



Effect of phosphorus and bioinoculants and their residual effect on succeeding chickpea (*Cicer arietinum*)

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ABSTRACT

A field experiments were conducted during *kharif* and *rabi* 2016–17 and 2017–18 at ZARS, Jhabua to study the effect of phosphorus and bioinoculants on growth attributes, yields, nutrient uptake and economics in maize - chickpea cropping system. Among the treatments, significantly higher growth and yield parameters of maize were recorded with the application of 60 kg P₂O₅/ha + NPK consortia as compared to other treatments. The highest grain yield (54.62 q/ha), stover yield (52.63 q/ha), biological yield (106.58 q/ha) were obtained under 60 kg P₂O₅/ha + NPK consortia which was at par to each other and significantly superior to control, PSB I, PSB II and NPK consortia. This treatment also observed the highest total N, P and K uptake by grain and stover. The residual study of phosphorus and bioinoculants on succeeding chickpea was found to have significant effect on growth and yield attributes. Among the various treatments, maximum seed yield (24.04 q/ha), and biological yield (60.69 q/ha) were observed under 60 kg P₂O₅/ha + NPK consortia. Similarly, the highest total uptake of N, P and K were recorded with the application of 60 kg P₂O₅/ha + NPK consortia. Treatment receiving 60 kg P₂O₅/ha + NPK consortia realized the maximum gross return ($\times 10^3$ 204.34 ₹/ha), net return ($\times 10^3$ 157.08 ₹/ha) and B:C ratio (3.32) as compared to other treatments.

Key words: Bioinoculants, Chickpea, Economics, Nutrient uptake, Phosphorus, Yields, Yield attributes

Maize (*Zea mays* L.) is one of the important cereal crops and is a very versatile grain that benefits mankind in many ways. It had 3rd position in production after wheat and rice in the world (Singh *et al.* 2018 and Yadav *et al.* 2018). Chickpea (*Cicer arietinum* L.) is one of the predominant *rabi* crops in pulse growing areas. Being a legume it responds well to phosphorus added through organic manure and chemical fertilizer. In India, the price of commonly used phosphatic fertilizer has increased considerably since the early seventies (Singh and Sharma 2011). The low productivity of maize and chickpea may be due to various reasons, viz. weeds, drought, environmental factors, improper nutrients management and biotic and abiotic factors etc. Among these, nutrient management plays a significant role in influencing the yields being an exhaustive crop requires a huge quantity of nutrients during growing periods (Kumar *et al.* 2015a).

Bioinoculants provide nutrients such as N, P and K through their activities in the soils or rhizosphere and

makes them readily available to the plants. Now-a-days bioinoculants are becoming more important because improving of soil fertility and health and also reduce pollutions in the environment by cutting down the use of chemical fertilizers (Roy chowdhury *et al.* 2017). Seed inoculations with *Rhizobium*, phosphorus solubilizing bacteria (PSB) and organic amendments increased yield of cereal crops (Siyal 2017). Liquid bioinoculants (LBs) are the most promising and latest technology which has many advantages over the chemical fertilizers. Shelf-life is the first and foremost problem of the carrier based biofertilizers which is up to 3 months and it does not retain throughout the crop cycle, LB on the other hand facilitates the long survival of the organism by providing the suitable medium which is sufficient for the entire crop cycle (Pindi and Satyanarayana 2012). Therefore, LBs are believed to be the best alternative for the conventional carrier based biofertilizers in the modern agriculture research community. Considering the above facts, the present study was undertaken to assess the effect of phosphorus and bioinoculants on yields, nutrient uptake and profitability under rainfed conditions of Jhabua hills, Madhya Pradesh.

MATERIALS AND METHODS

A field experiment was conducted at Research Farm, Zonal Agricultural Research Station, Jhabua during *kharif* and *rabi* 2016–17 and 2017–18 to assess the different liquid bioinoculants and phosphorus levels on yields, nutrient

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uptake and economics and its residual effect on chickpea under rainfed conditions. The soil of experimental site was sandy loam in texture with neutral in pH (7.6 and 7.5). Soil has low organic carbon (0.34 and 0.35), low in available N (130.4 and 132.5 kg/ha) and medium in P (16.1 and 16.8 kg/ha) and K (230.8 and 239.5 kg/ha), respectively. The experiment was laid out in a randomized block design (RBD) with 12 treatments, viz. control (recommended N and K), PSB-I, PSB-II, NPK consortia, 60 kg P₂O₅/ha, 30 kg P₂O₅/ha + PSB-I, 60 kg P₂O₅/ha + PSB-I, 30 kg P₂O₅/ha + PSB-II, 60 kg P₂O₅/ha + PSB-II, 30 kg P₂O₅/ha + NPK consortia, 60 kg P₂O₅/ha + NPK consortia and 90 kg P₂O₅/ha, replicated thrice. The experiment was conducted at the same location with fixed plots during both the years 2016–17 and 2017–18. Rasi-4794 and JAKI-9218 varieties were used for maize and chickpea, respectively and seed rate was 20 kg/ha with a spacing of 60 × 25 cm for maize and 80 kg/ha with spacing of 30 × 10 cm for chickpea. The chickpea crop was sown after harvesting of the maize at same location during both the years. Nitrogen and potassium were applied as uniform dose to all plots and phosphorus was applied as per treatment through single super phosphate (SSP). The liquid biofertilizers, viz. PSB-I, PSB-II and NPK consortia were used as seed treatment @50 ml/8 kg just before sowing. Other cultural operations and plant protection measures were followed as per the recommendation for both crops. Profitability of the system was calculated by combined yields of both crops and calculated the gross returns, net returns and B:C ratio of the maize-chickpea cropping system.

RESULTS AND DISCUSSION

Effect of weather: The meteorological data (Fig 1) showed marked variation in weather condition during both years of experimentation. Total rainfall received during 2016–17 (1138.8 mm) was quite high as compared to 2017–18 (909.8 mm). The maximum temperature was recorded in June (38.94 and 37.40°C in respective years), while the minimum temperature of 8.39 and 9.53°C were recorded in December and January in the respective years. Further, the temperature particularly at reproductive phases of both the crops was more conducive during second year.

This resulted in slightly better performance of the crops during 2016–17 than 2017–18.

Effect on growth and yield parameters of maize and chickpea: Pooled data pertaining to growth (plant height) and yield attributes (cob girth, cob length, cob weight/cob, rows/cob, grains/cob and test weight) as affected by different treatments have been presented in Table 1. Results revealed that significantly higher plant height (159.38 cm), cob girth (14.72 cm), cob length (17.67 cm), cob weight/cob (0.154 kg), no. of grains/row (41.37) and test weight (281.7 g) were recorded under 60 kg P₂O₅/ha + NPK consortia as compared to control, PSB I, PSB II and NPK consortia alone. Results showed that soil having medium P status, phosphorus along with bioinoculants improving the supply of macronutrients and their great translocation to photosynthetic parts may favor growth and development of yield attributes, finally leading to higher yields. Besides, bioinoculants might also have resulted in several favorable processes such as production of growth promoting substances, control of plant pathogen and proliferation of beneficial organisms in the rhizosphere. The results of significant improvement in overall growth characters are in close conformity with Rinku *et al.* (2014) and Sivamurugan *et al.* (2018).

Growth and yield attributes of succeeding chickpea, viz. plant height and no. of pods/plant were influenced significantly by phosphorus and bioinoculants during the study (Table 2). Significantly, the maximum plant height (53.39 cm) and no. of pods/plant (57.03) were recorded in 60 kg P₂O₅/ha + NPK consortia which was statistically at with 60 kg P₂O₅/ha + PSB I, 60 kg P₂O₅/ha + PSB II and 60 kg P₂O₅/ha as compared to control. While no. of branches/plant, seeds/pod and test weight were not influence by various treatments. Due to application of phosphorus and seed inoculation with NPK consortia and PSB culture resulting in vigorous growth of root system, which ultimately help in better absorption and utilization of nutrients from soil solution as well as applied phosphorus, which reflected in terms of better overall plant growth and yield attributes. These results are in close conformity with the findings of Das *et al.* (2013).

Effect on grain, stover and biological yield of maize and chickpea: The grain, stover and biological yield of

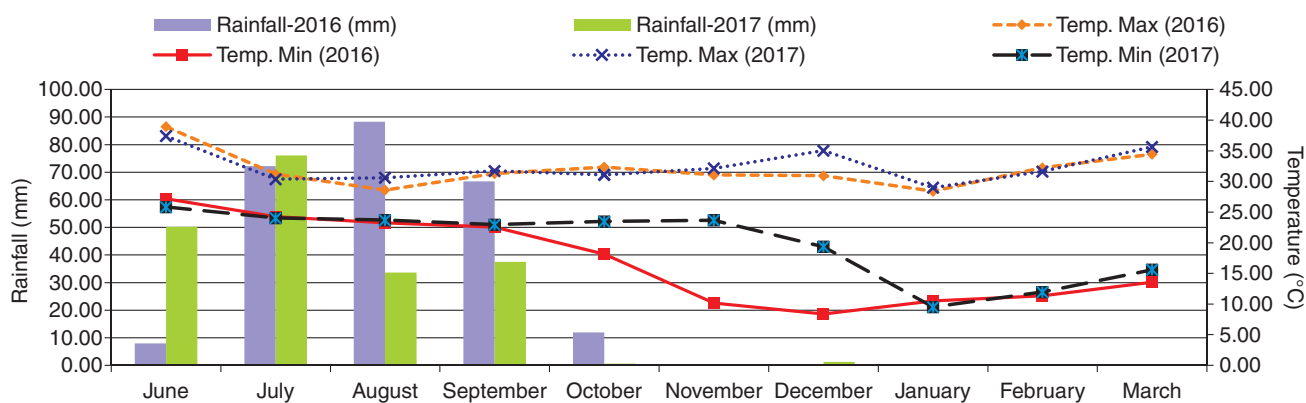


Fig 1 Monthly rainfall and temperature data during both the crops growing period (2016–17 and 2017–18).

Table 1 Growth, yield parameters and yields of maize as influenced by phosphorus + bioinoculants (Pooled data of 2 years)

Treatment	Plant height (cm)	Cob girth (cm)	Cob length (cm)	Cob weight/cob	No. of grams/row	Test weight (g)	Grain yield (q/ha)	Stover yield (q/ha)	Biological yield (q/ha)	Shelling (%)	Cost of cultivation ($\times 10^3$ ₹/ha)	Gross returns ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	B:C ratio
Control	133.50	13.22	15.68	0.102	34.63	247.5	41.10	40.59	81.69	74.33	44.63	155.09	110.46	2.48
PSB I	136.90	13.81	16.18	0.112	35.33	253.3	43.21	43.77	86.98	75.89	44.98	161.80	116.83	2.60
PSB II	138.30	13.91	16.60	0.113	36.40	258.8	43.72	44.00	87.72	75.17	44.98	162.43	117.46	2.61
NPK consortia	139.80	13.55	16.70	0.118	37.17	258.8	44.29	44.11	88.41	76.27	45.13	168.49	123.36	2.73
60 kg P ₂ O ₅ /ha	150.77	14.18	17.51	0.134	36.40	275.6	49.77	49.24	99.01	76.72	46.73	182.76	136.04	2.91
30 kg P ₂ O ₅ /ha + PSB I	145.92	14.15	17.48	0.127	38.63	273.1	49.85	45.32	95.17	76.38	46.03	184.84	138.81	3.02
60 kg P ₂ O ₅ /ha + PSB I	155.92	14.34	17.63	0.142	37.28	284.0	52.63	51.61	104.24	78.04	47.13	193.97	146.85	3.12
30 kg P ₂ O ₅ /ha + PSB II	152.03	14.24	16.94	0.134	38.40	266.6	49.43	42.89	92.33	75.61	46.03	183.88	137.86	3.00
60 kg P ₂ O ₅ /ha + PSB II	155.68	14.62	17.75	0.146	36.94	281.8	53.96	52.05	106.01	78.21	47.13	200.59	153.47	3.26
30 kg P ₂ O ₅ /ha + NPK consortia	149.40	13.84	16.97	0.133	40.60	270.0	49.61	42.77	92.38	76.40	46.18	189.64	143.47	3.11
60 kg P ₂ O ₅ /ha + NPK consortia	159.38	14.72	17.67	0.154	41.37	281.7	54.62	52.63	106.58	78.77	47.28	204.35	157.08	3.32
90 kg P ₂ O ₅ /ha	158.00	14.59	17.48	0.147	39.80	280.3	52.65	50.40	103.05	76.64	47.78	191.05	143.27	3.00
SEm \pm	3.05	0.30	0.44	0.005	0.93	4.75	1.66	2.05	2.85	1.99	-	7.12	6.85	0.09
LSD (P=0.05)	8.95	0.88	1.28	0.015	2.73	13.93	4.87	6.02	8.35	NS	-	21.37	20.56	0.26

Table 2 Residual effect of phosphorus + bioinoculants on growth, yield attributes and yields of succeeding chickpea (Pooled data of 2 years)

Treatment	Plant height (cm)	No. of pods/plant	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)	N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)	
							Seed	Straw	Seed	Straw	Seed	Straw
Control	44.03	40.80	18.08	31.77	49.85	37.14	48.70	40.73	7.95	3.67	57.22	40.22
PSB I	44.70	43.47	18.58	33.01	51.59	35.94	50.02	41.76	8.49	4.24	59.58	42.96
PSB II	46.13	41.50	18.57	32.26	50.83	36.89	50.10	41.66	8.54	4.08	61.64	42.28
NPK consortia	50.46	45.87	19.81	33.67	53.48	37.64	54.11	45.63	9.48	4.36	65.63	44.74
60 kg P ₂ O ₅ /ha	53.59	48.23	20.83	34.52	55.35	37.90	65.09	48.80	11.04	4.85	73.92	48.72
30 kg P ₂ O ₅ /ha + PSB I	45.10	37.57	21.83	34.00	55.83	39.55	62.29	46.83	11.30	4.32	76.47	46.93
60 kg P ₂ O ₅ /ha + PSB I	51.86	54.43	22.28	35.96	58.24	38.60	69.76	52.13	12.26	5.39	79.81	53.05
30 kg P ₂ O ₅ /ha + PSB II	50.33	40.90	22.00	34.75	56.75	39.32	63.06	48.78	11.87	4.53	77.17	50.17
60 kg P ₂ O ₅ /ha + PSB II	53.39	53.67	23.42	36.34	59.75	39.57	69.84	53.12	13.79	5.46	84.14	53.14
30 kg P ₂ O ₅ /ha + NPK consortia	44.79	47.50	23.42	34.40	57.82	41.19	67.40	48.49	12.82	4.81	82.76	48.77
60 kg P ₂ O ₅ /ha + NPK consortia	52.85	57.03	24.04	36.52	60.69	40.18	81.45	56.56	14.55	5.87	87.24	54.83
90 kg P ₂ O ₅ /ha	46.23	45.00	21.75	34.94	56.69	38.57	72.01	52.98	12.54	5.24	78.32	51.51
SEm±	2.77	3.52	1.17	1.63	1.97	1.84	2.55	2.48	0.68	0.31	4.30	2.47
LSD (P =0.05)	6.65	10.32	3.42	NS	5.77	NS	7.63	7.27	2.00	0.91	12.60	7.23

maize were significantly influenced with the application of various treatments (Tables 1). Among the various treatments, application of 60 kg P₂O₅/ha + NPK consortia produced highest grain yield (54.62 q/ha), stover yield (52.63 q/ha) and biological yield (106.58 q/ha), however, it was found statistically at par with 90 kg P₂O₅/ha, 60 kg P₂O₅/ha + PSB I, 60 kg P₂O₅/ha + PSB II and 60 kg P₂O₅/ha and significantly inferior over rest of the treatments. Due to this treatment (60 kg P₂O₅/ha + NPK consortia) increases the grain, stover and biological yield by 32.90, 29.66 and 30.47%, respectively over control. Shelling percentage was not influenced by the treatments. Application of phosphorus along with bioinoculants has played significant role in improving vegetative structure for nutrient absorption, photosynthesis and strong sink through development of reproductive structure and production of assimilates to fill economically sink. Thus, under higher availability of P and N due to its cumulative influence maintained balanced source sink through improving both vegetative and generative events of crop development which ultimately resulted in increased grain yield. Increased the availability of NPK in soil due to seed treatment with NPK consortia and its active involvement in shoot and root growth lead to improvement in various yield attributes which later boosted final yields. The results of present investigation are in close conformity with findings of Obid *et al.* (2016) and Dhiman and Dubey (2017).

Grain and biological yield of succeeding chickpea were influenced significantly by different doses of phosphorus and bioinoculants (Table 2). Highest seed yield (24.04 q/ha) and biological yield (60.69 q/ha) were obtained in 60 kg P₂O₅/ha + NPK consortia and it was found at par with 60 kg P₂O₅/ha +

PSB II and 30 kg P₂O₅/ha + NPK consortia. The application of 60 kg P₂O₅/ha + NPK consortia increased the grain and biological yield by 32.96 and 21.74%, respectively over control. The improving yield attributing parameters might be due to improved microbial activity in the rhizosphere with the application of phosphorus and bioinoculants in conjunction which resulted in balanced supply of nutrients and antipathogenic activity resulting in better growth, yield attributes and yield (Gautam *et al.* 2017). *Rhizobium* helps in the formation of root nodules and supplied nitrogen in the roots of plants while, phosphate solubilizing bacteria solubilised the applied and native unavailable phosphorus into readily available form resulting, improved the growth and yield attributes and finally yields of chickpea. Kumawat *et al.* (2009a), Das *et al.* (2013) and Shukla *et al.* (2017) also reported the similar findings. Straw yield and harvest index were not affected by different treatments.

Effect on nutrient uptake by maize and chickpea: Data pertaining to nutrient uptake and total uptake by maize as influenced by application of phosphorus and bioinoculants are presented in Table 2 and Fig 2. Among the various treatments, N (90.75 and 47.67 kg/ha), P (17.52 and 7.70 kg/ha) and K (26.36 and 78.47 kg/ha) uptake by grain and stover respectively, were recorded significantly higher under 60 kg P₂O₅/ha + NPK consortia as compared to control, PSB I, PSB II and NPK consortia. While the lowest values of these nutrients uptake was recorded in control. Similarly, the maximum total uptake of N, P and K were recorded under 60 kg P₂O₅/ha + NPK consortia (Fig 2). It might be ascribed to the fact that application of phosphorus along with bioinoculants provides more favourable environment for absorption and accumulation of macronutrients in the

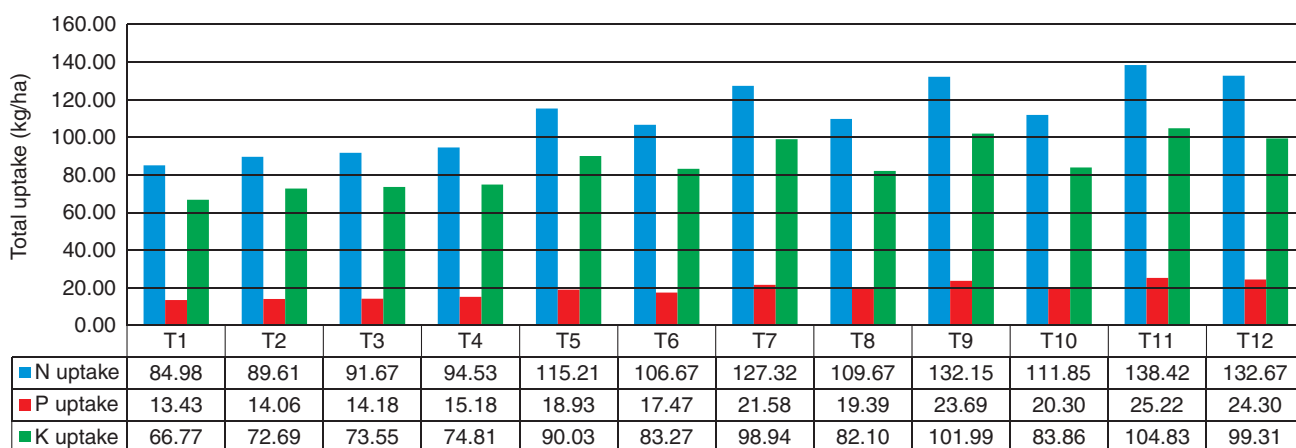


Fig 2 Total uptake of nutrients by maize crop as influenced by phosphorus + bioinoculants (Pooled data of 2 years).

plant part. Since uptake is the function of nutrient content and yield, the increase in these parameters resulting increase uptake of nutrients. The results of the present experiments are in line with the findings of Bashir *et al.* (2014), Kumar *et al.* (2015b) and Rinku *et al.* (2016).

The pooled data on nutrient uptake by seed and straw (NPK) by succeeding crop chickpea as influenced by different treatments are presented in Table 2. An examination of data revealed that significantly higher uptake of N (81.45 and 56.56 kg/ha), P (14.55 and 5.87 kg/ha) and K (87.24 and 54.83 kg/ha) by seed and straw, respectively were recorded in 60 kg P₂O₅/ha + NPK consortia. Similarly, highest total uptake of N, P and K were recorded with the application of 60 kg P₂O₅/ha + NPK consortia. The lowest values of these nutrients were recorded under control. This might be due to that phosphorus application improved the soil P content and hastens the solubilization of native soil P also. Similarly seed inoculations with bioinoculants have their effect on the addition and accumulation of N, P and K in the soil. That is responsible for the increased uptake of the nutrients (N, P and K). These results are attributive to the findings of Kumawat *et al.* (2009b), Kumawat *et al.* (2010) and Balai *et al.* (2017).

Effect on economics: It is evident from the pooled analysis data that application of various treatments markedly increased gross return, net return and B:C ratio of the cropping system over control (Table 1). The highest gross return ($\times 10^3$ 204.35 ₹/ha), net return ($\times 10^3$ 157.08 ₹/ha) and B:C ratio (3.32) were obtained under treatment receiving 60 kg P₂O₅/ha + NPK consortia followed by 60 kg P₂O₅/ha + PSB-I and 60 kg P₂O₅/ha + PSB-II. This was due to lower cost incurred for bioinoculants and higher yield recorded under respective treatment ultimately reflected into higher net return and benefit cost ratio. Similar results were also reported by Sivamurugan *et al.* (2018). Hence, from above findings, it may be concluded that application of 60 kg P₂O₅/ha along with bioinoculants (NPK consortia) in maize-chickpea cropping system under rainfed condition of Jhabua hill can be used for getting higher yields and monetary returns.

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