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Effect of various nutrients sources and bio-fertilizers on soil microbial diversity under late sown chickpea (*Cicer arietinum* L.)

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Abstract
A field experiment was conducted during two consecutive *seasons* of 2021-22 and 2022-2023 at Research Farm, Department of Agronomy, College of Agriculture, Jawaharlal Nehru Krishi Vishwavidhalya, and Jabalpur (M.P.). The experiment was laid out in split plot design with twenty treatment combinations were replicated thrice. The study on effect of nutrient sources and bio-fertilizers on microbial diversity of soil. It's cleared from the data highest microbial cells counts like *Rhizobium* (15.66 x 10^6 cfu g^{-1} soil), PSB (18.96 x 10^6 cfu g^{-1} soil) was recorded under the application of enriched vermicompost @ 2 t ha^{-1} followed by FYM @ 5 t ha^{-1} along with *Rhizobium* and PSB (14.83 x 10^6 cfu g^{-1} soil) and (17.05 x 10^6 cfu g^{-1} soil), *Rhizobium* and PSB respectively and same trends was observed for actinomycetes. Whereas, highest fungi population was observed under FYM @ 5 t ha^{-1} with combined application of bio-inoculants with respect to 39.83 x 10^4 cfu g^{-1} soil followed by control treatments 34.92 x 10^4 cfu g^{-1} soil and lowest fungi population was recorded under enriched vermicompost @ 2 t ha^{-1} along with combined application of bio-fertilizers (28.32 x 10^4 cfu g^{-1} soil).

Keywords: *Rhizobium*, PSB, actinomycetes, fungi, FYM, enriched vermicompost, RDF and Nano DAP, microbial counts.

Introduction
Chickpea commonly known as Gram and it is the third largest worldwide legume crop, having wide adaptability under different agro-climatic conditions. Among the pulses chickpea occupies a predominant position and is considered as a "King of pulses crop". India is the largest chickpea producing country, and it is basically grown in the dry regions of India. Recently, the problem arose in agriculture is the deterioration of soil quality and loss of fertility. It is due to loss of organic matter (OM) and degradation of agro chemicals in soil (Virmani, 1994) [12]. Addition of OM in the terms of compost increase the microbial population and organic carbon content of the soil and promote better plant growth. Since, it is a natural eco-friendly approach; it does not have any adverse effect neither on the soil nor on the environment. Microbial enrichment of compost through bio-inoculants further enhances the microbial population of the soil, nutrient mineralization, and availability of nutrients (Dhaliwal *et al.*, 2022)
[4]. The inoculations of microorganisms in soil are also beneficial for maintaining soil health th ough decomposition of organic matter, N fixation, solubilization or mineralization, production of antibiotics plant growth regulators etc. Vermicompost enriches soil and also increases the soil fertility, soil micro-organisms and organic manure is completely harmless and provides macro and micro nutrients that is good for crop growth (Asewar *et al.*, 2003) [1]. The application of FYM and compost boost up the activities of beneficial soil micro flora and improve the supply of mineral nutrients, soil structure, water retention capability and enzymatic activities (Dubey *et al.*, 2020) [5].

Material and Methods
A field experiment was conducted two consecutive seasons of 2021-22 and 2022-2023 at Research Farm, Department of Agronomy, College of Agriculture, JNKVV, Jabalpur (M.P.). The soil of experimental fields having clay content 48.54%, silt 28.80% and 21.94% sand. It is neutral in reaction (7.15), normal in EC (0.36), medium in organic carbon (0.59) and medium available nitrogen (281.54 kg ha^{-1}), phosphorus (13.25 kg ha^{-1}) and high in potassium (282.46 kg ha^{-1}).

Twenty treatment combinations consisted of five sources of nutrient (Control, enriched vermicompost @ 2 t ha^{-1}, FYM @ 5 t ha^{-1}, NPK (100% RDF) and Nano DAP (Seed treatment @ 5 ml kg^{-1} seed and foliar spray @ 0.4% at 30 DAS), put under main plot and four bio-fertilizers (Control, *Rhizobium* 10 g kg^{-1}, PSB 10 g kg^{-1} seed and *Rhizobium*+PSB (10 g of each kg^{-1} seed) allotted under sub plot. Samples of rhizospheric soil were used as fresh without grinding, sieving or any modifications.

The collected samples were kept in low density polyethylene bags and stored in refrigerator at 4-5°C and as per need. Population of microbes were estimated by following; YEMA (*Rhizobium*), Pikovskayas (PSB) and Casenak Agar medium (Rao, 1988) [10] and counts of microbial cells were calculated by following:

$$\text{Viable cells (CFU g}^{-1}\text{ soil)} = \frac{\text{Number of colonies}}{\text{1 g of soil}} \times \text{Dilution factor}$$

Results and Discussion

Microbial population under different sources of plant nutrition

The study on microbial population counts during both the years of experimentation and data were pooled and data present in Table 1. It is clear from the data counts of *Rhizobium* and PSB were recorded in post-harvest soil treatments and compared with initial counts. It was noted that the population of *Rhizobium* and PSB both was significantly increase over initial value 6.65 x 10^6 and 5.86 x 10^6 cfu g^{-1} soils respectively.

Table 1: Effect of different nutrient sources and bio-fertilizers on *Rhizobium* population in post-harvest of soil (pooled mean)

Microbial population (cfu g^{-1} soil)					
Initial value	**6.65**				
Bio-fertilizers / Nutrient Sources	***Rhizobium* x 10^6**				
	Control	***Rhizobium***	**PSB**	***Rhizobium* +PSB**	**Mean**
Control	6.31	10.17	5.67	13.68	8.96
Vermicompost	7.50	22.50	8.65	24.00	15.66
FYM	8.00	22.00	6.67	22.67	14.84
NPK (RDF)	6.83	10.33	10.00	12.00	9.79
Nano DAP	5.00	13.50	9.50	15.00	10.75
Mean	6.73	15.70	8.10	17.47	
	S.Em±		CD(P=0.05)		
Nutrient Source (S)	0.46		1.35		
Bio-fertilizers (B)	0.59		1.71		
Factor (B) at same level of S	0.93		2.81		
Factor (S) at same level of B	1.04		3.14		

Moreover, the organic sources i.e. vermicompost and FYM both were significantly superior over control as well as NPK (100% RDF) and Nano DAP it was also noted that the population of *Rhizobia* under control (8.96 x 10^6 cfu g^{-1} soils), NPK (9.79 x 10^6 cfu g^{-1} soils) and Nano DAP (10.75 x 10^6 cfu g^{-1} soils) were significantly lower to the vermicompost and FYM. Whereas the population of PSB was in control plot found significantly superior over NPK (9.79 x 10^6 cfu g^{-1} soils) as well as Nano DAP but markedly lower to vermicompost (15.66 x 10^6 cfu g^{-1} soils) and FYM (14.84 x 10^6 cfu g^{-1} soils). These findings are in accordance with the findings of Barik *et al.*, 2006 [2] and Palekar, 2006 [9]. As regards to inoculation of *Rhizobium* and PSB exert significant effect on counts of *Rhizobia* and PSB in post-harvest soil.

Table 2: Effect of different nutrient sources and bio-fertilizers on PSB population in post-harvest of soil (pooled mean)

Microbial population (cfu g^{-1} soil)					
Initial value	**5.86**				
Bio-fertilizers / Nutrient Sources	**PSB x 10^6**				
	Control	***Rhizobium***	**PSB**	***Rhizobium* +PSB**	**Mean**
Control	6.58	8.83	18.50	20.67	13.52
Vermicompost	10.30	11.07	26.17	28.33	18.96
FYM	9.15	10.80	22.18	26.10	17.05
NPK (RDF)	7.67	8.00	12.00	14.06	10.43
Nano DAP	7.00	9.45	15.00	18.00	12.36
Mean	8.14	9.53	18.77	21.43	
	SEm±		CD(P=0.05)		
Nutrient Source (S)	0.31		1.02		
Bio-fertilizers (B)	0.51		1.48		
Factor (B) at same level of S	0.62		1.95		
Factor (S) at same level of B	1.05		3.21		

It was noted that the inoculation of *Rhizobium* alone or in combination with PSB had higher count of (15.70 and 17.47 x 10^6 cfu g^{-1} soils) respectively. However the (9.53 x 10^6 cfu g^{-1} soils) counts of *Rhizobium* under PSB and (8.14 x 10^6 cfu g^{-1} soils) control plot was found at par to each other and similar to (5.86 x 10^6 cfu g^{-1} soils) initial value. It's clear from the Table 2 similarly trend was also noted that in case of PSB counts the higher population of PSB was under inoculation of PSB alone and combination with *Rhizobium* recorded (18.77 and 21.43 x 10^6 cfu g^{-1} soils) but significantly higher population of PSB (21.43 x 10^6 cfu g^{-1} soils) was noted in combine inoculation when it was significant superior to other treatments of the control (8.14 x 10^6 cfu g^{-1} soils) and *Rhizobia* inoculation (9.53 x 10^6 cfu g^{-1} soils) was found at par but significantly superior to (5.86 x 10^6 cfu g^{-1} soils) initial value. These findings are in accordance with the findings of Kiran *et al.,* 2016 [8].

The interaction between sources of nutrition and bio-fertilizer was found significant in both the cases of *Rhizobium* and PSB counts. The *Rhizobium* counts were significantly effected due to application of sources of plant nutrition with different bio-fertilizers. The highest counts of *Rhizobia* (24.00, 22.67, 22.50 and 22.00 x 10^6 cfu g^{-1} soils) were recorded in enriched vermicompost along with *Rhizobium*+PSB, FYM along with combination of *Rhizobium*+PSB, vermicompost along with *Rhizobium* and FYM along with *Rhizobium* respectively, and proved significantly superior over other sources with *Rhizobium* and combination of *Rhizobium* + PSB. The counts of PSB also effected due to combined application of sources of nutrition with bio-fertilizers it was noted that vermicompost @ 2 t ha^{-1} with combined application of *Rhizobium* + PSB recorded significantly superior higher counts of PSB (28.33 x 10^6 cfu g^{-1} soils) closely followed by FYM (26.10 x 10^6 cfu g^{-1} soils) with *Rhizobium* + PSB these two values are significantly superior over other combination nutrient sources and bio-fertilizers but at par with same inoculation of PSB (18.77 x 10^6 cfu g^{-1} soils). These findings are in accordance with the findings of Jagadeesha *et al.,* (2019) [7] and Selvi *et al.,* (2004) [11].

The study on total fungi and actinomycetes population counts during both the years of experimentation and data were pooled. Counts of total fungi and actinomycetes recorded in post-harvest soil of experimental plots are present in table 3 and 4 respectively. Data revealed that the more counts of fungi were observed in subsequent year over first year means population increase with the year after year further it was also noted that fungal population in all the treatments increase over initial value (24.25 x 10^4 cfu g^{-1} soils) but the variation among the treatments were not significantly during both the year and poold analysis the population of actinomycetes markable increase our initial value of 6.15 soil and control 6.95 x 10^3 cfu g^{-1} soils over two years. The interaction of source of nutrients and bio fertilizer was found non-significant during both the years and pooled data. These findings are in accordance with the findings of Das and Verma 2011 [3] and Hangare *et al.,* (2004) [6].

Table 3: Effect of different nutrient sources and bio-fertilizers on total fungi population in post-harvest of soil

Treatments	**Fungi x 10^4 cfu g^{-1} soil**		
Initial value	**24.25**		
Nutrient sources	**2021-22**	**2022-23**	**Pooled**
Control	33.42	36.42	34.92
Vermicompost	25.83	30.80	28.32
FYM	38.33	41.33	39.83
NPK (RDF)	30.75	32.17	31.46
Nano DAP	28.75	40.58	34.67
S.Em±	5.27	4.16	4.40
CD (P=0.05)	NS	NS	NS
Bio-fertilizers			
Control	28.20	30.80	29.50
Rhizobium	30.53	33.00	31.77
PSB	32.40	33.80	33.10
Rhizobium + PSB	34.53	36.27	35.40
S.Em±	2.21	2.27	2.24
CD (P=0.05)	NS	NS	NS

Table 4: Effect of different nutrient sources and bio-fertilizers on actinomycetes population in post-harvest of soil

Treatments	**Actinomycetes x 10^3 cfu g^{-1} soil**		
Initial value	**6.15**		
Nutrient sources	**2021-22**	**2022-23**	**Pooled**
Control	6.35	7.47	6.91
Vermicompost	11.59	13.25	12.42
FYM	10.58	12.43	11.50
NPK (RDF)	9.82	10.82	10.32
Nano DAP	9.78	11.29	10.54
S.Em±	2.10	2.15	2.13
CD (P=0.05)	NS	NS	NS
Bio-fertilizers			
Control	6.32	7.28	6.80
Rhizobium	11.12	11.98	11.55
PSB	10.18	11.80	10.99
Rhizobium + PSB	10.85	11.50	11.18
S.Em±	1.99	1.96	1.93
CD (P=0.05)	NS	NS	NS

Conclusion

Based on forgoing discussions it was conclude that addition of enriched vermicompost and FYM @ 2 and 5 t ha^{-1} respectively, showed the favourable effect on proliferation of *Rhizobium* + PSB cell as well as actinomycetes as observed under post-harvest soil. The populations of fungi proliferate of faster rate in FYM. Moreover the combined application of *Rhizobium* and PSB proved to be the best for enhancing the microbial diversity of rhozospheric soil under the chickpea ecosystem.

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