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Reducing the amount of mineral phosphorus and potassium fertilizers by using its natural sources for Red Globe grapevines

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Abstract

This investigation was conducted during three successive seasons of 2016, 2017 and 2018 in a private vineyard located at Samaloute district, Minia Governorate, Egypt on Red Globe grapevines to study the possibility of reducing the amount of mineral phosphorus and potassium fertilizers by using natural rocks, combined with organic manure (FYM), bio-fertilizers (BF) and elemental sulphur (S). The chosen vines were nine years old, grown in a clay loam soil, spaced at 1.75 x 3 m apart, irrigated under surface irrigation system, and spur-pruned, trellised by Gable supporting system and trained to quadrilateral cordon system. The results revealed the possibility of using 50 % natural rocks of P and K + FYM + BF + S as a partial substitute of mineral phosphorus and potassium fertilizers. Application of 50 % mineral P and K + 50 % natural rocks of P and K + FYM + BF + S exhibited the most suitable management combination for achieving the best yield with its components, physical properties of clusters, improved physical and chemical berry characteristics, vegetative growth, leaf chlorophyll and mineral content of Red Globe grapevines. The treatment also improved the soil properties.

Key words: Grape, Red Globe, mineral P and K, natural P and K, farmyard manure, bio-fertilizers and elemental sulphur.

Introduction

In Egypt, after citrus, grape (*Vitis vinifera* L.) is the most popular and favorite fruit crop. It has an excellent flavor, nice taste and being rich in sugars, vitamins, minerals and has high nutritional value. In the last two decades, the fruiting area of grape increased to about 82770 ha with total production of 1686706 tons (Ministry of Agriculture, 2016).

Fertilization is the most important management factor responsible for increased grape production. Added adequate phosphorus and potassium fertilizers are important for grape growth as appropriate amount of chemical P and K is required to increase their levels in soil for economic production. However, the use of high amounts of both fertilizers increases the production costs. The natural rock P and K may be a good alternative to costly P and K fertilizers (El- Sheref., 2012). The promotive effect of using natural rocks on enhanced grape productivity is reported by many investigators such as Hegazi *et al.* (2014) and Belal *et al.* (2017).

Farmyard manure can play an important role for sustaining the crops productivity by their high content of nutrients and through improving soil physical properties, consequently enhancing the efficiency of applied nutrients (Reddy and Aruna, 2008). Bokhtiar and Sakurai (2005) mentioned that the organic manure decomposition produce organic acids, which has a promotive effect on solubility of natural rocks, hence increasing available P and K from the applied rock P and K. Many workers stated that organic manure application also significantly stimulated growth characters, physical and chemical parameters of the berries (Abd El-Wahab, 2011; Abd El-Aziz *et al.,* 2014; Ozdemir, 2018).

Bio-fertilizers are microorganisms that improve the availability of nutrients in soil and plant and considered as promising alternative for chemical fertilizers being safe for human, animals and environment (Mostafa, 2008) Bacteria, fungi and cynobacteria are the main source of bio-fertilizers. The beneficial effect of bio-fertilizers are mainly due to reduced plant requirement of NPK by about 25 %, increased plant resistance to diseases, stimulated root growth and enhanced fruit tree productive performance (El-Akkad, 2004). El-Sayed (2002) reported that inoculation with bio-fertilizers improved cluster weight, number of cluster/vine and yield of grapevines. Phosphorine or potassine are bio-fertilizers which contain phosphate, or silicate dissolving bacteria, respectively and increase solubility of the insoluble P and K. The beneficial effects of these bio-fertilizers are mainly due to its role in cycling of minerals tied up in organic matter and excretion of organic acid which dissolve P and K into solution (Eweda *et al.*, 2007).

Recently, elemental sulphur was used to improve soil reaction, where it is oxidized by soil micro-organisms to sulphate, consequently decreasing soil pH and increasing nutrients solubility (Hilal *et al.*, 1990). Many workers stated that sulphur application increased growth and yield of Thompson Seedless grapevines (Zayan *et al.*, 2006). In addition, combined application of elemental sulphur with natural P and K rocks can improve the solubility of both P and K due to sulphuric acid produced by sulphur-oxidizing bacteria (Schofield *et al.*, 1981; Brahim *et al.*, 2017).

The present investigation was conducted to evaluate the possibility of reducing dose of chemical phosphorus and potassium fertilizers by using its natural rocks combined with organic manure, bio-fertilizers and elemental sulphur on Red Globe grapevines.

Materials and methods

This study was conducted during three successive seasons of 2016, 2017 and 2018 in a private vineyard located at Samaloute district, Minia Governorate, Egypt on Red Globe grapevines to study the possibility of reducing the amount of mineral phosphorus and potassium fertilizers by using its natural rocks in combination with organic manure, bio-fertilizers and elemental sulphur. The chosen vines were nine years old, grown in a clay loam soil, spaced 1.75 x 3 m apart, irrigated under surface irrigation system, and spur-pruned and trellised by Gable supporting system and trained to quadrilateral cordon system. For each experimental season, the pruning was done in last week of January, and 60 buds were left on each vine (30 fruiting spurs with two buds per spur). Each treatment was replicated 5 times, 3 vines per replication.

Surface soil sample (0-30 cm) was taken before beginning of the first season to determine some soil properties according to AOAC, (1995) and listed in Table 1. The normal agricultural practices for Red Globe vineyards in district were done, except those concerned with phosphorus, potassium, sulphur, organic manure and bio-fertilization. Chemical properties of rock P and rock K are listed in Table 2 according the data received by Alharam Company.

Table 1. Physical and chemical properties of the experimental soil before the beginning of experiment

Soil properties	Values
Particle size distribution	
Clay (%)	42.83
Silt (%)	31.66
Sand (%)	25.51
Texture grade	Clay
pH (in 1:2.5 soil water suspension)	8.03
EC, dSm^{-1} (in soil paste)	1.13
Soil organic matter (%)	1.36
Total carbonate (%)	1.65
Soil available N ($\mu g\ g^{-1}$)	22.3
Soil available P ($\mu g\ g^{-1}$)	10.2
Soil available K ($\mu g\ g^{-1}$)	176.1

Table 2. Chemical properties of the natural rocks used in three seasons

Oxides	Rock phosphate	Rock potassium
SiO_2 (%)	6.85	70.65
Al_2O_3 (%)	0.76	17.89
Fe_2O_3 (%)	4.17	0.14
MgO (%)	2.05	0.01
CaO (%)	41.05	0.58
K_2O (%)	0.20	10.30
SO_3 (%)	4.00	0.37
P_2O_5 (%)	13.00	0.38

The farmyard manure was received from Sids Research Station belonging to Animal Production Research Institute (APRI), ARC, Egypt. Whereas, rock phosphate, feldspar and elemental sulphur were procured from Al-Ahram Mining Company, Giza, Egypt. The bio-fertilizers, namely phosphorine (*Bacillus megaterium*) and potassiumag (*Bacillus circulans*) were procured from the Department of Microbiology, Soil, Water and Environment Institute, ARC, Egypt. Chemical properties of the used FYM were determined according the method described by AOAC (1995) and presented in Table 3.

Six treatments were arranged in a randomized complete block design in five replications, 3 vines per each, and the experimental treatments were applied as follows:

Table 3. Chemical properties of the used farmyard manure

Parameter	2016	2017	2018
Total nitrogen (%)	1.42	1.46	1.44
Total phosphorus (%)	0.31	0.29	0.34
Total potassium (%)	1.05	1.11	1.07
Organic matter (%)	45.22	47.31	46.35
Organic carbon (%)	26.23	27.44	26.88
C/N ratio	1:18	1:19	1:19
pH (1: 10 soil water suspension)	7.82	7.90	7.75
EC, dSm^{-1} (1:10 soil water extraction)	4.75	4.83	4.91

T1- 100 % mineral form of both phosphorus and potassium (control).
T2- 50 % mineral form of both P and K + 50 % natural rocks of P and K.
T3- 50 % mineral form of both P and K + 50 % natural rocks of P and K + farmyard manure (FYM).
T4- 50 % mineral form of both P and K + 50 % natural rocks of P and K + bio-fertilizers (BF).
T5- 50 % mineral form of both P and K + 50 % natural rocks of P and K + sulphur (S).
T6- 50 % mineral form of both P and K + 50 % natural rocks of P and K + FYM + BF + S.

Superphosphate 15.5 % P_2O_5 was added as a source of mineral phosphorus fertilization, potassium sulphate 49 % K_2O was added as a source of mineral potassium fertilization, rock phosphate 13 % P_2O_5 was added as a source of phosphorus fertilization and rock potassium (feldspar) 10.3 % K_2O was added as a source of potassium fertilization

Farmyard manure, bio-fertilizers and sulphur were mixed with natural rock fertilizers and added in soil in the second week of January of each season. During three seasons, the following parameters were determined to study the effects of different fertilization treatments on vegetative growth, clusters, berry, yield characteristics and soil properties. Among vegetative growth parameters, data on shoots length (cm) and numbers of leaves/shoot were recorded.

Leaf area (cm^2): It was measured in leaves samples taken randomly from each treatment by using leaf area meter, Model Cl. 203, USA.

Average cane thickness (cm): The parameter was determined in the five basal internodes of ten canes per vine just before winter pruning by using a vernier caliper.

Yield and physical characteristics of clusters and berries: Yield /vine was calculated by multiplying number of cluster/vine by cluster weight and expressed in kg. Average cluster weight (g) and average of number of cluster/vine, average berry weight (g), average berry length and diameter (cm) were calculated as per standard procedures.

Chemical constituents of berries

T.S.S.: Total soluble solids (%) were determined in juice by hand refractmeter (AOAC, 1995).

Acidity: Titratable acidity (as gram tartaric acid/100 mL juice) was estimated by titration against NaOH (AOAC, 1995). Total phenolic (mg/100 g fresh weight) was determined in berry juice by the method of Ranganna (1979).

Chemical constituents of grape leaves and canes

Chemical content: N, P and K percentage in petiole samples of leaves at opposite clusters at flowering stage were determined as per AOAC (1995).

Total chlorophyll: It was measured in mature 6th and 7th apical leaves of the shoots according to Mackinny (1941). Total carbohydrates of cane were determined according to the methods of Du-Bois *et al.* (1956).

Experimental design and statistical analysis: The randomized complete block design was adopted. The statistical analysis of the data was carried out according to Snedecor and Cochran (1980). Averages were compared using L.S.D. values at 5 % level (Steel and Torrie., 1980).

Results and discussion

Vegetative growth characteristics: The data in Table 4 clearly show that application with 50 % mineral P and K + 50 % natural rocks of P and K + FYM + BF + S produced highest leaf area, shoot length, cane thickness and number of leaves /shoot, which was at par with100 % mineral phosphorus and potassium (control). Moreover, the combined 50 % natural rocks with farmyard manure or bio-fertilizers with elemental sulphur significantly improved the vegetative growth parameters when compared with 50 % natural rocks only. It could be noticed that the effect of farmyard manure when combined with 50 % natural rocks exceeded the effect of bio-fertilizer and elemental sulphur. The beneficial effect of minerals or natural rocks P and K is mainly due to the nutrients considered as the most important macroelements needed for many metabolic processes. The enhancing effect of farmyard manure on improving the natural rock is mainly due to organic acids and chelating agents released during organic manure decomposition which consequently help in solubilizing P and K from rocks (Badr, 2006). Whereas, the promotive effect of bio-fertilizers may be due to its effect on solubilizing phosphorus and potassium from its natural rocks, production of growth promoting materials or organic acids and improving nutrient uptake (Samah, 2002). On the other hand, the positive effect of sulphur is mainly attributed to raising the oxidation rate of added sulphur resulting in improving soil properties and increasing the releasing of P and K from rocks as well as increasing other nutrients availability (Das *et al.*, 2016). These results are similar to those obtained by Mohamed (2008) for the effect of mineral and natural P and K rocks, Abd El-Wahab (2011) for organic manure and El-Sabagh *et al.* (2011) for bio-fertilizers.

Yield and physical characteristics of clusters and berries: Data in Table 5 reveal that the highest values of yield and cluster weight, number of cluster/vine as well as berry weight, berry length, berry width in the three studied seasons were obtained from vines supplied with 100 % mineral phosphorus and potassium (control) or application with 50 % mineral P and K + 50 % natural rocks of P and K + FYM + BF + S. Whereas, application with 50 % mineral P and K + 50 % natural rocks of P and K exhibited the lowest ones. In addition, combined farmyard manure, bio-fertilizer or elemental sulphur with 50 % from minerals plus natural P and K improved all berry and cluster characteristics and yield of Red Globe when compared with those which received 50 % from natural P and K rocks. It is worthy to observe that the positive effect of farmyard manure exceeded the effect of bio-fertilizer or elemental sulphur. The beneficial effect of mixed farmyard manure, bio-fertilizers and sulphur with minerals and natural rocks P and K fertilizers could be explained by its effect on vegetative growth of vine as discussed before (Table 4). These results are in line with those obtained by Mostafa (2008), Abd El-Aziz *et al.* (2014) and Hegazy *et al.* (2014).

Table 4. Effect of different treatments on some vegetative growth parameters

Treatments	Leaf area (cm^2)			Shoot length (cm)			Cane thickness (cm)			No. of leaves/ shoot		
	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
T1	129.4	133.8	134.9	181.3	184.5	185.1	1.17	1.19	1.23	30.70	31.30	31.70
T2	116.6	120.9	122.1	156.7	159.6	160.3	0.97	0.98	1.07	22.60	22.90	23.30
T3	123.3	127.5	129.7	166.1	168.4	170.4	1.08	1.09	1.18	26.20	27.00	27.40
T4	120.0	123.9	125.2	161.7	165.1	166.9	1.04	1.06	1.16	24.70	25.10	25.50
T5	118.3	120.2	121.9	159.8	162.8	164.5	1.01	1.03	1.11	23.40	23.90	24.20
T6	129.2	133.5	134.6	180.8	184.2	185.0	1.16	1.19	1.22	30.06	31.30	31.60
L.S.D at 0.05	1.35	1.37	1.37	1.45	1.46	1.48	0.13	0.13	0.15	0.87	0.89	0.89

T1:100 % mineral phosphorus and potassium (control), T2: 50 % mineral P and K + 50 % natural rocks of P and K, T3: 50 % mineral P and K + 50 % natural rocks of P and K + farmyard manure (FYM), T4: 50 % mineral P and K + 50 % natural rocks of P and K + bio-fertilizers (BF), T5: 50 % mineral P and K + 50 % natural rocks of P and K + sulphur (S), T6: 50 % mineral P and K + 50 % natural rocks of P and K + FYM + BF + S

Table 5. Effect of different treatments on yield, and cluster and berry characteristics

Treatments	Yield/vine (kg)			No. of cluster/vine			Cluster weight (g)			Berry weight (g)			Berry length (cm)			Berry diameter (cm)		
	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
T1	16.69	18.94	19.07	20.7	20.9	21.0	903	906	908	11.05	11.14	11.27	2.89	2.92	2.95	2.85	2.87	2.90
T2	15.48	15.60	15.82	19.8	19.9	20.1	782	784	787	9.12	9.25	9.54	2.73	2.78	2.40	2.66	2.69	2.72
T3	16.24	16.48	16.70	20.5	20.7	20.9	792	796	799	9.62	9.74	9.86	2.81	2.83	2.86	2.76	2.79	2.82
T4	16.02	16.22	16.40	20.3	20.5	20.6	789	791	796	9.58	9.70	9.81	2.79	2.81	2.84	2.72	2.75	2.77
T5	15.70	15.90	16.04	20.0	20.2	20.3	785	787	790	9.36	9.48	9.62	2.77	2.79	2.81	2.69	2.71	2.74
T6	18.56	18.91	19.14	20.6	20.9	21.1	901	905	907	11.01	11.12	11.24	2.88	2.93	2.94	2.83	2.86	2.91
L.S.D at 0.05	0.22	0.31	0.25	N.S.	0.42	0.42	4.16	4.18	4.22	0.34	0.35	0.36	0.26	0.27	0.30	0.19	0.21	0.24

T1:100 % mineral phosphorus and potassium (control), T2: 50 % mineral P and K + 50 % natural rocks of P and K, T3: 50 % mineral P and K + 50 % natural rocks of P and K + farmyard manure (FYM), T4: 50 % mineral P and K + 50 % natural rocks of P and K + bio-fertilizers (BF), T5: 50 % mineral P and K + 50 % natural rocks of P and K + sulphur (S), T6: 50 % mineral P and K + 50 % natural rocks of P and K + FYM + BF + S

Chemical constituents of berries: Data in Table 6 show that total soluble solids, total acidity, total soluble solids/ total acidity and total phenolic were significantly affected by the studied treatments. Vines supplied with 100 % mineral phosphorus and potassium (control) or application with 50 % mineral P and K + 50 % natural rocks of P and K + FYM + BF + S exhibited the highest values of T.S.S, T.S.S/total acidity and total phenolic and produced the lowest values of total acidity. 50 % mineral P and K+ 50 % natural rocks P and K recorded the lowest T.S.S., T.S.S./total acidity and total phenolic, and highest total acidity. Nevertheless, the promotive effect of combined farmyard manure with 50 % mineral P and K+ 50 % natural rocks P and K was more pronounced on increasing T.S.S, T.S.S/ acidity and total phenolic as well as reducing total acidity than bio-fertilizers and elemental sulphur.

These results may be attributed to organic manure which contains considerable amount of macro and micro nutrients (Mohamed, 2008), consequently improving the photosynthesis process, which means more nutrients are available for growth and fruit quality development. Also, organic manure improved total carbohydrates and plant pigments (Table 7) in turn reflected on advancing berries quality and ripeness. These results are similar to those obtained by Belal *et al.* (2017). Moreover, Zhang *et al.* (2014) and Ozdemir (2018) mentioned that organic manure application significantly increased total phenolic of grape berry. As for P and K, Khalil *et al.* (2018) reported that P enhanced sugar accumulation in berries, hence induced higher T.S.S. Also, K fertilization helps in translocation of sugar into berries. They added that this increment of T.S.S. may be due to the improving the hydrolysis of polysaccharides into monosaccharides. These findings are in line with those obtained by Abd El-Razek *et al.* (2011). The negative effect of the studied treatments on total acidity could be explained by the conversion of acids into sugar (Dhillon *et al.*, 1992). These results agree with those obtained by Hegazi *et al.* (2014). Concerning the effect of bio-fertilizer and sulphur, El-Shenawy and Fayed (2005) indicated that bio-fertilizers may enhance berry quality by increasing exchangeable K, Ca and Mg, consequently reducing acidity by the formation of insoluble potassium tartarate. Similarly, elemental sulphur improves berry quality.

Chemical constituents of grape leaves and canes: The statistical analysis of the results presented in Table 7 clearly show that farmyard manure, bio-fertilizers or sulphur when individually added with 50 % mineral P and K + 50 % natural rocks P and K or combined with others had a positive effect of N, P and K on the leaf petioles when compared with 100 % mineral P and K or 50 % mineral P and K+ 50 % natural rocks P and K.

The promotive effect of farmyard manure on N, P and K content may be due to farmyard manure application resulting increased soil organic matter, which consequently improved soil water holding capacity and solubility of nutrients (Reddy and Aruna, 2008). In addition, farmyard manure produces humate salts, which may adsorb nutrients in available form for absorption by the plant (Cook, 1982). These results are similar to those obtained by Abd El-Wahab (2011) and Belal *et al.* (2017). The beneficial effect of bio-fertilizers or elemental sulphur on N, P and K content may be due to their effect on increasing the availability of nutrients by enhancing soil reaction (Zayan *et al.,* 2006). These results are in accordance with those obtained by Mostafa (2008). As for natural rocks, the data indicated that P and K content were positively affected by minerals and/or natural rocks P and K, while N content was not affected. The effectiveness of natural rocks was more pronounced when combined with organic manure, bio-fertilizer and elemental sulphur. The beneficial effect of mineral and /or natural rocks on P and K content in vine petioles is mainly due to release of soluble P and K elements in soil (Mohamed, 2008).These results are similar to those obtained by Hegazi *et al.* (2014) and Belal *et al.* (2017).

With respect to total chlorophyll in leaves and total carbohydrates in vine cane, the data in Table 7 revealed that these two constituents were significantly affected by the studied treatments. The highest values of total chlorophyll and carbohydrates were recorded under 100 % mineral P and K or 50 % mineral P and K + 50 % natural rocks P and K + farmyard manure + bio-fertilizers + elemental sulphur. As the single application, it is worthy to notice that, farmyard manure and elemental sulphur exhibited the highest effect on total chlorophyll or total carbohydrates. On the other hand, 50 % mineral P and K + 50 % natural rock P and K recorded the lowest value. The positive effect of mineral (P + K) + natural rocks P and K and organic manure or elemental sulphur on increasing total chlorophyll and total carbohydrates may be attributed to more nutrient uptake such as N, Mg, K, P and Fe, involved in chlorophyll formation which consequently improve the photosynthesis process and carbohydrate content (Mohamed, 2008; Belal *et al.,* 2017).

Soil properties: The data in Table 8 represent the response of some soil properties after harvest under different treatments. It is evident from the data that soil reaction, salinity and organic matter and available N were significantly affected by farmyard manure, whether combined with other treatments or applied alone.

Table 6. Effect of different treatments on some chemical constituents of berries

Treatments	T.S.S (%)			Acidity (%)			T.S.S/ acid ratio			Total phenolic (mg/g, F.W)		
	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
T1	16.8	16.9	17.4	0.53	0.53	0.51	31.7	31.8	34.1	0.93	0.94	0.95
T2	15.9	15.9	16.5	0.61	0.60	0.60	26.1	26.5	27.5	0.69	0.68	0.69
T3	16.4	16.5	16.9	0.56	0.56	0.55	29.3	29.5	30.7	0.82	0.83	0.83
T4	16.3	16.4	16.7	0.58	0.59	0.57	22.1	27.8	29.3	0.76	0.75	0.77
T5	16.2	16.2	16.4	0.60	0.60	0.59	27.0	27.0	27.7	0.72	0.72	0.73
T6	16.8	16.8	17.4	0.54	0.53	0.51	31.1	31.7	34.1	0.92	0.93	0.93
L.S.D at 0.05	0.14	0.15	0.15	0.04	0.04	0.03	0.26	0.26	0.27	0.03	0.03	0.04

T1:100 % mineral phosphorus and potassium (control), T2: 50 % mineral P and K + 50 % natural rocks of P and K, T3: 50 % mineral P and K + 50 % natural rocks of P and K + farmyard manure (FYM), T4: 50 % mineral P and K + 50 % natural rocks of P and K + bio-fertilizers (BF), T5: 50 % mineral P and K + 50 % natural rocks of P and K + sulphur (S), T6: 50 % mineral P and K + 50 % natural rocks of P and K + FYM + BF + S

Farmyard manure application improved soil pH, soil organic matter and soil available nitrogen and increased soil salinity in the three seasons. The positive effect of farmyard manure on decreasing soil pH is mainly due to the acidifying effect of organic acids produced during the continuous decomposition of organic manure (Hizal, 1993). Increased soil organic matter and soil available N, P and K as a result of farmyard manure may be due to farmyard manure containing high amount of organic matter and total N, P and K (Table 3). Unfortunately, farmyard manure application increased soil salinity mainly due to the high salinity content of used farmyard manure as shown in Table 2 (Sayed, 2009). Similar results were reported by Ibrahim and Abd El-Hafeez (2017) for soil pH, Wong *et al.* (1999) and Abd El-Lattif (2012) for soil organic matter, Sarhan and Abd El-Gayed (2017) for soil salinity and soil available N, P and K.

The data also revealed that bio-fertilizers had positive effect only on soil available P and K when combined with 50 % mineral P and K + 50 % natural rocks P and K than 50 % mineral (P + K) + 50 % natural rocks P and K only. Benmett *et al.* (1998) mentioned that bio-fertilizers improved the solubility of P and K from the natural rocks through production and release of organic acids. These results are in harmony with those obtained by Verma *et al.* (2016). Elemental sulphur improved soil pH as well as soil available P and K which could be attributed to soil reaction (Garcia, 1992) . These results are in agreement with those obtained by Skwierawska *et al.* (2008).

Data on the effect of natural rocks clearly show that mineral P and K fertilizers affected only soil available P and K when compared with natural rocks. The relative increase in soil available P and K due to100 % mineral P and K reached to 38.9 and 24.1 % over 50 % mineral P and K + 50 % natural P and K rocks. It is obvious to notice that added 50 % mineral P and K + 50 % natural P and K rocks increased soil available P and K when compared to its native content in soil before beginning of the experiment (10.2 and 176.1 µg g^{-1}, Table 1). These finding may be due to the fact that mineral or natural rocks are considered as a source of P and K during its mineralization in soil (Goda *et al.,* 2011). Similar results were obtained by El-Sheref (2012). In addition mixed 50 % mineral P and K + 50 % natural rocks + farmyard manure + bio-fertilizers + elemental sulphur exhibited soil P and K content in soil after grapevine harvest was at par with 100 % mineral P and K. In general, the effect of farmyard manure, elemental sulphur or mineral and natural rocks increased with the seasons, mainly due to its residual affect resulted from the addition every season.

From this study, it could be concluded that application of 50 % mineral P and K + 50 % natural rocks of P and K + FYM + BF + S exhibited the best management system for achieving the higher yield with its components as well as the better physical properties of clusters, improving the physical and chemical characteristics of berries, vegetative growth, leaf chlorophyll and mineral content of Red Globe grapevines as well as improving soil properties.

Table 7. Effect of different treatments on some chemical constituents of leaves and canes

Treatments	Petiole nutrient content (%)									Total chlorophyll In leaves (mg/100 g. fw)			Total carbohydrates In canes (g/100 g)		
	N			P			K								
	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
T1	1.78	1.79	1.80	0.21	0.23	0.23	1.30	1.32	1.34	2.99	3.12	3.16	29.93	29.99	30.32
T2	1.62	1.63	1.62	0.12	0.14	0.16	1.15	1.16	1.18	2.73	2.78	2.80	25.10	25.18	26.11
T3	1.75	1.77	1.79	0.17	0.19	0.20	1.24	1.25	1.26	2.91	2.94	2.97	28.84	28.91	29.25
T4	1.72	1.73	1.72	0.15	0.17	0.18	1.21	1.22	1.24	2.85	2.88	2.90	26.38	26.41	26.83
T5	1.71	1.72	1.72	0.16	0.16	0.17	1.20	1.20	1.22	2.83	2.86	2.89	28.18	28.22	29.37
T6	1.79	1.80	1.82	0.22	0.24	0.23	1.30	1.31	1.33	2.98	3.11	3.16	29.91	29.96	30.30
LSD (P=0.05)	0.10	0.11	0.11	0.06	0.06	0.07	0.12	0.12	0.13	0.16	0.17	0.17	1.27	1.30	1.30

T1:100 % mineral phosphorus and potassium (control), T2: 50 % mineral P and K + 50 % natural rocks of P and K, T3: 50 % mineral P and K + 50 % natural rocks of P and K + farmyard manure (FYM), T4: 50 % mineral P and K + 50 % natural rocks of P and K + bio-fertilizers (BF), T5: 50 % mineral P and K + 50 % natural rocks of P and K + sulphur (S), T6: 50 % mineral P and K + 50 % natural rocks of P and K + FYM + BF + S

Table 8. Soil properties after harvest as affected by the different treatments

Treatments	pH			EC			Soil organic matter (%)			Soil available N (µg g^{-1})			Soil available P (µg g^{-1})			Soil available K (µg g^{-1})		
	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
T1	8.07	8.06	8.07	1.13	1.13	1.12	1.36	1.35	1.35	22.4	22.2	22.3	17.5	20.5	23.6	210.3	220.6	231.5
T2	8.07	8.07	8.06	1.13	1.14	1.13	1.35	1.36	1.36	22.3	22.3	22.3	12.6	13.7	14.4	190.6	199.6	211.6
T3	8.00	7.95	7.91	1.18	1.24	1.31	1.42	1.51	1.59	26.1	29.3	32.4	14.3	15.6	16.7	199.2	210.3	220.4
T4	8.07	8.06	8.07	1.12	1.13	1.14	1.36	1.35	1.35	22.4	22.3	22.3	13.3	14.6	15.3	194.6	205.6	216.7
T5	8.03	7.96	7.91	1.13	1.12	1.13	1.35	1.36	1.35	22.4	22.3	22.3	13.9	14.8	15.6	196.2	207.4	219.7
T6	7.98	7.93	7.90	1.19	1.25	1.31	1.43	1.51	1.60	26.1	29.4	32.5	17.3	20.3	23.3	210.1	219.8	230.2
L.S.D at 0.05	0.02	0.02	0.01	0.02	0.03	0.03	0.05	0.04	0.04	0.75	0.81	0.87	0.27	0.29	0.28	5.13	5.25	6.27

T1:100 % mineral phosphorus and potassium (control), T2: 50 % mineral P and K + 50 % natural rocks of P and K, T3: 50 % mineral P and K + 50 % natural rocks of P and K + farmyard manure (FYM), T4: 50 % mineral P and K + 50 % natural rocks of P and K + bio-fertilizers (BF), T5: 50 % mineral P and K + 50 % natural rocks of P and K + sulphur (S), T6: 50 % mineral P and K + 50 % natural rocks of P and K + FYM + BF + S

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