

Analysis of Nutrients, Heavy Metals and Microbial Content in Organic and Non-Organic Agriculture Fields of Bareilly Region- Western Uttar Pradesh, India

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Increasing consciousness about ill-effects and health hazards caused due to use of agrochemical and consumer's choice of chemical-free food has led to the transition in farming practices from non-organic to organic farming. The majority of agricultural practices rely on conventional farming of pouring heavy doses of agrochemicals for increasing the yield of agriculture product. Analysis of quantity and types of nutrients and soil microbes present in the field may help in minimizing the doses of chemical fertilizers and or biofertilizers/organic inputs. A comparative analysis of physicochemical parameters, heavy metal ions and bacterial count of soil samples collected from three types of agriculture fields, organic farming site, chemical fertilizer fields and buffer zone (i.e. between organic and chemical farming site) located in Tigra village Bareilly District, UP, India was performed. The results revealed that soil from organic farming sites contained good amounts of nutrients, rich bacterial count, and fewer amounts of heavy metals as compared to the soil collected from non-organic farming fields and buffer zone. This suggests that the organic farming practices as sustainable, as the best way to retain natural soil flora and to a way to minimize/prevent the contamination of agriculture fields with hazardous chemicals and toxic metal ions.

Keywords: Conventional farming; Heavy metals ions; Microbial load; Sustainable farming.

Liberal and continued use of expensive chemical (non-organic) fertilizers have posed serious environmental health hazards in terms of soil pollution, water pollution, excess production of greenhouse gases, leading to global climate change and eutrophication of water bodies causing

algal bloom^{1,2}. This compelled the search for cost-effective and eco-friendly fertilizers such as organic fertilizers. Organic farming employing the use of organic fertilizers has been regarded as the best farming method to provide good quality of food, air, water, and soil while leaving the

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environment safer³. Although the organic fertilizers are the best alternative soil amendments; however, they are not very popular among the farmers due to their slower nutrient release and requirement in large quantities for effective results¹. Therefore, there is an urgent need to improve the quality of organic-based fertilizers for food security and environmental protection. An “organic fertilizer” is a fertilizer that is derived from non-synthetic or organic sources such as plant or animal, microbes, rock powders, and they are produced through the process of drying, cooking, composting⁴, chopping, grinding, fermenting⁵ or other methods⁶.

Organic farming practices are beneficial for soil and water conservation as well as to reduce pollution. The way farmers grow and process agriculture practices is an important aspect of organic farming. However, a recent meta-analysis with global coverage shows that organic crop yields are on average lesser than crop yields obtained by conventional farming because, in organic farming areas, conventional methods to fertilize or to control weed and insects are not used⁷. Though the methods utilized in organic farming are more costly and labor-intensive, they are probably cost-effective in the long run⁸. The major objectivity of organic farming resides on the development of a self-sustainable farming system in harmony with nature which delivers ecologically and economically sustainable pure food with enrichment of surrounding biodiversity and its entire components⁶. India produces 30% of total organic production but accounts for only 2.59% of the total cultivation area^{9,10}.

In non-organic areas, chemical fertilizers are used to promote plant growth while a wide variety of insecticides/pesticides are used to control the population of pest and insect parasites. Hence, in non-organic farming, there is always a risk of soil contamination with an excess of toxic heavy metals contained in pesticides and fertilizers¹¹. Accumulation of these metal ions over the period results in increased toxicity due to biomagnification that leads to malfunctioning of organs, chronic syndromes, and even carcinogenic and neuro-toxic effects in humans and animals¹². Soil microbes present in the field are capable of chelating heavy metal ions and thus may help in bioremediation of these toxic heavy metal ions¹³. These soil microbes offer twin advantages of bioremediation and plant

growth promotion¹⁴. However, the population of such useful soil flora can be maintained in organic farming practices as agrochemicals added in non-organic farming inhibits their growth¹⁵. Organic farming helps the growth of useful soil rhizobia, uptake of nutrients; increase in disease resistance, and chelating heavy metals, leading to an increase in plant growth and crop yield¹. Thus an attempt was made to analyze nutrients, the density of bacterial population, and the level of heavy metal intoxication in soil samples of organic agriculture fields, non-organic fields, and buffer zone soil of the Bareilly region of Uttar Pradesh (UP), India.

Continuous practicing of organic farming enhances good amounts of soil nutrients; enriches soil microflora, and minimizes a load of toxic heavy metals as compared to the non-organic farming. This suggests the sustainability of organic farming practices and a way to maintain soil health.

MATERIALS AND METHODS

Collection of soil samples

The soil samples used in this study were collected from nine different sites of the organic farm, four different sites of non-organic farming area, and two samples were collected from buffer zone i.e. the intermediate zone between organic and inorganic zone from various agriculture field of Tigra village (28.4297 °N, 79.5407 °E), Bareilly, UP, India. Samples were collected from 8 to 15 cm depth from five different locations at each site and mixed well to make a composite sample. These samples were transported in polythene bags in an ice pack to the laboratory. If samples could not process immediately, they were stored at 4°C until further use.

Analysis of physicochemical parameters of soil samples

The soil samples were analyzed for major physical and chemical quality parameters such as pH, electrical conductivity (EC), total soil organic carbon (SOC), nitrogen (N), phosphorus (P), potassium (K), and sulfur (S).

Measurement of soil pH

Soil pH was determined according to the method of Kadam¹⁶ by using pH meter having a single combined glass electrode. For this purpose, 20 g soil was added in 40 mL distilled water and stirred at regular intervals for 30 min. The pH of

the soil suspension was measured by immersing the electrode in suspension¹⁶.

Measurement of EC

EC was measured using a conductivity meter according to the method of Kadam¹⁶. For this purpose, 20 g of soil was added in 40 mL distilled water and stirred for 30 min. The conductivity of the supernatant liquid was determined with the help of conductivity meter¹⁶.

Estimation of total SOC

Colorimetric estimation of total SOC was performed according to the method of Sawarkar¹⁷. For this purpose; 10 mL of 1.0 N $K_2Cr_2O_7$ and 20 mL of concentrated H_2SO_4 was added in 1g soil and mixed thoroughly. The reaction mixture was diluted with 200 mL of distilled water and added with 10 mL of H_3PO_4 and 10 mL sodium fluoride. The resulting solution was titrated with ferrous ammonium sulfate using diphenylamine as an indicator. Blank (without soil) served as control. SOC of soil sample was calculated with the help of blank and sample titer reading¹⁸.

Estimation of total nitrogen content

Total nitrogen content was determined by Micro Kjeldahl method¹⁸. For this purpose 1g soil sample, 10 mL concentrated H_2SO_4 and 5 g catalyst mixture was taken in digestion tube and digested in a digester. After cooling, the mixture was processed for distillation; distillate was collected and titrated with H_2SO_4 . Blank (without soil) served as control. Total nitrogen was calculated from the blank and sample titer reading¹⁸.

Estimation of total phosphate content

Estimation of P content was carried out according to the method of Thakur *et al*¹⁹. Soil phosphate was extracted with 0.5 N $NaHCO_3$ at pH 8.5. Phosphate ions in the solution were treated with ascorbic acid in an acidic medium which develops blue color. The intensity of blue color was measured spectrophotometer at 660 nm and the amount of soil P was calculated from the standard curve of phosphate prepared with 100 to 100 $\mu g mL^{-1}$.

Estimation of potassium content

The potassium content of the soil was measured by using a flame photometer according to the method of Baghel *et al*²⁰. For this purpose, 25 mL of ammonium acetate solution was added in 5 g of the soil sample, content was shaken for 5 min and filtered with Whatman filter paper No.

1. The amount of potassium from the extract was measured in a flame photometer²⁰.

Estimation of sulfur content

The sulfur content of the soil was estimated by turbidometric method²¹. In this method, 20 g soil sample was added into 100 mL mono-calcium phosphate solution followed by shaking for one hrs, followed by filtration. A 10 mL filtrate, 2.5 mL HNO_3 and 2 mL acetic phosphoric acid was added and diluted to 22 mL and incubated for 10 min at 28 °C. The resulting color intensity was measured at 440 nm and the amount of available sulfur in the soil sample was estimated.

Quantitative estimation of heavy metal ions

The concentration of heavy metal ions in soil samples was estimated²². The absorbance of each heavy metal ion was read at the atomic absorption spectrophotometer at a respective wavelength and the number of heavy metal ions was computed from the calibration curve prepared with a solution of each metal ion was in the range of 10 to 100 ppm.

Analysis of bacterial population

A 10 g of soil sample was dissolved in 90 mL of sterile water and shaken for 10 min at 120 rpm and used for serial dilution. Two aliquots of 0.1 mL of suitable dilution (10^{-6}) were separately poured and spread each on cetrimide and nutrient agar plates. The plates were incubated at 30°C for 24 to 48 h and observed for the formation of visible growth and colony - forming units (CFU) from each plate were counted²³.

RESULTS AND DISCUSSION

Agricultural soils are influenced by many anthropogenic factors, such as loss of total SOC, depletion of soil nutrients, soil compaction, and deposition of heavy metal due to the addition of non-organic fertilizers and pesticides^{1-3,24,25}.

The value of pH in the non-organic farming area ranged from 6.9 to 7.3 while in the organic area it ranged from 7.2 to 7.8. In two soil samples, collected from an area sharing a common boundary of the non- organic farming site and organic farming site administered by chemical fertilizers (buffer zone) pH was 6.4 and 6.9. So soil of all sites is normal as the normal range of pH should be 5.5 to 7.5 for soil.

The electrical conductivity of soil samples

Table 1. Physicochemical analysis of soil samples collected from organic and non-organic farming sites

Site	Samples	pH	EC(dsm ⁻¹)	SOC (%)	N (Kg/h)	P (Kg/h)	K (Kg/h)	S (ppm)
Soil samples collected from organic farming sites								
A.	Green manure area with <i>Sesbania</i> crop	7.3±0.20	0.20±0.42	0.46±0.25	276.00±4.4	29.7±3.3	245.6±4.1	8.14±0.37
B.	Compost pit area with leaves only	7.6±0.35	0.15±0.21	0.40±0.33	251.00±2.5	22.3±3.1	223.5±7.5	9.95±0.50
C.	Yellow turmeric	7.3±0.38	0.09±0.32	0.47±0.44	272.5±2.9	26.6±4.9	198.4±3.4	12.39±1.2
D.	Black turmeric	7.7±0.10	0.04±0.11	0.46±0.25	238.9±3.5	28.5±4.7	197.5±4.5	19.98±1.9
E.	Mustard	7.6±1.0	0.14±0.51	0.65±0.20	271.7±1.6	32.6±2.5	156.8±4.6	16.00±1.3
F.	Sesame	7.5±0.80	0.12±0.65	0.69±0.12	264.6±0.68	31.3±6.5	158.7±2.5	12.95±1.7
G.	Sindoor	7.8±0.90	0.17±0.41	0.65±0.10	220.0±1.5	24.6±2.5	139.7±2.8	17.6±1.1
H.	Sugarcane	7.2±0.45	0.11±0.34	0.62±0.13	267.0±0.68	23.7±3.5	265.6±3.6	14.12±1.3
I.	Wheat	7.8±0.65	0.08±0.33	0.50±0.08	245.0±3.8	24.3±2.7	156.2±3.2	16.6±0.66
Soil samples collected from the buffer zone								
J.	Sugarcane at the buffer zone	6.9±0.78	0.25±0.44	0.59±1.1	212.5±3.5	35.8±5.1	135.5±1.5	12.83±1.6
K.	Buffer zone without crop	6.4±0.85	0.17±0.54	0.58±1.8	237.5±0.34	30.1±4.1	131.9±1.8	10.24±0.56
Soil samples collected from non-organic farming sites								
1.	Sugarcane	6.9±0.98	0.85±0.44	0.20±0.10	200.6±0.23	35.0±1.4	189.0±1.7	6.01±0.48
2.	Mustard	7.0±1.2	0.76±0.46	0.24±0.03	220.0±0.34	33.9±1.0	240.8±1.5	5.32±3.3
3.	Wheat	7.2±1.9	0.72±0.35	0.29±0.07	222.5±0.36	38.9±0.73	117.0±1.8	8.01±0.81
4.	Cabbage	7.3±2.1	0.65±0.33	0.23±0.06	227.7±0.69	32.2±1.5	135.3±1.6	5.78±0.47

Values are the average of three replicates

± values are mean±SEM

Soil samples were collected from the organic, buffer zone, and inorganic farming sites of Tigra village, (28.4297 °N, 79.5407 °E), Bareilly, UP, India.

of organic sites fall between 0.08 to 0.20 dsm⁻¹, in the soil of buffer zone, it was 0.25 and 0.17 dsm⁻¹ while in soil samples of the non-organic farming area it ranged from 0.65 to 0.82 dsm⁻¹. In general, all soil samples possessed normal EC (< 1.0 dsm⁻¹). However, EC of soil from non-organic sites was significantly higher as compared to EC of soil from organic sites. This may be because the use of chemical fertilizers increases soluble salts in soil that increases in the soil EC of non-organic sites. Kadam¹⁶ studied EC and pH in soil samples collected from Maharashtra and categorized soil in the normal category with EC value >0.8 dsm⁻¹ and with pH in the range of 6.5 to 7.8.

We report higher values of SOC in organic farm vis-à-vis non-organic farm samples (Table 1). We report a significant increase in SOC value by 0.69 % in the organic farming site as compared to 0.20 to 0.29% SOC in soil that received chemical fertilizers. The organic carbon content of soil appeared between 0.40 to 0.69 %. A high SOC level is a key characteristic of soil fertility, as it promotes soil structure, aeration, water-holding capacity, chemical buffering capacity, soil microbial activity, plant root development,

and continuous release of plant nutrients through mineralization. According to a global review the soils in organic cropping systems have significantly higher levels of SOC than those in conventional systems²⁶. It is reported that fields that receive chemical fertilizers have less than 4.6 g C kg⁻¹ and the application of organic matter in the organic farming system does not always result in improved SOC content²⁷.

A high level of nitrogen (276 kg h⁻¹) was recorded in an organic field that received green manure. Nitrogen content in the soil sample from the organic field ranged from 220.0 to 276.0 kg ha⁻¹ whereas soil samples collected from the non-organic field showed less nitrogen content i.e. 200.65 to 227.75 kg ha⁻¹. The use of chemical fertilizers such as urea and nitrogen fertilizer in non-organic farming sites leads to precipitation of these compounds making them unavailable for plant uptake. Nitrogen enrichment in the organic field is due to the addition of green manure, which provides soluble and utilizable nitrogen and phosphorus for uptake by plants. Soil from organic farming sites contained good amounts of nutrients due to the addition of compost and

Table 2. The occurrence of heavy metals in soil samples of organic and non-organic agriculture fields

Site	Samples	Cu ²⁺ (ppm)	Pb (ppm)	Zn ²⁺ (ppm)	Cd (ppm)
Soil samples from different crop locations of organic farming sites					
A.	Green manure area with <i>Sesbania</i> crop	11.5±1.3	7.0±0.98	22.5±0.97	-
B.	Compost pit area with leaves only	13.5±1.9	10.5±0.95	32.0±0.89	-
C.	Yellow turmeric	7.5±0.98	10.5±1.2	18.5±1.1	-
D.	Black turmeric	10.5±2.1	18.0±1.4	24.0±1.3	-
E.	Mustard	11.5±1.4	13.5±1.2	22.0±1.8	-
F.	Sesame	16.5±1.6	12.0±1.4	36.0±0.67	-
G.	Sindoor	12.5±0.76	12.0±1.2	21.5±0.69	0.5±0.05
H.	Sugarcane	16.5±0.89	24.5±0.98	36.5±0.59	0.5±0.02
I.	Wheat	14.0±0.97	25.0±0.95	33.0±1.2	0.5±0.02
Soil samples from the buffer zone					
J.	Sugarcane at the Buffer zone	17.0±0.95	30.5±0.56	40.0±1.3	1.0±0.11
K.	Buffer zone without crop	18.0±0.95	16.5±0.45	29.0±1.6	0.5±0.03
Soil samples from different crop locations of non-organic farming sites					
1.	Sugarcane	27.5±0.75	46.5±1.5	35.2±0.20	0.5±0.02
2.	Mustard	26.0±1.6	43.5±1.6	40.1±0.68	-
3.	Wheat	29.5±2.0	44.5±1.4	29.0±0.56	-
4.	Cabbage	30.5±2.4	40.2±2.1	43.3±1.2	-

Values are the average of three replicates

± values are mean±SEM

Soil samples were collected from the organic, buffer zone, and inorganic farming sites of Tigra village, (28.4297 °N, 79.5407 °E), Bareilly, UP, India.

green manure. Such soil rich in nutrients especially nitrogen are referred to as fertile soil and have great potential to support plant growth and therefore crop productivity^{28,29}.

The phosphorus content in all the soil samples of the organic field ranged from 20.5 to 32.4 kg ha⁻¹. A higher concentration of phosphorus in samples of the non-organic farming site may be due to the addition of chemical fertilizers.

Potassium content in the soil of both farming sites was within normal range i.e. 110 to 280 kg ha⁻¹ (Table 1). Soil from organic farming sites contained good amounts of nutrients due to the addition of compost and green manure.

Soil samples collected from organic farming sites contained 8.14 to 19.98 ppm sulfur vis-à-vis 5.32 to 8.01 ppm sulfur in the soil of the non-organic farming area. Soil having sulfur <10 ppm and between 10 to 20 ppm are considered as deficient and medium soil, respectively³⁰. Thus the soil of organic farming can be said to be medium while the soil of the non-organic area can be considered as deficient.

Manjunatha *et al.*³¹ claimed that continuous use of organic fertilizers not only promotes plant growth and crop yield but also leads to a significant increase in the amount of soil organic carbon, nitrogen, phosphate, and potassium. They reported 2 fold enhancement in soil organic carbon, a 42.9% increase 46.2% rise in soil phosphorus, a 19.3% increase in potassium. They further reported a significant increase in soil health indicators with an increase in the frequency of practicing organic farming.

Improvement in the amount of soil organic carbon, nitrogen, phosphorus, and potassium contents of the soils due to organic farming could be attributed to increased microbial population and their activities. The more microbial population will have more activities that will result in increased solubilization leading to increased mobilization of insoluble nutrients.

The concentration of copper, lead, zinc, and cadmium in each soil sample was assayed to detect the level of heavy metal pollution. The level of copper, lead and zinc organic farm soil was ranged from 7.5 to 16.5 ppm, 7.0 to 25 ppm, and 18.5 to 36.5 ppm respectively, vis-à-vis slightly high i.e. 26 to 30.5 ppm, 40.2 to 46.5 ppm and 29 to 43.3 ppm respectively in soil from the nonorganic

farm. Copper level in soil samples of organic field and buffer zone falls within the permissible limit set by the WHO³². The concentration of the cadmium observed in some soil sample (Table 2) fall with the permissible limit as observed by MAFF³³ and EC³⁴. Mukhtar *et al.*³⁵ concluded that the application of organic fertilizer increased the yield of sweet potato, cereal, and legumes as well as improved the residual soil nutrient levels and crop yield. G³ odowska and Krawczyk¹¹ observed a significant reduction in the amounts of heavy metals in soil due to the addition of organic fertilizers.

Bacterial count in field fed with a green manure of sesbania crop was higher i.e. 8.8×10^6 CFU mL⁻¹ as compared to the other farming areas where it ranged between 6.5×10^6 to 4.5×10^6 CFU mL⁻¹. While in the soil of the buffer zone the microbial count was very less (2.5×10^6 to 3.5×10^6 CFU mL⁻¹). The non-organic farming site showed less CFU count. High CFU counts in organic farming soil may be due to nutrient richness and absence of high concentration of heavy metal ions that are inhibitory for the growth of microorganisms²⁵. The results of the present study are in line with earlier research on the effect of organic soil management where bacterial taxa were reported most active under organic soil management condition³⁶. Liao *et al.*³⁷ demonstrated the reduction in microbial abundance and diversity in top soil that receive the pesticides as compared to the soil that did not receive any chemicals. Harkes *et al.*³⁸ found that bacterial taxa were most active under organic soil management conditions. Soil rich in the microbial population is expected to perform more solubilization of insoluble nutrients that lead to the nutrient enrichment of the soil.

CONCLUSION

Physicochemical characteristics of the soil vary from location to location and are dependent on nature (non-organic or organic) of nutrient inputs. The addition of organic fertilizers seems to be a more reliable, productive, and sustainable approach of increasing nutrient content and microbial population in the soil. It also minimizes the addition of heavy metal ions in the soil and provides chemical-free food production while establishing an ecological balance. Thus the organic farming bears higher biodiversity, good

fertility, less or negligible concentrations of toxic elements such as heavy metal ions, and hazardous carcinogenic chemicals. Many studies suggested that organic farms are nutrient-rich and hence more productive due to higher price premiums as compared to conventional farms. Organic farming is a sustainable approach to increase soil nutrients and the population of beneficial soil microflora.

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