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ORIGINAL PAPER

The effect of the use of vermicompost, leonardite and pomace on some soil properties in olive cultivation*

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Abstract

This research was carried out on a 12-year-old Gemlik variety olive grove, located in the historical Deyrulzafaran Monastery in the Artuklu district of Mardin province, Turkey, in the years 2020-2021. The effect of the use of vermicompost, leonardite and pomace, which are known as organic soil improvers, on some properties of soil under olive trees was investigated. The treatments were applied in February 2020 and repeated in February 2021 during the pre-flowering period of olives. At the end of the applications, the soil was analyzed in July 2022. For this purpose, samples were taken from two different depths, 0-30 and 30-60 cm, to represent the orchard soil under an olive grove. According to the research results, the pH of the soil samples taken from the olive orchard, measured in the saturation sludge, varied between 7.18 and 7.69, and the soil was determined to be of neutral and slightly alkaline reaction. The organic matter content of the garden soil, which was determined to have loamy texture (L) with a salt-free structure, proved to rank as follows: pomace > leonardite > vermicompost--treated soil, with the latter having the highest organic matter content compared to the control group. The %N content in the soils increased in the order: vermicompost > pomace > leonardite, the latter being the highest compared to the control group. In soil samples, the following elements were determined in the following quantities: phosphorus 3.01-6.12 kg da^{-1}, potassium 40.00-44.80 kg da^{-1}, calcium 2500-7370 mg kg^{-1}, magnesium 350-422 mg kg^{-1}, sodium 4.42-6.02 mg kg^{-1}, iron 8.19-15.20 mg kg^{-1}, copper 8.44-13.10 mg kg^{-1} and manganese 26.30-38.70 mg kg^{-1}. It was determined that the phosphorus content of the soils was very low in soil samples taken from 30-60 cm depth, and moderate in soil samples taken from 0-30 cm depth. The potassium content of the soils was determined to be low. All the soil samples were determined to contain excess amounts of calcium. Finally, all the garden soil samples were found to contain adequate amounts of Mg, Na, Fe, Cu and Mn.

Keywords: plant nutrition, leonardite, pomace, soil, vermicompost, olive

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INTRODUCTION

Olive (*Olea europapea* L.) is an evergreen tree that belongs to the Oleaceae family. It is widely known for its economic, cultural, and culinary significance. The olive tree has a long history of cultivation, dating back approximately 8.000 years (Hegazi et al. 2007). Olive is an economically important fruit species, which is widely produced especially in the Mediterranean region, and is used both as olive oil and table olives (Hegazi et al. 2007, Sakar et al. 2016). In our country, in regions where the Mediterranean climate prevails, olive groves established on chalky arid soils do not generally have irrigation systems. Since the climate of the region has a direct effect on soil conditions, olive tree production techniques, product evaluation conditions and the general structure of olive trees, the distribution of roots, and soil character are the determining factors in any fertilization plan (Söylemez et al. 2017). Vermicompost, a type of organic fertilizer, is produced through the composting and digestion of various organic wastes by specific earthworm species, such as *Eisenia foetida* and *Lumbricus rubellus* (Mısırlıoğlu, 2011). The use of vermicompost as an organic fertilizer offers several benefits for both plants and the soil. One of the advantages of vermicompost is its slow and gradual release of nutrients throughout the growing season. Unlike mineral fertilizers that provide nutrients in a more immediate manner, vermicompost releases nutrients slowly, allowing for better nutrient uptake by plants over time (Tirol-Padre et al. 2007). Moreover, organic fertilizers like vermicompost have positive effects on soil properties and soil health. They contribute to the increase in soil organic carbon (C), enhance the cation exchange capacity (CEC), and promote microbial activity in soil (García-Orenes et al. 2016, Chatzistathis, Koutsos 2017, Li et al. 2017, Roussos et al. 2017). These improvements in soil properties are crucial for sustaining agro-ecosystems and supporting long-term soil fertility. In terms of nitrogen (N) fertilization, using organic waste substances as a source of N is considered beneficial. Organic fertilization with substances from organic waste is regarded as a good management practice for N application (Madejon et al. 2003). However, it is important to note that the mineralization of N from organic fertilizers is slower compared to mineral fertilizers, which may result in a delayed response of plants to organic fertilization (Leonel, Tecchio 2009). Overall, the use of organic fertilizers, including vermicompost, can contribute to the maintenance of optimal soil fertility, supporting plant growth and development, and potentially increasing crop yield. It also has long-term benefits for soil health and sustainability in agro-ecosystems. In recent years, interest in vermicompost has increased owing to its extraordinary physicochemical and biological properties (Edwards, Arancon 2004, Huang et al. 2014, Pandya et al. 2014, Soobhany et al. 2017, Blouin et al. 2019). Vermicompost positively affects soil structure, nutrient conversion and many other properties (Manivannan et al. 2009). Vermicompost provides a better environment for root development by improving the physical structure of the soil, including such attributes as porosity, aeration, drainage, resistance to corrosion and infiltration (Arancon et al. 2008). Leonardite is a product of oxidation of naturally occurring lignite (O'Donnell 1973), a brown or black metalloid that contains much carbon (C), 30 to 80% humic acid and 75% organic matter (Ece et al. 2007). The use of leonardite or humic acids produced from it as a soil improver or plant improver has positive effects on soil properties and plant growth, as well as reducing air and water pollution (Akinremi et al. 2000, Sun et al. 2016). Pomace is a solid by-product remaining after the mechanical processing of olives into oil (Akay et al. 2015). Many researchers confirm that olive pulp pomace is rich in organic matter (Chapman 1997, Abu-Zreig, Al-Widyan 2002). Studies have shown that the application of pomace, a by-product of fruit processing, can have positive effects on soil's physical properties, such as field capacity, available water, wilting point, and aggregate stability (Kavdir, Killi 2008, Tohumcu, Aydın 2016). This suggests that the application of pomace can contribute to improving soil quality and enhancing its ability to retain water. Excessive use of inorganic fertilizers, on the other hand, can lead to various negative effects on soil and the environment. These include soil quality deterioration through increased salinity or acidification, contamination of surface and groundwater, degradation of soil organisms, reduction in mycorrhizal colonization, and inhibition of symbiotic nitrogen fixation due to excessive nitrogen fertilization (Gruhn et al. 2000, Abedi et al. 2010, Miao et al. 2011, Hernández et al. 2014, Han et al. 2015). Therefore, there is a need to explore alternative nutrient sources to reduce reliance on inorganic fertilizers, considering their high consumption, high cost, and environmental impacts (Jakubus, Bakinowska 2018). Agricultural soils often have low organic matter content, which negatively affects soil fertility and ultimately crop yield (Innangi et al. 2017, Eren 2019, Bilge et al. 2021). Depending on the type of fertilizer used, its application can positively impact various soil fertility characteristics. Organic amendments such as manure or compost, which are applied in large quantities but have a relatively low nutrient concentration, can have positive effects on the physical, chemical, and biological properties of the soil (Zipori et al. 2020). These amendments can contribute to improving soil fertility and overall soil health. In this study, the effects of the use of organic remedial substances in different forms such as vermicompost, leonardite and olive pomace applied during the pre-flowering period of olives in 2020 and 2021 on 12-year-old olive trees grown in a closed garden on some soil properties were investigated.

MATERIAL AND METHODS

This research was carried out in the ecological conditions of Mardin province, in the olive garden of Deyrulzafaran Monastery, which is one the most important tourist destinations in the province. The olive garden has 12-year-old olive trees of the Gemlik variety, planted over an area of 20 decars and spaced at least 5x5 m. The olive garden lies on the premises of historical Deyrulzafaran Monastery, located in the Eski Kale District of the Artuklu district of Mardin province. The study was carried out in the years 2020-2021. The treatments were applied in February 2020 and repeated in February 2021 during the pre-flowering period of olives. The experiment was set up with 4 replications. Following the application of the tested substances, soil samples were analysed in July 2022. After the soil samples had been delivered to the laboratory, they were air-dried, passed through a 2 mm sieve and prepared for analysis. The following were determined in the soil samples: soil reaction (pH) saturation sludge – with a pH – meter according to Jackson (1958); organic matter – the Walkley-Black method according to Kacar (1995); lime iteratively – with a Scheibler calcimeter as described by Loeppert and Suarez (1996); texture – with the Bouyoucos hydrometer method (Bouyoucos 1951); % salt – according to the US Salinity Laboratory Staff (1954); total nitrogen (N) – using the method of Kjeldahl Bremner (1965); available phosphorus (P) – as described by Olsen et al. (1954); available potassium (K) – according to Richards (1954); available calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), zinc (Zn) and manganese (Mn) – in line with Lindsay and Norvel (1978). In this study, 12 kg olive pomace, 4.5 kg leonardite and 3 kg vermicompost were given to olive trees (per tree) in the pre-flowering period.

Pomace used in the experiment was obtained from 2-phase olive oil production facilities. Vermicompost and leonardite were obtained from commercial companies. Some physical and chemical properties of these organic improvers are given in Table 1.

The experimental area was arranged in a randomized plot design with 4 replications. For efficient fertilizer application, the way any fertilizer is applied is of critical importance. It has been observed that many farmers in our region do not mix organic fertilizer with the soil but randomly sprinkle it on the soil surface. In our experiment, each tested substance was sprinkled around each tree and mixed with the soil with a rake.

Arid and semi-arid climatic conditions in Mardin province create soils with high lime density in the lower layers of soils. The annual average temperature in Mardin is 18°C. The average temperature is 30°C in summer and 7°C in winter. The high difference between the summer and winter average temperatures is a very significant indication of the continentality of the local climate. The relative air humidity in the summer is quite low, leading to an increase in evaporation. The days when the temperature drops below 0°C are quite limited (Table 2).

Table 1

Some physical and chemical properties of organic improvers (pomace, vermicompost and leonardite) used in the study

Pomace		Vermicompost		Leonardite	
Total N (%)	0.62	organic matter (%)	42.00	humic acid (%)	75.00
Phenolic compounds (%)	0.31	total N (%)	3.20	organic matter (%)	67.00
Total C (%)	28.10	organic nitrogen N (%)	2.50	pH	5.50
C/N	52.90	P (%)	1.40	N (%)	1.70
P (%)	0.06	K (%)	1.00	C/N	18.00
K (%)	0.32	humic + fulvic acid (%)	25.00	C (%)	32.00
Ca (%)	0.39	organic carbon (%)	27.00	Moisture (%)	18.00
Moisture (%)	52.00	C/N (%)	8.40	Fe (%)	1.98
Oil (%)	3.91	moisture (%)	30.00	Ca (%)	1.35
Proteins (%)	3.56	conductivity ds m^{-1}	3.20	Mg (%)	0.16
Total sugar (%)	0.89	pH	7.00	P (%)	0.07
Cellulose (%)	16.50	Cu (mg kg^{-1})	2.00	K (%)	0.81
hemicellulose (%)	7.84	Zn (mg kg^{-1})	3.00		
Ash (%)	1.62				
Lignin (%)	11.10				

Table 2

The year 2021 climate data of Mardin province

	Jan,	Feb,	Mar,	Apr,	May	Jun,	Jul,	Aug,	Sep,	Oct,	Nov,	Dec,	Annual averages
Average min, temp, (°C)	4.00	4.70	5.50	13.70	19.10	22.10	26.70	26.70	21.10	16.20	11.10	4.10	14.58
Average max, temp, (°C)	9.70	11.90	13.10	21.90	29.00	32.20	36.70	36.30	29.80	24.30	17.50	9.80	22.68
Average temp, (°C)	6.40	7.80	8.80	17.30	23.80	26.90	31.30	31.00	24.80	19.70	13.70	6.60	18.18
Average relative humidity (%)	54.20	54.60	58.00	38.30	26.60	22.60	21.20	22.60	29.00	31.20	49.00	57.70	38.75
Total precipitation (mm)	99.20	25.50	62.60	7.10	2.10	0.00	0.00	0.00	0.00	9.50	17.60	41.60	22.10

General Directorate of Meteorology, 2022.

RESULTS AND DISCUSSION

Some physical and chemical properties of olive orchard soils

Some physical and chemical properties of soil samples in the olive orchard resulting from with the application of the three substances are given in Table 3. The pH content measured in the saturation sludge of the soil samples taken from the olive grove varied between 7.18 and 7.69, with an average of 7.55. When the pH of the soil samples was evaluated according to the limit values determined by the United States Salinity Laboratory Staff (1954), it was determined that they had neutral and slightly alkaline reaction (Table 3). Olive trees are plants that can grow over a wide range of soil reaction (Hartmann, Lilleland 1966, Ferreira Llamas 1984). On the other hand, although the olive plant adapts to pH ranges between 5.00-8.50, it is reported by Sağlam et al. (2008) that it develops better in pH ranges of 6.50-8.50. The organic matter of the garden soils varied between 1.20% and 2.68%, with an average of 1.71% (Table 3). When classified according to the limit values reported by Nelson and Sommers (1996), the organic matter content of the samples taken from 0-30 cm depth in the areas where pomace, leonardite and vermicompost were applied was moderate (2-3%), while it was low (1-2%) in the other treatments. It has been reported that the organic matter content of the surface soil should be around 3.00% for good olive tree growth (Leake 2001). The amount of lime, as the average of both depths of the soil samples, varied between 33.78% and 38.52%, and 37.49% on average (Table 3). When compared with the limit values reported by Hızalan and Ünal (1966), the soil of the examined olive grove fell into the very calcareous class in terms of the lime content (Table 3). It reported by Söylemez et al. (2017), olive trees are not sensitive to the lime content in soil and lime can even be positive in terms of plant growth. Sand, clay and silt ratios were the lowest at 31.10%, 20.20% and 38.60%, and the highest at 39.20%, 24.30% and 46.70%, respectively, as the average of both depths of the soils. The general average of the soils at both depths determined for the sand, clay and silt ratios, respectively, was 35.60%, 21.40% and 42.90%. The texture class of the olive orchard soil was determined as loam (Table 3). Ferreira Llamas (1984) reported that the olive plant is quite tolerant in terms of soil, but generally shows better growth in clayey and loamy soils. The salt content of the soil was determined as 0.02% (Table 3). When this value was evaluated according to the US Salinity Laboratory Staff (1954), all soil samples were determined to be in the salt-free class. Topography, salinity and alkalinity are among the most limiting factors among land features for olive production (Lake et al. 2009).

N, P, K, Ca, Mg and Na contents of olive orchard soils

The levels of some macronutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na) of the soil

Table 3

Some physical and chemical properties of olive orchard soil after application of organic improvers

Applications	Depth (cm)	pH	O.M. (%)	Lime	Sand	Clay	Silt	Salt	Structure
Control	0-30	7.18	1.26	33.78	37.20	20.00	42.80	0.02	L
	30-60	7.51	1.20	38.51	39.20	22.20	38.60	0.02	L
Pomace	0-30	7.60	2.68	37.74	37.10	20.20	42.70	0.02	L
	30-60	7.43	1.35	38.13	33.10	22.20	44.70	0.02	L
Leonardite	0-30	7.65	2.42	37.74	35.10	20.20	44.70	0.02	L
	30-60	7.65	1.28	38.13	35.10	24.30	40.60	0.02	L
Vermicompost	0-30	7.68	2.13	38.52	31.10	22.20	46.70	0.02	L
	30-60	7.69	1.37	37.36	37.10	20.20	42.70	0.02	L
Average		**7.55**	**1.71**	**37.49**	**35.60**	**21.40**	**42.90**	**0.02**	
Max.		**7.69**	**2.68**	**38.52**	**39.20**	**24.30**	**46.70**	**0.02**	
Min.		**7.18**	**1.20**	**33.78**	**31.10**	**20.20**	**38.60**	**0.02**	

in the study area are given in Table 4. The nitrogen (N) content of the soil samples varied between 0.13 and 0.17 kg da^{-1}, with an average of 0.15 kg da^{-1} (Table 4). When olive orchard soil was classified according to the limit values determined in Sillanpää (1990), it was determined that the N content of all soil samples was low. The available phosphorus (P) content of the soil varied between 3.01 and 6.12 kg da^{-1} as seen in Table 4, with an average of 4.25 kg da^{-1}. When the soil was classified according to the limit

Table 4

N, P, K, Ca, Mg and Na content of the soil under the olive grove

Applications	Depth (cm)	N (kg da^{-1})	P	K	Ca (mg kg^{-1})	Mg	Na
Control	0-30	0.14	4.12	43.60	3380	350	4.52
	30-60	0.13	3.95	40.20	4520	394	5.66
Pomace	0-30	0.16	6.12	44.80	4380	379	4.42
	30-60	0.14	3.55	42.40	4370	395	5.97
Leonardite	0-30	0.15	5.38	43.20	7370	422	5.12
	30-60	0.14	3.25	40.80	2500	404	5.59
Vermicompost	0-30	0.17	4.63	42.90	6130	398	6.02
	30-60	0.15	3.01	40.00	3750	408	5.79
Average		**0.15**	**4.25**	**42.24**	**4550**	**394**	**5.39**
Max.		**0.17**	**6.12**	**44.80**	**7370**	**422**	**6.02**
Min.		**0.13**	**3.01**	**40.00**	**2500**	**350**	**4.42**

values determined in Olsen et al. (1982), the soil samples taken from 0-30 cm depth had a very low (<4 kg da^{-1}) content of available phosphorus, and soil samples taken from 30-60 cm depth samples were determined to be medium (4-12 kg da^{-1}).

The fact that the P amounts of the surface (0-30 cm) soils are higher than the P amounts in the second depth (30-60 cm) in all soil samples indicates that the plant-available phosphorus in the soil originates from fertilizers rather than from the soil parent material (Gökceoglu, Cimrin 2022). The phytonutrient K contents of the soil samples were determined as stated by Richards (1954). The K amounts of the soil samples taken from the olive orchard, as the average of both depths, varied between 40.00 and 44.80 kg da^{-1}, and 42.24 kg da^{-1} on average (Table 4). When the K contents of the soil samples were evaluated according to Pizer (1967), it was determined that all soil samples were in the low (31-45 kg da^{-1}) class. Since plants easily absorb potassium dissolved in soil water, soil water must be on a sufficient level in order to absorb the element K in the soil (Prajapati, Modi 2012). When the olive orchard soil samples were examined for Ca content, it was determined to range from 2500 to 7370 mg kg^{-1}, with an average of 4550 mg kg^{-1} (Table 4). When garden soils are classified according to the limit values determined in Sumner and Miller (1996), it is seen that all of the tested soil samples contain excessive amounts of Ca. It has been reported that the Ca content rather than the pH of the soil has an effect on a good development of olive plantations, and the available Ca values in olive production should be more than 2000 mg kg^{-1} (Zincircioglu 2010, Özsayar, Çimrin 2022). When the olive orchard soil was examined for its Mg content, it varied between 350 and 422 mg kg^{-1}, with an average of 394 mg kg^{-1} (Table 4). When classified according to the limit values determined in Tüzüner (1990), it was determined that all of the garden soil samples contained adequate (160-480 mg kg^{-1}) amounts of Mg. Many scientific studies have shown that the addition of a fertilizer increases the exchangeable Ca and Mg content as well as the organic matter content in soil (Bhangoo et al. 1988). When the olive garden soil samples were examined in terms of its Na content, it was determined to range between 4.42 and 6.02 mg kg^{-1}, with an average of 5.39 mg kg^{-1} (Table 4). When classified according to the limit values determined by Jackson (1958), it was determined that all the garden soil samples contained sufficient (<46 mg kg^{-1}) Na.

Fe, Cu, Zn and Mn contents of olive orchard soils

The available Fe, Cu, Zn and Mn content of the soil is given in Table 5. The Fe content of the soil under the olive orchard varied between 8.19 and 15.20 mg kg^{-1}, with an average of 11.10 mg kg^{-1} (Table 5). When the Fe content of olive orchard soil was classified according to the limit values determined by Lindsay and Norwell (1978), it is seen that the soil contained adequate (>4.50 mg kg^{-1}) Fe.

Table 5

Fe, Cu, Zn and Mn content of soil under an olive grove

Applications	Depth	Fe	Cu	Zn	Mn
	(cm)	(mg kg^{-1})			
Control	0-30	15.20	12.90	3.59	36.60
	30-60	13.20	13.10	2.60	26.70
Pomace	0-30	11.40	9.01	2.85	36.70
	30-60	8.86	8.44	2.62	26.30
Leonardite	0-30	11.00	10.62	4.15	27.40
	30-60	10.90	8.87	2.93	24.30
Vermicompost	0-30	9.77	8.78	2.20	34.00
	30-60	8.19	9.15	1.79	38.70
Average		**11.10**	**10.10**	**2.84**	**31.30**
Max.		**15.20**	**13.10**	**4.15**	**38.70**
Min.		**8.19**	**8.44**	**1.79**	**26.30**

The Cu content of the soil varied between 8.44 and 13.10 mg kg^{-1}, with an average of 10.10 mg kg^{-1} (Table 5). When olive garden soil is classified according to the limit values determined by Lindsay and Norwell (1978), it is seen that the soil in question contains sufficient (>0.2 mg kg^{-1}) Cu. The Zn content of the soil varied between 1.79 and 4.15 mg kg^{-1}, with an average of 2.84 mg kg^{-1} (Table 5). When classified according to the limit values determined by Tüzüner (1990), it has been determined that the amount of Zn is adequate (0.70-2.40 mg kg^{-1}) in vermicomposted soil samples of the olive garden soil, and excessive (2.40-8.00 mg kg^{-1}) in the other applications. The Mn content of the soil varied between 26.30 and 38.70 mg kg^{-1}, with an average of 31.30 mg kg^{-1} (Table 5). When classified according to the limit values determined by Tüzüner (1990), it was found that all of the olive garden soil samples contained adequate (14.00-50.00 mg kg^{-1}) Mn.

CONCLUSIONS AND RECOMMENDATIONS

In this study, effects of the use of organic remedial substances in different forms such as vermicompost, leonardite and pomace applied in pre-flowering period of the Gemlik olive variety grown in a closed 12-year-old garden were investigated. As a result, the organic matter content of the garden soil, which was determined to be in the loamy (L) body class, with the pH content varying between 7.18 and 7.69, appeared in the order of treatments: pomace>leonardite>vermicompost relative to the control group. The % N content in the soil was listed as vermicompost>pomace>leonardite relative to the control group. The fact that both the amount of organic matter and the nitrogen content are quite low in two-thirds of Turkey's agricultural soils has encouraged us to investigate the possibilities of using vermicompost, leonardite and pomace, which are known as organic soil improvers. It has been determined that these organic materials have a positive effect on the amount of soil organic matter, nitrogen (N), phosphorus (P), Calcium (Ca) and magnesium (Mg) content. In the experiments, it was demonstrated that organic materials are a potential source of organic matter in soil within a sustainable agriculture system.

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