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Monitoring the Short-Term Effect of Banana Waste Compost on the Enzymatic Activities of Soil Associated with Nitrogen and Phosphorus

Muz Atıkları Kompostunun Toprağın Azot ve Fosfor ile İlişkili Enzimatik Aktiviteleri Üzerine Kısa Süreli Etkisinin İzlenmesi

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Abstract: A large amount of plant pruning waste occurs after annual care in banana production areas. This waste material contains significant amounts of organic substances and nutrients. In this study, banana waste compost (BWC) was applied to the soil both alone and in mixture with leonardite (LT) and vinasse compost (VC). Treatments include: control (CL), banana waste compost alone (BWC-2: 2 t da^{-1}; BWC-4: 4 t da^{-1}; BWC-8: 8 t da^{-1}), leonardite alone (LT: the recommended application rate), leonardite with banana waste compost (BWC-2+LT; BWC-4+LT; BWC-8+LT), vinasse compost alone (VC: the recommended application rate), vinasse compost with banana waste compost (BWC-2+VC; BWC-4+VC; BWC-8+VC). Afterwards, the changes in the activities of nitrogen (NH_4+NO_3) and phosphorus (available P) related enzymes (urease and alkaline phosphatase) were monitored through analyzes made on soil samples taken on certain days (0^{th}, 10^{th}, 20^{th}, 40^{th}, 80^{th}). During this period, the pH and EC values of the soil were also measured. According to the results obtained; it was determined that banana waste compost combined with leonardite generally positively affects the pH, EC, exchangeable NH_4-NO_3 and, available P of the soil, as well as the activity of urease and alkaline phosphatase compared to other treatments. In this regard, according to the control, the urease activity of the soil increased by 875%, the alkaline phosphatase activity by 149%, the exchangeable NH_4+NO_3 by 188%, available P by 83%, and the EC value by 100%. However, the pH value decreased by about 5%. As a result, it can be stated that the application of banana waste compost combined with leonardite as a soil conditioner at least 4 t da^{-1} will be economical and 10 to 20 days after this application, nitrogen and phosphorus availability will increase in the soil.

Keywords: Organic waste, organic matter, soil enzymes, soil quality.

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Öz: Muz üretim alanlarında her yıl yapılan muz bakımı sonrası çok miktarda bitki budama atığı ortaya çıkmaktadır. Bu atık malzeme önemli miktarlarda organik madde ve besin içermektedir. Bu çalışmada, muz atıkları kompostlandıktan (MAK) sonra hem tek başına hem de leonardit (LT) ve melas kompostu (MK) ile karıştırılarak toprağa uygulanmıştır. Yapılan uygulamalar şunlardır: Kontrol (K), tek başına muz atığı kompostu (MAK-2: 2 t da^{-1}; MAK-4: 4 t da^{-1}; MAK-8: 8 t da^{-1}), tek başına leonardit (LT: tavsiye edilen doz), muz atığı kompostu ile leonardit (MAK-2+LT; MAK-4+LT; MAK-8+LT), tek başına melas kompostu (MK), muz atığı kompostu ile melas kompostu (MAK-2+MK; MAK-4+MK; MAK-8+MK). Sonrasında azot (NH_4+NO_3) ve fosfor (alınabilir P) ile ilişkili enzimlerin (üreaz ve alkali fosfataz) aktivitelerindeki değişimler belirli günlerde (0., 10., 20., 40., 80.) alınan toprak örneklerinde yapılan analizler vasıtasıyla izlenmiştir. Bu sürede toprağın pH ve EC değerleri de ölçülmüştür. Elde edilen sonuçlara göre; leonardit ile kombine edilen muz atığı kompostunun genel olarak toprağın pH, EC, değişebilir NH_4-NO_3, alınabilir P, üreaz ve alkali fosfataz aktivitesini diğer uygulamalara göre olumlu yönde etkilediği belirlenmiştir. Bu bağlamda, kontrole göre toprağın üreaz aktivitesi % 875, alkali fosfataz aktivitesi % 149, değişebilir NH_4+NO_3 kapsamı % 188, alınabilir P kapsamı % 83, EC değeri % 100 oranında artmıştır. pH değeri ise yaklaşık % 5 oranında azalmıştır. Sonuçta, leonardit ile kombine edilen muz atığı kompostunun toprak iyileştiricisi olarak en az 4 t da^{-1} olacak şekilde uygulanmasının ekonomik olacağı ve bu uygulamadan 10 ila 20 gün sonra toprakta azot, fosfor yarayışlılığının artacağı ifade edilebilir.

Anahtar Kelimeler: Organik atık, organik madde, toprak enzimleri, toprak kalitesi.

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INTRODUCTION

The addition of materials derived from organic sources is a common approach of correcting the physical, chemical, and biological qualities of the soil and ensuring its continuity. In general, organic matter has a positive influence on soil nutrient content, nutrient absorption, soil aggregation, water holding capacity, aeration, plasticity, temperature, pH, microbial diversity, erosion sensitivity, and production capacity (Kome et al., 2019). It has been known for a long time that the production capacity of soils is directly related to the amount of organic matter they contain. In this context, it is reported that soils rich in organic matter are more efficient, serve as a source and storehouse for nutrients such as nitrogen, phosphorus, sulfur, and also serve as a source of energy and nutrients for soil organisms (Goss et al., 2013). In addition, organic matter is responsible for 20-70% of the cation exchange capacities of most soils. In other words, although it makes up a very small percentage of soils by weight, it is an important soil parameter that affects soil fertility and structure (Nawaz et al., 2013).

Compost is obtained from organic waste by microbiological oxidation under aerobic conditions by various methods. This material is a biologically sterilized substance of organic character, odorless, low in volume weight, high in water holding capacity, containing macro- and micronutrients favorable for the plant, in a granular structure (Wang et al., 2021). Despite the increasing use of compost in recent years in the world, this material still does not receive the attention it deserves. It has been shown that the application of this material to the soil increases the yield of plants, improves soil structure, increases cation exchange capacity, and also accelerates biochemical activity (Adugna, 2016). Tons of banana pruning waste occur every year in the regions where banana cultivation is intensively carried out in Turkey (Aksu, Serik, Manavgat, Alanya, Anamur, Gazipaşa, Bozyazı) and they cause serious environmental pollution. However, in tropical regions where banana cultivation is intensive, farm manure is never used as an organic fertilizer, instead, banana stems and leaves are used directly (Teixeira et al., 2021). In Turkey, relatively expensive farm manure is used as an organic fertilizer in banana cultivation. Plantain plant stems and leaves are very rich in plant nutrients. Every year in an area where bananas are grown, an average of about 20 tons of waste per decare comes out as stems and leaves during the maintenance-pruning period after harvest (Alzate Acevedo et al., 2021). It was reported that the amounts of nutrients thrown out of the plantation with these plant wastes every year are in the form of 60 kg N, 25 kg P_2O_5, 100 kg K_2O, 12.5 kg CaO and 3.0 kg MgO (Padam et al., 2014).

For microorganisms to benefit from large-molecule organic substances found in the soil, they must secrete their enzymes into the medium and break down these compounds into simple compounds of the size they can absorb (Jacoby et al., 2017). A very large part of the enzymes in the soil are extracellular enzymes that living soil microorganisms release to the outside to break down nutrients, as well as enzymes that become partially or completely free after the death of microorganisms and mix with the soil. These enzymes are adsorbed by inorganic (clay minerals) and organic (humus) colloids of the soil. Adsorbed enzymes are more resistant to external influences than other enzymes (compared to those secreted from plants and animals) and are able to maintain their activity for a long time (Datta et al., 2017). By measuring the activity of enzymes secreted by soil microorganisms, important information can be obtained about the state of soil fertility (Różyło and Bohacz, 2020). In each culture soil, there is a level of enzymes specific to that soil. The amount and types of enzymes also depend on the properties and amounts of harvest residues remaining in the soil, as well as the types and amount of organic and inorganic fertilizers supplied (Szostek et al., 2022). Within the scope of this study, banana pruning waste compost was applied to the soil both alone and together with leonardite and vinasse compost. In this context, the effects of banana waste compost on some chemical properties of the soil (exchangeable mineral nitrogen, available phosphorus, pH, EC) and enzyme activities (urease and alkaline phosphatase) were tried to determine by the compare with leonardite and vinasse compost.

MATERIAL AND METHOD

Preparation of Compost

Banana waste was obtained from a banana greenhouse (36° 21′ 3" N; 32° 15′ 47" E, altitude 185 m) belonging to a farmer located in the Alanya District of Antalya and then composted by heap composting method. The composting material was formed from the remaining parts of the banana plant and the seedlings left over from the harvest. The composting process was carried out according to the method reported by Torres-Climent et al. (2015). Accordingly, sawdust 20 cm high was spread on the surface as a substrate to ensure air passage, and a mixture of soil and farm manure 10 cm thick was added to it. After the mixture was sufficiently moistened, banana waste cut into small pieces was added to it so that it was 30 cm thick. 10 cm of soil-farm fertilizer mixture and 30 cm of banana waste were added to the pile again. After that, it was spread on a 10 cm soil-farm fertilizer mixture for the last time and after it was sufficiently soaked, it was covered with a nylon wrap and expected to reach the appropriate temperature. After one to three days, the wrap was opened and the pile was mixed uniformly, then some water was added to adjust the amount of moisture. After that, compost was obtained by 1 mixing process and moisture control per week for 14 weeks.

Experiment Management

Within the scope of the study, a potting experiment was established in the greenhouse located in the area where banana pruning waste was provided. The soil sample to be used in the pots was taken from an area where no previous application had been made. According to the analyses, it was determined that the composition of the experimental soil was clay-loam, moderate alkaline (pH 7.75). Its EC was salt-free (0.258 µS cm^{-1}), the amount of organic matter was poor in humus (1.88%), the amount of lime was high (19%). In addition, it was determined that it was also in the inadequate class in terms of some nutrient elements (total N: 0.082%; available P: 3.84 P_2O_5 kg da^{-1}). In order to better see the effectiveness of banana waste compost, leonardite and vinasse compost were also used. The leonardite and vinasse compost used in the experiment was obtained from a commercial company (Deryagri co. ltd.). The properties of all materials applied to the soil are listed in Table 1.

Table 1. Properties of materials applied to the soil.
Çizelge 1. Denemede toprağa uygulanan materyallerin özellikleri.

Parameter	**Banana waste compost (BWC)**	**Leonardite (LT)**	**Vinasse compost (VC)**
pH	8.2	5.8	7.4
Moisture (%)	30	20	20
Organic matter (%)	48	65	32
Organic carbon (%)	27.8	37.7	18.5
C/N rate	25/1	18/1	14/1
C/P rate	30/1	21/1	15/1
Humic+fulvic acid (%)	45	78	42
Total N (%)	1.1	2	1.3
Total P (%)	0.9	1.8	1.2

In the experiment, 5 mm sieved soils were filled into pots that received 3 kg of soil first. Then, according to the random plots experiment pattern, banana compost was applied to the soil in 4 different application rates (0, 2, 4, 8 t da^{-1}) both alone and in combination with leonardite and vinasse compost in a 3-repeat. Vinasse compost and leonardite were applied to pots at the commercially recommended dose. The treatments to the soil in the experiment are as follows: control (CL: no treatment), banana waste compost alone (BWC-2: 2 t da^{-1}; BWC-4: 4 t da^{-1}; BWC-8: 8 t da^{-1}), leonardite alone (LT: the recommended application rate), leonardite with banana waste compost (BWC-2+LT; BWC-4+LT; BWC-8+LT), vinasse compost alone (VC: the recommended application rate), vinasse compost with banana waste compost (BWC-2+VC; BWC-4+VC; BWC-8+VC). These materials were calculated and weighed to be in the indicated application rates. Next, it was poured into the potting soil uniformly and carefully mixed. During the experiment period, attention was paid to the fact that the moisture level of the mixture in the pots will be 60% of the field capacity of the soil. For this, the pots were weighed and the amount of water calculated according to the weight loss was supplemented with well water. In addition, the location of the pots was changed periodically. After the procedures of taking soil samples for analysis were completed, the experiment was terminated.

Collection of Samples and Methods of Analysis

Texture, total nitrogen (N), available phosphorus (P), pH, EC, lime, organic matter, and the activities of urease and alkaline phosphatase were determined in the soil sample taken before the experiment was established. In the obtained banana waste compost and leonardite and vinasse compost, the amount of moisture, pH, ~~EC,~~ amount of organic matter, and nutrients (total C, N, P) were determined. After the experiment was established, urease and alkaline phosphatase activities, ammonium-nitrate and available phosphorus were determined in the soil samples taken from 0-10 cm depth on the 0^{th}, 10^{th}, 20^{th}, 40^{th} and 80^{th} days. In addition, pH and EC measurements were also determined.

Soil texture was determined by according to the hydrometer method (Bouyoucos, 1951). pH and EC were measured by 1/2.5 soil-pure water mixture (Jackson, 1967). Soil lime was determined by according to the calcimeter method (Çağlar, 1949). Soil organic matter was determined by according to the modified Walkley-Black method (Black, 1965), and total nitrogen by according to the modified Kjeldahl method (Kacar, 1995). Soil exchangeable NH_4-NO_3 determined by according to the steam distillation method (Bremner, 1965), and available P by according to the Olsen method (Olsen and Sommers, 1982). The analyzes made on the materials applied to the soil are as follows: pH and EC were determined in 1/10 waste-pure water mixture (Jackson, 1967). Moisture, organic matter and, organic carbon were determined by weight loss which occurs as a result of burning in the muffle furnace (Kacar, 1990). Total N and total P were determined by according to the wet digestion method (Kacar and İnal, 2008). Total Humic + Fulvic acid was determined according to the by TS 5869 ISO method no 5073 (TSE, 2003).

The urease activity of soils was determined according to Hoffman and Teicher's (1961) method. Accordingly, 0.2 ml of toluene, 7.5 ml of citrate buffer solution (184 g of citric acid and 147 g of potassium hydroxide / 1 L, pH 6.7) and 10 ml of urea solution (10%) were added to 10 g of moist soil. Next, this mixture was incubated for 1 hours at 37 ° C. The final volume was brought to 100 ml and filtered. The ammonium released after the addition of the color solution was measured at 578 nm. Alkaline phosphatase activity was determined according to the method of Tabatabai and Bremner (1969). For this, 0.2 ml of toluene, 4 ml of MUB (12.1 g of tris, 11.6 g of maleic acid, 14.0 g of citric acid and 6.3 g of boric acid / 1 L, pH 11) and 1 ml of p-nitrophenyl phosphate (0.835 g of PNP phosphate/50 ml of MUB) were added to 1 g of soil. This mixture was incubated for 1 hour at 37 ºC, and after incubation, 1 ml of 0.5 M $CaCl_2$ and 4 ml of 0.5 M NaOH were added to the mixture and filtered. The intensity of the formed yellow color was determined at 410 nm. After calculating the moisture content of the soils for both enzyme activities, the results were expressed in terms of dry soil equivalents.

Statistical Analysis

The significance of the numerical data obtained in the experiment was determined at the 5% level by repeated measurement analysis (*r*ANOVA) in the SPSS 17.0 package program. The significant findings were grouped by Duncan multiple comparison test (SPSS, 2008).

RESULTS AND DISCUSSION

Urease Activity

The effects of interaction between applications and sampling times on the urease activity of soil were found to be statistically insignificant (Table 2). However, considering the average values depending on the time of application, the BWC-2+LT, BWC-4+LT and BWC-8+LT (69.57, 67.05 and 74.93 µg NH_4^+-N g^{-1} dw h^{-1}, respectively) applications were found to increase of soil urease activity statistically greater than that of others. On the other hand, it was determined that the urease activity of the soil reaches the highest levels during the 10^{th}, 20^{th}, and 40^{th} days. The increase in soil enzyme activity is parallel to the increase in soil organic matter. This situation reveals that enzymes are linked to the population dynamics of the soil biota (Myszura et al., 2021). It is reported that the increase in urease activity with the addition of organic matter to the soil is mainly attributed to the nitrogen content of the added material (Piotrowska-Długosz et al., 2022). It can be stated that the amount of both nitrogen (1.1%) and organic matter (48%) in the banana waste compost used in this study is not very low. In addition, it's the C/N ratio (25/1) is also high. However, since the leonardite added to the compost has better properties, it is considered that banana waste compost alone cannot be effective on urease activity. As a matter of fact, it can be stated that the leonardite used in the experiment is a good source of organic matter (65%), carbon (37.7%) and nitrogen (2%).

Table 2. Effect of applications on urease activity of soil (μg NH_4^+-N g^{-1} dw h^{-1}).
Çizelge 2. Uygulamaların toprağın üreaz aktivitesi üzerine etkisi.

Treatments	Sampling time (days)					
	0	10	20	40	80	*Mean*
CL	4.06	7.84	7.77	9.29	9.43	7.68e[1]
BWC-2	21.87	28.67	24.92	30.76	11.18	23.48de
BWC-4	35.65	34.52	38.89	35.68	26.46	34.24c
BWC-8	36.23	38.19	36.36	36.62	24.10	34.30c
VC	30.26	31.27	32.44	27.70	26.46	29.63d
BWC-2+VC	32.25	34.76	35.09	32.00	28.80	32.58c
BWC-4+VC	19.58	22.16	21.74	30.76	27.63	24.37de
BWC-8+VC	14.98	26.72	29.89	33.84	29.97	27.08d
LT	45.47	53.56	58.27	58.06	54.63	54.00b
BWC-2+LT	58.64	77.22	79.63	78.34	54.04	69.57a
BWC-4+LT	59.22	65.75	82.10	75.90	52.27	67.05a
BWC-8+LT	56.91	82.02	96.07	83.2608	56.38	74.93a
Mean	34.59b[2]	41.89a	45.26a	44.35a	33.44b	
			*r*ANOVA (LSD %5)			
Sampling time (S)	11.241***[3]					
Treatment (T)	62.181***					
S x T	Ns[4]					

[1] The values lettered are the mean of the applications. Differences between values not denoted by the same letter are significant at the 5% level.
[2] The lettered values are the mean of the sampling time. Differences between values not denoted by the same letter are significant at the 5% level.
[3] $p < 0.001$
[4] Ns: Not significant.

Alkaline Phosphatase Activity

The effects of interaction between applications and sampling times on the alkaline phosphatase activity of soil were found to be significant at the $p < 0.001$ level (Table 3). In addition, according to the time-dependent average values of the applications, it was found that the application of BWC-4+LT (53.69 μg PNP g^{-1} dw h^{-1}) statistically increased the urease activity of the soil more than others. On the other hand, it was determined that the alkaline phosphatase activity of the soil 10th day reaches the highest levels. It was shown that organic materials added to the soil increase the phosphatase activity of the soil, so there is a close relationship between the amount of soil organic matter and the phosphatase activity (Margalef et al., 2017). It is reported that organic fertilizers, which are widely used to increase soil organic matter, increase the activity of this enzyme by acting as a substrate for the phosphatase (Shang et al., 2020). Although the banana waste compost used in this study is not insufficient in terms of phosphorus (total P: 0.9%) and organic carbon (27.8%), the highest phosphatase activity value was obtained in the application of banana waste compost with the addition of leonardite (organic matter: 65%, total P: 1.8%). In this case, it can be said that the combined application is more stimulating on microorganisms that secrete the enzyme alkaline phosphatase. This situation is likely to occur as a result of the high C/P ratios of both banana waste compost (30/1) and leonardite (21/1). As a matter of fact, it has been shown that a significant increase in the activity of the alkaline phosphatase enzyme secreted from microorganisms also occurs with an increase in the amount of organic-bound P, which acts as a substrate in the soil (Cabugao et al., 2017).

Table 3. Effect of applications on alkaline phosphatase activity of soil (μg PNP g^{-1} dw h^{-1}).
Çizelge 3. Uygulamaların toprağın alkali fosfataz aktivitesi üzerine etkisi.

Treatments	Sampling time (days)					
	0	10	20	40	80	*Mean*
CL	14.97	23.68	24.18	18.65	26.04	21.50d[1]
BWC-2	18.40	69.75	39.72	29.82	33.50	38.24cd
BWC-4	18.70	79.51	47.02	35.57	44.50	45.06bc
BWC-8	22.98	72.58	42.99	38.80	39.22	43.31bc
VC	25.26	91.53	36.12	34.79	51.91	47.92b
BWC-2+VC	18.86	94	37.47	38.04	47.82	47.24b
BWC-4+VC	16.51	97.76	47.24	43.00	42.18	49.34b
BWC-8+VC	17.14	96.58	37.76	38.88	53.71	48.81b
LT	18.12	72.78	35.43	35.63	42.30	40.85c
BWC-2+LT	19.30	106.96	45.10	40.24	45.79	51.48ab
BWC-4+LT	23.40	91.24	43.12	50.09	60.62	53.69a
BWC-8+LT	22.93	77.79	46.42	45.46	63.98	51.32ab
Mean	19.71c[2]	81.18a	40.21bc	37.41bc	45.97b	
			*r*ANOVA (LSD %5)			
Sampling time (S)	83.132***[3]					
Treatment (T)	12.196***					
S x T	5.267***					

[1] The values lettered are the mean of the applications. Differences between values not denoted by the same letter are significant at the 5% level.
[2] The lettered values are the mean of the sampling time. Differences between values not denoted by the same letter are significant at the 5% level.
[3] $p < 0.001$

Exchangeable NH_4-NO_3

The effects of interaction between applications and sampling time on the exchangeable NH_4-NO_3 of soil were found to be statistically significant at the $p < 0.001$ level (Table 4).

Table 4. Effect of applications on exchangeable NH_4-NO_3 of soil (mg kg^{-1}).
Çizelge 4. Uygulamaların toprağın değişebilir NH_4-NO_3 kapsamı *üzerine etkisi.*

Treatments	Sampling time (days)					
	0	10	20	40	80	*Mean*
CL	7.27	10.42	14.55	10.13	5.64	9.60e[1]
BWC-2	10.27	26.59	24.26	20.59	6.44	17.63d
BWC-4	13.76	35.46	26.90	17.46	7.32	20.18c
BWC-8	13.36	27.73	32.19	16.67	14.06	20.80bc
VC	11.64	27.87	24.70	26.02	21.52	22.35b
BWC-2+VC	11.20	19.49	33.08	25.97	21.56	22.26b
BWC-4+VC	12.39	23.85	31.75	22.53	17.46	21.60bc
BWC-8+VC	22.76	31.05	32.19	13.62	18.96	23.72b
LT	25.93	30.08	20.73	19.58	22.09	23.68b
BWC-2+LT	19.44	29.02	31.31	14.15	19.00	22.58b
BWC-4+LT	24.61	25.79	32.63	14.86	17.99	27.66a
BWC-8+LT	32.10	27.69	34.84	21.52	22.14	23.18b
Mean	17.06bc[2]	26.25a	28.26a	18.59b	16.18c	
			*r*ANOVA (LSD %5)			
Sampling time (S)	61.125***[3]					
Treatment (T)	16.148***					
S x T	8.234***					

[1] The values lettered are the mean of the applications. Differences between values not denoted by the same letter are significant at the 5% level.
[2] The lettered values are the mean of the sampling time. Differences between values not denoted by the same letter are significant at the 5% level.
[3] $p < 0.001$

In addition, taking into account the time-dependent average values of the applications, it was found that the application of BWC-4+LT (27.66 mg kg^{-1}) statistically increased the exchangeable NH_4-NO_3 of the soil more than others. On the other hand, it was determined that the exchangeable NH_4-NO_3 of the soil on 10th and 20th days has reached the highest levels. According to Turan (1967), the amount of NO_3-N in the soil of the coastal region of Antalya Province varies between 2.0-52.5 mg kg^{-1}. Accordingly, the values obtained in the study seem to be compatible with the literature. In addition, when assessed according to FAO (1990), it was determined that the soil is in the adequate class of nitrogen coverage. Accordingly, it can be stated that the banana waste compost with the addition of leonardite enriches the soil with mineral nitrogen. Similarly, Ece et al. (2007) determined that the total N content of soils increased from 0.086% to 0.095% as a result of the application of different doses of leonardites. It can be said that the leonardite used in the study enriched the banana waste compost with nitrogen, which had a positive effect on soil application.

Available P

The effects of the interaction between the applications and the sampling time on the available P of the soil were found to be statistically insignificant (Table 5). However, when taking into account the time-dependent average values of applications, it was found that the application of BWC-4+LT (10.29 mg kg^{-1}) statistically increased the available P more than other. On the other hand, it was determined that the P value of the soil 20th day reaches the highest levels.

Table 5. Effect of applications on available P of soil (mg kg^{-1}).
Çizelge 5. Uygulamaların toprağın alınabilir P kapsamı üzerine etkisi.

Treatments	Sampling time (days)					
	0	10	20	40	80	*Mean*
CL	6.49	5.30	6.38	5.24	4.62	5.61d[1]
BWC-2	9.84	6.34	12.61	9.97	4.54	8.66b
BWC-4	8.64	5.70	11.05	6.59	9.61	8.32b
BWC-8	6.82	9.90	13.19	7.30	7.53	8.95b
VC	8.39	9.39	12.88	7.19	6.75	8.92b
BWC-2+VC	5.05	8.91	10.52	8.53	8.69	8.34b
BWC-4+VC	6.21	6.51	8.64	8.30	6.27	7.19c
BWC-8+VC	5.88	8.66	10.43	7.98	8.69	8.33b
LT	6.56	7.77	11.25	8.71	7.40	8.34b
BWC-2+LT	6.29	8.64	9.50	8.00	6.58	7.80c
BWC-4+LT	6.10	9.93	12.90	8.62	8.13	10.29a
BWC-8+LT	7.36	10.09	12.47	11.48	10.05	9.14ab
Mean	6.97d[2]	8.10b	10.99a	8.16b	7.41c	
			*r*ANOVA (LSD %5)			
Sampling time (S)	19.531***[3]					
Treatment (T)	4.129***					
S x T	Ns[4]					

[1] The values lettered are the mean of the applications. Differences between values not denoted by the same letter are significant at the 5% level.
[2] The lettered values are the mean of the sampling time. Differences between values not denoted by the same letter are significant at the 5% level.
[3] $p < 0.001$
[4] Ns: Not significant.

According to FAO (1990) range of 2.5-8 mg kg^{-1} is evaluated in the poor class for the P of soil. Accordingly, it can be stated that the banana waste compost combined with the leonardite used in the study increases the soil available P. However, Materechera and Morutse (2009) report that vegetable compost and manures are an important source of organic P required by plants and microorganisms. Similarly, in previous studies, it was shown that compost applications obtained from various organic wastes increase the total P content of the soil (Jakubus, 2016; Lanno et al., 2021; Santos et al., 2018). On the other hand, it was reported that humic and fulvic acid have effects on increasing the surface area in the soil, and this has an effect on capillary rooting and especially on the access of low mobility nutrients such as phosphorus to the plant roots (Noroozisharaf and Kaviani, 2018). From this point of view, it is considered important that the leonardite used in the experiment has a high humic +fulvic acid content (78%) compared to other materials.

pH

The effects of the interaction between the applications and the sampling time on the pH of the soil were found to be statistically significant at the $p < 0.01$ level (Table 6). In addition, taking into account the time-dependent average values, it was found that BWC-2+LT (7.16) and BWC-8+LT (7.18) applications statistically reduced the soil pH more than others. On the other hand, it was determined that the pH value of the soil has reached the lowest levels the 40th day. Organic matter applied to the soil by means of organic fertilizers, CO_2 and organic acids released when they are broken down by microorganisms cause drops in the pH of soils with alkaline reactions (Neina, 2019). However, when organic fertilizers with alkaline reaction are applied to soils with acid reaction, they cause a short-term increase in pH (Whalen et al., 2000). The usefulness of plant nutrients is determined by pH. In the study, the decrease in soil pH can be mainly attributed to the combination of banana waste compost with leonardite. Accordingly, it is believed that this material enriched with organic matter stimulates microorganisms more in the soil, and acids released as a result of microbial activity also cause a decrease in soil pH. It was reported that the application of organic fertilization material mostly causes a decrease in soil pH (Assefa and Tadessa, 2019).

Table 6. Effect of applications on soil pH.
Çizelge 6. Uygulamaların toprağın pH'sı üzerine etkisi.

Treatments	Sampling time (days)					
	0	10	20	40	80	*Mean*
CL	7.39	7.53	7.48	7.42	7.38	7.44ab[1]
BWC-2	7.35	7.55	7.44	7.01	7.17	7.30b
BWC-4	7.40	7.48	7.48	6.85	7.18	7.28b
BWC-8	7.31	7.74	7.53	6.83	6.82	7.25bc
VC	7.32	7.68	7.52	7.27	7.51	7.46ab
BWC-2+VC	7.50	7.67	7.43	7.27	7.39	7.45ab
BWC-4+VC	7.56	7.68	7.59	7.22	7.33	7.48a
BWC-8+VC	7.44	7.66	7.56	7.41	7.46	7.51a
LT	7.19	7.60	7.52	7.27	7.50	7.42ab
BWC-2+LT	7.43	7.58	7.36	6.64	6.80	7.16c
BWC-4+LT	7.43	7.66	7.43	6.71	7.14	7.27bc
BWC-8+LT	7.33	7.60	7.60	6.53	6.83	7.18c
Mean	7.39c[2]	7.62a	7.50b	7.04e	7.13d	
			*r*ANOVA (LSD %5)			
Sampling time (S)	39.128***[3]					
Treatment (T)	1.657**[4]					
S x T	1.238**					

[1] The values lettered are the mean of the applications. Differences between values not denoted by the same letter are significant at the 5% level.
[2] The lettered values are the mean of the sampling time. Differences between values not denoted by the same letter are significant at the 5% level.
[3] $p < 0.001$
[4] $p < 0.01$

EC

The effects of the interaction between the applications and the sampling time on electrical conductivity (EC) of the soil were found to be statistically significant at the $p < 0.001$ level (Table 7). In addition, taking into account the time-dependent average values of the applications, it was found that the application of BWC-8+LT (1401.17 μS cm^{-1}) statistically increased the EC of the soil more than others. On the other hand, it was determined that the EC value of the soil 40th day reaches the highest levels. The EC, which is the expression of the salinity state in the soil, is an important factor affecting plant nutrition and other soil properties. In saline soils, plant development and microorganism activity decrease due to the toxic effects of salts, increased osmotic pressure, and poor weathering conditions (Machado and Serralheiro, 2017). In general, it is reported that rapid EC increases do not occur in the soil with the application of organic fertilizers, so that there are no salinity problems in the soil (Shahid et al., 2018). In this study, it was determined that even in the application of banana waste compost combined with leonardite, which causes the highest EC increase, no salinity was formed in the soil. Similarly, it was reported that there is no rapid nutrient enrichment in the compost applied soil and, accordingly, there is no salinity problem (Lakhdar et al., 2009).

Table 7. Effect of applications on soil EC (μS cm^{-1}).
Çizelge 7. Uygulamaların toprağın EC'si üzerine etkisi (μS cm^{-1}).

Treatments	**Sampling time (days)**					
	0	**10**	**20**	**40**	**80**	***Mean***
CL	541.87	772.65	693.37	908.24	574.19	698.06e[1]
BWC-2	710.79	919.61	863.30	1285.73	588.58	873.60c
BWC-4	800.68	1186.25	977.68	1297.60	808.25	1014.09b
BWC-8	991.06	1419.81	1109.23	1669.28	739.32	1185.74b
VC	615.85	725.43	617.11	1420.82	572.17	790.28d
BWC-2+VC	735.28	922.64	821.64	1431.93	689.33	920.16bc
BWC-4+VC	765.08	964.30	1017.83	1307.95	677.71	946.57bc
BWC-8+VC	696.65	1309.21	1374.11	1537.22	754.22	1134.28b
LT	997.38	1196.35	1153.17	1481.67	762.05	1118.12b
BWC-2+LT	1077.67	1146.29	1411.22	1355.93	767.10	1151.64b
BWC-4+LT	1048.13	1502.38	1462.48	1396.07	830.22	1247.86b
BWC-8+LT	1352.14	1489.75	1467.03	1427.38	1269.57	1401.17a
Mean	861.05c[2]	1129.55b	1080.68b	1376.65a	752.72d	
	*r*ANOVA (LSD %5)					
Sampling time (S)	92.258***[3]					
Treatment (T)	1.425**[4]					
S x T	5.367***					

[1] The values lettered are the mean of the applications. Differences between values not denoted by the same letter are significant at the 5% level.
[2] The lettered values are the mean of the sampling time. Differences between values not denoted by the same letter are significant at the 5% level.
[3] $p < 0.001$
[4] $p < 0.01$

CONCLUSION

Within the scope of this study, banana pruning waste compost was applied to the soil both alone and together with leonardite and vinasse compost. In this context, some of the soil chemical properties of banana waste compost (subject to change of mineral nitrogen, available phosphorus, pH, EC) and enzyme activities (urease and alkaline phosphatase) in comparison with molasses and compost effects on leonardit determined. According to the results obtained; it was found that the mixtures of banana waste compost combined with leonardite have a more positive effect on the pH, EC, exchangeable NH_4-NO_3, available P, urease and alkaline phosphatase activity of the soil in general than other treatments. Considering the economic benefit, it can be stated that it will be appropriate to apply banana compost enriched with leonardite to the soil with a minimum of 4 t da^{-1} to improve the soil, and it may be possible to enrich the soil with nitrogen and phosphorus 10 to 20 days after this application. In order to increase the widespread effect of the results obtained, it is clear that banana waste compost is used in plant cultivation with different production models, and long-term studies are needed that include variables such as different climate and soil type.

CONFLICT OF INTERESTS

The author(s) declare that there are no conflicts of interest related to this article.

AUTHORS' CONTRIBUTIONS

The experimental design, management, experiments and data analysis of this article, its preparation according to the journal writing rules, and its editing were done by İsmail Emrah Tavalı.

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