Effect of Phosphorus and Bioinoculants on Soil Fertility, Nutrient Contentand Uptake of Black gram (*Vigna mungo* L.)

ABSTRACT

Being a leguminous crop black gram requires a generous amount of phosphorusfor its growth and development as phosphorus is one of the primary macronutrients. Through biological nitrogen fixation, black gram can improve the fertility status of the soil. Bioinoculants promote growth by improving nutrient uptake and making the nutrients more easily available to the host plant's root hairs. To investigate the effect of phosphorus and bioinoculants on soil fertility,nutrient content, and uptake of black gram a field study was conducted at the university farm of Lovely Professional University during the summer season (2023).The experiment was laid out in a randomized block design with nine treatment combinations(T_1-control, T_2- 20 kg $P_2O_5ha^{-1}$, T_3- 40 kg $P_2O_5ha^{-1}$, T_4-20 kg $P_2O_5ha^{-1}$+PSB, T_5-40 kg $P_2O_5ha^{-1}$+PSB, T_6-20 kg $P_2O_5ha^{-1}$+VAM, T_7-40 kg $P_2O_5ha^{-1}$+VAM, T_8-20 kg $P_2O_5ha^{-1}$+PSB+VAM, T_9-40 kg $P_2O_5ha^{-1}$+PSB+VAM), each replicated thrice. Based on analysis, the results demonstrated that the application of 40 kg P2O5 ha^{-1}+PSB+VAM(T_9) had a greater availability of nitrogen (188.63 kg ha^{-1}), and phosphorus (32.68 kg ha^{-1}) over control(176.04 and 19.41 kg ha^{-1}) respectively. The maximum nitrogen(3.88 and 1.64 %) and phosphorus content (0.408 and 0.228 %) in grain and stover were also overserved in the T_9 (40 kgP2O5 ha^{-1}+PSB+VAM) treated plots when compared to control(3.19 and 1.3%,0.309 and 0.141%) respectively. Similarly,the maximumtotal nitrogen and phosphorus uptake(80.04 and 9.71 kg ha^{-1}) was observed in T_9over control(31.09 and 3.19 kg ha^{-1}) respectively.

Keywords:Phosphorus; Phosphate Solubilizing Bacteria(PSB); VAM(Vesicular Arbuscular Mycorrhiza);Soil fertility;Nutrient content and uptake

1.INTRODUCTION

Legumes are crucial for sustainable agriculture due to their capacity to enhance soil fertility and health.With a symbiotic association with some bacteria in soil, legumes can improve nitrogen through biological nitrogen fixation. The extended utilization of input-intensive technologies in the cultivation of rice-wheat and rice-rice cropping patterns has resulted in the depletion of natural resources. The issue of declining productivity needs to be addressed urgently, as it threatens the sustainability of these cropping systems[1].Pulses are important source of amino acids and protein for diets, particularly for vegetarians.About 14% of the total protein in an average Indian diet comes from pulses[2].Black gram[(*Vigna mungo*L.)is a highly nutritious and important grain legume crop in India that is cultivated over a wider range of agro-climatic zones of the country.It occupies about 48.38 lakh hectares area in the country producing 27.28 lakh tons of grain with average productivity of 564 kg ha^{-1}[3].It contains 24 % protein,60 % carbohydrate, and 1.3% fat on a dry weight basis.

Phosphorus is an essential nutrient for all living organisms and no other nutrient can perform its functions. It is a crucial element for plant growth and development and is classified as a primary macronutrient. This means that crops require it in relatively high quantities[4].It is referred to as the “key of life” and the essential functions of Phosphorus are “energy storage” and transfer of energy(ADP and ATP), which act as “energy currency”.Phosphorus also plays a crucial role in the development of the symbiotic relationship between legumes and bacteria.

Bioinoculants contain living microorganisms that colonize the rhizosphere or the interior of the plant and stimulate growth by enhancing nutrient uptake and making the nutrients easily accessible to plant root hairs of the host plant.They play a pivotal role in solubilizing the inorganic phosphates in soil and making them accessible to plants and they are crucial for maintaining crop production, preserving soil health, and promoting biodiversity.Thesolubilization of soil Pis facilitated by Phosphate Solubilizing Bacteria(PSB)that can solubilize inorganic phosphorus from insoluble compounds.It has been demonstrated that PSB inoculation increases P uptake and crop production by altering the plants’P-acquisition strategy, thereby changing the P content in the roots and stems of plants, and the bioavailable P concentration in the soil[5].Mycorrhiza is a symbiotic relationship between a unique class of fungi and plant roots that promotes phosphorous translocation and uptake in plants[6].These fungi have been found to enhance the growth and yield of most field crops by increasing the absorption of phosphorus.Additionally,VAM biofertilizers have been proven effective in improving the availability of major and trace elements for plants. They also prevent pathogens from penetrating plant roots and protectthe plant roots from biotic and abiotic stresses[7].Considering the above facts the present experiment was undertaken to investigate the effects of phosphorus and bioinoculants on black gram.

2.MATERIALS AND METHODS

The experiment was conducted at the University farm of Lovely Professional University, Phagwara, District Kapurthala during the summer season (2023).The farm is situated at 31°25’ Nlatitude and 75°Elongitudewith 225 m average elevation from above mean sea level. Hot and dry summer prevails with an annual precipitation ranging from 577-748 mm.During the crop growing period,the maximum temperature was 36.12°Cand minimum temperature was 20.1°C,rainfall was 52 mm, and relative humidity was 45.5 %.The soil of the experimental field was sandy loam in texture with 51 %coarse sand,33% silt, 16 % clay,pHof7.61,EC(0.47dsm^{-1}),OC(0.57%),available nitrogen(182.9kgha^{-1}),available phosphorus (25.95 kgha^{-1}) and available potassium(191.87 kg ha^{-1}).The experiment was laid out in randomized block design with nine treatment combinations(T_1- control,T_2- 20 kgP_2O_5ha^{-1},T_3- 40 kgP_2O_5ha^{-1},T_4-20 kgP_2O_5ha^{-1}+PSB,T_5-40 kgP_2O_5ha^{-1}+PSB,T_6-20 kgP_2O_5ha^{-1}+VAM,T_7-40 kgP_2O_5ha^{-1}+VAM, T_8-20 kgP_2O_5ha^{-1}+PSB+VAM, T_9-40 kgP_2O_5ha^{-1}+PSB+VAM),each replicated thrice.The black gram variety Mash 1008 was sown@ 20 kg ha^{-1}in a plot size of 5x3 m^2 with a spacing of 30 x10 cm^2 at a depth of 4-6cm.The seeds were inoculated @ 2 mlkg^{-1}seed of liquid PSB culture according to the treatments, using a jaggery solution of 1 liter.The VAMwas applied with field soil @5 kgha^{-1} and incorporated into crop rows at the time of sowing to bulk the carrier as per treatment and thoroughly mixed manually in the plots.Before sowing the treated seeds were kept for shade drying for 30 minutes.A uniform dose of nitrogen@ 12.5 kg ha^{-1}was applied through urea and phosphorus was applied through SSP as per the treatment as a basal dose at the time of sowing to all the plots except the control plot.The soil samples were collected from each experimental plots at a depth of 0-15 cm before sowing and after the harvest of the crop.The soil samples were airdried, followed by grindingto pass through a 2 mm sieve. Furthermore,to determine theavailable N,P_2O_5,and K_2O as per the procedures[Available N -Alkaline permanganate method(Subbiah and Asija, 1956[8],AvailableP_2O_5-Olsen’s method[9],Available K_2O-Flame photometric method(Metson,1956)[10]]the soil samples were tested.The plant and grain samples were oven-dried after threshing.Furthermore, the sampleswere ground to pass through 40-mesh sieves for analysis of their[N-Kjeldahl’s method(Snell and Snell,1949)[11],P-Vanadomolybdo phosphoric acid,yellow color method(Jackson,1973)[12], and(Tri-acid digested material by using Flame photometer(Jackson,1973)][12]content.Thedata of available nitrogen,phosphorus,and potassium in the soil,nutrient content,and their uptake were further statistically analyzed by applying the analysis of variance (ANOVA) method With a significance level of 5%(P =0.05).The nutrient uptake was calculated by using the following formula.

Nutrient uptake(kg ha^{-1})= $\frac{\text{yield (kg ha}-1)\times\text{nutrient content(\%)}}{100}$

3.RESULT AND DISCUSSION

3.1Effect of phosphorus and bioinoculants on availability of Nitrogen, Phosphorus, and potassium in soil

3.1.1 Available Nitrogen (kg ha^{-1})

Further scrutinizing the data, it becomes evident that the T_9(40 kg$P_2O_5$$ha^{-1}$+ PSB+VAM) had greater availability of nitrogen(188.63 kg ha^{-1}) which was 7.15 and 5.35% higher than control(T_1) and T_2(20 kg$P_2O_5$$ha^{-1}$).The outcomes could be the consequences of applying bioinoculants to the soil,whichincreased soil fertility by converting unavailable nitrogen into available forms so that plants can use. These findingscorrespond with the observations reported by[13]and [14].By cycling the nutrient N, PSB helpsin the maintenance and restoration of fertility of the soil, which in turn results in improved soil fertility. The process includes biotic and abiotic elements with PSB that are thought to be among the primary biotic factors influencing the N cycle in the soil [i.e., converting N_2-fixation into plant-available NH_3; nitrification process(converting NH_4^+ into NO_2^-)[15].On the other basis, Phosphorus plays a pivotal role in root growth, proliferation, and nodule formation. The atmospheric nitrogen is fixed within these nodules through biological nitrogen fixation (BNF) which is conciliated by nitrogen-fixing rhizobia. An increased number of nodules may lead to greater nitrogen fixation, ultimately enhancing the fertility of soil.

3.1.2Available Phosphorous (kg ha^{-1})

It was clear from looking at the data that the availability of phosphorus in soil was enhanced by14.06,45.56, and 68.36% by applying 40kg$P_2O_5$$ha^{-1}$+PSB+VAM ($T_9$) over T_3(40 kg$P_2O_5$$ha^{-1}$)$T_2$(20 kg$P_2O_5$$ha^{-1}$),and control($T_1$) respectively.Being statistically at par with each other, the treatmentsT_7(30.69kg ha^{-1}) and T_5(30.66kg ha^{-1}),T_4(24.79kg ha^{-1}), and T_6(24.8kg ha^{-1}) also improved the availability of phosphorus in soil than control.Bioinoculants effectively solubilize phosphorus by extracting acids such as glutamic, lactic, succinic, glyoxalic, oxalic, fumaric, malic, formic, a-ketobutric, and propionic acid.The hydroxyl-acids, in particular, can form chelates which can effectively solubilize phosphates.These bioinoculants not only solubilize phosphates but also have the ability to mineralize organic phosphorus, releasing more P into soil solution that is necessary forplant growth and metabolism.This could be due to the PSB inoculation increasing soilnutrient availability.The results correlate with the findingsreported by[16].The dual inoculation of PSB and VAM substantially improved the availability of phosphorus in soil[17].

3.1.3 Available potassium (kg ha^{-1})

Upon analyzingthe data,the results indicated that of application of potassium and bioinoculants did not have any significant impact (Table 1) on the availability of this nutrient.

Table 1:Effect of phoshorus and bioinoculants on availability of Nitrogen, Phosphorus, and potassium in the soil

Tr.no.	Treatments	Available N (Kg ha^{-1})	Available P_2O_5 (Kg ha^{-1})	Available K_2O (Kg ha^{-1})
T_1	Control	176.04	19.41	173.11
T_2	20 kg $P_2O_5 ha^{-1}$	179.05	22.45	173.75
T_3	40 kg $P_2O_5 ha^{-1}$	185.77	28.65	174.22
T_4	20 kg$P_2O_5 ha^{-1}$+ PSB	182.69	24.79	173.95
T_5	40 kg$P_2O_5 ha^{-1}$+ PSB	187.09	30.66	175.16
T_6	20 kg $P_2O_5 ha^{-1}$+ VAM	182.74	24.80	175.23
T_7	40 kg$P_2O_5 ha^{-1}$+ VAM	186.41	30.69	175.33

T_8	20 kg $P_2O_5ha^{-1}$+ PSB+ VAM	185.70	27.11	174.84
T_9	40 kg$P_2O_5ha^{-1}$+ PSB+ VAM	188.63	32.68	175.40
	SE(m)±	0.93	0.66	1.04
	C.D.(P=0.05)	2.79	1.98	NS

PSB-Phosphorus,Phosphate Solubilizing Bacteria;VAM- Vesicular Arbuscular Mycorrhiza

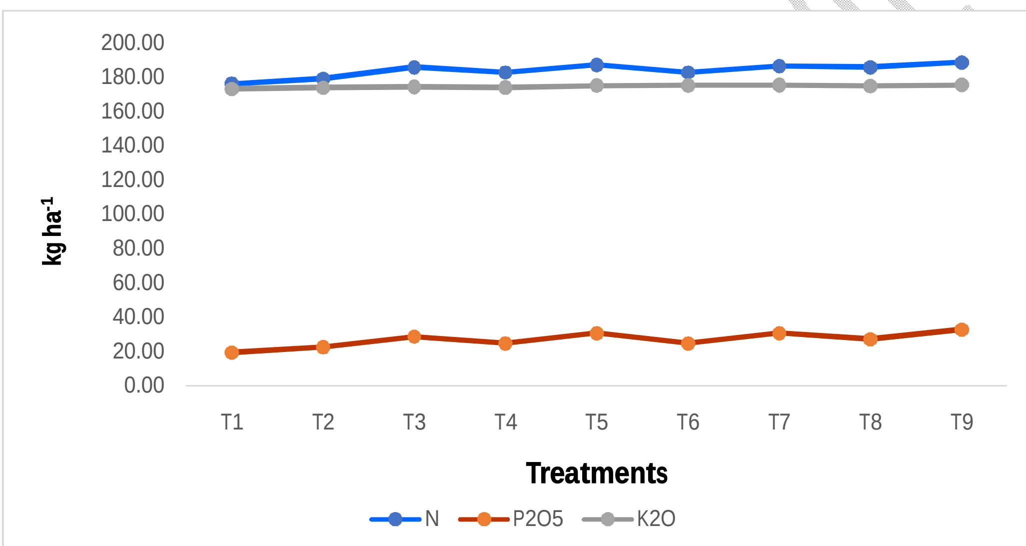

Fig 1: Effect of phosphorus and bioinoculants on availability of Nitrogen, Phosphorus, and potassium in soil

3.2 Effect of phosphorus and bioinoculants on nutrient content and uptake

3.2.1 Nitrogen content and uptake

After a comprehensive analysis,the results demonstrated that the treatment T_9exhibited the highest nitrogen content in grain and stover(3.88 and 1.64%)than control(T_1)(3.19 and 1.3%) and T_2 (3.59 and 1.45%) respectively.A similar pattern was followed in the case of nutrient uptake of the plant.The application of 40 kg$P_2O_5ha^{-1}$+ PSB+ VAM(T_9) showed a substantial increase in nitrogen uptake in grain and stover (41.86 and 38.17 kgha^{-1}) respectively.On the contrary, the control plot attained the lowestuptake of nitrogen (15.96 and 15.14 kg ha-

^{1})respectively.Among the other treatments,T_3 was found at par with T_8,T_4also remained at par with T_6.The conclusions from this experiment correspond with the findings reported by [18].The application of increasing levels of P fertilizer (from 20 to 40 kg ha^{-1}) resulted in higher plant N content in mungbean. The findings corroborate the observations recorded by [19] and [20]. The nitrogen content in grain and stover might have increased due to the synergistic effect between P and N that might have resulted in more nitrogen absorption and uptake by the plant.The improved accessibility of nitrogen in the root zone,in conjunction with enhanced cellular metabolic activity, may have augmented the nutrient uptake and their accumulation in the plant's vegetative parts[13].

3.2.2Phosphorous content and uptake

A perusal of the data described that the utilization ofphosphorus and bioinoculants had a significant effecton the phosphorus levels found in both the grains and stover.The concentration of P in grain and stover showed a significant increase with the successive dose of P. Upon a thorough examination, it becomes evident that the phosphorus content in the grain and stover(0.408 and 0.228%) of black gram was highest under $T_9$when compared to control (0.309 and 0.141%)and T_2(0.354and 0.174%) respectively followed byT_7(0.393and 0.216%)which remained statistically at par with T_5(0.392 and 0.215%) respectively.A similar trend was also observed in the case of the uptake of phosphorus.The T_9showcased the highest uptake of phosphorus in grain and stover (4.4 and 5.3 kg ha^{-1}) than control(1.55 and 1.64 kg ha^{-1}) respectively.The higher content of nutrients also showed a significant and positive correlation with yield.These consequences correlate with the observations reported by [21].Plants that undergo improved metabolism tend to accumulate a higher amount of essential nutrients in their vegetative parts. This, in turn, facilitates more efficient translocation of these nutrients to the reproductive organs of the crop. As a result, the grains and stover of the crop plant show a significant increase in nutrient content at the time of harvest of the crop.The uptake of nutrients is closely linked with the increased nutrient content and higher yield in both the grain and stover.This, in turn, leads to higher nutrient uptake by both grain and stover[18].

3.2.3Potassium content and uptake

The information regarding the effect of the phosphorus and bioinoculants displayed that the treatment combinations had no significant impact on the concentration of potassium in grain and stover.As per the discussion in the earlier paragraph, nutrient uptake is related to nutrient content and grain and stover yield.So, a higher yield may have increased the uptake of potassium.The maximum uptake in grain and stover was observed in T_9(9.11 and 42.58 kg ha^{-1}). Whereas, the control plot exhibited the lowest uptake (4.01 and 20 kg ha^{-1}) respectively.

Table 2:Effects of phosphorus and bioinoculants on nutrient content of black gram

Tr.no	**Treatments**	**Nitrogen content(%)**		**Phosphorus content (%)**		**Potassium content (%)**	
		Grain	Stover	Grain	Stover	Grain	Stover
T_1	Control	3.19	1.3	0.309	0.141	0.801	1.71
T_2	20 kg$P_2O_5ha^{-1}$	3.59	1.45	0.354	0.174	0.809	1.74
T_3	40 kg$P_2O_5ha^{-1}$	3.70	1.57	0.38	0.210	0.831	1.76
T_4	20 kg$P_2O_5ha^{-1}$+ PSB	3.60	1.48	0.366	0.183	0.821	1.72
T_5	40 kg $P_2O_5ha^{-1}$+ PSB	3.80	1.60	0.392	0.215	0.837	1.77
T_6	20 kg$P_2O_5ha^{-1}$+ VAM	3.62	1.50	0.367	0.185	0.842	1.81
T_7	40 kg$P_2O_5ha^{-1}$ +VAM	3.81	1.61	0.393	0.216	0.843	1.82
T_8	20 kg$P_2O_5ha^{-1}$+PSB+ VAM	3.74	1.56	0.379	0.209	0.841	1.84
T_9	40 kg$P_2O_5ha^{-1}$+ PSB+ VAM	3.88	1.64	0.408	0.228	0.844	1.83

	SE(m)±	0.02	0.007	0.002	0.001	0.012	0.032
	C.D.(P=0.05)	0.059	0.021	0.006	0.003	NS	NS

PSB-Phosphorus,Phosphate Solubilizing Bacteria;VAM- Vesicular Arbuscular Mycorrhiza

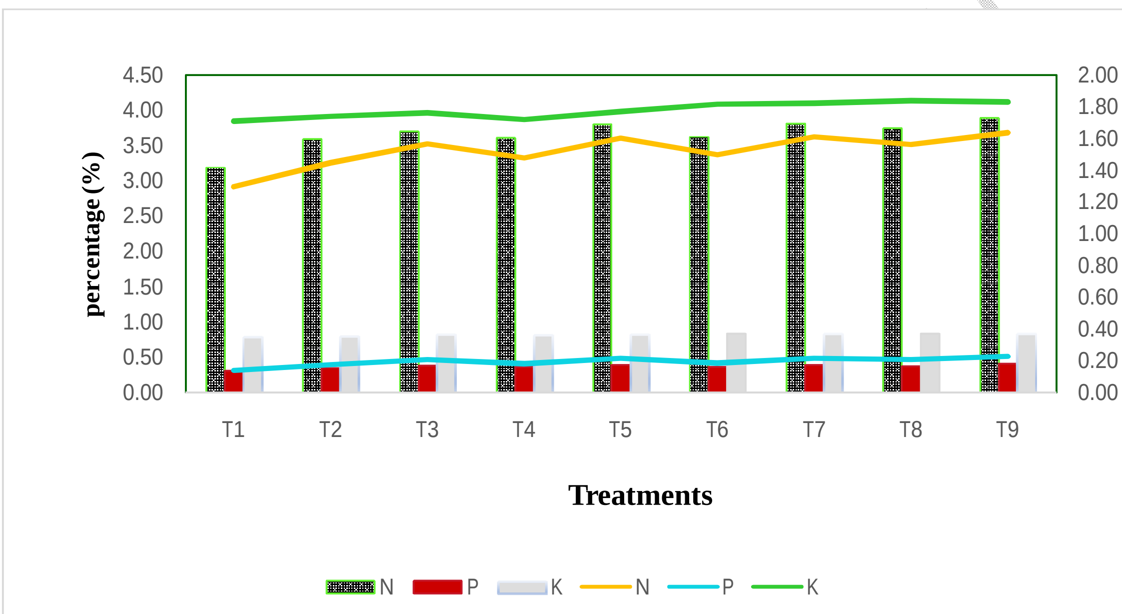

Fig 2:Effects of phosphorus and bioinoculants on nutrient content of black gram

Tr.no.	Treatments	Nitrogen Uptake (kg ha^{-1})			Phosphorus Uptake (kgha^{-1})			Potassium Uptake (kg ha^{1})		
		Grain	Stover	Total	Grain	Stover	Total	Grain	Stover	Total
T_1	Control	15.96	15.14	31.09	1.55	1.64	3.19	4.01	20.00	24.01
T_2	20 kg $P_2O_5ha^{-1}$	21.58	19.97	41.56	2.13	2.40	4.53	4.87	24.01	28.88
T_3	40 kg$P_2O_5ha^{-1}$	31.93	29.25	61.18	3.29	3.93	7.21	7.17	32.87	40.04
T_4	20 kg$P_2O_5ha^{-1}$+ PSB	25.67	23.50	49.17	2.61	2.91	5.52	5.85	27.32	33.17
T_5	40 kg$P_2O_5ha^{-1}$+ PSB	36.54	33.39	69.93	3.77	4.47	8.23	8.04	36.86	44.90
T_6	20 kg $P_2O_5ha^{-1}$+ VAM	26.93	24.20	51.13	2.73	2.99	5.72	6.27	29.34	35.62
T_7	40 kg$P_2O_5ha^{-1}$+ VAM	37.37	34.07	71.44	3.85	4.58	8.44	8.27	38.52	46.78
T_8	20 kg$P_2O_5ha^{-1}$+ PSB+VAM	31.63	28.57	60.20	3.20	3.82	7.03	7.11	33.61	40.72
T_9	40 kg$P_2O_5ha^{-1}$+ PSB+VAM	41.86	38.17	80.04	4.40	5.30	9.71	9.11	42.58	51.69
	SE(m)±	1.12	1.02	1.82	0.121	0.123	0.214	0.324	1.40	1.58
	C.D.(P=0.05)	3.38	3.06	5.46	0.364	0.369	0.641	0.971	4.2	4.74

Table-3:Effect of Phosphorus and bioinoculants on nutrient uptake of black gram

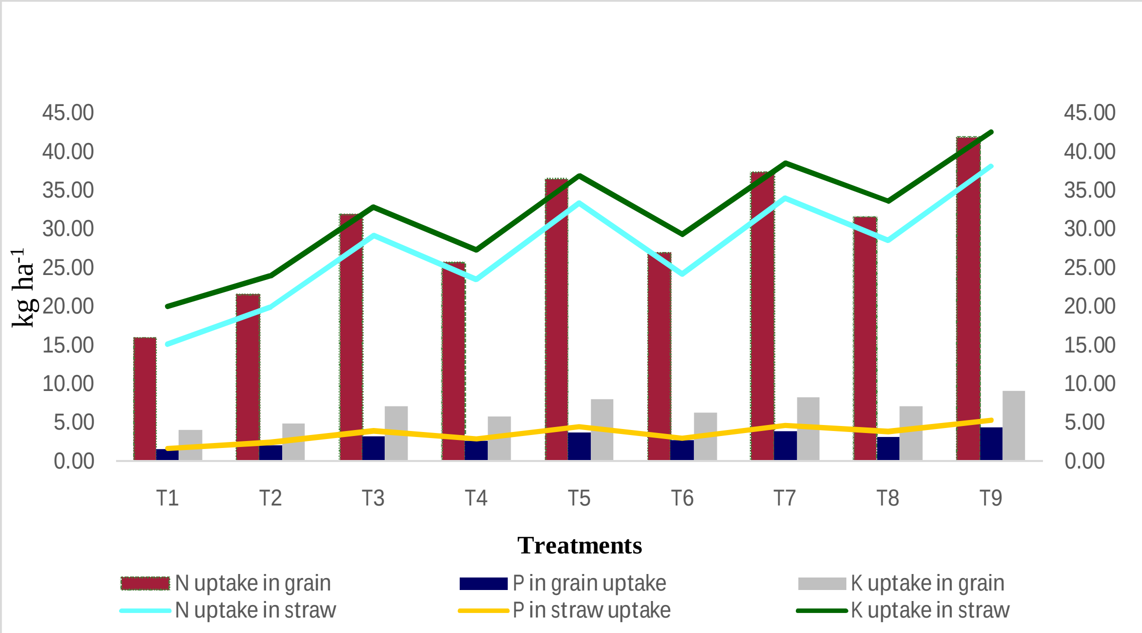

Fig 3: Effects of phosphorus and bioinoculants on nutrient uptake of black gram

CONCLUSION

Based on one one-year experiment,it may be concluded that the application of 40 kgP_2O_5ha^{-1} along with combined inoculation of PSB and VAM was found effective in improving the fertility status of the soil.The enhanced fertility status of the soil may have resulted in greater nutrient content and their uptake by plants.So,cultivation of black gram with 40 kgP_2O_5ha^{-1}+PSB +VAM can be a beneficial approach in maintaining soil health as well asin nutrient absorption andtheir utilizationby the crop.

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