Review Article
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The Effect Of Some Organic Materials On Soil Organic Content And Some Soil Physicochemical Properites, In Türkiye

Bazı Organik Materyallerin Türkiye Topraklarının Organik Maddesi ve Bazı Fiziko Kimyasal Özellikleri Üzerine Etkileri

Abstract

This review is written based on the actions that can be taken, especially on the presence of organic matter and plant nutrients decreasing day by day in Turkish soils. Agriculture has been a long-standing activity in our geography, which has hosted many civilizations throughout history. Therefore, our soils have been becoming poor in terms of plant nutrients for thousands of years. Previous research conducted in many parts of Turkey has shown a deficiency of organic matter in the majority of our soils. One of the sources of nitrogen in the soil is organic matter, and the deficiency of organic matter triggers nitrogen deficiency as well. When Turkey's soils are evaluated in terms of phosphorus, it is seen that they are supported by the use of chemical fertilizers. On the other hand, when studies are conducted with potassium, another macronutrient, no serious problems are encountered in Turkish soils. In recent years, some organic materials and soil conditioners that affect the physical and chemical structure of soils have been applied to support these nutrients through organic methods. Organic materials such as humic acid, leonardite, vermicompost, and biochar are evaluated within the scope of this review.

Keywords: Organic matter, humic acid, leonardite, biochar, vermicompost.

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Özet

Bu derleme Ülkemiz topraklarının özellikle organik madde ve bitki besin elementlerinin varlığının her geçen gün azalıyor olması üzerine yapılabilecekler üzerinden yola çıkılarak yazılmıştır. Tarih boyu birçok medeniyete ev sahipliği yapan coğrafyamızda tarım çok eski yıllardan beri yapılan bir faaliyettir. Dolayısıyla topraklarımız binlerce yıldır bitki besin elementleri açısından fakir hale gelmeye başlamıştır. Daha önce Türkiye'nin birçok yerinde yapılan araştırmalarda topraklarımızın büyük çoğunluğunda organik madde noksanlığına rastlanmaktadır. Topraktaki azotun kaynaklarından biri de organik maddedir. Organik madde noksanlığı beraberinde azot noksanlığını da tetiklemektedir. Yine Türkiye toprakları fosfor bakımından değerlendirildiğinde kimyasal gübre kullanımı ile desteklendiği ortaya çıkmaktadır. Bir diğer makro element olan potasyum ile yapılan çalışmalarda Türkiye topraklarında ciddi noksanlık gibi bir sorun olmadığı karşımıza çıkmamaktadır. Son yıllarda bu besin elementlerini organik yollarla destekleyebilmek adına toprakların fiziksel ve kimyasal yapılarına etkide bulunan bazı organik materyaller ve toprak düzenleyiciler uygulanmaktadır. Humik asit, leonardit, vermikompost ve biyokömür gibi organik materyaller bu derleme çerçevesinde değerlendirilmiştir.

Anahtar Kelimeler: Organik madde, humik asit, leonardit, biyokömür, vermikompost.

1. Introduction

The aim of this study is to investigate the effects of certain organic materials (humic acid, leonardite, vermicompost, and biochar) on the soil structure and nutrient content, particularly focusing on the improvement of soil organic matter, phosphorus, and potassium levels in Turkish soils. The study seeks to evaluate the effectiveness of these organic materials in addressing the issues of declining soil fertility and to promote sustainable agricultural practices. Turkey is located on the cradle of ancient civilizations that have hosted many civilizations since ancient times. It is known that vital activities have been carried out for periods equivalent to human history in the Anatolian geography we are in. In this geography, which has hosted many civilizations, there are, of course, numerous ongoing agricultural activities. It is known that the economies of the important cultures in Anatolia, dating back to the years before Christ such as the Hittites, Phrygians, Urartians, and Lydians, are based on agriculture and animal husbandry. Soil is not an unlimited resource. Soil organic matter is decreasing day by day with various agricultural activities, especially with the reduction of agricultural areas and some activities aimed at getting more product from unit areas causing serious losses in soil organic matter. In fact, soil organic matter consists of plant and animal residues found in the soil. Organic matter is one of the most important parameters affecting the physical and chemical properties of the soil. Soil organic matter not only improves the physical properties of soils such as good soil structure, stability of aggregates, water holding capacity, aeration, and tilth, but also facilitates the uptake of nutrients by plants due to its cation exchange capacity (Güçdemir, 2006). The cation exchange capacity of organic matter is approximately 250 me/100 g, and it absorbs plant nutrients from the soil solution into the plant. In this way, it contributes significantly to the nutrition and development of the plant (Ergene, 1993).

In addition to organic matter, there are certain elements necessary for the growth and continuation of vital functions of the plant. The elements that are absolutely necessary for plants to complete their growth and normal life processes, and whose functions cannot be fulfilled by other elements, are called "Plant Nutrients". The absolute necessity of nutrient elements for plants depends on the fulfillment of the following three factors: (Karaçal 2008)

1. The plant should not be able to complete its life cycle without the element.

2. The deficiency symptom of the element should be unique to that element.

3. The element should directly interact with plant nutrition.

Nitrogen (N), Phosphorus (P), and Potassium (K) are the main elements that constitute the backbone of fertilization, and they are the elements where we encounter deficiencies most frequently in our soils.

It is hypothesized that the organic materials evaluated in this study, humic acid, leonardite, vermicompost, and biochar will significantly increase the organic matter content of Turkish soils and enhance the availability of nitrogen, phosphorus, and potassium. Furthermore, it is anticipated that the application of these organic materials will positively impact soil structure, leading to improved plant growth and development.

2. The Status of Soil Organic Matter, Nitrogen, Phosphorus, and Potassium in Turkey's Soils

2.1 Soil Organic Matter Status in Turkey

As briefly mentioned in the introduction, it would not be wrong to say that the potential of organic matter in our country's geography is not very good. Numerous studies have been conducted on the organic matter contents of Turkish soils. The data presented at the workshop on organomineral fertilizers in Turkey regarding the organic matter content and its changes in Turkish soils are shown in Figure 2.1 (Anonymous 2018a). The results indicated that Turkish soils generally have low organic matter content, which poses a significant problem for sustainable agriculture. In the study conducted by Şenses et al., (2015) organic matter analyses were performed on soil samples collected from various provinces of the country, and regional differences were revealed. It is observed that the mineral part of our soils generally constitutes 96-99% of the upper part of our soils (especially 0-30cm) , while 1-4% consists of organic matter (Eyüpoğlu, 1999).

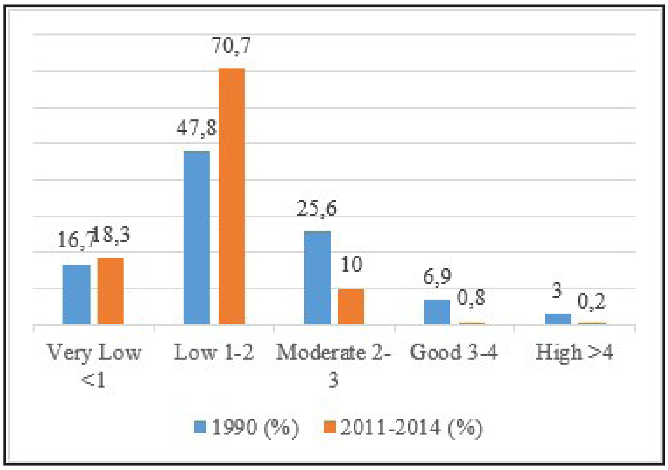

Figure 2.1 Distribution of Organic Matter Content in Turkish Agricultural Soils (Anonymous 2018a)

Comprehensive studies have been conducted on both organic matter and mineral substances in Turkish soils under the auspices of the Soil Fertilizer and Water Resources Central Research Institute Directorate. Within the scope of the Turkey Soil Productivity Inventory Project (TOVEP) conducted by the Soil Water General Directorate, approximately 250,000 soil samples were taken from Turkey and analyzed. According to these analysis results, the organic matter content of our soils is quite low. One of the main reasons for this is, as mentioned, the agricultural activities carried out in our soils for many years. Another reason is the errors in soil cultivation, the lack of established crop rotation systems, stubble burning, incorrect fertilization, human and natural environmental errors, and phenomena resulting from these factors, among others. These results are classified with the help of the table provided below (Güçdemir, 2006).

Table 2.1 Soil Organic Matter Contents Categorized According to Their Status (Güçdemir, 2006)

Organic Matter (%)	The Status of Soil Organic Matter
<1	Very Low
1-2	Low
2-3	Moderate
3-4	Good
>4	High

When the data is examined collectively, it is observed that the organic matter contents are low in regions dominated by a warm climate and high in regions with abundant rainfall and relatively moderate temperatures. Although evaluated regionally according to the assessment criteria provided in Table 2.1, a regional distribution table of organic matter contents as shown in Table 2.2 has been revealed.

Accordingly, the organic matter status of Turkish soils generally ranges between 1-2%, which can be considered low. When examined regionally, as mentioned above, in regions that can be considered within the warm and arid climate zone, organic matter levels are generally low and very low, while in places with abundant rainfall and relatively cool climates such as the Black Sea region, they are much higher compared to the average (Güçdemir, 2006).

Table 2.2 Regional Distribution of Organic Matter Content in Turkish Soils (Güçdemir, 2006)

Regions	Soil Samples	Very Low	Low	Moderate	Good	High
Trakya and Marmara	26563	20	42.5	23.6	8.9	5
Karadeniz	36291	8.1	29.2	30.6	16.8	15.3
Orta Anadolu	76688	24.5	50.2	19.2	4.3	1.8
Güney Doğu	25523	20.5	48	22.7	5.6	3.2
Doğu Anadolu	12023	10.7	42.2	28.1	11.8	7.2
Ege	22695	35.7	43.7	15.3	3.9	1.4
Göller	27575	26.3	40	21.9	7.9	3.9
Akdeniz	16095	13.4	40.7	27.8	10.9	7.2
Total	243453	51088	105164	55278	19467	12456
Average	%	21	43.2	22.7	8	5.1

2.2 Phosphorus Status of Turkey's Soils

Phosphorus is one of the main elements that plants require most, along with Nitrogen and Potassium. The sources of phosphorus in the soil are organic phosphorus compounds and mineral rocks, which are found in both organic and inorganic forms in the soil. The presence of phosphorus in the soil does not mean the amount of phosphorus available to the plant. Generally, only about 1 or 2% of the total phosphorus is found in the soil in a form that is beneficial to the plant.

Current studies on the phosphorus status of Turkish soils have also been conducted, and a comprehensive study has been carried out based on 240,000 soil samples (Eyüpoğlu, 1999). In order to interpret the evaluation made according to the Olsen phosphorus analysis method, Table 2.3 was used.

Table 2.3 Values Used to Determine Soil Phosphorus Status (Eyüpoğlu, 1999)

Fosfor Status (kg P_2O_5 da^{-1})	**Classification**
<3	Very Low
3-6	Low
6-9	Moderate
9-12	Good
>12	High

As a result of the study conducted in accordance with this classification criterion, it was found that 29% of Turkish soils are poor in phosphorus. Phosphorus deficiency is observed in 55% of Turkey overall. When evaluated regionally, it would be correct to say that phosphorus levels are sufficient and high in locations where irrigable areas are dense. In other words, phosphorus accumulation is observed in irrigable areas (Eyüpoğlu, 1999). The table established for these data is presented in detail in Table 2.4.

Table 2.4 Regional Distribution of Phosphorus Content in Turkish Soils (Eyüpoğlu, 1999)

Regions	Soil Samples	Very Low	Low	Moderate	Good	High
Trakya and Marmara	26563	17	19.1	16.2	12.8	34.9
Karadeniz	36291	35.8	24.9	11.9	7.6	19.8
Orta Anadolu	76688	31.3	27.5	18.3	8.8	14.1
Güney Doğu	25523	39.5	34.4	15.9	5.9	4.3
Doğu Anadolu	12023	36.2	27.5	15.8	8.8	11.7
Ege	22695	19.2	27.4	20.6	11.4	21.4
Göller	27575	24.2	28	19.2	12	16.6
Akdeniz	16095	14.5	24.7	21.3	13.7	25.8
Total	243453	69260	65102	41851	23505	43238
Average (%)	100	28.5	26.8	17.2	9.7	17.8

Especially in recent years, significant data have been obtained from studies conducted in certain locations in Turkey regarding phosphorus accumulation in irrigated areas. In a study conducted to determine the soil properties of the Kızılcahamam district of Ankara province, it was found that 17.65% of the soil samples taken from irrigated areas had low phosphorus, 23.53% had moderate phosphorus, 23.53% had excess phosphorus, and 35.29% had very high phosphorus levels (Işın and Aydın, 2019). When past studies are examined, it would be correct to say that the phosphorus content of soils in Turkey has gradually increased over the years, according to the data. While phosphorus deficiency was noticeable in 85-90% of Turkish soils in a study conducted by Ülgen and Yurtsever (1974), many analyses conducted up to the present day have revealed an increase in phosphorus accumulation in soils. It would not be wrong to say that there has been an increase in phosphorus levels in our soils over the years. Kaplan et al. (1992) noted this change in an assessment made to observe a change over the years. The data from their study are shown in Table 2.5.

Table 2.5 Distribution of Phosphorus Content in Turkish Soils in % (Kaplan et al., 1992)

Years	**Soil Sample**	**Very Low %**	**Low %**	**Moderate %**	**High%**	**Very High%**
Until 1974	31441	44.3	30.3	11.3	7.1	6.8
Until 1984	65008	33.3	32.8	18	8.7	7.2

The phosphorus status varies depending on the physical conditions of the regions. For example, in a study conducted to determine the basic productivity levels of agricultural soils in the Middle and Eastern Black Sea Region; it was understood that 35.71% of the soils had very little phosphorus, 23.12% had little phosphorus, 10.14% had moderate phosphorus, 5.53% had high phosphorus, and 25.50% had very high phosphorus content.Despite the application of phosphorus fertilizers, phosphorus deficiency is observed due to the runoff of phosphorus fertilizers applied to the surface of sloping lands and the depth of the soil in hazelnut orchards (Özyazıcı et al., 2016). According to the findings of this research, one of the reasons for phosphorus deficiency is that the applied fertilizers are not suitable for the fertilization techniques and land structure.

2.3 Potassium Status of Turkey's Soils

Due to Turkey's geological structure and climatic characteristics, it is a country rich in potassium resources. Potassium is a nutrient element that is abundant in soils nationwide due to our clayey soil structure and the abundance of potassium-rich minerals such as feldspar and mica. In general, Turkish soils are adequately rich in potassium content. A comprehensive study conducted on 240,000 soil samples has determined the potassium values of our soils (Ülgen and Yurtsever, 1995). Table 2.6 has been utilized to evaluate the obtained data .

Table 2.6 Values Utilized to Determine Soil Potassium Status (Ülgen and Yurtsever, 1995)Formun Üstü

Potassium Status (kg K_2O da^{-1})	**Classification**
<20	Low
20-30	Moderate
30-40	Sufficient (Good)
>40	High

According to both literature reviews and the aforementioned study, the potassium content of Turkish soils has been found to be quite high. The table for this data is given in detail in Table 2.7. Accordingly, it is stated that 92% of Turkish soils have sufficient to high potassium content, 5% have moderate levels, and 3% have insufficient levels (Eyüpoğlu, 1999).

Table 2.7 Regional Distribution of Potassium Content in Turkish Soils (Eyüpoğlu, 1999)

Regions	Soil Samples	Low	Moderate	Good	High
Trakya and Marmara	26563	5.6	10	12.2	72.2
Karadeniz	36291	6.5	9.3	17.3	66.9
Orta Anadolu	76688	0.5	1.9	2.7	94.9
Güney Doğu	25523	0.5	0.5	1.3	97.7
Doğu Anadolu	12023	0.8	2.3	3.9	93
Ege	22695	7.6	7.4	8.7	76.3
Göller	27575	2	3.2	4.5	90.3
Akdeniz	16095	4.6	10.1	12	73.3
Total	243453	7413	12069	17554	206437
Average %	100	3	5	7.2	84.8

Except for extreme cases, we can say that Turkish soils are quite rich in potassium based on the results obtained. In many studies conducted on this subject, potassium levels have been found to be quite high. In a study conducted by Işın and Aydın (2019) in the Kızılcahamam region, the average potassium level of the soils analyzed in the region was found to be 230.39 kg K_2O da^{-1}, ranging from 109.24 to 600.15 kg K_2O da^{-1}. The region has very high levels of potassium content due to both its rich mineral rocks and its clayey soil structure. This situation is true nationwide.

3. Impact of Some Organic Materials and Soil Amendments on the Physical and Chemical Properties of Soils

There are numerous materials applied to soils to meet the organic matter requirement. While some of these can be classified as fertilizers, others are referred to as soil conditioners. In terms of their nutrient content, the evaluation often establishes a correlation with nitrogen, phosphorus, and potassium. This correlation is based on either the presence of these elements in the structure of the added material or their ability to enhance their availability. Generally, most of these materials contain high levels of organic matter.

3.1 Humic Acid

Humic substances are natural materials formed in soils, lakes, rivers, and seas, exhibiting perhaps the most widespread distribution on Earth's surface. Despite their widespread occurrence, there are still unknown aspects regarding their origins, synthesis, chemical structures, and reactions. Research on identifying what humic substances are, how they are formed, and how they function continues from the past to the present.

Humic acid significantly improves soil structure and enhances nutrient availability. Its application can improve the cation exchange capacity of the soil, facilitating the uptake of essential nutrients by plants. Research has shown that humic acid contributes to the growth and productivity of various crops by improving soil aeration, water retention, and microbial activity (Hossain et al., 2016)

The contents of C, O_2, H, N, and S in humic acids are shown in Table 3.1 (Ok, 2007). Despite containing numerous mineral substances, they are not considered as fertilizers due to the lack of desired proportions. Instead, they are primarily recognized as soil conditioners, organic materials regulating soil properties.

Table 3.1 The Elemental Composition of Humic Acids (%) (Ok, 2007)

Elemental Composition (%)	
C	50-60
O_2	30-35
H	4-6
N	2-4
S	0-2

Through numerous studies conducted on humic acids, it has been demonstrated that they significantly improve soil structure. Being organic materials, they aid in the healthy development of plant roots, confer resistance to root diseases, and promote lateral root formation. Humic acids facilitate the uptake of essential nutrients by plants. Research has identified that humic acid and its derivatives enhance the permeability of plant membranes, thereby facilitating the absorption of nutrients by plants (Canellas and Olivares, 2014). Due to their high cation exchange capacity (CEC), they directly impact plant nutrition. Additionally, they have positive effects on soil organic matter and consequently on soil microbial activity. Several studies have found that humic acid applications increase the available phosphorus content in soils (Beneddetti et al., 1996; Erdal et al., 2000). In a study conducted by Demir and Çimrin (2011) in Van province, increasing doses of humic acid applications were found to significantly contribute to the soil's organic matter and available phosphorus content. In an experimental study aimed at determining the effects of organic soil conditioners on soil parameters, it was found that the application of humic acid at the highest dose increased the soil's organic matter content significantly. However, concerning phosphorus, while the addition of different doses and types of humic acid resulted in increased soil phosphorus levels compared to soils treated solely with chemical fertilizers, this increase was statistically insignificant. The material used potassium humate, was found to increase the potassium content of soils to a certain extent (Tamer et al., 2016).

3.2 Leonardite

Leonardite is a completely natural organic material that has not reached the level of very young coal and contains high levels of humic acids along with macro and micronutrients. Its formation is the result of specific geological conditions such as temperature, humidity, pressure, oxidation, and very special geological conditions, dating back millions of years to plant and animal residues, and is a natural material that is rarely found in nature and whose quality varies from region to region.

Leonardite, rich in humic substances, serves as an excellent soil conditioner. Its application can enhance the organic matter content of the soil, improve nutrient availability, and mitigate issues related to soil acidity and salinity. Incorporating leonardite into the soil can lead to improved crop yields and healthier soil ecosystems (Engin and Cöcen, 2012).

Due to its high content of humic acids, leonardite is of significant value. It appears black-brown and can be easily crumbled by hand, with a humic acid content ranging from 50% to 80%. Its density ranges from approximately 0.75 to 0.85 g cm^{-3}, and its pH value is between 3 and 5. It is highly soluble in 1% KOH and NaOH solutions but has low solubility in water. Its solution is shiny black in color, foamy, colloidal, and oily in appearance. It readily dissolves in saturated mud prepared with soil having a pH value of 8-9. The table 3.2 below provides the classification of leonardite quality. (Engin and Cöcen, 2012)

Table 3.2 Leonardite Quality Classification (Engin and Cöcen, 2012)

Composition	Low Quality	Medium Quality	High Quality
Humic Acid Content	35-50	50-65	65-85
Amount of Organic Matter	Min 35	Min 50	Min 65
pH	6.5 ± 1	5.5 ± 1	4 ± 1
C/N	21 ± 1	19 ± 1	17 ± 1
Specific Gravity (g/cm³)	1.4 ± 0.1	1.2 ± 0.1	0.8 ± 0.1
Solubility in Alkaline Solution	Low	Medium	High

Typically used as a substitute for animal manure, it is referred to as a soil conditioner and organic matter supplement. It is richer in organic matter compared to animal manure and contains higher levels of humic and fulvic acids. It does not contain nematodes or weed seeds. It is a rare organic product that provides a solution to problems such as soil acidity caused by excessive chemical use, calcification, soil infertility, and salinity. It is known as an organic soil conditioner. The most significant difference between it and soil lies in plant nutrients. Leonardite is high in phosphorus (P_2O_5) but low in potassium (K), with high levels of calcium carbonate content, making it a neutral substance in terms of soil reactions (pH). Moreover, it is rich in micronutrients that can be absorbed by plants (Fe, Mn, Cu, Zn). The desirable characteristics that should be present in high-quality leonardite are shown in Table 3.3.

Table 3.3 Sample Chemical Analysis Values of High-Quality Leonardite (Engin and Cöcen, 2012)

C	% 30.7		**Humic Asid**	% 65-85
H	% 2.4		**Moisture**	% 15-20
N	% 1.7		**Total Organic Matter**	% 86
S	% 1.5		**Ca**	% 1.2
O	% 34		**Mg**	% 0.12
C/N	18.3		**P**	% 0.05
Fe	% 1.85		**K**	% 0.76

3.3 Vermicompost

Vermicompost is a soil conditioner produced based on the activity of earthworm species known as *Lumbricus rubellus* and *Eisenia foetida*, which organically process the dung of large ruminant animals and organic plant materials (such as straw, tree bark and leaves, vegetable and fruit residues, etc.), altering their physical and chemical structures. The application of vermicompost effectively provides the plant's required nutrients in an accessible form and enhances the uptake of these nutrients by the plant. Additionally, various researchers have reported that the application of vermicompost to soil can improve its physical, chemical, and biological properties, thereby facilitating the cultivation of high-quality and high-yield crops. In heavy clay soils, it improves water and air permeability and prevents soil particles from sticking together. In light sandy soils, it helps retain water and nutrients and keeps soil particles together.

Vermicompost, produced through the activity of earthworms, is a valuable organic amendment that enriches the soil with essential nutrients and beneficial microorganisms. The application of vermicompost can enhance soil structure, improve water retention, and stimulate microbial activity, ultimately contributing to increased plant growth and crop productivity (Edwards and Arancon, 2004).

Research on vermicompost indicates that this material has virtually no adverse effects on soil structure. It enhances almost all physical properties of the soil, increases water retention capacity, and regulates pH. It rehabilitates problematic soils that have lost productivity, and organic content, and have been continuously exposed to chemicals. It provides plants with the trace elements they need externally. It enhances root development in plants and contributes to the development of vegetative parts. Additionally, it synergistically interacts with soil microorganisms, providing an additional contribution to the improvement of soil structure.

In a study conducted on worm fertilizers produced by producers in Turkey, analyses of solid worm fertilizers produced in different regions were provided for 16 facilities, and solid fertilizer results were obtained from accredited laboratories. Four kilograms of solid worm fertilizer were taken from each facility and sent to laboratories. Laboratories kept some of the solid fertilizers as reference samples, and the rest were analyzed for pH, EC, Total Nitrogen-N, Phosphorus-P, Potassium-K, organic matter, C/N ratio, and moisture content (Çıkrıkçı and Okumuş, 2019).

Table 3.4 pH, EC, Moisture, C/N ratio, Total NPK, and Organic Matter Values of Facilities Producing Solid Worm Fertilizers (Çıkrıkçı and Okumuş, 2019)

Facilities	**pH**	**EC**	**moisture %**	**C/N**	**Tot. N ppm**	**Tot. P ppm**	**Tot. K ppm**	**Org. Mat.%**	**Humic Fulvic%**
Ankara 1	7.02	323	30.39	8.42	2500	1400	9600	42.31	25.07
Ankara 2	7.21	742	15.50	9.01	2060	1390	8940	51.50	15.80
Ankara 3	8.20	298	22.60	13.90	2000	1440	8463	52.00	21.15
Balıkesir	8.01	620	25.41	15.16	2100	8259	10714	63.53	53.71
Çorum	7.98	510	35.10	16.12	1400	9327	9760	33.32	20.20
Denizli 1	7.23	590	48.43	18.01	380	1300	1100	26.84	21.46
Denizli 2	7.40	538	72.70	16.20	1900	1880	1600	53.10	-*
İstanbul	7.12	1870	20.34	12.02	2000	5230	8903	45.29	18.51
İzmir	7.34	1899	66.21	14.46	1770	1894	7626	58.58	19.05
Konya 1	7.51	554	90.73	26.65	180	1230	5800	6.54	4.94
Konya 2	8.36	990	46.12	13.32	1500	1583	6792	52.00	20.81
Samsun 1	7.31	1941	62.13	5.092	2651	5851	14620	67.55	29.80

Samsun 2	7.72	584	72.50	6.23	1900	8870	12374	53.20	47.62
Muğla	7.17	656	58.34	-*	2980	8300	14600	86.120	55.88
Tokat 1	7.88	1058	73.67	4.441	2175	6044	10330	60.15	24.93
Tokat 2	8.30	968	72.40	6.70	1360	4892	9873	47.72	28.90
Average	7.61	883.81	50.78	12.38	1803.5	4305.6	8818.4	49.98	27.18

3.4 Biochar

The carbon-rich byproduct produced when agricultural residues, wood, and other biomass materials are heated through pyrolysis in an oxygen-free environment is commonly referred to as "biochar." Biochar is an organic soil conditioner that is formed by the breakdown of organic materials under anaerobic or pyrolytic conditions (350-600 °C), resulting in a porous carbon source. Fine-grained carbon and mineral-rich products obtained after the gasification of organic matter with minimal oxygen are referred to as biochar. (Kwaku et al., 2023) Biochar can be made from any biomass, including wood, manure, food waste, organic by-products, bioenergy products, crop residues, or other organic materials. The nutritional qualities, absorption capacity, cation exchange capacity, and degradation period of biochar can vary depending on the raw material quality, pyrolysis process, and management type. Numerous studies have been conducted on biochar, and research is ongoing. Some studies mention its benefits, some report no effect, and others highlight negative aspects. Essentially, the excessively porous structure of biochar hosts numerous microorganisms, bacteria, and various soil organisms, making it permeable and airy. Additionally, it positively influences soil physical properties such as soil aeration and water retention capacity. As soil microorganism activity increases, significant organic matter is contributed to the soil, and nutrients become more easily retained by the soil.

According to Lehmann and Joseph (2015) biochar, produced from the pyrolysis of organic materials, enhances soil fertility by increasing the soil's carbon content and improving its physical properties. The addition of biochar to the soil can lead to enhanced nutrient retention, improved soil aeration, and increased microbial activity. Furthermore, biochar contributes to long-term soil health and sustainability by sequestering carbon.

4. Conclusion

All research results indicate that the applications of humic acid, leonardite, vermicompost, and biochar improve the physical structures of soils, increase organic matter content, and to some extent, elevate Nitrogen, Phosphorus, and Potassium contents. However, for these organic materials to serve as alternatives to chemical fertilizers, they need to be enriched, especially in terms of Nitrogen, Phosphorus, and Potassium. Studies have shown that these materials are beneficial but insufficient in terms of plant nutrition. Since each material may have different compositions, achieving standardization seems challenging. There is a need for studies to enrich these materials as organomineral fertilizers to become alternatives to chemical fertilizers. BÜGEM's registration processes need to be reviewed to establish standards for the desired parameters. Each organic material consists of different organic compounds, and their structures are homogeneous within themselves. For example, vermicompost may vary in content depending on the worm species, their diet, and even the environment. Therefore, it is not possible to determine which of these materials contributes more to the Nitrogen, Phosphorus, and Potassium contents in the soil. However, it would not be incorrect to say that each contributes to certain amounts. Recommendations on this subject can be listed as follows.

1-Promotion of Organic Materials Use:

It is essential to encourage the use of organic materials such as humic acid, leonardite, vermicompost, and biochar among farmers to improve soil health and increase agricultural productivity. The effective application of these materials, considering appropriate dosages and timing, can enhance the nutrient content of the soil (Demir ve Çimrin, 2011).

2-Selection of Organic Materials Suitable for Local Conditions:

The effectiveness of organic materials can vary depending on the soil structure, climatic conditions, and crop types. Therefore, farmers and agricultural specialists should select and apply organic materials that are appropriate for local soil and climate conditions. For instance, humic acid and leonardite may be particularly effective in more acidic soils, while vermicompost may be better suited for sandy and clay soils (Erdal et al., 2000).

3-Integrated Use with Chemical Fertilizers:

Organic materials may not provide sufficient nutrients on their own. Therefore, they should be integrated with chemical fertilizers as needed to address deficiencies in nitrogen, phosphorus, and potassium. However, care should be taken to avoid excessive use of chemical fertilizers (Kaplan and et al., 1991).

4-Development of Policies for Sustainable Agricultural Practices:

Agricultural authorities should establish support programs that promote the use of organic materials. This will encourage the adoption of sustainable agricultural practices and contribute to the long-term health of the soil (Tamer et al., 2016).

5-Education and Awareness Programs:

Farmers and agricultural sector workers should be educated about the benefits, proper application methods, and long-term effects of organic materials. Such educational programs will facilitate the more effective and widespread use of organic materials (Çıkrıkçı and Okumuş, 2019).

6-Establishment of Standards and Quality Control:

The effectiveness of organic materials can vary based on their composition. Therefore, quality standards should be established for the production and sale of organic materials, and strict quality control procedures should be implemented (Engin and Cöcen, 2012). This will ensure that users have access to reliable and effective products.

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