SSRG International Journal of Agriculture & Environmental Science
ISSN: 2394-2568/ https://doi.org/10.14445/23942568/IJAES-V10I4P102
Volume 10 Issue 4, 7-19, Jul-Aug 2023

Original Article

Impact of Organic Amendments- Seaweed and Vermicompost on Soil Health Parameters in North India

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Received: 26 April 2023 Revised: 30 June 2023 Accepted: 20 July 2023 Published: 31 August 2023

Abstract *- During recent decades, the use of chemical fertilizers and pesticides has increased at a rapid rate and caused the deterioration of soil organic matter and the nutritional value of soil. For the restoration of soil health, an experimental study was conducted for three consecutive years (2019 to 2021) in a field of North India in a randomized block design with conventional and organic farming systems. In organic farming, vermicompost and seaweed were used, and urea and muriate of potash were used in conventional farming. Control and treated experiments of soil organic matter and nutritional value were performed in both systems with rabi and kharif crops. Soil samples were taken at 0-100 cm depth for analysis. In 2019, soil was deficient in soil organic carbon (SOC), OM (organic matter) and other macroelements (N, P, K) and microelements (Fe, Zn, S). In the final year of experiments, SOC was found to increase (0.710 %) in organic farming compared to conventional farming (0.591%). N amount also increased in 2021 in organic farming (2.101 kg/ha) compared to conventional farming (1.210 kg/ha). Other macro and microelements were also found to be increased in organic farming so that it can be the best alternative for future farming systems.*

Keywords *- Element analyzer, Organic matter, Seaweed, Soil health, Vermicompost.*

1. Introduction

In the current era, different agriculture practices have been adopted to increase production and increase the food supply for such a galloping population (Akanmu et al. 2023). However, for massive grain production, the soil is treated with a lot of chemical fertilizers and pesticides. In this way, the soil has deteriorated faster than in previous decades. This loss of soil not only reduces its physical and chemical properties like pH, electric conductivity, ionic movement and moisture of soil but also reduces its nutritional level as well as the organic matter of the soil. This type of pattern has been detected in most parts of India (Srivastav, 2020) (Castro et al., 2020). So, to prevent soil degradation and maintain its function, agriculture practices should be changed (Iram et al., 2019; Iftikhar et al., 2018). Intensive use of pesticides and heavy chemical fertilizers increases the pressure on soil and loss of its natural activity (Iftikhar et al., 2019). Hence, soil health is an important issue to regain the natural activity of soil. According to FAO (Food and Agriculture Organisation), soil health is the "capability of the soil to work as a living ecosystem, which helps to sustain animal, microorganism and plant and increase the air and water quality" (FAO,2008). Healthy soil is an important component to sustaining best agriculture practices and a living place for many microorganisms.

At the global level, different type of agriculture systems like organic farming, crop rotation, and zero tillage system has been adopted to regain the soil's natural capacity. Many countries like the Netherlands, China, Kenya and Italy have practiced organic farming for soil health and sustainable production(Arb et al., 2020; Bai et al., 2018; Crittenden et al., 2015; Sacco et al., 2015).In India, different farming systems have also been adopted to prevent the degradation of soil and use nonconventional and organic methods (Velmourougane (2016), Suja et al., 2017; Manjunatha et al., 2013; Brar et al., 2015).In the present study, the soil is treated with an organic fertilizer like seaweed and vermicompost to increase the physical quality of soil in terms of pH, Electric Conductivity(EC), moisture, and chemical properties of soil like Soil Organic Carbon (SOC), Organic Matter (OM). Along with this, the nutritional value of soil is also increased in terms of macroelements (N, P, K) and microelements (Fe, Zn, S). So, organic fertilizer can be a suitable alternative for improving soil health and increasing quality parameters (Gamage et al., 2023).

Organic inputs like vermicompost and seaweed help to increase the total Soil Organic Carbon (SOC), and crop rotation is also an important method to increase SOC (King & Blesh 2017).

In the current study, soil samples were taken from northern India, where conventional farming was done for many decades with the application of a lot of chemicals, which resulted in the reduction of organic matter in the soil. Organic amendments involving the application of natural fertilizers like seaweed and vermicompost were done to improve soil health. Vermicompost is an organic system in which the combined activity of indigenous earthworm species such as *Eisenia fetida* and microbes in the soil transform and stabilize organic constituents into humus that mainly increase oxygen availability, soil porosity, water retention, yield, quality and growth of crops (Arora et al., 2011). Basically, vermicompost comprises 2–3 % N, 1.55–2.25 % P, humus, and other micro-nutrients (Rekha et al., 2018). Seaweed extract is useful in sustainable agriculture since it is organic and biodegradable. Seaweed products have become increasingly popular in organic farming (Shaji et al., 2021). Other than trace minerals, vitamins, amino acids, antibiotics, and micronutrients, its extract includes growth-promoting hormones such as auxins, gibberellins, cytokinins, ethylene, and polyamines. At low concentrations, seaweed extracts can induce various physiological plant responses, including increased plant growth, improved blooming and production, and improved fruit nutritional content and shelf life. These have become popular as biostimulants for various fruits, vegetables, flowers, and grasses production (Colla et al., 2017). This beneficial effect of seaweed extract on plant development is similar to the action of phytohormones found in it. Seaweed extracts have multiple growth regulators, including cytokinins, auxins, and gibberellins (Mosa et al., 2021). The foliar spray of seaweed extract is a common method to increase yield in many commercial crops (Khan et al., 2012). This has been an effective way to improve soil's physical and chemical properties. According to Hameedawi and Malikshah (2017), applying seaweed extract to plants raised the quantity of chlorophyll in the leaves, perhaps increasing the rate of photosynthesis. The rise in total sugars and reducing sugars might be attributed to a faster rate of photosynthesis, which could have resulted in more carbohydrate buildup in fruits.

In the past, several researchers have focussed on the impact of the application of seaweed on plant-related parameters like physiological and biochemical parameters and yield, etc. However, the impact of applying natural fertilizers like vermicompost on soil, which has been under conventional farming, for improving soil health parameters like macro and microelements, organic matter, organic carbon, microbial population, etc., has not been made so far.

In April 2019, an experimental setup was done with crop rotation methods to increase soil fertility. Here, in the duration of six seasons from (2019 to 2021) many aspects of soil were analyzed with the comparison of organic and conventional methods and crop rotation, and tillage was used as an advanced method to increase the nutrition and organic matter of the soil. The most important drawback of loamy soil is that it lacks nitrogen, one of the most important macroelements to increase soil production. The experimental setup has been described in Table 4.

In North India, Haryana loamy soil is generally found. Loamy soil is a combination of all three - sandy soil, clay soil and silt soil, in the ratio of 40:40:20. It is suitable for any and every kind of crop. A mixture of three soils, loam soil has the best of the characteristics of all. It has high nutrient content, warms up quickly in summer and rarely dries out in the dry weather.

2. Materials and Methods

2.1. Site Description

The study was conducted at village Karela, Tehsil Julana, District Jind. This site meets the characteristics of the major agroecological zone (Z-6 Zone, Trans Gangetic plains) in north India. The coordinates of the experimental site are 29° 7'17.6664"N and 76°23'51.7920" E and an altitude of 223 meters above sea level. The district is characterized by semiarid weather conditions, hot in summer and cold in winter. The average temperature of this area was 24℃ with a minimum of 6℃ and maximum of 40 ℃, and the average precipitation was 590 mm. The parent material of the soil in the experimental site is characterized by high weathering and poor fertility status. However, before the initiation of experiments in 2019, routine soil characterization indicated that the soils in the site were generally moderately base (pH-6.7) and very low in available nitrogen, phosphorus, and potassium. Also, Soil Organic Carbon (SOC), organic matter, and humidity of the soil were low in quantity. In addition, several micronutrients like sulfur, zinc, and iron were found to be high in composition. Rabi and Kharif crops were grown with crop rotation, and tillage with chisel and harrow from 0-100 cm depth was practiced after harvesting the crops so that nutritional, physical and microbial qualities could be analyzed (Table 4).

2.2. Field Layout and Experimentation

The field experiment was based on an eight complete block design having four parts; each part was 8 square meters. Conventional farming was used as control as conventional chemical fertilizers like urea (135 kg/ha), Diammonium Phosphate (DAP) (40 kg/ha) and muriate of potash (10 kg/ha) were used in this farming method. Vermicompost and seaweed were used in organic farming with the same ratio as urea, DAP and muriate of potash with a depth of 100 cm after tillage practices. All crops were shown in triplicate replicas; in each replicate, all crops served as a treatment unit. Irrigation was done homogenously in both farming systems just after sowing and after 15 days of sowing of crops, and then after one month, two months and once pods of a crop were grown, no irrigation was done. Chemical / natural fertilizers were applied in equal proportions according to the area of each plot. Fertilization treatments were given just after sowing, and after that, one dose was given after 1 month of sowing and the other after 2 months.

2.3. Soil Sampling & Analysis

With the help of bucket design, the soil sample was taken from all the selected crops at a depth of 0-100 cm in a range from 0-20 cm, 20-40 cm, 40-60 cm, 60-80 cm, and 80-100 cm. All the soil samples contained a loamy texture. Most of the samples contain soil moisture less than 15 % weight (Table 1) (Appendices). Only some conventional soil samples contain less than 7 % weight. These samples were air-dried before being crushed with a pestle and mortar and sieved at a size of 2mm. Several tests were performed on these samples. Nitrogen availability was determined by the Element analyzer, and phosphorus and potassium availability was determined by Olsen's methods (Sims, 2000). and Flame Photometer (Pratt,1965). Organic carbon was determined by the rapid titration method (Allison,1965). After preparing the soil samples for the microbial population, the soil sample was collected in a polythene bag and stored at 40℃. On Nutrient agar media, the initial microbial population was quantified using the serial dilution pour plate technique (Smith and Hussey, 2005). The pH of the soil was analyzed in soil suspension (1:1 soil and water) (Thomas, 1996). The electric conductivity of soil was analyzed by the method of Rhoades et al., 1989. Macroelements and microelements were determined by atomic absorption spectrophotometer (Combatt et al., 2021). The soil humidity was analyzed by the method of Lee & Pielke (1992).

2.4. Statistical Analysis

For each individual treatment, experiments were performed in triplicates. All data were represented as mean ± standard error for n=3. All experiment analyses were done by Analysis of Variance (ANOVA) in Origin Pro software. Then, Fischer's test was used to analyze all the data with a significant difference of ($p<0.05$) with the help of GraphPad Prism software.

3. Results & Discussion

3.1. Effect of Organic and Chemical Fertilizer on Physical and Chemical Properties of Soil

According to a research study, soil samples have shown the result of having a moisture of nearly 13 % weight as the soil of these samples (Singh et al., 2005). Also, the upper depth of soil (0-20 cm) has shown low moisture compared to the deeper level (20-100 cm) because the porosity of soil increases with root penetration at deeper levels, so moisture is high in deep soil. The pH of soil samples shows a trend from alkaline to neutral. Almost 90 percent of samples were alkaline (7.2-7.9) (Table 1) in nature, 10 percent was found to be neutral (7.0). Additionally, the EC of all soil samples shows the range from 0.30 to 0.51 and is defined as good to normal soil (USD, National Soil Survey 2017) (Table 1). The soil organic carbon (SOC) in conventional farming was found to be in low amounts in almost all types of soil except organic soil in the year 2021, having SOC (0.710 %) (Table 1& Fig.1) at a significant P–value of 0.001. The lower the P-value, the higher the significance between the two results of SOC. It was found to be low in 2019 in the conventional farming system (0.351 %) compared to the organic farming system (0.420). Similarly, in 2020, SOC (0.440 %) was found to be low in conventional farming systems as compared to organic farming systems (0.510 %). In the final year of experiments, SOC was increased in organic farming (0.710 %) as compared to conventional farming (0.591 %) (Table 1& Fig. 1). This property of soil was found to contain organic carbon in increased amounts as compared to different research data (Soil survey map Haryana 2016, Adhikary et al., 2010).

Along with this, as the depth of soil increased from 20 to 100 cm, the total Organic Matter (OM) of soil samples was found to be in decreased amount (0.24) (Table 1& Fig. 2) (Appendices). This type of pattern in soil according to depth was also found in different research studies and places like Jharkhand of India and Malaysia (Kumar et al., 2012; Azlan et al., 2012).

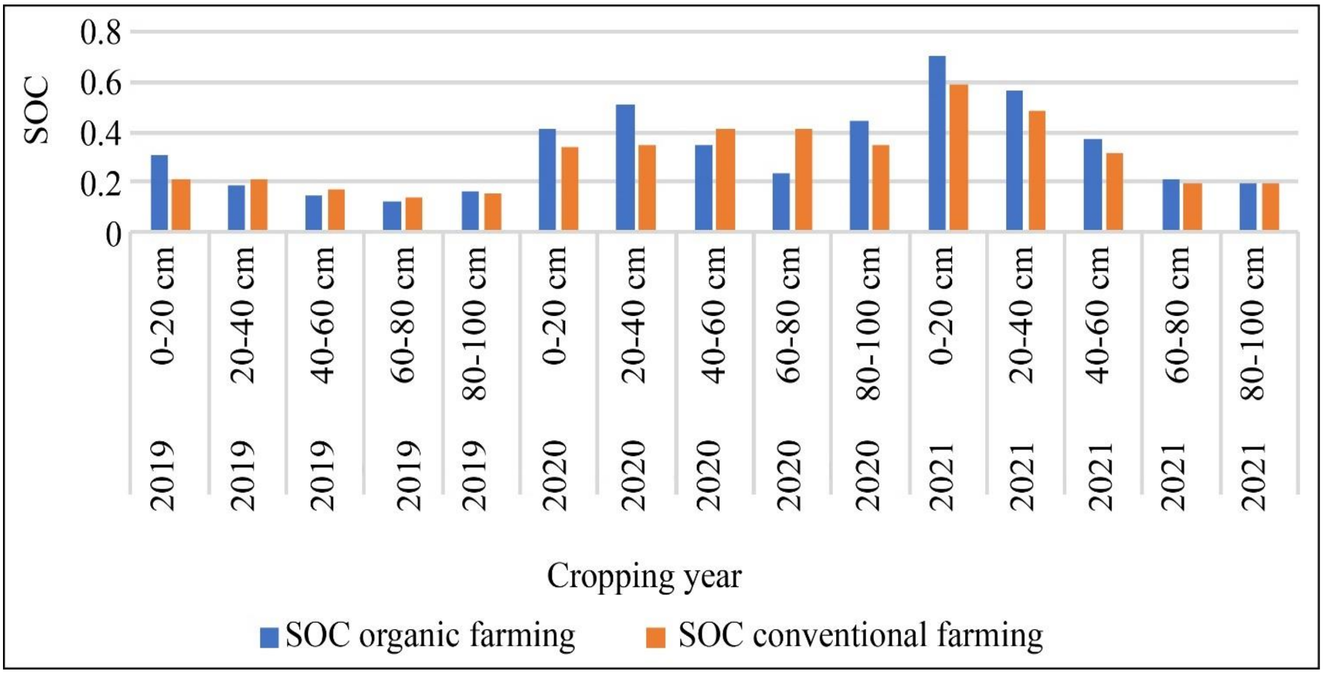

Fig. 1 Soil organic carbon present in soil from 2019 to 2021 in a depth from 0-20 cm to 80-100 cm in both organic and conventional farming systems

This pattern also shows that the litter and humus formed due to the falling of leaves help increase the organic matter and organic carbon of the uppermost soil. Also, organic soil during the experimental process was treated with vermicompost as well as seaweed. Hence, this is also an important factor for the increase in organic matter in 2021 (0.77) (Table 1& Fig. 2) as compared to conventional farming in 2021(0.52). Organic matter (OM) in 2019 was (0.49) in organic farming soil from 0-20 cm layer as compared to (0.34) in conventional farming soil at the same level (0-20 cm). Similarly, in 2020, the organic matter of soil carrying vermicompost at the same depth was (0.61) compared to the organic matter (0.41) of conventional soil carrying urea. These organic matter results also correlate with increasing the nitrogen, phosphorus and potassium nutrients in many parts of soil in Central India (Panwar et al., 2010) and the USA (Anderson et al., 2010).

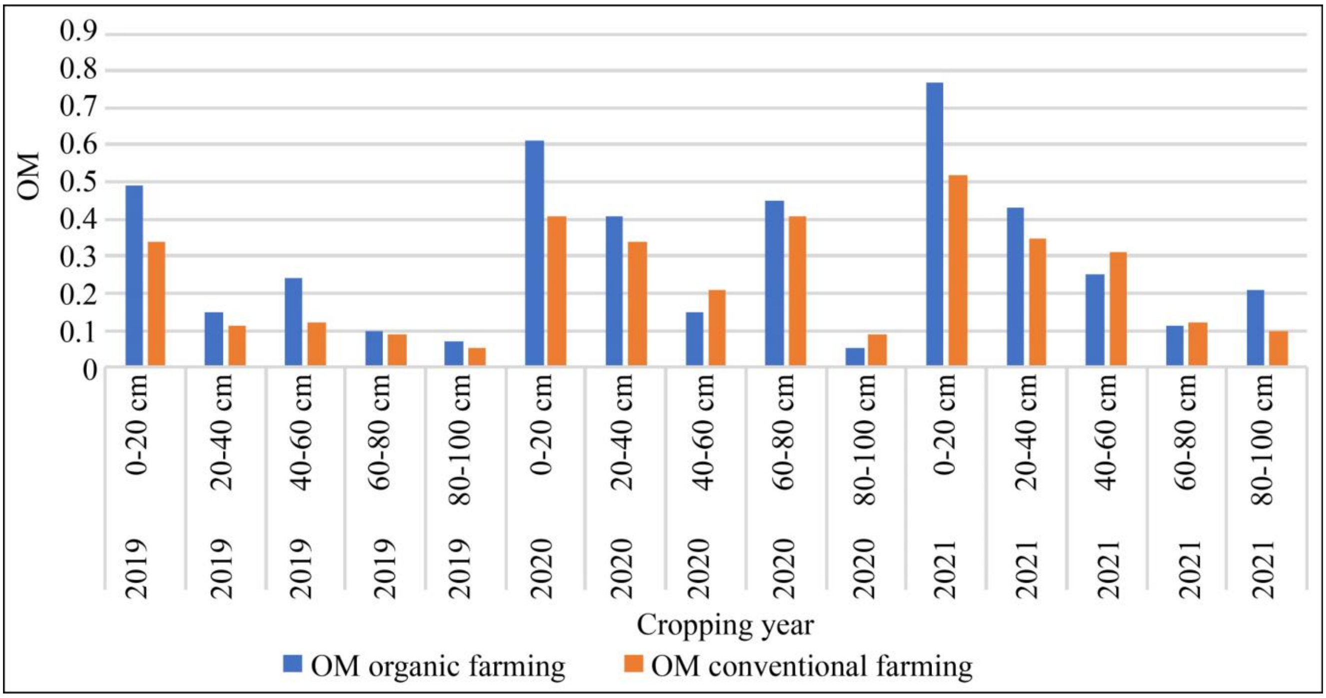

Fig. 2 Organic matter present in soil from 2019 to 2021 in depths from 0-20 cm to 80-100 cm in both organic and conventional

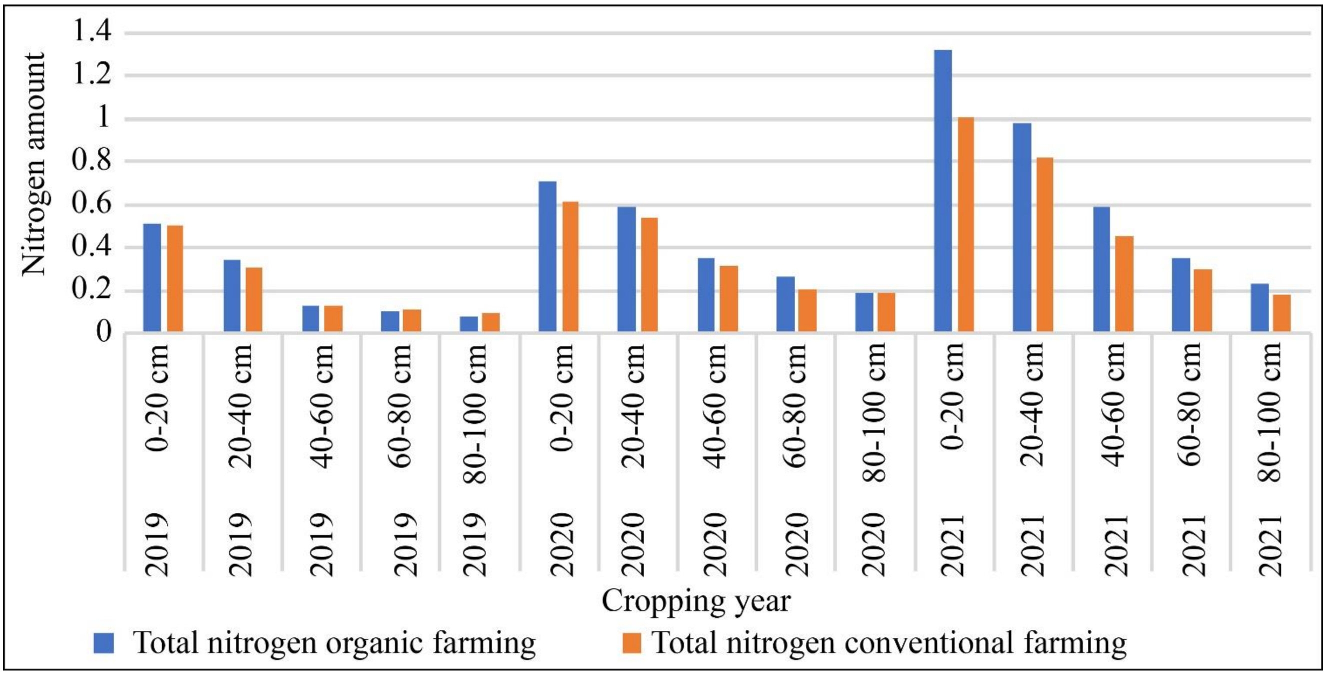

Fig. 3 Total nitrogen present in soil from 2019 to 2021 in a depth from 0-20 cm to 80-100 cm in both organic and conventional farming systems

3.2. Effect of Organic and Chemical Fertilizer on the Nutritional Quality of Soil

3.2.1. Macroelements in Soil

The organic amendments with seaweed and vermicompost had a significant effect on the available NPK status of soil, as shown in Table 2. In soil, compared to a conventional combination like urea, DAP, and muriate of potash compared to the nutritional value of soil greatly increased in 2021. Different macro elements found in soil were N, P, and K. In the initial year of the experiment in 2019, the amount of nitrogen was very low (0.501 kg/ha) (Table 2& Fig. 3) in the case of the conventional farming system. After one year of the experimental process, in the organic farming system, the N amount gradually increased (0.710 kg/ha) (Table 2& Fig. 3) as compared to conventional farming systems (0.612 kg/ha).

At the end of the final year of harvesting crops from the field, nitrogen (2.101 kg/ha) was found in an increased amount in organic farming at a much higher level as compared to conventional farming systems (1.210 kg/ha). So, nitrogen in the soil can be increased with the help of vermicompost and seaweed fertilizer, which can be a beneficial factor for the growth of plants. However, nitrogen was found to be the increased amount in the upper profile of soil (0-20 cm) (Table 2 & Fig. 3) as compared to the depth level of the soil (20-100 cm). This trend of nitrogen present in the upper layer of soil is similar to the total SOM present in the upper layer of soil. Also, N in soil is increased after adding organic fertilizer (Kaur et al., 2005). As the upper layer of soil organic matter binds with soil particles, nitrate is readily dissolved in soil water, gets leached easily, and does not penetrate the soil layers.

Along with N, other macroelements like P and K were also found to be in increased amounts in soil (6.20 kg/ha) and (172 kg/ha) (Table 2). The amount of N, P, and K was found to be similar in different research studies (Hathaway et al., 2011; Leeuwenet al., 2015; Marinari et al., 2006; Mader et al., 2002). In the case of organic farming, P and K were also found in increasing amounts compared to conventional farming (Armstrong et al., 2000; Stolze et al., 2000).

3.2.2. Microelements in Soil

Microelement concentration present in soil like Fe, Zn and S of two farming systems was also compared from years 2019 to 2021. Microelements were also found to increase concentration in the soil's uppermost layer. Fe concentration was found to be higher in 2021(16.09 mg/kg) (Table 2) in organic farming as compared to conventional farming (14.02 mg/kg) (Table 2). Zn in 2021(4.21 mg/kg), S (400 ppm), (Table 2) was also found in increased amount as compared to conventional farming in 2021 of Zn (3.12 mg/kg), S (356 ppm) (Table 2).

Similar research has been purposed for this type of experimental purpose (Patel et al., 2015). In this study, a higher amount of microelements was found to be increased in organic farming compared to conventional farming in the final year of 2021 harvesting.

Along with this, the soil of the Indian region contains a lot of micronutrients due to the application of organic fertilizers, Singh (2008). Also, increased organic matter increases the porosity of the soil to absorb nutrients from the soil, so this is also a main reason for the increase in the concentration of micro and macroelements in soil (Garcia-Marco et al. 2014). In addition, pH, EC and OM are important factors for increasing soil nutrition value (Vukašinović et al., 2015; Kumar and Babel (2011), Yan et al., 2012). An increase in the pH of the soil is also found in a negative correlation with micronutrient concentration as they become insoluble in soil (Yadav (2011). So, the mobility of microelements is also affected by a change in pH (Fageria and Baligar (1997). Increased microelements, macro elements, and organic matter were also due to using organic fertilizer (Manna et al., 2007; Kanchikerimath & Singh (2001). Several studies also show that all type of improvement in the soil is affected by management, like the crop rotation method (Table 4), which helps to increase the nutritional quality of soil and plants (Kaur et al., 2005; Ikemura et al., 2008).

3.3. Effect of Organic and Chemical Fertilizer on the Microbial Population of Soil

It is found that different organic amendments significantly affected soil microbial properties during three years in Table 3. The data showed that the maximum availability of bacteria counts (70.90 $\times 10^6$ CFU/g) and fungi count (24.40$\times 10^4$ CFU/g) was observed with the treatment of vermicompost and seaweed.

The total data of three years showed that the maximum availability of bacteria count was higher in organic farming as they both contained vermicompost and seaweed as fertilizer. Bacteria like Pseudomonas and rhizobacteria were present in the maximum amount in the plant's root and soil present in the root. Increasing trends of microorganisms are due to the organic fertilizer of seaweed and vermicompost that provides food to root exudates in the form of amino acids, carbohydrates, organic acid and some growth hormones.

These roots act as food substrates for microorganisms (Farooq et al., 2021). Also, vermicompost provides a suitable environment for microorganisms. In the process of vermicompost, earthworms intake some rhizosphere bacteria, such as *Bacillus, Azotobacter, Rhizobium,* etc., with soil and help increase their activity and numbers due to the ideal gut microenvironment. In this way, the total population of PGPR (plant growth-promoting bacteria) increased by a high number due to earthworm activity (Hiwale et al., 2010). Additionally, vermicompost provides a large surface area, which acts as a microhabitat for microbes to increase their microbial activity. Seaweed also provides a feed for microbes and helps enhance their population (Mir et al., 2013).

4. Conclusion

Soil is the habitat of many biotic components, so its physiological, nutritional and microbial parameters of soil should be preserved. Soil is being polluted day by day with the input of chemical fertilizers like urea, DAP and muriate of potash and the use of pesticides like imidacloprid and chlorpyrifos**.** The present study demonstrates that organic treatments like the use of seaweed and vermicompost were found to be very effective for improving soil quality in terms of organic matter, soil organic carbon, nitrogen efficiency, different macro- and microelements, microbial population, etc.

So, a balanced approach with sustainable and safe farming with organic fertilizers and crop rotation are effective measures for maintaining healthy soil. This study focussed mainly on biofertilizers, and further research may be done to partially or completely replace chemical pesticides using biopesticides.

Statements and Declarations

Authors Contributions

Author Madhu Rani designed the study, wrote the manuscript, performed statistical analysis, and drew the table and figures. Author Sonia Kapoor designed the study, protocol, manuscript editing, and data conceptualization.

Acknowledgments

We sincerely thank the central library of Maharshi Dayanand University, Rohtak, for internet sources, plagiarism check and literature collection.

Data Availability

Data associated with the current study are presented in the manuscript and also in the form of tables.

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Appendices:

Table 1. Physical and chemical properties of soil in conventional and organ agriculture from 2019 to 2021

Sample	Soil Moisture	pH	EC	SOC (%)	OM	P value (<0.05)
0-20 cm (2019) (C)	2.50	7.6	0.28	0.210	0.34	0.002
0-20 cm (O)	2.68	7.3	0.29	0.310	0.49	0.011
20-40 cm (C)	3.67	7.3	0.31	0.215	0.11	0.014
20-40 cm (O)	3.24	7.2	0.29	0.190	0.15	0.005
40-60 cm (C)	3.89	7.1	0.42	0.167	0.12	0.009
40-60 cm (O)	4.12	7.2	0.46	0.143	0.24	0.015
60-80 cm (C)	4.10	7.3	0.44	0.140	0.09	0.007
60-80 cm (O)	4.32	7.1	0.39	0.125	0.10	0.023
80-100 cm (C)	4.90	7.1	0.49	0.156	0.05	0.012
80-100 cm (O)	4.95	7.0	0.51	0.165	0.07	0.007
0-20 cm (2020) (C)	4.97	7.3	0.36	0.340	0.41	0.001
0-20 cm (O)	2.56	7.4	0.42	0.410	0.61	0.004
20-40 cm (C)	3.10	7.7	0.44	0.346	0.34	0.005
20-40 cm (O)	3.23	7.5	0.38	0.510	0.41	0.013
40-60 cm (C)	3.50	7.4	0.43	0.410	0.21	0.014

40-60 cm (O)	3.67	7.3	0.45	0.345	0.15	0.005
60-80 cm (C)	4.13	7.5	0.39	0.410	0.41	0.002
60-80 cm (O)	4.30	7.3	0.50	0.235	0.45	0.004
80-100 cm (C)	4.45	7.2	0.35	0.350	0.09	0.008
80-100 cm (O)	4.51	7.1	0.41	0.450	0.05	0.015
0-20 cm (2021) (C)	3.12	7.3	0.43	0.591	0.52	0.012
0-20 cm (O)	3.50	7.4	0.47	0.710	0.77	0.009
20-40 cm (C)	4.52	7.5	0.51	0.530	0.35	0.005
20-40 cm (O)	5.10	7.4	0.46	0.612	0.43	0.004
40-60 cm (C)	4.58	7.6	0.39	0.430	0.31	0.001
40-60 cm (O)	4.13	7.3	0.41	0.519	0.25	0.011
60-80 cm (C)	4.76	7.2	0.38	0.435	0.12	0.009
60-80 cm (O)	5.32	7.1	0.49	0.525	0.11	0.006
80-100 cm (C)	5.15	7.0	0.35	0.345	0.10	0.004
80-100 cm (O)	5.70	6.9	0.38	0.418	0.21	0.002

O-organic agriculture, C-Conventional agriculture

Table 2. Macronutrients and micronutrients of soil in conventional and organic agriculture from 2019 to 2021

Sample	N (kg/ha)	P (kg/ha)	K (kg/ha)	Fe (mg/kg)	Zn (mg/kg)	S (PPM)	P value (<0.05)
0-20 cm (2019) (C)	0.501	4.10	140	10.34	1.910	250	0.001
0-20 cm (O)	0.515	4.50	145	11.10	2.101	270	0.012
20-40 cm (C)	0.312	4.12	130	10.05	2.151	241	0.009
20-40 cm (O)	0.340	4.10	138	9.56	2.315	258	0.005
40-60 cm (C)	0.129	3.90	129	10.12	1.450	190	0.008
40-60 cm (O)	0.132	4.25	132	9.70	1.550	198	0.005
60-80 cm (C)	0.110	3.78	126	9.50	2.104	219	0.007
60-80 cm (O)	0.108	4.50	135	9.85	2.150	255	0.013
80-100 cm (C)	0.091	3.98	127	8.98	1.940	200	0.008
80-100 cm (O)	0.081	4.96	139	8.95	1.560	243	0.009
0-20cm (C) (2020)	0.612	5.10	155	11.30	2.12	290	0.001
0-20 cm (O)	0.710	5.30	152	12.10	2.56	310	0.004
20-40 cm (C)	0.540	5.42	160	12.45	2.20	295	0.005
20-40 cm (O)	0.590	5.50	155	13.10	2.19	313	0.003

40-60 cm (O)	0.350	5.70	162	12.50	1.98	290	0.005
60-80 cm(C)	0.210	5.90	145	10.95	2.50	303	0.002
60-80 cm (O)	0.265	6.10	150	11.02	2.90	319	0.004
80-100 cm (C)	0.190	5.10	160	11.50	2.10	275	0.008
80-100 cm (O)	0.185	5.98	165	12.90	2.98	289	0.006
0-20cm (2021) (C)	2.101	6. 10	160	14.02	3.12	356	0.002
0-20 cm (O)	1.210	6.20	172	16.09	4.21	400	0.009
20-40 cm (C)	1.980	5.97	160	13.54	3.02	310	0.005
20-40 cm (O)	1.850	6.02	158	13.98	3.45	316	0.007
40-60 cm (C)	1.550	5.40	159	13.01	3.10	275	0.004
40-60 cm (O)	1.430	5.90	160	13.59	2.90	278	0.003
60-80 cm (C)	1.210	4.75	156	12.90	2.98	245	0.009
60-80 cm (O)	1.138	5.00	158	13.04	2.50	265	0.006
80-100 cm (C)	1.121	4.23	149	12.01	2.40	270	0.004
80-100 cm (O)	1.110	4.50	155	12.50	2.54	290	0.010

O-organic agriculture, C-Conventional agriculture, PPM-parts per million
Mean ± Standard deviation and significant level ($P \leq 0.05$) were calculated using Graph Pad Prism at a 95 % confidence interval. Less the P value, the more significant the data.

Table 3. Bacterial and fungal population in organic and conventional agriculture per gram of soil from 2019 to 2021

Sample	Bacteria count	Fungus count	P value (≤ 0.05)
2019 (O)	50.90	20.30	0.011
2019 (C)	52.62	18.45	0.120
2020 (O)	55.72	21.50	0.145
2020 (C)	59.60	20.60	0.156
2021 (O)	70.90	24.40	0.012
2021 (C)	61.71	22.30	0.134

O-organic agriculture
C-Conventional agriculture

Table 4. Crop sowing, harvesting along with crop rotation methods with tillage and fertilizers practices in conventional and organic farming during the three-year study with six treatments

Year	Crop /Crop Rotation	Conventional Farming	Organic Farming
2019 (April) Sowing month	Rabi crops -Wheat, pea, mustard, fenugreek, Berseem	Rabi Crops	Rabi crops
Harvesting Month- October	Tillage-chisel & harrow from 0-100 cm.	0-20 cm and up to 100 cm.	Same as conventional
	Fertilizer (kg/ha)	Urea- 135 kg/ha, DAP-40 s kg/ha	Vermicompost- 140 kg/ha, Seaweed- 40 kg/ha
2020 (November) Sowing Month	Kharif crops- Rice, cotton, sesame, sorghum, millet	Kharif crops	Kharif crops
Harvesting Month- March/April	Tillage- Chisel and Harrow from 0-20 cm and up to 100 cm.		
	Fertilizers used (kg/ha)-		
2020 (April) Sowing Month	Rabi crops -Wheat, pea, mustard, fenugreek, Berseem		
Harvesting- October	Tillage- chisel & harrow from 0-100 cm.		
	Fertilizer(kg/ha)		
2020 (November) Sowing Month	Kharif crops- Rice, cotton, sesame, sorghum, millet		
Harvesting Month- March/April	Tillage- Chisel and Harrow from 0-20 cm and up to 100 cm.		
	Fertilizers used (kg/ha)		
2021 (April) Sowing Month	Rabi crops -Wheat, pea, mustard, fenugreek, Berseem		
Harvesting Month- March/April	Tillage-Chisel & Harrow from 0-20 cm and up to 100 cm.		
	Fertilizer(kg/ha)-		
2021 (November) Sowing Month	Kharif crops- Rice, cotton, sesame, sorghum, millet		
Final Harvesting Month- March 2022			

For each season, crop rotation with rabi and kharif crops was done in both farming systems with homogenous conditions of irrigation, tillage and fertilizer amount. In organic vermicompost and seaweed were used as fertilizers, and in conventional farming, urea and DAP were used.