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Effect of phosphorus and biofertilizers on growth, quality, yield and economics of chickpea (*Cicerarietinum* L.)

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Abstract
A field experiment was carried out during *rabi* season of 2020-21 and 2021-22 in the Instructional-cum-research Farm, IGKV, Raipur, Chhattisgarh, to study the "effect of phosphorus and biofertilizers on growth, quality, yield and economics of chickpea (*Cicer arietinum* L.)". The experiment was laid out in randomized block design with three replications. The experiment comprised of ten treatments *viz*., Control (T_1), 40 kg P_2O_5 ha^{-1} + PSB (T_2), 50 kg P_2O_5ha^{-1} + PSB (T_3), 60 kg P_2O_5ha^{-1} + PSB (T_4), 40 kg P_2O_5ha^{-1} + VAM (T_5), 50 kg P_2O_5ha^{-1} + VAM (T_6), 60 kg P_2O_5ha^{-1} + VAM (T_7), forty kg P_2O_5ha^{-1} + PSB + VAM (T_8), 50 kg P_2O_5ha^{-1} + PSB + VAM (T_9), 60 kg P_2O_5ha^{-1} + PSB + VAM (T_{10}). Results revealed that the growth parameter (Plant height), quality parameter (Protein yield), yield (Seed and stover), economics (Gross returns, net returns and benefit cost ratio) were recorded significantly higher with application of 60 kg P_2O_5 ha^{-1} + PSB + VAM during 2020-21 and 2021-22 and in mean data.

Keywords: Chickpea Phosphorus management, PSB, VAM, Quality, yield and Economics

Introduction
Chickpea (*Cicer arietinum* L.) is an edible legume of the family fabaceae having chromosome no. 2n = 14, rich in protein and one of the earliest cultivated vegetables (Zohary and Maria, 2000) [18]. Chickpea is the most important pulse crop after pigeon pea in the world for human diet and the most important winter season pulse crop. Chickpeas also provide dietary phosphorus (49–53 mg/100 g). In the semi-arid tropics, chickpea seeds contain on an average 23% protein, 64 % total carbohydrates (47% starch, 6% soluble sugar), 5% fats, 6% crude fiber, phosphorus (340 mg/100 g), calcium magnesium (140 mg/100 g), iron (7 mg/100 g) and zinc (3 mg/100 g) (Deppe 2010) [4]. Chickpea ranks first in cultivated area among the pulse in India, grown over an area of 9996.00 million ha. during 2020-21 with production of 1191.10 metric tonnes with the average productivity of 1192 kg ha^{-1} (Anonymous, 2020-21). Madhya Pradesh, Uttar Pradesh, Rajasthan, Maharashtra, Gujarat, Andhra Pradesh and Karnataka are the major chickpea-producing states sharing over 95% cultivated area.
Phosphorus is one of the major essential nutrients elements required for the optimum growth of grain legumes. Phosphorus is the most limiting nutrient for the production of crop (Jiang 2006) [11]. Phosphorus has central role in energy transfer and protein metabolism and also associated with increased root growth and early maturity of crop (Siag, 1995) [16]. The phosphorus solubilizing bacteria (PSB) aids in converting the insoluble phosphate which is chemically fixed into to available form which eventually result in higher crop yields (Gull, *et al*. 2004) [9]. The beneficial effect of co-inoculation of VAM have also been observed in maize, tomato and chickpea (Bajwa, *et al*. 1995) [3]. VAM (*Vascular Arbascular mycorrhizae*) are obligate mutualistic symbionts and are ubiquitouasis the root of vascular plant in nature (Gabor, 1992) [6].

Materials and Methods
Experimental site was located instructional Cum Research Farm, IGKV, Raipur (C.G.), where adequate facilities for irrigation and drainage were available. The soil of experimental field was clay classified as "Vertisol" in texture locally called as "Kanhar." It is deep, and therefore has a high capacity to hold water.

The initial soil pH was neutral 7.1 during 2020-21 respectively. It had low in nitrogen (189.34 kg ha^{-1}) medium in phosphorus (16.20 kg ha^{-1}) and sulphur (16 kg ha^{-1}) and high potassium (320 kg ha^{-1}).

The experiment was laid out in randomized block design with 3 replications. The experiment comprised of ten treatments *viz*., control (T_1), 40 kg P_2O_5 ha^{-1} + PSB (T_2), 50 kg P_2O_5 ha^{-1} + PSB (T_3), 60 kg P_2O_5 ha^{-1} + PSB (T_4), 40 kg Three P_2O_5 ha^{-1} + VAM (T_5), 50 kg P_2O_5 ha^{-1} + VAM (T_6), 60 kg P_2O_5 ha^{-1} + VAM (T_7), 40 kg P_2O_5 ha^{-1} + PSB + VAM (T_8), 50 kg P_2O_5 ha^{-1} + PSB + VAM (T_9), 60 kg P_2O_5 ha^{-1} + PSB + VAM (T_{10}). Chickpea was taken as test crop cultivar "Indira chana -1". Sowing was done manually in line with the previously opened small furrows at 30 cm a part, using seed rate of 80 kg ha^{-1} on 20th November in 2020 and on 26th November in 2021, respectively. The seeds were covered with soil manually irrigated. The chickpea crop was fertilized with common dose of 20 kg N and 20 kg K_2O ha^{-1}, while phosphorus was applied as per the treatment. The nitrogen was applied through urea (46% N) and phosphorus was applied as per treatment keeping different level of 40, 50 and 60 P_2O_5 kg h^{-1} with PSB and VAM.). The observations on various growth parameters, quality parameters, yield and economics were recorded and data were analyzed statistically. (Gomez and Gomez 1984) [8].

Results and Discussion

Growth

Successive increase in plant height was observed with increasing level of phosphorus from 40 to 60 kg P_2O_5 ha^{-1} in combination with PSB and VAM at all stages of observation during both the years and in pooled data.

Higher plant height was recorded with application of 60 kg P_2O_5 ha^{-1} + PSB +VAM at 60 DAS (42.67, 41.17 and 41.92), 90 DAS (61.33, 59.00 and 60.17) and at harvest (59.87, 57.87 and 58.87) during 2020-21, 2021-22 and in mean data, respectively. However, it was at par with application of 60 kg P_2O_5 ha^{-1} + PSB, 60 kg P_2O_5 ha^{-1} ha + VAM and 50 kg P_2O_5 ha^{-1} + PSB + VAM at all the stages of observations during both the years and in mean data. Minimum plant height was recorded under control (No phosphorus) (T_1) at all stages of observations during both of the years and in mean data (Table No. 1). Dixit *et al.* (1983) [6] and Saraf *et al*. (1997) [6] clearly indicated an increase in plant height due to phosphorus application. Jain *et al*. (1999) [10] reported that plant height positively increased with PSB inoculation.

Quality

The protein content was not influenced significantly due to different phosphorous management during both the years and in the mean data. Generally the highest protein content was recorded with application of 60 kg P_2O_5 ha^{-1} + PSB + VAM during both of the years and in mean data.

Higher protein yield of chickpea were recorded with application of 60 kg P_2O_5 ha^{-1} + PSB + VAM during 2020-21 (369.69 kg ha^{-1}), 2021-22 (355.77 kg ha^{-1}) and in mean data (362.73 kg ha^{-1}), respectively, which was at par with the application of 60 kg P_2O_5 ha^{-1} + PSB and 60 kg P_2O_5 ha^{-1} + VAM during both the years and in mean data. Minimum protein yield of chickpea seed were obtained under control (T_1) during both the years and in mean data (Table No. 2). Increase in protein yield might have resulted from markedly increased content of nitrogen due to phosphorus, which might have helped in more protein synthesis, as nitrogen is a constituent of various essential metabolites including proteins and amino acids. These results are in agreement with those reported by Rooge *et al.* (1998) [14], Meena *et al.* (2006), Agrawal *et al.* (2007) [1].

Yield

Higher seed yield obtained with application of 60 kg $P_2O_5ha^{-1}$ + PSB + VAM for the duration of 2020-21 (1850 kg ha^{-1}), 2021-22 (1776 kg ha^{-1}) and in mean data (1813 kg ha^{-1}), respectively, which was remained at par with application of 60 kg $P_2O_5ha^{-1}$ + PSB, 60 kg $P_2O_5ha^{-1}$ + VAM and 50 kg $P_2O_5ha^{-1}$ + PSB + VAM during both the years and in mean data. Minimum seed yield was obtained under control (T_1) during both the years and in mean data. (Table No.3). The application of phosphorus at the rate of 60 kg P_2O_5 ha^{-1} was significantly enhance yield and yield components of chickpea. The higher seed yield was owing to combine effect of PSB and *Rhizobium* might be due to better growth and yield attributes. The favorable effect of bacterial inoculation could be attributed to the increased supply of the nutrients in inoculation plants resulting into more uptake of nutrients, thereby enhances the grain and straw yield. (Meena *et al*. 2006) [13].

Higher straw yield was obtained with application of 60 kg P_2O_5 ha^{-1} + PSB + VAM during 2020-21 (2780 kg ha^{-1}), 2021-22 (2695 kg ha^{-1}) and in mean data (2738 kg ha^{-1}), respectively, which was remained at par with application of 60 kg $P_2O_5ha^{-1}$ + PSB, 60 kg $P_2O_5ha^{-1}$ + VAM and 50 kg $P_2O_5ha^{-1}$ + PSB + VAM during both the years and in mean data. Minimum straw yield became obtained under control (T_1) during both the years and in mean data. (Table No. 3). The increased dose of phosphorus produced significantly higher seed yield over its lower dose. PSB produces growth substances like IAA & GA and also helps for formation of growth hormones which promotes seed maturation. This could be reason for increased grain and straw yield of chickpea (Bhattacharyya and Jain, 2000) [10]. Similar reported that combined application of phosphorus and PSB caused significant increased in grain and straw yield of chickpea.

Economics

Maximum gross returns was obtained with application of 60 kg $P_2O_5ha^{-1}$ + PSB + VAM during 2020-21 (90171 Rs ha^{-1}), 2021-22 (90593 Rs ha^{-1}), and in mean data (90382 Rs ha^{-1}). Minimum gross returns (Rs. ha^{-1}) were recorded under control (T_1) during 2020-21, 2021-22 and in mean data (Table No. 4). The increased in gross income, net income and benefit cost ratio may be due to higher production because more availability of nutrient with combined application of nutrient source. Similar results were also reported by Kushwaha (2008) [12]. similar findings were reported by Yadav *et al*. (2015) [17] and Gangaiah and Ahalawat (2008) [7].

Maximum net returns were obtained with application of 60 kg $P_2O_5ha^{-1}$ + PSB + VAM during 2020-21 (59467 Rs ha^{-1}), 2021-22 (58635 Rs ha^{-1}) and in mean data (59051 Rs ha^{-1}). Minimum net returns (Rs. ha^{-1}) was recorded under control (T_1) during both the years and in mean data (Table No. 4). The increase in gross income, net income and and benefit cost ratio may be due to higher production because more availability of nutrient with combine application of nutrient sources. Similar finding were also reported by Kushwaha (2008) [12]. Similar findings were reported by Yadav *et al*. (2015) [17] and Gangaiah and Ahalawat (2008) [7].

Higher benefit cost ratio was recorded with application of 60 kg P_2O_5 ha^{-1} + PSB + VAM during 2020-21 (2.94), 2021-22 (2.83) and in mean data (2.89). Minimum benefit cost ratio was recorded with no phosphorus application (T_1) during both the years and in mean data (Table No. 4). The increase in gross income, net income and benefit cost ratio may be due to higher production because more availability of nutrient with combine application of nutrient sources. Similar finding were also reported by Kushwaha (2008) [12]. Similar findings were reported by Yadav *et al*. (2015) [17] and Gangaiah and Ahalawat (2008) [7].

Table 1: Effect of phosphorus management on plant height of chickpea

Treatment	Plant height (cm)					
	30 DAS			60 DAS		
	2020-21	2021-22	Mean	2020-21	2021-22	Mean
T_1: Control	21.17	18.86	20.02	34.71	33.90	34.30
T_2: 40 kg $P_2O_5$$ha^{-1}$ + PSB	20.85	19.20	20.03	37.00	35.50	36.25
T_3: 50 kg $P_2O_5$$ha^{-1}$ + PSB	22.78	20.80	21.79	38.33	36.87	37.60
T_4: 60 kg $P_2O_5$$ha^{-1}$ + PSB	20.52	18.53	19.53	41.83	39.97	40.90
T_5:40 kg $P_2O_5$$ha^{-1}$ + VAM	20.55	19.06	19.81	36.67	35.16	35.91
T_6:50 kg $P_2O_5$$ha^{-1}$ + VAM	22.70	20.73	21.71	38.04	36.53	37.29
T_7:60 kg $P_2O_5$$ha^{-1}$ + VAM	20.36	19.39	19.87	40.80	39.27	40.03
T_8: 40 kg $P_2O_5$$ha^{-1}$ + PSB + VAM	20.48	18.49	19.49	37.33	35.80	36.57
T_9: 50 kg $P_2O_5$$ha^{-1}$ + PSB + VAM	21.19	19.16	20.18	39.67	38.10	38.88
T_{10}: 60 kg $P_2O_5$$ha^{-1}$ + PSB + VAM	22.82	21.00	21.91	42.67	41.17	41.92
S.Em±	0.89	0.78	0.82	1.03	1.07	1.04
CD (P=0.05)	NS	NS	NS	3.06	3.18	3.10

Cont. Table 1: Effect of phosphorus management on plant height of chickpea

Treatment	Plant height (cm)					
	90 DAS			At-harvest		
	2020-21	2021-22	Mean	2020-21	2021-22	Mean
T_1: Control	48.00	46.10	47.05	46.40	45.06	45.73
T_2: 40 kg $P_2O_5$$ha^{-1}$ + PSB	52.00	50.07	51.03	50.47	49.03	49.75
T_3: 50 kg $P_2O_5$$ha^{-1}$ + PSB	54.67	52.80	53.73	53.10	51.75	52.43
T_4: 60 kg $P_2O_5$$ha^{-1}$ + PSB	60.00	58.13	59.07	58.47	57.07	57.77
T_5:40 kg $P_2O_5$$ha^{-1}$ + VAM	51.67	49.77	50.72	50.07	48.68	49.38
T_6:50 kg $P_2O_5$$ha^{-1}$ + VAM	53.17	51.27	52.22	52.07	50.57	51.32
T_7:60 kg $P_2O_5$$ha^{-1}$ + VAM	59.00	57.13	58.07	57.60	56.07	56.83
T_8: 40 kg $P_2O_5$$ha^{-1}$ + PSB + VAM	53.00	51.37	52.18	51.70	50.27	50.98
T_9: 50 kg $P_2O_5$$ha^{-1}$ + PSB + VAM	56.67	54.73	55.70	55.33	53.67	54.50
T_{10}: 60 kg $P_2O_5$$ha^{-1}$ + PSB + VAM	61.33	59.00	60.17	59.87	57.87	58.87
S.Em±	1.56	1.59	1.57	1.56	1.58	1.55
CD (P=0.05)	4.63	4.72	4.67	4.64	4.69	4.61

Table 2: Effect of phosphorus management on protein content and protein yield of chickpea

Treatment	Protein content and protein yield					
	Protein content (%)			Protein yield (kg ha^{-1})		
	2020-21	2021-22	Mean	2020-21	2021-22	Mean
T_1: Control	18.77	18.83	18.49	257.16	248.48	252.82
T_2: 40 kg $P_2O_5$$ha^{-1}$ + PSB	19.04	19.10	18.76	283.81	273.47	278.64
T_3: 50 kg $P_2O_5$$ha^{-1}$ + PSB	19.44	19.50	19.38	317.72	307.31	312.51
T_4: 60 kg $P_2O_5$$ha^{-1}$ + PSB	19.94	20.00	19.97	353.05	342.35	347.70
T_5:40 kg $P_2O_5$$ha^{-1}$ + VAM	18.96	19.02	18.66	275.95	265.64	270.80
T_6:50 kg $P_2O_5$$ha^{-1}$ + VAM	19.33	19.40	19.21	307.39	296.94	302.16
T_7:60 kg $P_2O_5$$ha^{-1}$ + VAM	19.77	19.83	19.80	340.73	330.33	335.53
T_8: 40 kg $P_2O_5$$ha^{-1}$ + PSB + VAM	19.17	19.23	19.00	295.09	284.71	289.90
T_9: 50 kg $P_2O_5$$ha^{-1}$ + PSB + VAM	19.54	19.60	19.42	328.36	317.85	323.10
T_{10}: 60 kg $P_2O_5$$ha^{-1}$ + PSB + VAM	20.04	20.10	20.07	369.69	355.77	362.73
S.Em±	0.45	0.49	0.47	13.04	12.59	12.80
CD (P=0.05)	NS	NS	NS	38.73	37.40	38.03

Table 3: Effect of phosphorus management on yields and harvest index of chickpea

Treatment	Seed yield (kg ha^{-1})			Stover yield (kg ha^{-1})		
	2020-21	2021-22	Mean	2020-21	2021-22	Mean
T_1: Control	1370	1319	1345	2370	2273	2322
T_2: 40 kg P_2O_5ha^{-1} + PSB	1490	1431	1461	2500	2386	2443
T_3: 50 kg P_2O_5ha^{-1} + PSB	1635	1577	1606	2633	2519	2576
T_4: 60 kg P_2O_5ha^{-1} + PSB	1770	1711	1741	2720	2606	2663
T_5:40 kg P_2O_5ha^{-1} + VAM	1455	1396	1426	2473	2333	2403
T_6:50 kg P_2O_5ha^{-1} + VAM	1590	1531	1561	2580	2465	2523
T_7:60 kg P_2O_5ha^{-1} + VAM	1724	1666	1695	2697	2582	2640
T_8: 40 kg P_2O_5ha^{-1} + PSB + VAM	1539	1480	1510	2527	2416	2472
T_9: 50 kg P_2O_5ha^{-1} + PSB + VAM	1680	1621	1651	2680	2597	2639
T_{10}: 60 kg P_2O_5ha^{-1} + PSB + VAM	1850	1776	1813	2780	2695	2738
S.Em±	57.25	58.03	57.60	45.62	46.86	45.98
CD (P=0.05)	170	172	171	135	139	136

Table 4: Economics of different phosphorus management of chickpea

Treatment	Cost of cultivation			Gross returns (Rs ha^{-1})			Net returns (Rs ha^{-1})			Benefit-cost ratio		
	2020-21	2021-22	Mean	2020-21	2021-22	Mean	2020-21	2021-22	Mean	2020-21	2021-22	Mean
T_1: Control	26689	27943	27316	66788	67286	67037	40099	39343	39721	2.50	2.41	2.46
T_2: 40 kg P_2O_5ha^{-1} + PSB	28599	29853	29226	72654	72998	72826	44055	43145	43600	2.54	2.45	2.49
T_3: 50 kg P_2O_5ha^{-1} + PSB	29051	30305	29678	79723	80410	80066	50672	50105	50388	2.74	2.65	2.70
T_4: 60 kg P_2O_5ha^{-1} + PSB	29504	30805	30155	86311	87285	86798	56807	56480	56644	2.93	2.83	2.88
T_5:40 kg P_2O_5ha^{-1} + VAM	29699	30953	30326	70850	71213	71032	41151	40260	40706	2.39	2.30	2.34
T_6:50 kg P_2O_5ha^{-1} + VAM	30151	31405	30778	77513	78081	77797	47362	46676	47019	2.57	2.49	2.53
T_7:60 kg P_2O_5ha^{-1} + VAM	30604	31858	31231	84040	84966	84503	53436	53108	53272	2.75	2.67	2.71
T_8: 40 kg P_2O_5ha^{-1} + PSB + VAM	29799	31053	30426	75043	75497	75270	45244	44444	44844	2.52	2.43	2.47
T_9: 50 kg P_2O_5ha^{-1} + PSB + VAM	30251	31505	30878	81900	82671	82286	51649	51166	51408	2.71	2.62	2.67
T_{10}: 60 kg P_2O_5ha^{-1} + PSB + VAM	30704	31958	31331	90171	90593	90382	59467	58635	59051	2.94	2.83	2.89
S.Em±	-	-	-	2791	2959	2873	2791	2851	2766	0.09	0.10	0.09
CD(P=0.05)	-	-	-	8293	8793	8536	8292	8473	8219	0.28	0.28	0.28

Conclusion

The two years present study revealed that the application of 60 kg P_2O_5 ha^{-1} + PSB + VAM recorded heigher plant height, protein yield, seed (1850, 1776 and 1813), stover(2780, 2695 and 2738) yield and net returns (59467, 58635 and 59051), benefit cost ratio (2.94, 2.83 and 2.89) during 2020-21, 2021-22 and in mean data.

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