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Effect of different fertility levels and bio-fertilizers on growth, yield and economics of chickpea (*Cicer arietinum* L.) in mid-hills of Himachal Pradesh

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Abstract
The present experiment titled "Effect of different fertility levels and bio-fertilizers on growth, yield and economics of chickpea (*Cicer arietinum* L.) in Mid-hills of Himachal Pradesh" was conducted during *rabi* season of 2023-24 at Kalaghat Agriculture Farm (Located at an elevation of 1,270 meters above mean sea level lying between latitude 30º51'67.26.9 N and longitude 77º09'29.6 E), MS Swaminathan School of Agriculture, Shoolini University, Solan, Himachal Pradesh. The soil of the experimental site was sandy loam in texture, slightly alkaline in reaction in reaction with EC in safer range, medium in organic carbon, available nitrogen, phosphorus and potassium. The field experiment was laid out in split plot design comprising 12 treatments viz. In main plot (F1) Control, (F2) 75% RDF, (F3) 100% RDF and (F4) 125% RDF, in sub plot (B1) *Rhizobium*, (B2) PSB, (B3) *Rhizobium* + PSB with three replications. Result reveled that among the fertility levels significantly higher values of growth characters yield attributes and yield along with higher gross returns, net returns and B:C ratio were recorded under application of (F4) 125% RDF which was statistically at par with (F3) 100% RDF over the rest of the treatments. In case of bio-fertilizers, significantly higher growth characters, yield attributes and yield along with higher gross returns, net returns and B:C ratio were recorded under application of (B_3) *Rhizobium* + PSB under mid hill conditions of Himachal Pradesh.

Keywords: Chickpea, fertility levels, bio-fertilizers, *Rhizobium*, PSB, yield, economics

Introduction
Pulses play a pivotal role and occupy a unique position in Indian agriculture by virtue of their inherent capacity to grow on marginal lands. It is an easily available source of protein in the rural heart of India. India is the largest producer and consumer of pulses in the world. Among the pulses, chickpea is the most important grown in every part of India. In India, chickpea is grown on an area of about 10.91 M ha, with an average productivity of 13.25 M tonnes (Ministry of Agriculture and Farmers Welfare, 2022) [5]. In Himachal Pradesh, chickpeas are produced on an area of about 350 ha producing 0.34 M tonnes with an average productivity of 1285.71 kg ha^{-1} (HPDA, 2022) [2].
Generally, Indian soils are lacking in effective and specific strains of *rhizobium* which are responsible for symbiotic nitrogen fixation. Some important strains are mentioned as plant growth promoting rhizobacteria (PGPR) and that can be used as bio-fertilizers i.e. *Rhizobium*, *Pseudomonas. Azospirillum*, *Azotobacter*, *Bacillus*, *Burkholdaria*, *Erwinia*, *Mycobacterium*, *Flavobacterium*, etc. Singh *et al*. (2018) [12] was told that the bio-fertilizers are cheap and eco-friendly source for nutrient supply that can substitute a part of chemical fertilizers resulting reduce the soil, water and air pollution. Rhizobium and phosphate solubilizing bacteria (PSB) assume a great importance an account of their vital role in N_2 fixation and P solubilizations. Use of Rhizobium and PSB had shown advantage in enhancing chickpea productivity (Rudresh *et al*., 2005) [11]. Some important inoculants are rhizobium, azotobacter, arbuscular mycorrhiza (AM), blue green algae, azolla, phosphate solubilizing bacteria (PSB) inoculants etc. *Rhizobium* inoculant are widely used as bi-fertilizer to enhance chickpea growth and yield as they fix

atmospheric nitrogen symbiotically. In agriculture it can be improved by inoculation of legume crops with suitable *Rhizobium*. Knowledge of the biodiversity of Rhizobia and local populations in important for the design of successful inoculation strategies (Lindstrom *et al.*, 2010) [4]. The formation of an effective symbiosis requires the existence of specific rhizobia in the soil that can nodulated host legume or inoculation of with effective rhizobia, and suitable environmental factors. The major factors affecting the BNF (Panchali, 2011) [7]. Phosphate solubilizing bacteria are also known to increase phosphorus uptake resulting in better growth and higher yield of crop plants. The combined inoculation of *Rhizobium* and phosphate solubilizing bacteria has increased nodulation, growth and yield parameters in chickpea (Rudresh *et al*., 2005) [11].

Materials and Methods

The experiment was conducted during *rabi* season of 2023-24 at Kalaghat Agriculture Farm, MS Swaminathan School of Agriculture, Shoolini University of Biotechnology and Management Sciences, Solan. Geographically, Kalaghat Agriculture Farm is situated 12 Km away from Solan city at an elevation of 1,270 meters above mean sea level lying between latitude 30º51’67.26.9 N and longitude 77º09’29.6 E. It falls under the mid-hill zone of Himachal Pradesh. Generally, December and January months are the coldest while, May and June are the hottest months. The average annual rainfall of this area is 1262 mm and is mostly received during the month of July to September. The field of the experimental site represented ideal spatial unit in respect of texture, make up and fertility status. The soil of the experimental site was sandy loam in texture, slightly alkaline in reaction with EC (0.35 dS m^{-1}) in safer range, medium in organic carbon (0.55%), available nitrogen (383 kg ha^{-1}), phosphorus (77 kg ha^{-1}) and potassium (263 kg ha^{-1}). The field experiment was laid out in split plot design comprising 12 treatments viz. In main plot (F1) Control, (F2) 75% RDF, (F3) 100% RDF, (F4) 125% RDF, in sub plot: (B1) *Rhizobium*, (B2) PSB and (B3) *Rhizobium* + PSB with three replications. Recommended dose of N, P, K (30:60:30 kg ha^{-1}) through urea, SSP and MOP at time of sowing. Him-palam channa-1 variety of chickpea was used for sowing. Other crop management practices were followed as per the recommendation of the area. Observations were taken as per standard procedure. The treatments difference was compared with the critical difference (CD) at 5% level of significance to ascertain their significance.

Results and Discussion

Effect on crop growth characters

Marked variation in crop growth characters were recorded with fertility levels and bio-fertilizers. Among the fertility levels, significantly higher plant height (48.67 cm), number of branches (19.06 $plant^{-1}$) and dry matter accumulation (8.58 g $plant^{-1}$) were recorded with application of (F_4) 125% RDF which was statistically at par with the treatment (F_3) 100% RDF over rest of the treatments..

In case of bio-fertilizers, significantly higher plant height (47.19 cm), number of branches $plant^{-1}$ (18.48) and dry matter accumulation (8.23 g $plant^{-1}$) were recorded under the treatment (B_3) *Rhizobium* + PSB.

The main effect of fertility level indicated that increase in fertilizers by 25% i.e. 125% RDF over recommended level of significantly increased plant height at periodic intervals as well as positively influenced various growth characters (number of branches and dry matter accumulation). Chickpea plant attained maximum height, number of branches and dry matter accumulation at higher level of NPK. This is probably due to adequate moisture supply during critical growth stages. Moisture during critical growth stages to the plant favourably influenced the metabolic activities in terms of higher rate of cell enlargement which directly reflected into better plant growth regarding plant height. Similar positive effect of fertility on growth of chickpea had been reported by Begum and Agarwal (2011) [1]. The beneficial effect of fertility levels at different stages on chickpea was probably due to fact that there may be micronutrients by root exudates of chickpea plant. Additional advantage of synergistic association and extra micronutrients met from chickpea crop might be resulted in overall development of the crop in terms of plant height and dry matter accumulation per plant.

In case of bio-fertilizers, the bio-fertilizer inoculation enhanced the nitrogen, phosphorus and all other major nutrient for enhanced the vegetative growth and thus the plant height, Number of branches $plant^{-1}$ and dry matter accumulation may be increase with the application of bio-fertilizer. Similar results are also reported by Rabieyan *et al.* (2011) [10].

Effect on yield attributes and yield

Result reveled that among the fertility levels significantly higher number of pods (14.21 $plant^{-1}$), number of seeds (2.72 pod^{-1}), grain yield (1339 kg ha^{-1}), stover yield (2237 kg ha^{-1}) and biological yield (3576 kg ha^{-1}) were recorded with application of (F_4) 125% RDF which was statistically at par with (F_3) 100% RDF over the rest of the treatment.

In case of bio-fertilizers, significantly higher number of pods (14.98 $plant^{-1}$), number of seeds (2.51 pod^{-1}), grain yield (1280 kg ha^{-1}), stover yield (2149 kg ha^{-1}) and biological yield (3430 kg ha^{-1}) were observed with application of (B_3) *Rhizobium* + PSB over the rest of the treatments.

The overall development in growth and yield attributes of chickpea in association with fertility level component crops owing to better nutritional and competition free environment led to increase in photosynthetic efficiency and translocation of photosynthesis towards pod might have resulted in higher yield of chickpea. Enhanced yield attributes under fertility practices, which contributed favourable condition for plant growth by increasing the availability of nutrients to plant and enhancing the branching and leaf area for photosynthesis. These findings are on the line with those reported by Nazo and Agarwal (2011) [6]; Pramanik and Bera (2012) [8].

In case of bio-fertilizers, this might be due to the inoculation of *Rhizobium* and PSB enhance the phosphorus availability and this available phosphorus enhances the number of grain yield and straw yield. Treatments inoculated with PGPR also showed higher nitrogen, phosphorus, and potassium content, along with higher nodulation, providing additional evidence for increased yield in bio-fertilizer-inoculated treatments. This could be due to the secretion of growth-promoting substances by microbial inoculants, leading to improved root development, better water transpiration, and enhanced nutrient uptake and deposition, as noted by Pyare and Dwivedi. 2005 [9].

Effect on Economics

Among the fertility levels, significantly higher gross returns (₹ 98669 ha^{-1}), net returns (₹ 65010 ha^{-1}) and benefit: cost ratio (1.93) was recorded with application of (F_4) 125% RDF. In case of bio-fertilizers, higher gross returns (₹ 94339 ha^{-1}), net returns (₹ 64429 ha^{-1}) and benefit: cost ratio (2.14) was recorded with application of (B_3) *Rhizobium* + PSB showed superiority over rest of treatments. The higher benefits are attributed to higher yield and high market price of crops. The higher B:C ratio under these fertility patterns were because of more gross returns obtained and marginal increase/decrease in cost of cultivation invested under these systems. Inclusion of fertility with chickpea is more profitable and stable in comparison to other sequences. These findings are close conformity with the results reported by Thenua *et al.* (2010) [13].

Table 1: Crop growth characters of chickpea as influenced by different fertility levels and bio-fertilizers at harvest

Treatment	Crop growth characters		
Main plots (Fertility levels)	Plant height (cm)	Number of branches plant^{-1}	Dry matter accumulation (g plant^{-1})
F_1: Control	42.18	16.38	4.71
F_2: 75% RDF	44.86	17.52	7.36
F_3: 100% RDF	46.78	17.80	8.08
F_4: 125% RDF	48.67	19.06	8.58
SEm±	0.97	0.40	0.16
CD (P=0.05)	3.35	1.40	0.54
Sub plots (Bio-fertilizers)			
B_1: *Rhizobium*	45.10	17.43	6.94
B_2: PSB	44.58	17.16	6.38
B_3: *Rhizobium* + PSB	47.19	18.48	8.23
SEm±	0.66	0.28	0.11
CD (P=0.05)	1.98	0.83	0.31
Interaction (FxB)	NS	NS	NS

Table 2: Yield attributes of chickpea as influenced by different fertility levels and bio-fertilizers

Treatment	Yield attributes		
Main plots (Fertility levels)	No. of pods plant^{-1}	No. of seeds pod^{-1}	Seed index (g)
F_1: Control	8.67	1.16	19.49
F_2: 75% RDF	11.39	1.94	19.92
F_3: 100% RDF	13.53	2.51	20.29
F_4: 125% RDF	14.21	2.72	22.19
SEm±	0.26	0.07	0.65
CD (P=0.05)	0.90	0.19	NS
Sub plots (Bio-fertilizers)			
B_1: *Rhizobium*	11.37	1.71	20.41
B_2: PSB	8.75	1.68	20.32
B_3: *Rhizobium* + PSB	14.98	2.51	20.68
SEm±	0.17	0.05	0.50
CD (P=0.05)	0.52	0.13	NS
Interaction (FxB)	NS	NS	NS

Table 3: Yield (kg ha^{-1}) and harvest index (%) of chickpea as influenced by different fertility levels and bio-fertilizers

Treatment	Yield (kg ha^{-1})			Harvest index (%)
	Grain yield	Stover yield	Biological yield	
Main plots (Fertility levels)				
F_1: Control	731	1234	1965	37.18
F_2: 75% RDF	1144	1924	3068	37.27
F_3: 100% RDF	1257	2112	3369	37.39
F_4: 125% RDF	1339	2237	3576	37.57
SEm±	24	43	65	0.79
CD (P=0.05)	83	147	227	NS
Sub plots (Bio-fertilizers)				
B_1: *Rhizobium*	1080	1814	2893	37.31
B_2: PSB	993	1667	2661	37.35
B_3: *Rhizobium* + PSB	1280	2149	3430	37.39
SEm±	17	28	44	0.60
CD (P=0.05)	50	84	131	NS
Interaction (FxB)	NS	NS	NS	NS

Table 4: Economics (₹ ha^{-1}) of chickpea as influenced by different fertility levels and bio-fertilizers

Treatment	Economics (₹ ha^{-1})			B:C ratio
	Cost of cultivation	Gross returns	Net returns	
Main plots (Fertility levels)				
F_1: Control	22885	53850	30965	1.35
F_2: 75% RDF	29416	84284	54868	1.76
F_3: 100% RDF	31343	92676	61273	1.95
F_4: 125% RDF	33269	98669	65400	2.01
SEm±	-	1735	1735	0.06
CD (P=0.05)	-	6003	6003	0.22
Sub plots (Bio-fertilizers)				
B_1: *Rhizobium*	29303	79544	50241	1.67
B_2: PSB	28909	73181	44272	1.50
B_3: *Rhizobium* + PSB	29472	94339	64867	2.21
SEm±	-	1221	1221	0.05
CD (P=0.05)	-	3661	3661	0.14
Interaction(FxB)	NS	NS	NS	NS

Conclusion

On the basis of one year experiment it is to be concluded that significant improvement in growth, yield attributes and yield along with gross returns, net returns and B:C ratio were observed with application of 125% RDF with bio-fertilizer application of *Rhizobium* + PSB which was statistically at par with treatment 100% RDF under mid hill conditions of Himachal Pradesh.

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