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RESEARCH ARTICLE

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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

Mohyeldein I. Slama (Slama, MI)[1], Alaa E. K. Omar (Omar, AEK)[1,2], Saber S. Bassiony (Bassiony, SS)[3] and Ghoneem M. Ghoneem (Ghoneem, GM)[3]

[1]*Kafresheikh University, Faculty of Agriculture, Horticulture Dept., Kafr El-Sheikh 33516, Egypt.* [2]*Institute of Research and Consulting, King Fasil University, Kingdom of Saudi Arabia.* [3]*Agricultural Research Center, Horticulture Research Institute, Viticulture Research Dept., Giza, Egypt.*

Abstract

Aim of study: To evaluate the use of compost and natural rocks as partial replacement of mineral fertilizers in 'Flame' seedless grape vineyards.

Area of study: The present work was conducted during three successive seasons (2016, 2017 and 2018), being the first season a preliminary trial on 4-yr old grapes cultivated in two different soil types (sandy and clay) at two different locations, Egypt (Abo Galeb, Giza governorate; EL-Mahala, Gharbia governorate).

Material and methods: Treatments were applied as natural raw materials at 20, 40, 60, 80 and 100% out of recommended mineral NPK rate. The mineral fertilizers used were ammonium sulfate (21.6% N), calcium super phosphate (15.5% P_2O_5) and potassium sulfate (48% K_2O). The natural rocks used were phosphate rock (22.0% P_2O_5) and Feldspar (10.12% K_2O). Yield and fruit characteristics and leaf mineral content were determined.

Main results: Using compost in combination with natural rocks enriched with NPK mobilization bacteria and mineral NPK enhanced leaf nutrients content and gave the highest yield and cluster weight. This mix also improved berries physical and chemical characteristics. There was an increase in soluble solids content (SSC), SSC/acid ratio, and anthocyanin content, associated with a reduction in nitrate content of the berry juice. The most pronounced effect was related to using 60% mineral fertilization + 40% organic and natural rocks in both vineyard locations.

Research highlights: We can reduce the recommended doses of mineral NPK by about 40%, reducing then the soil pollution.

Additional keywords: mineral fertilization; organic fertilizer; phosphate rock; feldspar.

Abbreviations used: DMRT (Duncan's multiple range tests); SSC (soluble solids content); TSS (total soluble solids).

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Correspondence should be addressed to Alaa El-Din K. Omar: alaa.omr@agr.kfs.edu.eg; omaradks2@yahoo.com

Introduction

Grapes are ranked as the second fruit crop after citrus in Egypt. Total area harvested reached 74,873 ha with a total production of 1,716,846 tons according to FAO (http://www.fao.org/faostat/en/#data/QC). 'Flame' seedless grape is considered as one of the most important grape cultivars due to its large clusters and berries, sweet flavor, and early ripening by the end of May under the Egyptian conditions. Several studies were conducted to produce organic fruit through using organic and bio-fertilizers, and gradually reduce the use of mineral fertilizers and artificial growth regulators (Pinamonti, 1998; Morlat, 2008; Calleja-Cervantes *et al.*, 2015).

The intensive use of mineral fertilizers in agriculture results in negative effects on the environment and the composition of fruit and vegetable crops (Bogatyre, 2000). The application of organic materials show some advantages on soil characteristics, such as structure, aeration, moisture content, and pH (Nasser, 1998). Application of organic manure and mineral N improves vegetative growth, leaf mineral content, yield and fruit quality of different grapevine cultivars as compared to the use of mineral N (EL-Rawy, 2007; Mostafa, 2008). Nitrogen fertilization in form of 50% mineral N and 50% organic manure improve yield and cluster characteristics and reduce nitrate content of 'Superior' seedless grapes (Ahmed *et al.*, 2015). Khalil (2012) found that using 75% or 50% of the recommended mineral fertilizers (N, P and K) in combination with 25% or 50% bio-fertilizers (Nitrobeine, Phosphorein and Halex), increased yield, clusters weight, and leaf NPK content of 'Flame' seedless grapes.

Natural rocks such as phosphate rock and feldspar have received a significant attention in recent years, as natural, inexpensive and available fertilizers. Natural rocks are important because they release soluble forms of macro-nutrients like P, K, Ca, and Mg (El-Haggar *et al.*, 2004).

Shaheen *et al.* (2012) found that the application of compost at 11 kg (containing 35 g N), 250 g phosphate rock, and 500 g feldspar/vine of 'Crimson' seedless grapevines tremendously improves fruit soluble solids content (SSC), total acidity, and total sugars content, as compared to vines receiving the recommended doses of mineral NPK fertilizers. In the same context, Hegazi *et al.* (2014) stated that the application of a mixture containing compost, natural rocks, and three bio-fertilizers effectively improved fruit berries chemical characteristics of 'Flame' seedless grapes compared to the sole use of mineral fertilizers or compost.

Shaheen *et al.* (2013) found an improvement in fruit total soluble solids (TSS), acidity, TSS/acid ratio, and total sugars with a reduction in fruit nitrite content in 'Superior' seedless grapevines that received 50% of the recommended NPK mineral fertilizers (157 g N/vine + 87 g P_2O_5/vine + 112 g K_2O/vine) and 50% organic fertilizer (compost) and natural fertilization sources (phosphate rock and feldspar), in addition to bio-fertilizer [Biogen (*Azotobacter chroococcum*) for N, Phosphorien (*Bacillus megaterium*) for P and Potasiumag (*Bacillus circulans*) for K] showed fruit physical characteristics were also improved.

Therefore, in view of the beneficial effects of natural fertilizers, this study was conducted to evaluate the effect of the partial replacement of mineral fertilizers by compost and natural rocks on yield and fruit quality of 'Flame' seedless grapevines grown in two soil types under different environmental conditions.

Material and methods

This study was carried out in Egypt during three successive seasons (2016, 2017 and 2018) on 4 old vigorous and fruitful 'Flame' seedless (*Vitis vinifera* L.) grapevines (planted as stem cuttings) grown in two locations under different weather conditions (Table 1). First location was in Abo Galeb, Giza governorate, where vines were planted in sandy soil at 2 × 3 m in rows. Pruning was carried out in late December to the

Table 1. Weather conditions of clay (El-Mahala) and sandy (Abo Galeb) soil locations during two growing seasons.

Month	Air temperature (ºC)				Relative Humidity (%)		Precipitation (mm/day)		Wind speed (m/s)		Radiative flux (Mj/m²/day)	
	Maximum		Minimum									
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
					Clay soil (El-Mahala)							
Mar	24.2	29.3	10.9	12.1	53.1	44.2	0.25	0.06	2.7	2.4	19.1	20.2
Apr	29.0	31.5	12.5	14.3	49.3	43.4	0.00	0.00	2.8	2.6	21.1	21.7
May	34.8	36.1	17.4	19.2	40.1	40.8	0.00	0.00	3.0	3.1	23.2	24.9
Jun	38.0	37.9	20.3	21.2	40.3	39.7	0.00	0.00	3.0	3.0	24.5	25.0
Jul	40.2	39.1	22.9	22.6	41.9	44.4	0.00	0.00	2.8	2.9	25.9	25.4
Aug	38.7	38.3	23.0	22.9	46.4	48.4	0.00	0.00	2.6	2.7	25.9	25.8
Sep	36.4	36.7	20.4	21.6	49.0	49.6	0.00	0.00	2.6	2.5	24.0	25.2
					Sandy soil (Abo Galeb)							
Mar	27.5	30.5	9.5	10.7	48.8	39.8	0.00	0.00	3.9	3.6	22.7	22.8
Apr	30.2	33.7	11.2	12.9	44.9	39.0	0.00	0.00	4.0	3.8	23.7	24.4
May	36.1	38.3	16.1	17.5	35.8	36.4	0.00	0.00	4.2	4.3	25.8	27.6
Jun	40.1	40.2	19.0	18.8	36.0	35.3	0.00	0.00	4.2	4.2	27.1	27.6
Jul	42.5	41.4	21.5	20.3	37.5	40.0	0.00	0.00	4.0	4.1	28.5	28.0
Aug	41.0	40.6	21.6	20.5	42.0	44.1	0.00	0.00	3.8	3.9	28.5	28.5
Sep	36.7	38.9	19.0	20.3	44.7	45.3	0.00	0.00	3.8	3.7	26.6	27.9

load of 82 buds/vine (12 fruiting canes × 6 buds + 5 spurs × 2 eyes) in a Spanish-paron training system. The second location was in EL-Mahala, Gharbia governorate. The vines were planted in clay soil at 1 × 3 m in rows. Pruning was carried out in early January to the load of 42 buds/ vine (spurs with 2 eyes) in a Gable training system. Drip irrigation system using tow irrigation tubes (right and lift of each vine row) with four droppers (4L/h for each dropper) for each vine in both tested locations. Usual viticulture practices were carried out in both vineyards. Mineral NPK fertilizers were partially replaced by compost as organic fertilizer (mix of plant and animal residuals) and natural rocks (phosphate rock and Feldspar). Soil physical and chemical analyses of both locations are displayed in Table 2, determined according to Wilde *et al.* (1985). Compost and natural rocks (Tables 3 and 4) were analyzed according to Jackson (1973).

The amount of mineral NPK, feldspar, phosphate rock, and organic fertilizers were calculated according to the Egyptian Ministry of Agriculture recommendations for grapes in both locations as showed in Table 5. In this respect, the mineral fertilizers used were ammonium sulfate (21.6% N), calcium super phosphate (15.5% P_2O_5) and potassium sulfate (48% K_2O). The natural rocks used were phosphate rock (22.0% P_2O_5) and Feldspar (10.12% K_2O).

Table 2. Physical and chemical properties of the soils at the experimental sites.

Soil properties	Sandy location	Clay location
Sand (%)	91.4	15.5
Clay (%)	4.7	57.7
Silt (%)	3.9	28.9
Texture	Sandy soil	Clay soil
pH in 1:2.5 suspension	8.2	8.6
Soil organic matter (%)	0.5	2.4
EC (dS/m) 1:5 extraction	1.7	1.4
Available N (mg/kg)	14.2	17.2
Available P (mg/kg)	4.8	3.5
Available K (mg/kg)	74.1	74.1
SAR	2.79	1.46
Soluble Ca^{++} (meq/L)	12.04	11.21
Soluble Mg^{++} (meq/L)	6.18	5.36
Soluble Na^+ (meq/L)	7.80	5.64
Soluble K^+ (meq/L)	1.19	1.82
Soluble CO_3^{2-} (meq/L)	1.44	—
Soluble HCO_3^- (meq/L)	5.73	4.32
Soluble Cl^- (meq/L)	8.55	6.53
Soluble SO_4^{2-} (meq/L)	11.45	13.10

EC = electrical conductivity; SAR = sodium adsorption ratio.

Table 3. Physical and chemical properties of the compost.

Compost properties	Values
Bulk density (kg/m³)	220
Moisture content (%)	18
pH (1:10)	7.2
EC value (1:10) (dS/m)	2.95
Total nitrogen (%)	2.60
NH_4^+ (mg/kg)	303
NO_3^- (mg/kg)	30
Organic matter (%)	55.75
Organic carbon (%)	31.34
Ash (%)	44.20
C/N ratio	1:12.4
P_2O_5 (%)	1.21
K_2O (%)	0.57

The treatments in both sandy and clay soil vineyards were arranged as follows: T1=100% mineral fertilizers (Control); T2=80% mineral fertilizers + 20% natural fertilizers; T3=60% mineral fertilizers + 40% natural fertilizers; T4=40% mineral fertilizers + 60% natural fertilizers; T5=20% mineral fertilizers + 80% natural fertilizers and T6=100% natural fertilizers.

The calculated amounts of mineral fertilizers were divided into three doses and distributed throughout the growth season, as follows: 25% added at bud burst (flowering stage), 50% after fruit set (harvesting stage), and 25% after harvesting stage. The amount of compost and natural rocks (phosphate rock and Feldspar) were added to the soil at 20 cm depth after winter pruning in both locations. Biofertilizer was prepared by the Soils, Water and Environment Dept., Sakha Agriculture Research Station, Kafr El-sheikh, Egypt (containing *Azotobacter chroococcum* for N mobilization, *Bacillus megaterium* for P mobilization, and *Bacillus circulans* for K mobilization with a cell density ~1×10^8 CFU/g of each strain) This bio-fertilizer was mixed with compost and natural rocks, and vines received them as soil application at a rate of 30g/vine. Fifty four vines were

Table 4. Chemical properties of the natural rocks.

Components (%)	Feldspar	Phosphate rock
Loss on ignition	0.07	12.87
SiO_2	68.23	10.60
Al_2O_3	16.25	0.65
Fe_2O_3	0.40	1.35
CaO	0.47	48.63
MgO	0.03	0.33
K_2O	10.12	0.03
Na_2O	3.25	0.18
TiO_2	0.04	0.03
MnO_2	0.02	0.08
P_2O_5	0.02	22.00
SO_3	Nil	0.32

Table 5. Amounts of mineral and natural fertilizers (kg/ha) used in clay and sandy soils during the two study seasons.

Fertilizers (kg/ha)	T1	T2	T3	T4	T5	T6
Clay soil						
$(NH_4)_2SO_4$	663.3	530.7	398.0	265.3	132.7	0.0
P_2O_5	451.7	361.3	271.0	180.7	90.3	0.0
K_2O	453.6	362.9	272.1	181.4	90.7	0.0
Compost	0.0	1100.0	2200.0	3300.0	4400.0	5500.0
Phosphate rock	0.0	56.7	113.3	170.0	226.7	283.3
Feldspar	0.0	463.6	927.1	1390.7	1854.3	2317.0
Sandy soil						
NO_3	774.8	619.8	464.9	309.9	155.0	0.0
P_2O_5	859.5	687.6	515.7	343.8	171.9	0.0
K_2O	507.4	405.9	304.4	203.0	101.5	0.0
Compost	0.0	1282.9	2565.7	3848.6	5131.4	6414.3
Phosphate rock	0.0	117.6	235.2	352.9	470.5	588.1
Feldspar	0.0	518.3	1036.0	1555.0	2073.3	2591.7

used in each vineyard location. All treatments were arranged in randomized complete block design each one replicated three times (6 treatments × 3 replicates × 3 vines) for both locations.

Yield and fruit characteristics and leaf mineral content were determined.

Yield and fruit characteristics

— Total yield. Fruit were harvested at the commercial harvest time (SSC=16-17%). The number of clusters per vine and the average weight of cluster were recorded and the total yield per hectare was calculated (ton/ha).

— Cluster physical characteristics. During harvest, a sample of 6 clusters per each replicate was randomly taken and then cluster lengths as well as the two first shoulders length per cluster were measured (cm).

—Berry physical characteristics. Berry length and diameter (mm) were determined in ten berries/cluster using vernal clipper. Berry firmness and berry shattering force in gram force (gf) were measured in ten berries per cluster using a hand dynamometer apparatus model FDP1000 with a 1 mm thump.

—Berry chemical characteristics. Juice soluble solids content (SSC %) was estimated using a hand refractometer (Atago, Japan) apparatus and titratable acidity (%) was determined as mg of tartaric acid equivalent using NaOH (0.1 N) in 100 mL of berries juice (AOAC, 1995). The SSC/acid ratio was calculated. Total anthocyanine content of berries was determined according to Ranganna (1986) using 50 g as a sample of each replicate that blended with 50 mL of ethanolic HCl solvent (150 mL of 1.5 N HCl + 850 mL of 95% ethanol) for 24 h at 4ºC, and the absorbance was recorded using spectrophotometer (Nebraska, USA) at 535 nm wavelength; then values were expressed as mg/100 g fresh weight. In addition, nitrate and nitrite content in the berry juice (mg/kg) were determined in a sample of fruit extracted with 2% acetic acid, and then measured colorimetrically according to Sen & Donaldson (1978).

Leaf mineral content

Leaf N, P and K content were determined in mature leaves (5-7th leaves from shoot top) using the acid digesting solution method described by Chapman & Pratt (1961). Nitrogen (%) was determined by the modified Microkjeldhal method (AOAC, 1995), P (%) was determined colorimetrically (Murphy & Riley, 1962), and K (%) was estimated using the flame-photometer method (Cottenie *et al.*, 1982).

Statistical analysis

Data were subjected to analysis of variance according to Snedecor & Chocran (1980), and treatment means were compared using DMRT at 5% level according to Duncan (1955).

Results and discussion

Leaf mineral content

Table 6 shows that the combination of compost, natural rocks and mineral fertilizers affects leaf mineral content (NPK) in both locations. The highest significant percentage of N was obtained in vines fertilized with T_1, T_2, T_3 and T_4 in both seasons of sandy soil and first one of clay soil location. However, the highest values of P were detected with vines grown in clay soil that received T_1, T_2 or T_3 treatments. Meanwhile, vines

Table 6. Effect of partial replacement of mineral fertilizers with organic compost and natural rocks on leaf mineral contents of 'Flame seedless' grapevines grown in two soils during 2017 and 2018 seasons.

Treatments	N (%)		P (%)		K (%)	
	2017	2018	2017	2018	2017	2018
Clay soil						
T_1	1.83[a]	1.72[a]	0.45[a]	0.58[a]	1.65[a]	1.54[a]
T_2	1.62[a]	1.55[a]	0.31[a]	0.38[a]	1.42[a]	1.32[a]
T_3	1.68[a]	1.63[a]	0.37[a]	0.42[a]	1.54[a]	1.41[a]
T_4	1.61[a]	1.41[b]	0.31[ab]	0.32[ab]	1.38[b]	1.31[a]
T_5	1.42[ab]	1.23[c]	0.21[b]	0.22[b]	1.24[c]	1.21[b]
T_6	1.21[b]	1.17[d]	0.23[b]	0.24[b]	1.25[c]	1.23[b]
Sandy soil						
T_1	1.75[a]	1.53[a]	0.54[a]	0.59[a]	1.52[a]	1.47[a]
T_2	1.52[a]	1.32[a]	0.30[b]	0.44[b]	1.42[a]	1.30[a]
T_3	1.64[a]	1.44[a]	0.43[a]	0.53[a]	1.48[a]	1.37[a]
T_4	1.56[a]	1.32[a]	0.24[b]	0.41[b]	1.41[a]	1.31[a]
T_5	1.41[b]	1.16[b]	0.26[b]	0.40[b]	1.33[a]	1.25[ab]
T_6	1.32[c]	1.10[b]	0.21[b]	0.32[c]	1.28[b]	1.20[b]

T_1=100% mineral fertilization, T_2=80% mineral fertilization + 20% organic and natural rooks, T_3=60% mineral fertilization + 40% organic and natural rooks, T_4=40% mineral fertilization + 60% organic and natural rooks, T_5=20% mineral fertilization + 80% organic and natural rooks, T_6=100% organic and natural rooks. In a column under each soil type, numbers followed by the same letter had no significant difference at 0.05 levels by DMRT.

treated with T_1 or T_3 showed the highest values in both seasons of sandy soil. Concerning leaf K concentrations, the vines treated with T_1, T_2 or T_3 as well as T_1, T_2, T_3 or T_4 showed the highest values in both seasons, respectively, in the clay soil location. A similar trend was found in sandy soil during both seasons. On the other hand, the lowest leaf N, P and K content were generally showed in vines treated with T_6 under both study locations. These results are in line with the findings of Shaheen *et al.* (2013), who concluded that application of 50% (compost + phosphate rock + feldspar) + 50% of NPK mineral fertilizers + bio-fertilizer showed the best vegetative growth characteristics and leaf mineral content.

Cluster physical characteristics

Table 7 shows that cluster physical characteristics were positively affected by the partial replacement of mineral fertilizers with organic and natural rocks. Cluster number per vine significantly increased in vines treated with T_3 or T_4 in clay soil during both seasons; in vines receiving T_4 or T_5 in the first season and treated with T_2, T_3 or T_4 in the second one significantly increased under sandy soil condition. On the other hand, vines that were completely treated with organic and natural rocks (T_6) produced the lowest number of clusters in both locations and seasons.

Cluster length and the first two shoulders length of cluster increased significantly in vines fertilized with T_3 in comparison with other treatments in both locations. The lowest cluster length was detected in vines treated with T_6 in both locations and seasons. However, the lowest length of the first two shoulders was recorded in vines fertilized with T_5 and T_6 in both locations and seasons, except in the second season of the sandy soil location. The positive effect of partial replacement of mineral NPK with natural rocks and bio-fertilizers might be due to the effect of these materials on soil physical and chemical properties, which is reflected on plant growth and productivity (Ahmed *et al.*, 2012; Abdelaal *et al.*, 2013; Shaaban, 2014). These results are in line with those of Masoud (2012) and Ahmed *et al.* (2015) that showed a remarkable enhancement in the yield and cluster characteristics of 'Superior' seedless grapes using 50% mineral N + 50% manures + 30 mL of a commercial bio-fertilizer named EMas fertilizer program.

Yield and cluster weight

Table 8 shows that 'Flame' seedless grapevines receiving T_3 or T_4 treatments had a significant increase in cluster weight under sandy soil condition in both seasons, whereas the highest cluster weight was recorded with vines receiving T1 and T3 in the first season and T3 in the second one in the clay soil location. The enhancement effect on total yield was more pronounced under the sandy soil condition, where the highest values were detected in vines treated with T_4 in both seasons. As for clay soil, the vines treated with T_2, T_3 or T_4 in 2017 as well as those treated with

Table 7. Effect of partial replacement of mineral fertilizers with organic compost and natural rocks on cluster physical quality characters of 'Flame seedless' grapevines grown in two soil types during 2017 and 2018 seasons.

Treatments	Number of clusters/vine		Cluster length (cm)		The first two shoulders length (cm)	
	2017	**2018**	**2017**	**2018**	**2017**	**2018**
Clay soil						
T_1	31.3^{bc}	26.7^{c}	28.7^{bc}	25.7^{b}	23.7^{b}	22.7^{ab}
T_2	33.0^{ab}	28.0^{c}	30.3^{b}	26.3^{b}	22.0^{bc}	22.7^{ab}
T_3	34.7^{a}	30.3^{b}	33.0^{a}	28.8^{a}	26.0^{a}	24.5^{a}
T_4	33.3^{ab}	38.2^{a}	30.0^{b}	26.3^{b}	21.7^{bc}	20.7^{b}
T_5	31.7^{bc}	24.0^{d}	27.0^{cd}	24.0^{b}	20.0^{c}	17.0^{c}
T_6	29.7^{c}	22.7^{d}	25.3^{d}	21.7^{c}	20.3^{c}	16.8^{c}
Sandy soil						
T_1	30.3^{c}	27.3^{c}	19.8^{b}	20.7^{b}	20.7^{b}	19.3^{b}
T_2	29.3^{c}	33.3^{a}	19.5^{b}	22.5^{b}	20.4^{b}	19.2^{b}
T_3	26.7^{d}	33.4^{a}	21.7^{a}	25.3^{a}	23.8^{a}	21.7^{a}
T_4	38.0^{a}	35.0^{a}	18.8^{b}	22.7^{b}	19.3^{b}	19.2^{b}
T_5	33.0^{a}	30.0^{b}	18.8^{b}	20.5^{b}	16.8^{c}	17.3^{b}
T_6	23.7^{e}	25.3^{d}	16.5^{c}	18.2^{c}	16.8^{c}	17.3^{b}

See treatments T_1 to T_6 in Table 7. In a column under each soil type, numbers followed by the same letter had no significant difference at 0.05 levels by DMRT.

T_3 or T_4 in 2018 showed a significant increase in total yield. On the other hand, the vines that received the recommended dose of T_6 showed the lowest values of both cluster weight and total yield in both locations and seasons. The positive effect of organic and bio-fertilization combined with mineral NPK fertilization on fruit trees were discussed by Dahama (1999) and David (2002). Also, these results are in accordance with those reported by Abdelaziz *et al.* (2014) who stated that the application of mineral N in combination with plant compost enriched with algae was as effective as the use of mineral sources on yield and cluster quality characteristics; however, reducing the mineral N below 50% of recommended doses was associated with a reduction in total yield.

Berries physical characteristics

Table 9 shows that berry characteristics were greatly affected by the partial replacement of mineral fertilizers

Table 8. Effect of partial replacement of mineral fertilizers with organic compost and natural rocks on cluster weight and yield per vine of 'Flame seedless' grapevines grown in two soil types during 2017 and 2018 seasons.

Treatments	Cluster weight (g)		Total yield (ton/ha)	
	2017	**2018**	**2017**	**2018**
Clay soil				
T_1	415.9^{a}	381.9^{c}	21.7^{b}	17.0^{b}
T_2	429.6^{b}	404.2^{b}	23.7^{a}	18.8^{b}
T_3	432.1^{ab}	439.8^{a}	25.0^{a}	22.2^{a}
T_4	441.2^{a}	412.0^{b}	24.5^{a}	21.8^{a}
T_5	355.9^{d}	348.8^{d}	18.8^{c}	14.0^{c}
T_6	324.7^{e}	335.7^{e}	16.0^{d}	12.7^{c}
Sandy soil				
T_1	431.3^{b}	442.8^{b}	17.0^{cd}	20.2^{c}
T_2	434.0^{b}	440.9^{b}	21.2^{b}	24.5^{b}
T_3	482.8^{a}	454.8^{a}	21.5^{b}	25.3^{ab}
T_4	479.1^{a}	452.8^{a}	30.3^{a}	26.5^{a}
T_5	336.6^{c}	414.5^{c}	18.5^{c}	20.7^{c}
T_6	309.6^{d}	380.8^{d}	15.7^{d}	16.2^{d}

See treatments T_1 to T_6 in Table 7. In a column under each soil type, numbers followed by the same letter had no significant difference at 0.05 levels by DMRT.

Table 9. Effect of partial replacement of mineral fertilizers with organic compost and natural rocks on berries length, diameter, firmness and removal force of 'Flame seedless' grapevines grown in two soil types during 2017 and 2018 seasons.

Treatments	Berry length (mm)		Berry diameter (mm)		Berry firmness (gf)		Berry removal force (gf)	
	2017	2018	2017	2018	2017	2018	2017	2018
Clay soil								
T_1	17.6^{bc}	18.5^{a}	17.3^{ab}	17.3^{ab}	194.2^{b}	365.0^{e}	328.5^{d}	420.0^{d}
T_2	18.0^{bc}	18.8^{a}	17.5^{ab}	17.2^{ab}	194.2^{b}	375.0^{d}	400.2^{b}	450.8^{b}
T_3	19.4^{a}	19.4^{a}	18.2^{a}	18.0^{a}	206.7^{a}	421.7^{a}	430.8^{a}	475.8^{a}
T_4	18.5^{ab}	18.4^{a}	17.3^{ab}	17.1^{ab}	193.3^{b}	409.2^{b}	341.7^{c}	452.0^{b}
T_5	17.1^{c}	17.1^{b}	16.3^{b}	16.5^{b}	190.7^{bc}	404.2^{c}	317.5^{e}	440.0^{c}
T_6	17.0^{c}	16.6^{b}	16.8^{b}	16.1^{b}	188.3^{c}	357.5^{f}	315.0^{e}	404.2^{e}
Sandy soil								
T_1	18.1^{a}	17.4^{bc}	17.3^{ab}	17.0^{b}	149.7^{cd}	297.0^{c}	365.0^{c}	379.2^{c}
T_2	18.0^{a}	18.2^{b}	17.1^{ab}	17.7^{b}	160.0^{b}	312.5^{b}	370.8^{b}	385.8^{b}
T_3	18.5^{a}	19.3^{a}	18.0^{a}	18.4^{a}	175.5^{a}	319.2^{a}	388.3^{a}	414.2^{a}
T_4	18.1^{a}	17.7^{bc}	17.3^{ab}	17.8^{ab}	158.3^{b}	294.2^{c}	345.8^{d}	371.7^{d}
T_5	16.1^{b}	17.2^{bc}	16.2^{b}	16.3^{b}	152.7^{c}	285.8^{d}	329.2^{e}	341.7^{e}
T_6	15.8^{b}	16.7^{c}	16.1^{b}	16.2^{b}	146.2^{d}	277.5^{e}	313.3^{f}	330.0^{f}

See treatments T_1 to T_6 in Table 7. In a column under each soil type, numbers followed by the same letter had no significant difference at 0.05 levels by DMRT. gf = gram force

with the natural ones in both locations and seasons. Vines fertilized with T_3 produced the highest significant values of berry diameter, firmness, and removal force in both locations during both seasons. However, berry length data did not show a clear trend under both soil study locations. The lowest values of berry physical characteristics were recorded in vines treated with T_5 and T_6 in both locations and seasons in most cases. The positive effect of combination of compost, biofertilizers, natural rocks and mineral fertilizers may be related to the richness in essential nutrients increasing the availability of soil nutrients and uptake by plant roots, which in turns is reflected on vines nutritional status and total yield (Nijjar, 1985). Similar results were reported by El-Rawy (2007) and Mostafa (2008), who found that application of inorganic N greatly improved the berry quality characteristics of various grapevines cultivars respect to using mineral N fertilizers only. Abd El-Wahab (2011) reported that 'Red Globe' grapevines fertilized with 50% compost and chicken manure combined with the application of 50% mineral N resulted in the highest yield, yield components and physical properties of bunches and berries.

Berries chemical characteristics

Nitrate and nitrite contents

Table 10 shows that berries content of nitrates, nitrites and their total greatly decreased with increasing rates of natural fertilizers. The highest significant values were recorded in berries of vines treated with T_1, followed by those treated with T_2 in both locations and seasons. On the other hand, vines treated with T_3, T_4, T_5 or T_6 showed the lowest values of nitrites with no significant differences among them in both locations during the first season. The lowest values of nitrates were recorded in berries harvested from vines treated with T_6 in the first season as well as T_5 or T_6 in the second one under the clay soil location. The same trend was found in vines treated with T_5 or T_6 in 2017, as well as in those treated with T_4, T_5 or T_6 in 2018, in the sandy soil location. The lowest significant values of total nitrites and nitrates were showed in vines treated with T_5 or T_6 in both locations and seasons in most cases. This effect could be related to the slowly releasing of N from organic fertilizers which make it available for plant uptake for long time (Hallberg & Keeriey, 1993). Similar results were reported by Ahmed *et al.* (2016) on 'Superior' seedless grapes. Abd El-Wahab (2011) reported that the application of compost mixed with chicken manure and 50% of the recommended mineral N fertilizers improved the chemical characteristics of berries and reduced nitrate and nitrite content of 'Red Globe' grapes.

SSC, SSC/acid ratio, acidity and anthocyanine

Table 11 shows that juice SSC was enhanced with the use of natural fertilizers in moderate rates. The vines treated with T_3 resulted in the highest significant percentage of SSC in both locations and seasons. On the other hand, the lowest values were recorded in vines fertilized with T_1 or T_5 in the clay soil vineyard in 2017 and 2018, respectively. However, the differences

Table 10. Effect of partial replacement of mineral fertilizers with organic compost and natural rocks on berries nitrite, nitrate and nitrite plus nitrate content of 'Flame seedless' grapevines grown in two soil types during 2017 and 2018 seasons.

Treatments	Nitrite (mg/kg)		Nitrate (mg/kg)		Nitrate + Nitrite (mg/kg)	
	2017	2018	2017	2018	2017	2018
Clay soil						
T_1	3.7[a]	4.9[a]	16.5[a]	17.2[a]	20.2[a]	22.1[a]
T_2	2.5[b]	3.8[b]	15.2[b]	12.2[b]	17.7[b]	16.0[b]
T_3	1.6[c]	3.1[bc]	14.9[bc]	8.7[c]	16.5[bc]	11.8[c]
T_4	1.7[c]	2.7[cd]	14.4[bcd]	7.0[d]	16.1[bc]	9.7[cd]
T_5	1.6[c]	2.0[de]	13.9[cd]	5.5[e]	15.5[c]	7.5[d]
T_6	1.5[c]	1.7[e]	13.5[d]	5.7[e]	15.0[c]	7.4[d]
Sandy soil						
T_1	2.8[a]	4.6[a]	15.3[a]	15.1[a]	18.1[a]	19.7[a]
T_2	2.2[ab]	3.2[b]	14.2[b]	12.3[b]	16.4[ab]	15.5[b]
T_3	1.5[b]	3.1[b]	13.5[b]	7.1[c]	15.0[bc]	10.2[c]
T_4	1.5[b]	3.0[b]	13.2[b]	5.5[d]	14.7[bc]	8.5[c]
T_5	1.2[b]	2.3[c]	12.1[c]	5.0[d]	13.3[c]	7.3[c]
T_6	1.2[b]	2.2[c]	11.7[c]	4.5[d]	12.9[c]	6.7[c]

See treatments T_1 to T_6 in Table 7. In a column under each soil type, numbers followed by the same letter had no significant difference at 0.05 levels by DMRT.

among treatments were not significant in most cases in sandy soil during both seasons.

Data of juice acidity generally showed a reduction trend with increasing natural fertilizers as compared with application of 100% mineral fertilizers. The highest values were noticed with vines that received T_1 in clay soil location during both seasons. The lowest significant values of acidity were noticed with T_5 or T_4 in clay soil in 2017 and 2018, respectively. Regarding sandy soil vineyard, the lowest acidity percentage was recorded with vines treated with T_3 and T_4 in the second season only.

The highest SSC/acid ratio was recorded in vines treated with T_5 and with T_3 & T_4 in 2017 and 2018, respectively; meanwhile the lowest ratio was found in vines that received T_1 in clay soil in both seasons. Concerning the sandy soil, the highest values were recorded in vines treated with T_3 or T_4 in both seasons. Berries anthocyanine content showed the highest significant values in 'Flame' seedless grapevines fer-

Table 11. Effect of partial replacement of mineral fertilizers with organic compost and natural rocks on berries SSC, acidity, SSC/acid ratio and anthocyanine content of 'Flame seedless' grapevines grown in two soil types during 2017 and 18 seasons.

Treatments	SSC (%)		Acidity (%)		SSC/Acid ratio		Anthocyanine (mg/g FW)	
	2017	2018	2017	2018	2017	2018	2017	2018
Clay soil								
T_1	16.2[b]	17.2[ab]	0.66[a]		24.6[f]	26.1[d]	0.41[a]	0.42[c]
T_2	16.8[ab]	17.4[ab]	0.61[ab]		27.5[e]	28.8[c]	0.43[a]	0.53[a]
T_3	18.2[a]	18.3[a]	0.51[bc]		35.6[b]	34.5[a]	0.48[a]	0.51[ab]
T_4	17.4[ab]	17.9[ab]	0.52[bc]		33.5[c]	35.0[a]	0.47[a]	0.44[bc]
T_5	17.4[ab]	17.1[b]	0.47[c]		37.0[a]	33.1[b]	0.47[a]	0.29[d]
T_6	16.8[ab]	17.7[ab]	0.54[bc]		31.1[d]	32.2[b]	0.45[a]	0.24[d]
Sandy soil								
T_1	16.5[b]	16.3[b]	0.68[a]	0.67[a]	24.2[c]	24.4[c]	0.44[a]	0.33[ab]
T_2	17.2[ab]	16.4[b]	0.66[a]	0.68[a]	26.1[b]	24.2[c]	0.45[a]	0.37[a]
T_3	18.1[a]	17.7[a]	0.61[a]	0.47[b]	29.7[a]	37.6[a]	0.49[a]	0.40[a]
T_4	17.2[ab]	16.9[ab]	0.60[a]	0.45[b]	28.6[a]	37.7[a]	0.42[a]	0.32[abc]
T_5	16.0[b]	16.2[b]	0.62[a]	0.58[a]	25.8[b]	27.9[b]	0.40[a]	0.26[bc]
T_6	16.4[b]	16.2[b]	0.61[a]	0.64[a]	26.9[b]	25.5[c]	0.40[a]	0.24[c]

See treatments T_1 to T_6 in Table 7. FW = fresh weight. In a column under each soil type, numbers followed by the same letter had no significant difference at 0.05 levels by DMRT.

tilized with T_2 under clay soil condition as well as T_2 and T_3 in sandy soil vineyard in the second season of both locations. These effects may be due to the richness of natural fertilizers in macro and microelements, which enhance plant photosynthesis and led to more available sugars that can be used for growth and fruit ripening (Belal, 2006). Similar results were reported by Abd El-Wahab (2011) on 'Red Globe' grapes. Masoud (2012) concluded that the use of bio-fertilizers or organic manure, or even the combined mixture, greatly improved total soluble solids and anthocyanine content of 'Flame' seedless and 'Ruby' seedless grapes in comparison to using mineral N fertilization only.

It can be concluded that the application of 60% mineral NPK + 40% organic fertilizers and natural rocks effectively enhanced the nutritional status of 'Flame' seedless grapevines and gave the optimum yield and fruit quality. Using natural fertilization reduced nitrate and nitrite content of the berries. This mixture can also reduce the use of mineral fertilizers by about 40%, reducing then soil and environmental pollution.

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