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Original research paper

ORGANIC VS. CONVENTIONAL: EFFECTS ON PHYSICO-CHEMICAL AND BIOCHEMICAL INDICES OF SOILS

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Abstract

The present study was carried out to evaluate the different soil indices in respect of physico-chemical and biochemical properties as affected by two different farming systems, conventional vs. organic. To do this, soil samples were collected from different crop fields practiced under conventional and organic systems. All the soil samples were analyzed following standards procedures. The results showed significantly ($p<0.05$) lower pH and higher electrical conductivity (EC) of soils in most of the crop fields under organic farming system compared to their corresponding conventional fields. Though organic carbon (OC) was non-significantly ($p>0.05$) higher in soils of organic crop fields, total nitrogen (TN) was significantly ($p<0.05$) higher in organic crop fields than the conventional one. The activities of urease, phosphatase and arylsulfatase among different crop fields significantly differed ($p<0.05$) under both organic and conventional farming systems. With the exception of brinjal (which is commonly known as eggplant in the United Kingdom and North America) field, the urease enzyme activity was found higher in all the crop fields under organic farming practices compared to their corresponding crop fields of conventional system. On the other hand, the arylsulfatase activity was found higher in soils of all the crop fields except for tomato under conventional farming system relative to their respective organic crop fields. As for phosphatase, there were higher activities in chili and tomato fields, while lower in brinjal, bean and fallow under organic farming system. A negative significant ($p<0.05$) correlation between OC and pH while a positive significant ($p<0.05$) correlation between OC and TN was observed in organic farming system. The hierarchical clustering dendrogram based on soil enzyme activities and physico-chemical properties showed clear separation between organically and conventionally managed soils. The present study concludes that management practices significantly shape soil biochemical properties.

Key words: *conventional farming, enzymatic activity, organic farming, soil health.*

INTRODUCTION

Agriculture is the most significant sector on which billions of people depend on their livelihood playing significant role in the economy of their respected countries. The sustainable production of crop maintaining soil health has become a challenging issue to soil scientists. A huge revolution as mechanized agriculture took place along with the availability of synthetic fertilizers, pesticides and selective breeding during the last few decades (Reid, 2011).

Intensive or conventional agriculture is associated with low fallow ratio and high input of water, agrochemicals and motorization to intensify the productivity. Through the application of modern inventions in agriculture along with the synthesized nitrogen fertilizer, populated countries became successful in the adequate grain production to feed themselves. It helped producing huge grains in limited land. But synthetic fertilizers and pesticides have major consequences on human health and environment (Sharma & Singhvi, 2017). Because of the injudicious application of chemical fertilizers and pesticides, intensive farming practices have been related to increased nutrient losses, decreasing soil fertility, and declining biological activity (Bisht & Chauhan, 2020). Continuous high-input conventional farming methods have been linked to assertions that yield growth has decreased repeatedly since the green revolution (Rezvi, 2018).

Such role of conventional farming system raised concern to look for new sustainable farming ways which will not only help to feed the growing mouths but also conserve the natural resources. In the meantime, organic farming is continuously being supported as the proper substitute for this conventional farming system. Organic farming is a holistic approach consisting of a set of conservation activities such as green manures, composting, cultural practices, bio-fertilizer and biologically nitrogen fixation for environmentally friendly production (Leifeld, 2012). Organic farming has positive impact on soil quality (Furtak & Gałązka, 2019) as well as reduce soil erosion (Jin et al., 2009). Addition of compost, straw and natural amendments are found to influence the microbiological and biochemical process in soil in a positive way which in turn increase soil microbial biomass content (Araújo & Melo, 2010). Organic way of farm management improves soil biological activity and biodiversity (Furtak & Gałązka, 2019), enhance the growth of different groups of microbes (Bonanomi et al. 2016).

More than 65% of total agricultural area of Bangladesh is under declining soil fertility, and around 85% of the country's net cultivable area has less organic matter than is required to maintain soil productivity (Rasul & Thapa, 2004). The result is that crop yields are progressively dropping despite the increasing use of agricultural inputs (Rezvi, 2018). Adverse economic and educational level, illiteracy about organic farming of farmers along with insufficiency of organic input are creating barriers between farmers and organic farming in Bangladesh (Prabal & Syed, 2021). However, with the increasing awareness about the deleterious effect of conventional farming system, now-a-days Bangladeshi farmers and common people are prioritizing the organic way of food production. Although several authors have noted improvements in soil quality as a result of organic management (García-Ruiz et al., 2008; Rosen & Allan, 2007), a very little data on physico-chemical and biochemical indices is available to evaluate the effects of organic management in the tropical environment. Thus, the present research was carried out to measure and compare the physico-chemical and biochemical indices of agricultural soils of different crop fields as influenced by the conventional and organic farming practices.

MATERIAL AND METHODS

Study area and management practices

Organic and conventional vegetable fields located in the southeastern hilly region of Chattogram (formerly known as Chittagong) division in Bangladesh were chosen for collection of soil samples. The fields under both farming practices differed in area, and therefore their sizes were not uniform. To ensure representation, soils were sampled from one field from each of the crop types under both organic and conventional practices. Details of management practices of organic and conventional fields are given in the Table 1. The location of the sampling sites is shown in Figure 1.

Table 1. Management practices of organic and conventional crop fields.

Management practices	Organic fields	Conventional fields
Irrigation from Sangu River	√	√
Crop rotation	√	×
Organic fertilizers	√	×
Inorganic fertilizers and pesticides	×	√
Mulches	√	×
Reduced tillage	√	×
Pheromone traps	√	×
Yellow sticky cards	√	×
Nets to exclude pests	√	×
Practicing fallow	√	×
High yielding variety	×	√
Personal/community seed bank	√	×
Training on agriculture	√	×

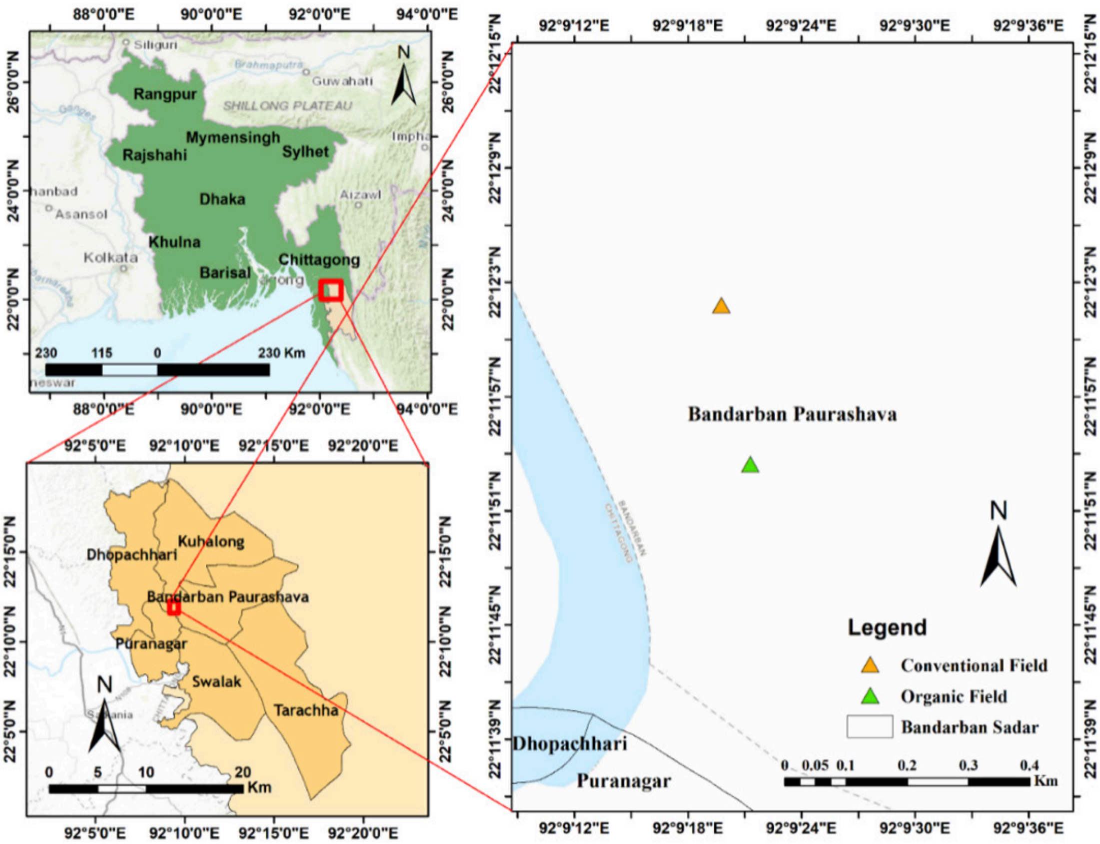

Figure 1. Location of the sampling sites.

Collection and processing of soil samples

Soil samples from a depth of 0-15 cm (root zone) were collected from 10 distinct crop fields (five organic and five conventional- brinjal, chili, tomato, bean and fallow). Whole samples were divided into two portions where one portion was kept in the refrigerator immediately after collection for biochemical analysis, while the remaining portion was left in the shady place to be air died and sieved through 2 mm sieve for physico-chemical analysis.

Analysis of soil samples

The pH and EC of soil samples were measured by using a pH meter (Seven CompactTM pH/ Ion S220) and an EC meter (Adwa AD 330), respectively after preparing the suspension at the ratio of soil to water 1:5 (Jackson, 1973). Soil organic carbon (OC) content was determined by Walkley and Black wet oxidation method as described in Huq & Alam (2005). The content of total nitrogen (TN) was determined by alkali (40% NaOH) distillation using the micro Kjeldahl apparatus (Jackson, 1973) after digesting the soil samples with concentrated sulfuric acid (H_2SO_4).

Urease activity was determined by distillation and volumetric assay, a method suggested by Tabatabai & Bremmer (1972) with a little modification. In this method, freshly prepared urea (CH_4N_2O) was used to prepare substrate solution. Hydroxymethyl aminomethane was used to prepare tris buffer maintaining pH 9. Samples were incubated for 2 hours at 37°C and the extraction of samples was made by 2.5M potassium chloride (KCl). Acid phosphomonoesterase activity was determined by following little modification of the original method suggested by Eivazi & Tabatabai (1977). Disodium p-nitrophenyl phosphate hexahydrate was used to prepare a substrate solution that was 115mM. Hydroxymethyl aminomethane ($C_4H_{11}NO_3$), maleic acid ($C_4H_4O_4$), citric acid monohydrate ($C_6H_8O_7 \cdot H_2O$) and H_3BO_3 were used to prepare a modified universal buffer stock solution. Solution was colored (yellow) with the addition of 0.5M NaOH solution. To prevent humic substances calcium chloride ($CaCl_2$) was used. The samples were incubated at 37°C for 1 hour and extraction was made by distilled water. Finally, the intensity was measured with a spectrophotometer (Shimazdu UV-1800 Spectrophotometer) at 400 nm. Arylsulfatase activity was determined by the method of Strobl et al. (1996). Soil samples were incubated at 37 °C for 1 hour. The color intensity of the extract was measured with a spectrophotometer at the wavelength of 420 nm.

Statistical analysis

All the results were the mean of three replications. The mean and standard deviations were calculated through Microsoft Excel 2010. The significant differences at $p<0.05$ in the means of the soil parameters were tested by one-way analysis of variance (ANOVA) and further Duncan's Multiple Range Test (DMRT) using Statistical Packages for Social Sciences (SPSS) software. Correlations was performed using the Microsoft Excel 2016 program. The dendrogram grouping for cluster analysis of soil samples under different farming practices was done by IBM SPSS.

RESULTS AND DISCUSSION

Physico-chemical indices of soils

Table 2 shows different physico-chemical properties of crop fields under organic and conventional farming practices. The pH of soil was significantly lower in crop fields under organic farming system compared to their respective conventional fields except for chili and brinjal. The pH range, however, was wider in conventional site (4.28 to 5.80). All crop fields except chili under organic farming practice had significantly higher EC values compared to conventional crop fields. The EC values of organic fields had relatively narrow range compared to conventional fields. The OC content of crop fields in organic practice did not vary significantly with their corresponding crop fields in conventional practice except for brinjal. The TN content of organic fields significantly exceeded than that of the TN of respective conventional fields. Tomato field showed the highest TN value both for organic (2.12%) and conventional (1.49%) sites.

Low pH of organically managed soils could be the result of light carbonic acid from the decomposition of organic matter added regularly. Such result was in support with the findings of Bai et al. (2018) and Maltas et al. (2018). But Kwiatkowski et al. (2020) and Partelli et al. (2012) found opposite findings. However, Van Diepeningen et al. (2006) did not find any significant difference between the soil pH of organic and conventional systems. Wider range of pH values in conventional site could be due to the continuous application of chemical fertilizers that interfere with soil pH (Pahalvi et al., 2021). However, such factors as soil types and buffering capacity, type of organic amendments and fertilizers added must be considered to make any conclusion on soil pH (Bai et al., 2018). The cause of such overall low pH in the study area could be leaching of the basic cations (Ca^{2+} and Mg^{2+} mainly) from the soil profile which was in agreement with the result of Adhikary et al., (2019).

Table 2. Physico-chemical properties of different crop fields under organic and conventional farming practices.

Farming systems	pH	EC (µS/cm)	Organic carbon (%)	Total nitrogen (%)
Organic				
Brinjal	4.77 ± 0.07f	398.67 ±3.06b	0.78 ± 0.02c	0.79 ± 0.05e
Chili	5.20 ± 0.13d	315.67 ± 4.62c	0.68 ± 0.02de	1.12 ± 0.29cd
Bean	4.98 ± 0.03e	150.73 ± 1.88f	0.85 ± 0.00b	1.22 ± 0.08c
Tomato	4.80 ± 0.15f	249.00 ± 2.65e	0.98 ± 0.00a	2.12 ± 0.13a
Fallow	5.37 ± 0.03bc	67.63 ± 0.92i	0.71 ± 0.02d	0.91 ± 0.12e
Conventional				
Brinjal	4.28 ± 0.10g	220.33± 0.58e	1.02 ± 0.06a	0.42 ± 0.07f
Chili	4.87 ± 0.03ef	924.00 ± 8.18a	0.66 ± 0.04e	0.95 ± 0.01de
Bean	5.25 ± 0.02cd	122.97 ± 2.3g	0.83 ± 0.02b	0.16 ± 0.04g
Tomato	5.47 ± 0.06b	90.17 ± 1.74h	1.00 ± 0.02a	1.49 ± 0.07b
Fallow	5.80 ± 0.00a	53.73 ±0.15j	0.67 ± 0.02de	0.16 ± 0.03g

Means followed by the same letter(s) within the same column did not differ significantly at 5% level of significance

Significantly higher EC values of all organic fields except chili was similar with the finding of Naik & Babu (2005). The highest EC of chili field found under conventional system could be due to the fertilization of field about 7 days before sampling (according to local farmer's opinion). Relative stable EC values of organic fields indicated that organic manure and compost did not affect soil salinity to the great extend (Wang et al., 2012).

In consistent of our findings, Pittarello et al. (2021) did not find any significant difference in OC content under organic farming practice. On the contrary, Bai et al. (2018) found opposite outcome. The reason of insignificant difference on OC could be ascribed to either application of inorganic fertilizers solely or low input of organic manures. Carbon content of a soil increases significantly either by larger input of organic amendments or fresh cattle manure (Maltas et al., 2018). The higher TN in organic fields was in consistent with the findings of other authors (Kwiatkowski et al., 2020; Lepcha & Suwanmaneepong, 2022). The low TN in conventional fields might be due to the application of synthetic N fertilizer which are subjected to loss by quick leaching (Duraisami et al., 2001).

Bio-chemical indices of soils

The urease, phosphatase and arylsulfatase activities under different farming systems are shown in Figure 2 (a-c). There were significant differences in urease, phosphatase and arylsulfatase activities among different crop fields under both organic and conventional farming systems. Organic fields showed higher urease and phosphatase enzyme activities but lower sulfatase activity than the corresponding conventional fields. Among different crop fields under organic farming system, the lowest (154.2 μgNg-1dm2h-1) urease activity was found in brinjal and the highest (800 μgNg-1dm2h-1) urease activity was found in tomato field. On the other hand, the lowest urease activity (210 μgNg-1dm2h-1) was found in tomato field, while the highest (577.5 μgNg-1dm2h-1) was observed in brinjal field under conventional farming system. The phosphatase activity varied from 323 μgNPg-1dmh-1 in chili field to 669 μgNPg-1dmh-1 in bean field under conventional system, while the range of phosphatase activity was from 394 μgNPg-1dmh-1 in brinjal field to 717 μgNPg-1dmh-1 in bean field under organic farming system. The highest arylsulfatase activity of 69 μg pNP g-1dmh-1 was found in fallow field, while the lowest of 18 μg pNP g-1dmh-1 was observed in brinjal among different crop fields under organic system. On the contrary, the lowest and highest amount of arylsulfatase activity were found in tomato (6 μg pNP g-1dmh-1) and bean (111 μg pNP g-1dmh-1) fields, respectively under conventional practice. The urease and phosphatase activities under organic farming system were found as highest as 280.95% and 10.40%, respectively regardless of the types of crop fields. On the other hand, the arylsulfatase activity under conventional farming system was as highest as 54.80% irrespective of the types of crop fields.

The higher urease and phosphatase activities, while lower sulfatase activity of organic fields was in opposite of the finding of Maharjan et al. (2017). On the other hand, significantly higher phosphatase and urease activities in organic field was found by other authors (Lori et al., 2017; Kwiatkowski et al., 2020). The highest enzymatic activity in organic farming system could be due to the increased nutrient availability and root exudates (Tamilselvi et al., 2015). However, the enzymatic activity in soil depends on a variety of factors such as crop rotation, the quantity and quality of organic matter, microbial count, amount of organic materials, other microscopic living organisms and their activities (Banerjee et al., 2012; Kwiatkowski et al., 2020). Conventional tillage had been found to negatively influence on the urease enzyme activity (Heidari et al., 2016). Lower enzymatic activity in conventional system might be due to such factors as conventional tillage, application of inorganic fertilizers and so on. The higher arylsulfatase activity and lower urease or phosphatase activity in conventional sites might be the influence of actinomycetes. Although we did not analyze the bacteria and fungi species in soil samples, but previous research mentioned about a– negative correlation between arylsulfatase and actinomycetes (Pintarič et. al., 2024); and positive influence of actinomycetes on urease and phosphatase (Bhatti et al., 2017). Besides, it was reported that pH ranges of 6.5–7.1 and 8.3–9.0 is supportive to arylsulfatase producing microorganisms (Yu et al. 2023). In that case, our conventional fields showed average higher pH (4.2 to 5.8) compared with the organic ones (4.3 to 5.3) which could be a factor for higher arylsulfatase activity in conventional soils. Additionally, lower availability of sulfur in conventional soil (data not shown here) might be the another reason for higher arylsulfatase activity. According to Kunito et al. (2022), there is an inverse relation between available sulfur and arylsulfatase activity i.e., lower availability of sulfur increases the arylsulfatase activity and vice versa.

Co-efficient of correlation

The most striking correlations between different parameters under organic and conventional farming practices are shown in Figure 3. A negative and significant correlation was found between OC and pH in organic fields. Along with that, organic soils also showed highly significant) positive correlation between OC and TN. While the relations of OC with that of the urease, phosphatase and arylsulfatase activities under organic farming system were positive, negative relationships were found between OC with that of all the enzymatic activities under conventional practice.

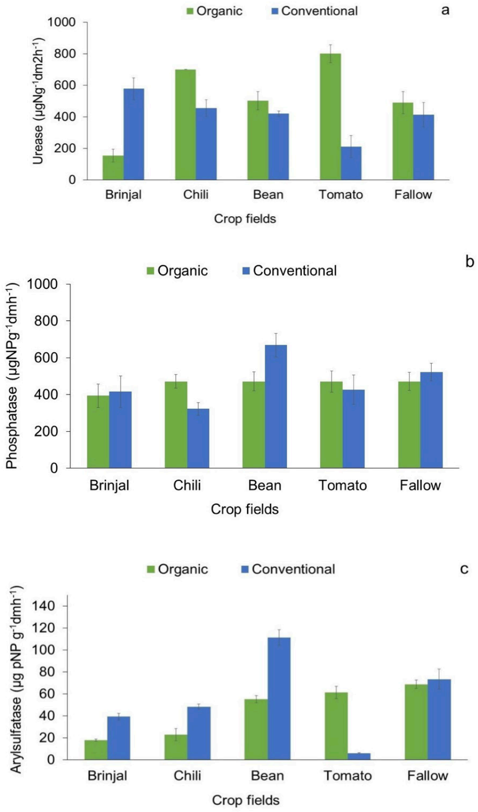

Figure 2. Effects of different farming practices on soil a) urease, b) phosphatase and c) arylsulfatase activities in different crop fields under two farming systems.
(Fields differed significantly at 5% level of significance under both organic and conventional farming systems.)

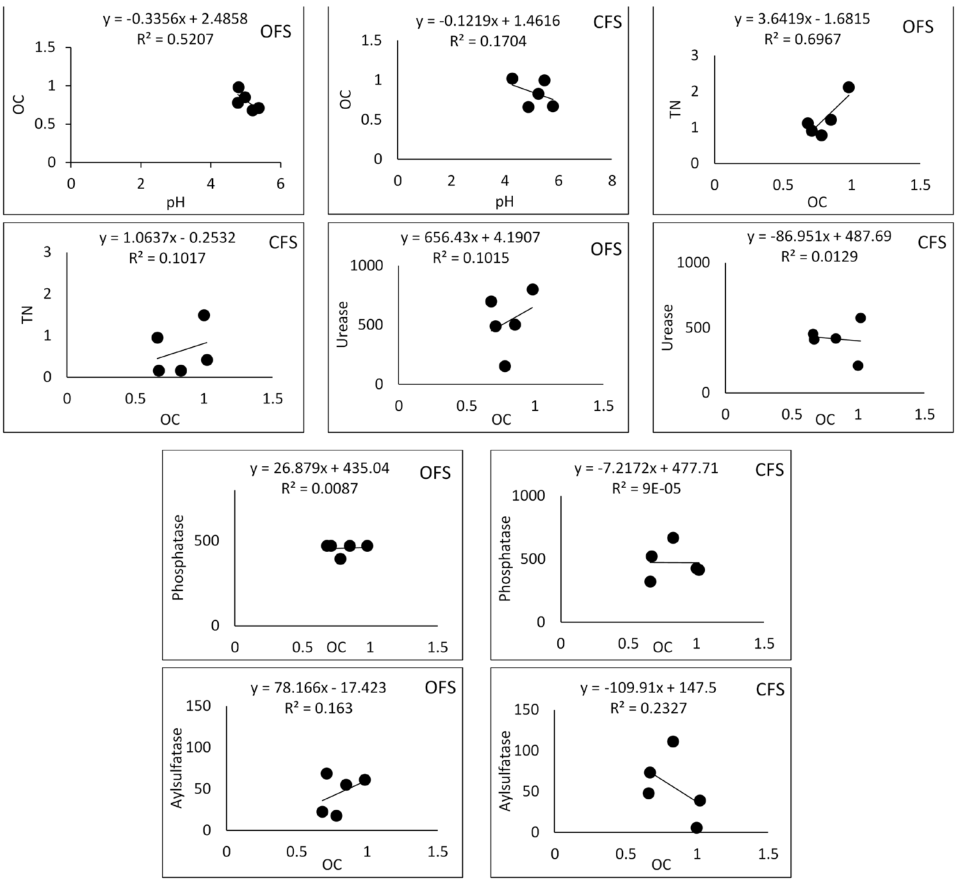

Figure 3. Correlations between different parameters of crop fields under organic and conventional farming practices.
(OFS= Organic Farming System, CFS= Conventional Farming System, OC= Organic Carbon, TN= Total Nitrogen. Correlation of soil parameters differed significantly at 5% level of significance.)

The dendrogram groups samples into clusters based on soil enzyme activities and physicochemical properties is shown in Figure 4. A clear separation was observed between organically treated soils (prefix "O") and conventionally treated soils (prefix "C"). Samples such as OBnT, OTT, and OFT cluster together, indicating similar enzyme profiles and nutrient conditions. In contrast, conventional samples like CBn, CFT, and CCT form a separate cluster, suggesting divergent biochemical dynamics. The dendrogram supports the hypothesis that management practices significantly shape soil biochemical properties.

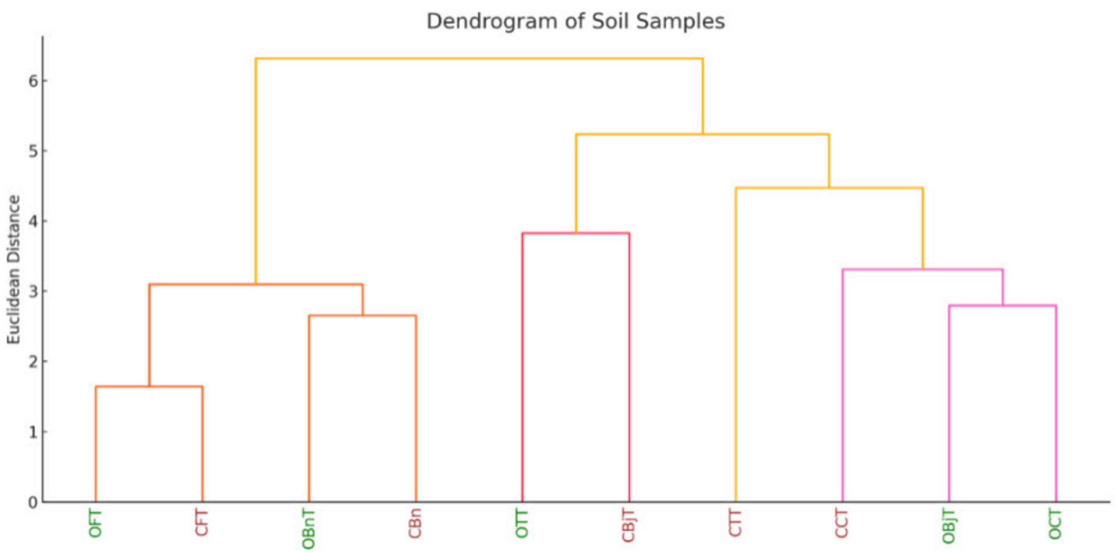

Figure 4. Hierarchical clustering based on enzyme activities and physicochemical properties at 0–15 cm depth from organic and conventional crop fields.

(Green: Samples starting with "O" (organic fields), Brown: Samples starting with "C" (conventional fields); ObjT= Organic Brinjal, OCT= Organic Chilli, ObnT= Organic Bean, OTT= Organic Tomato, OFT= Organic Fallow, CBjT= Conventional Brinjal, CCT= Conventional Chilli, CBn= Conventional Bean, CTT= Conventional Tomato and CFT= Conventional Fallow.)

CONCLUDING REMARKS

The present study was conducted to evaluate and compare the physico-chemical and biochemical properties of soils under two distinct farming practices, with the overarching goal of identifying strategies for sustainable crop production while maintaining long-term soil health. Results indicated that the organic farming system supported higher levels of organic matter and TN compared to conventional practices. Moreover, enzymatic activities, which serve as sensitive indicators of soil biological functioning, also responded more favorably under organic management. While conventional farming continues to play a dominant role in ensuring global food and fiber supply through practices such as intensive tillage, and the widespread application of chemical fertilizers, herbicides, and pesticides, these approaches often compromise soil quality over time. In contrast, organic farming emerges as a promising sustainable alternative that not only enhances soil physico-chemical and biochemical properties but also contributes to long-term ecological balance. Besides, the universal problem of nitrogen loss from agricultural fields can be mitigated through the application of nitrogen-rich organic amendments, which improve nutrient retention and cycling within the soil. Therefore, farmers should be motivated and supported to adopt organic management systems to ensure resilient agricultural production and safeguard soil resources for future generations.

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ОРГАНСКО НАСПРОТИ КОНВЕНЦИОНАЛНО: ЕФЕКТИ ВРЗ ФИЗИЧКО-ХЕМИСКИТЕ И БИОХЕМИСКИТЕ ИНДИКАТОРИ НА ПОЧВИТЕ

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Резиме

Оваа студија беше спроведена за да се проценат различните индикатори на почвата во однос на физичко-хемиските и биохемиските својства под влијание на два различни земјоделски системи, конвенционален наспроти органски. За таа цел беа собрани примероци од почва од различни земјоделски површини на кои се практикуваат конвенционални и органски системи. Сите примероци од почва беа анализирани според стандардни процедури. Резултатите покажаа значително ($p < 0,05$) пониска pH вредност и повисока електрична спроводливост (EC) на почвите во повеќето земјоделски површини под органско земјоделско производство во споредба со конвенционалните земјоделски површини. Иако органскиот јаглерод (OC) беше незначително ($p > 0,05$) повисок во почвите на органските земјоделски површини, вкупниот азот (TN) беше значително ($p < 0,05$) повисок на органските земјоделски површини во споредба со конвенционалните. Активностите на уреазата, фосфатазата и арилсулфатазата меѓу различните земјоделски површини значително се разликуваа ($p < 0,05$) и во органските и во конвенционалните земјоделски системи. Со исклучок на патлиџанот, активноста на ензимот уреаза беше повисока во сите земјоделски површини под органско земјоделско производство во споредба со нивните соодветни култури од конвенционалниот систем. Од друга страна, активноста на арилсулфатазата беше повисока во почвите на сите култури освен кај доматот во конвенционален земјоделски систем во однос на нивните соодветни органски култури. Што се однесува до фосфатазата, таа имаше повисоки активности во земјоделските површини со чили и домати, додека пониски во патлиџан, грав и угар во органски земјоделски систем. Негативна значајна ($p < 0,05$) корелација помеѓу OC и pH, додека позитивна значајна ($p < 0,05$) корелација помеѓу OC и TN беше забележана во органскиот земјоделски систем. Хиерархискиот дендрограм на групирање базиран на активностите на ензимите во почвата и физичко-хемиските својства покажа јасна поделба помеѓу органски и конвенционално управуваните почви. Оваа студија заклучува дека практиките на управување значително ги обликуваат биохемиските својства на почвата.

Клучни зборови: *конвенционално земјоделство, ензимска активност, органско земјоделство, здравје на почвата.*