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Efficacy of different liquid biofertilizer under varying fertility levels on nutrient use efficiency, apparent recovery and factor productivity of chickpea (*Cicer arietinum* L.)

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Abstract
The field experiment to study the "Efficacy of different Liquid Biofertilizer under varying Fertility Levels on Growth and Yield of Chickpea (*Cicer arietinum* L.)" was laid out at research farm, RARI, Durgapura for two conductive years during *rabi* seasons of 2015-16 and 2016-17 on loamy sand soil. In all twenty eight treatment combinations consisting of four fertility levels *i.e.* control (F_0), 50%N + 75%P_2O_5 + 75%K_2O + 50%S (F_1), 75%N + 85%P_2O_5 + 85%K_2O + 75S% (F_2) and 100% NPKS (F_3) and seven liquid biofertiliser combinations *i.e.* control (B_0), Rhizobium (B_1), PSB+PMM (P-Solublizer & Mobilizer) (B_2), KMB (K-Mobilizer) (B_3), Rhizobium + PSB + PMM + KMB (B_4), SSB (S-solublizer) (B_5) and Rhizobium + PSB + PMM + KMB + SSB (B_6) were laid out in split plot design with three replication. Results showed that the dose of 50%N+75% P_2O_5+75%K_2O+50% S recorded highest nutrient use efficiency and apparent recovery and 75%N+85% P_2O_5+85%K_2O+75% S recorded highest factor productivity of nitrogen and Rhizobium + PSB + PMM + KMB + SSB recorded highest nutrient use efficiency and apparent recovery of N during both the years and in pooled analysis than control.

Keywords: Fertility level, liquid bio fertiliser, Chickpe, nutrient use efficiency, apparent recovery and factor productivity

Introduction
The chickpea (*Cicer arietinum* L.) as a healthy vegetarian food has an important role in human food and domestic animal feed in India. It is a cheap source of high quality protein in the diets of millions of people in developing countries, who cannot afford animal protein for balanced nutrition. Also chickpea play a key role in organic cropping systems. In such agro ecosystem with limited availability of nitrogen, chickpea potentially constitute both a cash crops and a source of N incorporation into the system via biological nitrogen fixation. To be sustainable, organic farming needs to be self-sufficient in nitrogen (N) through the fixation of atmospheric dinitrogen (N_2) by legumes, recycling of crop residues (green manures) (Elfstrand *et al*., 2007) [3]. Green manures application to the soil is considered a good management practice in all agricultural production system because of increasing cropping system via sustainability by reducing soil erosion, improving soil physical properties and increasing soil organic matter and fertility levels (Power 1990) [10]. Phosphorus is present as mineral deposits, which are a non renewable natural resource. There is global concern about the energy and costs involved in mining the phosphate rock and its transport to manufacturing sites, as well as in the manufacture of different fertilizers and their transport to farm fields and application to the crops. Photosynthesis and stomatal conductance are reduced by P deficiency (Guidi *et al*., 1994) [6]. 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) [12].

Liquid Bio-fertilizers are special liquid formulation containing not only desired microorganisms and their nutrients, but also special cell protestants' or substances that encourage formation of resting spores or cysts for longer shelf life and tolerance to adverse condition. (Chandra *et al*. 2006) [2]. Biofertilizers play a main key role for selective adsorption of immobile (P, Zn, Cu) and mobile (C, S, Ca, K, Mn, Cl, Br, and N) elements to plants (Tinker, 1984) [17]. In addition to proteins, chickpea is a good source of carbohydrates, minerals and trace elements. Biofertilizers are living microorganisms, which when applied through seed or soil treatment, promote growth by increasing the supply or availability of nutrients to the host plant (Moin Uddin *et al*., 2014) [8]. In plants, they also increase the content of growth hormones such as IAA and GA, leading to enhancement in the growth of plants (Selvakumar *et al*., 2009) [14]. These biofertilizers include the N_2 fixing, phosphate solubilizing and plant growth promoting microorganisms (Mahdi *et al*., 2010) [7]. Rhizobium bacteria (BNF) through biological N_2 fixation, meet about 80-90% of total N requirements of legumes (Verma, 1993) [18]. Phosphate solubilizing microorganisms play a key role in the plant metabolism and crop productivity. They are known to increase P uptake and overall P-use efficiency resulting in better growth and higher yield of crop plants. As a matter of fact, supply of N and P biofertilizers along with inorganic P fertilizer could play an important role in manifestation of improved nutrient uptake and enhanced crop yield and quality of chickpea in a cost-effective manner.

Material and Method

Field experiments were conducted at Rajasthan Agricultural Research Institute, Durgapura (75^0 47' East longitudes and at $26^0$51' North latitude and at an altitude of 390 m above mean sea level), during 2015-16 and 2016-17 growing seasons. Experiments were arranged in split plot design with three replications. Main plots consisted of using fertility levels *i.e.* control (F_0), 50%N + 75%P_2O_5 + 75%K_2O + 50%S (F_1), 75%N + 85%P_2O_5 + 85%K_2O + 75S% (F_2) and 100% NPKS (F_3). Sub-plots were seven strategies of supplying the liquid biofertilizer *i.e.* control (B_0), Rhizobium (B_1), PSB+PMM (P-Solublizer & Mobilizer) (B_2), KMB (K-Mobilizer) (B_3), Rhizobium + PSB + PMM + KMB (B_4), SSB (S-solublizer) (B_5) and Rhizobium + PSB + PMM + KMB + SSB (B_6) were arranged in sub-sub plots. Fertilizer was given as per the treatment. Full dose of Nitrogen, phosphorus, potassium and sulphur were applied as basal and Biofertiliser were applied as per treatment. All Biofertilisers were applied before sowing the seed at the rate of 4-5 ml per kg seed. Biofertiliser applied seed kept in shade for drying the extra moisture were mixed then.

Before sowing the seeds of chickpea were treated with carbendazim 50% WP at the rate of 5 g kg^{-1} to protect from funghal diseases. Seeds of chickpea variety RSG-973 (Abha) were sown manually (Kera method) by labour at about 8 cm depth in rows 30 cm apart using seed rate of 80 $kgha^{-1}$. In order to reduce the weed competition, two hand weeding were done at 30 and 60 days after sowing respectively. In order to maintain a uniform plant stand at an intra-row spacing of 10 cm, extra plants were thinned 21 DAS and 23 DAS during 2015-16 and 2016-17 respectively.

Nutrient use efficiency

The nutrient use efficiency for nitrogen, phosphorous, potash and sulphur were worked with the following formula given by Craswell and Godwin (1984) and expressed in kg seed per kg nutrient.

$$\text{NUE (kg seed/kg Nutrient)} = \frac{\text{Yield in treated plot (kg/ha)} - \text{Yield in control plot (kg/ha)}}{\text{Amount of nutrient applied (kg/ha)}}$$

Apparent recovery of nutrients (Kg/ha)

Apparent recovery of nutrient is also known as per cent utilization of fertilizers. It can be calculated by using the following relationship:

$$\text{Apparent nutrient recovery (kg ha}^{-1}) = \frac{\text{Nutrient uptake in fertilized plot(kgha}^{-1}) - \text{Nutrient uptake in control plot (kgha}^{-1})}{\text{Nutrient applied (kgha}^{-1})}$$

Factor productivity (Kg grain/kg of NPKS)

Factor productivity is the seed yield in relation to nutrient uptake. It can be calculated by using the following relationship:

$$\text{Factor productivity(Kg grain /kg of NPKS)} = \frac{\text{Grain yield in nutrient applied plot(kgha}^{-1}) - \text{Grain yield in control plot (kgha}^{-1})}{\text{Nutrient uptake in fertilized plot (kgha}^{-1}) - \text{Nutrient uptake in control plot (kgha}^{-1})}$$

Result and Discussion

Nutrient use efficiency (kg grain/kg), apparent recovery (kg ha^{-1}) and Factor productivity (kg seed/kg) of Nitrogen

Data (Table 1) indicated that different fertility levels differ significantly in nutrient use efficiency, apparent recovery and factor productivity of nitrogen. The dose of 50% N+75% P_2O_5+75% K_2O+50% S recorded highest nutrient use efficiency and apparent recovery and 75% N+85% P_2O_5+85% K_2O+75% S recorded highest factor productivity of nitrogen as compared to control. The same table revealed that different fertility levels significantly influenced nutrient use efficiency, apparent recovery and factor productivity of Phosphorus. The dose of 100% NPKS recorded highest nutrient use efficiency of phosphorus. 75%N+85% P_2O_5+85% K_2O+75% S recorded maximum apparent recovery and factor productivity of phosphorus. The dose of 100% NPKS recorded highest Nutrient use efficiency and 75% N+85% P_2O_5+85% K_2O+75% S attained highest apparent recovery and factor productivity of potassium. Levels of different fertility influenced significantly the nutrient use efficiency, apparent recovery and factor productivity of sulphur. 50% N+75% P_2O_5+75% K_2O+50% S recorded highest Nutrient use efficiency. 75% N+85% P_2O_5+85% K_2O+75% S attained highest apparent recovery. Further 75% N+85% P_2O_5+85% K_2O+75% S and 100% NPKS recorded highest factor productivity.

Data presented in table 1 showed that different liquid biofertiliser combinations influenced nutrient use efficiency, apparent recovery and factor productivity of NPKS. Rhizobium + PSB + PMM + KMB + SSB (B_6) recorded highest nutrient use efficiency and apparent recovery of nitrogen, phosphorus, potassium and sulphur than rest of the treatments. Factor productivity of nitrogen, phosphorus, potassium and sulphur recorded highest in control plot.

Different liquid biofertilisers significantly affected nutrient use efficiency, apparent recovery and factor productivity of Pover control. On pooled data basis, Rhizobium + PSB + PMM + KMB + SSB recorded highest nutrient use efficiency and apparent recovery of P and recorded highest factor productivity of P over rest of the treatments.

Application of frtilisers in crop at incresing level would led to increas the amount of nutrint uptake in plant. But nutrient use efficiency would be higher in less fertilised plot because of less fertilised plot produce per killogram nutrient more seed than 100% fertilised plot. Increased level of phosphorus also increased the uptake of N and P content in both grains and straw this might be due to the better synregestic effect of N and P that ultimatly led to more nutrients uptake in plant as well as in grains and straw. Similar result reported by Balai *et al*. (2017) [1]. Highest uptake of nitrogen, phosphorus and potassium was observed with increasing level of K_2O Goud *et al*. (2014) [5].

Application of the biofertilizer increased N, P, and K uptakes compared with the control. Beneficial microorganisms can keep the soil environment rich in all kinds of micro- and macronutrients via nitrogen fixation, phosphate and potassium mineralization and solubilization release of plant growth regulators, the production of antibiotics, and the biodegradation of organic matter in the soil (Sinha *et al.* 2010) [15]. The N-fixing biofertilizers make a net addition to nitrogen supplies by fixing atmospheric N for the soil-plant system. The increased in total N uptake also contributes to increase in the P availability in the soil due to the production of inorganic polyphosphate promoted by the addition of carbon elegant in accordance with Franco *et al.* (2004) [4]. Similar results were observed by Oliveira *et al.* (2016) [6] using different fertilization treatments (biofertilizer, bio protector, soluble fertilizers). Application of Rhizobium + PSB, enhance the nutrient availability and nutrient use efficiency of chickpea. Santana *et al.* (2014) [13] described the availability of P and K to the soil and plants using organic biofertilizer from phosphate and potassic rocks with elemental sulfur inoculated with the sulfur oxidative bacteria thiobacillus mixed with earthworm compost. Singh *et al.* (2018) reported that Biofertilizers can enhance the nutrient content, uptake and yield of crop. Rhizobium fixes the atmospheric nitrogen in to the soil and PSB solubilize the unavailable P and make it available for plants. The higher P utilization by chickpea crop could be attained because of increased microbial activity in improving the availability of soil nutrients for their absorption. The favorable effect of nutrients obtained when the biofertilizer applied. It might be due to increase in availability of P and K contained in the phosphate and potassic biofertilisers and the effect of the sulfuric acid produced by the oxidative bacteria thiobacillus. Legume plants have ability to access sparingly soluble nutrients specially P, due to root induced process (Pypers *et al.*, 2006) [11]. Rhizobium inoculation and PSB application significantly increased the protein in seed because of better nodule development vis-a-vis nitrogen fixation and its utilization towards protein synthesis due to better availability of nutrients like nitrogen, phosphorus and potash. The results are in agreement with work of Nishita and Jashi (2010) who have also reported an increased in protein content in seed with application of biofertilizers. The inoculation of seeds with Rhizobium increased the N and P contents in seeds as well as straw. This might be due to better nitrogen fixation by the bacteria which in turn might have helped in better absorption and utilization of all the plant nutrients, thus resulted in more N and P content in seed and straw and protein content in seed.

Table 1: Effect of different liquid biofertilizer under varying fertility levels on nutrient use efficiency, apparent recovery and factor productivity of NPKS

Treatments	Nutrient use efficiency of N (kg grain/ kg N)	Apparent recovery of N	Factor productivity of N (kg seed/kg N)	Nutrient use efficiency of P (kg grain/ kg P)	Apparent recovery of P (%)	Factor productivity of P (kg seed/kg P)	Nutrient use efficiency of K (kg grain/ kg K)	Apparent recovery of K (%)	Factor productivity of K (kg seed/kg K)	Nutrient use efficiency of S (kg grain/ kg S)	Apparent recovery of S (%)	Factor productivity of S (kg seed/kg S)
Fertility levels												
F_0-Control	0.00	0.00	0.000	0.00	0.00	0.000	0.00	0.00	0.000	0.00	0.00	0.000
F_1- 50%N+75%P_2O_5+75%K_2O+ 50% S	29.49	173.25	0.059	9.83	13.28	0.014	9.83	38.49	0.039	29.49	28.33	0.010
F_2 75%N+85%P_2O_5+85%K_2O+ 75% S	27.53	172.14	0.065	12.14	17.36	0.015	12.14	52.86	0.046	27.53	28.76	0.011
F_3-100% NPKS	24.46	147.73	0.062	12.23	17.33	0.014	12.23	51.54	0.043	24.46	25.82	0.011
S.Em+	0.42	3.02	0.001	0.21	0.23	0.000	0.18	0.90	0.000	0.48	0.59	0.000
CD (P=0.05)	1.30	9.31	0.002	0.65	0.70	0.000	0.54	2.77	0.001	1.48	1.81	0.001
CV (%)												
Liquid Biofertilizers												
B_0- Control	8.92	61.55	0.055	3.54	5.65	0.012	3.54	17.66	0.039	8.92	10.51	0.010
B_1- Rhizobium (N-Fixing)	21.20	127.83	0.045	8.87	12.41	0.010	8.87	36.59	0.031	21.20	21.25	0.008
B_2- PSB+PMM (P-Solublizer & Mobilizer)	21.38	127.22	0.045	8.89	12.26	0.010	8.89	36.02	0.030	21.38	20.89	0.007
B_3- KMB (K-Mobilizer)	19.59	118.78	0.046	8.18	11.49	0.011	8.18	34.43	0.031	19.59	19.49	0.008
B_4- Rhizobium + PSB + PMM + KMB	22.90	138.64	0.046	9.65	13.62	0.011	9.65	41.11	0.032	22.90	23.91	0.008
B_5- SSB (S-Solublizer)	19.93	119.09	0.045	8.35	11.55	0.010	8.35	34.15	0.031	19.93	20.55	0.008
B_6- Rhizobium + PSB +	28.67	169.84	0.045	12.37	16.97	0.010	12.37	50.10	0.030	28.67	28.50	0.007

PMM + KMB + SSB												
S.Em+	0.47	3.42	0.001	0.26	0.25	0.000	0.21	0.91	0.001	0.56	0.70	0.000
CD (P=0.05)	1.32	9.56	0.002	0.72	0.70	0.001	0.58	2.55	0.002	1.56	1.95	0.001
CV (%)												

Conclusion

According to the followed result it can be concluded that the nutrient use efficiency inversely proportionate to the fertility levels but liquid biofetilsers possitively affect it. It is might be due to metabolic activities of plant would be increases upto a perticuler nutrient level, after it there is no significant increase in nutrient use eficiency. But in case of apperent recovery and factor productivity, it is directly proportionate to nutrient level aplied. It might be due to uptake of nutrient in plant increases with gradually increasing does of fertilisers.

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