LONG-TERM EFFECT OF ORGANIC AND CONVENTIONAL FARMING PRACTICES ON MICROBIAL BIOMASS CARBON, ENZYME ACTIVITIES AND MICROBIAL POPULATIONS IN DIFFERENT TEXTURED SOILS OF HARYANA STATE (INDIA)

SHEORAN, H. S.[1*] – PHOGAT, V. K.[1] – DAHIYA, R.[1] – GERA, R.[2]

[1]*Department of Soil Science, CCS Haryana Agricultural University*
Hisar, Haryana 125004, India

[2]*Department of Microbiology, CCS Haryana Agricultural University*
Hisar, Haryana 125004, India

**Corresponding author*
e-mail: sheoranhardeep2008@gmail.com

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Abstract. The aim of the present study was to evaluate the impact of management practices on soil biological properties of texturally different soils of Haryana. Surface soil samples were collected from 25 organic farms and their adjoining conventional farms at 11 districts of Haryana and assayed for microbial biomass carbon (MBC), dehydrogenase and phosphatase activities along with total bacterial, actinomycetes and fungi populations in soil. The overall dehydrogenase and phosphatase activities at different locations were found to increase from 35.3 to 56.1 µg TPF g^{-1} soil 24 hr^{-1} and from 275.8 to 364.1 µg PNP g^{-1} soil, respectively under organic farming i.e. an increase of 57.5 and 32.01%. Overall a significantly higher MBC (69.1 %) was observed under organically managed soils (274 mg kg^{-1}) compared to conventional (162 mg kg^{-1}). The total bacterial, fungal and actinomycetes counts increased by 56.9, 55.2 and 49.5%, respectively, in comparison to those in the conventionally managed soils. The study concluded that soils under organic farming were found to be superior in terms of biological properties than conventionally managed soils which are essential for enhancing soil production and other functions in the given ecosystem.
Keywords: *management practices, microbial growth, organic farming, soil quality*

Introduction

Land management practices in present day agriculture are getting more and more important where food grain production and fertilizer use run parallel to meet the food requirements of over increasing population of India and leading to over exploitation of our natural resources like soil and water and therefore, soil is degrading day by day with respect to its fertility and productivity. This may be attributed to the fact that removal of nutrient resources from the soil strata is higher than their replenishment, so soil is becoming deficient in major available macro and micronutrients, which consequently leads to the decline of organic matter in soil and the overuse of chemical fertilizers and pesticides are adversely affecting the ecosystem (Yang et al., 2000). Thus, most soils are far from being ideal in fertility and should therefore be improved only by adopting appropriate management practices which includes amendments, like organic manures for enhancing the activity of "soil life". Enzymes and microorganisms like bacteria, actinomycetes and fungi present in soil are sensitive to changing soil environment and hence are considered to be one of the best soil health indicators. These microbes found to have direct role in sustaining soil fertility and its production by playing a crucial role in transformation of various nutrients and thereby improving the soil functioning in a

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given ecosystem. Thus, the study of the microbes and responses of enzymatic activities to disturbing agricultural activities is vital to understand how management practices contribute to sustaining soil fertility and productivity to improve soil (Wardle et al., 1999). Microbial populations and their activity are of immense importance in maintaining or sustaining soil health. Providing habitat and transformation of nutrients are complex processes brought about by succession of different micro-organisms in the soil which affect the soil fertility and over use of pesticides in conventional farming may inhibit these vital processes (Baum et al. 2003; Jolankai et al., 2006). Moreover, when soil applied pesticides fail to reach the target, they affect adjacent ecosystems through leaching or aerial drift affecting the diversity and abundance of non-targeted microorganisms causing negative effects on ecosystem processes and trophic interactions (Pimentel and Edwards, 1982). Different land management practices and continuous cultivation without any addition to soils are imposing variations in organic matter levels of soils and subsequent loss of soil organic carbon from the fields under intensive agricultural practices and leads to the alteration of microbial biomass (Srivastava and Singh, 1989). Therefore, there is a growing intention among farmers and researchers to adopt alternative farming practices that enhance or improve the biological properties of soils and thereby sustain soil health and productivity. Among different farming systems, organic farming is popular and its adoption level is increasing day by day to achieve the target of sustainability. In India, it has been estimated that cultivated area under certified organic farming has grown almost 17 fold in the last decade (0.042 mha in 2003-04 to 1.49 mha in 2016-17). The State of Haryana, one of the major agriculture based state of the country situated in the NCR region. It has about 4000 ha of land under organic farming (Anonymous, 2016). The key characteristics of organic farming include protecting the long-term fertility of soils by maintaining organic matter, fostering soil biological activity, careful mechanical intervention, providing nitrogen self-sufficiency through the use of legumes and biological nitrogen fixation, effective recycling of organic materials including crop residues, livestock wastes and weed, and diseases and pest control relying primarily on crop rotations, natural predators, diversity and resistant varieties. At present, the most optimistic estimates show that about 25-30 percent of nutrient needs can be met by various organic sources. Many researchers reported that in organically managed fields activity of earth worms is higher than in inorganic field (Edwards and Lofty, 1974; Kotcon, 2011; Rai et al., 2014; Velmourougane, 2016). In the biodegradation process, earthworms and microbes work together and produce vermicompost, which provides macro (N, P, K, Ca, and Mg) and micro nutrients (Fe, Mn, Zn, and Cu) (Amir and Fouzia, 2011). In organic farming, use of manures and crop residues instead of a synthetic fertilizer is reported to reduce groundwater contamination, improve microbial activity, recycle dairy/poultry wastes, and improve soil properties (Poudel et al., 2002). However, the information regarding the long-term effect of organic farming practices on soil biological properties and its feasibility are very scanty. Keeping in view the above concerns, the present study was planned to evaluate the long-term impact of management practices on soil biological properties like microbial biomass carbon (MBC), dehydrogenase and phosphatase activities along with bacterial, actinomycetes and fungi populations in fields particularly of vegetables and horticultural crops with texturally different soils in Haryana.

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Materials and Methods

Study area

Organic farms under different cropping systems, vegetables and horticultural crops and their adjoining conventional farms were identified at eleven districts of Haryana, namely, Sirsa, Fatehabad, Hisar, Jind, Kaithal, Karnal, Kurukshetra, Ambala, Panchkula, Yamunanagar and Panipat and their soil properties were studied. Locations of different sampling sites are presented in *Figure 1*. A total of 150 soil samples (three replications) of 0-15 cm depth were collected from the two types of farming systems, which were pooled to make 50 composite samples and analysed for microbial biomass, dehydrogenase and alkaline phosphatase activity, total bacterial, fungal and actinomycetes counts. The texture of soils varied between sand to clay loam, representing almost all the soil types of the State and is presented in *Table 1*.

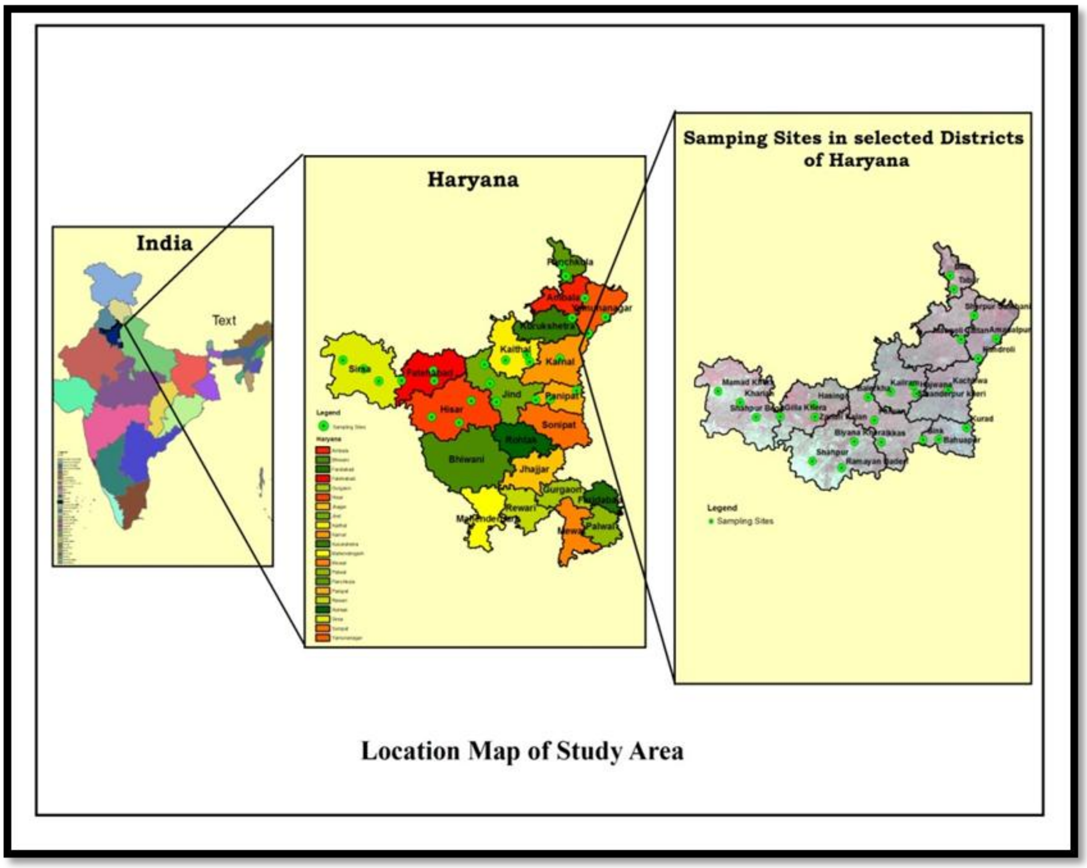

Figure 1. *Sampling sites in selected districts of Haryana*

Collection of soil samples

The soil samples collected were representative of the area sampled. A field was treated as a single sampling and recently fertilized fields, bunds, channels, areas near trees, farm ways, buildings, wells, compost piles or other non-representative locations were avoided during sampling. Three soil samples were taken randomly from field and finally one composite sample was prepared.

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Table 1. *Soil texture at different locations under conventional and organic farming systems*

Location	District	Village	Texture
L_1	Panchkula	Billa	Sand
L_2	Sirsa	Mamad Khera	Sand
L_3	Panipat	Kurad	Loamy sand
L_4	Panchkula	Tabar	Loamy sand
L_5	Sirsa	Kharian	Loamy sand
L_6	Fatehabad	Zandli Kalan	Loamy sand
L_7	Fatehabad	Hasinga	Loamy sand
L_8	Hisar	Shahpur	Loamy sand
L_9	Hisar	Biyana Khera	Sandy loam
L_{10}	Panipat	Bahuapur	Sandy loam
L_{11}	Jind	Ikkas	Sandy loam
L_{12}	Yamunanagar	Amadalpur	Sandy loam
L_{13}	Jind	Balerkha	Loam
L_{14}	Kaithal	Kailram	Loam
L_{15}	Kurukshetra	Mangoli Jattan	Loam
L_{16}	Kaithal	Hajwana	Loam
L_{17}	Hisar	Ramayan Daderi	Loam
L_{18}	Panipat	Sink	Silt loam
L_{19}	Yamunanagar	Kandroli	Silt loam
L_{20}	Fatehabad	Gilla Khera	Silt loam
L_{21}	Sirsa	Shahpur Begu	Sandy clay loam
L_{22}	Kaithal	Sikanderpur kheri	Sandy clay loam
L_{23}	Jind	Palwan	Clay loam
L_{24}	Karnal	Kachhwa	Clay loam
L_{25}	Ambala	Sherpur Sulkhani	Clay loam

Processing of soil samples

After collection soil samples were kept refrigerated at 0°C for analysis of the microbiological properties. Growth media used for the total bacterial, fungal and actinomycetes counts are given in *Table 2*.

Table 2. *Growth media used for microbial analysis*

Sr. No.	Microbe	Medium
1.	Bacteria	Nutrient Agar
2.	Fungi	Potato Dextrose Agar
3.	Actinomycetes	Ken-Knight's Medium

Soil enzymatic activities

Dehydrogenase activity

Dehydrogenase activity was determined by using the method of Casida et al. (1964). Five gram soil was taken and mixed with 3% solution of 2,3,5-triphenyl tetrazolium chloride and 2.5 ml of distilled water, and incubated for 24 h at 37°C temperature in an incubator. After incubation, 10 ml methanol was added and shaken for 1 minute and filtered through Whatman No. 1 filter paper. The absorbance was measured at 485 nm by using a spectrophotometer.

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Alkaline phosphatase activity

Alkaline phosphatase activity was determined by using the method of Tabatabai and Bremner (1969). Enzyme activity was measured by taking 1 g of soil in a flask and adding 0.2 ml of toluene, 4 ml of modified universal buffer (MUB), 1 ml of p-nitrophenyl phosphate solution to it. After incubating for 1 hour, 1 ml of 0.5 M $CaCl_2$ and 4 ml of 0.5 M NaOH were added. After stirring for a few seconds, suspension was filtered through Whatman No. 1 filter paper and absorbance of the filtrate was measured at 420 nm using a spectrophotometer.

Microbial biomass carbon (soil fumigation-extraction method)

Microbial biomass carbon (MBC) was determined by soil fumigation-extraction method (Vance et al., 1987). 10 g of soil was fumigated with 20 ml of $CHCL_3$ in vacuum desiccators for 24 hours in dark and another 10 g of the same soil sample was refrigerated, then both samples (fumigated and non-fumigated) were extracted with 0.5 M K_2SO_4 for half an hour and then the extract was treated with H_2SO_4 and orthophosphoric acid, and heated on hot plate at 120 ^oC for 30 minutes. After diluting to 250 ml with distilled water, 2-3 drops of ferroin indicator was added and titrated against 0.05 N FAS (Ferrous Ammonium Sulphate) and MBC was calculated:

$$MBC(\mu g/g\ soil) = \frac{OC_F - OC_{UF}}{K} \quad \text{(Eq.1)}$$

where,

- OC_F = Total amount of EC (Extractable C) in fumigated soil.
- OC_{UF} = Total amount of EC (Extractable C) in non-fumigated soil.
- K = The proportion of microbial C evolved as CO_2= 0.45 for 10 days of incubation at 25°C (Jenkinson and Ladd, 1981).

Microbial counts

Total bacterial, fungal and actinomycetes counts were estimated using serial dilution plate technique. One gram of soil was transferred into 10 ml of sterilized water in 250 ml flask. Sample was mixed by vigorous shaking and now the sample was diluted ten-fold (10^{-1} dilution). From this, 1 ml of soil suspension was transferred to another 9 ml water blank with the help of sterile pipette and hence sample was diluted to 10^{-2}. Similarly, dilutions were made up to 10^{-7}. Different dilutions were made to estimate the different microbial parameters (*Table 3*).

Table 3. *Dilution used for different microbes in the appropriate nutrient media*

Sr. No.	Microbe	Dilution factor
1.	Bacteria	10^{-6}-10^{-7}
2.	Fungi	10^{-3}-10^{-4}
3.	Actinomycetes	10^{-4}-10^{-5}

Now, 1 ml of different diluted samples i.e.10^{-6}-10^{-7} were transferred in appropriate pre-sterilized labeled Petri-plates in front of laminar flow. Then 25-30 ml of appropriate media was poured into each dilution plate and shaken to ensure uniform dispersal of the

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cells/suspension in the media. These plates were allowed to solidify on working table of the laminar. Further, the plates are incubated in an inverted position (upside down) for 2-5 days at 28 ± 2°C temperature in an incubator and number of colonies on different dilution media plates were recorded and populations per gram soil were enumerated.

Statistical analysis

The significance of treatment effects was analyzed using two factorial RBD analysis with OP Stat, CCS HAU Hisar software (Sheoran et al., 1998). Spatial variability graphs were prepared by using ArcGIS software.

Results and Discussion

Dehydrogenase and phosphatase activity

Data on dehydrogenase activity in soils under the two farming systems given in *Table 4* revealed that organic farming led to significant improvement in dehydrogenase activity over conventional practice. The dehydrogenase activity under organic farming was observed significantly higher than in conventional practice at all the locations with different soil textures. The soil dehydrogenase activity in different locations varied between 18.5 to 46.0 µg TPF g^{-1} soil 24 hr^{-1} in conventional farming while it ranged from 23.8 to 78.6 µg TPF g^{-1} soil 24 hr^{-1} under organic farming. The extent of increase in dehydrogenase activity under organic farming was, however, found to increase with fineness of the texture at different locations. For example, the increase in dehydrogenase activities were 28.6 % in sand (L_1), 55.1 % in loamy sand (L_8), 68.1% in sandy loam (L_{12}), and 76.6% in clay loam soil at location L_{24}. The overall dehydrogenase activity which was 35.3µg TPF g^{-1} soil 24 hr^{-1} under conventional farming at different locations was found to increase to 56.1 µg TPF g^{-1} soil 24 hr^{-1} under organic farming i.e. an increase of 57.5%. The interactive effect of location and farming system on dehydrogenase activity was also found significant. The significant increase in the dehydrogenase activity in texturally different soils of different locations under conventional and organic farming is presented in *Figure 2*.

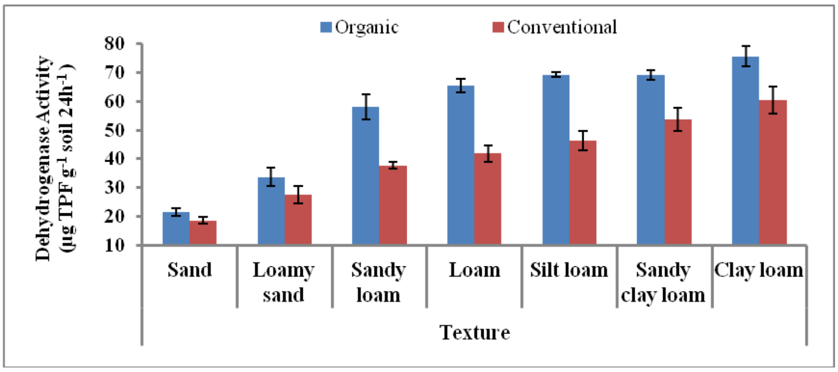

Figure 2. *Dehydrogenase activity in different textured soils under conventional and organic farming*

Moreover, adoption of organic farming showed a significant increase of alkaline phosphatase in different textured soils over the conventional farming. In general, both

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the farming systems were found to enhance the phosphatase activity with increase in clay content of soil but the extent of increase of alkaline phosphatase was greater under organic farming system than in conventional practice .The values of phosphatase activity varies from 132.6 to 453.1 µg PNP g^{-1} soil hr^{-1}among different locations under conventional system of farming while it ranged from 151.8 to 642.8 µg PNP g^{-1} soil hr^{-1} under organic system of farming. The conversion of conventional system of farming to organic farming resulted in a significant increase in phosphatase activity from 275.8 to 364.1 µg PNP g^{-1} soil hr^{-1}. The per cent increase in the phosphatase activity under organic farming over conventional in different textured soils showed an increase of 22.8 % in sand which further increased to 36.8% in clay loam soil. The phosphatase activity in different textured soils of different locations under conventional and organic farming is represented in *Figure 3*.

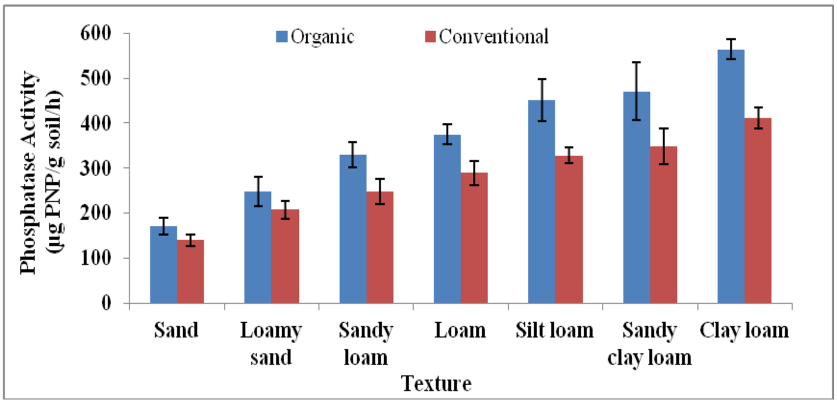

Figure 3. *Phosphatase activity in different textured soils under conventional and organic farming*

The study confirmed the positive influence and higher microbial activity indices of organic farming (higher enzymatic activity, higher soil microbial biomass carbon content) compared to conventional farming system and the higher enzyme activities under organic practices might be attributed to enhanced nutrient availability from added organics, increase in release of root exudates due to improved crop growth and favorable environment for microbial growth (Burns et al., 2013; Tamilselvi et al., 2015).

Farmyard manure and crop residues provide a source of organic matter, and when returned to soil they increase organic C in soil (Banger et al., 2010) and further, the prevalence of organic substrates stimulated soil microorganisms to produce enzymes responsible for the conversion of unavailable nutrients to plant available forms. Most importantly, a closer look at the relationship between physicochemical and biological indicators of soil health evidenced the significance of organic matter to enzyme activities suggesting enhanced nutrient cycling in systems receiving organic amendments (Sihi et al., 2017). Moreover, phosphatase activity in the soils occurs either in response to plant roots exudates or from microbes such as bacteria or fungi (Dinkelaker and Marschner, 1992) and changes in phosphatase activity can indicate changes in the soil phosphoryl substrates (Rao and Tarafdar, 1992).

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Table 4. *Dehydrogenase, phosphatase activities and soil microbial biomass carbon under conventional and organic farming at different locations*

Location (L)	**Dehydrogenase (µg TPF g^{-1} soil 24hr^{-1})**			**Alkaline phosphatase (µg PNP g^{-1} soil hr^{-1})**			**Microbial biomass carbon (mg kg^{-1})**		
	Conventional	**Organic**	**Mean**	**Conventional**	**Organic**	**Mean**	**Conventional**	**Organic**	**Mean**
L_1	18.5	23.8	**21.1**	146.4	191.5	**168.9**	132	152	**142**
L_2	28.7	24.2	**26.5**	132.6	151.8	**142.2**	87	105	**96**
L_3	29.6	36.7	**33.1**	196.2	211.7	**204.0**	99	166	**132**
L_4	22.6	37.9	**30.2**	195.2	286.4	**240.8**	137	173	**155**
L_5	27.4	43.6	**35.5**	236.7	242.6	**239.6**	122	199	**160**
L_6	25.4	38.0	**31.7**	226.7	230.8	**228.7**	114	173	**143**
L_7	28.7	41.5	**35.1**	203.3	244.2	**223.7**	101	198	**149**
L_8	23.3	36.1	**29.7**	165.6	219.7	**192.6**	129	167	**148**
L_9	36.1	52.8	**44.4**	249.1	321.3	**285.2**	111	211	**161**
L_{10}	38.1	56.7	**47.4**	274.8	334.6	**304.7**	109	209	**159**
L_{11}	28.4	59.4	**43.9**	209.4	292.8	**251.1**	146	258	**202**
L_{12}	37.6	63.2	**50.4**	237.6	365.4	**301.5**	137	328	**232**
L_{13}	42.3	62.7	**52.5**	209.2	349.2	**279.2**	132	278	**205**
L_{14}	41.8	67.8	**54.8**	335.1	407.4	**371.2**	176	293	**234**
L_{15}	40.3	63.9	**52.1**	278.6	366.8	**322.7**	268	402	**335**
L_{16}	46.3	67.9	**57.1**	267.3	378.2	**322.5**	212	391	**301**
L_{17}	38.8	60.3	**49.5**	289.4	382.7	**336.0**	183	394	**288**
L_{18}	42.4	68.7	**55.9**	367.2	497.6	**432.4**	145	343	**244**
L_{19}	40.5	70.3	**55.4**	321.1	452.8	**386.9**	168	355	**261**
L_{20}	39.5	68.7	**54.1**	314.1	402.7	**358.4**	176	300	**238**
L_{21}	41.7	64.3	**53.0**	402.2	425.2	**413.7**	204	344	**274**
L_{22}	43.2	69.2	**56.2**	453.1	516.4	**484.6**	176	305	**240**
L_{23}	46.0	76.4	**61.2**	368.2	627.4	**497.3**	269	404	**336**
L_{24}	44.5	78.6	**61.5**	412.3	642.8	**527.5**	256	310	**283**
L_{25}	39.8	71.9	**55.8**	403.7	561.8	**482.5**	271	411	**341**
Mean	**35.3**	**56.1**		**275.8**	**364.1**		**162**	**274**	
CD at 5%	Location (L) = 1.6, Farming system (F) = 4.7, L x F = 7.5			Location (L) = 9.9, Farming system (F) = 2.8, L x F = 14.1			Location (L) = 7.9, Farming system (F) = 2.2, L x F = 11.1		

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These findings agree with several research studies (Mader et al., 2002; Dinesh et al., 2010; Lazcano et al., 2013; Sunita, 2016) where higher microbial biomass and enzyme activities were reported even in a single growing season in response to short-term incorporation of organic manures in organics compared to conventional systems.

This indicates that instant increase in soil enzymatic activities which are associated with a rapid increase in availability of organic substrates required for microbial growth.The dehydrogenase (*Figure 4a*) and phosphatase (*Figure 4b*) activities in soils plotted for organic farming against adjoining soils under conventional farming (intercept set at zero) also showed clearly that organic farming is very effective in enhancing dehydrogenase (y = 0.663x) and phosphatase (y = 0.738x) over conventional system in Haryana (*Figure 4*). Moreover, the spatial variability maps for different location are also presented in *Figure 5* and *Figure 6*.

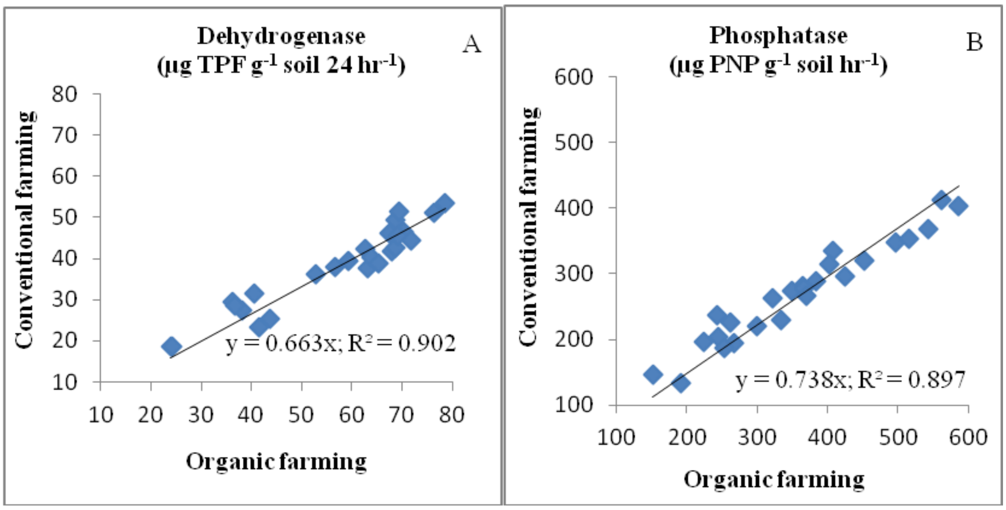

Figure 4. *The relationship of dehydrogenase (A) and phosphatase (B) activities in soils under organic and conventional farming systems*

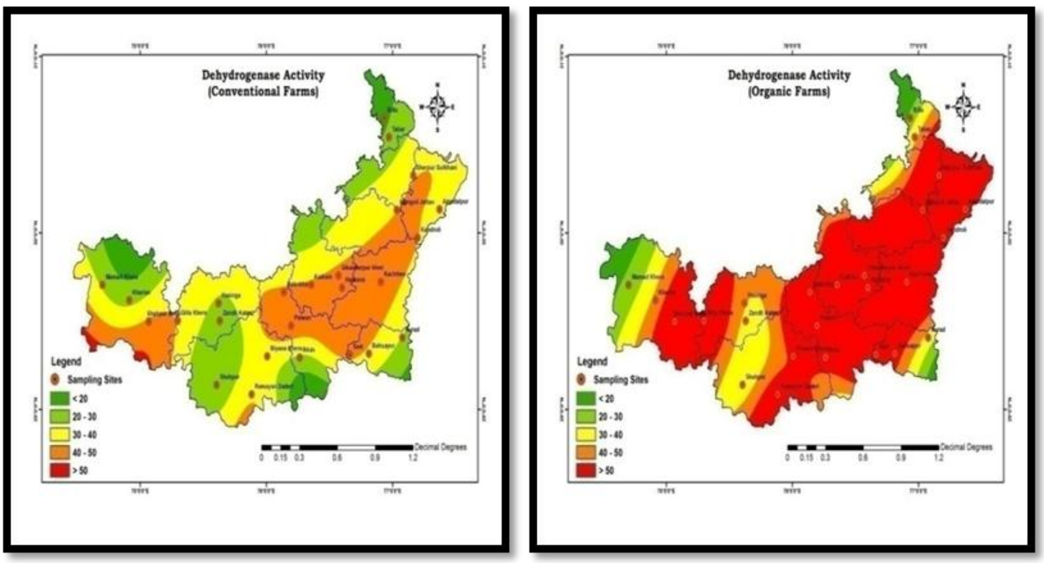

Figure 5. *Spatial variability map of dehydrogenase activity in soils under conventional and organic farming systems at different locations of Haryana*

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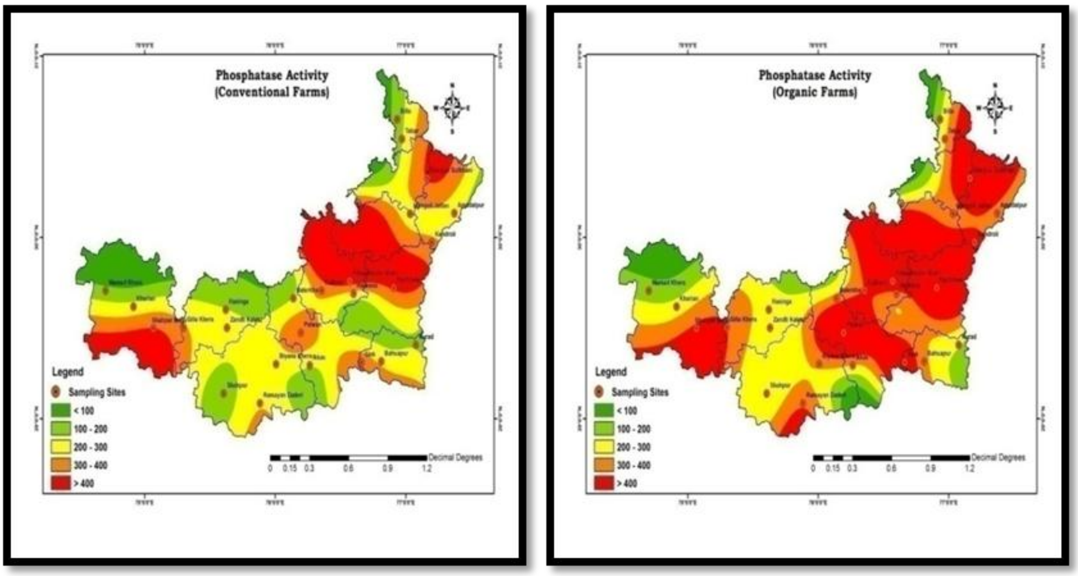

Figure 6. *Spatial variability map of phosphatase activity in soils under conventional and organic farming systems at different locations of Haryana*

Microbial biomass carbon (MBC)

The MBC is one of the fractions of SOC which constitutes a very small portion but considered as a good indicator of soil health. Organic farming had significant effect on soil microbial biomass carbon in texturally different soils at different locations (*Table 4*). Locations with fine textured soils have significantly higher amount of MBC as compared to locations with light textured soils i.e. L_1 to L_{25}. Under conventional farming, the MBC was lowest (87 mg kg^{-1}) in sand at location L_2, while it was highest in clay loam soil at location L_{25} (271 mg kg^{-1}). Similarly, the values of lowest and highest MBC were found to be 105 and 411 mg kg^{-1} in sand (L_2) and clay loam soil (L_{25}) under organic farming. Overall a significantly higher MBC (69.1 %) was observed under organically managed (274 mg kg^{-1}) as compared to conventional (162 mg kg^{-1}). The interactive effect of location and farming system was also found significant and the highest MBC content (411mg kg^{-1}) was observed at location L_{25} under organic farming. Variations in MBC in different textured soils under conventional and organic farming have also been presented in *Figure 7*. MBC serves as an important reservoir of plant nutrients (Marumoto et al., 1982; Okur et al., 2009) and soil microbial C decrease with decrease in fineness of soil texture due to declining C input but observed to be higher in organically managed soils than in conventionally managed due to the permanent input of organic residues with high C/N ratio (Schjonning et al., 2002; Crecchioa et al., 2004; Melero et al., 2006; Araujo et al., 2009; Amaral et al., 2011). Furthermore, higher soil microbial biomass carbon in organic farming is mainly due to the regular application of farmyard manure and large carbon inputs in the form of organic amendment. Additionally, farmyard manure supplies readily available N, resulting higher plant biomass. Consequently, more crop residues are incorporated in soil and thereby higher organic matter levels are maintained (Roldan et al., 2005). This also provides a favorable environment for microorganisms, contributing to a highly diverse and stable microbial community structure in organic farming systems (Wada and Toyota, 2007).

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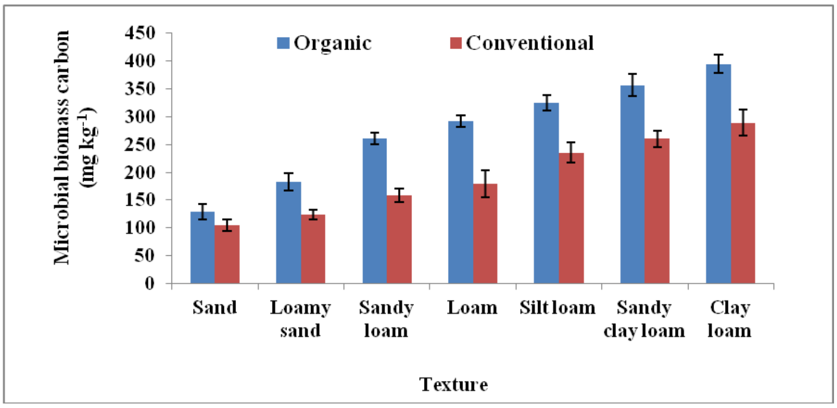

Figure 7. *Microbial biomass carbon in different textured soils under conventional and organic farming*

The plot of the microbial biomass carbon of soils under organic farming against the microbial biomass carbon of the adjoining soils under conventional farming (intercept set at zero) showed that organic farming in general increases microbial biomass carbon (y = 0.638x) of soils (*Figure 8*). The spatial variability maps of MBC for different location are also presented in *Figure 9*.

Total bacterial, fungal and actinomycetes counts

Wide variation of soil microbial populations has been recorded at different locations under organic and conventional farming systems as well (*Table 5*). The consistent increase was noticed in the population of bacteria, fungi and actinomycetes at all the locations under organic farming but the extent of increase was more pronounced in heavy textured soils subjected to organic manures such as FYM, neem cake or vermicompost.

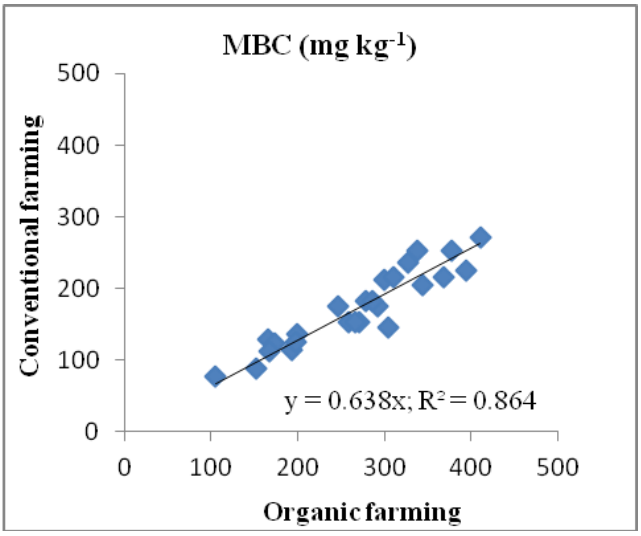

Figure 8. *The relationship of microbial biomass carbon activities in soils under organic and conventional farming systems*

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Table 5. *Effect of organic and conventional farming practices on microbial population in soil at different locations*

Location (L)	Bacteria (CFU g^{-1} soil × 10^6)			Fungi (CFU g^{-1} soil × 10^3)			Actinomycetes (CFU g^{-1} soil × 10^4)		
	Conventional	**Organic**	**Mean**	**Conventional**	**Organic**	**Mean**	**Conventional**	**Organic**	**Mean**
L_1	6.00	8.75	**7.38**	5.81	6.23	**6.02**	7.89	11.55	**9.72**
L_2	5.75	6.75	**6.25**	4.54	5.69	**5.12**	5.84	9.62	**7.73**
L_3	9.89	13.11	**11.50**	8.01	10.62	**9.32**	8.11	12.59	**10.35**
L_4	11.61	17.84	**14.73**	9.40	14.45	**11.93**	12.08	17.94	**15.01**
L_5	10.96	16.77	**13.87**	8.88	13.58	**11.23**	10.18	14.23	**12.20**
L_6	12.42	20.16	**16.29**	10.06	16.33	**13.19**	10.35	13.28	**11.82**
L_7	14.19	21.92	**18.06**	11.50	17.75	**14.63**	13.63	21.56	**17.59**
L_8	8.81	15.94	**12.38**	7.14	12.91	**10.03**	9.31	15.61	**12.46**
L_9	13.33	17.84	**15.59**	10.80	14.45	**12.63**	14.32	19.84	**17.08**
L_{10}	16.72	24.37	**20.54**	13.54	19.74	**16.64**	17.02	23.12	**20.07**
L_{11}	12.26	19.99	**16.13**	9.93	16.20	**13.06**	14.16	20.87	**17.52**
L_{12}	14.53	21.10	**17.82**	11.76	17.10	**14.43**	12.85	20.32	**16.59**
L_{13}	14.86	22.04	**18.45**	12.04	17.85	**14.94**	10.35	21.17	**15.76**
L_{14}	16.12	25.70	**20.91**	13.06	20.81	**16.94**	16.44	26.57	**21.50**
L_{15}	18.49	29.03	**23.76**	14.98	23.51	**19.24**	15.35	23.29	**19.32**
L_{16}	13.61	22.58	**18.10**	11.03	18.28	**14.66**	14.66	24.32	**19.49**
L_{17}	14.90	21.07	**17.98**	12.07	17.07	**14.57**	16.96	22.62	**19.79**
L_{18}	14.26	19.35	**16.80**	11.55	15.68	**13.61**	19.49	27.43	**23.46**
L_{19}	16.81	24.51	**20.66**	13.62	19.85	**16.74**	14.83	25.53	**20.18**
L_{20}	18.49	30.74	**24.62**	14.98	24.90	**19.94**	18.78	27.77	**23.28**
L_{21}	15.48	31.39	**23.44**	12.54	25.42	**18.98**	20.46	29.64	**25.05**
L_{22}	18.49	33.81	**26.15**	14.98	27.39	**21.19**	20.87	31.39	**26.13**
L_{23}	20.37	35.47	**27.92**	16.50	28.74	**22.62**	26.15	43.99	**35.07**
L_{24}	28.16	40.42	**34.29**	22.81	32.74	**27.78**	24.53	35.66	**30.09**
L_{25}	25.16	39.13	**32.15**	20.38	31.69	**26.04**	22.60	41.06	**31.83**
Mean	**14.87**	**23.19**		**12.08**	**18.76**		**15.09**	**23.24**	
CD at 5%	Location (L) = 1.57, Farming system (F) = 0.44, L x F = 2.22			Location (L)= 1.34, Farming system (F) = 0.38, L x F = 1.90			Location (L)= 1.91, Farming system (F) = 0.54, L x F = 2.7		

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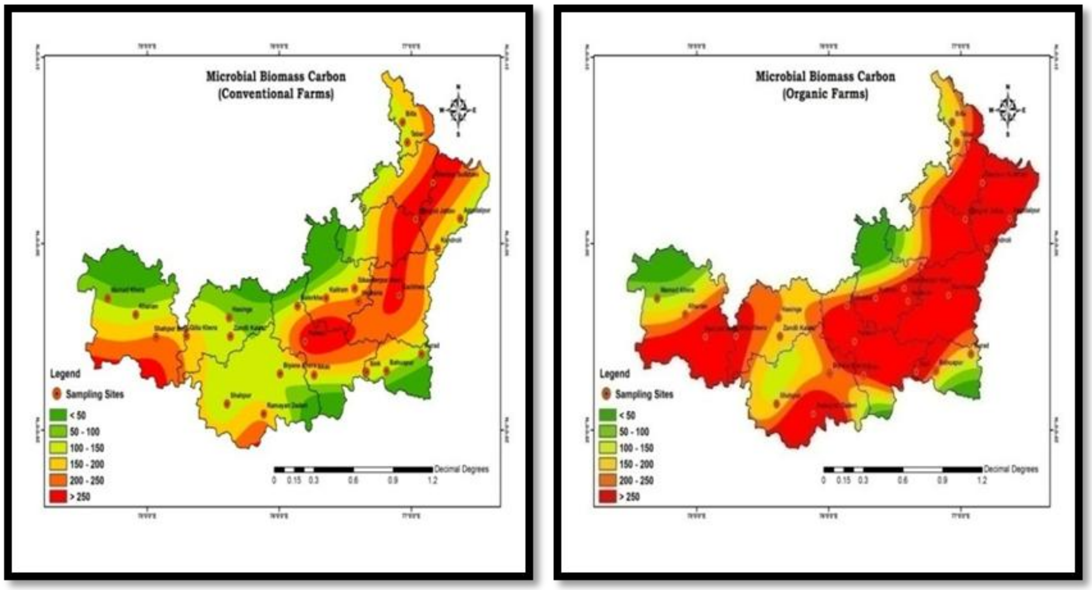

Figure 9. *Spatial variability map of MBC in soils under conventional and organic farming systems at different locations of Haryana*

The mean value of different locations pertaining to population of bacteria was observed to be 14.87×10^6 CFU g^{-1} soil under conventionally managed soils which was significantly increased to 23.34×10^6 CFU g^{-1} soil upon conversion to organic farming. Similarly, fungi population was significantly increased from 12.08×10^3 CFU g^{-1} soil to 18.76×10^3 CFU g^{-1} soil and actinomycetes population from 15.09×10^4 CFU g^{-1} soil to 22.57×10^4 CFU g^{-1} soil under organic farming as compared to conventional farming practices. The average populations of bacteria, fungi and actinomycetes in the soils at different locations under organic farming were 56.9%, 55.2% and 49.5%, respectively, higher than those in the conventionally managed soils. In different textured soils, the bacteria showed variations from 6.25×10^6 in sand to 24.56×10^6 CFU g^{-1} soil in clay loam soil whereas fungal and actinomycetes population varied from 5.17×10^3 in sand to 23.58×10^3 in clay loam soil and 6.86×10^4 in sand to 28.89×10^4 CFU g^{-1} soil in clay loam, respectively, under conventional farming (*Figures 10 to 12*).

Addition of various nutrient inputs through various sources such as FYM, neem cake and vermicompost under organic farming practices exhibited huge variation and resulted in rapid stimulation of microbial growth and subsequently, the increase in bacteria, fungi and actinomycetes population was observed to be 7.75×10^6, 5.96×10^3 and 8.28×10^4 CFU g^{-1} soil in sand to 38.34×10^6, 31.06×10^3 and 35.89×10^4 CFU g^{-1} soil, respectively, in clay loam soil. The significant increase in population of these microorganisms under organic farming, however, observed to be significant only in loamy soils as compared to conventional farming system.

Growth of bacteria, fungi and actinomycetes on different nutrient media has also been shown in *Plates 1 to 3*. The average populations of bacteria, fungi and actinomycetes in the soils at different locations under organic farming were 56.9%, 55.2% and 49.5%, respectively, higher than those in the conventionally managed soils.

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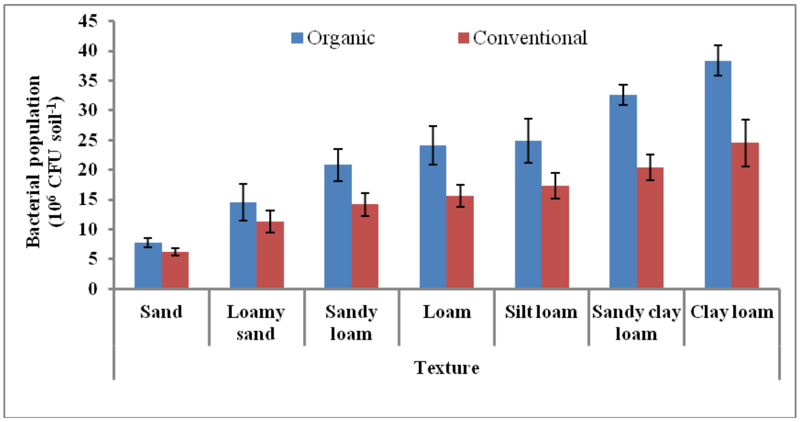

Figure 10. *Bacterial populations in different textured soils under conventional and organic farming systems*

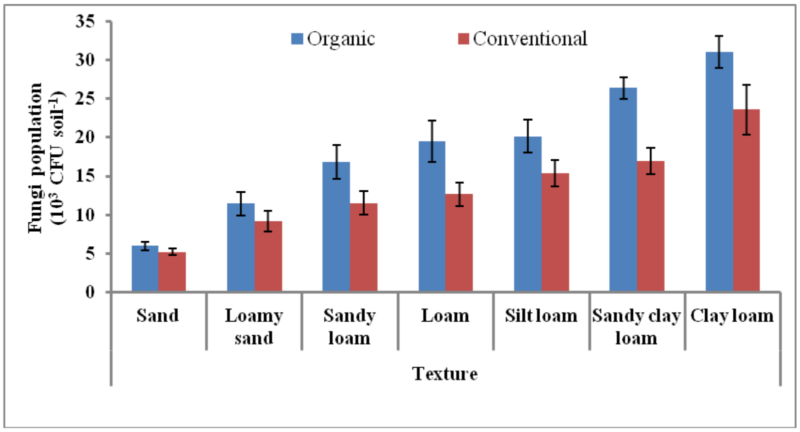

Figure 11. *Fungal populations in different textured soils under conventional and organic farming systems*

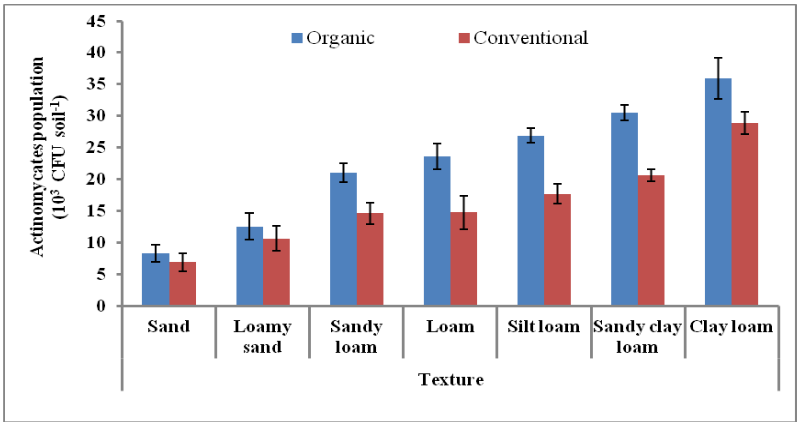

Figure 12. *Actinomycetes populations in different textured soils under conventional and organic farming systems*

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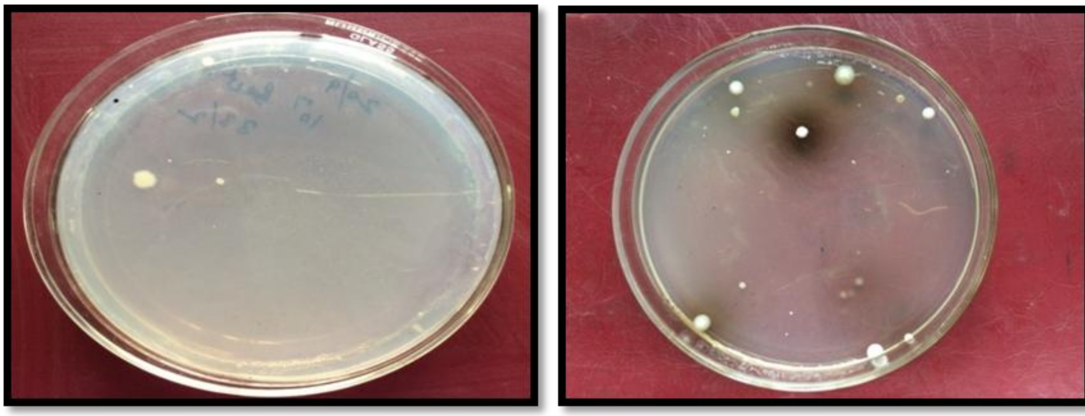
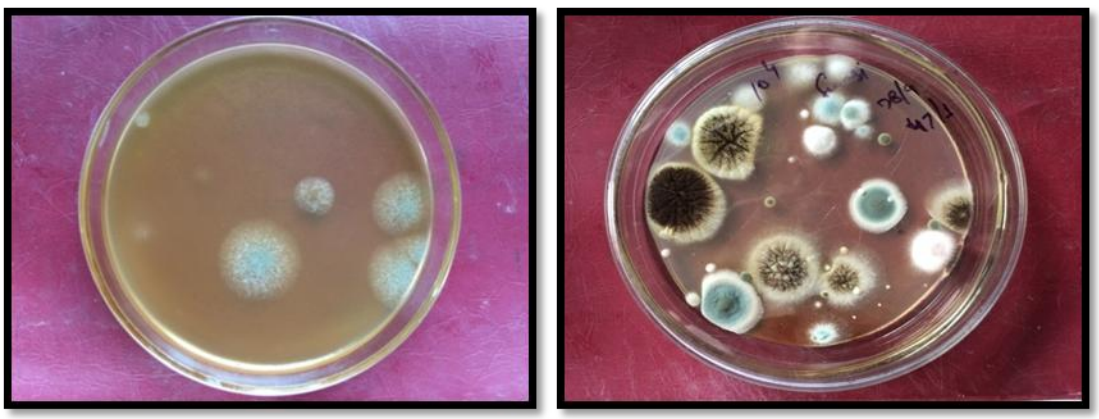


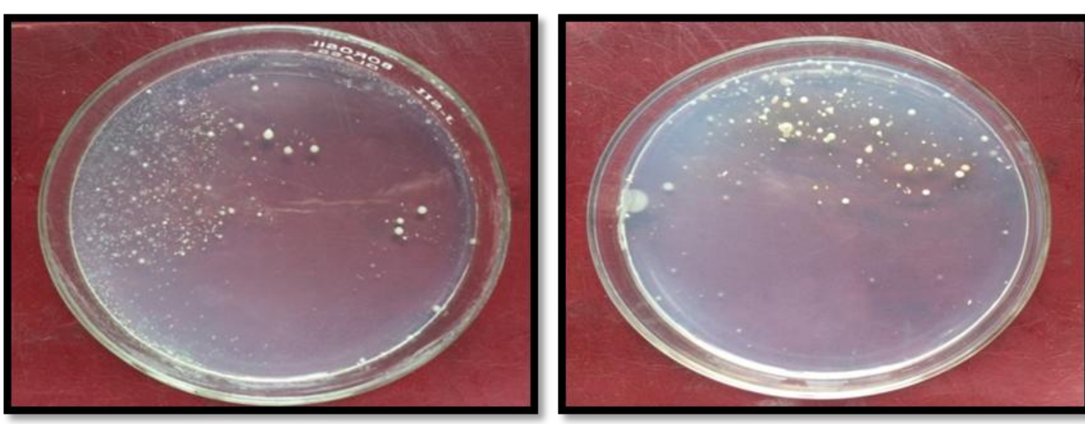
Conventional *Organic*

Plate 1. *Growth of different bacterial species on nutrient agar media*



Conventional *Organic*

Plate 2. *Growth of different fungal species on potato dextrose media*



Conventional *Organic*

Plate 3. *Growth of different actinomycetes species on kenknight media*

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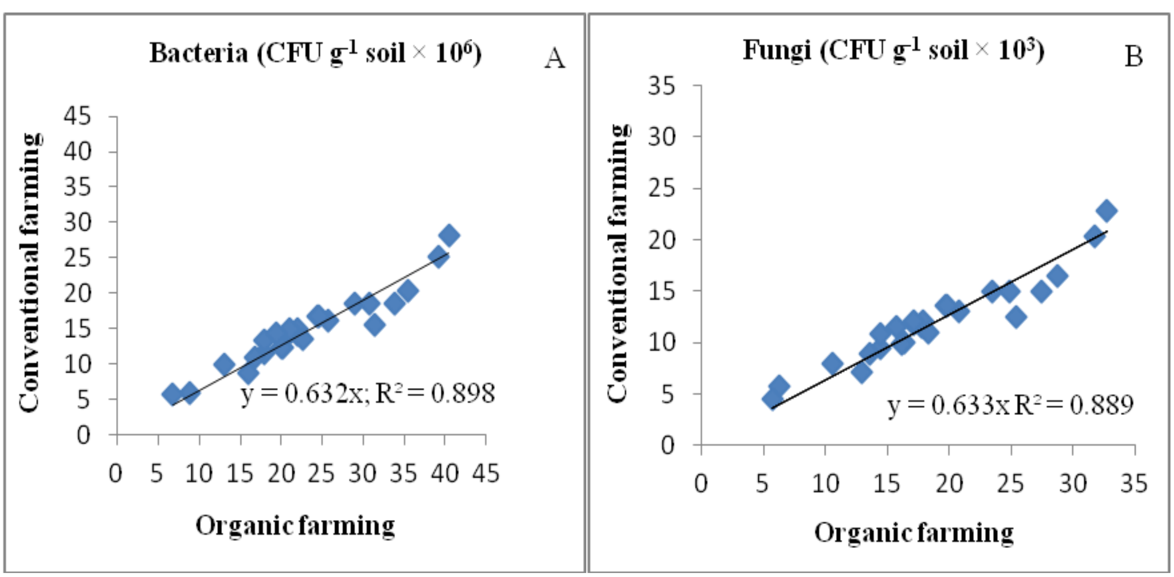
The addition of FYM, neem cake, vermicompost and other organic sources of nutrients enhanced growth of microbial populations which may be attributed to the increment in organic matter in soil that serves as a food and energy source for microbes. These results are supported by the findings of Bobulska et al. (2015). In recent years, multiple studies comparing conventional and organic agriculture have reported differences in soil properties, increased microbial activity and diversity in organically managed soils, or distinct microbial profiles between the two systems (Wu et al., 2008; Moeskops et al., 2010; Bobulska et al., 2015). Results from our study clearly indicated that soil texture significantly affected bacteria, fungi and actinomycetes populations, and higher growth of microbial populations was observed in heavy textured soils (clay loam) than light textured soils (sand). Among six textural classes, the highest growth of microbial populations was observed in clay loam and the lowest in sand and there was positive a correlation between soil organic carbon and growth of microbial populations. Several researches documented that fine soils were found to be more suitable for bacteria, fungi and actinomycetes survival because smaller size particles provide a protective habitat for microorganisms through pore size exclusion of predators (Sessitsch et al., 2001 and Zhang et al., 2007). Alternatively, higher microbial population in clay loam soils may be due to a higher organic matter content, water retention characteristics and nutrient availability (Grayston et al., 2004). Microbial activity in soil is strongly influenced by the clays and humates which bind organic chemicals, inorganic ions, and water films to their surfaces (Van et al., 1996).

The bacterial (*Figure 13a*), fungal (*Figure 13b*) and actinomycetes (*Figure 13c*) populations of soils plotted for organic farming against adjoining soils under conventional farming (intercept set at zero) also showed clearly that organic farming had a promising effect in increasing bacterial (y = 0.632x), fungal (y = 0.633x) and actinomycetes populations (y = 0.642x) over conventional system in Haryana (*Figure 13*). The spatial variability maps of bacteria, fungi and actinomycetes at different locations are also presented in *Figures 14 to 16*.



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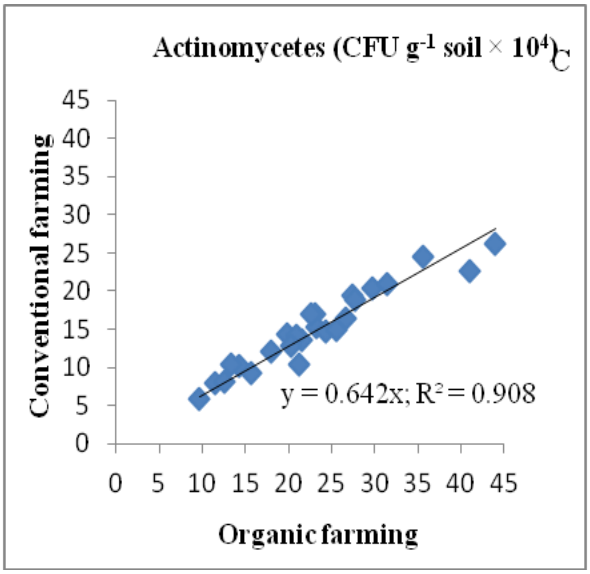

Figure 13. *The relationship of bacteria, fungi and actinomycetes populations in soils under organic and conventional farming system*

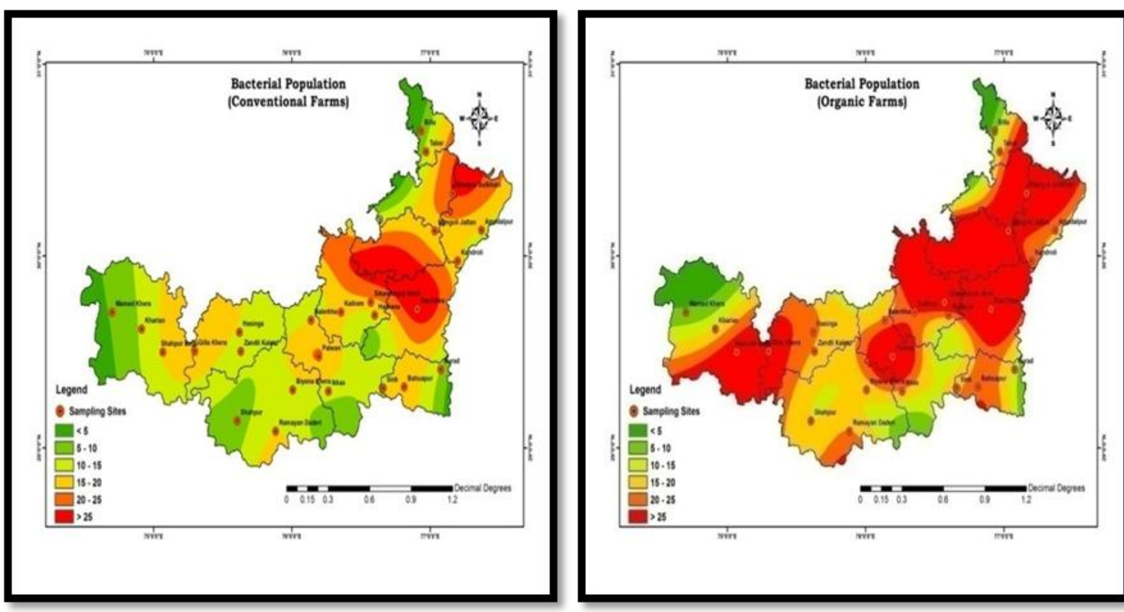

Figure 14. *Spatial variability map of bacterial populations in soils under conventional and organic farming systems at different locations of Haryana*

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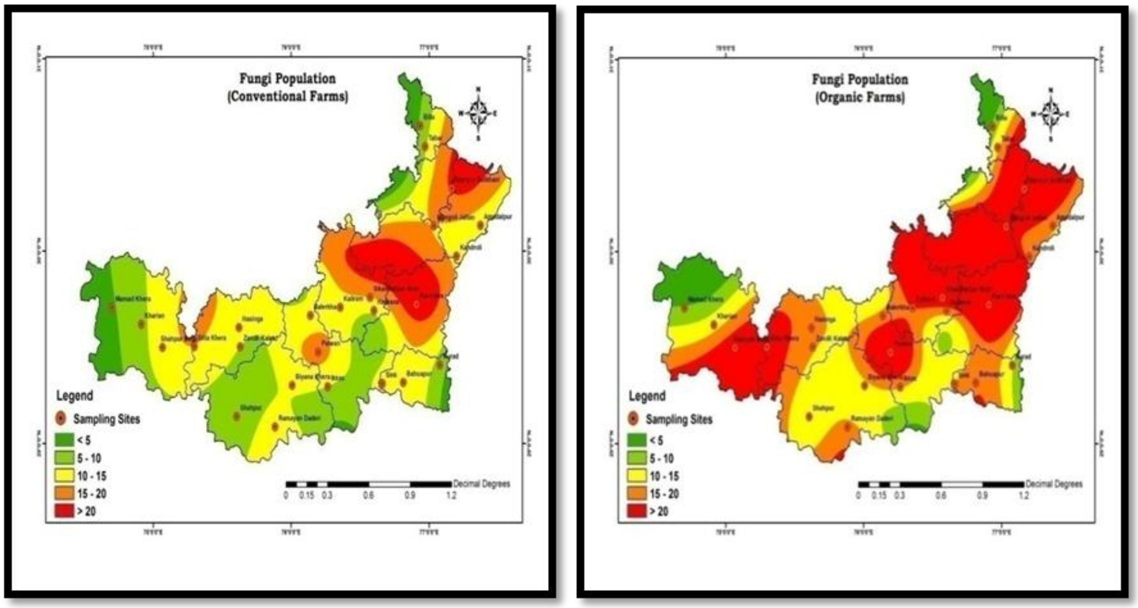

Figure 15. *Spatial variability map of fungal populations in soils under conventional and organic farming systems at different locations of Haryana*

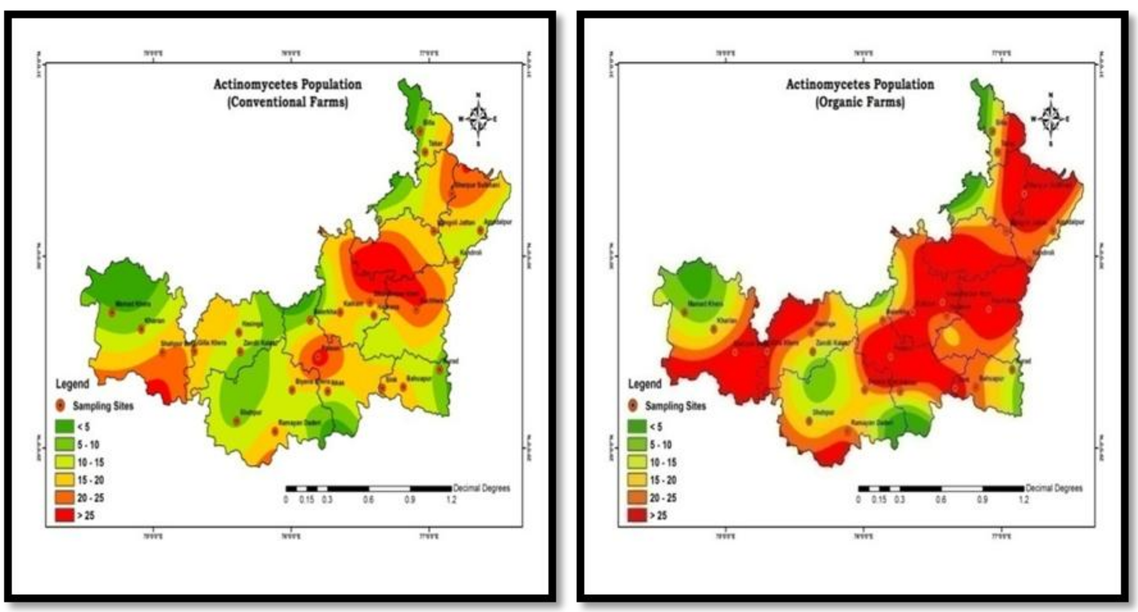

Figure 16. *Spatial variability map of actinomycetes populations in soils under conventional and organic farming systems at different locations of Haryana*

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Conclusion

The biological properties of soils in terms of enzymatic activities, microbial biomass carbon and total CFU of bacterial, fungal and actinomycetes populations were studied for the organic and conventional farming practices and they were found to be superior in the case of organic farming practices as compared to their counterparts. Higher organic matter input through application of various organic manures under organic farming practices is the key factor in enhancing the enzymatic activities and soil microbial biomass carbon along with higher growth of microbial populations in soil. The results from the study indicate that the management practices have clear positive and significant effects on various biological properties of soils. Enzymatic and microbial responses to chemical fertilizers and pesticides under conventional farming indicated the resource limitation and substrate availability to these biological communities in soil. Thus, microbiological properties of soil can serve as potential heath indicator of soils as being affected by different management practices.

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