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Direct and residual effect of phosphorus and phosphate solubilising bacteria in pearl millet (*Pennisetum glaucum*)-mustard (*Brassica juncea*) cropping system

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ABSTRACT

A field experiment was conducted during 2015-16 and 2016-17 to evaluate the direct effect of phosphorus levels and its solubilizer on pear millet [Pennisetum glaucum (L) R. Br] and residual effect on succeeding mustard [Brassica juncea (L) Czernj & Cosson].The treatments i.e. four levels of P (0, 30, 60 and 90 kg P_2O_5 ha^{-1}) and P solubilizer (control and Psendomonas striata) were evaluated in randomized block design with three replications. The results revealed that the grain and stover yield and P uptake of pearl millet were significantly increased up to 60 kg P_2O_5 ha^{-1}, whereas the available P status of the soil after pearl millet harvest increased up to 90 kg P_2O_5 ha^{-1}. Inoculation of Pseudomonas striata significantly enhanced the pearl millet yield, P uptake by grain and stover as well as the available P in post harvest soil. Residual effect of increasing P levels up to 90 kg P_2O_5 ha^{-1} significantly increased the seed and stover yield, P uptake and the status of available P in soil after mustard harvest. Residual effect of PSB also had a marked positive impact on these aspects of mustard crop as well as available P in soil. Application of 90 kg P_2O_5 ha^{-1} along with PSB was adequate for sustaining crop productivity and maintaining soil available P in pearl millet-mustard cropping sequence.

Keywords: Phosphorus, PSB, direct and residual effect, pearl millet-mustard sequence.

INTRODUCTION

Pearl millet [*Pennisetum glaucum* (L) R. Br.] hardiest warm season cereal crop, ranks fourth in India after, rice, wheat and maize. Being a dual purpose crop, pearl millet is cheap after native source for meeting growing demand of non-food uses (cattle and poultry feed, alcohol and starch industries). Mustard is a major oil seed crop in India next in importance only to groundnut. Pearl millet-mustard crop sequence coupled with faulty nutrient management has resulted in the appearance of multiple nutrient deficiencies like available N, P and K. Among major nutrients, P is required for plant growth, development and productivity. Phosphate fertilizer has a carryover effect on the succeeding crop. The utilization efficiency of applied phosphatic fertilizers seldom exceeds 15% by the first crop, but a substantial amount of it is left as residue for the next crop. Pearl millet-mustard is one of the important crop sequences in Agra region of Uttar Pradesh, which requires higher amounts of nutrients for successful cultivation. Phosphorus is an important nutrient needed for normal growth and development of the plants. Major part of water soluble P of added phosphatic fertilizers soon becomes unavailable due to chemical fixation in soils. Hence, solubilization of fixed soil P through use of solubilizing microorganism is a viable option to augment the availability of P in easily assimilable form by the crops. Phosphate solubilizing bacteria play an important role in enhancing P availability to plants by lowering soil pH and by microbial production of organic acids and mineralization of organic P. Introduction of PSB in rhizosphere of crop also increase the efficiency of phosphatic fertilizers. However, information on the combined use of P solubilizing microorganism along with phosphorus levels in pearl millet and their residual effect on mustard under semi-arid condition of Agra region (Uttar Pradesh) is lacking. Therefore, a field experiment was conducted to study the direct and residual effect of P levels and P solubilizers in pearl millet-mustard cropping sequence.

MATERIALS AND METHODS

A field experiment was conducted during kharif and rabi seasons of 2013-14 and 2014-15 at Panwari village of Agra district, Uttar

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Pradesh. The experimental soil was sandy loam in texture, alkaline in reaction having pH 8.2, EC 0.25 dSm^{-1}, low in organic carbon (3.2 g kg^{-1}), low in available N (164 kg ha^{-1}), available P (9.5 kg ha^{-1}) and available K (108 kg ha^{-1}). The experiment consisted of four levels of P (0, 30, 60 and 90 kg P_2O_5 ha^{-1}) and two levels of bio-fertilizer (no inoculation and *Psudomonas striata* inoculation) was laid out in a randomized block design with three replications. Recommended dose of N and K of 100 kg N and 40 kg K_2O ha^{-1} for pearl millet was applied as urea and muriate of potash, respectively. Phosphorus was applied as single superphosphate as per treatments. Pearl millet seeds (variety Pioneer hybrid 86 M.86) were inoculated with P Seudomonas striata at the rate of 200 g culture $acre^{-1}$ seed. After inoculation seeds were sown at a spacing of 45 cm x 110 cm in first week of July and harvested in first week of October during both the years. After pearl millet harvesting, the seeds of mustard (variety Bio-902) were sown in last week of October and harvested in first week of February during both the years. Recommended dose of 80 kg N and 40 kg K_2O ha^{-1} respectively for mustard were applied at the time of sowing. All the cultural operations were followed as per the package of practices. Plant samples collected from pearl millet (grain and stover) and mustard (seed and stover) at harvest were dried, processed and digested with HNO_3:$HClO_4$(2:1) mixture. Digested digests were used to determine P by vanadomolybdo yellow colour method (Jackson 1973). Nitrogen content in both crops was determined by Kjeldahl method. The oil content in mustard seeds was determined with the help of Nuclear Magnetic Resonance (NMR). The uptake of nutrients was calculated by multiplying yield data and nutrient contents. The collected soil samples after harvest of both crops were analysed for available P by Olsen *et al.* (1954) method.

RESULTS AND DISCUSSION

Direct effect of Phosphorus

Yield: Grain and stover yield of pearl millet increased significantly up to 60 kg P_2O_5 ha^{-1}. Further increase in P from 60 to90 kg P_2O_5 ha^{-1}, though increased the grain and stover yield, failed to record statistical significance. Application of 60 kg P_2O_5 ha^{-1} increased the grain and stover yield by 24.2 and 21.1 per cent, respectively over control (Table 1). Enhanced availability of P and its active involvement in shoot and root growth led to better plant growth, which later translated in to higher yield attributes and resulted yield of pearl millet. These results are in close conformity with the findings of Mahala *et al.* (2006) in maize and Pandey *et al.* (2018) in pearl millet. Sole inoculation of PSB significantly improved the grain and stover yield of pearl millet over no inoculation. The increase was 11.3 and 8.9 per cent higher grain and stover yield of pearl millet over control, respectively. The increase in grain and stover yield of pearl millet with inoculation of PSB may be due to increase in availability through solubilization of insoluble inorganic phosphate by organic acids and production of growth promoting substances (Gaur and Sunita 1999).

Quality: The protein content in pearl millet grain recorded a significant increase over control with application of graded doses of P up to 90 kg P_2O_5 ha^{-1}. Enhanced protein content in grain may be attributed to involvement of phosphorus in nitrogen metabolism. Similar results were reported by Mahala *et al.* (2006) and Pandey *et al.* (2018). Inoculation of PSB slightly increased the protein content in pearl millet grain over no inoculation.

Uptake of nutrients: Nitrogen uptake by pearl millet crop improved significantly with increasing levels of P and maximum values of N uptake by grain (50.0 kg ha^{-1}) and stover (36.6 kg ha^{-1}) were recorded with 90 kg P_2O_5 ha^{-1}. This increase in N uptake by pearl millet crop may be attributed to higher grain and stover production and P content of grain and stover of pearl millet (Gaur and Sunita 1999).Significant improvement in P uptake by grain and stover of pearl millet was observed with each increment of P up to 90 kg P_2O_5 ha^{-1} (Table 1). This might be due to higher availability of phosphorus in the soil, resulting in marked increase in the concentration of P and its uptake by the crop. Similar results were reported by Singh *et al.* (2011). Sole inoculation of PSB significantly increased P uptake by pearl millet grain and stover of pear millet over uninoculation. This increase in P uptake by the crop due to PSB inoculation may be attributed to higher grain and straw yield of pearl millet (Kushwala *et al.* 2014).

Table 1: Direct effect of phosphorus and PSB on yield and uptake of P in pearl millet

Treatment	Yield (q ha^{-1})		N uptake (kg ha^{-1})		Protein (%)	P uptake (kg ha^{-1})		Available P (kg ha^{-1})
	Grain	Stover	Grain	Stover		Grain	Stover	
Phosphorus (kg ha^{-1})								
0	27.01	64.78	42.0	27.0	10.2	4.9	5.8	8.7
30	29.92	70.08	45.2	30.1	10.4	6.7	7.0	10.4
60	31.90	75.60	47.5	33.0	10.6	7.7	9.1	11.2
90	33.57	78.48	50.0	26.6	10.7	8.7	10.2	13.0
CD (P= 0.05)	1.08	2.80	2.28	1.15	0.45	1.21	0.80	1.20
Inoculation								
Control	28.97	69.14	45.2	30.0	10.5	5.8	7.6	10.2
PSB	32.26	75.30	47.0	33.2	10.6	7.8	9.0	11.6
CD (P= 0.05)	0.78	2.00	1.65	0.83	NS	0.86	0.60	0.80

Residual effect

Yield: The seed and stover yields of mustard increased significantly under the residual effect of increasing P levels up to 90 kg P_2O^5 ha^{-1}. The residual effect of 90 kg P_2O_5 ha^{-1} increased the seed and straw yield of mustard by 31.9 and 31.4 per cent over control, respectively. This might be due to increased dry matter with higher levels of P which resulted increased supply of phosphorus to plant for better and metabolic process as well as its resultant positive effect on yield attributes led to enhanced seed yield (Solanki *et al.* 2015). Based on mean data, inoculation of *Pseudomonas striata* in the preceding pearl millet crop also had significant residual effect on mustard yield no inoculation. The inoculation with PSB recorded maximum residual effect on seed and stover yield of mustard (20.27 and 54.02 q ha^{-1}). Beneficial effect of PSB could be attributed to the fact that PSB solubilize the native as well as applied P and also synthesize growth promoting substances like auxin, indole acetic acid which augment the plant growth (Solanki *et al.* 2015).

Quality: Protein content in mustard seed increased significantly with residual P application over control and maximum value (20.5%) was recorded with residual 90 kg P_2O_5 ha^{-1}. Similar results were reported by Solanki *et al.* (2017). Inoculation with PSB resulted in significant increased in protein content in mustard seed over no inoculation. The oil content showed an increase up to 90 kg P_2O_5 ha^{-1} over control. Increase in oil content may be due to synthesis of fatty acids in plants occurring through conversion of acetyl CoA to mainly CoA in presence of ATP and phosphate. Secondly, the higher oil content could be attributed to formation of more lecithin, due to favourable supply of P through external additions. These results corroborate the findings of solanki *et al.* (2017). PSB inoculation also increased the oil content over uninculated control. The results are in accordance with those of Solanki *et al.* (2017).

Table 2: Residual effect of phosphorus and PSB on yield, quality and uptake of P in mustard

Treatment	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		Yield (q ha^{-1})		Protein (%)	Oil (%)	Available P (kg ha^{-1})
	Seed	Stover	Seed	Stover	Seed	Stover			
Phosphorus (kg ha^{-1})									
0	46.5	30.0	8.0	8.2	17.05	45.52	19.8	38.9	7.9
30	50.2	35.6	9.3	10.9	18.96	50.43	20.0	39.1	9.0
60	55.0	39.0	10.8	12.4	21.25	56.53	20.2	39.3	9.9
90	59.5	42.6	12.1	14.3	22.49	59.83	20.5	39.4	11.0
CD (P= 0.05)	2.91	2.05	0.38	1.11	0.75	2.50	0.20	0.19	0.77
Inoculation									
Control	50.5	35.2	9.8	10.9	19.60	52.14	20.1	39.1	8.5
PSB	54.9	38.4	10.3	11.8	20.27	54.02	20.3	39.2	9.9
CD (P= 0.05)	2.10	1.48	0.27	0.80	0.54	1.82	0.14	NS	0.56

Nutrient uptake: Nitrogen uptake by mustard seed and stover increased significantly with increasing levels of P and the highest N uptake was recorded with 90 kg P_2O_5 ha^{-1} i.e. 59.5 and

42.6 kg ha^{-1} and lowest in control i.e. 46.5 and 30.0 kg ha^{-1} (Table 2). This increase in N uptake with P levels might be due to higher seed and stover production. Similar results were reported by Solanki *et al.* (2015). The uptake of N by mustard crop also increased significantly with DSB inoculation. The magnitude of increase in N uptake with inoculation was 8.7 and 9.0% in seed and stover of mustard over no inoculation. The results are in accordance with the findings of Solanki *et al.* (2015). The residual effect of P applied to the preceding pearl millet crop had significant effect on P uptake of mustard crop up tp 90 kg P_2O_5 ha^{-1}. This might be ascribed to higher residual soil available phosphorus after pearl millet crop harvest resulting in significant increased concentration and uptake of P by the mustard crop. PSB inoculation significantly influenced the uptake of P by the mustard crop which may be due to solubilization of native P in soil by PSB.

From the results, it may be concluded that application of 90 kg P_2O_5 ha^{-1} alongwith inoculation of PSB produced highest yield, P uptake by pearl millet grain and stover. Residual effect of P also had significant beneficial effect on seed and stover yield of mustard. Thus, application of 90 kg P_2O_5 ha^{-1}alongwith PSB appears to be the best combination for obtaining higher productivity and maintaining available p in soil in pearl millet-mustard crop sequence under agro climatic conditions of Agra region.

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