INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 5, No. 8, p. 25-36, 2014

RESEARCH PAPER OPEN ACCESS

Effect of biological potassium fertilization (BPF) on the availability of phosphorus and potassium to maize (*Zea Mays* L.) under controlled conditions

Sammer Fatima*, Abida Akram, Muhammad Arshad, Sunbal Khalil Chaudhari, Muhammad Shoaib Amjad, Huma Qureshi

[1]*Department of Botany, Pir Mehr Ali Shah Arid Agriculture University, Murree Road, Rawalpindi, Pakistan*

Key words: *Bacillus mucilaginous,* Macronutrients, Micronutrients, Chemical fertilizer

http://dx.doi.org/10.12692/ijb/5.8.25-36 Article published on October 23, 2014

Abstract

The main aim of the present study was to examine the benefits of inoculating the maize seeds with Biological Potassium fertilizer (BPF) with relevance to Phosphorus and Potassium nutrition to maize and its growth. The experiment was accomplished on combined use of Chemical and Biological Potassium Fertilizer with nitrogen as a basal dose added in each pot. There were nine treatments with different combinations of PK and BPF, to see the best treatment. Best results were obtained by the treatment which is supplied by full dose of PK and then comparable results were observed by treatment supplied with half dose of PK and BPF, while for micronutrients BPF performed best. We can reduce the amount of chemical fertilizers as it is hazardous to environment and costly too by using BPF. It is concluded that application of BPF has a significant effect on biomass yield, potassium uptake due to higher solubilization of K. Thus, bio intervention of BPF could be an alternative and viable technology to solubilize insoluble K into soluble form and could be used efficiently as a source of K fertilizer for sustaining crop production and maintaining soil potassium.

* **Corresponding Author:** Sammer Fatima ✉ sammer.botanist@gmail.com

Introduction

Maize (*Zea mays* L.) is one of the most important cereals which is widely planted in Pakistan. It is an important cereal crop after wheat and rice. It adds 6.4% to the total food grain production in Pakistan. It inhabits a superior position in the national economy as it is a good basis of food, feed and fodder. In 2010-2011 the cultivated area for Maize was 939 thousand hectares and production was 3341 thousand tons (Ministry of Food and Agriculture, 2011). Pakistani soils are deficient in N (100 %) and P (90 %) while deficiencies of K (20 %) are crop and soil specific, hence response to N and P is worldwide (Anon., 2003).

Fertilizer is the most significant input for enhancing productivity. In Pakistan, fertilizer use is insufficient and imbalanced (MINFAL, 2011). The increased use of chemical fertilizer helped in food grains production; but it also contaminated the environment. Biofertilizers are microbes that make nutrients available. Different types of microorganisms are available that make P, N and potassium available like Phosphate solubilizing bacteria, nitrogen fixing bacteria and potassium solubilizing bacteria (Kumar, 2003).

Biological potassium fertilizer (BPF), a carrier based biofertilizer product containing *Bacillus mucilaginous strain* was obtained from the Hebei Research Institute of Microbiology, Hebei Academy of Science, Baoding City, Hebei Province, and P.R. China. BPF enhances the availability of phosphorus and potassium for crops (Sheng *et al.* 2002; Wu *et al.* 2005; Sheng and He 2006). Need of the hour is to get maximum output from minimum input. This is only possible if we supplement chemical fertilizers with bio fertilizers. The present study was therefore concluded to find out the usefulness of BPF on the availability of P and K.

The present research project was designed with following objectives: To evaluate the effectiveness of Biological Potassium Fertilizer applied alone or in combination with chemical fertilizer beside this to investigate the best combination of inoculum and inorganic fertilizer for higher biomass production of maize crop. To evaluate the effect of Biological Potassium Fertilizer on the availability of macronutrients and micronutrients in soil and to determine the effect of Biological Potassium Fertilizer on the uptake of macronutrients and micronutrients in maize.

Aterials and methods

To study the effect of BPF on the availability of P and K for maize under controlled conditions, a pot experiment was conducted at the Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi in the growth chamber. The bulk soil was collected from PMAS-Arid Agriculture University, Rawalpindi research farm. The soil was air dried, crushed and screened through 2 mm sieve. Each pot was filled with 6 kg of prepared soil. The required amount of phosphorus and potassium was applied in the form of single super phosphate and sulphate of potash while urea was added as basal dose of nitrogen in equal amount in all treatments @ 261 mg pot^{-1} viz 60mgNKg^{-1} soil.

Following treatments were applied on maize crop.

T1 = Control

T2 = BPF

T3 = Full P @ 500 mg SSP pot^{-1} (45 mg P_2O_5 Kg^{-1} soil)

T4 = BPF + Full P @ 500 mg SSP pot^{-1}

T5 = Full K @ 120 mg SOP pot^{-1} (30 mg K_2O Kg^{-1} soil)

T6 = BPF + Full K @ 120 mg SOP pot^{-1}

T7 = Full P @ 500 mg SSP pot^{-1}

T8 = Half P @ 250 mg SSP pot^{-1} + Half K @ 60 mg SOP pot^{-1}

T9 = BPF + Half P @ 250 mg SSP pot^{-1} + Half K @ 60 mg SOP pot^{-1}

Pot experiment

Seeds were dressed with BPF according to treatments. The experiment was conducted in completely randomized design with three replications. Five seeds per pot were sown to a depth of 2.5cm in dry soil. The soil in pots was soaked with water to field capacity moisture level. Throughout the experiment the moisture was maintained at field capacity level.

Plant parameters

The following plant data was recorded at 60 days after sowing of maize at the end of experiment.

Plant Height (cm)

The plant height of all plants in each treatment was measured with the help of meter rod and average height of plants in each pot was worked out.

Leaves Count (# plant^{-1})

The number of leaves of all plants in each pot was recorded and average number of leaves per pot was worked out.

Leaf Area (cm^{2})

The leaf area of one mature middle leaf per plant in each pot was measured with the help of leaf area meter and average leaf area per pot was worked out.

Fresh Weight (g plant^{-1})

All the plant from each pot were harvested \ cut at flag leaf stage, immediately, washed and blotted dry. Then, their fresh weight was recorded and average for fresh weight per pot was worked out.

Dry Weight (g plant^{-1})

After recording fresh weight, plant samples were air dried and then oven dried at 65°C till constant weight and dry weight was recorded.

Moisture Content (%)

From each pot fresh and dry weight of plants was determined and moisture content was calculated with the formula.

Percent moisture = Fresh weight - Dry weight x 100
Fresh weight.

Root Lenght (cm)

Root length was recorded by measuring length of the longest root of each plant in cm with meter rod.

Root Volume (cm^{3} Root volume was measured by putting roots of all the plants present in a pot in graduated cylinder, determined the radius of cylinder and increased in water column was noted and determined root volume by formula 3.14 x r^2 x l.

Soil analysis

The soil was analyzed for physical and chemical characteristics which were as under, Soil samples were collected from rhizosphere of maize. Samples were placed in polythene bags and labelled properly. Ammonium Bicarbonate-DTPA extract method was used to determine the amounts of phosphorus, potassium and micronutrients in the soil samples. Soil extract was obtained of 10 g. Ten gm air-dried (2-mm) soil was taken into a 125 ml conical flask. 20 ml of extracting solution was added and shaked on a reciprocal shaker for 15 minutes at 180 cycles' \ minutes with flask kept open. The extract was then filtered through Whatman No.42 filter paper (Soltanpour and Workman, 1979).

Soil Texture

Particle size analysis was carried out using Bouyoucos hydrometer method, as described by Moodie *et al* (1959). Soil sample (40g) was dispersed with 1 % sodium hexameta phosphate solution. The density of soil water suspension was measured by using Hydrometer. Soil texture class was determined by using triangle in USDA Handbook 60.

pH

The pH of saturated soil paste was measured by using pH meter. The paste was prepared by mixing 250 gm of soil with distilled water. The pH meter was standardized using buffer solution of pH 4 and 9. After calibration, the pH of paste was recorded (McLean, 1982).

Electrical Conductivity

Soil extract was obtained from the saturated soil paste by using Buckner funel. Temperature of the extract was noted and electrical conductivity was recorded by using electrical conductivity meter (Richards, 1954).

Cation Exchange Capacity

A 5 gm soil was saturated with 1N sodium acetate (pH

8.2). Extraction was made by ammonium acetate (pH 7.0) and sodium was determined by using flame photometer (Rhoades, 1982).

Organic Matter

A 1 g of soil was mixed with 10 ml of 1.0 N Potassium dichromate solution and 20 ml of concentrated sulphuric acid. Two hundred ml distilled water and 10 ml orthophosphoric acid were added and let cool then added 10-15 drops of Di phenyl amine indicator and titrated against 0.5 N ferrous ammonium sulphate solution until the colour changed from blue to sharp green (Walkey, 1947).

Nitrate Nitogen in Soil

With 1:2 soil to extractant (0.5 M K_2SO_4) ratio (50 g soil to 100 ml extractant). Soil solution was shaken solution for one hour, filtered through a Whatman 42 filter paper into a vial. Accurately micro-pipetted 0.5 ml of each standard or sample extract into a marked test tube. Rinsed the tip by pipetting distilled water between each sample and standard. Added 1.0 ml of 5% salicylic acid reagent solution to each test tube, vortexed and left the tube to sit for 30 minutes. Added 10 ml of the NaOH reagent to each test tube and vortex. Left the test tube for at least one hour for colour development. Read the absorbance at 410 nm on the spectrophotometer (Vendrell and Zupanic, 1990).

Phosphorus in Soil

One ml aliquot of the soil extract to 10 ml with distilled water. Added 2.5 ml color developing reagent carefully to prevent loss of sample due to excessive foaming. Stirred, left it for 30 minutes, and measured color intensity at 880 nm wavelenght using a spectrophotometer. Prepared working standards containing 0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 ppm P using KH_2PO_4. Standard calibration curve was obtained using absorbance values for standards (Soltanpour and Workman, 1979).

Potassium in Soil

AB-DTPA extract was used for estimating potassium directly by flame photometer. Prepared working standards of 20, 40, 60, 80, 100, 150 and 200 ppm K using KCl (Soltanpour and Workman, 1979).

Micronutrients in Soil

Zn, Cu, Fe, and Mn were determined by atomic absorption spectrophotometer. The standards of these metals were made in the extracting solution (Soltanpour and Workman, 1979).

Plant analysis

Plant samples were collected from each pot at boot stage and washed with distilled water, air dried and oven dried at 65^{o}C till constant weight. The samples were ground and thoroughly mixed.

Nitrogen in Plant

Total nitrogen in the plant was determined by following method. A sample of 0.2 g of finally ground plant material was digested with 4.4 ml of digestion mixture (selenium powder, lithium sulphate) at 380^{o}C for 2 hours. After digestion, volume of digest was made to 100 ml. A 0.1 ml of digest was treated with 5 ml of N1 reagent (sodium salicylate, Sodium citrate and sodium tartrate) and reagent N2 (sodium hydroxide and sodium hypochlorite), kept for 1 hour for colour development. The intensity of yellow colour was determined at 655 nm wavelenght using spectrophotometer (Anderson and Ingram, 1993).

Phosphorus in Plant

Phosphorus, potassium and micronutrients in plant were determined through wet digestion. One gram of dried plant sample was taken in a digestion tube. 10 ml of concentrated HNO_3 was added to the tube followed by addition of 5 ml of concentrated 70% $HClO_4$. The contents were digested in digester block till colour cleared up. The digested materials was made to 100 ml volume using distilled-deionized water and used for determination of P, K and micronutrients. 1 ml of the digested material was taken into a 10 ml tube. 2 ml of 2N HNO_3 solution was added and diluted to 8 ml of distilled water. Thereafter, 1 ml of molybdate vanadate solution was added and column made to 10 ml with distilled water. The tube was shaken and to stand for 20 minutes. The absorbance was measured by spectrophotometer at 430 nm and determined concentration of phosphorus (Rashid, 1986).

Potassium in Plant

One ml of extract was taken in a test tube and added to it 5 ml distilled water followed by 4 ml of lithium chloride solution. Test tube was shaken and potassium was determined using flame analyzer (Hussain and Jabbar, 1985).

Micronutrients in Plant

Micronutrients like Zn, Cu, Fe, and Mn were determined directly from above digest used for phosphorus and potassium (Rashid, 1986).

Statistical analysis

The data collected for various characteristics were analyzed statistically by the analysis of variance (ANOVA) technique using CRD. The treatment means were compared by Duncan's Multiple Range Test (DMRT) as given by Steel and Torrie (1980).

Results

The original soil was analyzed for general characteristics. The soil had sandy loam texture with 7.9 ppm, organic matter 0.78 % and electrical conductivity (ECe) 0.28dSm, the cation exchange capacity (CEC) of soil was 11.05 c mol kg^{-1}. The nitrate nitrogen and available phosphorus (P) contents were 1.2 ppm and 6.5 $mgKg^{-1}$ respectively. Soil Potassium was 95 $mgKg^{-1}$ soil. Micronutrients in soil were as Zn 1.25 ppm, Cu 3.21 ppm, Fe 4.65 ppm and Mn 1.065 ppm respectively. The influence of various studied treatments on the diverse growth and yield parameters of maize was presented in Table (7). In comparison with the positive control, comparable results for plant height (cm), leave count, leaf area (cm^2), fresh weight, root length and root volume were obtained due to the treatments of half dose of NPK + BPF.

Table 1. Effect of different treatments on plant height, leave count and leaf area.

Treatment	Plant height (cm)	Leave count	Leaf area (cm^2)
T1 Control	14.00g	3.00d	48.00 g
T2 (BPF)	21.67e	3.16d	55.00e
T3 (P)	23.67d	3.56c	57.00d
T4 (BPF+P)	28.00c	4.10b	61.00b
T5 (K)	18.00f	3.10d	52.00f
T6 (BPF+K)	25.00d	3.76c	59.00c
T7 (P+K)	33.00a	5.83a	65.00a
T8 (1/2P+1/2K)	29.00bc	5.56a	60.00bc
T9 (BPF+1/2P+1/2K)	30.00b	5.73a	63.33a

Table 2. Effect of different treatments on fresh weight, Dry weight, Moisture contents, root length and root volume.

Treatment	Fresh weight (g)	Dry weight (g)	Moisture contents (%)	Root length (cm)	Root volume (cm^3)
T1 Control	3.75g	1.07e	71.34b	15.00d	172d
T2 (BPF)	4.95e	1.25 cd	74.65a	18.33c	183bc
T3 (P)	5.18de	1.28cd	74.25a	10.00e	194a
T4 (BPF+P)	5.33d	1.29cd	75.48a	14.00d	198a
T5 (K)	4.56f	1.16de	75.70a	17.33c	178c
T6 (BPF+K)	5.46d	1.32bc	75.17a	13.00d	185b
T7 (P+K)	6.55a	1.50 a	77.83a	19.00c	196a
T8 (1/2P+1/2K)	5.81c	1.46ab	74.82a	22.33a	193a
T9 (BPF+1/2P+1/2K)	6.19b	1.47ab	75.97a	21.00ab	195a

Effect of different treatments on plant height, leave count and leaf area

Data regarding the effect of Biological Potassium Fertilizer (BPF) on plant height, leaves count and leaf area showed that it has significantly affected these parameters (table1). Maximum plant height (33 cm), leaves count (5.8) and leaf area (65 cm^2) was observed in T7 (P+K). Next best values of these parameters were obtained in T9 where a combination of BPF and half of the recommended doses of P and K. Minimum values were noted in control treatment. Application of biological potassium fertilizer alone did not produce good results.

Table 3. Effect of different treatments on NO_3-N, Available P, extractable K and micronutrients of soil (ppm).

Treatment	NO_3-N	Available P	Extract-able K	Fe	Cu	Zn	Mn
T1 Control	6.42^{NS}	5.18f	135de	4.77^{NS}	3.17^{NS}	1.23b	1.07^{NS}
T2 (BPF)	5.67	7.32de	131ef	4.53	3.25	1.16bc	1.40
T3 (P)	6.11	11.84ab	123g	3.74	2.99	0.93bc	0.82
T4 (BPF+P)	5.84	12.35a	129f	4.11	3.11	1.98a	0.95
T5 (K)	6.27	6.25ef	145ab	3.89	3.21	1.11bc	0.88
T6 (BPF+K)	6.08	8.65c	148a	4.39	3.08	1.15bc	0.98
T7 (P+K)	5.63	11.64ab	143bc	3.60	2.87	0.84c	0.74
T8 (1/2P+1/2K)	5.94	8.5cd	137cd	3.86	3.14	0.88c	0.85
T9 (BPF+1/2P+1/2K)	5.73	10.82b	145ab	4.14	3.21	1.01bc	0.91

Table 4. Effect of different treatments on macronutrient content of shoot and root of plants (ppm).

Treatment	Total N	Total P	Total K	Total N	Total P	Total K
	Shoot			Root		
T1 Control	2.32^{NS}	0.17h	1.96^{NS}	1.52^{NS}	0.16g	1.62^{NS}
T2 (BPF)	2.12	0.19f	2.20	1.39	0.18f	1.71
T3 (P)	1.95	0.23b	1.81	1.31	0.21ab	1.49
T4 (BPF+P)	1.84	0.25a	1.90	1.26	0.21a	1.54
T5 (K)	2.01	0.18g	2.15	1.36	0.16g	1.81
T6 (BPF+K)	1.90	0.19f	2.26	1.32	0.20c	1.94
T7 (P+K)	1.69	0.20d	2.05	1.23	0.19d	1.68
T8 (1/2P+1/2K)	1.81	0.20e	2.08	1.27	0.19e	1.60
T9 (BPF+1/2P+1/2K)	1.75	0.21c	2.14	1.25	0.207b	1.65

Effect of different treatments on fresh weight, dry weight, root length and root volume

Fresh weight, dry weight, moisture contents, root length and root volume were affected positively with the application of BPF (Table 2). Maximum fresh weight (6.55 g), dry weight (1.50 g), root length (19 cm) of plants was noted in T7 (P+K). Next best value for fresh weight (6.19 g) was obtained in T9 where a combination of BPF and half dose of P and K fertilizers had been added.

Table 5. Effect of different treatments on micronutrient content of shoot of plants (ppm).

Treatment	Fe	Cu	Zn	Mn
T1 Control	219.7bc	21.6bc	47.00cd	248.7c
T2 (BPF)	238.3a	29.83a	56.10a	258.0a
T3 (P)	209.3d	18.17de	44.63f	232.7f
T4 (BPF+P)	214.0cd	19.37cd	45.17ef	240.7de
T5 (K)	213.3cd	18.63d	48.47c	243.3d
T6 (BPF+K)	223.3b	24.27b	50.57b	254.7ab
T7 (P+K)	201.0e	15.60e	42.07g	226.7g
T8 (1/2P+1/2K)	209.3d	18.97cd	43.57fg	237.0ef
T9 (BPF+1/2P+1/2K)	221.3bc	23.53b	46.53de	250.7bc

P+K (T7) treatment showed maximum moisture contents (77 %) as compared to rest of treatments. After P+K (T7), it was the T9 treatment which was fertilized with ½PK and BPF and produced better results than T8 treatment because it lacked BPF and contained only ½ PK. From this it is clear that chemical fertilizer is universal in its importance but BPF is bio fertilizer which contributes to some extant for the availability of P+K for crop.

Highest dry weight content (1.497 g) exhibited by P+K (T7) treatment. It was observed that P+K (T7) treatment contained combined phosphorus and potassium and produced highest biological yield. In T8 treatment the amount of P+K was reduced to half and it affected on resultant dry weight (1.46 g).

Table 6. Effect of different treatments on micronutrient content of root of plants (ppm).

Treatment	Fe	Cu	Zn	Mn
T1 Control	255.3bc	28.97a	47.07e	245.7b
T2 (BPF)	265.7a	29.43 a	53.90 a	263.3a
T3 (P)	245.7d	23.77c	45.17f	224.7e
T4 (BPF+P)	250.3cd	26.73b	48.73d	229.7de
T5 (K)	254.7bc	25.10 c	51.43c	232.0d
T6 (BPF+K)	257.7b	27.90ab	53.30ab	238.3c
T7 (P+K)	223.3f	21.40 d	43.10 g	219.7f
T8 (1/2P+1/2K)	235.0e	23.70c	46.80e	225.7e
T9 (BPF+1/2P+1/2K)	251cd	27.27b	52.23bc	229.7de

In case of root length, T8 treatment again showed best results, which is comparable with T9 treatment which is supplied with BPF and half dose of PK. Application of BPF also promoted the root growth 18.33 cm, T2 over control and its effect was more than the application of P and K fertilizer alone. Highest amount of root volume was observed by T4 (BPF+P) which is significantly same with other four treatments that is T3, T7, T8 and T9 treatments.

Meyer *et al.* (1973) evaluated the behavior of phosphate solubilizing microorganisms (*Bacillus Polymixia* and *Bacillus Firmg*). The results indicated that the use of these bio inoculants with field crops even in low available P increased yield up to 200-500kg/ha. In this way use of more than 30 % of phosphate fertilizer could be saved.

Effect of different treatments on macro and micronutrients of soil

No_3-N level of the soil remained unaffected by the application of different treatments (Table 3). However P and K content of the soil were affected significantly. Maximum P (12.35 ppm) was noted in T4 (BPF+P) while maximum K (148 ppm) was noted in T6 (BPF+K), so the application of BPF along with P and K fertilizer led to their increased availability in soil. Minimum value of P (5.18 ppm) was noted in control treatment. So far as micronutrients are concerned application of different treatments had non-significant effect on the dynamics of Cu, Fe and Mn while only Zn was affected significantly. Maximum Zn content (1.98 ppm) was observed in T4.

***Effect** of different treatments on macro and micronutrient content of plants*

Total Nitrogen and K content of plants were remained unaffected while total P content was affected significantly (Table 4). Maximum P content (0.213 ppm) was noted in T4 (BPF+P). Least P content (0.16 ppm) was noted in control treatment. For nitrogen in plant (root), all treatments differed from each other non-significantly. For phosphorus in plant (root), highest amount of phosphorus which differed significantly as compared to rest of treatments was observed in BPF+P (T_4) having value 0.23 ppm except P (T3) which did not differ significantly having value 0.21 ppm. Least amount of phosphorus (0.16 ppm) was observed in control (T_1) and K (T_5) which were non-significant to each other, might be due to rapid metabolism rate. The observation were similar as experienced by Zaghloul *et al.* (1996) studied wheat seeds inoculation with *Azospirillum brasilense* plus *Bacillus megaterium* in green house. They reported that inoculation of wheat seeds with PSB gave the highest count of inorganic phosphate dissolvers. For Potassium in Plant (root), all treatments differed from each other non-significantly.

Application of different treatments had significant effect on Fe, Cu, Zn and Mn content in shoot of plants (Table 5). The highest concentration of Cu (29.8 ppm), Zn (56.1 ppm), Fe (238 ppm) and Mn (258 ppm) were noted in T2 (BPF). T7 (P+K) and T8 (1/2P+1/2K) had statistically similar effect on Zn content of plants.

Table 7. Statistical analysis of all attributes.

Traits		DF	SS	MS	F-Value	Prob	CV	LSD
Plant height	Between	8	899	112.398	91.962	0.000	4.4	1.896
	Within	18	22	1.222				
	Total	26	921.185					
Leaves count	Between	8	33.61	4.201	130.382	0.000	4.27	0.3069
	Within	18	0.58	0.032				
	Total	26	34.19					
Leaf area	Between	8	711.407	88.75	85.75	0.000	1.76	1.74
	Within	18	18.667	1.037				
	Total	26	730.074					
Fresh weight	Between	8	17.204	2.15	65.764	0.000	3.4	0.3116
	Within	18	0.589	0.033				
	Total	26	17.792					
Dry weight	Between	8	0.511	0.064	9.53	0.000	6.24	0.1435
	Within	18	0.121	0.007				
	Total	26	0.632					
Moisture contents	Between	8	60.262	7.533	2.707	0.0378	2.22	2.862
	Within	18	50.088	2.783				
	Total	26	110.349					
Root length	Between	8	382	47.75	28.65	0.000	7.75	2.21
	Within	18	30	1.667				
	Total	26						
Root volume	Between	8	1963	245.426	21.798	0.000	1.78	5.756
	Within	18	202.667	11.259				
	Total	26						
Potassium in soil	Between	8	1728.67	216.083	27.782	0.000	2.02	4.7
	Within	18	140	7.778				
	Total	26	1868.67					
Phosphorus in soil	Between	8	163.716	20.464	39.323	0.000	7.87	1.237
	Within	18	9.368	0.52				
	Total	26	173.083					
Nitrate nitrogen in soil	Between	8	1.819	0.227	0.661		9.83	
	Within	18	6.193	0.344				
	Total	26	8.012					
Zinc in soil	Between	8	2.8	0.35	11.73	0.000	15.05	0.2971
	Within	18	0.537	0.03				
	Total	26	3.337					
Copper in soil	Between	8	0.354	0.044	0.627		8.52	
	Within	18	1.27	0,071				
	Total	26	1.624					
Iron in soil	Between	8	3.588	0.449	1.022	0.4551	16.1	
	Within	18	7.903	0.439				
	Total	26	11.491					
Manganese in soil	Between	8	O.885	0.111	2.01	0.1043	24.55	
	Within	18	0.991	0.055				
	Total	26	1.876					
Nitrogen in plant (shoot)	Between	8	0.925	0.116	1.045	0.4406	17.22	
	Within	18	1.992	0.111				
	Total	26	2.917					
Phosphorus in plant	Between	8	0.015	0.002	9.856	0.000	6.8	0.005
	Within	18	0.003	0				

(shoot)	Total	26	0.019					
Potassium in plant (shoot)	Between	8	0.527	0.066	0.767		14.21	
	Within	18	1.546	0.086				
	Total	26						
Nitrogen in plant (root)	Between	8	0.197	0.025	0.178		28.13	
	Within	18	2.494	0.139				
	Total	26	2.691					
Phosphorus in plant (root)	Between	8	0.009	0.001	3.021	0.0245	10.38	0.005425
	Within	18	0.007	0				
	Total	26	0.016					
Potassium in plant (root)	Between	8	0.466	0.057	1.304	0.3025	12.6	
	Within	18	0.793	0.044				
	Total	26	1.253					
Iron in plant (shoot)	Between	8	2747.63	343.454	16.413	0.000	2.11	7.847
	Within	18	376.667	20.926				
	Total	26	3124.3					
Manganese in plant (shoot)	Between	8	2591.85	323.981	38.706	0.000	1.19	4.963
	Within	18	150.667	8.37				
	Total	26	2742.52					
Copper in plant (shoot)	Between	8	434.892	54.361	23.597	0.000	7.19	2.604
	Within	18	41.467	2.304				
	Total	26	476.359					
Zinc in plant (shoot)	Between	8	428.56	53.57	58.416	0.000	2.03	1.64
	Within	18	16.507	0.917				
	Total	26	445.067					
Iron in plant (root)	Between	8	3810.74	476.343	38.051	0.000	1.42	6.069
	Within	18	225.333	12.519				
	Total	26	4036.07					
Manganese in plant (root)	Between	8	4254.3	531.787	63.252	0.000	1.24	4.974
	Within	18	151.333	8.407				
	Total	26	4405.63					
Copper in plant (root)	Between	8	175.743	21.968	26.912	0.000	3.47	1.55
	Within	18	14.693	0.816				
	Total	26	190.436					
Zinc in plant (root)	Between	8	350.907	43.863	79.007	0.000	1.52	1.278
	Within	18	9.993	0.555				
	Total	26	360.901					

For Iron in plant (root), BPF (T2) with value (265 ppm) showed significantly higher value for iron as compared to rest of treatments. For copper in plant (root), maximum value for copper was showed by BPF (T2) with value 29.4 ppm. Lowest value was observed in P+K (T7) with value 21.4 ppm, the value indicates that there might be rapid uptake of nutrients and deficiency might be resulted. For Zinc in plant (root) in table 6, BPF (T2) showed significantly higher value (53.9 ppm) as compared to rest of treatments. For Manganese in plant (root), highest value of manganese was showed by BPF (T2) with value 263 ppm. These results are supported by Gaur (1990) who reported that the use of rock phosphate as substitute to super phosphate also increased the grain yield but coupled with inoculation with microphos culture resulted in significant additional gains. When wheat seeds were treated with different combinations of sulfur, municipal refuse and N fixing and phosphate solubilizing bacteria (PSB) an increase in yield was obtained as compared to control.

Discussion

BPF contains *Bacillus mucilaginous* strain which enhances the biomass production in any plant species. Increased macro and micronutrients of *Zea mays* L. was observed with addition of BPF compared to control. The poor biomass production in potassium-unfertilized soil (control) may be due to low in available K. Inoculation of *Bacillus mucilaginous* strain had shown significant increase in biomass yield in the present work than un inoculated pots. When PK was inoculated with BPF, it enhanced the biomass production. This may be due to mobilization of potassium from BPF because of secretion of organic acids by the bacterial strain, which in turn increased the biomass yield. It is stated that potassium solubilizing microorganism are able to solubilizing the unavailable forms of K in K-bearing minerals through excretion and production of organic acids (Song and Huang 1988; Friedrich *et al.* 1991; Bennett *et al.* 1998). Role of organic acids derived from root in the mobilization of nutrients from the rhizosphere has been assessed (Jones and Darrah 1994; Jones *et al.* 1996; Jones 1998). Jones *et al.* (2003) described that organic acids have been imagined to do many jobs in soil including mineral weathering, root nutrient acquisition, microbial chemotaxis and metal detoxification.

Bacillus mucilaginous performed considerably in improving K uptake by Maize. The results approved the findings of earlier workers where they reported greater total uptake of K by crop when K bearing minerals were inoculated with potassium solubilizing bacteria (Sheng *et al.* 2002). Sheng (2005) also reported significant rise in shoot and root dry yield with potassium releasing strain *Bacillus edaphicus* NBT. By mean of which we can say that the potassium dissolving bacteria play an important role in plant nutrition by increasing K uptake by the plant (Sheng and He 2006). Han *et al.* (2006) also stated the beneficial effect of *Bacillus mucilaginous* on mobilization K from potassium mineral, and nutrient uptake and growth of pepper and cucumber from Korea.

Han and Lee (2005) reported the synergistic effects of soil fertilization with rock P and K materials and co-inoculation with phosphate solubilizing bacteria (PSB) *Bacillus megatherium* and potassium solubilizing bacteria (KSB) *Bacillus mucilaginous* on the improvement of P and K uptake by eggplant grown under limited P and K soil in greenhouse. The higher mobilization of K and its subsequent uptake by Maize due to inoculation with *Bacillus mucilaginous* could be attributed to increase population of bacteria in the root and rhizosphere soil. As successful plant growth endorsing inoculants, bacteria must be capable of to quickly colonize the root system throughout the growing season (Defreitas and Germida, 1992).

Conclusion

It is concluded that application of Biological Potassium Fertilizer (BPF) has a significant effect on potassium uptake due to higher solubilization of K and led to an increase presence of macro (N, P, K) and micronutrients (Cu, Zn, Fe, Mn) in soil and to a higher uptake by plant. Thus, bio intervention of BPF could be an alternative and viable technology to solubilize insoluble K into soluble form and could be used efficiently as a source of K fertilizer for sustaining crop production and maintaining soil potassium. Further studies are needed to see the effect of the new fertilization method tested is promising for big scale field application.

References

Anonymous. 2003. Fertilizer and Their Use in Pakistan. Govt. of Pakistan, Planning and Development Division, Nat. Fert. Dev. Centre, Islamabad.

Anderson JM, Ingram JSI. 1993. Colorimetric determination of nitrate. In "Tropical Soil Biology and fertility: A handbook of methods", 2nd ed., CAB Int., Wallingford, U.K. 74-75 p.

Bennett PC, Choi WJ, Rogera JR. 1998. Microbial destruction of feldspars. Mineralogical Magazine, 62A, 149-150.

De Freitas JR, Germida JJ. 1992. Growth promotion of winter wheat by fluorescent Pseudomonas under field conditions. Soil Biology and Biochemistry **24,** 1137-1146. http://dx.doi.org/10.1016/0038-0717(92)90064-5.

Friedrich S, Platonova NP, Karavaiko GI, Stichel E, Glombitza F. 1991. Chemical and microbiological solubilization of silicates. Acta

Biotechnologica **11,** 187–196.
http://dx.doi.org/10.1002/abio.370110302.

Han HS, Lee KD. 2005. Phosphate and potassium solubilizing bacteria effect on mineral uptake, soil availability and growth of eggplant. Research Journal of Agriculture and Biological Sciences **1,** 176-180.

Han HS, Supanjani, Lee KD. 2006. Effect of co-inoculation with phosphate and potassium solubilizing bacteria on mineral uptake and growth of pepper and cucumber. Plant, Soil and Environment. **52,** 130–136.

Hussain T, Jabbar A. 1985. Soil and plant analysis. Dept. of Soil Sci. Univ. of Agri. Faisalabad, Pakistan.

Jones DL. 1998. Organic acids in the rhizosphere, a critical review. Plant and Soil **205,** 25–44. http://dx.doi.org/10.1023/A:1004356007312

Jones DL, Darrah PR. 1994. Role of root derived organic-acids in the mobilization of nutrients from the rhizosphere. Plant and Soil **166,** 247–257. http://dx.doi.org/10.1007/BF00008338

Jones DL, Darrah PR, Kochian LV. 1996. Critical-evaluation of organic-acid mediated iron dissolution in the rhizosphere and its potential role in root iron uptake. Plant and Soil **180,** 57–66. http://dx.doi.org/10.1007/BF00015411.

Jones DL, Dennis PG, Owen AG, van Hees PAW. 2003. Organic acid behavior in soils misconceptions and knowledge gaps. Plant and Soil **248,** 31–41.
http://dx.doi.org/10.1023/A 1022304332313.

Kumar A. 2003. Environmental challenges of 21st century. A. P. H. Publishing corporation. 5 Ansari road, Darya Ganj. New Delhi. 110-200 p.

McLean EO. 1982. Soil pH and lime requirement. In Page, A. L., R. H. Miller and D.R. Keeney (eds.) Methods of soil analysis. Part 2 - Chemical and microbiological properties. (2nd Ed.). Agronomy **9,** 199-223.

Meyer BS, Anderson BD, Bohning RH, Fratianne DG. 1973. Introduction to plant physiology. D. Van Nostrand Company, New York. 293-322 p.

Ministry of Food and Agriculture, Economic Survey. 2010-11, Annual Plan 2010-11.

Moodie CD, Smith HW, Mc Creeny RA. 1959. Laboratory Manual for Soil Fertility. State College for Washington, Pullman.

Rashid A. 1986. Mapping Zinc fertility of soil, using indication plants and soil analysis. Ph.D. Dissertation, University of Hawaii, HI, USA.

Richards LA. 1954. Diagnosis and improvement of saline and alkali soils. USDA Agric. Handbook 60. Washington, D. C.

Rhoades JD, Polemio M. 1977. Determining cation exchange capacity: A new procedure for calcerious and gypsiferous soils. Soil Science Society of America **41(5),** 24-300.
http://dx.doi.org/10.2136/sssaj1977.03615995004100030018x.

Sheng XF, He LY, Huang WY. 2002. The conditions of releasing potassium by a silicate-dissolving bacterial strain NBT. Agriculture Science in China **1,** 662–666.

Sheng XF, He LY. 2006. Solubilization of potassium-bearing minerals by a wildtype strain of *Bacillus edaphicus* and its mutants and increased potassium uptake by wheat. Canadian Journal of Microbiology **52,** 66–72.
http://dx.doi.org/10.1139/w05-117.

Sheng XF. 2005. Growth promotion and increased potassium uptake of cotton and rape by a potassium releasing strain of Bacillus edaphicus. Soil Biology and Biochemistry **37,** 1918–1922. http://dx.doi.org/10.1016/j.soilbio.2005.02.026.

Soltanpour PN, Workman S. 1979. Modification of AB-DTPA soil test to omit carbon black. Communications in Soil Science and Plant Analysis. **10,** 1411-1420.

Song SK, Huang PM. 1988. Dynamics of potassium release from potassium-bearing minerals as influenced by oxalic and citric acids. Soil Science Society of America **52,** 383–390. http://dx.doi.org/10.2136/sssaj1988.03615995005200020015x.

Steel RGD, Torrie JH. 1980. Principles and Procedures of Statistics 2nd Edition. McGraw Hill Book Company Inc. New York. 121-127 p.

Vendrell PF, Zupanic J. 1993. Determining of soil nitrate by transnitration of salicylic acid. Communication in Soil Science and Plant Analysis **21,** 1705-1713. http://dx.doi.org/10.1080/00103629009368334