Influence of supplementation of vineyard soil with organic substances on nutritional status, yield and quality of 'Black Magic' grape (*Vitis vinifera* L.) and soil microbiological and biochemical characteristics

Semih Tangolar*[1], Serpil Tangolar[1], Ayfer Alkan Torun[2], Melike Ada[1] and Selçuk Göçmez[3]

[1] Department of Horticulture, Faculty of Agriculture, University of Cukurova, Adana, Turkey
[2] Department of Soil Science and Plant Nutrition, Faculty of Agriculture, University of Cukurova, Adana, Turkey
[3] Department of Soil Science and Plant Nutrition, Faculty of Agriculture, University of Aydın Adnan Menderes, Aydın, Turkey

*corresponding author: tangolar@cu.edu.tr

ABSTRACT

Cost effective and environmentally friendly strategies in plant nutrition are prime considerations for sustainable viticulture in the face of ever-increasing stress factors throughout the world. Therefore, the present study aimed to investigate the effects of applying different types of organic and inorganic material [control (C; no application), basaltic pumice (P), commercial dry compost (DC), pruning residue:farm manure mixture (1:2, v:v) compost (PR+FM), straw:farm manure mixture (1:2, v:v) compost (S+FM), pumice:dry compost (P+DC), pumice+straw:farm manure compost (P+(S+FM)) and pumice+pruning residue:farm manure compost (P+(PR+FM))] to 'Black Magic' grapevines on their agronomic and nutrient acquisition during two consecutive years: 2017 and 2018.

The highest yield (6172 g/vine and 7874 g/vine) and cluster weight (411.4 g and 463.2 g) were obtained for the application of S+FM in both years. In terms of berry weight, the highest value was obtained for P+(PR+FM) in 2017, although no significant difference was found between treatments in 2018. PR+FM slightly accelerated berry ripening. The differences between macro and micro element contents of the leaves were statistically significant. The leaf mineral values obtained from pumice were generally higher whether it was applied alone or in combination with other materials. N, P, Ca, Fe and Mn concentrations were sufficient for all applications, while K, Mg and Zn values were within the limits of deficiency. Regarding CO_2 production, P+(PR+FM) application in 2017 and S+FM application in 2018 gave the highest values. The effect of organic materials used on microbial biomass-C in soil was higher for S+FM in 2017 and for S+FM and P+DC in 2018 than the other treatments. The application of P+(PR+FM) in 2017 and PR+FM in 2018 had the highest efficiency in terms of dehydrogenase enzyme activity. Urease and phosphatase enzyme values showed a higher activity for P+(PR+FM) in 2017 and P+DC in 2018 than for the other treatments.

In this study, we found that applications of organic and inorganic material generally provided good improvement in terms of the agronomic and nutritional properties examined. In order to be able to provide recommendations for appropriate material, it would be useful to evaluate the accumulated effects of the treatments in further research.

INTRODUCTION

Constraints such as drought (Chaves *et al.*, 2007) and organic matter deficiency in soils (Costantini *et al.*, 2015; Priori *et al.*, 2018) are among the predominating issues limiting the sustainability of viticulture globally. Since grape ripening mostly takes place in the dry summer season, when water requirement is high, drought impact is becoming more menacing in viticulture.

Soils in the Mediterranean Basin have the following general characteristics: highly variable structure, low organic matter content, unfavourable physical conditions, shallowness, and depth, stoniness and erosion caused by irregular and frequent, heavy rains, especially in sloping areas (Çelik *et al.*, 1998; Jones *et al.*, 2005; Rodeghiero *et al.*, 2011; Costantini *et al.*, 2015; Priori *et al.*, 2018). According to Rodeghiero *et al.* (2011), most of the soils under the influence of the Mediterranean climate have low organic carbon content (0.5-1.0 % organic carbon) and climatic conditions are not suitable for the accumulation of organic matter in soils.

Low organic matter not only negatively affects plant growth, but also the development of natural microbial populations. Therefore, the application of compost to soil to increase its organic matter levels is one of the priority issues of sustainable agricultural management (Calleja-Cervantes *et al.*, 2015; Burg *et al.*, 2019).

On a worldwide scale, it is necessary to find low-cost and environmentally friendly plant nutrition sources to be used by farmers as an alternative to chemical fertilisers, due to economic difficulties and the latter's contribution to environmental pollution. Compost consisting of vineyard pruning residue and farm manure (Gaiotti *et al.*, 2017) or mixture of different types of straw has a high potential that can meet this essential need of degraded soils of the Mediterranean.

Compost is one of the most important organic materials recommended for use in viticulture (Powell *et al.*, 2007; Mugnai *et al.*, 2012; Ramos, 2017). Its benefits include: increased soil water holding capacity (Curtis and Claassen, 2005; Mylavarapu and Zinati, 2009), provision of plant nutrients, increased total porosity (Aggelides and Londra, 2000), aggregate formation (Sodhi *et al.*, 2009), and soil hydraulic conductivity (Curtis and Claassen, 2009).

While compost is an organic resource used in viticulture, an important inorganic material that can also be used is basaltic pumice, which contains natural minerals. Relevant studies have indicated that the use of such materials during organic fertilisation of vine could prevent erosion and preserve the physical, chemical and biological properties of the soil (Manson, 1967; Altieri, 1987; Lampkin, 1990; Özdemir *et al.*, 2008; Mugnai *et al.*, 2012; Blaya *et al.*, 2016; Gaiotti *et al.*, 2017; Özdemir *et al.*, 2018; Burg *et al.*, 2019).

The aim of this study was to determine the effect of applying commercial dry compost and pumice, both of which are abundant organic and inorganic materials in Turkey used for soil amendment.

Thus, the aim was to reuse the vineyard pruning residues and the straw produced as a by-product of cultivation for plant nutrition and the improvement of soil properties, such as organic matter content, porosity and aggregation. In addition, increasing the use of such materials in viticulture can have economical benefits as the need for chemical fertilizers is reduced while the use and growth of plants is maximized.

MATERIALS AND METHODS

1. Experimental area and treatments

The study was carried out in the experimental vineyard of Çukurova University, Adana, Turkey (70 m above sea level) (37° 01'49" N, 35° 22' 46" E) in 2017 and 2018. Four-year-old 'Black Magic' (*Vitis vinifera* L.) cultivar grafted onto 1103 Paulsen rootstock were used. The vines were grown with a 1.0 x 1.5 m spacing in a south-north orientation and trained to a Guyot system (0.50 m high) with a density of 6666 plants/ha. Plant age did not differ between replications. Grafted-rooted vines were planted at the same time, and the same management practices were applied to all vines. Cluster and berry thinning and growth regulator treatments were not applied. Only 15 buds per vine were left after pruning to maintain homogeneity among the plants.

The soil in the experimental plot was slightly alkaline (pH 7.83), calcareous (Total and active $CaCO_3$ were 53.6 % and 13.34 % respectively), non-saline (EC: 0.3 dS./m) with clay-loam on top soils (0-30 cm). Climatic data were obtained from the Yüreğir Climate Station of Regional

Directorate of Meteorology in Adana, Turkey. From April through to October, the average daily temperatures were 24.5 °C and 25.1 °C, relative humidity was 64.9 % and 64.5 % and total precipitation was 210.6 and 205.2 mm, with a 2.98 and 2.81 m/s wind speed, in 2017 and 2018 respectively. Total precipitation was 148.9 mm and 286.4 mm in January, February and March in 2017 and 2018 year respectively.

In the study, the effects of applying eight types of compost were studied: the control (Control; no treatment), pumice (P; 50 t/ha/yr), commercial dry compost (DC; 4 t/ha/yr), pruning residue:farm manure mixture (1:2, v:v) (PR+FM;50 t/ha/yr), straw:farm manure mixture (1:2, v:v) (S+FM; 50 t/ha/yr), pumice:dry compost (P+DC). Mixture of pumice+straw:farm manure (P+(S+FM)), pumice+ pruning residue:farm manure (P+(PR+FM)) (Table 1).

Basaltic pumice was obtained from the Delihalil and Üçtepeler quarries located in the town of Osmaniye, 80 km east of Adana. Basaltic rocks are rich in plant nutrient sources such as P, K, Ca, Na, Fe, Mn, Zn, Mo, Co Cu, and Se (Manson, 1967). Basaltic pumice is a dark blackish-brown volcanic rock with a high porosity (55-80 %; a result of the separation of gases during the rapid cooling of the magma) and a density of approximately 0.9 g cm^{-3}. The pruning residue used in the study was obtained from the experimental vineyard of the Department of Horticulture of the Faculty of Agriculture at the University of Cukurova, and the wheat straw and mature farm manure (containing mostly cattle manure) from the animal husbandry facilities at the Faculty of Agriculture. PR+FM and S+FM composts were prepared in the same experimental vineyard every year and used about three months after preparation.

The material was applied to the experimental soil surface in February of the first year and in January of the second year. They were incorporated into the top 0-20 cm of soil by a hand rotator.

Drip irrigation was applied. Midday leaf water potential (LWP) values were measured by a Pressure Chamber (Model 600, PMS Instrument Co. Albany, Oregon, USA) to decide when to irrigate the vines. Irrigation was carried out when the average LWP value decreased to -1.2 MPa. When calculating the irrigation amount, 50 % of the evaporation values measured from the Class-A Evaporation Pan (METOS Inc., Mersin, Turkey) between irrigations was taken into account (Tangolar *et al*., 2015).

2. Grape yield, cluster and berry characteristics

Five clusters from each plot were randomly collected during the ripe stage of the grapes (Table 2); more precisely, when the Brix:Acid ratio (maturity index) exceeded 20:1 (Winkler *et al*., 1974). The clusters were transported to the laboratory to measure cluster weight (g), berry weight (g/100 berries) and berry volume (mL/100 berries). Total soluble solids (TSS) concentration was measured using a digital refractometer (Atago, Japan) and expressed as °Brix (%). Titratable acidity (TA; g tartaric acid

TABLE 1. Some selected parameters of the materials used in the study.

Treatments [x]	Macro elements (mg/100 g)				Micro elements (mg/kg)			pH	EC (dS/m)
	P	K	Ca	Mg	Fe	Mn	Zn		
Control	27.7 c [y]	403 cd	4234 ab	308 bc	7.56 bc	13.42 bc	2.12 c	7.68	0.361 cd
P	30.8 c	354 d	3911 d	202 d	5.50 d	11.34 c	2.26 c	7.72	0.335 d
DC	28.2 c	456 cd	4306 a	303 c	6.58 cd	13.18 bc	2.48 bc	7.76	0.383 cd
PR+FM	52.6 a	776 ab	3740 e	341 abc	8.40 ab	20.62 ab	2.73 ab	7.75	0.511 abc
S+FM	53.5 a	767 ab	3889 d	381 ab	8.19 ab	19.76 ab	2.98 a	7.75	0.638 a
P+DC	33.4 bc	479 c	4170 bc	274 cd	5.86 d	13.29 bc	2.24 c	7.66	0.449 bcd
P+(S+FM)	53.3 a	660 b	3598 f	288 c	8.11 ab	21.57 a	2.78 ab	7.79	0.510 abc
P+(PR+FM)	43.8 ab	818 a	4044 c	399 a	9.24 a	23.10 a	3.01 a	7.69	0.561 ab
p	***	***	***	***	***	**	***	NS	**

[x]: P = Pumice, S = Straw, DC = Dry compost, PR = Pruning residue, FM = Farm manure.
[y]: Significant difference (*p* ≤ 0.05) was found between the means indicated by different letters in the same column.
* = *p* ≤ 0.05, ** = *p* ≤ 0.01, *** = *p* ≤ 0.001, NS = non significant.

in 100 mL of grape juice) was measured using a periodically calibrated pH meter. The maturity index was calculated using the ratio TSS/TA. Grape yield (g/vine) was obtained by multiplying the number of clusters by the average cluster weight.

3. Soil water content and temperature measurements

Soil water content (%) and temperature (ºC) in the root-zone (0-30 cm and 30-60 cm) were measured weekly during the vegetation period using a capacitance probe (Decagon; Aquacheck, Model AQMOB-X).

4. Analysis of leaf samples

In order to determine how the different treatments affected plant nutrition, ten leaf samples from each treatment were taken from opposite the clusters in full bloom and at veraison (Table 2) (Winkler *et al.*, 1974; Weaver, 1976; Bhangoo *et al.*, 1988; Tangolar and Ergenoğlu, 1989; Çelik *et al.*, 1998; Çelik, 2011; Benito *et al.*, 2015). In the laboratory, the leaf samples were washed twice with tap water and then twice with distilled water. The moisture deposited on the leaf surface was removed using coarse filter paper and the leaf samples were dried at 65 °C for 72 hours (Kacar, 1972). The dry leaf samples were then ground for analysis using an agate mill. N, P, K, Ca, Mg, Fe, Zn and Mn contents were then determined as follows:nitrogen according to the Kjeldahl method (Bremner, 1965); phosphorus according to vanadomolibdophosphoric yellow colour method using the Shimadzu model UV 1201 spectrophotometer (Kacar, 1995); potassium with an Eppendorf Elex 6361 fluorimeter; and leaf calcium, magnesium, iron, zinc and manganese content by Atomic Absorption Spectrophotometer (Analytik Jena contrAA 700).

5. Microbiological and biochemical soil analyses

To perform the microbiological and biochemical soil analyses, samples from the experiment plots were taken during the spring and autumn months (i.e., twice a year) with a steel soil auger at a distance of 20 cm and 0-20 cm from the vines. Soil samples taken randomly from 4 different areas at the foot of each vine were mixed homogenously in polyethylene tubs, then labelled and placed in bags and delivered to the soil microbiology laboratory of the Department of Soil Science and Plant Nutrition at the Adnan Menderes University (Faculty of Agriculture) within 24 hours in insulated boxes. Soil samples were sifted through a 2 mm sieve in natural air moisture, put in perforated plastic boxes, and preserved at +4 C for microbiological analysis (Schinner *et al.*, 1995).

CO_2 production (respiration of the soil) was determined at the end of a 7-day incubation period at 27 ºC using 0.1 N KOH solution (Isermeyer, 1952).

Microbial Biomass-C was determined by measuring the amount of CO_2 emitted after a 4-hour incubation at 25 ºC based on the glucose dissolution rate of anaerobic organisms in the soil samples, which had been moisturized to up to 55-60 % of their water retention capacity (Anderson and Domsch, 1978).

Dehydrogenase Enzyme Activity was determined using the modified method of Thalmann (1968). Soil samples were suspended in a triphenyltetrazolium chloride solution and incubated for 16 h at 25 °C. The produced triphenyl formazan (TPF) was extracted with acetone and measured photometrically at 546 nm.

Urease activity was assayed according to the method of Kandeler and Gerber (1988). After the addition of a buffered urea solution, soil samples were incubated for 2 h at 37 °C. The released ammonium was extracted with potassium chloride solution, and determined via a modified Bertholet reaction.

Phosphatase activity was measured using the method of Tabatabai and Bremner (1969) and Eivazi and Tabatabai (1977). After the addition

TABLE 2. Phenological dates (day/month) recorded for the Black Magic grape variety.

Years	Bud burst		Full bloom		Veraison		Harvest	
	2017	2018	2017	2018	2017	2018	2017	2018
Dates	28 March	15 March	8 May	26 April	21 June	11 June	10 July	25 June

of a buffered p-nitrophenyl phosphate solution, soil samples were incubated for 1 h at 37 °C. The p-nitrophenol released by phosphomonoesterase activity was extracted and coloured with sodium hydroxide and determined photometrically at 400 nm.

6. Statistical analysis

The trial comprised three replications of two vines per experimental unit. Treatments were randomly distributed in each block. One way analysis of variance (ANOVA) was performed according to the randomised complete block design using the JMP statistical programmer-based SAS, and the least significant difference (LSD) test was used for separation of the means at 5 % significance level ($P \leq 0.05$).

RESULTS

1. Yield, cluster, berry and juice characteristics

In both study years, the highest grape yield and cluster weight values were obtained from vines treated with S+FM compost (Table 3): 6172 g/vine and 411.4 g respectively in 2017, and 7874 g/vine and 463.2 g respectively in 2018. In the second year of the experiment, yield and cluster weight were found to increase for all treatments, except P+DC compared to the control. In 2017, the highest values berry weight values were obtained for P+(PR+FM), as shown

in Table 3. In 2018, none of the compost treatments significantly affected the berry weight.

The effects of the treatments on TSS, acidity and pH differed between 2017 and 2018 (Table 4). While the effect of the TSS, acidity and pH values on the Maturity index was not significant in 2017, in 2018 they were higher for PR+FM, and subsequently S+FM and P+(S+FM) (36.85, 28.61 and 28.28 respectively).

2. Leaf macro and micro nutrients

The results of the analysis of the leaf samples performed during the flowering period of 2017 and 2018 showed that the treatments significantly affected all macro and micro elements, except N in 2017 and Zn in 2018 (Tables 5 and 6). For this phenological stage, the values in 2017 and 2018 respectively ranged as follows: N = 3.27-3.60 % and 3.21- 3.71 %; P = 0.26-0.42 % and 0.31-0.55 %; K = 0.46-0.75 % and 0.42-0.68 %. The highest Ca values were found for S+FM (2.23 and 1.71 % in 2017 and 2018 respectively) and the highest Mg values for P+(PR+FM) (0.35 and 0.28 % in 2017 and 2018 respectively). It was observed that P+(PR+FM) values were generally higher than those obtained for the other treatments (Table 6).

As can be seen in Tables 7 and 8, in 2017 P+(PR+FM) showed the highest values for N (2.44 %), P (0.17 %), Mg (0.33 %) and

TABLE 3. Effects of different treatments on yield, cluster and berry properties.

Treatments[x]	Yield (g/vine)		Cluster weight (g)		Berry weight (g/100 berries)	
	2017	2018	2017	2018	2017	2018
Control	5690 abc[y]	6255 cd	379.3 abc	367.9 cd	548.9 ab[y]	537.2
P	6100 ab	6659 bc	406.6 ab	391.7 bc	537.9 ab	558.7
DC	4479 c	7075 b	298.6 c	416.2 b	495.9 b	552.7
PR+FM	4502 bc	7022 b	300.1 bc	413.1 b	505.8 b	550.3
S+FM	6172 a	7874 a	411.4 a	463.2 a	513.6 b	580.5
P+DC	5293 abc	6033 d	352.8 abc	354.9 d	496.6 b	563.0
P+(S+FM)	5578 abc	6790 bc	371.8 abc	399.4 bc	522.5 b	552.4
P+(PR+FM)	5230 abc	6672 bc	348.7 abc	392.9 bc	601.9 a	557.4
p	*	***	*	***	*	NS

[x]: P = Pumice, S = Straw, DC = Dry compost, PR = Pruning residue, FM = Farm manure.
[y]: Significant difference ($p \leq 0.05$) was found between the means indicated by different letters in the same column.
* = $p \leq 0.05$, ** = $p \leq 0.01$, *** = $p \leq 0.001$, NS = non significant.

TABLE 4. Effects of different treatments on juice properties.

Treatments [x]	TSS (%)		Acidity (%)		pH		Maturity index	
	2017	2018	2017	2018	2017	2018	2017	2018
Control	14.7 b [y]	12.63 c	0.435	0.491 bc	3.48 c	3.52 cd	33.91	25.91 bc
P	15.7 ab	13.93 ab	0.411	0.531 a	3.70 a	3.56 cd	38.14	26.24 bc
DC	15.4 ab	12.77 bc	0.442	0.474 c	3.47 c	3.49 d	35.02	26.96 bc
PR+FM	15.7 ab	14.23 a	0.449	0.387 d	3.59 abc	3.75 a	34.89	36.85 a
S+FM	16.7 a	13.67 abc	0.466	0.478 c	3.68 a	3.71 ab	35.86	28.61 b
P+DC	15.6 ab	13.40 abc	0.467	0.528 ab	3.55 bc	3.61 bc	33.78	25.34 bc
P+(S+FM)	15.5 ab	14.37 a	0.411	0.508 abc	3.65 ab	3.68 ab	37.93	28.28 b
P+(PR+FM)	16.2 ab	12.62 c	0.415	0.523 ab	3.67 ab	3.61 bc	38.99	24.19 c
p	*	*	NS	***	**	***	NS	***

[x]: P = Pumice, S = Straw, DC = Dry compost, PR = Pruning residue, FM = Farm manure.
[y]: Significant difference ($p \leq 0.05$) was found between the means indicated by different letters in the same column.
* = $p \leq 0.05$, ** = $p \leq 0.01$, *** = $p \leq 0.001$, NS = non significant.

TABLE 5. Macro nutrient concentrations (g/100 g) in leaf blade at flowering.

Treatments [x]	N		P		K		Ca		Mg	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Control	3.60	3.32 ab [y]	0.41 ab	0.39 ab	0.50 bc	0.45 b	1.83 abc	1.14 b	0.29 ab	0.19 c
P	3.55	3.34 ab	0.42 a	0.46 ab	0.62 ab	0.68 a	1.28 cd	1.10 b	0.20 cd	0.18 c
DC	3.27	3.21 b	0.26 c	0.55 a	0.60 abc	0.47 b	1.22 d	1.23 ab	0.19 d	0.20 bc
PR+FM	3.45	3.53 ab	0.35 abc	0.46 ab	0.56 bc	0.42 b	1.71 abcd	1.52 ab	0.24 bcd	0.24 abc
S+FM	3.54	3.39 ab	0.29 c	0.38 ab	0.75 a	0.48 ab	2.23 a	1.71 a	0.26 bc	0.26 ab
P+DC	3.46	3.53 ab	0.31 bc	0.51 a	0.56 bc	0.55 ab	1.57 bcd	1.24 ab	0.24 bcd	0.23 abc
P+(S+FM)	3.47	3.58 ab	0.30 c	0.31 b	0.57 bc	0.55 ab	1.69 abcd	1.58 ab	0.22 bcd	0.23 abc
P+(PR+FM)	3.57	3.71 a	0.32 bc	0.44 ab	0.46 c	0.43 b	2.05 ab	1.47 ab	0.35 a	0.28 a
p	NS	*	*	*	*	*	*	*	**	**
SR [z] Low	<2.08		<0.14		<0.61		<0.94		<0.13	
Optimal	2.08-3.25		0.14-0.32		0.61-1.94		0.94-2.47		0.13-0.38	
High	>3.25		>0.32		>1.94		>2.47		>0.38	

[x]: P = Pumice, S = Straw, DC = Dry compost, PR = Pruning residue, FM = Farm manure.
[y]: Significant difference ($p \leq 0.05$) was found between the means indicated by different letters in the same column.
* = $p \leq 0.05$, ** = $p \leq 0.01$, *** = $p \leq 0.001$, NS = non significant
[z]: SR, Sufficiency ranges have been adopted from Jones *et al*. (1991) and Benito *et al*. (2015).

Mn (106.8 ppm). In 2017, the highest K value was obtained from the application of pumice (0.86 %). The highest Fe value was obtained from S+FM (120.7 ppm) and that of Zn from DC (28.1 ppm). The 2018 veraison values showed that there were significant differences between the treatments in terms of all macro and micro elements examined. In the second year of the experiment, the highest values for the macro and micro elements were obtained from the following treatments: N from P+(S+FM), P from Control, K from pumice, Ca from P+(S+FM) and Mg from PR+FM. In terms of the micro elements, the highest values were obtained from P+(BA+CG) and Control.

When comparing the values obtained from all treatments with the limits for the full flowering period, (according to Jones *et al.* (1991) and Benito *et al.* (2015)), the amounts were found to be high for nitrogen, optimal-high for phosphorus, optimal for calcium and Mg and low for potassium (Table 5). Fe and Mn were evaluated as being optimal and zinc values as being low (Table 6).

Similarly, in terms of the veraison limit values, N, P and Ca were found to be optimal-high, while Mg and K were optimal for all treatments (Table 7). In terms of the micro elements, Fe and

Treatments [x]	Fe		Mn		Zn	
	2017	2018	2017	2018	2017	2018
Control	162.9 bc [y]	57.7 bc	108.2 b	69.1 bc	20.5 a	11.1
P	123.8 c	51.8 c	86.0 bc	42.0 d	17.2 b	11.6
DC	190.4 ab	51.5 c	74.8 c	65.8 bcd	16.1 b	9.5
PR+FM	205.8 ab	53.9 c	99.8 b	58.1 cd	16.4 b	9.7
S+FM	211.9 a	59.1 bc	94.8 bc	63.5 bcd	17.0 b	9.5
P+DC	186.4 ab	56.5 bc	89.7 bc	85.2 ab	15.3 b	10.8
P+(S+FM)	132.5 c	63.9 ab	88.0 bc	53.3 cd	15.1 b	9.6
P+(PR+FM)	183.7 ab	68.2 a	142.5 a	94.3 a	21.4 a	12.0
p	**	**	***	**	***	NS
SR [z] Low	<45		<25		<18	
Optimal	45-197		25-145		18-250	
High	>197		>145		>250	

[y]: P = Pumice, S = Straw, DC = Dry compost, PR = Pruning residue, FM = Farm manure.
[y]: Significant difference ($p \leq 0.05$) was found between the means indicated by different letters in the same column.
* = $p \leq 0.05$, ** = $p \leq 0.01$, *** = $p \leq 0.001$.
[z]: SR: Sufficiency ranges have been adopted from Jones *et al.* (1991) and Benito *et al.* (2015).

Treatments[x]	N		P		K		Ca		Mg	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Control	2.28 ab[y]	2.81 b	0.15 ab	0.33 a	0.42 d	0.90 e	2.64	3.28 b	0.32 ab	0.22 b
P	2.27 ab	2.73 b	0.17 a	0.18 b	0.86 a	1.79 a	2.96	4.05 ab	0.22 b	0.24 ab
DC	2.31 ab	2.77 b	0.15 ab	0.27 ab	0.48 cd	0.87 e	2.91	3.56 ab	0.28 ab	0.32 ab
PR+FM	2.21 abc	2.97 b	0.17 a	0.21 ab	0.61 bc	1.33bcd	2.62	4.52 a	0.30 ab	0.33 a
S+FM	2.01 c	2.97 b	0.14 b	0.20 ab	0.61 bc	1.40 ab	3.30	4.16 ab	0.30 ab	0.28 ab
P+DC	2.36 ab	2.69 b	0.16 ab	0.29 ab	0.42 d	1.01 cde	3.13	3.75 ab	0.35 a	0.26 ab
P+(S+FM)	2.16 bc	5.57 a	0.15 ab	0.24 ab	0.77 ab	1.36 bc	3.43	4.27 a	0.32 ab	0.29 ab
P+(PR+FM)	2.44 a	2.95 b	0.17 a	0.28 ab	0.42 d	0.98 de	2.79	4.12 ab	0.33 a	0.30 ab
p	*	***	*	*	***	***	NS	*	*	*
SR[z] Low	<1.41		<0.11		<0.40		<0.86		<0.10	
Optimal	1.41-2.28		0.11-0.19		0.40-1.56		0.86-3.28		0.10-0.47	
High	>2.28		>0.19		>1.56		>3.28		>0.47	

[x]: P = Pumice, S = Straw, DC = Dry compost, PR = Pruning residue, FM = Farm manure.
[y]: Significant difference ($p \leq 0.05$) was found between the means indicated by different letters in the same column.
* = $p \leq 0.05$, ** = $p \leq 0.01$, *** = $p \leq 0.001$.
[z]: SR = sufficiency ranges have been adopted from Jones *et al.* (1991) and Benito *et al.* (2015).

Mn were found to be sufficient and Zn values were within the low-optimal limits (Table 8).

3. Soil moisture and temperature

In both study years, adding organic material to the soil affected the soil moisture content at two soil depths (Table 9). The highest values in a soil depth of 0-30 cm were found to be 19.50 % (Control) in 2017 and 20.72 % (P+(PR+FM)) in 2018. At a depth of 30-60 cm, they were 24.02 % (Control) in 2017, and 23.58 % and 23.26 % (Control and P+(PR+FM) respectively) in 2018.

The treatments did not significantly affect soil temperature measured at depths of 0-30 cm and 30-60 cm in either year (Figure 1).

TABLE 8. Micro nutrient concentrations (mg/kg) in leaf blade at verasion

Treatments[x]	Fe		Mn		Zn	
	2017	2018	2017	2018	2017	2018
Control	102.4 b[y]	105.0 a	86.4 ab	145.1 a	23.8 ab	16.3 a
P	112.8 ab	88.2 ab	60.1 c	108.3 b	20.5 bc	12.0 b
DC	115.2 ab	73.0 b	82.0 abc	97.6 b	28.1 a	12.9 b
PR+FM	113.9 ab	85.7 ab	73.6 bc	102.7 b	24.2 ab	12.9 b
S+FM	120.7 a	96.6 a	76.4 bc	106.9 b	24.0 ab	14.8 ab
P+DC	112.8 ab	87.4 ab	79.2 bc	108.0 b	24.7 ab	12.8 b
P+(S+FM)	118.0 a	90.2 ab	57.6 c	117.2 b	18.8 c	13.8 ab
P+(PR+FM)	113.8 ab	102.6 a	106.8 a	166.1 a	21.8 bc	16.1 a
p	*	*	**	***	*	*
SR[z]	Low	<50		<25		<15	
	Optimal	50-235		25-187		15-160	
	High	>235		>187		>160	

[x]: P = Pumice, S = Straw, DC = Dry compost, PR = Pruning residue, FM = Farm manure.
[y]: Significant difference ($p \leq 0.05$) was found between the means indicated by different letters in the same column.
* = $p \leq 0.05$, ** = $p \leq 0.01$, *** = $p \leq 0.001$.
[z]: SR, Sufficiency ranges are from Jones *et al.* (1991) and Benito *et al.* (2015).

TABLE 9. Effects of different treatments on soil moisture content at depths of 0-30 cm and 30-60 cm.

Treatments[x]	Soil moisture (%) 0-30 cm		Soil moisture (%) 30-60 cm	
	2017	2018	2017	2018
Control	19.50 a[y]	19.86 abc	24.02 a	23.58 a
P	18.19 b	19.01 c	20.41 e	20.46 c
DC	18.92 ab	19.44 bc	22.08 b	21.97 b
PR+FM	18.96 ab	19.74 abc	20.40 e	21.96 b
S+FM	19.00 ab	20.32 ab	20.90 cd	22.28 b
P+DC	18.31 b	19.87 abc	21.24 c	22.61 b
P+(S+FM)	16.58 c	16.18 d	20.77 de	20.85 c
P+(PR+FM)	18.48 b	20.72 a	22.40 b	23.26 a
p	***	***	***	***

[x]: P = Pumice, S = Straw, DC = Dry compost, PR = Pruning residue, FM = Farm manure.
[y]: Significant difference ($p \leq 0.05$) was found between the means indicated by different letters in the same column.
* = $p \leq 0.05$, ** = $p \leq 0.01$, *** = $p \leq 0.001$.

4. Microbiological and biochemical characteristics of the soil

In terms of the microbiological and biochemical characteristics of the soil, the treatments were found to have a significant effect on CO_2 production, microbial biomass, dehydrogenase, urease and phosphatase enzyme activities (Table 10).

The highest values for CO_2 production were obtained from P+(PR+FM) in 2017 and from S+FM in 2018 (Table 10), and the lowest was from pumice in both years. Table 10 shows the effect of the organic materials used on soil Microbial Biomass C; the highest values were obtained from the application of S+FM in 2017, and S+FM, P+DC and P+(PR+FM) in 2018. Meanwhile, the application of pumice gave the lowest value, which was similar to that of CO_2 production. Enzyme activity was also affected by the treatments. In terms of the effect of the organic materials used in this study on dehydrogenase enzyme activity in soils, the application of P+(PR+FM) in 2017 and of
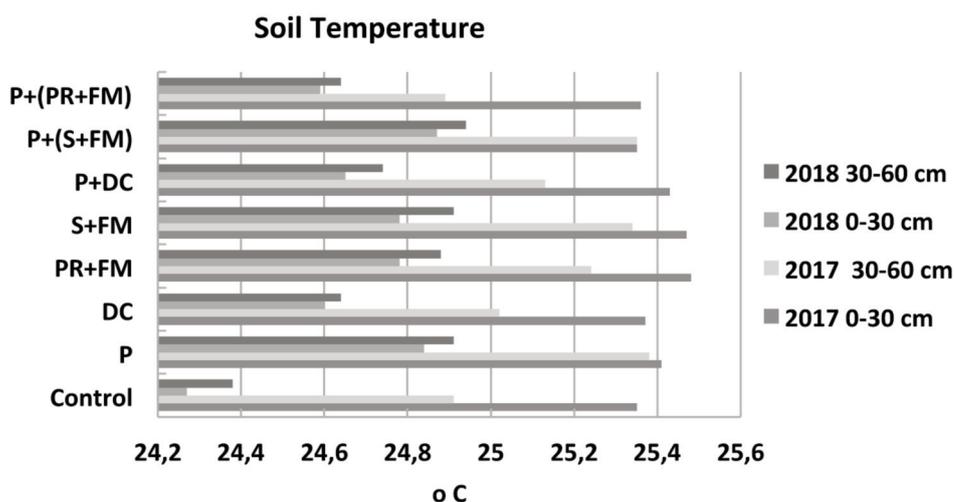
FIGURE 1. Effects of the different treatments on soil temperature at depths of 0-30 cm and 30-60 cm.
P = Pumice, S = Straw, DC = Dry compost, PR = Pruning residue, FM = Farm manure.

PR+FM in 2018 yielded the highest figures. The highest urease activity was recorded for P+(PR+FM), P+DC and Control in 2017 and for P+DC in 2018, and among the lowest values were those for P manifested lowest values compared to the others in both of the years (Table 10). In terms of phosphatase activity, the highest values were measured for the application of P+(PR+FM) in 2017 and for P+DC in 2018 (Table 10). Meanwhile, the lowest values were found for pumice only.

DISCUSSION

Soil type, structure, precipitation, temperature, vegetation, land use history, latitude, slope and cultural practices all have a strong influence on the distribution of organic matter in soils (Powers and Schlesinger, 2002; Mueller and Pierce, 2003; Krishnan *et al.*, 2007; Schulp and Veldkamp, 2008; Zhang *et al.*, 2011). Due to these factors, it may not be possible to clearly determine the effects of short-term applications of organic material on plant and soil properties, and the effects can vary depending on the applied material type, treatment method and ecosystem features of the experimental area.

In the present study, the highest grape yield and cluster weight values were obtained from the application of S+FM compost in both years, but the order of superiority for the other treatments is not clear. This is assumed to be due to the young age of the vines and their ability to find sufficient nutrients and water in the soil at this stage. In

Table 3, it can be seen that the efficiency increase in 2018 was higher for DC and PR+FM compared to 2017. In these practices, it is highly probable that the low grape yield in 2017 caused an increase in the productivity of the buds during the vegetation period of 2017, thus setting the product of the next year. Because the productivity of the winter buds increased in 2017, the shoots caused the number and weight of bunches to increase for DC and PR+FM applications, and therefore the yield also increased normally. For the application of S+FM, the grape yield in 2017 and 2018 was 6172 g/vine (41.1 t/ha) and 7874 g/vine (52.5 t/ha) respectively, which is more than the average yield of Turkey. The average grape yield per hectare in Turkey is approximately 9 tons (OIV, 2019). The differences between the treatments in terms of berry weight and must properties were not clear for either year.

Different results have been obtained in previous studies regarding the effect of compost and other organic materials on the growth, yield and quality of grapevine (Pinamonti, 1998; Morlat, 2008; Mugnai *et al.*, 2012; Tardaguila *et al.*, 2018; Burg *et al.*, 2019). Overall, the effects of compost on yield were found to be minor in some studies. Pinamonti (1998) and Morlat (2008) did not find any significant effects of compost on yield. Conversely, in an experiment by Mugnai *et al.* (2012), the effects of treatments changed significantly over 9 years. In this study, the presence of Green Waste compost in the soil

Semih Tangolar *et al.*

TABLE 10. Effects of different treatments on microbiological and biochemical characteristics of the soil.

Treatments[x]	CO₂ - Production (mg CO2/g P.M./7days)		Microbial Biomass (mg Biomass-C/100 g dry soil)		Dehydrogenase E.A. (µg TPF/g dry soil)		Urease E.A. (µg N/g dry soil/2h)		Phosphatase E.A. (µg p-NP/g dry soil./h)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Control	11.04 bc[y]	17.27 bc	44.47 bc	56.22 ab	107.72 b	224.88 cd	75.68 a	87.72 c	395.10 ab	598.65 abc
P	8.24 d	13.33 d	34.33 d	43.40 c	51.00 e	152.19 d	51.09 c	93.96 bc	221.49 e	460.17 e
DC	9.02 cd	15.91 cd	40.98 cd	47.35 bc	61.74 cde	224.11 cd	69.54 ab	117.55 ab	284.91 d	513.75 de
PR+FM	10.26 bcd	15.88 cd	40.90 cd	53.00 ab	67.53 cde	374.59 a	54.58 bc	99.16 abc	297.18 cd	565.83 cd
S+FM	12.50 ab	20.04 a	51.59 a	60.65 a	76.92 cd	316.15 abc	67.32 ab	114.49 ab	351.94 bc	596.38 bc
P+DC	11.77 ab	17.90 abc	46.09 abc	59.81 a	85.29 bc	246.51 bcd	74.54 a	123.52 a	293.78 cd	674.31 a
P+(S+FM)	10.09 bcd	19.12 ab	49.23 ab	54.18 ab	59.01 de	309.19 abc	49.26 c	97.08 bc	256.33 de	536.65 cde
P+(PR+FM)	13.68 a	19.99 ab	51.48 ab	61.47 a	149.10 a	346.09 ab	76.13 a	106.42 abc	445.15 a	645.85 ab
p	**	***	***	**	***	**	**	*	***	***

x: P = Pumice, S = Straw, DC = Dry compost, PR = Pruning residue, FM = Farm manure.
y: Significant difference (*p* ≤ 0.05) was found between the means indicated by different letters in the same column.
* = *p* ≤ 0.05, ** = *p* ≤ 0.01, *** = *p* ≤ 0.001.

was not found to significantly affect *V. vinifera* growth, and the application of compost gave contrasting results related to yield and quality of grape, which greatly varied over the years. The organic amendment statistically affected the average cluster weight, except in 2003, 2004 and 2005, and grape quality (determined by pH and °Brix) was not affected by compost, except in 2006 when °Brix was higher for compost treatments compared to the control. Morlat and Symoneaux (2008) found that juice pH increased with an increasing organic amendment rate. However, in our experiment, although the effect of applying compost and other organic material on berry weight and other properties was not clear, grape yield and cluster weight significantly increased in the second year. Furthermore, in terms of the effects on vegetative growth, yield and grape quality, Tardaguila *et al*. (2018) found no significant differences between the control, soil green manure, dry mulching and vine pruning residue compost management strategies in degraded areas. Similar to our results, the researchers concluded that this might have been due to the study period not being long enough to obtain the effects of organic additive responses to plants and soil, which need more than a couple of years. Cabilovski *et al*. (2014) mentioned that the permanent effect of compost lasts longer and only 11 % of organic N from composted fertiliser applied in autumn and 21 % of non-composted fertiliser was mineralised the following year.

Although Burg *et al*. (2019) stated that applications of organic matter improve soil fertility and physical properties (such as soil water retention, soil aggregation, water and aeration of soil, etc.) the effects of applications on yield and quality components (including soil moisture and temperature) was not seen in their two-year study. The reason for this may have been a lack of sufficient precipitation prior to harvest (from January and June) in 2017 and 2018, and an insufficient volume of irrigation in all plots.

In addition, the organic material applied over the two years did not sufficiently decompose; the soil moisture and temperature did not seem to change as a result of the treatments.

According to the results of the leaf nutrient analysis, N, P and Ca were optimal-high, Mg, K, Fe and Mn were optimal, and Zn was within the low-optimal limits across the vines. These results indicate that in the first year there were enough

nutrients in the soil for the young vines. The compost and the other treatments are expected to be more effective in the following years in terms of availability of nutrients.

Baronti *et al*. (2014) note that the addition of compost or compost-like substances to soil in vineyards positively influences the soil water holding capacity, water infiltration, soil water availability, nutrient retention, and soil aeration. They found that adding Biochar to soil increased the soil water holding capacity by 3.2 % to 45 % when pruning waste was applied at the rates of 22 and 44 ton/ha.

In research carried out by Gaiotti *et al*. (2017), the effect of compost on soil fertility, vine growth, yield and grape quality (2009–2013) were investigated in a private vineyard in northeastern Italy over 5 years. Two different types of compost (compost from vine pruning waste and from cattle manure) and two application methods (inter-row and under-row distribution) were tested on mature 'Cabernet Sauvignon' vines. The compost stimulated high vegetative growth and high root development; the latter occurred when the compost was locally supplied to the under-row. In both cases, a reduction in fruit quality was observed, likely due to competition between the canopy or roots and the fruit. The inter-row application of compost from vineyard pruning waste produced the best overall performance, displaying well-balanced root/canopy growth, increased yield, and satisfactory grape quality.

Heterotroph microorganisms use organic carbon as a source of carbon and energy, and the amount of CO_2 that they thereby produce in different organic materials provides information about C-mineralisation (Göçmez *et al*., 2019).

The amount of microbial biomass has been frequently used in recent years to characterise the microbiological structure of soil. The concept of microbial biomass can be defined as the weight of living microorganisms in the soil. It is useful for the storage of nutrients, such as C, N, S and P, and is an indicator of any transformations taking place in the soil organic matter (Jenkinson and Ladd, 1981). Although microbial biomass represents a very small amount of total soil N and C, the latter are reported to contribute to the nutrition of plants due to their rapid cycle, resulting in the mineralisation of nitrogen and other plant nutrients.

Pumice and compost did not affect soil microbial biomass more when applied alone, in contrast to the mixtures of pumice and straw. This is thought to be due to the mixtures creating a more suitable environment for microorganism activity compared to other organic materials. Manson (1967) reported that basaltic pumice is among the most important plant inorganic nutrient sources, as it has high porosity (55-80 %) and aeration capacity.

It is possible to obtain information about the amount of various dehydrogenase enzymes in the soil by measuring the activity of the respiratory enzyme, dehydrogenase. This is also an indicator of aerobic and facultative anaerobic living organisms, which supply hydrogen from organic compounds and transport it to a hydrogen scavenger (Çengel, 1995). Wittling *et al*. (1995) suggested that dehydrogenase enzyme activity is a reliable indicator of overall microbial activity in soils. Many soil and climatic factors affecting microbial life and applications to soil affect the activity of dehydrogenase enzyme, because it is used by the live soil microbial population. Urease is an enzyme that catalyses the hydrolysis of urea to CO_2 and ammonia, and it is commonly found in high plants and microorganisms (especially bacteria). Urease is the only enzyme that strongly affects the decomposition and usefulness of urea, which is an important nitrogenous fertilizer for soil. Urease activity increases in parallel with an increase in soil organic matter content and it decreases in salty and alkaline soils.

The mineralisation of organic phosphorus compounds to orthophosphate involves phosphomono esterases (acid and alkaline phosphatases), which are released by plant roots and soil microorganisms (Göçmez *et al*., 2019). Phosphatases are mainly produced under low phosphate availability conditions. Microbial phosphatases are more present in such soils (Tabatabai, 1982).

The values obtained for the samples to which only pumice was applied were generally low, but it is worth noting that there was an improvement in enzyme activity for the mixtures with Pumice, especially for P+(PR+FM), which contained pruning residues. As well as the nutrient

contribution it provides, Pumice is thought to contribute to soil properties, such as aeration and water retention, alongside the other materials in compost mixtures. Slama *et al.* (2019) also reported that using compost in combination with natural rocks enriched with NPK mobilisation bacteria and mineral NPK enhanced leaf nutrient content and gave the highest yield and cluster weight. This mix also improved the physical and chemical characteristics of the berries.

Consequently, the treatments with high enzyme activities were found to perform better than mixtures with low enzyme activity. The use of mixtures based on their enzyme activity can thus be recommended for increasing plant nutrition efficiency in vineyards.

We therefore hope that this knowledge will play a role in encouraging the utilisation of pumice, which is a natural and low-cost inorganic material for good agricultural practices.

CONCLUSIONS

The results obtained in this study demonstrated that the application of compost and other inorganic materials to vineyard soil can improve grape yield and quality. However, previous studies have shown that the origin and chemical composition of the materials and the method and rate of treatments are crucial factors to be taken into consideration when assessing optimal uses. Under conditions similar to those in our study (i.e., corresponding to a semi-arid region with soil limitations), the inter-row application (around 50 t/ha) of compost from vine pruning waste or straw can successfully replace mineral fertilisation, and give satisfactory yield and grape quality. In addition to crop quality aspects, the application of compost is also beneficial for soil, and therefore the adoption of compost amendments as a sustainable vineyard management practice should be encouraged. In general in this study, high values for the application of P+(PR+FM) and S+FM were recorded, especially in terms of treatment effects on the microbiological and biochemical characteristics of the soil.

While the application of compost alone or with inorganic materials generally provided some improvement compared to the control for most of the properties studied, further studies should focus on observing the accumulated effects of such treatment on the development of grapevine

in order to make sound recommendations regarding suitable material.

In sustainable viticulture, issues related to soil fertility - particularly increasing spells of drought and degradation of soils - still need a lot of attention. Therefore, more efforts should be directed at replacing traditional chemical fertilisers with local organic and inorganic materials which are abundant and economically advantageous, such as farm manure, pumice, pruning residue, and straw, etc.

REFERENCES

Aggelides, S.M. & Londra, P.A. (2000). Effects of compost produced from town wastes and sewage sludge on the physical properties of a loamy and a clay soil. *Bioresource Technology,* 71, 253-259. doi:/10.1016/S0960-8524(99)00074-7

Altieri, M.A. (1987). *Agroecology*. Westview Press (Boulder). IT Publications. London. 227 p.

Anderson, T.H., & Domsch, K.H. (1978). A Physiological method for the quantitative measurement of microbial biomass in soil. *Soil Biology & Biochemistry*, 215-221. doi:/10.1016/0038-0717(78)90099-8

Baronti, S., Vaccari, F.P., Miglietta, F., Calzolari, C., Lugato, E., Orlandini, S., ... & Genesio, L. (2014). Impact of biochar application on plant water relations in *Vitis vinifera* L. *European Journal of Agronomy*. 53, 38-44. doi:/10.1016/j.eja.2013.11.003

Benito, A., García-Escudero, E., Romero, I., Domínguez, N., & Martín, I. (2015). Sufficiency ranges (sr) and deviation from optimum percentage (dop) references for leaf blade and petiole analysis in 'Red Grenache' grapevines. *Journal international science vigne vin,* 49, 1, 47-58. doi:/10.20870/oeno-one.2015.49.1.94

Bhangoo, M. S., Day, K.S., Sudanagunta, V.R., & Petrucci, V.E. (1988). Application of paultry manure influences Thompson Seedless grape production and soil properties. *Hort Science*, 23, 6, 1010-1012.

Blaya, J., Marhuenda, F. C., Pascual, J. A., & Ros, M. (2016). Microbiota characterization of compost using omics approaches opens new perspectives for phytophthora root rot control. *PloS one*, 11, 8. doi:/10.1371/journal.pone.0158048

Bremner, J.M., 1965. Total bitrogen. Methods of soil analysis. (Ed. C.A Black) Part 2. *Amer. Soc. of Agr. Inc., Publısher*, Madison, Wisconsin – USA, p: 1149-1178. doi:/10.2134/agronmonogr9.2.c32

Burg, P.,Masan, V., Alice Cizkova, A., & Barbora Badalikova, B. (2019). Impact of compost application in vineyards on changes of physical properties of soil. *Jelgava*, 576-582. doi:/10.22616/ERDev2019.18.N263

Cabilovski, R., Manojlovic, M., Bogdanovic, D., Magazin, N., Keserovic, Z., & Sitaula, B.K. (2014). Mulch type and application of manure and composts in strawberry *(Fragaria × ananassa* Duch.) production: impact on soil fertility and yield. *Zemdirbyste-Agriculture,* 101, 1, 67-74. doi:/10.13080/z-a.2014.101.009

Calleja-Cervantes, M. E., Fernández-González, A. J., Irigoyen, I., Fernández-López, M., Aparicio-Tejo, P. M., & Menéndez, S. (2015). Thirteen years of continued application of composted organic wastes in a vineyard modify soil quality characteristics. *Soil Biology and Biochemistry*, 90, 241-254. doi:/10.1016/j.soilbio.2015.07.002

Çelik, H., Ağaoğlu. S. Fidan. Y.. Marasalı. B., & Söylemezoğlu, G. (1998). Genel Bağcılık. Sunfidan A. Ş. Mesleki Kitaplar Serisi: 1. *Fersa Matbacılık* San. Tic. Ltd. Şti. Kızılay- Ankara.

Çelik, S. (2011). Bağcılık (Ampeloloji), Cilt I. Namık Kemal Univ. Ziraat Fak. Bahçe Bitkileri Böl. Tekirdağ, 428s.

Chaves, M.M., Santos, T.P., Souza, C.R., Ortuno, M.F., Rodrigues, M.L., Lopes, C.M., Maroco, J.P., & Pereira, J.S. (2007). Deficit irrigation in grapevine improves water-use-efficiency without controlling vigour and production quality. *Annals of Applied Biology,* 150, 237-252. doi:/10.1111/j.1744-7348.2006.00123.x

Costantini, E. A. C., Agnelli, A. E., Fabiani, A., Gagnarli, E., Mocali, S., Priori, S., ... & Valboa, G. (2015). Short-term recovery of soil physical, chemical, micro-and mesobiological functions in a new vineyard under organic farming. *Soil*, 1, 443-457. doi:/10.5194/soil-1-443-2015

Curtis, M.J., & Claassen, V.P. (2005). Compost incorporation increases plant available water in a drastically disturbed serpentine soil. *Soil Science*, 170, 939-953. doi:/10.1097/01.ss.0000187352.16740.8e

Curtis, M.J., & Claassen, V.P. (2009). Regenerating topsoil functionality in four drastically disturbed soil types by compost incorporation. *Restoration Ecology*, 17, 1, 24-32. doi:/10.1111/j.1526-100X.2007.00329.x

Çengel, M. (1995). Toprak Mikrobiyolojisi ve Biyokimyası Ders Teksiri. Ege Üniv. Ziraat Fak. Teksir No: 78. Bornova.

Eivazi, F., & Tabatabai, M.A. (1977). Phosphatases in Soils. *Soil Biology and Biochemistry*, 9, 3, 167-172.

Gaiotti, F., Marcuzzo, P., Belfiore, N., Lovat, L., Fornasier, F., & Tomasi, D. (2017). Influence of compost addition on soil properties, root growth and vine performances of *Vitis vinifera* cv. Cabernet-Sauvignon. *Scientia Horticulturae*, 225, 88-95. doi:/10.1016/j.scienta.2017.06.052

Göçmez, S., Bellitürk, K., Görres, J. H., Turan, H. S., Üstündağ, Ö., Solmaz, Y., & Adiloğlu, A. (2019). The Effects of the use of vermicompost in olive tree farming on microbiological and biochemical characteristics of the production material. *Erwerbs-Obstbau*, 61, 4, 337-344. doi:/10.1007/s10341-019-00437-1

Isermeyer, H. (1952). Eine Einfache Methode zur Bestimmung der Karbonate im Boden, Z. Pflanzenern. Düng., Bodenkde. doi:/10.1002/jpln.19520560107

Jenkinson, D.S., & Ladd, J. N. (1981). Microbial biomass in Soil: Measurement and turnover. *In* E.A. Paul, and J.N. Ladd (Eds.). *Soil Biochemistry*, 5, 415-471. Marcel Dekker, New York.

Jones, A., Montanarella, L., & Jones, R. (2005). *Soil atlas of Europe*. European Commission.

Jones, J.B., Wolf, Jr. B., & Mills, H.A. (1991). *Plant analysis handbook. I. methods of plant analysis and interpratation*. Micro-Macro Publishing Inc.,183 Paradise Blvd, Suite 108, Athens Georgia 30607 USA.

Kacar, B. (1972). *Bitki ve Toprağın Kimyasal Analizleri: II. Bitki Analizleri.* Ankara Üniversitesi Ziraat Fakültesi Yayınları: 453. Uygulama Kılavuzu:155. Ankara.

Kacar, B. (1995). Toprak Analizleri. Bitki ve Toprağın Kimyasal Analizleri: III. Ankara Üniversitesi Ziraat Fakültesi Eğitim Araştırma ve Geliştirme Vakfı Yayınları: No: 3. 705s. Ankara.

Kandeler, E., & Gerber, H. (1988). Short-term assay of soil urease activity using colorimetric determination of ammonium. *Biol Fertil Soils*, 6, 68- 72. doi:/10.1007/BF00257924

Krishnan, P., Bourgeon, G., Lo Seen, D., Nair, K.M., Prasanna, R., Srinivas, S., Muthusankar, G., Dufy, L. & Ramesh, B.R. (2007). Organic carbon stock map for soils of southern India: A multifactorial approach. *Curr. Sci.*, 93, 706–710.

Lampkin, N. (1990). *Organic Farming.* Farming Press Books. U.K. 701 p.

Manson, V. (1967). *Geochemistry of basaltic rocks: major elements*. Ed. H.H. Hess. Vol:1. Interscience publication. London. 215-271.

Morlat, R. (2008). Long-term additions of organic amendments in a Loire valley vineyard on a calcareous sandy soil. II. Effects on root system, growth, grape yield, and foliar nutrient status of a Cabernet Franc vine. *American Journal of Enology and Viticulture,* 59, 364-374.

Morlat, R., & Symoneaux, R. (2008). Long-term additions of organic amendments in a Loire valley vineyard on a calcareous sandy soil. III. Effects on fruit composition and chemical and sensory characteristics of a Cabernet franc wine. *American Journal of Enology and Viticulture,* 59, 375-386.

Mueller, T.G., & Pierce, F.G. (2003). Soil carbon maps: enhancing spatial estimates with simple terrain attributes at multiple scales. *Soil Science Society of America Journal,* 67, 258-267. doi:/10.2136/sssaj2003.2580

Mugnai, S., Masi, E., Azzarello, E., & Mancuso, S. (2012). Influence of long-term application of green waste compost on soil characteristics and growth, yield and quality of grape (*Vitis vinifera* L.). *Compost Science and Utilization*, 20, 1, 29-33. doi:/10.1080/1065657X.2012.10737019

Mylavarapu, R.S., & Zinati, G.M. (2009). Improvement of soil properties using compost for optimum parsley production in sandy soils. *Scientia Horticulturae*, 120, 2, 426-430. doi:/10.1016/j.scienta.2008.11.038

OIV (2019). 2019 Statistical Report on World Vitiviniculture. International Organisation of Vine and Wine Intergovernmental Organisation. http://oiv.int/public/medias/6782/oiv-2019-statistical-report-on-world-vitiviniculture.pdf. Accessed on 4 Nov 2020.

Özdemir, G., Kitir, N., Turan, M., & Ozlu, E. (2018). Impacts of organic and organo-mineral fertilizers on total phenolic, flavonoid, anthocyanin and antiradical activity of Öküzgözü (*Vitis vinifera* L.) grapes. *Acta Scientiarum Polonorum Hortorum Cultus,* 17, 3, 91-100. doi:10.24326/asphc.2018.3.9

Özdemir, G., Tangolar, S., Gursoz, S., Cakir, A., Tangolar, S. G., & Ozturkmen, A.R. (2008). Effect of different organic manure applications on grapevine nutrient values. *Asian Journal of Chemistry*, 20, 3, 1841-1847.

Pinamonti, F., 1998. Compost mulch effects on soil fertility. Nutritional status and performance of grapevine. *Nutrient Cycling in Agroecosystems*, 51, 3, 239-248. doi:/10.1023/A:1009701323580

Powell, K.S.. Burns. A., Norng, S., Granett, J., & McGourty, G. (2007). Influence of composted green waste on the population dynamics and dispersal of grapevine phylloxera *Daktulosphaira vitifoliae*. *Agriculture, ecosystems & environment,* 119, 1-2, 33-38. doi:/10.1016/j.agee.2006.06.016

Powers, J.S., & Schlesinger, W.H. (2002). Relation-ships between soil carbon distributions and biophysical factors at nested spatial scales in rainforests of north eastern Costa Rica. *Geoderma,* 109, 165–190. doi:/10.1016/S0016-7061(02)00147-7

Priori, S., D'Avino, L., Agnelli, A.E.,Valboa, G., Knapič, M., Schroers, H.J., Akca, E., Tangolar, S., Kiraz, M.E., Giffard, B., & Fulchin, E. (2018). Effect of organic treatments on soil carbon and nitrogen dynamics in vineyard. *EQA-International Journal of Environmental Quality,* 31, 1-10.

Ramos, M.C. (2017). Effects of compost amendment on the available soil water and grape yield in vineyards planted after land levelling. *Agricultural Water Management*, 191, 67-76. doi:/10.1016/j.agwat.2017.05.013

Rodeghiero, M., Rubio, A., Díaz-Pinés, E., Romanyà, J., MarañónJiménez, S., Levy, G.J., Fernandez-Getino, A.P., Sebastià, M.T., Karyotis, T., Chiti, T., Sirca, C., Martins, A., Madeira, M., Zhiyanski, M., Gristina, L., & La Mantia, T. (2011). Soil carbon in Mediterranean ecosystems and related management problems. *In: Soil Carbon in Sensitive European Ecosystems*. Ed. by: Jandl, R., Rodeghiero, M., Olsson, M., John Wiley & Sons. Chichester, 175–218. doi:/10.1002/9781119970255.ch8

Schinner, F., Ohlinger R., Kandeler, E., & Margenis, R. (1995). Methods in soil biology, *Springer Verlag*, Berlin, Heidelberg, Newyork, pp:189-191. doi:/10.1007/978-3-642-60966-4

Schulp, C.J. E., & Veldkamp, A. (2008). Long-term landscape–land use interactions as explaining factor for soil organic matter variability in Dutch agricultural landscapes. *Geoderma,* 146, 457-465. doi:/10.1016/j.geoderma.2008.06.016

Slama, M. I., Omar, A. E., Bassiony, S. S., & Ghoneem, G. M. (2019). Effect of compost and natural rocks as partial substitutes for NPK mineral fertilizers on yield and fruit quality of 'Flame'seedless grapevine grown in two different locations of Egypt. *Spanish Journal of Agricultural Research*, 17, 3, 0903. doi:/10.5424/sjar/2019172-14355

Sodhi, G.P.S., Beri, V., & Benbi, D.K. (2009). Soil aggregation and distribution of carbon and nitrogen in different fractions under long-term application of compost in rice-wheat system. *Soil and Soil and Tillage Research, 103, 2, 412-418.* doi:/10.1016/j.still.2008.12.005

Tabatabai, M. A. (1982). Soil enzymes. p. 903-915, 943-947. *In* A. L. Page, R. H. Miller, and D. R. Keeney (Eds.), *Methods of soil analysis, Part 2.* American Society of Agronomy, Madison, Wisconsin. doi:/10.2134/agronmonogr9.2.2ed.c43

Tabatabai, M.A., & Bremner, J.M. (1969). Soil enzymes. *In:* Page, A.L., Miller, R.H., Keeney, D.R. (Eds) *Methods of soil snalysis, Part 2*. Soil Science Society of America, Madison, Wisconsin, pp 903-947. doi:/10.2134/agronmonogr9.2.2ed.c43

Tangolar, S., & Ergenoğlu, F. (1989). Değişik anaçların erkenci bazı üzüm çeşitlerinde yaprakların mineral besin maddesi ve çubukların karbonhidrat içerikleri üzerine etkisi. *Turkish Journal of Agriculture and Forestry*, 13, 3b, 1267-1283.

Tangolar, S., Tangolar, S., & Topcu, S. (2015). Effects of different bud loads and irrigations applied at different leaf water potential levels on Kalecik Karası grape variety. *Turkish Journal of Agriculture and Forestry*, 39, 6, 887-897. doi:/10.3906/tar-1502-39

Tardaguila, J., Storchi, P., Puccioni, S., Zombardo, A., Tangolar, S., Tangolar, S., Ada, M., Kiraz, M.E., Giffard, B., Fulchin, E., Schroers, Pelengić, R., Moreda, E., Fernandez-Novales, J., & Costantini, E.A.C. (2018). Effects of soil degradation and organic treatments on vegetative growth, yield and grape quality. *EQA-International Journal of Environmental Quality,* 30, 31-35.

Thalmann, A. (1968). Zur methodik der bistimmung der dehydrogenase aktivitaet im boden mittels triphenyltetrozoliumchlorid (TTC). *Landwirtsch. Forsch,* 21, 249-258.

Weaver, R. J. (1976). *Grape growing*. A Wiley Inter science Publication, 371 p.

Winkler, A. J., Cook. J. A.. Kliewer. W. M., & Lider, L.A. (1974). *General Viticulture*. University of California Press. Berkeley. 710 p.

Wittling, C., Houot, S., & Barriuso, E. (1995). Soil enzymatic response to addition of municipal solid-waste compost. *Biology and Fertility of Soils*, 20, 4, 226. doi:/10.1007/BF00336082

Zhang, C., Tang, Y., Xu. X., & Kiely, G. (2011). Towards spatial geochemical modelling: Use of geographically weighted regression for mapping soil organic carbon contents in Ireland. *Applied Geochemistry*, 26, 7, 1239-1248.