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Effect of phosphorus and biofertilizers on growth and yield of chickpea (*Cicer arietinum* 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, I.G.K.V, Raipur, Chhattisgarh, to study the "Effect of phosphorus and biofertilizers on growth and yield 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_5 ha^{-1} + PSB (T_3), 60 kg P_2O_5 ha^{-1} + PSB (T_4), 40 kg 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}). Results revealed that the growth parameters (Total number of branches $plant^{-1}$ and dry matter accumulation, yield attributes (Number of pods $plant^{-1}$ and test weight), seed and stover yield 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, yield attributes and yield

Introduction
Chickpea (*Cicer arietinum*) is an edible legume of the family Fabaceae having chromosome no. 2 n = 14, rich in protein and one of the earliest cultivated vegetables (Zohary and Maria, 2000) [22]. Chickpea is the second 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% fat, 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) [6].
Chickpea ranks first in cultivated area among the pulse crops 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) [1]. 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 nutrient elements required for optimum growth of grain legumes. Phosphorus is the most limiting nutrient for the production of crops (Jiang 2006) [13]. Phosphorus has central role in energy transfer and protein metabolism and also associated with increased root growth and early maturity of crops (Siag, 1995) [21]. The phosphorus solubilizing bacteria (PSB) aids in converting the insoluble phosphate which is chemically fixed into available form which eventually results in higher crop yields (Gull, *et al.* 2004) [11]. The beneficial effect of co-inoculation of VAM have also been observed in maize, tomato and chickpea (Bajwa, *et al.* 1995) [2]. VAM (Vascular Arbascular mycorrhizae) are obligate mutualistic symbionts and are ubiquitous is root of vascular plant in nature (Gabor, 1992) [9]. These fungi impart many benefits to plant such as nutrient absorption, stimulation of growth regulating substance, increased rate of photosynthesis, osmotic adjustment under drought stress, enhancement of nitrogen fixation by symbiotic bacteria, increased resistance to soil pathogens and tolerance to environmental stress (Bethlenfalvay & Linderman, 1992) [4].

Materials and Methods
Experimental site was located at Instructional Cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, 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 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_5 ha^{-1} + PSB (T_3), 60 kg P_2O_5 ha^{-1} + PSB (T_4), 40 kg 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 in the previously opened small furrows at 30 cm apart, 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 treatments. The nitrogen was applied through urea (46% N) and phosphorus was applied as per the treatment keeping different levels of 40, 50 and 60 P_2O_5 kg ha^{-1} with PSB and VAM. The observations on various growth parameters, yield attributes and yield were recorded and data were analyzed statistically (Gomez and Gomez 1984) [10].

Results and Discussion

Growth

Total number of branches and dry matter accumulation increased with increasing levels 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 total number of branches $plant^{-1}$ was recorded with application of 60 kg P_2O_5 ha^{-1} + PSB +VAM, at 60 DAS (23.78, 22.50 and 23.14), 90 DAS (29.33, 27.37 and 28.35) and at harvest (30.00, 28.03 and 29.02) 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 observation during both the years of experimentation and in mean data. Minimum total number of branches $plant^{-1}$ was recorded with under control (T_1) at all growth stages of observation during both the years and in mean data (Table No. 1). The application of NPK fertilizers and biofertilizers (PSB & VAM) in soil might be help in vigorous vegetative growth of plants and subsequently increase the number of branches through cell elongation, cell expansion, cell division, photosynthesis and turbidity of plant cell. Jain *et al.* (1999) [12] and Mukherjee and Rai (2000) [16]. Similar findings were also reported by Basir Abdul, Khan Zada and Shah Z. (2005) [3].

Higher dry matter accumulation $plant^{-1}$ was recorded with application of 60 kg P_2O_5 ha^{-1} + PSB +VAM, at 60 DAS (11.70, 10.13 and10.92), 90 DAS (24.60, 22.23 and 23.42) and at harvest (31.57, 29.52 and 30.54) 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 observation during both the years and in mean data. Minimum dry matter accumulation $plant^{-1}$ was recorded under control (T_1) at all stages of observation during both the investigation and in mean data (Table No. 2). Increased dry matter accumulation per plant may be attributed to the significant increased in morphological parameters which were responsible for the photosynthetic capacity of the plant. There by increased biomass production of chickpea. The increase in dry matter production due to application of phosphorus also reported by Karwasra and Dahiya (1977) [14], Sarawgi *el al.* (1999) [18], Shivakumar *el a1.* (2004) [20].

Yield attributes

Application of 60 kg P_2O_5 ha^{-1} + PSB + VAM was recorded significantly higher number of pod per plant during 2020-21 (70.44), 2021-22 (67.28) and in mean data (68.86), respectively, and remained 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 during both the years and in mean data. Minimum number of pod $plant^{-1}$ was recorded with no phosphorus application (T_1) during both the years and in mean data (Table No. 3). The possible reason might be the improvement in number of pods $plant^{-1}$ due to sufficient phosphorus supply. Similar results were also reported by Dixit *et al.* (1993) [8].

Application of 60 kg P_2O_5 ha^{-1} +PSB + VAM was recorded significantly higher 100 seed weight (g) during 2020-21 (23.98 gm), 2021-22 (23.60) and in mean data (23.79), respectively. However, it was at par with application of 60 kg P_2O_5 ha^{-1} + PSB, 60 kg P_2O_5 ha^{-1} + VAM and 50 kg P_2O_5 ha^{-1} + PSB +VAM during both the years and in mean data. Minimum 100 seed weight (g) was recorded under control (T_1) during both the years and in mean data (Table No. 3). The application of 40 kg P_2O_5 ha^{-1} in mothbean significantly increased number of pods per plant, seeds per pod, seed and straw yield. However, test weight increased up to 20 kg P_2O_5 ha^{-1} only. This might be due to rendering the insoluble phosphorus into available form reported by Puniya (2011) [17].

Yield

Higher seed yield was obtained with application of 60 kg P_2O_5 ha^{-1} + PSB + VAM during 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_5 ha^{-1} + PSB, 60 kg P_2O_5 ha^{-1} + VAM and 50 kg P_2O_5 ha^{-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. 4). The application of phosphorus at the rate of 60 kg P_2O_5 ha^{-1} was significantly enhanced yield and yield components of chickpea. The higher seed yield owing to combined 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 enhanced the grain and straw yield. (Meena *et al.* 2006) [15].

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_5 ha^{-1} + PSB, 60 kg P_2O_5 ha^{-1} + VAM and 50 kg P_2O_5 ha^{-1} + PSB + VAM during both the years and in mean data. Minimum straw yield was obtained under control (T_1) during both the years and in mean data (Table No. 4). 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) [5]. Similar reported that combined application of phosphorus and PSB caused significant increased in the grain and straw yield of chickpea (Dinesh and Kumar *et al.* 2014) [7].

Table 1: Effect of phosphorus management on total number of branches of chickpea

Treatment	Total number of branches plant^{-1}					
	30 DAS			60 DAS		
	2020-21	2021-22	Mean	2020-21	2021-22	Mean
T_1: Control	6.40	7.47	6.93	15.11	14.07	14.59
T_2: 40 kg P_2O_5 ha^{-1} + PSB	6.60	7.63	7.12	19.80	18.60	19.20
T_3: 50 kg P_2O_5 ha^{-1} + PSB	6.93	7.83	7.38	20.47	19.33	19.90
T_4: 60 kg P_2O_5 ha^{-1} + PSB	7.13	8.00	7.57	23.50	22.28	22.89
T_5: 40 kg P_2O_5 ha^{-1} + VAM	6.93	7.60	7.27	18.30	17.23	17.77
T_6: 50 kg P_2O_5 ha^{-1} + VAM	7.00	7.50	7.25	20.10	19.57	19.83
T_7: 60 kg P_2O_5 ha^{-1} + VAM	6.83	8.00	7.42	23.00	21.90	22.45
T_8: 40 kg P_2O_5 ha^{-1} + PSB + VAM	6.97	7.67	7.32	19.91	18.79	19.35
T_9: 50 kg P_2O_5 ha^{-1} + PSB + VAM	7.03	7.70	7.37	21.82	20.34	21.08
T_{10}: 60 kg P_2O_5 ha^{-1} + PSB + VAM	7.70	8.20	7.95	23.78	22.50	23.14
SEm±	0.42	0.44	0.41	0.83	0.78	0.79
CD (P=0.05)	NS	NS	NS	2.46	2.32	2.34

Treatment	Total number of branches plant^{-1}					
	90 DAS			At-harvest		
	2020-21	2021-22	Mean	2020-21	2021-22	Mean
T_1: Control	20.44	18.61	19.53	21.11	19.28	20.19
T_2: 40 kg P_2O_5 ha^{-1} + PSB	24.80	22.63	23.72	25.47	23.30	24.38
T_3: 50 kg P_2O_5 ha^{-1} + PSB	25.47	23.90	24.68	26.13	24.57	25.35
T_4: 60 kg P_2O_5 ha^{-1} + PSB	29.00	27.03	28.02	29.67	27.70	28.68
T_5: 40 kg P_2O_5 ha^{-1} + VAM	23.27	21.30	22.28	23.93	21.97	22.95
T_6: 50 kg P_2O_5 ha^{-1} + VAM	25.65	23.62	24.63	26.31	24.28	25.30
T_7: 60 kg P_2O_5 ha^{-1} + VAM	29.00	26.83	27.92	29.67	27.50	28.58
T_8: 40 kg P_2O_5 ha^{-1} + PSB + VAM	24.91	22.83	23.87	25.58	23.50	24.54
T_9: 50 kg P_2O_5 ha^{-1} + PSB + VAM	26.22	25.00	25.94	27.55	25.67	26.61
T_{10}: 60 kg P_2O_5 ha^{-1} + PSB + VAM	29.33	27.37	28.35	30.00	28.03	29.02
SEm±	0.79	0.78	0.81	0.86	0.78	0.81
CD (P=0.05)	2.35	2.31	2.41	2.55	2.31	2.41

Table 2: Effect of phosphorus management on dry matter accumulation of chickpea

Treatment	Dry matter accumulation (g plant^{-1})					
	30 DAS			60 DAS		
	2020-21	2021-22	Mean	2020-21	2021-22	Mean
T_1: Control	0.57	0.60	0.58	6.50	5.03	5.77
T_2: 40 kg P_2O_5 ha^{-1} + PSB	0.59	0.62	0.60	9.13	7.67	8.40
T_3: 50 kg P_2O_5 ha^{-1} + PSB	0.59	0.64	0.62	10.23	8.77	9.50
T_4: 60 kg P_2O_5 ha^{-1} + PSB	0.60	0.64	0.62	11.50	10.07	10.78
T_5: 40 kg P_2O_5 ha^{-1} + VAM	0.59	0.62	0.60	8.83	7.37	8.10
T_6: 50 kg P_2O_5 ha^{-1} + VAM	0.60	0.63	0.62	10.00	8.53	9.27
T_7: 60 kg P_2O_5 ha^{-1} + VAM	0.59	0.63	0.61	11.30	9.80	10.55
T_8: 40 kg P_2O_5 ha^{-1} + PSB + VAM	0.59	0.62	0.61	9.43	7.97	8.70
T_9: 50 kg P_2O_5 ha^{-1} + PSB + VAM	0.61	0.65	0.63	10.63	9.10	9.87
T_{10}: 60 kg P_2O_5 ha^{-1} + PSB + VAM	0.62	0.66	0.64	11.70	10.13	10.92
SEm±	0.01	0.01	0.01	0.49	0.41	0.38
CD (P=0.05)	NS	NS	NS	1.46	1.22	1.14

Treatment	Dry matter accumulation (g plant^{-1})					
	90 DAS			At-harvest		
	2020-21	2021-22	Mean	2020-21	2021-22	Mean
T_1: Control	17.83	16.17	17.00	24.44	22.51	23.48
T_2: 40 kg P_2O_5 ha^{-1} + PSB	20.87	19.35	20.11	27.10	25.17	26.13
T_3: 50 kg P_2O_5 ha^{-1} + PSB	21.60	20.12	20.86	28.46	26.53	27.50
T_4: 60 kg P_2O_5 ha^{-1} + PSB	24.38	22.03	23.21	31.10	29.07	30.08
T_5: 40 kg P_2O_5 ha^{-1} + VAM	20.57	19.07	19.82	26.93	24.87	25.90
T_6: 50 kg P_2O_5 ha^{-1} + VAM	21.23	19.73	20.48	27.73	25.80	26.77
T_7: 60 kg P_2O_5 ha^{-1} + VAM	24.10	21.93	23.02	30.67	28.60	29.63
T_8: 40 kg P_2O_5 ha^{-1} + PSB + VAM	21.08	19.53	20.31	27.63	25.50	26.57
T_9: 50 kg P_2O_5 ha^{-1} + PSB + VAM	22.97	21.47	22.22	29.07	27.13	28.10
T_{10}: 60 kg P_2O_5 ha^{-1} + PSB + VAM	24.60	22.23	23.42	31.57	29.52	30.54
SEm±	0.84	0.63	0.70	1.02	0.97	1.00
CD (P=0.05)	2.49	1.86	2.09	3.05	2.89	2.96

Table 3: Effect of phosphorus management on yield attributes of chickpea

Treatment	No. of pod plant^{-1}			100 -Seed weight (g)		
	2020-21	2021-22	Mean	2020-21	2021-22	Mean
T_1: Control	48.00	44.87	46.43	20.33	20.00	20.17
T_2: 40 kg P_2O_5 ha^{-1} + PSB	63.00	59.79	61.39	21.30	21.17	21.23
T_3: 50 kg P_2O_5 ha^{-1} + PSB	66.61	63.44	65.03	22.20	22.07	22.13
T_4: 60 kg P_2O_5 ha^{-1} + PSB	69.55	66.27	67.91	23.20	23.07	23.13
T_5: 40 kg P_2O_5 ha^{-1} + VAM	62.55	58.70	60.63	21.17	21.10	21.13
T_6: 50 kg P_2O_5 ha^{-1} + VAM	64.77	62.05	63.41	22.07	22.00	22.03
T_7: 60 kg P_2O_5 ha^{-1} + VAM	69.03	65.87	67.45	22.82	22.57	22.69
T_8: 40 kg P_2O_5 ha^{-1} + PSB + VAM	63.89	60.72	62.30	21.90	21.77	21.83
T_9: 50 kg P_2O_5 ha^{-1} + PSB + VAM	68.20	64.45	66.33	22.53	22.40	22.47
T_{10}: 60 kg P_2O_5 ha^{-1} + PSB + VAM	70.44	67.28	68.86	23.98	23.60	23.79
SEm±	1.24	1.13	1.18	0.50	0.46	0.45
CD (P=0.05)	3.68	3.36	3.51	1.48	1.37	1.34

Table 4: 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_5 ha^{-1} + PSB	1490	1431	1461	2500	2386	2443
T_3: 50 kg P_2O_5 ha^{-1} + PSB	1635	1577	1606	2633	2519	2576
T_4: 60 kg P_2O_5 ha^{-1} + PSB	1770	1711	1741	2720	2606	2663
T_5: 40 kg P_2O_5 ha^{-1} + VAM	1455	1396	1426	2473	2333	2403
T_6: 50 kg P_2O_5 ha^{-1} + VAM	1590	1531	1561	2580	2465	2523
T_7: 60 kg P_2O_5 ha^{-1} + VAM	1724	1666	1695	2697	2582	2640
T_8: 40 kg P_2O_5 ha^{-1} + PSB + VAM	1539	1480	1510	2527	2416	2472
T_9: 50 kg P_2O_5 ha^{-1} + PSB + VAM	1680	1621	1651	2680	2597	2639
T_{10}: 60 kg P_2O_5 ha^{-1} + PSB + VAM	1850	1776	1813	2780	2695	2738
SEm±	57.25	58.03	57.60	45.62	46.86	45.98
CD (P=0.05)	170	172	171	135	139	136

Conclusion

The two years present study revealed that the application of 60 kg P_2O_5 ha^{-1} + PSB + VAM recorded higher total number of branches plant^{-1}, dry matter accumulation, number of pods plant^{-1}, 100 seed weight, seed (1850, 1776 and 1813) and stover (2780, 2695 and 2738) yield during 2020-21, 2021-22 and in mean data.

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