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Research Article

Integrated application of phosphorus (P) and phosphate solubilizing bacteria (PSB) improve maize yield

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Abstract

Phosphorous deficiency in soils has become the prominent limiting factor for plant and root growth. A field experiment was laid out at theagronomic researchfarm of Department of Agriculture, University of Swabi to assess the response of maize to P rates (60, 90 and 120 Kg P_2O_5 ha^{-1}) and PSB (with and without PSB). Two factorial randomized complete block design (RCBD) with three replications was used for this experiment. With the increasing P from 60 to 120 Kg P_2O_5 ha^{-1} both with and without PSB inoculation plant height, 1000 grains weight, grain and biological yield were significantly increased. Similarly, PSB inoculation (on average) meaningfully increased plant height, 1000 grains weight, grain and biological yield by 11, 1, 10 and 6% respectively, at all P level compared to un-inoculated control. Significant interactive effect of PSB and P over mentioned yield attributes exhibited that PSB application can reduce dependence on chemical P fertilizer up to 30 Kg P_2O_5 ha^{-1} when P is applied from SSP. Thus it may be suggested that PSB should be applied with 90 Kg P_2O_5 ha^{-1} chemical P fertilizer for efficient P utilization and profitable crop yield.

Keywords: Grain yield; Maize; Phosphorus; Phosphate solubilizing bacteria

Introduction

Maize (*Zea mays* L.) belongs to family Poaceae and is grown inspring as well as summer season in Pakistan. In Pakistan it is the third important cereal crop after wheat and rice.It is high economic crop and has great significance for developing countries like Pakistan where population is incessantly increasing. **[1]**.Total cultivated area of maize is 140 M ha with a production around 420 M tons worldwide **[2]**.The area under maize cultivation in Pakistan and Khyber Pakhtunkhwa was 935.1 Kg ha^{-1} and 421.9 Kg ha^{-1}, with production of

3261.5 Kg ha^{-1} tons and 752.2 Kg ha^{-1}tons, and the average yields of 3488 Kg ha^{-1} and 1135 kg ha^{-1} respectively[3]. Khyber Pakhtunkhwa and Punjab contribute 68% and 30% of the total production, respectively; while Sindh and Balochistan contribute a very a small percentage i.e. 2-3% [4]. Maize grains counted a great importance on the basis of their Pharmaceutical and industrial usage [5].

Phosphorus (P) is the second important plant essitional nutrient which effectson plant growth by inducing the basic metabolic processes such as cell splitting up and enlargement, energy carrying (ATP, ADP), macromolecular biosynthesis, photosynthesis and respiration [6].Phosphorus applied in the form of organic and inorganic fertilizers to the soil. However, a large portion of soluble inorganic phosphate applied to the soil as chemical fertilizer is immobilized rapidly and becomes unavailable to plants [7]. Phosphorus ranges from 0.02 to 0.05 %(w=w) in the soil; [8], from this values is just 0.1 % is available to plants [9]. On which P sufficient requirement to plant not be accessible thus need to be applied to soils as inorganic soluble P fertilizers; a small part of these applied inorganic P fertilizer only 1%uptake by plants and the rest (~ 99 %) is rapidly transformed into unsolvable complexes [10]in alkaline soils [11]. These cation complexes precipitate about 80 % of applied inorganic P fertilizer. While, the recapture efficacy of P is less than 20 % of the added P in the world soils [12].

Microorganisms are take an integral part in transformation, solublization and organic matter decomposition processes which are effective in releasing P from inorganic and organicsources of P [13]. Hence, soil microorganisms play a vital role in P availability to the plants applied to inorganic and organic sources [14].In particular, P-solubilizing bacteria (PSB) are reported to play an important role in enhancing the P efficiency of both natural and applied P and improving the productivity of field crops [11]. Nutrition of P is improve by PSB through the release of low-molecular-weight organic acids [15], which through their hydroxyl and carboxyl groups chelate the cations bound to phosphate, thereby converting it into soluble forms[16].

As most of our soils in Pakistan are alkaline and calcareous in nature, due to which bio availability of P is a major problem in our soil. That's why the present study was initiated with the following objectives to evaluate the impact of PSB and P on the growth and yield of maize crop.

Materials and methods

Experimental procedure

A field experiment was conducted at the agronomic research farm of Department of Agriculture, University of Swabi to evaluate the combine impact of P fertilization (60, 90 and 120 Kg P_2O_5 ha^{-1})and PSB inoculation (control and inoculated) on the yield of maize crop. The experiment was design in two factorial randomize complete block design (RCBD) with three replication. The soil of the experimental field was silt loam in texture, non- saline, alkaline and calcareous in nature and low in organic matter and AB-DTPA extractable P (Table 1).

Table 1.Physio-chemical properties of composite sample

Property	Concentration	Units
Textural class	Silt loam	-
EC	1.75	dSm^{-1}
pH	7.4	-
Organic matter	0.74	%
Lime	13.6	%
P (AB-DTPA extractable)	2.24	mg kg^{-1}

PSB inoculums was obtained from Department of Microbiology University of Hazara. The seed of maize verity Azamwas inoculated with PSB as per proposed treatment via using stander inoculation procedure. For this purpose maize seed were placed in 10% sugar solution and then amended with PSB inoculums. Seeds were shade dried. P was applied at the rate of 60, 90 and 120 P_2O_5Kg ha^{-1} according to the treatment structure of the experiment using SSP as a source. Inoculated maize seed were sown at the rate of 25 Kg ha^{-1} while using a row to row and plant to plant distance of 75 and 50 cm respectively. Basal dose of N and K was applied at the rate of 150 and 90 Kg ha^{-1} through Urea and SOP fertilizers. Normal recommended cultural practices were followed throughout the growing season.

Agronomic parameters

Plant height was recorded in cm from the base of the plant to the base of flag leaf with the help of meter rod. The data were calculated as the average of five randomly selected plants from each row.Thousand grains weight in g was taken by weighting 1000 grains selected from every pot after sun drying. Biological yield per hectare was taken by weighing the total harvest obtained from each treatment plot after sun drying the biomass and was converted into kg ha^{-1}. Grain yield per hectare was taken by weighing the grains obtained from each treatment plot after sun drying the grains and was converted into kg ha^{-1}.

Statistical analysis

The data was analyzedfor Analysis of Variance (ANOVA) according to the procedure of Steel and Torrie **[17]**. After getting the significant variations for various studied parameters, the means for each parameter were further separated and compared by using the least significant difference (LSD) test at 5% level of probability.

Results and discussion

A field experiment was conducted at the Research Farm of Department of Agriculture, University of Swabi. The aim of this experiment was to evaluate the impact of phosphatic fertilizers and PSB on growth and yield of maize crop. The results obtained in this experiment are as follow:

Plant height

Upon ANOVA result indicated that P, PSB inoculation and their interaction significantly affected plant height cm of maize (Table 2). It was exhibited by the result that PSB inoculation improved maize plant height over un inoculated treatment. Phosphorus applied at the rate of 120 kg ha^{-1} produced plant height of 166.82 cm which was significantly higher than that of 90 kg ha^{-1} where the lowest was observed for 60 kg ha^{-1}. The interaction effect of PSB and P indicated that P applied at the rate of 120 kg ha^{-1} along with PSB produced taller plants while 60 kg P_2O_5 ha^{-1} without PSB produced dwarf plant. P applied at the rate of 60 kg P_2O_5 ha^{-1} with PSB produced statistically similar plant height to that of 90 kg P_2O_5 ha^{-1} with and without PSB and 120 kg P_2O_5 ha^{-1} P without PSB. These result demonstrated that PSB inoculation can reduce or may minimize dependence on chemical P fertilizer up to 100% under exist soil and climatic conditions.

Our results are is agreement to those of **[18]**, who also reported that plant height improves with PSB inoculation over 27%. PSB inoculation improves the availability of minerals content and nutrients which in result promotes plant growth, increase Phosphorus uptake and photosynthesis.

1000 Grain weight

Result indicated that P levels, PSB inoculation and their interaction significantly affected 1000 grains weight (Table 3). It was exhibited by the result that PSB inoculation improved maize 1000 grain weight over un inoculated treatment. Phosphorus applied at the rate of 120 kg P_2O_5 ha^{-1} produced 1000 grain weight of 307.13 g which was significantly higher than that of 90 kg P_2O_5 ha^{-1} where the lowest was observed for 60 kg P_2O_5 ha^{-1}. The combine effect of PSB and P indicated that P applied at the rate of 120 kg ha^{-1} along with PSB showed heaver grains

while P applied at the rate of 60 kg P_2O_5 ha^{-1} without PSB produced lighter. P applied at the rate of 60 kg P_2O_5 ha^{-1} with PSB produced statistically similar 1000 grain weight to that of 90 kg P_2O_5 ha^{-1} P with and without PSB and 120 kg P_2O_5 ha^{-1} P without PSB. These result proved that PSB inoculation can decline the use of chemical P fertilizer up to 100% under exist soil and climatic conditions.

Our results are is agreement to those of [12] who also reported that PSB inoculation improved the grain weight over 8.08, 7.93 and 7.57 % over 30, 60 and 90 kg P ha^{-1}, respectively. The experiment indicates that the PSB inoculation and Phosphorus fertilizer (P_2O_5) can promote growth stages of plants, emergence of seeds, photosynthesis, cell wall permeability and availability of nutrients in root zone, due to which grain weight improves.

Table 2. Plant height of maize (cm) as affected by P levels and PSB inoculation

Phosphorus (Kg ha^{-1})	Inoculation		Mean
	With PSB	Without PSB	
60	150.10 cd	143.60 e	146.85 c
90	159.57 b	146.30 de	152.93 b
120	181.40 a	152.23 c	166.82 a
Mean	163.69 a	147.38 b	----------

LSD (α=0.05) P = 3.7295, PSB = 3.0451 and PSB×P = 5.2743, Mean with different liters in each row and column are significantly (α=0.05) different from each other

Table 3.1000 grain weight of maize (g) as affected by P levels and PSB inoculation

Phosphorus (Kg ha^{-1})	Inoculation		Mean
	With PSB	Without PSB	
60	293.00 c	288.80 c	290.90 c
90	300.33 b	293.40 c	296.87 b
120	306.00 a	308.27 a	307.13 a
Mean	299.78 a	296.82 b	----------

LSD (α=0.05) P = 3.2808, PSB = 2.6788 and PSB×P = 4.6398Mean with different liters in each row and column are significantly (α=0.05) different from each other

Biological yield(Kg ha^{-1})

Result regarding the effect of PSB, P and their interaction on biological yield is presented (Table 4). Upon analysis of various result indicated that P, PSB inoculation and their interaction significantly affected biological yield of maize. It was showed by the result that PSB inoculation improved maize biological yield over un inoculated treatment. Phosphorus applied at the rate of 120 kg P_2O_5 ha^{-1} produced biological yield of 7134 kg ha^{-1} which was significantly higher than that of 90 kg P_2O_5 ha^{-1} where the lowest was observed for 60 kg P_2O_5 ha^{-1}. The interaction effect of PSB and P demonstrated that P applied at the rate of 120 P_2O_5 kg ha^{-1} along with PSB produced highest by which P applied at the rate of 60 kg P_2O_5 ha^{-1} without PSB produced lowest. P applied at the rate of 60 kg P_2O_5 ha^{-1} with PSB produced statistically similar biological yield to that of 90 kg P_2O_5 ha^{-1} P with and without PSB and 120 kg P_2O_5 ha^{-1} P without PSB. These result demonstrated that PSB inoculation can reduce or may minimize dependence on chemical P fertilizer up to a maximum of 100% under exist soil and climatic conditions.

Our results are is agreement to [19] who also concluded in his experiment that PSB inoculation along with Phosphorus fertilizers improved biological yield of plants over 30-40%. PSB inoculation can minimize use of chemical fertilizers and also improves the biological yield of plants.

Table 4.Biological yield (Kg ha^{-1})of maize as affected by P levels and PSB inoculation

Phosphorus (Kg ha^{-1})	Inoculation		Mean
	With PSB	Without PSB	
60	6845.7 b	6093.7 c	6469.7 c
90	6997.0 ab	6753.0 b	6875.0 b
120	7241.7 a	7027.3 ab	7134.5 a
Mean	7028.1 a	6624.7 b	----------

LSD (α=0.05) P = 197.08, PSB = 160.91 and PSB×P = 278.71Mean with different liters in each row and column are significantly (α=0.05) different from each other

Grain yield (Kg ha^{-1})

Our findings regarding the response of grain yield to P, PSB and their interaction present in (Table 5). Upon analysis of various result showed that P, PSB inoculation and their interaction significantly affected grain yield (Kg ha^{-1}) of maize. It was exhibited by the result that PSB inoculation improved maize grain yield over un inoculated treatment. Phosphorus applied at the rate of 120 kg ha^{-1} produced grain yield of 3521.1 kg ha^{-1} which was significantly higher than that of 90 kg ha^{-1} where the lowest was observed for 60 kg ha^{-1}. The interaction effect of PSB and P indicated that P applied at the rate of 120 kg ha^{-1} along with PSB produced highest and P applied at the rate of 60 kg ha^{-1} without PSB produced lowest. P applied at the rate of 60 kg P_2O_5 ha^{-1} with PSB produced statistically similar grain yield to that of 90 and 120 kg ha^{-1} P without PSB. These result demonstrated that PSB inoculation can reduce or may minimize dependence on chemical P fertilizer up to 100% under exist soil and climatic conditions.

Our results are is agreement to **[12]** also studied that PSB inoculation with phosphorus can improve grain yield of plants over 17.24, 12.50 and 15.63% and 4.56, 5.29 and 5.22% at 30, 60 and 90 kg P ha^{-1}. PSB inoculation improves the growth and yield of plants, photosynthesis and microbial activity which in result shows significant interaction of PSB and Phosphorus fertilizers.

Table 5.Grain yield (kg ha^{-1}) of maize as affected by P levels and PSB inoculation

Phosphorus (Kg ha^{-1})	Inoculation		Mean
	With PSB	Without PSB	
60	3140.5 c	2923.7 d	3032.1 c
90	3358.0 b	3027.9 cd	3192.9 b
120	3717.9 a	3324.4 b	3521.1 a
Mean	3405.4 a	3092.0 b	----------

LSD (α=0.05) P = 83.266, PSB = 67.986 and PSB×P = 117.76Mean with different liters in each row and column are significantly (α=0.05) different from each other

Conclusions and recommendations

PSB inoculation, P fertilization and their interaction significantly improved plant height, 1000 grains weight, grain and biological yield. Highest grain and biological yield of maize was observed at 120 kg P_2O_5 ha^{-1} applied with PSB. Furthermore, PSB inoculation may reduce the use of chemical P fertilizer up to 30 kg ha^{-1}. Thus it is advised that, maize seed must be inoculated with PSB along with 90 kg P_2O_5 ha^{-1} for obtaining profitable yield of maize in agro-climatic conditions of Swabi.

Authors' contributions

Conceived and designed the experiments: M Adnan, Performed the experiments: Fazlullah & A Hussain, Analyzed the data: M Noor, S Fahad & S Iqbal, Contributed materials/ analysis/ tools: M Arshad, D Muhammad & F Wahid, M Roman & R

Perveez, Wrote the paper: Fazlullah, M Adnan & A Hussain.

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