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Effect of Phosphate and Potash Solubilizing Bacteria on Nutrient Uptake, Quality Parameter and Economics of Popcorn (*Zea mays* L. Var. *Everta*)

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ABSTRACT

A field experiment was carried out during rabi season of 2016-17 to evaluate the effect of different levels of PSB and KSB on and nutrient uptake, quality parameter and economics of popcorn (Zea mays L. Var. Everta). The experimental results revealed that application of 45 kg P_2O_5/ha + PSB seed inoculation + PSB soil application promoted enhanced biochemical parameters viz., leaf chlorophyll content, protein yield and nutrient content, grain P content, fodder N and P content in grain and fodder, it leads to enhanced N, P and K uptake, P and K use efficiency and ultimately gave higher grain yield (3452 kg/ha) and straw yield (5300 kg/ha) with higher net return (₹ 40018 ha) and B:C ratio (2.11) over the control. Application of 45 kg K_2O/ha + KSB seed inoculation + KSB soil application enhanced quality parameters viz., leaf chlorophyll content, protein yield and nutrient content, grain and fodder N, P and K uptake, P and K use efficiency and resultantly gave higher grain and straw yield of 3476 and 5295 kg/ha, respectively along with higher net return (₹ 40695/ha) and B: C ratio (2.14) over the control. It could be concluded that seed inoculation and soil application of PSB and KSB enhanced microbial count in soil which is capable for solubilizing insoluble form of nutrient and enhanced nutrient uptake and saving of 25% fertilizer dose of phosphorus and potash.

Key words: *Popcorn, (Zea mays L. Var. Everta), Phosphate solubilizing bacteria, Potash solubilizing bacteria, Nutrient uptake, Quality parameter, Net return, B:C ratio.*

INTRODUCTION

The importance of corn is due to its wide diversity of uses. It is used both as food for human and feed for animals. Corn is directly consumed as feed. Green cobs are roasted and eaten by people with great interest. Corn is converted in to a variety of foods such as popped snack food and staple alkali-cooked "Mexican" foods. Among the cereals, maize (*Zea mays* L.) ranks third in total world production after wheat and rice and it is principal staple food in many countries, particularly in the tropics and subtropics.

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Maize is considered as the "Queen of Cereals" Popcorn (Zea mays L. var. *Everta*) also known as popping corn. It possesses exceptional popping qualities. . Its kernels are composed of hard starch, when heated, swell and brust. Because of low sugar, fat and calories it is good food for health. It contains dietary fiber 15 g, thiamine 0.2 mg, riboflavin 0.3 mg, 12 g protein, 4 g fat and 2.7 mg iron per 100 g of edible portion. It is richest source of oil (6%), which is good source of fatty acids and has very low cholesterol contents. Starch is used for manufacture of medicines, fructose and glycosides. It has tremendous potentially because it gives more remuneration to the farmer. India stands sixth in world with respect to maize production. In India, maize is cultivated on 9.26 million ha with a production of 23.67 million tones and productivity 2557 kg ha^{-1}.

Why we need to use of biofertilzer?

Due to high in price of fertilizers, especially those of phosphatic and potassic fertilizers, and also the shortage of fertilizers, searching of alternate option hold promise for reducing cost of cultivation. Further, efficiency of phosphatic and potassic fertilizers is low due to fixation in calcareous soil. Organic manures can replace fertilizers up to 50%, but the availability and cost of organic manures are further become constraints. It thus becomes urgent to investigate the bio-solubilisation of soil P and K reserves so as to alleviate the phosphatic and potassic fertilizer shortage. Several strains of bacteria and fungi have been identified for P and K solubilization.

To satisfy crop nutritional requirements, P is usually added to soil as chemical P fertilizer, however synthesis of chemical P fertilizer is highly energy intensive processes, and has long term impacts on the environment in terms of eutrophication, soil fertility depletion carbon. More over plants can use only a small amount of this P since 75–90 % of added P is precipitated by metal cation complexes, and rapidly becomes fixed in soils. Such environmental concerns have led to the search for sustainable way of P nutrition of crops. In this regards phosphate-solubilizing microorganisms (PSM) have been seen as best eco-friendly means for P nutrition. Phosphorus is the second important key element after nitrogen as a mineral nutrient in terms of quantitative plant requirement. Although abundant in soils, in both organic and inorganic forms, its availability is restricted as it occurs mostly insoluble forms. The P content in an average soil is about 0.05% (w/w) but only 0.1% of the total P is available to plant because of poor solubility and its fixation in soil[1].

Fundamentally, potassium is a macronutrient in plants and animals. Potassium is essential macronutrient for plant growth and plays significant roles in activation of several metabolic processes including protein synthesis, photosynthesis, enzymes, as well as in resistance to diseases, insects, abiotic stress *etc.*[2]. Potassium though present as abundant element in soil or is applied to fields as natural or synthetic fertilizers, only one to two percent of this is available to plants, the rest being bound with other minerals and therefore unavailable to plants. The most common soil components of potassium, 90 to 98%, are feldspar and mica[3]. Soil microorganisms influence the availability of soil minerals, playing a central role in ion cycling and soil fertility[4]. Very little of this potassium source is available for plant use. Potassium solubilising bacteria (KSB) such as Bacillus mucilaginous and Bacillus edaphicus are an example of microorganisms that used in bio fertilizer. KSB is able to solubilise potassium rock through production and secretion of organic acids. Recent studies have proved that potassium can increase the plant height, fresh plant weight and also increase herbage and oil yield on the patchouli. However, during the last decades, the issue of sustainable soil potassium management has partly been ignored since the potential environmental impact of nitrogen and phosphorus has been considered a more important problem. Furthermore, the application of biofertilizer somehow has not achieved constant effects compared to chemical fertilizer. The mechanisms and interactions among these microbes still are not well understood, especially in real applications. Therefore, the aim of this study to increase the bio-fertilizers effect on the crop growth by optimizing the growth of KSB is very important.

A wide range of bacteria namely Pseudomonas, Burkholderia, Acidothiobacillus ferrooxidans, Bacillus mucilaginosus, Bacillus edaphicus, Bacillus circulans and Paenibacillus spp. has been reported to release potassium in accessible form from potassium-bearing minerals in soils[5]. These potassium solubilizing bacteria (KSB) were found to dissolve potassium, silicon and aluminium from insoluble K-bearing minerals such as micas, illite, and orthoclases, by excreting organic acids which either directly dissolved rock K or chelated silicon ions to bring K into the solution. Their uses as bio-fertilizers for agriculture improvement and environmental protection have been a focus of recent research.

MATERIAL AND METHODS

The field experiment was conducted during *rabi* season of 2016-17 at Junagadh Agricultural University, Junagadh, Gujarat. Soil of the experimental plot was clayey in texture and slightly alkaline in reaction (pH 7.9 and EC 0.33 dS/m). The soil was medium in available nitrogen (254-269 kg/ha), available phosphorus (28.4-30.7 kg/ha) and available potash (183-185 kg/ha) from 0-15 and 15-30 cm depth. The soil was free from any kind of salinity or sodicity hazards. Maize variety 'Amber' was sown at 60 cm row spacing and 20 cm spacing maintain between two plants within row. 120 kg N/ha in two equal splits at sowing and 30 DAS was applied uniformly to all the plots. Entire dose of phosphorus and potash as per treatments was applied at sowing.

The experiment conducted on 16 treatment combinations with four levels each of PSB and KSB was laid out in Factorial Randomized Block Design (FRBD) with three replications. Treatment include four level of phosphate treatment *viz.*, Control (P_0), 60 kg P_2O_5/ha (P_1), 45 kg P_2O_5/ha + PSB seed inoculation (P_2), 45 kg P_2O_5/ha + PSB seed inoculation + PSB soil application (P_3) and four level of phosphate treatment viz., Control (K_0), 60 kg K_2O/ha (K_1), 45 kg K_2O/ha + KSB seed inoculation (K_2), 45 kg K_2O/ha + KSB seed inoculation + KSB soil application (K_3). Application of 120 kg N/ha in two equal splits at sowing and 30 DAS was applied uniformly to all the plots. Entire dose of phosphorus and potash as per treatments was applied at sowing.

Liquid formulation of PSB (*Bacillus subtilis*) obtained from Department of Plant Pathology, College of Agriculture, Junagadh Agricultural University, Junagadh, and KSB (*Frateuriaaurantia*), obtained from Department of Plant Pathology, N. M. College of Agriculture, Navsari Agricutural University, Navsari, were used for seed treatment as well as for soil application. For seed treatment, seeds were spreaded and PSB/KSB culture (10^8 viable cells/g) @ 30 mL/kg of seed was sprinkled on the seeds and then dried in shade. For soil application, PSB/KSB culture (10^8 viable cells/g) @ 3000 mL/ha was mixed with FYM and than applied in furrows just after sowing before irrigation. The effectiveness of either seed and/or soil inoculation with fertilizer was assessed in the quality parameters *viz.*, leaf chlorophyll content, protein yield, nutrient content, nutrient uptake and he economics of different treatment combinations was worked out in terms of net returns/ha and B:C (benefit cost) ratio.

Grain protein content

Protein content in grain was determined by multiplying nitrogen percentage by a factor 6.25[6]. The modified kjeldahl method was adopted to find out nitrogen content[8].

Protein yield

Protein yield was calculated by grain yield multiplied with protein content of grain in each net plot and averaged for protein yield.

$$\text{Protein yield (kg/ha)} = \frac{\text{Protein content of grain (\%) x Grain yield (kg/ha)}}{100}$$

Nutient content and uptake by grain and fodder

Nitrogen content in grain and fodder was determined on per cent dry weight basis as per method of Modified Kjeldahl's described by Jackson[8]. Nitrogen uptake was calculated by the following formulae. Phosphorus was determined by Vanadomolybdo phosphoric yellow colour method by Jackson[8]. Estimation of K content in grain and fodder was carried out by flame photometer method as described by Jackson[8].

Nutient uptake by grain and fodder determined by following formula

$$\text{Nutrient uptake by grain (kg/ha)} = \frac{\text{Nutrient content in grain (\%) x Grain yield (kg/ha)}}{100}$$

RESULTS AND DISCUSSION

EFFECT OF PSB

Effect of PSB on nutrient content and uptake

A perusal of data revealed that different levels of PSB exhibited significant impact on nitrogen content in fodder given in Table 1. Significantly the highest nitrogen content in fodder (0.54%), also observed that significantly the highest phosphorus content in grain (0.473%), phosphorus content in fodder which remained statistically at par with application of 45 kg P_2O_5/ha + PSB seed inoculation (P_2) observed in Table 1. On the other hand, significantly the lowest nitrogen content in fodder and phosphorus content in grain (0.426%) was registered under control. An appraisal of data revealed that treatment P_3 exhibited their significant influence on nitrogen uptake by grain and fodder, phosphorus uptake by grain and fodder and potassium uptake by grain and fodder given in Table 2. Yet, significantly the lowest nutrient uptake was registered under the control P_0 treatment. PSB solubilized the fixed soil phosphorus and readily hydrolysed the organophosphate and degraded them in the soil and increase the availability of fixed P and applied P to the plant owing to its favourable effects on division and multiplication of cells. Moreover, phosphorus is the important constituent of co-enzymes which are important for photosynthesis and protein synthesis. One of the main roles of the phosphorus in plant is in transfer of energy through ATP and also involved in root development and in metabolic activities especially in synthesis of protein. The results are in conformity with those reported by Kaur and Reddy[9] maize.

Effect of PSB on quality parameter, yield and economics of maize

Application of 45 kg P_2O_5/ha + PSB seed inoculation + PSB soil application (P_3) and 45 kg P_2O_5/ha + PSB seed inoculation (P_2) Quality parameter *viz.*, leaf chlorophyll content at 30 DAS and 60 DAS and protein yield was significantly highest as compared to the control (P_0) (Table 3). Maize crop fertilized with 45 kg P_2O_5/ha + PSB seed inoculation + PSB soil application (P_3) produced significantly the highest grain yield (3452 kg/ha) and fodder yield (5301 kg/ha), which was 22.45 and 21.01% higher, but it was remained comparable with application of 45 kg P_2O_5/ha + PSB seed inoculation (P_2) produced high grain yield (3276 kg/ha) and fodder yield (5128 kg/ha) (Table 3), which was 16.18 and 17.08% over the control (P_0) (Table), However, application of 45 kg P_2O_5/ha + PSB seed inoculation + PSB soil application (P_3) gave maximum net return (₹ 40018/ha) and B:C ratio (2.11) (Table 3), followed by application of 45 kg P_2O_5/ha + PSB seed inoculation (P_2) with net return of ₹ 36531/ha and B:C ratio of 2.02 given in Table 3 might be due to higher grain yield and straw yield recorded with these PSB levels (P_3 and P_2) along with comparatively less cost than additional income. Result conformed by Meena *et al.*[10]. The increase in grain and fodder yields with these treatments might be due to PSB produces phytohormones and growth promoting substances, resulted in vigorous growth and consequently produce higher biomass per plant and also providing better nutrition throughout the growth period and availability of phosphorus at flowering and grain filling stages which help in formation of more number of grains/cob. PSB stimulate absorption of nutrient particularly nitrogen, phosphorus and potassium by maize grain, which provide better nourishment, filling and development of grain and consequently the highest test weight. Result conformity with Jat *et al.*[7] and Firtian *et al.*[11].

RESULTS AND DISCUSSION

EFFECT OF KSB

Effect of KSB on nutrient content and uptake

Various levels of KSB did exhibit significant influence on, application of 45 kg K_2O/ha + KSB seed inoculation + KSB soil application (K_3) recorded significantly the highest nitrogen content in grain and fodder, phosphorus content in grain and potassium content in grain and fodder which was found statistically comparable to application of 45 kg K_2O/ha + KSB seed inoculation (K_2) except in case of potassium content in fodder given in Table 1. A perusal of data showed that different levels of KSB did not exert significant effect on nitrogen content in grain and phosphorus content in fodder. Significantly the highest nitrogen uptake by grain and fodder, phosphorus uptake by fodder and potassium uptake by grain and fodder was registered under the treatment P_3 followed by P_2 except in case of nitrogen uptake by fodder and phosphorus uptake by fodder given in Table 2. The response of KSB may be attributed to mobilization of K from soil because of secretion of organic acids by the bacterial strains, thereby enhanced plant growth and development, and finally greater acquisition of nutrients. The results are supported by other workers who have observed increase in plant assimilation of K by the use of potassium solubilizing microorganisms in soil. These results are in close conformity with the finding of Shengh *et al.*[15], Padma and Sukumar[13] and Yallapa *et al.*[14] in maize.

Effect of KSB on quality parameter, yield and economics of maize

Quality parameter (Table 3) *viz.*, leaf chlorophyll content at 30 DAS and 60 DAS and protein yield were significantly enhanced with application of 45 kg K_2O/ha + KSB seed inoculation + KSB soil application (K_3) and 45 kg K_2O/ha + KSB seed inoculation (K_2) over the control (K_0). Ferti`lization of 45 kg $K_2O$/ha + KSB seed inoculation + KSB soil application ($K_3$) and 45 kg $K_2O$`/ha + KSB seed inoculation (K_2) significantly increased grain yield by 22.43 and 17.12 % and fodder yield by 21.00 and 17.04 % high over the control (K_0), respectively (Table 3), might be due to chlorophyll is a major green pigment found in green leaves and is undoubtedly determining the photosynthetic efficiency and productivity of plants. Notably K also played an important role in the synthesis of chlorophyll by taking part in various enzyme activities. Since K is found to influence the total chlorophyll and carotenoid contents of the leaves it may also directly and/or indirectly improve crop yield through increased photosynthesis observed in Table 3. Similar observations were also recorded by Panwar and Singh (2000). However treatment K_3 earned maximum net return (**₹** 40695/ha) and B: C ratio (2.14), followed by 45 kg K_2O/ha + KSB seed inoculation (K_2) by giving net return of **₹** 37770/ha and B: C ratio of 2.06 (Table 3). This can be attributed to higher grain yield and straw yield recorded with comparatively less cost than additional income under these treatments. These results are in close conformity with the finding of Mikhailouskaya *et al.*[17], Basak and Biswas[18] and Savliya *et al*.[19].

Table 1: Effect of different treatments on nutrient content in grain and fodder

Treatment	Nitrogen content (%)		Phosphorus content (%)		Potassium content (%)	
	Grain	Fodder	Grain	Fodder	Grain	Fodder
P_0	1.67	0.34	0.426	0.108	0.46	1.08
P_1	1.77	0.44	0.439	0.140	0.44	1.08
P_2	1.75	0.46	0.459	0.158	0.45	1.12
P_3	1.86	0.54	0.473	0.163	0.49	1.16
S.Em.±	0.05	0.02	0.007	0.004	0.01	0.03
C.D. at 5%	NS	0.05	0.020	0.012	NS	NS
K_0	1.74	0.36	0.431	0.134	0.40	1.03
K_1	1.71	0.43	0.438	0.141	0.44	1.06
K_2	1.75	0.48	0.454	0.144	0.48	1.16
K_3	1.85	0.51	0.475	0.149	0.51	1.18
S.Em.±	0.05	0.02	0.007	0.004	0.01	0.03
C.D. at 5%	NS	0.05	0.020	NS	0.04	0.09

Table 2: Effect of different treatments on nutrient uptake by plant and nutrient use efficiency

Treatment	Nitrogen uptake (kg/ha)		Phosphorus uptake (kg/ha)		Potassium uptake (kg/ha)		Nutrient use efficiency (kg grain/kg fertilizer applied)	
	Grain	Fodder	Grain	Fodder	Grain	Fodder	Phosphorus	Potash
P_0	47.34	16.98	12.07	4.71	13.06	47.63	0.00	4.88
P_1	55.31	27.17	13.71	6.78	13.80	52.36	4.81	6.44
P_2	57.31	31.49	15.03	8.48	14.78	57.66	10.14	6.85
P_3	64.78	38.80	16.39	8.66	17.22	61.34	13.88	9.74
S.Em.±	2.61	1.23	0.49	0.27	0.64	1.99	-	-
C.D. at 5%	7.54	3.55	1.40	0.79	1.86	5.76	-	-
K_0	49.87	19.46	12.27	5.90	11.58	45.32	5.07	0
K_1	51.65	26.48	13.38	7.00	13.39	51.88	8.52	3.01
K_2	58.48	31.89	15.11	7.44	16.14	59.46	8.96	10.84
K_3	64.86	36.60	16.55	7.94	17.74	62.33	6.51	14.15
S.Em.±	2.61	1.23	0.49	0.27	0.64	1.99	-	-
C.D. at 5%	7.54	3.55	1.40	0.79	1.86	5.76	-	-

Table 3: Effect of different treatments on quality parameters, yield and economics of maize

Treatment	Leaf chlorophyll content (SPAD value) at		Grain protein yield (kg/ha)	Grain yield (kg/ha)	Fodder yield (kg/ha)	Net return (₹/ha)	B:C ratio
	30 DAS	60 DAS					
P_0	33.28	47.34	295.87	2819	4380	28931	1.87
P_1	34.37	50.68	345.66	3109	4840	32366	1.90
P_2	35.39	52.86	359.07	3276	5128	36531	2.02
P_3	37.03	54.91	404.88	3452	5301	40018	2.11
S.Em.±	0.64	1.27	16.31	98.35	125.32	-	-
C.D. at 5%	1.84	3.66	47.10	284.04	361.95	-	-
K_0	32.66	47.57	311.72	2839	4376	28628	1.84
K_1	34.75	48.65	322.84	3015	4858	30749	1.86
K_2	35.87	52.67	365.52	3325	5121	37770	2.06
K_3	36.78	56.91	405.40	3476	5295	40695	2.14
S.Em.±	0.64	1.27	16.31	98.35	125.32	-	-
C.D. at 5%	1.84	3.66	47.10	284.04	361.95	-	-

CONCLUSION

Now a day liquid formulations containing efficient strains of phosphate and potash solubilizing bacteria are available in market. The use of bio-fertilizer could replace phosphatic and potassic fertilizer which ultimately reduce the cost of cultivation and also minimize pollution hazards of fertilizers to some extent. So looking to the problem, it is worth while to evaluate the effectiveness of phosphate and potash solubilizing bacterial cultures in maize for practical recommendation to the farmers. On the basis of one year field experimentation, it seems quite logical to conclude that higher nutrient uptake and net returns from popcorn (var. Amber) can be secured by application of 45 kg P_2O_5/ha + PSB seed inoculation (30 mL *Bacillus subtilis*/kg seed) + PSB soil application (3 L *Bacillus subtilis*/ha) and 45 kg K_2O/ha + KSB seed inoculation (30 mL *Frateuria aurantia*/kg seed) + KSB soil application (3 L *Frateuria aurantia*/ha) at sowing along with 120 kg N/ha (50% as basal + 50% as top dressing at 30 DAS) on medium black calcareous clayey soil having medium status of available N, P and K under South Saurashtra Agro-climatic Zone. It could be concluded that seed inoculation and soil application of PSB and KSB enhanced grain yield with higher net return and saving of 25% fertilizer dose of phosphorus and potash.

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