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Research Paper

Effect of varying levels of phosphorus and bio-fertilizers on growth and yield of chickpea under sub-tropical condition

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ABSTRACT

A field experiment was conducted at the Crop Research Centre of School of Agriculture, ITM University, Gwalior, Madhya Pradesh during *rabi* 2021–22 and 2022–23 to study the influence of phosphorus and bio-fertilizers on growth and yield of chickpea under sub-tropical condition of Madhya Pradesh. The experiment was laid out in randomized complete block design (factorial experiment) by taking four levels of phosphorus, viz. 0 kg P_2O_5/ha, 30 kg P_2O_5/ha, 40 kg P_2O_5/ha, 50 kg P_2O_5/ha and bio-fertilizers (No inoculation, PSB *(B. thuringiensis*) @ 20 g/kg of seed, Rhizobium (*Mesorhizobium)* @ 20 g/kg of seed PSB *(B. thuringiensis*) + Rhizobium *(Mesorhizobium)* which were replicated thrice. The chickpea variety "JG-16" was uniformly fertilized by 20 kg N/ha through Urea. However, phosphorus and bio-fertilizers were applied as per the requirement of the treatments. The crop was managed as per the recommended package and practices. The experimental study revealed that among the phosphorus levels, the application of 50 kg P/ha recorded significantly highest plant height, number of nodules, shoot dry matter accumulation, number of primary and secondary branches. Further, it also produced highest seed, stover, biological yield and harvest index. Similar, result showed in N, P, K uptake. However, among the bio-fertilizers, application of Phosphate solubilizing bacteria *(B. thuringiensis*) + Rhizobium *Mesorhizobium* resulted in highest plant height, number of nodules, shoot dry matter accumulation, number of primary and secondary branches, seed and stover yield, biological yield and harvest index of chickpea. Application of 50 kg ha^{-1} phosphorus and combined treatment of Phosphate solubilizing bacteria *(B. thuringiensis*) + Rhizobium (*Mesorhizobium*) resulted in highest gross return, net return and Benefit: cost ratio.

Key words**:** Biofertilizers, Chickpea, Economics, Phosphorus, Yield

India is the largest producer and consumer of pulse crops throughout the world. It is one of the most important legume crops in South and South East Asia. It contributes around 25% of the world's total production of pulses. Even though India accounts for one-third of the world's total area cultivated with pulses, these crops are essential to the Indian food system. Pulses are a significant group of crops in India, and because they make up a substantial percentage of the country's exports. Pulses serve as a main crop, green manure crop, catch crop, cover crop, and intercrop. They are equally essential in Indian agriculture because of their high productivity and low-input requirement. Of the major pulses, chickpea (*Cicer arietinum* L.) also known as the gram pea, garbanzo bean, or ceci bean is the third most significant pulse crop grown worldwide, behind dry beans and peas.

The excessive cultivation and growing of nutrient-exhausting crops have caused the soil deficient in macro- as well as in micronutrients due to nutrient mining (khaleeq *et. al*., Nowadays, the use of only nitrogenous fertilizers has contributed to soil nutrient imbalance, notably in terms of the availability of micronutrients. The nutrient application must be adjusted for agricultural production because unbalanced use lowers crop yields. Nonetheless, a little amount of nitrogenous fertilizer is needed during the early stages of crop establishment because gram is a leguminous crop and can meet a large portion of its nitrogen needs by fixing atmospheric nitrogen. Chickpea has the ability to fix 140 kg of atmospheric nitrogen per hectare with its ability of symbiotic nitrogen fixation.

A key macronutrient that is needed by plants for growth and development is phosphorus. Orthophosphate anion is the form of phosphorus that plants take up from soil solution. It is a major component of ATP, RNA, and DNA and hence plays a crucial role in the transmission of

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genetic information and intracellular energy within living cells. It conducts a wide range of activities associated to growth and development and is required by the majority of young, rapidly growing tissues (Ogola *et al.*, 2012). Phosphorus boosts the symbiotic organic process because it makes bacterium cells mobile, which is necessary for their migration to plant organs for nodulation. Phosphorus aids in healthy root growth, which increases root nodules and then speeds up the organic process. Accordingly, 80% of India's soils require the use of P at recommended amounts (Motsara, 2002), and the application of some P fertilizer would be necessary to stop P mining from the soils in order to maintain high agricultural yields.

Bio-fertilizers, also known as microbial inoculants, are substances used to treat soil and seeds that contain living or dormant cells of beneficial microorganism strains (Mishra *et al*., 2010). These organisms aid crop plants in absorbing nutrients through their interaction in the rhizosphere and have the capacity to biologically change nutritionally important elements from an unavailable to an available form. The biofertilizers that reside in the root zone encourage plant development and nutrient uptake by releasing auxins and gibberellins. They also raise the levels of the powerful plant growth hormones gibberellic acid and indole acetic acid in plants. For plants to use atmospheric nitrogen, it must be altered or fixed. In addition to promoting plant growth and development, biofertilizers lower production costs because they tend to utilize fewer chemical fertilizer doses. They can be utilized for leguminous crops, vegetables, food, and fodder (Ali *et al*., 2006). Three regularly used microorganisms as biofertilizers (PGPR) are rhizobia, plant growth-promoting rhizobacteria, and phosphate-solubilizing bacteria (PSB). Pulses have similar nutritional needs as cereal, however because of their special biological nitrogen fixation ability, just 20 kg/ha of nitrogen is advised. Rhizobium and phosphate solubilizing bacteria (PSB) play a crucial part in N_2 fixation and P solubilizations, which gives them a significant amount of significance. Rhizobium and PSB use have been beneficial in raising chickpea productivity (Rudresh *et al*., 2005). Hence, applying phosphatic fertilizers coupled with PSB enhances the uptake of phosphorus by plants as well as significantly raising crop production (Kachave *et al*., 2018). In order to increase yield and economic return from chickpea, it is essential to apply sufficient fertilizers and the right strain of biofertilizers (*B. thuringiensis*) and Mesorhizobium). Thus, keeping the above fact in view, an experiment was conducted to assess the productivity and profitability of chickpea as influenced by varying levels of phosphorus and bio-fertilizers under sub-tropical conditions of Madhya Pradesh.

MATERIALS AND METHODS

Weather and climate details: The experimental site, in general is bestowed with sub-tropical climate which experiences the mean annual rainfall of 900 mm and is having the hot and dry early summers followed by hot and humid monsoon season and cold winters. Of the total rainfall received in the Gwalior outskirts, only 70–75 per cent of rainfall is received from June to early October, whereas the remaining 25–30 per cent of rain is received throughout the year with a major portion of rains during the winters.

Experimental site: An investigation was conducted in the *Rabi* 2021–22 and 2022–23 at the at the Crop Research Centre of School of Agriculture, ITM University, Gwalior, (M.P.). Geographically, the experimental site is located at an elevation of 206 meters above mean sea level (AMSL) which is having a value of 26^0 14′ N latitude and 78^0 14′ E longitude It falls in the sub-tropical areas on the outskirts of Gwalior, Madhya Pradesh.

Soil type: The soil of the experimental field was sandy loam in texture available sand, silt and clay are 61.8%, 22.5%, 15.7%, Particle density (2.8 g/cm^3), Bulk density (1.58 g/cm^3), Cation Exchange Capacity (16.14 cmol/kg), slightly alkaline in reaction (pH 7.57), low in organic carbon (4.0 g/kg), available nitrogen (183.50 kg/ha) and potassium (243.0 kg/ha) but medium in available phosphorus (14.40 kg/ha) with electrical conductivity in the safer range (0.57 dS/m),

Experimental design and treatment details: The factorial experiment comprised of sixteen treatment combinations, which were laid out in randomized complete block design with three replications. The treatments comprised of 2 factors, i.e. phosphorus levels, viz. 0 kg P_2O_5/ha, 30 kg P_2O_5/ha, 40 kg P_2O_5/ha, 50 kg P_2O_5/ha and biofertilizers, i.e. no inoculation, PSB *(B. thuringiensis*) @ 20 g/kg of seed, Rhizobium (*Mesorhizobium*) @ 20 g/kg of seed, PSB (10g) + *Rhizobium* (10g)

Methodology and crop management: The green gram crop variety, 'JG-16' was sown in lines at a spacing of 30 cm between the rows × 10 cm between the plants. Chickpea crop was fertilized with recommended dose of nitrogen through urea @ 20 kg/ha which was broadcasted in the field a day before the sowing. However, phosphorus application was made as per the requirement of the treatment and application of biofertilizers, i.e. Rhizobium *(Mesorhizobium)* and PSB *(B. thuringiensis*) were applied through seed treatment just before sowing as per the treatment. Further, the crop was managed as per regional recommendations of the crop.(Nawange *el al*.,2011)

Growth attributes: Data pertaining to growth attributes were recorded at harvest stage, five plants from each plot were randomly selected for recording growth attributes like plant height, number of nodules, dry matter accumulation ,The plant samples whose dry weight to be recorded were firstly air dried and thereafter shifted in the oven to dry at a temperature of 70±1°C till a constant weight attained., number of primary and secondary branches excluding the border row plants and tagged with a label.

Yield and yield attributes: Data on yield was obtained at harvest. From the individual plot, net plot was harvested and subsequently, the grain, stover and biological yield thus obtained were weighed and expressed in kg ha^{1}.

Statistical analysis: Statistical analysis of yield and yield attributes was performed to examine the effect of different treatments. The analysis of variance was conducted using OP-Stat developed by CCSHAU, Hisar for all observations recorded during the years. Fisher's test of significance was used to compare the difference between means at 5 % probability level. Standard errors along with critical difference at 5 % of significance were computed for discriminating the treatment effects for chance effects.

RESULTS AND DISCUSSION

Growth Parameters

Data related to plant height presented in Table 1 revealed that plant height was observed to be less in the initial stages then gained momentum and acquired maximum increase between 60-90 DAS and thereafter, a slow rate of decrease in plant height was observed at harvest. The data revealed that maximum plant height, number of primary and secondary branches, number of root nodules, plant population at 20 and at harvest stage and shoot dry weight accumulation was recorded with the application of 50 kg P_2O_5 ha^{-1} which was found to be statistically at par with 40 kg P_2O_5 ha^{-1}. This is due to fact that plant height increased gradually with the optimum phosphorus application which improved the root system through accelerating various metabolic processes such as cell division, cell development and cell enlargement in roots. This result is similar with the findings of Sharma and Jat (2002), Sathyamoorthi *et al*. (2012), Chaudhari *et al*. (2016). The later stage of plant growth, plant height became slow which may be due to the fact that plants started entering from vegetative to the reproductive phase of growth and development and the dry matter accumulation were concentrated in reproductive parts of plant (Kachave *et al*., 2018). The results are further supported by the findings of Balai *et al* (2017) and Singh *et al* (2017b) in chickpea who recorded significant increase in plant height of chickpea with successive levels of phosphorus. Phosphorus increased the photosynthesis and then translocated the synthase to different parts for promoting meristematic development in potential apical buds and intercalary meristems and hence increased growth parameters of the crop. These results corroborated the findings of Khaswa *et al*. (2014).

Among the bio-fertilizers, the maximum plant height,

Table 1. Effect of varying levels of phosphorous and biofertilizers on plant height, number of primary and secondary branches and number of root nodules of chickpea

Treatment	Plant height (cm)	Number of Primary branches	Number of secondary branches	Number of nodules
P_0, 0 kg P_2O_5 /ha	62.68	4.64	15.18	28.77
P_1, 30 kg P_2O_5/ha	65.14	5.29	17.11	31.98
P_2, 40 kg P_2O_5/ha	68.46	5.86	18.89	34.64
P_3, 50 kg P_2O_5/ha	70.72	6.32	21.18	39.15
SEm±	1.16	0.19	0.87	1.58
CD (P=0.05)	3.35	0.56	2.50	4.57
Biofertilizer				
B_0, No inoculation (Control)	61.92	4.49	14.66	28.00
B_1, PSB (BACILLUS SPP.)	67.99	5.84	18.39	34.23
B_2, Mesorhizobium	65.57	5.36	17.46	31.80
B_3, PSB (BACILLUS SPP.) + Mesorhizobium	71.53	6.42	21.85	40.51
SEm±	1.16	0.19	0.87	1.58
CD (P=0.05)	3.35	0.56	2.50	4.57
P×B				
CD (P=0.05)	NS	NS	NS	NS

Table 2. Effect of varying levels of phosphorous and biofertilizers on shoot dry weight accumulation and plant population at 20DAS and at harvest stage of chickpea

Treatment	Plant population at 20 DAS	Plant population at harvest	Shoot dry weight accumulation
P_0, 0 kg P_2O_5 /ha	28.51	27.61	3067.18
P_1, 30 kg P_2O_5/ha	29.13	28.16	3158.09
P_2, 40 kg P_2O_5/ha	29.44	28.79	3363.95
P_3, 50 kg P_2O_5/ha	29.74	29.26	3509.98
SEm±	0.43	0.22	75.80
CD (P=0.05)	NS	0.63	218.92
Biofertilizer			
B_0, No inoculation (Control)	28.40	27.48	2998.25
B_1, PSB (BACILLUS SPP.)	29.31	28.69	3327.00
B_2, Mesorhizobium	29.17	28.21	3210.81
B_3, PSB (BACILLUS SPP.) + Mesorhizobium	29.93	29.45	3563.15
SEm±	0.43	0.22	75.80
CD (P=0.05)	NS	0.63	218.92
P×B			
CD (P=0.05)	NS	NS	NS

Table 3. Effect of varying levels of phosphorous and biofertilizers on yield and harvest index of chickpea

Treatment	Grain yield (kg/ha)	Stover yield (kg/ha)	Biological yield (kg/ha)	Harvest Index (%)
Phosphurs levels				
P_0, 0 kg P_2O_5 /ha	910.46	2360.75	3271.21	27.94
P_1, 30 kg P_2O_5/ha	946.51	2418.50	3365.84	28.12
P_2, 40 kg P_2O_5/ha	1035.37	2535.50	3570.87	28.94
P_3, 50 kg P_2O_5/ha	1108.10	2615.58	3715.35	29.57
SEm±	31.28	58.36	80.67	0.59
CD (P=0.05)	90.33	168.56	232.99	NS
Biofertilizer				
B_0, No inoculation (Control)	888.78	2317.67	3207.28	27.81
B_1, PSB (BACILLUS SPP.)	1033.75	2495.17	3528.91	29.26
B_2, Mesorhizobium	961.64	2462.33	3419.81	28.13
B_3, PSB (*Bacillus spp.*) + Mesorhizobium	1116.28	2655.17	3767.28	29.36
SEm±	31.28	58.36	80.67	0.59
CD (P=0.05)	90.33	168.56	232.99	NS
P×B				
CD (P=0.05)	NS	NS	NS	NS

Number of primary and secondry branches, number of root nodules plant population at 20 and at harvest stage and shoot dry weight accumulate on was recorded with the application of PSB+ *Rhizobium* followed by application of PSB while the lowest plant height was observed with no inoculation. The is due to reason that increase in plant height might be due to favourable actively of micro-organism which provides the required nutrient for growth of chickpea. Similar trend in plant height was observed at 40, 60 DAS and at harvest. The findings are in agreement

Table 4. Effect of varying levels of phosphorous and biofertilizers on relative economics of chickpea

Treatments	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
Application of P_2O_5 @ 0 kg/ha 1 under without seed inoculation	27,108.31	65,312.29	38,203.98	1.41
Application of P_2O_5 @ 0 kg/ha 1 under seed inoculation with PSB (Bacillus spp.)	27,258.31	69,166.45	41,908.14	1.54
Application of P_2O_5 @ 0 kg/ha 1 under seed inoculation with Mesorhizobium	27,258.31	66,056.05	38,797.74	1.42
Application of P_2O_5 @ 0 kg/ha 1 under seed inoculation with PSB (Bacillus spp.)& Mesorhizobium	27,258.31	72,337.89	45,079.58	1.65
Application of P_2O_5 @ 30 kg/ha 1 under without seed inoculation	29,005.92	67,296.20	38,290.28	1.32
Application of P_2O_5 @ 30 kg/ha 1 under seed inoculation with PSB (Bacillus spp.)	29,155.92	71,407.56	42,251.64	1.45
Application of P_2O_5 @ 30 kg/ha 1 under seed inoculation with Mesorhizobium	29,155.92	70,644.05	41,488.13	1.42
Application of P_2O_5 @ 30 kg/ha 1 under seed inoculation with PSB (Bacillus spp.) & Mesorhizobium	29,155.92	72,580.54	43,424.62	1.49
Application of P_2O_5 @ 40 kg/ha 1 under without seed inoculation	29,638.55	66,261.20	36,622.65	1.24
Application of P_2O_5 @ kg/ha 1 under seed inoculation with PSB (Bacillus spp.)	29,788.55	80,160.67	50,372.12	1.69
Application of P_2O_5 @ 40 kg/ha 1 under seed inoculation with Mesorhizobium	29,788.55	74,171.50	44,382.95	1.49
Application of P_2O_5@ 40 kg/ha 1 under seed inoculation with PSB (Bacillus spp.) & Mesorhizobium	29,788.55	87,386.23	57,597.68	1.93
Application of P_2O_5 @ 50 kg/ha 1 under without seed inoculation	30,271.18	66878.20	36607.02	1.21
Application of P_2O_5 @ 50 kg/ha 1 under seed inoculation with PSB (Bacillus spp.)	30,421.18	86426.33	56005.15	1.84
Application of P_2O_5 @ 50 kg/ha 1 under seed inoculation with Mesorhizobium	30,421.18	75486.11	45064.93	1.48
Application of P_2O_5 @50 kg/ha 1 under seed inoculation with PSB (Bacillus spp.) & Mesorhizobium	30,421.18	100003.24	69582.06	2.29

with those of Ghetiya *et al*. (2019), Patel (2012), Patel and Kumawat *et al*. (2015), (Kumar *et al*., 2015 and Saket and Rahi, 2019)

Yield (kg/ha)

The data on seed, stover yield and harvest index of chickpea was influenced by varying levels of phosphorus and bio-fertilizers (Table 1) Among the varying levels of phosphorus, the application of 50 kg P ha^{-1}recorded highest grain yield, stover yield, ultimately the biological yield and harvest index. On the other hand, the minimum grain yield, stover yield and ultimately the biological yield and harvest index was observed with the application of phosphorus was applied @ 0 kg/ha. The maximum seed yield per plant as well as per hectare with optimum phosphorus rates was attributable to better nodulation and efficient functioning of nodule bacteria for fixation of nitrogen to be utilized by plants during seed development stage in the synthesis of protein which in turn led to increase in seed yield. Khan *et al.* (2004) found that the increase in phosphorus levels was significantly increased seed yield of chickpea. This could be attributed to better supply of phosphorus resulting in higher branch and pod and there by higher yield. It is an established fact that phosphorus plays an important role in the formation of new shoots and number of branches/ plant. In addition, it regulates the photosynthetic and carbohydrate metabolism which can be considered to be one the major factors limiting growth particularly during the reproductive phase.

Among the bio-fertilizers, the maximum grain yield, stover yield, biological yield and harvest index was recorded with the application of PSB+ *Rhizobium* followed

Table 5. Effect of varying levels of phosphorus and bio-fertilizers on average nitrogen, phosphorus and potassium uptake by grain and stover of chickpea

Treatment	Nitrogen uptake (kg/ha)		Phosphorus uptake (kg/ha)		Potassium uptake (kg/ha)	
	Grain	Stover	Grain	Stover	Grain	Stover
Phosphorus level						
P_0, 0 kg P_2O_5 /ha	27.59	26.48	4.965	3.93	0.43	27.19
P_1, 30 kg P_2O_5/ha	29.85	28.36	5.525	4.16	0.525	29.115
P_2, 40 kg P_2O_5/ha	33.12	30.12	6.155	4.4	0.535	30.895
P_3, 50 kg P_2O_5/ha	35.31	32.26	6.61	4.62	0.525	32.93
SEm±	1.23	0.81	0.19	0.12	0.01	0.835
CD (P=0.05)	3.54	2.34	4.965	3.93	0.035	2.41
Biofertilizer						
B_0, No inoculation (Control)	26.90	25.97	4.84	3.84	9.04	26.67
B_1, PSB (Bacillus spp.)	32.57	29.62	6.05	4.35	10.92	30.415
B_2, Mesorhizobium	30.17	28.71	5.575	4.2	10.125	29.47
B_3, PSB (Bacillus spp.) + Mesorhizobium	36.23	32.92	6.795	4.71	12.1	33.575
SEm±	1.23	0.81	0.19	0.12	0.27	0.835
CD (P=0.05)	3.54	2.34	0.55	0.335	0.775	2.41
Phosphorus level × Biofertilizers						
CD (P=0.05)	NS	NS	NS	NS	NS	NS

by application of PSB while the lowest grain yield, stover yield , biological yield and harvest index was observed with no inoculation. This is due to Bulk inoculation of beneficial microbes plays important role in improving three major aspects of determination i.e. strong sink development of reproductive structure, formation of vegetative higher photosynthesis and production of assimilates to fill economically to sink (Kumar *et al.*, 2015 and Saket and The data related to nitrogen, phosphorus and potassium uptake by seed and stover uptake (presented in Table 6,7 and 8) by chickpea was significantly influenced by varying levels of phosphorus and bio-fertilizers. Among the varying levels of phosphorus, the maximum values of nitrogen, phosphorus and potassium uptake by seed and stover uptake were recorded with the application of 50 kg P/ha followed by application of 40 kg P/ha This may be due to fact that nitrogen, phosphorus and potassium marked improvement in N uptake by grain ad stover of plants seems to be on account of its greater availability in soil environment and enhanced translocation in plant system. The nutrient N, P, K might have been utilized in greater quantities due to their abundant availability. An improved metabolism to greater translocation of the crop and ultimately increased the content in seed and straw. These results are in close conformity with those of Das *et al.* (2013). These findings are in close proximity with other researchers (Das *et al.,* 2013, Balai *et al.,*2017) who also observed enhancement in Nutrient uptake by grain and straw with incremental levels of phosphorus. Further, among the biofertilizers, nitrogen, phosphorus and potassium uptake by seed and stover was also significantly affected due to application of bio-fertilizers in chickpea as compared to no inoculation. The highest values of nitrogen, phosphorus and potassium by seed and stover uptake were recorded under the application of PSB+ *Rhizobium* and the lowest nitrogen, phosphorus and potassium was recorded no inoculation respectively. The nutrient uptake by crops were enhanced due to seeds inoculation prior to sowing which can be explained to the increased specific activities of isocitric and malic dehydrogenase, the source of electrons for fixation, creating a better nutritional Environment (Deshwal *et al.* (2003). The interaction effect of different level of phosphorus and bio-fertilizers showed statistically non-significant results on the nitrogen, phosphorus and potassium uptake by grain and stover.

Economics

The data on economics as influenced by different levels of phosphorus and bio fertilizers are presented in Table 2 revealed that among the phosphorus levels, the higher cost of cultivation was incurred with the application of 50 kg P_2O_5/ha followed by the application of 40 kg P_2O_5/ha.

Further, the highest gross returns, net returns and benefit: cost ratio were fetched with the application of 50 kg P_2O_5/ha followed by the application of 40 kg P_2O_5/ha.

Among the biofertilizers, the highest cost of cultivation were obtained with the application of PSB+ Rhizobium followed by the application of PSB. Further, the highest gross returns, net returns and benefit: cost ratio was recorded with the application of PSB+ Rhizobium followed by the application of PSB. This was possibly due to proportionately highest net return as compared to the cost involved which contributed to B: C ratio. These results are in close agreement with the findings reported by Rabari *et al.* (2022).

It can be concluded that the among the phosphorus levels, the application of 50 kg P/ha recorded significantly highest plant height, number of nodules, shoot dry matter accumulation, number of primary and secondary branches. Further, it also produced highest seed and stover yield. However, among the bio-fertilizers, application of Phosphate solubilizing bacteria + *Rhizobium* resulted in highest plant height, number of nodules, shoot dry matter accumulation, number of primary and secondary branches, seed and stover yield of chickpea. Therefore, for chickpea cultivation, application of 50 kg/ha phosphorus and treatment of Phosphate solubilizing bacteria+ *Rhizobium* was found to be most promising treatment in enhancing the growth, yield and economics in chickpea.

REFERENCE

Ali, H., Khan, M.A. and Randhawa, S.A. 2004. Interactive effect of seed inoculation and phosphorus application on growth and yield of chickpea (*Cicer arietinum* L.). *International Journal of Agriculture and Biology* **6**(1): 110–112.

Bhattacharjya, S. and Chandra, R. 2013. Effect of inoculation methods of Mesorhizobium ciceri and PGPR in chickpea (*Cicer arietinum* L.) on symbiotic traits, yields, nutrient uptake and soil properties. *Legume Research* **36**: 331–337.

Jat, P.C., Rathore, S.S. and Sharma, R. 2014. Effect of Integrated Nitrogen Management and Intercropping Systems on Yield Attributes and Yield of Maize. *Indian Journal of Hill Farming* 27: 65–73.

Kachave, R.R., Indulkar, B.S., Vaidya, P.H., Ingole, A.J. and Patil, N.M. 2018. Effect of phosphorus and PSB on growth yield and quality of black gram (Vigna mungo L.) in inceptisol. *International Journal of Current Microbiology and Applied Science* **7**: 3,359–3,365.

Kaur, N., Sharma, P. and Sharma, S. 2015. Co-inoculation of Mesorhizobium sp. and plant growth promoting rhizobacteria Pseudomonas sp. as bio-enhancer and bio-fertilizer in chickpea (*Cicer arietinum* L.). *Legume Research* **38**: 367–374.

Khan, M.A., Ali, A. and Tanveer, A. 2004. Effect of seed inoculation and different levels of phosphorus on the yield and yield components of chickpea. *Pakistan Journal of Life and Social Sciences* **1**: 106–108.

Balai, K., Sharma, Y., Jajoria, M., Deewan, P. and Verma, R. 2017. Effect of phosphorus and zinc on growth, yield and economics of chickpea (*Cicer aritinum* L.). *International Journal of Current Microbiology and Applied Science* **6**(3): 1,174–1,181.

Kumar, D., Arvadiya, L.K., Desai, K.L., Usadadiya, V.P. and Patel, A.M. 2015. Growth and yield of chickpea (*Cicer arietinum* L.) as influenced by graded levels of fertilizers and bio-fertilizers. *The Bioscan* **10**(1): 335–338.

Kumawat, N., Yadav, R.K., Singh, M., Dudwe, T.S. and Tomar, I.S. 2020. Effect of phosphorus and bioinoculants and their residual effect on succeeding chickpea (*Cicer arietinum* L.). *Indian Journal of Agricultural Sciences* **90**(2): 320–325.

Jat, M.L., Sharma, S.K., Gupta, R.K., Sirohi, K. and Chandana, P. 2005. Laser land leveling: The precursor technology for resource conservation in irrigated eco-system of India. In: I.P. Abrol, *et al.* (Eds.), Conservation Agriculture-Status and Prospects, CASA, New Delhi, pp. 145–154.

Khaleeq, K., Rathore, S.S., Hemmat, N., Shekhawat, K. Padhan, S.R. Babu, S. and Singh, R.K. 2023. Optimization of phosphorus levels for enhancing groundnut productivity under different land configuration in semi-arid ecologies of Afghanistan. *Journal of Agronomy* **68**(4): 455–458. https://doi.org/10.59797/ija.v68i4.5473.

Malik, D.K. and Sindhu, S.S. 2011. Production of indole acetic acid by Pseudomonas sp.: effect of co-inoculation with *Mesorhizobium* sp. Cicer on nodulation and plant growth of chickpea (*Cicer arietinum* L.). *Physiology and Molecular Biology of Plants* **17**: 25–32.

Mishra, A., Prasad, K. and Geeta, R. 2010. Effect of bio-fertilizer inoculation on growth and yield of dwarf field pea (*Pisum sativum* L.) in conjunction with different doses of chemical fertilizers. *Indian Journal of Agronomy* **9**(4): 163–168.

Motsara, M.R. 2002. Promoting balanced fertilization in India – Policies and economic issues. *Fertilizer News* **47**: 15–21

Nawange, D.D., Yadav, A.S. and Singh, R.V. 2011. Effect of phosphorus and sulphur application on growth, yield attributes and yield of chickpea (*Cicer arietinum* L.). Legume Research **34**(1): 48–50.

Ogola, A.H., Odhiambo, G.D., Okalebo, J.R. and Muyekho, F.N. 2012. Influence of phosphorus on selected desmodium growth and nodulation parameters. ARPN Journal of Agriculture and Biological Science **7**: 294–301.

Patel, H.K., Patel, P.M., Suthar, J.V. and Patel, M.R. 2012. Yield, quality and post-harvest nutrient status of chickpea as influenced by the application of sulphur and phosphorus fertilizer management. *International Journal of Science Research Publication* **4**: 1–3.

Rudresh, D.L., Shivaprakasha, M.K. and Prasad, R.D. 2005. Effect of combined application of Rhizobium, phosphate-solubilizing bacterium, and Trichoderma spp. on growth, nutrient uptake, and yield of chickpea (*Cicer aritenium* L.). *Applied Soil Ecology Journal* **28**: 139–146.

Saket, A.K. and Rahi, S. 2019. Response of black gram (*Phaseolous mungo* L.) to applied sulphur and biofertilizers. *International Journal of Advance Science and Research* **4**: 1–4.

Tiwari, K.S., Mehera, B. and Kumar, N. 2022. Effect of biofertilizers and phosphorus on growth and yield of blackgram (*Vigna mungo* L.). *The Pharma Innovation Journal* **11**(5): 2,269–2,272.