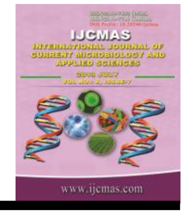
Int.J.Curr.Microbiol.App.Sci (2019) *8*(6): 3378-3391

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 8 Number 06 (2019)**
Journal homepage: http://www.ijcmas.com



Original Research Article https://doi.org/10.20546/ijcmas.2019.806.401

Soil Microbial Population As Influenced By Direct and Residual Effect of Organic and Inorganic Sources of Nutrients in Cowpea- Little Millet Cropping Sequence

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Keywords

Soil microbial population, Yield, Organic manures, Cowpea, Phosphorus, Residual effect, Direct effect, Little millet

Article Info

Accepted:
30 May 2019
Available Online:
10 July 2019

A B S T R A C T

Field experiments were conducted during 2017-18 and 2018-19 in sandy loam soils of Tirupati (AP) to evaluate the direct and residual effect of organic and inorganic sources of nutrients on soil microbial population and yield of cowpea-little millet cropping sequence. Three levels of organic manures (no organic manure, FYM @ 5 tonnes ha^{-1} and poultry manure @ 2 tonnes ha^{-1}) and 3 phosphorus levels (0, 40 and 60 kg P_2O_5 ha^{-1}) applied to preceding cowpea and 3 graded levels of nitrogen *viz.*, 0, 10 and 20 kg ha^{-1} applied to succeeding *rabi* little millet. Soil microbial population and yield of *kharif*, cowpea varied with manures and phosphorus levels. Poultry manure @ 2 tonnes ha^{-1} recorded higher soil microbial population and pod yield which was on par with application of FYM @ 5 tonnes ha^{-1}. Among the phosphorus levels, application of 60 kg P_2O_5 ha^{-1} resulted higher soil microbial population and pod yield of cowpea. Soil microbial population and grain yield of little millet was influenced by the residual effect of organic manures and phosphorus applied to preceding cowpea, as well as direct nitrogen levels applied succeeding little millet, where 20 kg N ha^{-1} resulted higher values of microbial population and yield compared to 10 kg N ha^{-1} and control. This study concluded that the application of poultry manure @ 2 t ha^{-1} and 60 kg P_2O_5 ha^{-1} to preceding cowpea and 20 kg N ha^{-1} to succeeding little millet increased the soil microbial population and yield in main and residual cropping compared to respective control.

Introduction

Organic manures play a vital role in maintenance of physical, chemical and biological environment of soil and supply macro and micronutrients to crops, besides maintaining humic substances in soil (Sharma, 1992). The judicious combination of organic manures and fertilizers should be used for improving crop productivity and maintaining soil fertility (Dikshit and Khatik, 2002).

The soil is crowded with millions of living organisms which make it a living and a dynamic system. These organisms not only help in development of soils but also carry out a number of transformations and facilitating the availability of nutrient to the plants.

Cowpea [*Vigna unguiculata* (L.) Walp] is of immense importance, as it is a multipurpose grain legume extensively cultivated in arid and semiarid tropics. The cowpea is used as grain, green pods and fodder. Cowpea is grown as a catch crop, weed smothering crop, intercrop, mixed crop and green manure crop. It has ability to fix atmospheric nitrogen in soil in association with symbiotic bacteria under favourable conditions (Yadav, 1986).

The little millet is one among the six small millets grown in most of the regions of scanty and eratic rainfall on poor and marginal soils. Cultivation of this crop is mostly confined to hilly tract and poor tribal community of the country. The demand for little millet is increasing now-a-day due to its high nutritional profile with low glycemic index particularly by the people suffering from diabetes. It has good nutritive value as it is rich in carbohydrates (66.3%), protein (7.5 to 13.8%), fat (3.54%) crude fiber (5.73%), iron (1.38 mg 100 g^{-1}) and calcium (21.21 mg 100 g^{-1}) (Kulkarni *et al.*, 1992).

Inclusion of legumes with the use of organic and inorganic sources of nutrients in cropping sequence results in improvement of base as well as succeeding crop to achieve food, nutritional security, increased productivity, profitability and sustainability. The present study was carried out to study the impact of different organic manures and inorganic fertilizers on yield and microbial population in post-harvest soil after main and residual crop.

Materials and Methods

The field experiments were conducted during two consecutive years (2017-18 and 2018-19) at S.V. Agricultural college farm, Tirupati of Andhra Pradesh. The soil of the experimental field was sandy loam in texture, low organic carbon (0.39 %) and available N (168.5 kg ha^{-1}) medium in P_2O_5 (18.8 kg ha^{-1}), available K_2O (161.3 kg ha^{-1}) and neutral in reaction (6.94). Initial bacteria (12.5 CFU x 10^6 g^{-1}), fungi (7.8 CFU x 10^4 g^{-1}) and actinomycetes (12.9 CFU x 10^3 g^{-1}). The experiment was laid out in split-split design with three replications at same site during both the years. The treatments consisted of three organic manures, viz., control, (M_1) FYM @ 5 t ha^{-1} (M_2) and poultry manure @ 2 t ha^{-1} (M_3) as main plot treatments and three phosphorus levels, viz., 0 (P_1), 40 kg P_2O_5 ha^{-1} (P_2) and 60 kg P_2O_5 ha^{-1} as sub- plot treatments imposed to cowpea crop during *kharif* season. Three nitrogen levels 0 kg ha^{-1} (S_1), 10 kg ha^{-1} (S_2) and 20 kg ha^{-1} (S_3) as sub- sub plot treatments imposed to little millet during *rabi* season. As per treatments, FYM and poultry manure were incorporated 15 days before sowing and phosphorus was applied at basal to cowpea during both the years. Cowpea variety “TPTC-29” was sown in rows 30 cm apart using a seed rate of 20 kg ha^{-1}. The green pods of cowpea were picked in three spells and haulms were incorporated into the soil thoroughly for full decomposition followed by sowing of little millet. As per treatment half of the nitrogen dose was applied as basal and remaining half was applied after 30 DAS. Little millet variety ‘OLM-203’ was raised in rows 20 cm apart using a seed rate of 10 kg ha^{-1}.

Results and Discussion

Soil microbial population after harvest of cowpea

Higher microbial population *viz*., bacteria, fungi and actinomycetes in soil was observed with application of poultry manure, which was comparable with that of farm yard manure applied soil. Lower microbial population was recorded with no manure application (Table 1). This might be due to relatively higher rate of multiplication of microbes associated with organic manures, which act as a substrate for stimulation and rapid multiplication of microorganisms. Further, increase in microbial population could be the result of enhancement of soil organic matter in the soil as indicated by positive correlation of enzyme activities with soil organic carbon. This can be ascribed to the decomposed food material available from organic sources. The similar results were reported by Vineela *et al.,* (2008), Nath *et al.,* (2015). Poultry manure might have stimulated the microorganisms by serving of carbon, energy and other nutrients essential for their growth and multiplication, and thus increased the soil biotic activities in poultry manure applied soils. These results are in conformity with findings of Boomiraj (2003).

With regard to the phosphorus levels, application of 60 kg P_2O_5 ha^{-1} recorded the higher microbial population in soil followed by 40 kg P_2O_5 ha^{-1} addition and both were higher than no phosphorus application (Table 1). Phosphorus provided energy and constituents for new cell synthesis and favoured the multiplication of these microorganisms. This might be due to higher root activity in rhizosphere due to more availability of nutrients. These results are in conformity with findings of Babu *et al.,* (2008).

Soil microbial population after harvest of little millet

Among the organic manures, residual effect of poultry manure incorporation increased the soil microbial population followed by farm yard manure, during both the years of study (Table 2). This might be due to the addition of poultry manure or FYM in soil which leads to an increase in microbial population and activity due to more amounts of available carbon and nutrients like nitrogen and posphorus to soil micro-organism which provide more energy. The addition of organic inputs enhanced the microbial counts in soil, which might be due to carbon addition and changes in physico-chemical properties of soil. Similar results were obtained by Meena *et al.,* (2015). Higher population of microbes under organic manures acted as an index of soil fertility because it serves as temporary sink of nutrients flux as observed by Hassink *et al.,* (1991).

Residual effect of 60 kg P_2O_5 ha^{-1} applied to preceding cowpea recorded the higher microbial population in soil followed by 40 kg P_2O_5 ha^{-1} and both were superior over no phosphorus application (Table 2). This might be due to that as phosphorus is the key element which regulates the growth and activities of microorganisms and it's provide energy and constituents for new cell synthesis and favoured the multiplication of these microorganisms. This might be due to higher root activity in rhizosphere due to more availability of nutrients. These results are in conformity with findings of Babu *et al.,* (2008). In addition to the residual effect of manures and phosphorus levels, the direct application of nitrogen also altered the microbial population in soil. With regard to nitrogen levels, application of 20 kg N ha^{-1} (S_3) recorded the higher microbial population followed by application of 10 kg N ha^{-1} (S_2) and was higher than no nitrogen application (S_1). The microbial population in rhizosphere of crop increased with increase of nitrogen from 0 to 20 kg N ha^{-1}. Singh *et al.,* (1998) reported similar results of increased population of microbes due to nitrogen application.

Yield of cowpea

The green pod and haulm yield of cowpea was higher with incorporation of poultry manure, however, it was on par with those resulted due to FYM incorporation and both were significantly superior to no manure application during both the years of study (Table 3).

Table.1 Soil microbial population (CFU g^{-1} soil) at harvest of cowpea as influenced by organic manures and phosphorus levels

Treatment	Bacteria ($x 10^6$)		Fungi ($x 10^4$)		Actinomycetes ($x 10^3$)	
	***kharif*, 2017**	***kharif*, 2018**	***kharif*, 2017**	***kharif*, 2018**	***kharif*, 2017**	***kharif*, 2018**
Organic manures						
M_1: Control (No manures)	32.0	30.4	21.4	18.7	48.9	39.9
M_2: FYM @ 5t ha^{-1}	38.9	44.4	28.8	26.1	63.1	56.3
M_3: Poultry manure @ 2t ha^{-1}	39.8	45.4	30.3	27.2	64.0	56.9
S Em ±	0.79	0.82	0.25	0.51	0.73	0.77
CD (P=0.05)	3.1	3.3	1.0	2.0	2.9	3.1
Phosphorus levels (kg P_2O_5 ha^{-1})						
P_1: Control	30.7	27.9	21.2	15.2	46.5	40.4
P_2: 40	39.5	45.3	28.7	27.3	64.2	55.6
P_3: 60	40.5	47.1	30.5	29.5	65.4	57.1
S Em ±	0.57	0.53	0.32	0.41	0.57	0.68
CD (P=0.05)	1.7	1.6	1.0	1.2	1.8	2.1
Interaction						
P at M						
S Em ±	1.37	1.43	0.43	0.88	1.26	1.34
CD (P=0.05)	NS	NS	NS	NS	NS	NS
M at P						
S Em ±	1.13	1.12	0.52	0.78	1.09	1.24
CD(P=0.05)	NS	NS	NS	NS	NS	NS
Pre experimental soil microbial population	12.5	13.7	7.8	8.3	12.9	14.2

Table2 Soil microbial population (CFU g^{-1}) at harvest of little millet as influenced by residual effect of manures and phosphorus applied to preceding cowpea and by direct application of nitrogen

Treatment	Bacteria (x 10^6)		Fungi (x 10^4)		Actinomycetes (x 10^3)	
	rabi, 2017	*rabi,* 2018	*rabi,* 2017	*rabi,* 2018	*rabi,* 2017	*rabi,* 2018
Organic manures						
M_1: Control (No manures)	25.9	24.4	11.9	10.7	34.6	29.3
M_2: FYM @ 5t ha^{-1}	31.1	29.4	15.4	13.0	39.0	39.5
M_3: Poultry manure @ 2t ha^{-1}	34.4	33.7	17.7	15.5	42.6	43.5
SEm±	0.36	0.43	0.22	0.16	0.63	0.47
CD (P=0.05)	1.4	1.7	0.8	0.6	2.4	1.8
Phosphorus levels (kg P_2O_5 ha^{-1})						
P_1: Control	27.2	26.0	13.3	11.7	35.2	34.4
P_2: 40	30.9	29.5	15.0	13.4	38.6	37.4
P_3: 60	33.3	32.0	16.6	14.1	42.4	40.3
SEm±	0.33	0.23	0.21	0.12	0.46	0.27
CD (P=0.05)	1.0	0.7	0.6	0.3	1.4	0.8
Nitrogen levels (kg ha^{-1})						
S_1: Control	27.2	26.0	13.9	11.9	32.5	34.8
S_2: 10	30.9	29.5	15.0	13.1	38.7	37.5
S_3: 20	33.3	32.0	16.0	14.2	45.1	39.8
SEm±	0.23	0.24	0.20	0.12	0.32	0.25
CD (P=0.05)	0.6	0.6	0.5	0.3	0.9	0.7
Interaction						
Organic manures x Phosphorus levels						
SEm±	0.57	0.40	0.37	0.21	0.80	0.48
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Organic manures x Nitrogen levels						
SEm±	0.40	0.42	0.34	0.21	0.57	0.44
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Phosphorus levels x Nitrogen levels						
SEm±	0.40	0.42	0.34	0.21	0.57	0.44
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Organic manures x Phosphorus levels x Nitrogen levels						
SEm±	0.70	0.73	0.60	0.37	0.98	0.77
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table.3 Green pod and haulm yield (kg ha^{-1}) of cowpea as influenced by organic manures and phosphorus levels

Treatment	Green pod yield		Haulm yield	
	kharif, 2017	*kharif*, 2018	*kharif*, 2017	*kharif*, 2018
Organic manures				
M_1: Control (No manures)	1771	1916	9600	8414
M_2: FYM @ 5t ha^{-1}	2607	2754	12703	10794
M_3: Poultry manure @ 2t ha^{-1}	2719	2872	13162	11137
SEm±	50.3	66.3	118.9	110.0
CD (P=0.05)	203	267	479	443
Phosphorus levels (kg P_2O_5 ha^{-1})				
P_1: Control	1964	2094	10061	8053
P_2: 40	2492	2650	12571	10954
P_3: 60	2641	2798	12833	11339
SEm±	70.3	71.0	146.6	158.2
CD (P=0.05)	219	221	456	492
Interaction				
P at M				
SEm±	87.2	114.8	205.9	190.5
CD (P=0.05)	NS	NS	NS	NS
M at P				
SEm±	111.4	120.3	239.0	249.3
CD (P=0.05)	NS	NS	NS	NS

Table.4 Grain yield (kg ha^{-1}) of little millet as influenced by residual effect of manures and phosphorus applied to preceding cowpea and by direct application of nitrogen

		rabi, 2017					*rabi*, 2018				
		S_1	S_2	S_3	Mean for M	Mean for P	S_1	S_2	S_3	Mean for M	Mean for P
M_1	**P_1**	1036	1173	1460	**1283**	**1376**	1002	1129	1412	**1233**	**1317**
	P_2	1096	1240	1536			1046	1186	1476		
	P_3	1116	1320	1574			1066	1266	1514		
M_2	**P_1**	1260	1444	1651	**1474**	**1426**	1179	1363	1560	**1392**	**1364**
	P_2	1233	1471	1667			1153	1391	1581		
	P_3	1233	1558	1754			1153	1478	1667		
M_3	**P_1**	1164	1468	1729	**1514**	**1470**	1123	1427	1659	**1464**	**1408**
	P_2	1269	1595	1725			1219	1545	1675		
	P_3	1302	1617	1757			1252	1567	1711		
Mean for S		**1190**	**1432**	**1650**			**1133**	**1373**	**1584**		

Interaction between residual organic manures and nitrogen levels									
rabi, 2017					*rabi*, 2018				
	S_1	S_2	S_3	Mean of M		S_1	S_2	S_3	Mean of M
M_1	1083	1244	1523	**1283**	M_1	1038	1194	1467	**1233**
M_2	1242	1491	1690	**1474**	M_2	1161	1411	1603	**1392**
M_3	1245	1560	1737	**1514**	M_3	1198	1513	1682	**1464**
Mean of S	**1190**	**1432**	**1650**		Mean of S	**1133**	**1373**	**1584**	

	rabi, 2017		*rabi*, 2018	
	SEm ±	CD (P = 0.05)	SEm ±	CD (P = 0.05)
M	23.21	90.6	23.45	91.5
P	16.05	49.4	14.96	46.1
S	13.47	38.6	12.79	36.7
MxP	27.81	NS	25.91	NS
MxS	23.34	66.9	22.16	63.5
PxS	23.34	NS	22.16	NS
MxPxS	40.43	NS	38.39	NS

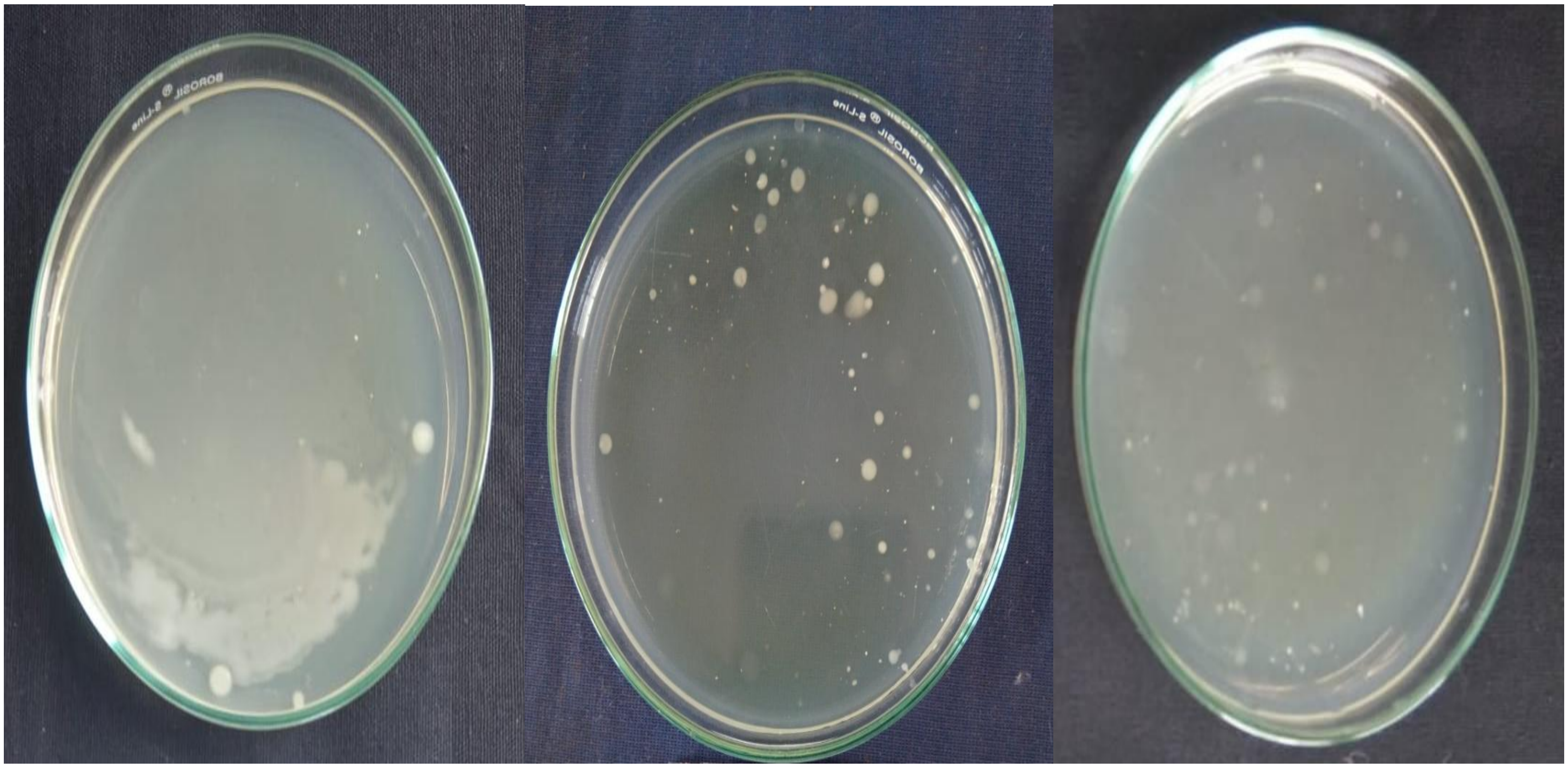
Table.5 Straw yield (kg ha^{-1}) of little millet as influenced by residual effect of manures and phosphorus applied to preceding cowpea and by direct application of nitrogen

		rabi, 2017					*rabi*, 2018				
		S_1	S_2	S_3	Mean for M	Mean for P	S_1	S_2	S_3	Mean for M	Mean for P
M_1	P_1	1299	1429	1719	**1568**	**1633**	1298	1425	1708	**1532**	**1598**
	P_2	1396	1540	1836			1346	1486	1776		
	P_3	1416	1610	1864			1366	1566	1814		
M_2	P_1	1473	1657	1864	**1712**	**1709**	1430	1614	1811	**1662**	**1657**
	P_2	1483	1721	1917			1433	1671	1861		
	P_3	1483	1808	2004			1433	1758	1947		
M_3	P_1	1462	1766	2027	**1815**	**1752**	1419	1723	1955	**1763**	**1701**
	P_2	1569	1895	2025			1519	1845	1975		
	P_3	1602	1917	2069			1552	1867	2011		
Mean for S		**1465**	**1705**	**1925**			**1422**	**1662**	**1873**		

Interaction between residual organic manures and nitrogen levels									
rabi, 2017					*rabi*, 2018				
	S_1	S_2	S_3	Mean of M		S_1	S_2	S_3	Mean of M
M_1	1370	1526	1806	**1568**	M_1	1337	1492	1766	**1532**
M_2	1479	1729	1928	**1712**	M_2	1432	1681	1873	**1662**
M_3	1544	1859	2040	**1815**	M_3	1497	1812	1980	**1763**
Mean of S	**1465**	**1705**	**1925**		Mean of S	**1422**	**1662**	**1873**	

	rabi, 2017		*rabi*, 2018	
	SEm ±	CD (P = 0.05)	SEm ±	CD (P = 0.05)
M	26.75	104.4	27.04	105.5
P	16.43	50.63	16.87	51.9
S	13.87	39.80	14.62	41.9
MxP	28.46	NS	29.22	NS
MxS	24.02	68.93	25.32	72.6
PxS	24.02	NS	25.32	NS
MxPxS	41.61	NS	43.86	NS

Bacterial population

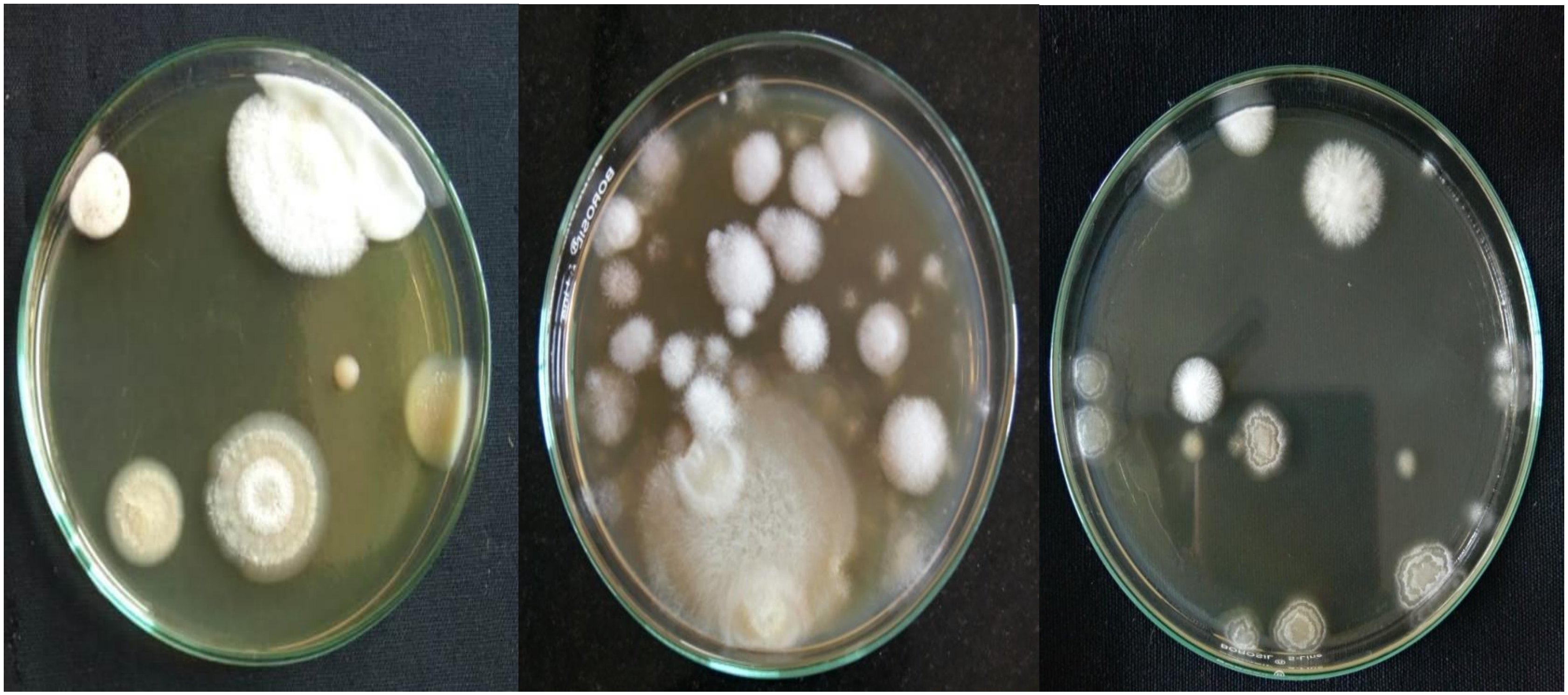


Pre experimental

After harvest of cowpea (M_3P_3) (Poultry manure @2 t ha^{-1} and 60 kg P_2O_5)

After harvest of little millet ($M_3P_3S_3$) (Residual Poultry manure @ 2 t ha^{-1} and 60 kg P_2O_5 and direct effect of 20 kg N ha^{-1})

Fungal population

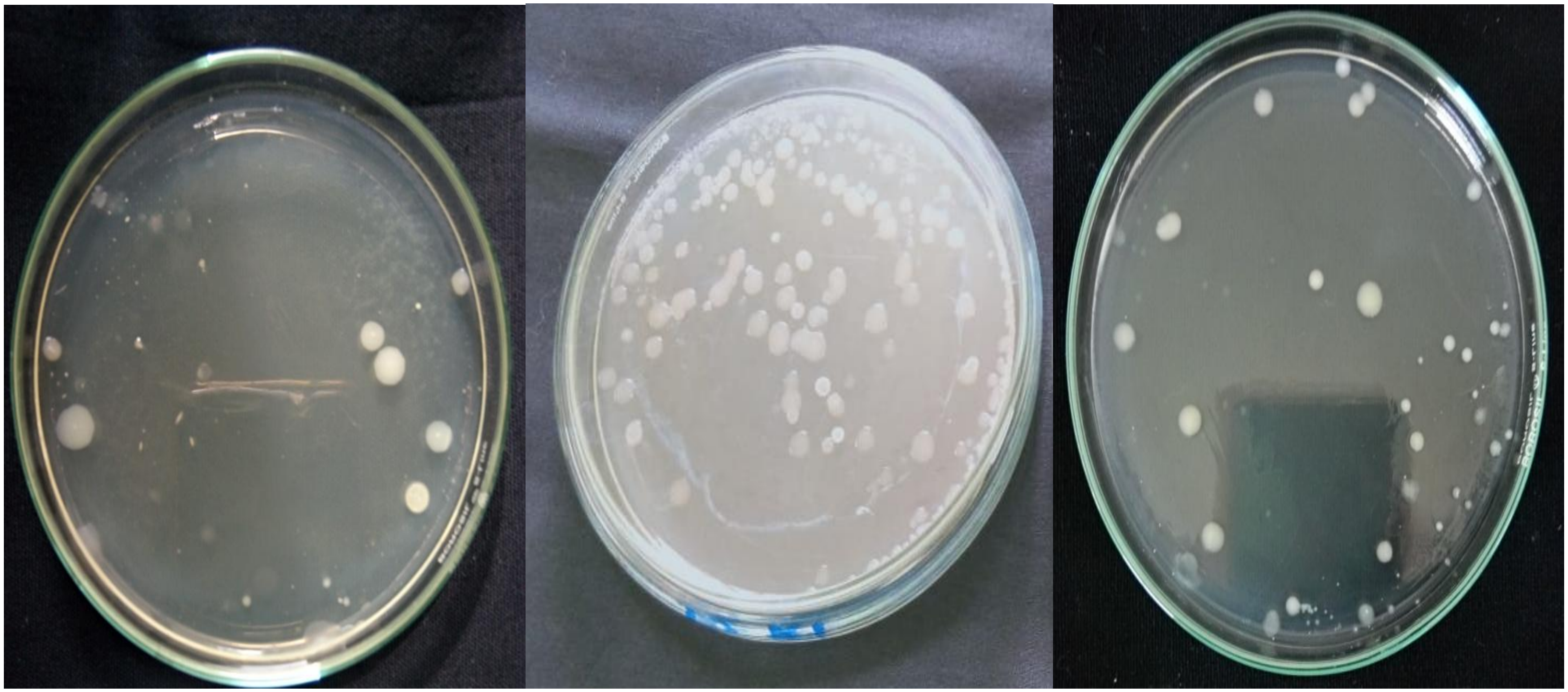


Pre experimental

After harvest of cowpea (M_3P_3)
(Poultry manure @2 t ha^{-1} and 60 kg P_2O_5)

After harvest of little millet ($M_3P_3S_3$)
(Residual Poultry manure @ 2 t ha^{-1} and 60 kg P_2O_5 and direct effect of 20 kg N ha^{-1})

Actinomycetes population



Pre experimental

After harvest of cowpea (M_3P_3)
(Poultry manure @2 t ha^{-1} and 60 kg P_2O_5)

After harvest of little millet ($M_3P_3S_3$)
(Residual Poultry manure @ 2 t ha^{-1} and 60 kg P_2O_5 and direct effect of 20 kg N ha^{-1})

Fig.1 Soil microbial population (CFU g^{-1}) as influenced by organic manures and phosphorus levels applied to preceding cowpea and nitrogen applied to succeeding little millet during 2017-18

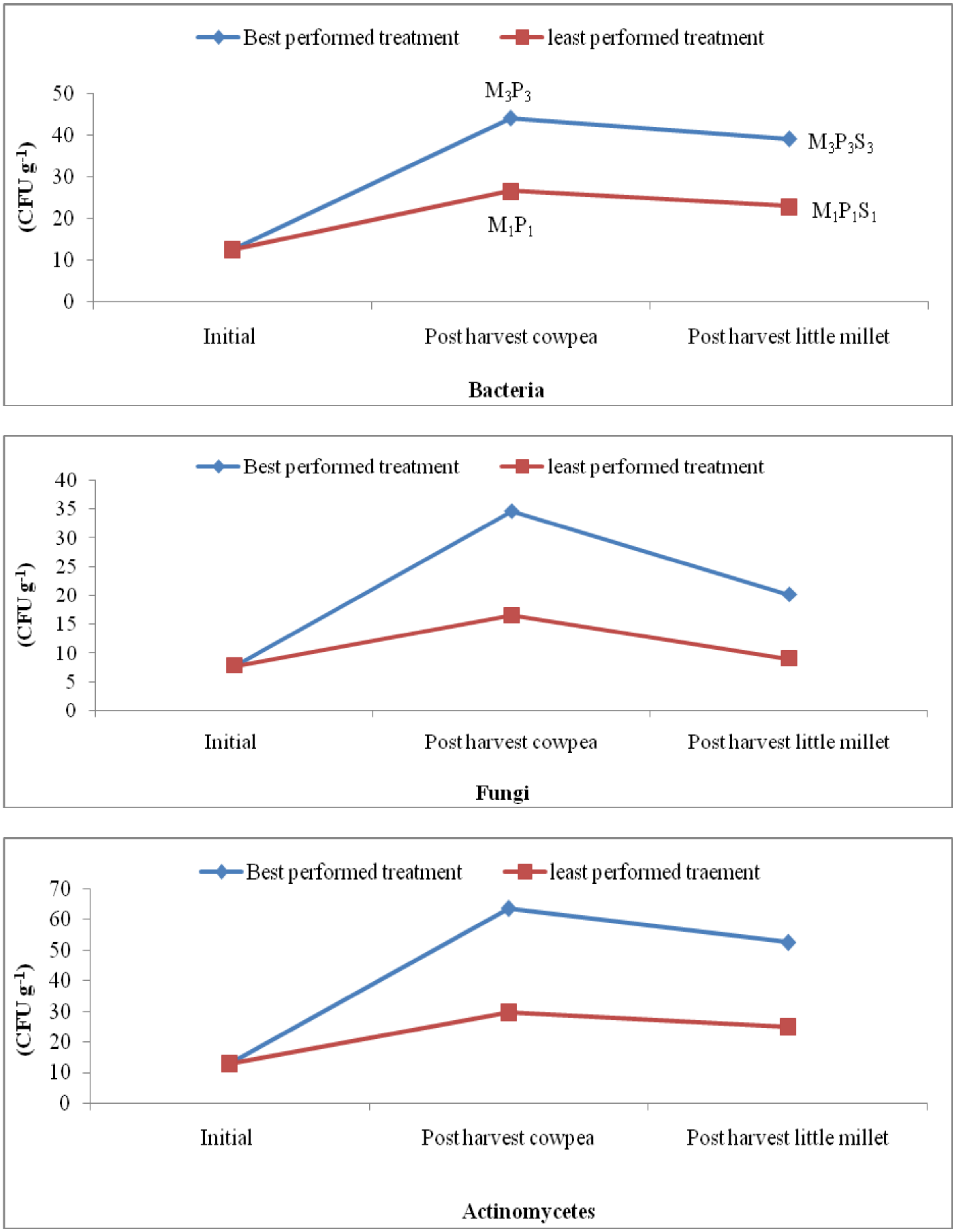
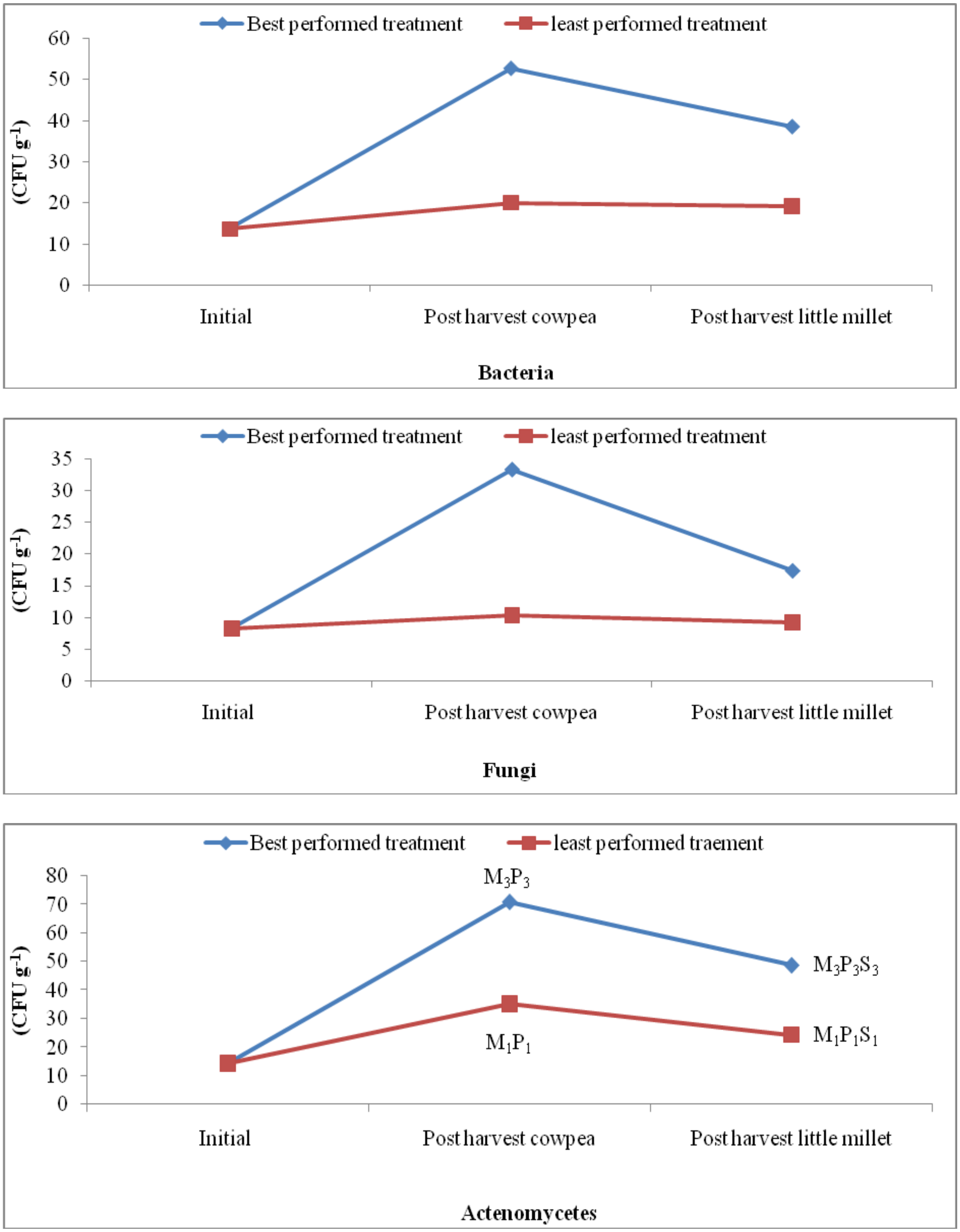


Fig.2 Soil microbial population (CFU g^{-1}) as influenced by organic manures and phosphorus levels applied to preceding cowpea and nitrogen applied to succeeding little millet during 2018-19



This might be due to the fact that organic manures supplied balanced nutrition to the crop, improved soil condition and there by resulting in better growth and development leading to higher yield attributes and yield. The same was obvious through the findings of Yadav *et al.,* (2007), Rao *et al.,* (2013) and Singh *et al.,* (2015).

Successive increase in P levels had positive effect on pod as well as haulm yield of cowpea over their preceding level. Application of 60 kg P_2O_5 ha^{-1} recorded higher pod and haulm yield which was comparable with that resulted with 40 kg P_2O_5 ha^{-1} and both were superior over control (Table 3). Application of phosphorus might have resulted in increased the energy transfer as phosphorus is constituent of many enzymes and their remobilization to reproductive parts of the plants. Hence, resulted in increased flowering, fruiting and seed formation might attributed to more pod yield. These results are in conformity with the findings of Kumawat, (2006).

Yield of little millet

The grain and straw yield of little millet was higher due to residual effect of poultry manure followed by FYM incorporation, during both the years of study (Table 4 and 5). Similarly, residual effect of 60 kg P_2O_5 ha^{-1} reflected on enhanced yield attributes and yield of succeeding little millet. However it was on par with those resulted with 40 kg P_2O_5 ha^{-1}.

In addition to the residual effect of manures reflected on yield of little millet, direct application of nitrogen also altered the yield attributes and yield. Higher grain and straw yield was recorded with 20 kg N ha^{-1} (Table 4 and 5). This might be attributed to better availability and uptake of nitrogen which in turn lead to efficient metabolism and higher biomass accrual and efficient translocation of photosynthates from source to sink. The increase in sink capacity resulted in improved yield attributes and consequently enhanced the grain yield. The above results are in conformity with the findings of Kalaghatagi *et al.,* 2000 and Hasan *et al.,* 2013.

Regarding the interaction effect, the grain and straw yield of little millet was significant with combined effect of residual manures and direct nitrogen levels, where, the poultry manure residual effect along with 20 kg N ha^{-1} resulted in higher grain and straw yield of little millet.

The experimental results concluded that in the areas where cowpea little millet crop sequence is followed, manures applied to preceding crop preferably poultry manure conserve the nitrogen dose to succeeding little millet crop and also poultry manure was the best source in increasing post-harvest soil microbial population in main and residual crops.

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How to cite this article:

Umadevi G. D., V. Sumathi, A. Pratap Kumar Reddy, P. Sudhakar and Lavanya Kumari K. 2019. Soil Microbial Population As Influenced By Direct and Residual Effect of Organic and Inorganic Sources of Nutrients in Cowpea- Little Millet Cropping Sequence. *Int.J.Curr.Microbiol.App.Sci.* 8(06): 3378-3391. doi: https://doi.org/10.20546/ijcmas.2019.806.401