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Approach for Reducing the Quantity of Mineral Fertilizers for Thompson Seedless Grapevines using Fulvic Acid

[1]Mohamed M. Ibrahim and [2]Mohamed K. Abdel-Fattah

[1]*Horticulture Department, Fac. of Agric., Zagazig Univ., Egypt.*
[2]*Soil Science Department, Fac. of Agric., Zagazig Univ., Egypt.*

ABSTRACT

A field experiment was conducted on 13-year-old Thompson Seedless grapevines grown in sandy soil under drip irrigation system in a private vineyard at Belbeis district, Sharkia Governorate, Egypt during the two successive seasons of 2013 and 2014. This study aimed to assess the response of grapevines to partial replacement of mineral fertilizers by fulvic acid. Nitrogen, phosphorus and potassium were applied at four rates with or without fulvic acid (FA) spraying at 0.2 g / l. These three elements were applied (fertigated) at 100, 75, 50 and 25 % from the recommended rate for each, i.e. 190.5, 142.56 and 285.71 kg/ ha for N, P and K, respectively. The results showed that application of different rates of N, P and K fertilizers with or without FA significantly influenced the yield and its components as well as other attributes. Application of the recommended dose of each element (190.5 kg N ha^{-1} + 142.56 kg P_2O_5 ha^{-1} + 285.71 kg K_2O ha^{-1}) with or without FA gave the highest yield components and quality without significant differences between them and applying these elements at 75 % of the recommended dose (142.88 kg N ha^{-1} + 106.92 kg P_2O_5 ha^{-1} + 214.28 kg K_2O ha^{-1}) in the two studied seasons. The results showed also that application of FA led to increase the yield and NPK contents in leaf petioles. This study suggests that Thompson Seedless grapevines response to different levels of nitrogen, phosphorus and potassium fertilization with or without fulvic acid under sandy soil conditions. The best combination treatment was FA + 142.88 kg N ha^{-1} + 106.92 kg P_2O_5 ha^{-1} + 214.28 kg K_2O ha^{-1} which reduce the mineral fertilization as a pollutant in agriculture and save farmers money. The results of this study showed that it could provide 25% of mineral fertilizers with obtaining higher yields with better fruit quality by fulvic acid spraying at 0.2 g / l.

Key words: Thompson seedless, Nitrogen, Phosphorus, Potassium, Fulvic acid, Sandy soil, Fertilization.

Introduction

Improving yield and fruit quality of Thompson Seedless grapevines is an important target for grape growers in Egypt. It could be achieved through conducting new horticultural practices depending on controlled amounts of mineral fertilizers and using fulvic acid to substitute the saved amounts. Nitrogen, P and K are essential macronutrients in many plant metabolic processes. They have many important functions, especially in the synthesis and translocation of proteins, carbohydrates and plant pigments (Adriano, 1985 and Nijjar, 1985).

The balance between N, P and K levels at adequate amounts had an important role for enhancing grapevines productivity and fruit quality. The application of mineral fertilizers to a vineyard renders a positive influence on the structural elements of plants and rises the yield. Previous studies emphasized the remarked influence of NPK fertilization on the flowering, berry setting and vegetative growth of various grape cvs. (Bacha *et al*., 1995; Boselli *et al*., 1995; Abed Hady and Ibrahim, 2001). Liquid fertilizer containing humic acid increased apple fruit weight, yield and soluble solids content (Li *et al*., 1999).

Fulvic acid is a part the humic structure in rich composting soils. It is an acid created in extremely small amounts by the action of millions of beneficial microbes, working on decaying plant matter in a soil environment with adequate oxygen. It is of low molecular weight and is biologically very active. Because of its low molecular weight, fulvic acid has the necessity and ability to readily bond mineral and elements into its molecular structure causing them to dissolve and become mobilized fulvic complexes. Fulvic acid usually carries 70 or more mineral and trace elements as part of molecular complexes. Fulvic acid maintains the ideal environment for dissolved mineral complexes and elements. It is also the most powerful antioxidant and free-radical scavenger known. Fulvic acid can scavenge heavy metals and detoxify pollutants (Donnell, 1973; Tatini *et al*., 1991 and Pettit, 2009). Foliar fertilizers are also more economical because smaller quantities of fertilizer are required to obtain significant plant response. Plant nutrients within foliar fertilizers are rapidly absorbed by plant leaves. Within 8 hours after application of humic substances, changes in many different metabolic processes are detected (Pettit, 2009).

When HA or FA are applied to plant leaves, the chlorophyll content increased (Pettit, 2009). Moreover, uptake of major plant nutrients was mediated by humic substances, one stimulative effect of humic substances

Corresponding Author: Mohamed M. Ibrahim, Horticulture Department, Fac. of Agric., Zagazig Univ., Egypt.
E-mail: mohamednasr79@yahoo.com

on plant growth is enhancing the uptake of major plant nutrients (N, P and K). When adequate humic substances were present within the soil, the requirement for NPK fertilizer application was reduced (Senn and Kingman, 1973; Russo and Berlyn, 1990 and Pettit, 2009).

Therefore, this work was planned to reduce the quantity of N, P and K fertilizer requirements of Thompson Seedless grapevines using fulvic acid foliar spray in combination with N, P and K fertilizers.

Materials and Methods

A field experiment was conducted on 13 years old Thompson Seedless grapevines grown in sandy soil in a private vineyard at 2 x 2.5 m under drip irrigation system at Belbeis district, Sharkia Governorate, Egypt during two successive seasons of 2013 and 2014. Physical and chemical properties of the experiment soil were determined according to the methods described by USDA (1954), Van Reeuvijk (2002) and Jackson (1967). The data are illustrated in Table (1).

Table 1: Physical and chemical properties of the experiment soil

Property	Value
Texture class	
Sand	90.50
Silt	3.73
Clay	5.77
Soil texture	Sandy
Organic matter [g kg^{-1}]	2.10
$CaCO_3$ [g kg^{-1}]	49.50
Soluble ions, EC and pH:	
EC in soil extract 1:2.5 (mScm^{-1})	2.44
pH [Soil suspension 1:2.5]	8.20
Soluble ions (mmol$_c$ l^{-1})	
Na^+	11.96
K^+	0.29
Ca^{2+}	6.80
Mg^{2+}	5.35
Cl^-	11.25
HCO_3^-	6.36
$SO_4^=$	6.79
SAR	4.85
Nutrients(ppm)	
N	65.35
P	2.60
K	57.73
Fe	2.12
Zn	1.17
Mn	0.91
Cu	2.25

The vines were trained according to the traditional cane pruning system on three-wire trellis, supported by telephone system. Winter pruning was carried out in the first week of January in both seasons leaving 108 buds (8 fruiting canes x 12 eyes beside 6 renewal spurs x two eyes). The selected vines for this study received the usual horticultural practices applied in the vineyard, except those dealing with the application of study treatments. The experimental vines were subjected to the following eight fertilization treatments in a randomized complete block design with three replicates (one vine per replicate)

1- 190.5 kg N ha^{-1} + 142.56 kg P_2O_5 ha^{-1} + 285.71 kg K_2O ha^{-1} (100% NPK)
2- 142.88 kg N ha^{-1} + 106.92 kg P_2O_5 ha^{-1} + 214.28 kg K_2O ha^{-1} (75% NPK)
3- 95.25 kg N ha^{-1} + 71.28 kg P_2O_5 ha^{-1} + 142.86 kg K_2O ha^{-1} (50% NPK)
4- 47.63 kg N ha^{-1} + 35.64 kg P_2O_5 ha^{-1} + 71.43 kg K_2O ha^{-1} (25% NPK)
5- FA + 190.5 kg N ha^{-1} + 142.56 kg P_2O_5 ha^{-1} + 285.71 kg K_2O ha^{-1} (FA + 100% NPK)
6- FA + 142.88 kg N ha^{-1} + 106.92 kg P_2O_5 ha^{-1} + 214.28 kg K_2O ha^{-1} (FA + 75% NPK)
7- FA + 95.25 kg N ha^{-1} + 71.28 kg P_2O_5 ha^{-1} + 14.86 kg K_2O ha^{-1} (FA + 50% NPK)
8- FA + 47.63 kg N ha^{-1} + 35.64 kg P_2O_5 ha^{-1} + 71.43 kg K_2O ha^{-1} (FA + 25% NPK)

The vines were sprayed with fulvic acid solution at 0.2 g l^{-1} three times/ year beginning after fruit setting and 20 days intervals. The untreated vines were sprayed with tap water. The spray solution was amended with Tween-20 (0.1%) as a spreading agent. A handheld sprayer was used for spraying vines until runoff in the early morning.

The chemical analysis of fulvic acid according to Lgagro Co. are as follows: appearance (dark brown powder), pH (neutral), Fulvic (80-85%), N (3-5%), P (0.5 – 1%), K (6 – 8%), amino acids (2 – 3%) and solubility (>99%).

The source of nitrogen was ammonium nitrate (335 g N kg^{-1}), and ammonium sulfate (206 g N kg^{-1}), whereas potassium sulfate (480 g K_2O kg^{-1}) was the source of potassium. Two third of these fertilizers were added weekly during the period from the beginning of budburst until harvest and the other third was added after harvest. The source of phosphorus was calcium superphosphate (155 g P_2O_5 kg^{-1}) at 357 kg ha^{-1} added in winter beside phosphoric acid 85% was added at eight equal doses at the beginning of budburst until harvest at weekly intervals.

At harvest time (late July), the clusters of each replicate were picked and weighed, the yield as (kg/ vine) and number of clusters per vine were recorded and the average weight of cluster was calculated. A random sample of five clusters per replicate were randomly takes at harvest and saved in plastic bags and immediately transformed to fruit physiology laboratory of Hort. Dept. Fac. Agric. Zagazig Univ. for the subsequent determinations according to the A.O.A.C. (1995): a) berry physical characteristics: berry diameter and length (cm), weight of 100 berries (g), juice volume / 100 berries (ml), berry attachment force and firmness (g/cm^2); b) juice chemical constituents: total soluble solids (TSS) was determined using a digital refractometer device (Atago RX 7000 Alpha), pH value, titratable acidity (TA, as g tartaric acid per 100 ml juice) and the maturity index (TSS/ acid ratio) was finally calculated by division of TSS to TA percentage.

Chlorophyll content was determined in the field with a SPAD-502-meter (Minolta Camera Co., Osaka, Japan), which estimates SPAD value according to the method of Castelli *et al*. (1996). The SPAD readings were performed in August and five SPAD readings were made for each leaf sample and their average represent the chlorophyll content.

Leaf mineral contents (total N, P and K %) were determined in petioles of mature leaves and total carbohydrate content in the canes was estimated according to the methods described in Wilde *et al*. (1985).

Statistical analysis

The obtained data were statistically analyzed according to Snedecor and Cochran (1982) using COSTAT program, differences between means were compared using Duncan's multiple range test at 0.05 level (Duncan, 1958).

Results and Discussion

1. Yield and yield components

1.1. Yield per vine and per hectare

As shown in Table (2), the tested fertilization treatments significantly affected yields per vine and the hypothetic yield per hectare in the two seasons of investigation (2013 and 2014). However, the highest yields per vine and per hectare came from FA + 100 % NPK (8.28 & 9.40 kg/vine and 16.55 & 21.67 tons/ha) and FA + 75 % NPK (7.96 & 9.50 kg/vine and 15.92 & 21.54 tons/ha), without significant differences between them in the two seasons. The two treatments surpassed the control (100 % NPK without FA) by 8.52 & 4.33 % and 5.74 & 6.86 % in 1st & 2nd seasons, respectively. The yield of control grapevines (7.63 & 8.89 kg/vine and 15.25 & 20.80 tons/ha) and that of those fertilized by FA + 50 % NPK and 75 % NPK were insignificantly different in the first season only. On the other hand, the least yields per vine (6.16 & 5.04 kg/vine) and per hectare (12.32 & 10.23 tons/ha) were recorded for 25 % NPK treatment in the first and second seasons, respectively.

All vines fertilized with mineral fertilization in combination with foliar FA spray surpassed those mineral fertilized without FA foliar application.

1.2. Number of clusters per vine

It is quite evident from Table (2) that, the number of clusters per vine was not significantly affected by the tested fertilization treatments in the first season (2013). But in the second one (2014), the number of clusters/ vine recorded the highermost values (around 23 clusters/ vine) with three treatments, namely: the control (100 % NPK) (23.00 clusters/ vine) and FA + 100 or 75 % NPK (23.67 clusters/ vine for both treatments). The differences between the three treatments were insignificant. The least number of clusters/ vine (14.33 clusters/ vine) came from 25 % NPK treatment. The other tested fertilization treatments recorded significantly different and intermediate numbers of clusters/ vine ranging between 16.67 and 20.00 clusters.

In general, the number of clusters/ vine in the second season was significantly affected by the tested fertilization treatments applied in the first season.

Table 2: Effect of different rates of soil NPK fertilization and foliar fulvic acid spray on yield (kg/vine), number of clusters/ vine and cluster weight of Thompson Seedless grapevines (2013 and 2014 seasons).

Treatments	Yield/ vine (kg)		Hypothetic yield, (ton ha^{-1})		Number of clusters per vine		Cluster weight (g)	
	2013	2014	2013	2014	2013	2014	2013	2014
100 % NPK (cont.)	7.63 bc	8.89 b	15.25 bc	20.80 b	21.67 a	23.00 a	357.50 b	380.75 b
75 % NPK	7.19 c	6.83 d	14.38 c	18.05 c	20.67 a	18.33 c	348.00 b	372.42 c
50 % NPK	6.65 d	6.07 e	13.30 d	13.50 e	20.67 a	17.00 d	321.67 c	356.67 d
25 % NPK	6.16 e	5.04 f	12.32 e	10.23 f	20.67 a	14.33 e	298.28 d	351.72 d
FA + 100 % NPK	8.28 a	9.40 a	16.55 a	21.67 a	21.33 a	23.67 a	381.85 a	397.05 a
FA + 75 % NPK	7.96 ab	9.50 a	15.92 ab	21.54 a	21.33 a	23.67 a	373.18 a	401.30 a
FA + 50 % NPK	7.29 c	7.62 c	14.57 c	16.14 d	20.67 a	20.00 b	352.42 b	380.86 b
FA + 25 % NPK	6.64 d	6.14 e	13.28 d	13.74 e	20.67 a	16.67 d	321.22 c	368.71 c

Values within the same column of every season with different letters are statistically different ($P < 0.05$) according to Duncan's multiple range test.

1.3. Cluster weight

Data in Table (2) clearly show that cluster weight was significantly affected by the different fertilization treatments in both seasons. The uppermost cluster weight (381.85 & 373.18 and 397.05 & 401.30 g) was gained by FA + 100 % NPK and FA + 75 % NPK treatments in both seasons, respectively, followed by vines fertilized with 100 % NPK only (control), FA + 50 % NPK and 75 % NPK in 2013 season and 100 % NPK and FA + 50 % NPK in 2014 one without significant differences between them. Vines of the treatments 25 % NPK in 2013 season and 25 & 50 % NPK in 2014 season gave the lowermost cluster weight (298.28 and 351.72 & 356.67 g), respectively.

These findings are in agreement with those of Pire and Rivas (1987) on Fernao Pires grapevine, Monga *et al*. (1990) on Perlette and Salem *et al*. (2004) on Thompson Seedless grapevines. They all stated that the higher levels of NPK increased yield.

The effect of mineral fertilizers on the grape yield was studied by many authors, who determined their optimum rates under humid subtropical conditions of Abkhazia, the yield increased by 40 dt/ha at the application of N120-P120-K60 (Adamadze, 1981). The application of nitrogen fertilizers at 60 kg/ha on the background of P120-K60 gained the largest bunches and the highest yield (Skipina and Bushina, 1977).

Furthermore, Chen (2010) indicated that N application at 100 g/ plant, P at 400 g/ plant, K at 150 g per plant had the best effect on yield and fruit quality of Jingya grape. In addition, Ming (2010) indicated that the rational NPK fertilization led to the high yielding, good quality and high production efficiency of the seedless grape variety Crimson.

In addition, Xiaojun *et al* (2007) and Lu *et al* (2010) showed that spraying FA at 1.250 g/l on apple trees gained fruit yield higher than the control by 3.67 %. Also, fertilization of pea plants with 100% or 75% NPK of the recommended rate with or without foliar spray with fulvic acid at 0.1% or 50% NPK with fulvic acid at 0.1% increased yield/ plant (Boghdady and Nawar, 2011).

2. Berry physical characteristics

Results in Table (3) show that all N, P and K fertilizer treatments in combination with FA significantly increased 100- berry weight, juice volume/ 100 berries, berry length, berry diameter, berry attachment force and berry firmness as compared to N, P and K fertilization without FA. In the first season, the highest values of 100-berry weight (163.25 g), juice volume/ 100 berries (127.67 ml), Berry length (1.72 cm), Berry diameter (1.42 cm) and berry attachment force (590.67 g.cm^{-2}) were recorded for the FA + 100% NPK treatment without significant differences between them and FA + 75 % NPK treatment, while the lowest values were obtained from the 25% NPK treatment. The same trend of the previous attributes was found in the second season. The highest berry firmness values (406.33 and 600.00 g.cm^{-2}) were produced by FA + 25 % NPK treatment, while the lowest values (342.00 and 465.67 g.cm^{-2}) were obtained from the 100 % NPK treatment without FA (control) in the first and second seasons, respectively. Clusters of vines receiving the highest nitrogen fertilization rate led to a decrease in berry firmness compared with those received lower ones. In addition, foliar FA spray led to an increase in berry firmness.

The obtained results are in harmony with those reported by Salem *et al*. (2004), who cleared that improvement in cluster quality of Thompson Seedless grapevines was related to NPK ratio, with an optimum achieved in response to 1: 1: 3 NPK ratio. Fruits from trees under high N rates had slightly lower firmness. This result is in agreement with that of Fallahi (1999) on Redspur Delicious apple, perhaps because this combination of humic acid and N increases fruit maturity. In addition, Huan-pu *et al*. (2004) on Red Globe grape and Xiaojun *et al.* (2007) & Hong *et al*. (2010) on apple trees showed that foliar fulvic acid improved the quality of fruits. Also, spraying apple trees by FA at 1.00 g / l increased fruit firmness (Lu *et al*., 2010).

At contrast, Cheng *et al* (2012) working on Jumeigui grape showed that, when the NPK compound fertilizer level exceeded 300 kg/h.m^2, there were no significant differences of average berry weight and fruit firmness among the treatments.

Table 3: Effect of different rates of soil NPK fertilization and foliar fulvic acid spray on some berry physical characteristics of Thompson Seedless grape (2013 and 2014 seasons).

Treatments	100- berry weight (g)		Juice volume / 100 berries (ml)		Berry length (cm)		Berry diameter (cm)		Berry attachment force (g cm^{-2})		Berry firmness (g cm^{-2})	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
100 % NPK(cont.)	158.66 ab	158.45 abc	123.45 b	127.88 bc	1.71 a	1.70 a	1.43 a	1.43 bc	515.00 e	399.00 e	342.00 h	465.67 h
75 % NPK	155.00 bc	157.47 bc	124.06 b	128.57 b	1.66 c	1.70 a	1.42 a	1.43 bc	510.67 f	366.33 f	352.67 f	526.33 f
50 % NPK	153.89 c	157.02 bc	123.67 b	126.95 cd	1.65 c	1.71 a	1.40 a	1.41 c	489.67 g	359.67 h	393.67 d	541.33 d
25 % NPK	151.83 c	156.27 c	121.42 c	126.46 d	1.65 c	1.71 a	1.40 a	1.41 c	454.33 h	363.33 g	403.67 b	598.00 b
FA + 100 % NPK	163.25 a	164.89 a	127.67 a	130.67 a	1.72 a	1.71 a	1.42 a	1.47 a	590.67 a	410.00 b	350.33 g	476.00 g
FA+ 75 % NPK	161.80 a	164.42 a	126.83 a	131.00 a	1.71 a	1.72 a	1.43 a	1.47 a	569.33 b	418.33 a	386.00 e	534.00 e
FA+ 50 % NPK	154.82 bc	164.39 a	123.50 b	127.69 bc	1.70 ab	1.72 a	1.42 a	1.46 ab	553.67 c	403.33 d	399.00 c	575.00 c
FA+ 25 % NPK	154.65 bc	163.26 ab	124.01 b	127.80 bc	1.67 bc	1.71 a	1.41 a	1.46 ab	518.33 d	407.00 c	406.33 a	600.00 a

Values within the same column of every season with different letters are statistically different (P < 0.05) according to Duncan's multiple range test.

3. Juice chemical constituents

Data in Table (4) clearly demonstrate that juice chemical constituents of Thompson Seedless grapes was significantly affected by soil NPK fertilization treatments with or without foliar fulvic acid spray during 2013 and 2014 seasons. The highest TSS percentages (22.33 and 21.67 %) was recorded by vines fertilized by FA + 100 % NPK and FA + 75 % NPK in both seasons. However, in the second season 100 % NPK and 75 % NPK treatments gained higher TSS percentages (22.33 and 21.50 %) without significant differences between them. The lowest TSS percentages (19.90, 19.93 and 20.56 %) were recorded for 25, 50 and 75 % NPK treatments without FA spray in 2013, while in 2014 season the other treatments gave statistically similar values.

Table 4: Effect of different rates of soil NPK fertilization and foliar fulvic acid spray on juice chemical constituents of Thompson Seedless grapevines (2013 and 2014 seasons).

Treatments	TSS %		TA %		TSS/ TA ratio		pH	
	2013	2014	2013	2014	2013	2014	2013	2014
100 % NPK (cont.)	21.53 b	22.33 a	0.523 f	0.530 f	41.19 a	42.15 a	5.132 a	5.150 a
75 % NPK	20.56 cd	21.50 ab	0.560 d	0.570 d	36.74 c	37.73 b	5.004 d	5.130 b
50 % NPK	19.93 d	20.33 c	0.595 bc	0.584 c	33.50 d	34.81 c	4.909 f	5.064 c
25 % NPK	19.90 d	19.90 c	0.611 a	0.600 b	32.57 d	33.17 c	4.786 g	4.817 f
FA + 100 % NPK	22.33 a	22.17 a	0.541 e	0.520 g	41.28 a	42.63 a	5.094 b	5.156 a
FA + 75 % NPK	21.67 ab	21.67 a	0.551 de	0.560 e	39.32 b	38.70 b	5.055 c	5.134 b
FA + 50 % NPK	21.33 bc	20.53 bc	0.587 c	0.587 c	36.34 c	34.98 c	4.934 e	4.997 d
FA + 25 % NPK	21.50 b	20.33 c	0.607 ab	0.610 a	35.42 c	33.33 c	4.611 h	4.889 e

Values within the same column of every season with different letters are statistically different (P < 0.05) according to Duncan's multiple range test.

The effect of the studied treatments on total acidity percentage (TA) in berry juice followed, approximately, an opposite trend to their effect on TSS percentage in the two seasons. Vines receiving 25 % NPK with or without foliar FA spray increased total acidity percentage (0.611 and 0.607 %) in 2013 season. In 2014, 25 % NPK with FA spraying recorded (0.610 %) berry juice acidity compared to vines fertilized by 100 and 75 % NPK with foliar FA spray (0.541and 0.551 %) and 100 % NPK with foliar FA spray (0.520 %) in the two seasons, respectively which induced significantly lower acidity percentages. The effect of the studied treatments on pH vales entirely followed an opposite trend to their effect on TA percentage in the two experimental seasons.

Data in Table (4) reveal that TSS/ acid ratio was significantly affected by the tested fertilization treatments in both seasons. The highest TSS/ acid ratios (41.28 & 41.19 and 42.63 & 42.15) were recorded by vines received 100 % NPK with or without foliar FA spray in the first and second seasons, respectively, without significant differences between them, followed by 75 % NPK with or without foliar FA spray treatments. The lowest TSS/ acid ratio was induced by vines fertilized with 25 and 50 % NPK (32.57 and 33.50) in the first season. But in the second season, the other treatments induced insignificant different TSS/ acid ratios. The obtained findings are in agreement with those reported by Lu *et al* (2010) who showed that spraying FA at 1.00 or 1.25 g / l made the soluble solids up to 12.53% and sugar-acid ratio up to 44.89%.

At contrast, Cheng *et al* (2012) working on Jumeigui grape showed that, when the NPK compound fertilizer level exceeded 300 kg/h.m^2, there were no significant differences of total soluble solid content (TSS) and titrate-acid (TA) among the treatments.

4. Leaf petioles mineral content, canes carbohydrate content and leaf total chlorophyll content

Data presented in Table (5) clearly show that leaf petiole N and K contents as well as cane carbohydrates and leaf total chlorophyll contents were significantly affected by the tested fertilization treatments, but P was not affected in both seasons. The highest values of NPK contents were recorded for vines received 75 or 100 % NPK with foliar FA, while vines untreated with FA with all doses of mineral fertilizers gained the lowest contents in both seasons.

As shown in Table (5), application of FA + mineral fertilization had significant effects on carbohydrate content of canes during 2013 and 2014 seasons. The highest cane carbohydrate content was obtained after the application of 100 % NPK with or without foliar FA spray and FA + 75 % NPK in both seasons without significant differences between them in most cases. The highest rate of N, P or K fertilization increased carbohydrate content compared to the lowest one. Leaf total chlorophyll content of Thompson Seedless grapevines during the two seasons followed the same trends of carbohydrate content and that of N, P and K rates. These results go in line with those reported by Neilsen *et al*. (1987) who stated that petiole N, P and K concentrations were increased by their respective fertilizer additions. Meanwhile, Qinglin *et al*. (1994) reported that when rape trees (*B. campestris*) were sprayed with different concentrations of fulvic acid (FA) (0, 50, 100 and 200 mg/kg) in the flowering period the chlorophyll content of leaf increased. Also, fertilization of pea plants with 100% or 75% NPK of the recommended rate with or without foliar spray with fulvic acid at 0.1% or 50% NPK with fulvic acid at 0.1% increased total chlorophyll and N, P, K and total carbohydrates percentage compared to control (zero NPK and without FA spray) and other treatments (Boghdady and Nawar, 2011).

Table 5: Effect of different rates of soil NPK fertilization and foliar fulvic acid spray on leaf petioles mineral elements content, canes carbohydrate percentage and leaf total chlorophyll content of Thompson Seedless grapevines (2013 and 2014 seasons).

Treatments	Leaf petiole mineral content						Canes Carbohydrate content (%)		Leaf total chlorophyll content SPAD value	
	Nitrogen (%)		Phosphorus (%)		Potassium (%)					
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
100 % NPK (cont.)	2.35 d	2.43 c	0.29 a	0.30 a	1.36 c	1.41 c	28.30 ab	29.35 a	37.80 a	39.95 a
75 % NPK	2.30 e	2.34 d	0.29 a	0.29 a	1.20 e	1.29 d	22.01 d	26.85 b	36.65 b	38.51 bc
50 % NPK	2.18 f	2.25 e	0.29 a	0.28 a	1.16 f	1.13 e	21.40 d	23.59 c	36.10 bc	37.90 c
25 % NPK	1.97 h	2.19 f	0.28 a	0.28 a	0.99 h	0.95 f	16.47 e	18.48 e	33.44 d	35.59 d
FA + 100 % NPK	2.50 b	2.58 a	0.30 a	0.30 a	1.53 a	1.51 a	28.92 a	30.25 a	37.76 a	40.10 a
FA + 75 % NPK	2.53 a	2.58 a	0.30 a	0.30 a	1.48 b	1.50 a	27.99 b	29.30 a	37.83 a	40.00 a
FA + 50 % NPK	2.42 c	2.45 b	0.30 a	0.30 a	1.29 d	1.43 b	24.07 c	27.37 b	37.76 a	39.23 ab
FA + 25 % NPK	2.03 g	2.26 e	0.28 a	0.28 a	1.10 g	1.12 e	17.30 e	20.96 d	35.81 c	38.33 bc

Values within the same column of every season with different letters are statistically different ($P < 0.05$) according to Duncan's multiple range test.

Conclusion

A field experiment was conducted to assess the response of Thompson Seedless grapevines to partial replacement of mineral fertilizers by fulvic acid (FA) regarding yield components and cluster quality. The results showed that application of N, P and K fertilizers at different rates with or without FA significantly influenced the yield and its components. Application of 190.5 kg N ha^{-1} + 142.56 kg P_2O_5 ha^{-1} + 285.71 kg K_2O ha^{-1} with or without FA spraying gave the highest yield, yield components and quality indicators, followed by those received 75 % of the recommended rates (142.88 kg N ha^{-1} + 106.92 kg P_2O_5 ha^{-1} + 214.28 kg K_2O ha^{-1}) without significant differences between them in the two studied seasons. Generally, it is possible to replace parts of mineral fertilizers by spraying FA at 0.2 g /l. This well reduce the mineral fertilization as a pollutant in agriculture and save farmers money.

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