms (unavailable, slowly available or fixed, readily available or exchangeable) in soils.

In natural K cycle microorganisms play a key role. Some species of rhizobacteria are capable of mobilizing potassium in accessible form in soils. There was considerable population of K solubilizing bacteria in soil and rhizosphere (Sperber, 1958). Silicate bacteria were found to dissolve potassium, silicon and aluminium from insoluble minerals (Aleksandrov *et al.*, 1964). Most of the potassium in soil exists in the form of silicate minerals. (Bertsch *et al.*, 1985).

MATERIAL AND METHODS

This experiment was conducted to study the effect of dual inoculation of potassium and phosphorus solubilizing bacterial strains on growth, yield and nutrient uptake in maize under field condition over the varied levels of K and P fertilizers as a control at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. The experiment was laid out in Randomized Complete Block Design (RCBD) with twelve treatments and three replication. N was applied as per recommended dose to maize crop. The KSB – 11, KSB -27 and PSB - 98 (2) for the treatments were grown on (Aleksandrov media for KSB isolates and Pikovskyas media for PSB isolate) medium for 48 hr. After this all the isolates were mixed with the sterilized lignite powder separately then the seed treatment were done for according to treatment details selected for field experiment. After inoculation of seeds with KSB and PSB isolate line sowing was done in field.

Treatment T_1 - Potassium and phosphorus control 1+ RDN (P and K at 75%), T_2 - Isolate KSB 11 + RDN (P and K at 75%), T_3- Isolate KSB 27 + RDN (P and K at 75%), T_4- Isolate PSB 98 (2) + RDN (P and K at 75%), T_5- Isolate KSB 11 + PSB 98 (2) + RDN (P and K at 75%), T_6 - Isolate KSB 27 + PSB 98 (2) + RDN (P and K at 75%), T_7- Potassium and phosphorus control 2 + 100% RDF, T_8-Isolate KSB 11 + 100% RDF, T_9- Isolate KSB 27 + 100% RDF, T_{10}- Isolate PSB 98 (2) + 100% RDF, T_{11}- Isolate KSB 11 + PSB 98 (2) + 100% RDF, T_{12}- Isolate KSB 27 + PSB 98 (2) + 100% RDF.

RESULT AND DISCUSSION

A field experiment was conducted to study the effect of PSB and KSB on growth and yield of maize and observations were recorded at 30, 60 and 90 DAS. Among the different treatments, the plant height, leaf area, increased significantly in dual inoculation of potassium solubilizing bacteria and phosphate solubilizing bacteria as

Table 1: Effect of dual inoculation of potassium solubilizing bacteria (KSB) and phosphorus solubilizing bacteria (PSB) on height (cm) of maize

S. No.	Treatments	30 DAS	60 DAS	90 DAS
T_1	Potassium and Phosphorus control 1+ RDN (P and K at 75%)	30.90	144.54	147.80
T_2	KSB 11 + RDN (P and K at 75%)	38.01	169.21	171.28
T_3	KSB 27 + RDN (P and K at 75%)	38.21	170.17	172.09
T_4	PSB 98 (2) + RDN (P and K at 75%)	38.12	165.71	168.16
T_5	KSB 11 + PSB 98 (2) + RDN (P and K at75%)	40.92	189.01	192.03
T_6	KSB 27 + PSB 98 (2) + RDN (P and K at 75%)	46.15	179.01	183.58
T_7	Potassium and Phosphorus control 2 +100% RDF	35.33	154.05	157.67
T_8	KSB 11 + 100% RDF	39.91	173.14	176.96
T_9	KSB 27 + 100% RDF	40.61	174.58	175.02
T_{10}	PSB 98 (2) + 100% RDF	41.41	180.01	182.19
T_{11}	KSB 11+PSB 98(2) + 100% RDF	43.40	182.09	186.22
T_{12}	KSB 27 + PSB 98(2) + 100% RDF	42.14	186.78	189.15
	S. Em ±	2.58	8.08	8.86
	CD @ 5%	7.57	23.69	25.98

Recommended N was applied to all the treatments.
RDN- Recommended dose of nitrogen, KSB- Potassium solubilizing bacteria, RDF- Recommended dose of fertilizer.

compared to control. The maximum plant height was recorded in treatment T_5 receiving both dual inoculation of KSB 11 and PSB 98 (2) + 75 percent RDP and RDK (192.03 cm) and lowest plant height was recorded in the treatment $T_{1,}$ potassium and phosphorus control 1 + RDN (P and K at 75%) (30.90 cm, Table 1). Similarly, more leaf area was recorded in the treatment T_6 receiving both dual inoculation of KSB 27 and PSB 98 (2) plus 75 percent RDP and RDK (815.10 cm^2) and lowest leaf area is recorded in the treatment $T_{1,}$ potassium and phosphorus control 1 + RDN (P and K at 75%) (325.03 cm^2) (Table 2).

In the present study, the increase plant

Table 2. Effect of dual inoculation of potassium solubilizing bacteria (KSB) and phosphorus solubilizing bacteria (PSB) on leaf area (cm2) of maize

S. No.	Treatments	30 DAS	60 DAS	90 DAS
T_1	Potassium and Phosphorus control 1+ RDN (P and K at 75%)	325.03	377.06	529.03
T_2	KSB 11 + RDN (P and K at 75%)	424.69	481.83	652.28
T_3	KSB 27 + RDN (P and K at 75%)	440.82	492.33	617.05
T_4	PSB 98 (2) + RDN (P and K at 75%)	448.23	522.42	668.53
T_5	KSB 11 + PSB 98 (2) + RDN (P and K at 75%)	500.51	625.07	785.97
T_6	KSB 27 + PSB 98 (2) + RDN (P and K at 75%)	530.67	591.31	815.10
T_7	Potassium and Phosphorus control 2 +100% RDF	350.08	395.25	549.61
T_8	KSB 11 + 100% RDF	464.79	555.43	734.23
T_9	KSB 27 + 100% RDF	473.57	561.35	774.38
T_{10}	PSB 98 (2) + 100% RDF	494.17	563.86	768.81
T_{11}	KSB 11+PSB 98(2) + 100% RDF	513.54	612.66	805.15
T_{12}	KSB 27 + PSB 98(2) + 100% RDF	503.68	608.73	802.38
	S. Em ±	28.89	31.97	37.97
	CD @ 5%	84.73	93.78	111.36

Recommended N was applied to all the treatments.
RDN- Recommended dose of nitrogen, KSB- Potassium solubilizing bacteria, RDF- Recommended dose of fertilizer.

Table 3. Impact of dual inoculation of Potassium solubilizing bacteria (KSB) and Phosphorus solubilizing bacteria (PSB) on yield and yield parameters of maize at harvest

S. No.	Treatments	Cob length (cm)	Cob girth (cm)	Cob weight (g)	Test weight (g)
T_1	Potassium and Phosphorus control 1+ RDN (P and K at 75%)	13.50	12.80	71.72	13.84
T_2	KSB 11 + RDN (P and K at 75%)	15.33	13.74	74.90	17.43
T_3	KSB 27 + RDN (P and K at 75%)	15.32	13.77	76.96	18.60
T_4	PSB 98 (2) + RDN (P and K at 75%)	15.37	13.69	78.66	17.63
T_5	KSB 11 + PSB 98 (2) + RDN (P and K at 75%)	20.06	16.62	101.10	32.12
T_6	KSB 27 + PSB 98 (2) + RDN (P and K at 75%)	17.26	17.00	91.19	27.58
T_7	Potassium and Phosphorus control 2 + 100% RDF	14.19	13.42	73.48	14.05
T_8	KSB 11 + 100% RDF	16.27	13.95	82.82	20.61
T_9	KSB 27 + 100% RDF	16.27	14.16	84.26	20.94
T_{10}	PSB 98 (2) +(100% RDF	16.28	15.00	84.46	21.05
T_{11}	KSB 11+PSB 98(2) + 100% RDF	17.31	16.56	87.04	25.96
T_{12}	KSB 27 + PSB 98(2) + 100% RDF	18.20	16.18	94.12	28.11
	S. Em ±	1.07	0.94	5.63	1.61
	CD @ 5%	3.14	2.78	16.53	4.73

Recommended N was applied to all the treatments.
RDF- Recommended dose of fertilizer. Test weight- 100 seed weight
RDN- Recommended dose of nitrogen, KSB- Potassium solubilizing bacteria,

growth may be due to synergetic effect of combined inoculation of the potassium solubilizing bacteria and phosphorus solubilizing bacteria. It may be due to co-inoculation of KSB and PSB strains which can synergistically solubilized rock P and rock K that were added into soil and make them available for uptake by plant roots which was increased in the plant growth (Sheng 2005). These results were in accordance with the findings of Han and Han (2005) who reported that co-inoculation of PSB and KSB increased in higher uptake of NPK resulting in higher plant growth. Similar results were also obtained by Badar (2006). Similarly, Archana *et al.* (2008) they reported that inoculation of the potassium solubilizing bacteria (KSB) increased the plant growth and yield of maize crop under glasshouse condition.

Yield and yield attributes

Dual inoculation of potassium solubilizing bacteria (KSB) and phosphorous solubilizing bacteria (PSB) had significant influenced on different plant yield and yield parameters. There was significant increase in plant yield and yield parameters (cob length, cob girth, cob weight, test weight, grain yield per cob, and grain yield per hectare).

The maximum cob length, cob girth, cob weight, test weight, grain yield per cob, grain yield per plot and grain yield per hectare (Table 3 and 4) was recorded in the treatment T_5 receiving both dual inoculation of KSB 11 and PSB plus 75 per cent RDP and RDK (20.06 cm, 17.00 cm, 101.10 g, 32.12 g, 97.10g, 14.40 kg and 7.11 t/ha respectively) and lowest cob length, cob girth, cob weight, test weight, grain yield per cob, grain yield per plot and grain yield per hectare in the treatment $T_{1,}$ potassium and phosphorus control 1 + RDN (P and K at 75%) (13.50 cm, 12.80 cm, 71.72 g, 13.84 g, 67.72 g, 86.54 g, 7.32 kg and 3.81 t/ha). There was 30.21 per cent increase in grain yield per ha in the treatment T_5 as compare to control-1.

Table 4. Impact of dual inoculation of potassium solubilizing bacteria (KSB) and phosphorus solubilizing bacteria (PSB) on yield and yield parameters of maize at harvest

S. No.	Treatments	Grain yield/cob(g)	Grain yield/ plot(Kg)	Grain yield/ ha(tonns)
T_1	Potassium and Phosphorus control 1+ RDN (P and K at 75%)	67.72	7.32	3.81
T_2	KSB 11 + RDN (P and K at 75%)	71.84	9.48	4.45
T_3	KSB 27 + RDN (P and K at 75%)	73.59	10.07	4.17
T_4	PSB 98 (2) + RDN (P and K at 75%)	74.90	10.34	4.41
T_5	KSB 11 + PSB 98 (2) + RDN (P and K at 75%)	97.10	14.40	7.11
T_6	KSB 27 + PSB 98 (2) + RDN (P and K at 75%)	87.44	12.27	6.08
T_7	Potassium and Phosphorus control 2 + 100% RDF	70.00	8.00	4.03
T_8	KSB 11 + 100% RDF	79.54	11.15	5.18
T_9	KSB 27 + 100% RDF	78.53	11.30	5.35
T_{10}	PSB 98 (2) + 100% RDF	79.70	11.66	5.57
T_{11}	KSB 11+PSB 98(2) + 100% RDF	88.91	12.45	6.87
T_{12}	KSB 27 + PSB 98(2) + 100% RDF	89.57	12.76	6.44
	S. Em ±	4.61	0.67	0.38
	CD @ 5%	13.52	1.98	1.13

Recommended N was applied to all the treatments.
RDN- Recommended dose of nitrogen, KSB- Potassium solubilizing bacteria,
RDF- Recommended dose of fertilizer.

All the dual inoculation of KSB and PSB showed higher yield of maize crop as compared to the control plants. The results were in agreement with the findings of Wu *et al.*, (2005) they recorded significantly increase in the maize crop yield and also improve in soil properties such as organic content due to co inoculation of KSB and PSB. The results were also comparable with the findings of Balasubramanian and Subramanian (2006), they studied the increase in rice grain yield in a field experiment due to effect of silicate solubilizing bacteria recorded 5218 kg per ha grain yield as compare to control 4419 kg per ha. Similarly, Abou *et al.* (2011) they reported that co-inoculation of phosphorus dissolving bacteria (*Bacillus megaterium var. phosphaticum*) and potassium dissolving bacteria (*Bacillus mucilaginosus* and *Bacillus subtilis*) increases the phosphorus and potassium availability for uptake of maize crop under P and K limited soils (calcareous soil) which was finally increases the maize crop yield.

CONCLUSION

Phosphorus and Potassium are most important nutrients for maize crop growth but most of the Phosphorus and Potassium are in unavailable form in soil which makes difficult to absorb by crop plants. Therefore application of PSB and KSB to soil make unavailable form of Phosphorus and Potassium in to available for for better uptake by crop plants. In the present study dual inoculation of the PSB and KSB to the maize crop increased the plant growth and development which were finally increased the maize crop yield as compare to control plot.

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