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Effect of phosphorus and biofertilizers on soil physico-chemical properties and nutrient uptake by black gram (*Vigna mungo* L. Hepper) under rainfed condition of Nagaland

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Abstract
A field experiment was conducted at Agronomy farm, School of Agricultural Sciences and Rural Development (SASRD), Nagaland University, Medziphema during *kharif* season of 2019, to evaluate the effect of phosphorus and biofertilizers on soil physico-chemical properties and nutrient uptake by black gram (*Vigna mungo* L. Hepper) under rainfed condition of Nagaland. The treatment comprised of four levels of phosphorus (0, 20, 40 and 60 kg ha^{-1}) and different seed inoculation (single and dual) of biofertilizer *Rhizobium* and PSB. Results revealed that combined application of 60 kg P_2O_5 ha^{-1} along with dual inoculation of seeds with both *Rhizobium* and PSB significantly recorded higher uptake of nitrogen in seed (32.97) and stover (41.87) and phosphorus in seed (3.00) and stover (5.23) over the rest of the treatments. The same treatment had a significant effect on soil physico-chemical properties *viz.*, soil organic carbon (%), available nitrogen (kg ha^{-1}), available K_2O (kg ha^{-1}), however, soil pH and available P_2O_5 of the post-harvest soil did not had a significant effect under the same treatment.

Keywords: Black gram, phosphorus, *Rhizobium*, PSB, nutrient uptake, physico-chemical properties of soil

Introduction
Black gram (*Vigna mungo* L. Hepper) is one of the most important pulse grown in India. It is a drought hardy crop and can be grown as a main crop, intercrop, catch, cover or as a green manure crop. Nagaland is also one of the potential areas where pulse production could be increased horizontally by utilizing a part of the area under *jhum* cultivation. Although there are many factors that limit the pulse production in the state, yet there is also a vast scope for cultivation of different pulses. The area under black gram cultivation in Nagaland is 830 hectares with the production of 680 metric tons (Statistical handbook of Nagaland, 2021). Phosphorus is one of the most important plant nutrient required by the pulses as it plays an important role in proper root development, hastens maturity and improves the quality of the crop produced (Venkatarao *et al.*, 2018) [13]. Addition of phosphorus fertilizer also stimulates the activity of symbiotic nitrogen fixing bacteria, which in turns increases the availability of atmospheric nitrogen in the soil and enhances the efficiency of pulse as soil renovator (Choudhary *et al.*, 2017) [3]. Non addition of phosphorus fertilizer in the soil leads to reduction in quality as well as yield of the crop (Patel *et al.* 2016) [8]. Biofertilizers are organic resources with specific strain of microorganism which when applied to plants plays a vital role in providing various nutrients and overall growth of the plants. Among various biofertilizer, *Rhizobium* is of paramount importance as it fixes atmospheric nitrogen in symbiosis with legumes (Nissa *et al.*, 2017) [7]. Phosphate Solubilizing Bacteria (PSB) have the consistent capacity to enhance phosphorus availability to plants by mineralizing organic phosphorus compounds (Patel *et al.*, 2016) [8]. Therefore, based on the above perspectives, the present investigation was carried out to study the effect of phosphorus and biofertilizers on soil physico-chemical properties and nutrient uptake by black gram under rainfed condition of Nagaland.

Materials and Method
The field experiment entitled "Effect of phosphorus and biofertilizers on soil physico-chemical properties and nutrient uptake by black gram (*Vigna mungo* L. Hepper) under rainfed condition of Nagaland." was conducted at Agronomy farm, School of Agricultural Sciences

and Rural Development (SASRD), Nagaland University, Medziphema campus, Nagaland, during *kharif* season of 2019. The soil of the experimental field was well drained and sandy loam in texture, acidic in reaction (pH 4.6), medium in available nitrogen (256.99 kg ha^{-1}), low in available P_2O_5 (18.95 kg ha^{-1}) and medium in available K_2O (212.56 kg ha^{-1}). The experiment was laid out in factorial randomized block design with sixteen treatment combination comprised of four levels of phosphorus and four levels of biofertilizers. The treatment combination includes T_1 (control), T_2 (Control + *Rhizobium*), T_3 (Control + PSB), T_4 (Control + *Rhizobium* + PSB), T_5 (20 kg P_2O_5 ha^{-1}), T_6 (20 kg P_2O_5 ha^{-1} + *Rhizobium*), T_7 (20 kg P_2O_5 ha^{-1} + PSB), T_8 (20 kg P_2O_5 ha^{-1}+ *Rhizobium* + PSB), T_9(40 kg P_2O_5 ha^{-1}), T_{10} (40 kg P_2O_5 ha^{-1} + *Rhizobium*), T_{11} (40 kg P_2O_5 ha^{-1} + PSB), T_{12} (40 kg P_2O_5 ha^{-1}+ *Rhizobium* + PSB), T_{13}(60 kg P_2O_5 ha^{-1}), T_{14} (60 kg P_2O_5 ha^{-1} + *Rhizobium*), T_{15} (60 kg P_2O_5 ha^{-1} + PSB), T_{16} (60 kg P_2O_5 ha^{-1}+ *Rhizobium* + PSB). The black gram variety PU-31 was sown in rows at 30 cm apart at a depth of 3-4 cm using a seed rate of 15 kg ha^{-1} on 17th August, 2019. Uniform basal dose of nitrogen @ 20 kg ha^{-1}, potassium @ 20 kg ha^{-1} and different phosphorus levels *i.e.*, 20, 40, 60 kg ha^{-1} were applied in the soil as per the treatment details. Seed inoculation with *Rhizobium* and Phosphate Solubilizing Bacteria (PSB) culture @ 20 g kg^{-1} seeds were done before sowing as per treatments. The seed and stover samples were collected from each plot at harvest and were analysed for N and P uptakes. Organic carbon (%) in soil was estimated by Walkley and Black rapid titration method (Piper, 1966) [9], available nitrogen in the soil was estimated by alkaline potassium permanganate method (Subbiah and Asija, 1956) [11], available P_2O_5 by Bray's method (Bray and Kurtz, 1945) [2] and available K_2O by flame photometer (Hanway and Heidal, 1952) [4]. The data recorded from the experiment were statistically analysed by using standard techniques.

Result and Discussion

Nutrient uptake

N uptake by seed and stover (kg ha^{-1}): The highest uptake of N by seed and stover was recorded with the application of 60 kg P_2O_5 ha^{-1} as compared to the other levels of phosphorus fertilizer. Dual inoculation of seeds with *Rhizobium* and PSB recorded the highest uptake of nitrogen by seed and stover. In alone inoculation of seeds with biofertilizer, inoculation of seeds with *Rhizobium* recorded the highest uptake of N by seed and stover as compared to alone inoculation with PSB and control. The increase in the uptake of N by seed and stover in dual treatment with *Rhizobium* + PSB and alone *Rhizobium*, might be due to reason that inoculation of seeds with *Rhizobium* increase the availability of atmospheric N in the soil which in turn ultimately increase the uptake of N by seed and stover. Application of 60 kg P_2O_5 ha^{-1} + *Rhizobium* + PSB (T_{16}) recorded the highest N uptake by seed (32.97) and stover (41.87) compared to rest of the treatment (Table 1). The reason in increased uptake of N with this treatment might be due to the fact that the interaction between phosphorus and biofertilizers helps in more availability of nutrients and better root development thereby increasing the absorption of nutrients by plants. This results were supported by the research work done by Kant *et al*. (2017) [5] and Yadav *et al*. (2017) [14].

P uptake by seed and stover (kg ha^{-1}): The highest uptake of P by seed and stover was recorded in application of 60 kg P_2O_5 ha^{-1}. The increase in the uptake of P by seed and stover of black gram might be due to vigorous root development that ultimately results in higher absorption of nutrients. Seeds inoculated with both *Rhizobium* and PSB recorded the highest uptake of phosphorus by seed and stover. In case of alone inoculation of seeds with biofertilizer, seeds inoculated with PSB recorded the highest P uptake by seed and stover as compared to inoculation of seeds with *Rhizobium* alone. Data recorded represents that application of phosphorus along with dual inoculation of seeds with *Rhizobium* and PSB appreciably increased the uptake of nutrients in both seed and stover (Table 1). Application of 60 kg P_2O_5 ha^{-1} + *Rhizobium* + PSB (T_{16}) recorded the highest P uptake by seed (3.00) and stover (5.23) compared to rest of the treatments. This findings were supported with the research results reported by Tanwar *et al.* (2003) [12] and Kant *et al*. (2017) [5].

Table 1: Effect of phosphorus and biofertilizers on nutrient uptake by seed and stover

Treatments	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})	
	Seed	Stover	Seed	Stover
T_1- P_0B_0	19.70	23.96	1.42	2.24
T_2- P_0B_1	23.82	28.05	1.64	2.58
T_3- P_0B_2	21.00	25.92	1.72	2.85
T_4- P_0B_3	24.56	29.80	1.77	3.20
T_5- P_1B_0	21.98	26.27	1.60	2.65
T_6- P_1B_1	26.77	33.00	1.76	3.42
T_7- P_1B_2	24.64	30.88	1.90	3.76
T_8- P_1B_3	28.95	34.70	2.12	4.25
T_9- P_2B_0	23.70	27.18	1.70	3.40
T_{10}- P_2B_1	29.02	36.10	1.92	3.98
T_{11}- P_2B_2	26.40	32.38	2.50	4.52
T_{12}- P_2B_3	32.48	39.90	2.46	4.55
T_{13}- P_3B_0	25.75	31.52	1.84	3.88
T_{14}- P_3B_1	31.36	37.20	2.15	4.02
T_{15}- P_3B_2	29.40	35.36	2.95	5.21
T_{16}- P_3B_3	32.97	41.87	3.00	5.23
S.Em±	0.50	0.76	0.07	0.14
CD (p=0.05)	1.44	2.20	0.19	0.39

Physico-chemical properties of post-harvest soil

Soil Organic carbon (%): Application of 60 kg P_2O_5 ha^{-1} recorded the highest soil organic carbon as compared to the other levels of phosphorus. Inoculation of seeds with both *Rhizobium* and PSB recorded the highest organic carbon (%) in the soil compared to alone inoculation of seeds with either *Rhizobium* or PSB or no inoculation. A significant increase in organic carbon (%) of the soil was observed with application of 60 kg P_2O_5 ha^{-1} + *Rhizobium* + PSB (T_{16}) and remained at par with application of 40 kg P_2O_5 ha^{-1} + *Rhizobium* + PSB (T_{12}) (Table 2). The increase in organic carbon (%) of the soil might be due to interaction effect of phosphorus and biofertilizers on the plants, as the same treatments recorded the highest biomass and thus an increased amount of residues in the form of roots or fallen leaves might have added more organic matter to the soil which in turn increased the organic carbon (%) in the soil. The results are in close conformity with the findings of Kant *et al*. (2017) [5] and Nissa *et al*. (2017) [7].

Soil pH: The soil pH was found non-significant in all the treatments.

Available Nitrogen (kg ha^{-1}): Available N in the soil was recorded highest with application of 60 kg P_2O_5 ha^{-1} as compared to the other levels of phosphorus. Dual inoculation of seeds with both *Rhizobium* and PSB recorded the highest available N in the soil over alone inoculation or no inoculation of seeds. In alone inoculation of seeds with biofertilizer, treatment that consist of inoculation of seeds with *Rhizobium* recorded an appreciably higher yield as compared to inoculation of seeds with PSB or no inoculation, the reason behind is due to the fact that *Rhizobium* helps in better development of effective root nodules, which in turn ultimately increased the fixation of atmospheric nitrogen in the soil and increased of N in the soil increased the yield of the plant. Application of 60 kg P_2O_5 ha^{-1} + *Rhizobium* + PSB (T_{16}) recorded the highest N availability in the soil (343.40 kg ha^{-1}) (Table 2). The reason behind increase in available N in the soil is due to the fact that phosphorus applied in the soil enhances the rhizobia activity of the legume which in turn increases the fixation of atmospheric N. This result were supported by the research work done by Niraj and Prakash (2014) [6] and Kant *et al*. (2017) [5].

Available Phosphorus (kg ha^{-1}): The available P in the soil was significantly influenced with the application of different levels of phosphorus. Application of 60 kg P_2O_5 ha^{-1} recorded the highest available P in the soil as compared to the rest of the other phosphorus levels. Inoculation of seeds with both *Rhizobium* +PSB recorded the highest availability of P in the soil. It was observed that inoculation of seeds with *Rhizobium* alone did not effectively increase the availability of P in soil as compared to treatment that consists of inoculating the seeds with *Rhizobium* + PSB and PSB. This reason is due to the fact that PSB increases the availability of P to the plants by hydrolysing the insoluble P in soil. The interaction of phosphorus and biofertilizers had a non-significant effect on availability of P in the soil. However, the highest availability of P in the soil was recorded with the application of 60 kg P_2O_5 ha^{-1} + *Rhizobium* + PSB (Table 2). Similar results were also reported by Kant *et al*. (2017) [5].

Available Potassium (kg ha^{-1}): Available K in the soil was recorded highest with the application of 60 kg P_2O_5 ha^{-1} over other levels of phosphorus treatment. Inoculation of seeds with biofertilizers had a significant effect on the availability of K in the soil. Treatment of seeds with *Rhizobium* +PSB recorded the highest available K in the soil over alone inoculation of seeds with either *Rhizobium* or PSB or no inoculation. Application of 60 kg P_2O_5 ha^{-1} + *Rhizobium* + PSB (T_{16}) significantly recorded the highest availability of K in the soil (238.82 kg ha^{-1}) over the rest of the treatments (Table 2). The result obtained were confirmed by work done by Balai *et al.* (2016) [1] and Nissa *et al.* (2017) [7].

Table 2: Effect of phosphorus and biofertilizers on Physico-chemical properties of post harvest soil

Treatments	Soil pH	Organic carbon (%)	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
T_1- P_0B_0	4.50	1.19	248.12	19.88	207.05
T_2- P_0B_1	4.60	1.25	285.65	21.26	220.32
T_3- P_0B_2	4.63	1.24	282.42	22.10	221.67
T_4- P_0B_3	4.63	1.27	293.80	22.05	231.00
T_5- P_1B_0	4.70	1.22	264.34	23.17	232.58
T_6- P_1B_1	4.70	1.30	292.57	24.20	236.00
T_7- P_1B_2	4.53	1.30	278.32	25.22	236.05
T_8- P_1B_3	4.67	1.34	309.20	25.28	237.07
T_9- P_2B_0	4.67	1.24	280.38	25.80	231.38
T_{10}- P_2B_1	4.63	1.30	317.72	26.32	236.45
T_{11}- P_2B_2	4.70	1.35	305.50	27.60	234.52
T_{12}- P_2B_3	4.57	1.40	331.02	27.92	237.47
T_{13}- P_3B_0	4.60	1.32	288.25	26.88	232.58
T_{14}- P_3B_1	4.63	1.38	329.80	27.52	237.15
T_{15}- P_3B_2	4.70	1.36	317.52	28.20	236.03
T_{16}- P_3B_3	4.63	1.45	343.40	28.52	238.82
S.Em±	0.06	0.01	2.96	0.39	2.52
CD (p=0.05)	NS	0.04	8.54	NS	7.27

Conclusion

From the above study, it is concluded that the application of 60 kg P_2O_5 ha^{-1} along with dual inoculation of seeds with both *Rhizobium* and PSB in treatment T_{16} significantly increase the nutrient uptake in both seed and stover as well as the physico-chemical properties of the post-harvest soil over the rest of the treatments.

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