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MACRONUTRIENT AVAILABILITY AND MICROBIAL POPULATION DYNAMICS OF SOILS UNDER ORGANIC AND CONVENTIONAL FARMING OF LEGUME CROP

Debasmita Chhotaray *et al*.

Organic farming

Conventional farming

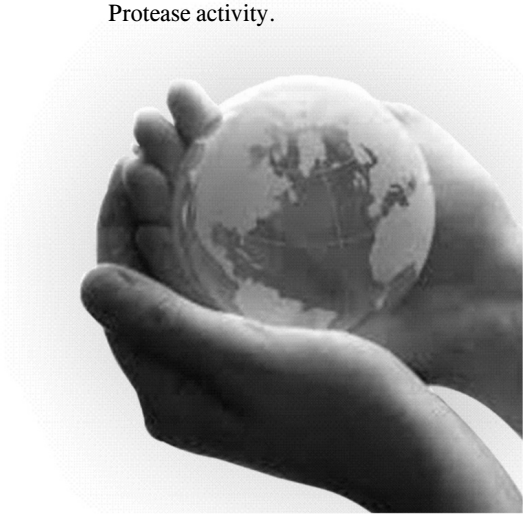
Legume crop field

Microbial population

Soil nutrients

Dehydrogenase activity

Protease activity.



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DEBASMITA CHHOTARAY[1], P. K. MOHAPATRA[2*] AND C. S. K. MISHRA[3]
[1]Post Graduate Department of Botany, Utkal University, Bhubaneswar-751 004, India
[2]Department of Botany, Ravenshaw University, Cuttack-753 003, India.
[3]Department of Zoology and Biotechnology, College of Basic Sciences and Humanities, Orissa University of Agriculture and Technology, Bhubaneswar-751 003, INDIA
E-mail: pradiptamoha@yahoo.com

ABSTRACT

TThe seasonal dynamics of microbial population, nutrients *i.e.,* OC, N, P, and K; dehydrogenase and protease activity of soil, and the relationship of their activities to soil depth were compared in organically grown legume fields with the conventionally cultivated fields. Significantly higher ($P < 0.01$) bacteria and fungi population was observed in organic than in the conventional farming. In both the cultivation systems there was a depth wise decrease of microbial density excepting summer months, where inner soil layers had higher quantity of microbes than the surface soil.The organic carbon and inorganic nutrients as well as dehydrogenase and protease activities of soil were higher in the surface than the sub-surface layers in both the agroecosystems. Positive relationships between soil nutrients and enzyme activities with microbial population showed that organic farming increased microbial activity and carbon turnover in legume crops.

***Corresponding author**

INTRODUCTION

Microbial biomass and activities determine the fertility of the soil through regulation of the bioavailability of soil nutrients. A number of soil ecological factors influence soil microbial population dynamics and enzyme activities, which in turn affect soil fertility (Liu *et al*., 2008; Araujo *et al*., 2009). Soil enzymes play an important role in organic matter decomposition and nutrient cycling and its mobilization to different soil strata (Pavel *et al*., 2004; Shi *et al*., 2006). In tropical conditions temperature and soil moisture level (Li and Sarah, 2003), influence nutrient cycling, microbial growth and enzyme activity. In addition the agricultural practices are also known to alter the soil microbial biomass and its associated enzymatic activities (Pavel *et al*., 2004; Alvear *et al*., 2005). Reports are scanty on the variation of microbial density, their systematic activity and nutrient levels in organically managed and conventional cultivation practices especially under legume cultivation.The present report deals with a comparative analysis of such practices on the soil microbial activities and nutrient availability in legume crop cultivated fields.

MATERIALS AND METHODS

The study was conducted during March 2007 to January 2009 in three different seasons *i.e.* summer (March-May), rainy (July-September) and winter (November-January) each year. Soil samples were collected from legume crop (*Vigna* spp.) grown fields under both organic and conventional farming practices. The samples were collected in triplicates from each field and at least 5 plots of the same zone were sampled. The 15 replicates of one sample zone were averaged and served as one replicate. Fifteen such zones were sampled, each of which was considered as a replicate. The average yearly ambient temperature of the sample sites ranged from 11.1°C to 44.6°C, and annual normal rainfall was 1449.1 mm characteristic of a humid tropical climate (SMD, Govt. of Odisha). Soil samples from top 20 cm were collected in sterilized polythene bags using a steel corer and segregated to five depth classes at each 4 cm interval and each sample was divided into three replicates for further use. The isolation and enumeration of bacteria and fungi and measurement of soil enzyme activity were done within 24 h of sampling. The remaining soil samples were used for quantification of soil nutrients.

Isolation of bacteria and fungi was done by spread plate method using Nutrient Agar and Potato Dextrose Agar medium respectively. Soil microbial population was estimated by dilution plate method. The inoculated plates were incubated at 37°C for 24 h for bacteria and 25 °C for 72 h for fungi. The colonies were counted with the help of a digital colony counter and expressed as number of colony forming units per gram dry soil (cfu/g) (ICMSF, 1978). The activity of dehydrogenase (Casida *et al*., 1964) and protease enzymes (Speir and Ross, 1975) were done using TPF and tyrosine respectively as standard.

Soil Organic carbon (SOC) was estimated titrometrically (Walkey and Black, 1934) and mineralisable nitrogen (MN) was quantified by the method as described by Subbiah and Asija (1956). Available Phosphorus (AP) and Potassium (AK) were carried out by Olsen method (Olsen *et al*., 1954) and Ammonium acetate flame photometric method (Lu, 1999), respectively.

The statistical analysis of all the data has been done using M Stat C Software (Michigan State University, USA). The data were analyzed through ANOVA to determine significance of differences among the seasons and the soil depths. Correlation among bacteria and fungi populations with soil nutrients and the activity of the enzymes were made to determine the soil depth dependent variations. Standard statistical procedures were followed for data analysis.

RESULTS AND DISCUSSION

The farming practice could cause significant change of the soil nutrient status and the soil organic carbon (SOC) content during the observation period (Table 1). Though in both organic and conventional farming practices the SOC level decreased with increase of soil depth, the rate of reduction in the organically

Table 1: Depth wise variation of soil organic carbon organic carbon (SOC: g/kg), mineralizable nitrogen (MN: kg/ ha), available phosphorus (AP: kg/ ha) and available potassium (AK: kg/ha) in organic (O) and conventional (C) farming systems

Depth	SOC		MN		AP		AK	
(cm)	O	C	O	C	O	C	O	C
	Winter							
0-4	9.71±0.19	5.03±0.11	161.69±1.15	137.35±3.06	32.31±0.15	22.62±0.13	187.49±5.51	150.17±2.08
4-8	9.27±0.21	4.02±0.01	150.67±1.53	135.39±2.23	31.28±0.58	21.51±0.32	158.05±0.09	136.11±0.02
8-12	8.29±0.36	5.01±0.05	144.35±2.08	139.09±1.51	27.15±0.01	19.33±0.03	148.04±1.52	125.13±2.64
12-16	7.47±0.03	4.69±0.08	132.83±1.26	133.67±0.58	25.38±0.58	18.32±0.11	133.62±1.53	115.15±0.04
16-20	7.40±0.03	4.35±0.03	131.68±0.58	131.81±0.29	23.61±0.03	17.75±0.01	122.36±0.03	109.52±0.02
	Summer							
0-4	7.73±0.15	4.02±0.01	147.02±0.11	127.29±0.58	25.43±0.01	19.52±0.01	129.04±0.03	113.67±0.02
4-8	7.37±0.55	3.93±0.06	138.05±0.02	126.39±1.15	21.51±0.01	17.250.02	108.31±0.41	106.61±0.51
8-12	7.11±0.18	3.80±0.11	138.19±0.01	127.16±0.01	19.68±0.58	16.59±0.01	111.71±0.02	102.12±0.01
12-16	6.85±0.02	3.39±0.12	129.32±0.05	124.28±0.03	20.710.58	15.16±0.01	108.67±1.51	98.39±0.01
16-20	6.53±0.14	3.53±0.01	129.35±0.01	122.34±0.04	20.15±0.58	15.18±0.02	95.34±0.03	85.33±0.04
	Rainy							
0-4	9.45±0.05	9.45±0.05	153.62±0.01	130.67±0.05	33.33±0.01	22.67±0.58	152.88±0.03	145.64±0.02
4-8	8.02±0.02	4.77±0.01	152.28±0.01	130.39±0.58	30.67±0.53	21.31±0.25	131.43±1.53	125.35±0.03
8-12	7.89±0.06	4.61±0.02	147.67±0.11	131.65±0.05	26.28±0.01	17.19±0.01	148.52±0.03	115.38±0.01
12-16	7.03±0.02	4.45±0.06	144.31±0.02	126.25±0.01	24.68±0.01	17.29±0.51	115.67±0.02	104.75±0.02
16-20	7.02±0.01	3.89±0.02	139.39±0.01	124.51±0.01	23.66±0.05	16.15±0.01	110.62±0.01	92.68±0.02

Table 2: Depth wise variation of bacterial (x 10^4 cfu/g soil) and fungal population (x 10^3 cfu/g soil), dehydrogenase (µg TPF/g soil) and protease activity (µg tyrosine/g soil) in organic (O) and conventional (C) farming systems

Depth	Bacteria		Fungi		Dehydrogenase		Protease	
(cm)	O	C	O	C	O	C	O	C
	Winter							
0-4	295.35±13.23	191.65±10.13	57.39±3.23	41.01±3.15	19.07±1.78	11.39±1.54	117.36±5.34	82.92±7.45
4-8	295.35±12.51	186.61±7.58	53.38±3.35	38.03±4.35	16.79±1.81	9.08±1.34	107.34±4.34	76.23±3.24
8-12	280.41±11.15	173.08±6.84	42.26±4.67	37.31±5.89	16.53±0.97	8.56±0.89	104.45±6.23	72.89±2.78
12-16	251.66±8.21	162.27±7.12	38.15±2.27	35.61±2.15	15.87±0.89	7.79±0.45	103.43±7.11	69.56±2.67
16-20	231.29±8.56	151.15±6.83	37.51±2.34	35.43±2.14	11.82±1.15	6.12±0.76	85.89±5.56	62.87±1.89
	Summer							
0-4	64.31±2.37	44.61±3.12	34.15±2.22	31.39±2.15	8.05±0.56	6.69±2.02	69.56±4.32	57.39±3.12
4-8	66.72±3.11	60.75±3.35	36.45±1.89	33.08±2.03	9.36±0.58	7.13±1.23	75.11±4.26	64.36±3.11
8-12	76.45±3.68	66.43±3.56	36.64±2.89	37.57±3.45	10.36±0.62	7.43±1.04	79.56±3.17	64.66±1.07
12-16	80.62±4.31	69.59±4.11	35.31±3.11	35.63±4.11	11.13±1.38	8.04±1.03	82.89±3.67	66.27±1.34
16-20	84.13±3.45	71.01±4.31	36.03±3.67	35.29±3.78	11.89±0.71	8.25±1.05	86.22±5.11	67.37±2.11
	Rainy							
0-4	282.15±9.22	174.31±9.24	45.04±2.67	35.11±2.56	24.71±1.17	12.92±0.76	139.56±7.31	89.59±1.04
4-8	280.15±6.53	176.79±9.81	44.37±2.41	35.02±2.34	23.69±0.76	10.81±1.31	136.22±6.13	80.67±2.03
8-12	270.79±8.67	165.46±9.36	41.11±2.71	37.05±2.67	23.45±0.45	9.39±1.02	135.17±6.17	74.23±2.04
12-16	245.14±7.34	159.24±8.24	36.43±1.67	34.31±1.89	22.92±0.79	8.82±1.03	134.35±5.78	71.78±1.04
16-20	201.52±7.12	121.02±7.11	35.04±2.17	34.62±2.07	20.16±0.78	7.53±1.02	124.76±4.89	65.13±1.05

cultivated field was significantly higher than of conventional one. Corresponding changes were also reported with respect to soil nutrient levels. Araujo *et al.,* (2009) observed that SOC levels not only facilitate the microbial activity but also lower bulk density. Further, the SOC levels in organic farming steadily increases with continuation of the farm practice causing positive soil conditioning. However, the differences of the mineralizable nitrogen (MN), available potassium (AK) and available phosphorus (AP) between the two farming types were found less than of the SOC indicating that the conventionally managed soil could enjoy an acceptable level of nutrients despite of significantly low quantity of SOC due to the reinforcement of soil with chemical fertilizers to maintain crop production.

Table 3: Analysis of variance of parameters of legume field soil

		S	D	OC	SxD	SxOC	DxOC	SxDxOC
Bacteria	S.E(M)±	0.63	0.81	0.52	1.41	0.89	1.15	2.00
	C.D	1.79	2.31	1.46	4.00	2.53	3.27	5.66
	F	17944.4*	293.3*	8909.9*	194.19*	1523.1*	26.64*	8.41*
	C.V (%)	2.09						
Fungi	S.E(M)±	0.35	0.46	0.29	0.80	0.51	0.65	1.13
	C.D	1.01	1.31	0.83	2.27	1.43	1.85	3.21
	F	83.19*	24.87*	129.55*	19.88*	26.72*	20.95*	3.66*
	C.V (%)	5.15						
SOC	S.E(M)±	0.03	0.04	0.02	0.06	0.04	0.05	0.09
	C.D	0.08	0.11	0.06	0.18	0.11	0.14	0.26
	F	444.4*	214.2*	10919.4*	8.98*	4.65*	59.44*	10.54*
	C.V (%)	2.59						
MN	S.E(M)±	0.29	0.37	0.23	0.64	0.41	0.53	0.91
	C.D	0.82	1.06	0.67	1.83	1.16	1.49	2.59
	F	267.2*	207.13*	1455.4*	9.26*	82.25*	73.73*	11.47*
	C.V (%)	1.16						
AP	S.E(M)±	0.19	0.25	0.16	0.44	0.27	0.37	0.62
	C.D	0.55	0.71	0.45	1.23	0.78	1.08	1.74
	F	182.3*	120.9*	1027.5*	5.38*	31.24*	4.31*	1.88*
	C.V (%)	4.58						
AK	S.E(M)±	0.56	0.72	0.46	1.25	0.79	1.02	1.78
	C.D	1.58	2.04	1.29	3.54	2.24	2.89	5.02
	F	8851.6*	522.4*	598.3*	24.49	35.51*	11.67*	11.41*
	C.V (%)	2.50						
Dehydrogenase	S.E(M)±	0.17	0.22	0.14	0.39	0.24	0.31	0.54
	C.D	0.49	0.63	0.39	1.09	0.69	0.89	1.54
	F	495.8*	20.17*	1517.1*	21.60*	234.5*	1.82ns	1.22ns
	C.V (%)	7.53						
Protease	S.E(M)±	1.14	1.47	0.93	2.55	1.62	2.09	3.62
	C.D	3.24	4.18	2.64	7.24	4.58	5.91	10.23
	F	218.3*	8.23*	762.2*	10.05*	98.63*	2.41ns	0.16ns
	C.V (%)	7.10						

Note: ns =Not significant; * = significant at p = 0.01. Abbreviations: SOC-soil organic carbon; MN-mineralizable nitrogen; AP- available phosphorus; AK- available potassium

Table 4: Coefficient of correlation of bacteria and fungi count with soil nutrients in organic (O) and onventional (C) systems

Soil nutrients	Organic carbon		Mineralisable nitrogen		Available Phosphorus		Available Potassium	
	O	C	O	C	O	C	O	C
Bacteria								
Winter	0.99**	0.79 ns	0.97**	0.68ns	0.77ns	0.91*	0.95**	0.99**
Rainy	0.89*	0.53 ns	0.97**	0.76ns	0.95**	0.25ns	0.85*	0.32ns
Summer	-0.56 ns	-0.57 ns	-0.51 ns	-0.25ns	-0.93*	-0.81*	-0.71ns	-0.55ns
Fungi								
Winter	0.98**	0.65ns	0.90*	0.58ns	0.83*	0.69ns	0.97**	0.99**
Rainy	0.90*	-0.27ns	0.95**	-0.30ns	0.96**	-0.34ns	0.75ns	0.95**
Summer	0.90*	-0.97**	0.80ns	-0.87*	0.39ns	-0.95**	0.96**	-0.96**

Note: * = significant at $p < 0.05$, ** = significant at $p< 0.01$, ns = not significant.

The bacteria (x 10^4 cfu/g dry soil) and fungi (x 10^3 cfu/g dry soil) population were consistently higher in organically managed soil than of conventionally cultivated legume field in all the seasons as well as in all the sampled soil depths (Table 2). There was significant depth wise variation of the microbial density with highest count observed in top 4 cm soil layer in both the farming types. However, in summer the innermost soil layer of the legume fields was denser in microbes. In all seasons and soil layers the microbial density of organically cultivated fields was significantly higher. The bacterial density of conventionally managed legume field soil was only 65% of that of an organically managed field. Similarly the fungal density of the

Table 5: Coefficient of correlation of bacteria and fungi count with dehydrogenase and protease activity in organic (O) and conventional (C) systems

Enzymes	Microbes	Bacteria		Fungi	
		O	C	O	C
Dehydrogenase	Winter	0.87*	0.94**	0.89*	0.97**
	Rainy	0.97**	0.79ns	0.98**	0.60ns
	Summer	0.98**	0.92**	0.96**	0.91*
Protease	Winter	0.82*	0.97**	0.81ns	0.97**
	Rainy	0.88*	0.20ns	0.84*	0.72ns
	Summer	0.60ns	0.63ns	0.60ns	0.53ns

Note: * = significant at $p < 0.05$, ** = significant at $p< 0.01$, ns = not significant.

conventional legume field was 72% of that of organic field indicating that the bacteria are more sensitive to the farm practices than of soil fungi. The difference in the annual average of the microbial count of two farming systems was more prominent in the top 4 cm of soil than in other soil depths and also there was consistently higher density of microbes in organically cultivated field than conventional ones.

The activities of dehydrogenase (μg TPF/g soil) and protease enzymes (μg tyrosine/g soil) progressively declined with increasing soil depth, and the innermost soil layer exhibited minimum activity in winter and rainy seasons but a reverse trend was observed in summer (Table 2). This was in conformity with the pattern of the microbial counts in both the farming practices. There was significant difference between the organically cultivated soil and conventionally grown soil with the activity of soil enzymes and the rate of reduction also differed with increase in the soil depth particularly in rainy season. Further, organically cultivated legume field soils exhibited higher enzyme activity during all the seasons in comparison to the soil under conventional cultivation.

In tropical climate the winter season provides the moderate temperature and soil moisture conditions facilitating the microbial growth and activity. The distribution of microbial population in soil is determined by important environmental factors such as soil moisture, pH and organic matter. In this finding significantly higher microbial count was reported in the rainy season, which was same as for other tropical agroecosystems (Table 3) (Arunachalam *et al.*, 1997; Liu *et al.*, 2008; Araujo *et al.*, 2009). Increase in number of microbial population in summer towards deeper soil layers corroborates that during hot summer months, the sub- layer of soil harbours more fungal population caused by favourable temperature and moisture regimes than the top soil layer (Classen *et al.* 2007). The correlation between microbial population with soil nutrients (SOC, MN, AP, AK) (Table 4) and enzyme activites (Table 5) were significant in rainy and winter seasons which supports the results of Cheng and Cao (2007).
Generally, top soil contains high organic matter which, in presence of adequate moisture supply, is acted upon by microbes to decompose complex organic residues into simpler forms resulting in the release of essential nutrients. Therefore, microbial counts are higher in the surface soil layer than in the inner ones. Further, overall reduction in microbial population in the lower soil depths has been attributed to lesser amounts of minerals, oxygen availability and higher carbon dioxide concentration (Shukla *et al.*, 1989). Our results showed that organic farms contain higher levels of soil organic matter, which are essential for microbial growth and activity. The retention of organic matter has also been reported to be higher in organic farms in comparison to conventional farms (Pavel *et al.*, 2004; Shi *et al.*, 2006).

The decrease in microbial enzyme activity with increased soil depth was attributed to higher abundance of soil microorganisms and organic matter content at upper soil layers. In periods of higher soil moisture and lower temperature there was greater enzyme activity in all soil depths. Matinizadeh *et al.*, (2008) reported that soil enzyme activity is a measure of the intensity of microbial metabolism in soil and is favoured by high soil moisture and favourable temperature regime as well as the organic matter content. Our results also showed that soil enzyme activities depend on soil composition and agronomic practices.

CONCLUSION

Enzymatic activity is an important indicator of soil microbiological properties. Dehydrogenases are enzymes

produced by various microorganisms and act intra cellular. From the present research it is evident that soil enzyme activities are influenced by the agriculture practices, and decrease with soil depth. Dehydrogenases originate from soil microbes and these help soil organisms in their efforts to satisfy their nutritional needs. It is therefore apparent that soils with organic farming have higher quantity of soil nutrients and microbial activity, which subsequently enhance soil enzyme synthesis and accumulation. The present findings also indicated that besides high productivity in conventional or integrated faming, organic farming is more superior and ecofriendly practice.

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