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Response of Washington Navel Orange Trees to Some Soil Amendments and Foliar application of GA_3 under Clay Soil Conditions

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THIS STUDY was carried out during the two successive growing seasons of 2014 and 2015 on eight years old Washington navel orange trees budded on sour orange rootstock grown in a private orchard located at Shino village, Kafrelsheikh governorate, Egypt, to evaluate the effects of some soil amendments and GA_3 foliar application on vegetative growth, nutritional status, yield and fruit quality as well as soil properties. The experiment was arranged in a randomized complete blocks design with eleven combination treatments as follows: (T_1) control or untreated trees, (T_2) mycorrhizae at 15g/tree/year, (T_3) mycorrhizae at 15g/tree /year + sulphur at 1kg/tree /year, (T_4) mycorrhizae fungi at 15 g/tree/year + Nile fertile at 750 g/tree /year, (T_5) mycorrhizae at 15 g/tree/year + bio-tol at 2 cm/l was sprayed from Feb. up to May, (T_6) mycorrhizae + sulphur + 30 ppm GA_3 was sprayed at full bloom stage, (T_7) mycorrhizae + Nile fertile + 30 ppm GA_3, (T_8) mycorrhizae + bio-tol + 30 ppm GA_3, (T_9) phosphorine (bio-fertal) at 11 g/tree/year + Nile fertile, (T_{10}) Phosphorine + bio-tol + 30 ppm GA_3 and (T_{11}) phosphorine + sulphur + 30 ppm GA_3. The results indicated that trees treated with T_{11} had remarked effect followed by T_7 than the other treatments in most of vegetative growth parameters (canopy volume, leaf area, leaf dry weight and specific leaf weight, at the spring growth cycle) and increased leaf chlorophyll and mineral contents in both seasons. T_{11} followed by T_{10}, T_9, T_8 and T_7 achieved the best fruit yield and fruit quality compared with untreated trees. Soil pH and salinity (EC) were decreased while available macronutrients (N, P and K), soil microorganisms content and dehydrogenase activity were increased with applying T_{11}, T_{10}, T_9, T_8, T_7, T_6 and T_5 comparing with control (T_1). Therefore, both T_{11} and T_7 treatments are recommended for citrus orchard to improve growth, yield and quality as well as soil properties and comforting higher return for orange trees growers under Kafrelsheikh governorate conditions.

Keywords: Washington Navel orange, Soil amendments, Mycorrhizae, Sulphur, Nile fertile, .Bio-tol, GA_3, Vegetative growth, Yield, Soil properties

Introduction

Citrus is one of the greatest important world fruit crops grown in many tropical and subtropical regons. In Egypt citrus trees occupies the greatest acreage among all fruit trees. The fruiting acreage of citrus occupies about 439024 fed and produced about 4098590 tons with average of 9.336 tons/ fed as stated by Ministry of Agriculture and Land Reclamation (2014). Bio-fertilization is considered an important tool to enhance the yield and fruit quality of citrus and it becomes a positive alternative to chemical fertilizers. They are safe for human, animal and environment and using them was attended with reducing the great pollution occurred on our environment as well as for producing organic foods for export. They are favorable in increasing N fixation (El-Khawaga, 2007). The availability and uptake of nutrients as well as stimulation of natural hormones biosynthesis and the production of antibiotics (Subba-Rao, 1993). So the use of microorganisms was favorable in increasing N fixation (*Azospirillum lipoferum*), solubilize phosphate (*Bacillus megaterium*) and potassium (*Bacillus circulans*), the availability and uptake of nutrients as well as stimulation of natural hormones biosynthesis and the production of antibiotics (Sherif, 1997). Arbuscular mycorrhizal

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(AM) fungi are universal soil organisms that can form mutualistic relations with the roots of the common of vascular plant species, also the establishment of AM association is often favorable for plant nutrition specially enhance absorption of phosphours and other relatively immobile micronutrients, particularly zinc and copper also AM fungi produce plant growth hormones such as auxines, cytokinines, gibberellins and increasing water uptake (Lindermann, 1988). Elemental sulphur, as a soil amendment, is of special interest to increase plant nutrient availability in the soil system since it possesses a slow release acidifying characteristic and is readily available (Chien *et al.*, 2011). In the North Nile Delta region, major agricultural land is heavy clay soil relatively high pH, resulting in high pH of the soils, which directly influence the availability of nutrients for plant growth. Elemental sulfur (S) can be used as a nutrient and an acidifier (Neilsen *et al*., 1993). The acidity produced during elemental S oxidation increases the availability of nutrients such as P, Mn, Ca and SO_4 in soil (Lindemann et al., 1991). Various studies reported the importance of sulfur in increasing growth and leaf mineral content of some fruit trees, such as orange trees, grapevine and persimmon (Abdel-Nasser and El-Shazly, 2000). Plant growth regulators like as GA_3 have been used in citrus production with numerous purposes like as bloom reduction, increased fruit setting and improving fruit quality. Therefore, the main objective of study is to evaluate the possible effects of some soil amendments and foliar application of GA_3 on, growth, nutritional status, yield and quality of Washington Navel orange trees grown in clay soil along with soil properties.

Materials and Methods

The present investigation was carried out during the two successive growing seasons of 2014 and 2015 on eight years old Washington navel orange trees (Citrus sinensis L., Osbek) budded on sour orange (Citrus aurantium L.), planted at 5 x 5 meters apart (168 trees/fed.) and grown on clay soil in private orchard located at Shino village, Kafrelsheikh governorate, Egypt. The trees were irrigated with Nile water by flood irrigation system and received the same cultural practices as usually done in this area. Some chemical and physical properties of the experimental soil were determined according to Page *et al*. (1982) are presented in Table 1.

TABLE 1. Some physical chemical properties of the experimental soil

Soil depth (cm)	Particle size distribution (%)			pH	EC, dS m^{-1}	OM (g kg^{-1})	Available macronutrients ($mg\ kg^{-1}$)		
	Sand	Silt	Clay				N	P	K
0-30	14.75	30.55	54.70	8.10	2.42	12.0	25.11	7.30	386.11
30-60	14.48	32.67	52.85	8.30	2.11	11.5	33.09	7.11	375.12
60-90	15.56	29.96	54.48	8.28	2.11	11.5	22.15	7.05	370.11

The experiment was arranged in a randomized complete blocks design with eleven combination treatments (each treatment was represented by three replicates, three trees /replicate) as follows:

T_1 -Control or untreated trees
T_2 -Mycorrhizae fungi at 15 g /tree /year.
T_3 -Mycorrhizae fungi at 15 g /tree /year + Sulphur at 1 kg /tree / year.
T_4 -Mycorrhizae fungi at 15 g /tree /year + Nile fertile at 750 g /tree /year.
T_5 -Mycorrhizae fungi at 15 g /tree /year + Bio-tol at 2cm /l were sprayed from Feb. up to May.
T_6 -Mycorrhizae + Sulphur + 30 ppm GA_3 sprayed at full bloom stage.
T_7 -Mycorrhizae + Nile fertile + 30 ppm GA_3.
T_8 -Mycorrhizae + Bio-tol + 30 ppm GA_3.
T_9 -Phosphorine (Bio-fertal) at 11 g /tree / year + Nile fertile.
T_{10} -Phosphorine (Bio-fertal) + Bio-tol + 30 ppm GA_3.
T_{11} -Phosphorine (Bio-fertal) + Sulphur + 30 ppm GA_3.

The recommended doses of mineral fertilization N, P and K were 120, 30 and 80 units per fed., respectively were added. Sulphur and Nile fertile 30% S were added to the soil on the last week of January in two trenches with depth of 10 cm and 100 cm apart from the tree trunk at both sides. Bio-fertilizers namely Bio-tol (*Azospirillum ssp* and *Azotobacter ssp*) for N-fixing bacteria and *Bacillus megaterium* for phosphate-dissolving micro-organisms) and sprayed from Feb. up to May, Phosphorine (Bio-fertal) and Mycorrhizae (*Glomus gigaspora*) for P, the counts of Mycorrhizae was (1 x 10^8 cfu/ml (colony forming units). Nile fertile (NF) contains 30% S, some essential elements, (2.3% N, 5.5% P, 0.5% K, 9% Ca, 1.5% Mg and 30% S) and sulphur bacteria, *Thiobacillus ssp.* (10^6 CFU/g). Phosphorine (Bio-fertal), Mycorrhizae and Nile fertile were applied once during winter agricultural management by mixing with soil in wetting zone adhesive to the roots. During the growing season for each year, the following measurements and determinations were carried out.

Vegetative growth parameters

Number of shoots, shoot length, shoot diameter and number of leaves were calculated at the spring growth cycles. Tree canopy volume (CV) was measured according to (Castle, 1983) as follows: CV= 0.528 x H x D^2. Whereas, H = tree height, D = tree diameter. However, leaf area was estimated according to Chou (1966) via formula: Leaf area = 23/ (length x width), leaf dry weight and specific leaf weight (mg/cm^2) was calculated according to Ferre and Forshey (1988) as follows:

$$\text{Specific leaf weight (SLW)} = \frac{\text{Leaf dry weight (mg)}}{\text{Leaf area (cm}^2\text{)}}$$

Nutritional status

Chlorophyll a, b and its total were determined according to the method defined by Moran (1982), temporarily, leaf macro and micro nutrients contents were determined as follows: Total nitrogen was determined by micro-kjeldahl method described by Chapman and Pratt (1978). Phosphorus was determined colorometrically using spectrophotometer 882 UV at the wave length of 660 um according to method described by Murphy and Riely (1962). Potassium was determined by Flame photometer according to method suggested by Jackson (1967).

Yield and its components

At harvest time (20*th* and 25*th* December in 2014 and 2015 seasons, respectively), yield as fruit number/tree, kg / tree, and ton/fed were calculated.

Fruit quality

To determine fruit quality, ten healthy fruits were taken at random from each tree at harvest time of both seasons and prepared for determination of physical and chemical fruit quality assessment according to (A.O.A.C., 1990).

Soil properties

At the end of experiment (20*th* December, 2015) soil samples for all treatments were collected at two depths 030- and 3060-cm and data was expressed as average to measure some soil properties such as pH, EC, organic matter % and determine some chemical analysis, *i.e.* total nitrogen using Kjeldahl method, phosphorus and potassium (Page *et al*. 1982). Also, microorganisms were calculated as number of colonies/g soil according to Saleh (2002) and dehydrogenase activity (mg g^{-1} dry soil/ 96 h) was estimated according to Tabatabai (1982).

Statistical analysis

Data were statistically analyzed as analysis of variance according to Snedecor and Cochran (1990). Duncan's multiple range test (Duncan, 1955) at 5% level was used to compare the mean values.

Results and Discussion

Vegetative growth

Data presented in Table 2 show the effect of some soil amendments and foliar application of gibberellic acid on vegetative growth parameters in terms of canopy volume, number of shoot/branch, number of leaves/shoot, leaf area and specific leaf weight in 2014 and 2015 seasons. Trees treated with Phosphorine (Bio-fertal) + Sulphur + 30 ppm GA_3 (T_{11}) followed by T_{10} had remarked effect than the other treatments as for canopy volume in both seasons. Regarding to number of shoot/branch and number of leaves/shoot, data revealed that there were non-significant differences among treatments in both seasons. Looking for leaf area, T_7 followed by T_9 and T_{10} resulted the largest leaf area compared to the other treatments. However, treatments T_7, T_8, T_9, T_{10} and T_{11} significantly increased specific leaf weight without significant differences among them compared to lowest value obtained by control (T_1) in both seasons. Generally, the above mentioned results indicated that, T_{11} and T_{10} followed by T_9, T_8 and T_7 were the best for improving the most of vegetative growth parameters of Washington Navel orange trees compared to other treatments and control (untreated trees). This may be attributed to the role of bio-fertilizers in increasing the level of available minerals from the organic matter (Ibrahim and Abd El-Aziz, 1977) and this improvement in vegetative growth of mycorrihizal inoculated trees could be attributed to produce a greater root having relatively higher total potential absorbing surface over than of the uninfected system which enhanced nutrient absorption particulary phosphorus and zinc (Nawar *et al*., 1988). In addition, Marks and Kozlowski (1973) reported that mycorrihiza fungi provide the host plant with growth hormones including auxins, cytokinins gibbrellines and vitamins which stimulate plant growth. The obtained increase in vegetative growth parameters as a result of sulphur application might be due to the role of S in reducing soil pH after oxidization by soil micro-organisms to sulphuric acid and improving the availability of most soil nutrients (Koriem, 1994). These results are in agreement with those obtained by Shamshiri *et al* (2012) on kinnow trees, El-Deeb *et al* (2013) on Valencia orange trees, Pawar *et al*. (2014) on acid lime trees, Soliman and Aaid (2016) on Le Conte pear and Zayan *et al*. (2016) on Washington navel orange trees. They found the application of all soil amendment treatments, biofertilizers and arbuscular mycorrhizae (AM) significantly increased vegetative growth parameters (trunk circumference, tree height, tree width and canopy volume) compared with control. However, Abd El Raheem *et al*. (2013) on navel orange trees noticed that, sparing trees with 4ppm CPPU + 30 ppm GA_3 gave the largest leaf area when compared with untreated trees.

TABLE 2. Effect of some soil amendments and GA_3 foliar application on vegetative growth parameters of Washington Navel orange trees in 2014 and 2015 seasons

Characters / Treatments	No. of leaves /shoot		Leaf area (cm^2)		Specific leaf weight (mg/cm^2)	
	2014	2015	2014	2015	2014	2015
T_1	5.75a	6.58a	16.53 c	17.08 d	0.011 c	0.011 d
T_2	6.46a	7.17a	18.15 bc	18.41 cd	0.012 bc	0.012 bcd
T_3	6.00a	6.73a	19.04 ab	19.92 abc	0.013 abc	0.012 cd
T_4	6.58a	7.15a	19.53 ab	20.68 ab	0.013 bc	0.011 cd
T_5	6.67a	7.27a	17.95 bc	18.65 bcd	0.011 c	0.013 a-d
T_6	6.62a	7.25a	17.93 bc	18.82 bcd	0.015 abc	0.014 a-d
T_7	6.68a	7.43a	20.42 a	21.27 a	0.016 ab	0.017 a
T_8	6.19a	7.23a	18.20 bc	18.92 bcd	0.017 a	0.015 ab
T_9	6.34a	6.87a	18.12 bc	19.08 bcd	0.015 abc	0.015 abc
T_{10}	6.33a	7.25a	19.50 ab	20.72 ab	0.017 a	0.016 ab
T_{11}	6.91a	7.75a	19.70 ab	20.78 ab	0.017a	0.017 a

TABLE 2. Cont.

Characters / Treatments	Canopy volume (cm^3)		No. of shoot / branch	
	2014	2015	2014	2015
T_1	4.57 f	4.83 f	18.50a	24.92a
T_2	5.14 c-f	5.44 e	19.17a	20.92a
T_3	5.35 cde	5.52 de	22.33a	24.08a
T_4	5.24 cde	5.58 cde	21.33a	20.83 a
T_5	5.57 bcd	6.05 a-d	17.67a	23.00a
T_6	5.06 def	5.55 de	24.08a	25.83a
T_7	5.39 cde	5.93 b-e	25.75a	27.40a
T_8	5.77 abc	6.13 abc	19.17a	21.65a
T_9	4.89 ef	5.42 e	24.25a	20.00a
T_{10}	6.22 a	6.57 a	22.42a	23.83a
T_{11}	6.03 ab	6.40 ab	26.25 a	27.40a

Any values on the same vertical line for the same character having the same letter are not statistically different according to DMRT.
T_1= Control (Untreated trees). T_2= Mycorrhizae fungi at 15 g/tree/ year.
T_3= T_2+ Sulphur at 1 kg/tree/ year. T_4= T_2+ Nile fertile at 750 g/tree/year.
T_5= T_2+ 2cm Bio-tol /lL water was sprayed at Feb. up to May. T_6= T_2 + Sulphur + 30 ppm GA_3 was sprayed at full bloom stage.
T_7= T_2 + Nile fertile + 30 ppm GA3. T_8= T_2 + Bio-tol + 30 ppm GA_3.
T_9= Phosphorine (Bio-fertal) at 11 g/tree/ year + Nile fertile. T_{10}= Phosphorine (Bio-fertal) + Bio-tol + 30 ppm GA_3.
T_{11}=Phosphorine (Bio-fertal) + Sulphur + 30 ppm GA_3.

Nutritional status

Leaf chlorophyll contents

Data in Table 3 declared that leaf chlorophyll contents (a, b and its total) were significantly influenced by the tested treatments in both seasons. The highest values of chlorophyll were recorded with T_{11} followed by T_7, T_8, T_9 and T_{10} without significant differences among them comparing with the lowest values obtained by T_1 (control) in both seasons. The increasing of leaf chlorophyll might be resulted from balanced concentration of N and Fe always lead to active synthesis of chlorophyll. This balance was clear in the obtained results on leaf mineral analysis in this study as shown in Table 3. These results are similar to those obtained by Mikhael *et al*. (2009) on young persimmon trees, Shaban and Mohsen (2009) on Valencia orange, Abou-Zeed *et al*. (2014) on Balady mandarin trees, Merwed *et al*. (2014) on Valencia orange tree and Navarro *et al*. (2014) on Cleopatra mandarin trees.

Leaf macronutrients contents

Table 3 displayed that leaf N, P and K responded to treatments. Hence, fertilized Washington Navel orange trees with T_7, T_{10} and T_{11} had statistically the richest leaves in N without significant differences .among them in the second season only

TABLE 3. Effect of some soil amendments and GA_3 foliar application on leaf macronutrients and chlorophyll contents of Washington Navel orange trees in 2014 and 2015 seasons

Characters / Treatments	Leaf chlorophyll content (µg/cm²)					
	Chlorophyll a		Chlorophyll b		Total chlorophyll	
	2014	2015	2014	2015	2014	2015
T_1	28.21 d	26.82 c	13.47 d	13.00 d	41.68 e	39.82 c
T_2	33.03 bc	35.73 ab	16.27 abc	15.82 c	49.30 bcd	51.55 b
T_3	32.50 c	35.77 ab	16.10 bc	16.57 c	48.60 cd	52.33 b
T_4	35.71 abc	36.30 ab	17.48 ab	17.07 abc	53.20 abc	51.30 b
T_5	32.84 bc	34.20 b	15.47 c	16.73 bc	48.31 d	50.93 b
T_6	34.90 abc	34.03 b	16.87 abc	17.27 abc	51.77 a-d	52.27 b
T_7	36.47 ab	35.20 ab	17.07 ab	18.20 ab	53.06 abc	54.50 ab
T_8	35.99 abc	36.63 ab	17.20 ab	17.07 abc	53.67 ab	53.70 ab
T_9	36.35 ab	36.85 ab	17.33 ab	17.42 abc	53.68 ab	54.27 ab
T_{10}	36.47 ab	36.67 ab	17.37 ab	17.30 abc	53.83 ab	53.97 ab
T_{11}	36.85 a	37.73 a	17.75 a	18.57 a	54.60 a	56.30 a

TABLE 3. Cont.

Characters / Treatments	leaf macronutrients (%)					
	N		P		K	
	2014	2015	2014	2015	2014	2015
T_1	2.10a	2.20e	0.20 e	0.21 d	1.40 e	1.57a
T_2	2.47a	2.63 abc	0.28 cd	0.33 bc	1.48 de	1.67a
T_3	2.37a	2.50 a-e	0.23 e	0.32 bc	1.33 e	1.42a
T_4	2.30a	2.30 cde	0.29 c	0.37 abc	1.62 b-e	1.83a
T_5	2.70a	2.60 a-d	0.30 bc	0.25 d	1.53de	1.66a
T_6	2.43a	2.70 ab	0.28 cd	0.32 c	1.47 de	1.95a
T_7	2.50a	2.73 a	0.24 de	0.38 ab	1.73 a-d	1.62a
T_8	2.17a	2.27 de	0.21 e	0.38 ab	1.58 cde	1.90a
T_9	2.27a	2.37 b-e	0.30 bc	0.37 abc	1.88 ab	1.85a
T_{10}	2.77a	2.80 a	0.34 ab	0.40 a	1.82 abc	1.96a
T_{11}	2.37a	2.83 a	0.37 a	0.40 a	2.00 a	2.03a

Any values on the same vertical line for the same character having the same letter are not statistically different according to DMRT.

T_1= Control (Untreated trees). T_2= Mycorrhizae fungi at 15 g/tree/ year.

T_3= T_2+ Sulphur at 1 kg/tree/ year. T_4= T_2+ Nile fertile at 750 g/tree/year.

T_5= T_2+ 2cm Bio-tol /lL water was sprayed at Feb. up to May. T_6= T_2 + Sulphur + 30 ppm GA_3 was sprayed at full bloom stage.

T_7= T_2 + Nile fertile + 30 ppm GA3. T_8= T_2 + Bio-tol + 30 ppm GA_3.

T_9= Phosphorine (Bio-fertal) at 11 g/tree/ year + Nile fertile. T_{10}= Phosphorine (Bio-fertal) + Bio-tol + 30 ppm GA_3.

T_{11}=Phosphorine (Bio-fertal) + Sulphur + 30 ppm GA_3.

tree, data revealed that number of fruits /tree was significantly increased under T_{11} and T_{10} treatments without significant differences between them compared to the lowest fruit number/ tree obtained with control (T_1) in the first season only, while in the second one the differences were non-significant. As for yield (kg/tree), the results showed that there were statistically different within all treatments. Trees treated with T_{11} recorded the highest fruit yield /tree compared with the lowest yield recorded with control (T_1) in both seasons. The maximum yield (ton/fed.) was produced with trees treated by T_{10} and T_{11} without significant differences between them in the first season. Meanwhile, T_{11} gave the highest yield in the second one followed by T_{10} which gave the second rank. Increasing yield by using soil amendments and GA_3 could be attributed to improve vegetative growth and nutritional status of the treated trees. This conclusion finds support in data presented in Tables 2 and 3. These results are in agreement with those reported by El-Deeb et al. (2013), EL-khawaga and Makled, (2013), Merwed *et al.* (2014) on Valencia orange trees and Zayan *et al.*. (2016) on Washington Navel orange trees. They found that treated trees with bio-fertilizer and Mycorrhizal fungi (VAM) achieved the best fruit yield. Wherease, Ashour *et al.*. (2009) on Balady orange trees and Murovhi (2013) on Valencia oranges trees. They found that application of sulphur or Nile fertile increased fruit yield as fruit weight and number of citrus fruits tree comparing with untreated trees. Also, Koller et al. (2000), Schafer *et al.*. (2000), Mohamed (2005) on Navel orange trees, Shinde *et al.*. (2008) and Manju and Rawat (2015) on local malta orange. They reported that spraying citrus trees with GA_3 at full bloom increased the number of fruits and fruit yield when compared with untreated trees.

Yield and its components

Data presented in Table 4 disclose that T_{11} increased fruit weight followed by T_{10}, T_9. T_8 and T_7 without significant differences among them compared to T_1 and T_2 which recorded the lowest values in this respect in the first season only, while in the second one the differences were not significant. Concerning number of fruit /tree, data revealed that number of fruits /tree was significantly increased under T_{11} and T_{10} treatments without significant differences between them compared to the lowest fruit number/ tree obtained with control (T_1) in the first season only, while in the second one the differences were non-significant. As for yield (kg/tree), the results showed that there were statistically different within all treatments. Trees treated with T_{11} recorded the highest fruit yield /tree compared with the lowest yield recorded with control (T_1) in both seasons. The maximum yield (ton/fed.) was produced with trees treated by T_{10} and T_{11} without significant differences between them in the first season. Meanwhile, T_{11} gave the highest yield in the second one followed by T_{10} which gave the second rank. Increasing yield by using soil amendments and GA_3 could be attributed to improve vegetative growth and nutritional status of the treated trees. This conclusion finds support in data presented in Tables 2 and 3. These results are in agreement with those reported by El-Deeb et al. (2013), EL-khawaga and Makled, (2013), Merwed *et al*. (2014) on Valencia orange trees and Zayan *et al*. (2016) on Washington Navel orange trees. They found that treated trees with bio-fertilizer and Mycorrhizal fungi (VAM) achieved the best fruit yield. Wherease, Ashour *et al*. (2009) on Balady orange trees and Murovhi (2013) on Valencia oranges trees. They found that application of sulphur or Nile fertile increased fruit yield as fruit weight and number of citrus fruits tree comparing with untreated trees. Also, Koller et al. (2000), Schafer *et al*. (2000), Mohamed (2005) on Navel orange trees, Shinde *et al*. (2008) and Manju and Rawat (2015) on local malta orange. They reported that spraying citrus trees with GA_3 at full bloom increased the number of fruits and fruit yield when compared with untreated trees.

Regarding to P content, data in the same table showed that there were significant differences among treatments in both seasons. Trees treated with T_{10} and T_{11} increased P in leaves without significant differences between them in the first season, while in the second one T_{10} and T_{11}followed by T_7 and T_8 recorded the highest values comparing with control (T_1). Moreover, treated trees with T_{11} followed by T_{10} and T_9 significant increased K in leaves comparing to control (T_1) in the first season but in the second one the differences were not significant. This may be attributed to increase of nutrients availability as a result to reduction in soil pH Table 7.

Moreover, Singh and Kappor (1999) point out that, plant hormones being released by mycorrhiza which increase plant root growth cause in turn increasing plant root surface which improves nutrients absorption. However, the observed benefits sulphur application might be attributed to increase of nutrients availability as a result of decreasing in soil pH. A similar observation has been reported by, El-Deeb *et al*. (2013), on Valencia orange trees and El-Zawily (2016) on Washington Navel orange trees. They showed that the highest leaf N, P and K resulted with orange tree inoculated with Mycorrhizal fungi or bio-fertilizer compared with untreated trees. In addition, Ashour *et al*. (2009) on Balady orange trees, Rizk-Alla and Tolba (2010) on Black Monukka grapevines, Murovhi (2013) on Valencia oranges and Soliman and Aaid (2016) on Le Conte pear trees. They found that all soil amendment treatments (Nile fertile at + AM fungi + biofertilizers) significantly increased leaf mineral contents (N, P and K) compared with control. While, Ismail (2007) on Tanarif sweet orange and Abo El-Enin (2012) on Navel orange trees, they reported that spraying trees with 25 ppm GA_3 at full bloom increased leaf N, P and K content.

TABLE 4. Effect of some soil amendments and GA_3 foliar application on yield and its components of Washington Navel orange trees in 2014 and 2015 seasons

Characters / Treatments	Fruit weight (g)		No. of fruit / tree	
	2014	2015	2014	2015
T_1	214.07 c	332.33 a	305.00 i	188.33a
T_2	218.40 c	403.13 a	310.00 h	194.00a
T_3	223.07 bc	350.25 a	312.10 gh	183.33a
T_4	222.87bc	327.57 a	315.07 fg	190.00a
T_5	225.90abc	371.20 a	318.23 ef	205.00a
T_6	225.73abc	390.77 a	320.23 e	187.33a
T_7	238.47ab	344.53 a	325.23 d	191.67a
T_8	231.67abc	370.00 a	330.23 c	193.33a
T_9	239.87 ab	361.27 a	335.07 b	187.33a
T_{10}	241.55 ab	379.73 a	338.17 ab	199.33a
T_{11}	243.60 a	358.00 a	340.07 a	205.00a

TABLE 4. Cont.

Characters / Treatments	Yield (kg /tree)		Yield (Ton /fed)	
	2014	2015	2014	2015
T_1	65.29 j	62.58 i	10.96 f	10.51 h
T_2	67.70 i	73.30 d	11.35 e	12.33 c
T_3	69.62 h	64.21 h	11.96 de	10.79 g
T_4	72.45f	62.78 i	12.61 bc	10.99 f
T_5	71.88 g	76.09 b	12.07 cd	12.78 b
T_6	72.28 f	73.20 d	12.14 cd	12.29 c
T_7	75.11 e	65.46 g	12.17 bc	10.54 h
T_8	76.50 d	71.53 e	12.85 b	12.02 d
T_9	80.37 c	67.71 f	13.50 bc	11.37 e
T_{10}	81.67 b	75.60 c	13.72 a	12.72 b
T_{11}	82.82 a	78.20 a	13.91 a	13.13 a

Any values on the same vertical line for the same character having the same letter are not statistically different according to DMRT.

T_1= Control (Untreated trees). T_2= Mycorrhizae fungi at 15 g/tree/ year.

T_3= T_2+ Sulphur at 1 kg/tree/ year. T_4= T_2+ Nile fertile at 750 g/tree/year.

T_5= T_2+ 2cm Bio-tol /lL water was sprayed at Feb. up to May. T_6= T_2 + Sulphur + 30 ppm GA_3 was sprayed at full bloom stage.

T_7= T_2 + Nile fertile + 30 ppm GA3. T_8= T_2 + Bio-tol + 30 ppm GA_3.

T_9= Phosphorine (Bio-fertal) at 11 g/tree/ year + Nile fertile. T_{10}= Phosphorine (Bio-fertal) + Bio-tol + 30 ppm GA_3.

T_{11}=Phosphorine (Bio-fertal) + Sulphur + 30 ppm GA_3.

Fruit quality

Physical fruit properties

Data in Table 5 show that there were significant differences among treatments in first season only as for fruit length and diameter, but the differences were not significant in the second one. Treated trees by T_{11}, $T1_0$ and T_9 improved fruit dimention compared with the other treatments. The present results are in agreement with those found El-Mohamedy and Ahmed (2009) on mandarin trees, Vadak *et al*. (2014) on sweet oranges and El-Zawily (2016) on Washington Navel orange trees. They indicated that the trees inoculated with bio-fertilizers and Mycorrhizal fungi improved physical fruit quality in terms of fruit length and diameter in comparison to un-inoculated trees. Ahmed et al. (2013) on Valencia orange trees. They found that using sulpher as soil application was significantly very effective in improving fruit quality compared with the check treatment.

Also, Zaghloul (2004), Abo El-Enin (2005) on Washington navel oranges and Ismail (2007) on Tanarif sweet orange, reported that spraying GA_3 increased fruit length and diameter compared with non-treated trees. Concerning peel thickness, data revealed that all treatments compared to control tended to increase peel thickness especially trees treated by $T_{11.}$ These results are in harmony with those obtained by Abd El-Migeed *et al*. (2007) and Reastegar and Rahemi (2008) on Washington Navel orange trees. Data also recorded a significant increase in juice weight percentage by T_{11} and T_7 in the first season without significant differences between them while in the second one treated trees with T_{11} followed by T_{10} increased juice weight percentage compared with the other treatments and control. These results herein are in line with those obtained by Mohamed *et al*. (2009) on mandarin trees, and El-Zawily (2016) on Washington Navel orange trees. They showed that the usage of commercial bio fertilizers increased fruit juice weight percentage compared with control. However, Manju and Rawat (2015) on sweet orange trees, found that, spraying GA_3 on trees increased juice weight percentage.

Chemical fruit properties

Data in Table 6 indicate that T_{11} gave fruits with higher SSC % followed by T_{10}, T_9, T_8 and T_7 compared to the lowest value resulted from T_1 (control). The highest juice acidity (%) was resulted under T_{11}, T_{10}, T_9, T_8, T_7 and T_6 without significant difference among them. Meanwhile, the control treatment (T_1) had significantly low value. Concerning of vitamin C, data in the same table recorded that T_{11} and T_{10} gave the highest contents of vitamin C without significant differences between them in the first season while in the second one T_{11}, T_{10} and T_7 gave the highest values followed by T_9 and T_8 without significant differences between them compared to control (T_1) in both seasons

TABLE 5. Effect of some soil amendments and GA_3 foliar application on physical quality of Washington Navel orange fruits in 2014 and 2015 seasons

Characters / Treatments	Fruit length (cm)		Fruit diameter (cm)	
	2014	2015	2014	2015
T_1	7.44 f	8.72 a	7.37 d	8.39 a
T_2	7.71 de	9.25 a	7.48 cd	8.65 a
T_3	7.83 cd	8.98 a	7.58 bcd	8.64 a
T_4	7.96 bcd	8.58 a	7.95 abc	8.78 a
T_5	7.55 ef	8.90 a	7.50 cd	8.73 a
T_6	7.90 cd	9.54 a	7.51 cd	8.80 a
T_7	7.87 cd	8.67 a	7.36 d	8.40 a
T_8	8.09 abc	8.87 a	8.00 ab	8.74 a
T_9	8.18 ab	8.63 a	8.07 a	8.59 a
T_{10}	8.25 a	9.21 a	8.17 a	8.87 a
T_{11}	8.32 a	8.72 a	8.35 a	8.73 a

TABLE 5. Cont.

Characters / Treatments	Peel thickness (cm)		Juice weight (%)	
	2014	2015	2014	2015
T_1	0.54 b	0.29 b	39.58 g	24.67 c
T_2	0.59 ab	0.35 ab	39.39 g	16.61 h
T_3	0.59 ab	0.29 b	44.21 d	22.55 e
T_4	0.56 b	0.36 ab	47.70 d	22.05 e
T_5	0.56 b	0.42 a	42.31 e	19.44 g
T_6	0.60 ab	0.32 b	42.33 e	21.98 f
T_7	0.60 ab	0.32 b	48.06 a	22.09 e
T_8	0.61 ab	0.34 ab	41.79 f	15.94 i
T_9	0.64 a	0.32 b	47.93 c	23.80 d
T_{10}	0.65 a	0.35 ab	47.85 b	25.80 b
T_{11}	0.66 a	0.42 a	48.62 a	28.78 a

Any values on the same vertical line for the same character having the same letter are not statistically different according to DMRT.

T_1= Control (Untreated trees). T_2= Mycorrhizae fungi at 15 g/tree/ year.
T_3= T_2+ Sulphur at 1 kg/tree/ year. T_4= T_2+ Nile fertile at 750 g/tree/year.
T_5= T_2+ 2cm Bio-tol /lL water was sprayed at Feb. up to May. T_6= T_2 + Sulphur + 30 ppm GA_3 was sprayed at full bloom stage.
T_7= T_2 + Nile fertile + 30 ppm GA3. T_8= T_2 + Bio-tol + 30 ppm GA_3.
T_9= Phosphorine (Bio-fertal) at 11 g/tree/ year + Nile fertile. T_{10}= Phosphorine (Bio-fertal) + Bio-tol + 30 ppm GA_3.
T_{11}=Phosphorine (Bio-fertal) + Sulphur + 30 ppm GA_3.

TABLE 6. Effect of some soil amendments and GA_3 foliar application on chemical quality of Washington navel orange fruits in 2014 and 2015 seasons

Characters / Treatments	SSC (%)		Acidity (%)	
	2014	2015	2014	2015
T_1	10.65 d	9.07 a	1.07 d	0.99 a
T_2	12.15abc	8.82 a	1.21 c	0.99 a
T_3	11.65bcd	8.40 a	1.28 abc	0.97 a
T_4	11.27 cd	9.00 a	1.26 bc	1.07 a
T_5	12.03 a-d	8.50 a	1.21 c	1.01 a
T_6	12.53abc	8.52 a	1.34 abc	1.04 a
T_7	11.73 a-d	9.08 a	1.30 abc	1.02 a
T_8	12.66abc	8.12 a	1.36 ab	1.03 a
T_9	12.68abc	8.40 a	1.37 ab	1.16 a
T_{10}	12.93 ab	8.50 a	1.39 ab	1.07 a
T_{11}	13.13 a	8.77 a	1.41 a	1.26 a

TABLE 6. Cont.

Characters / Treatments	SSC/Acid ratio		Vitamin C (mg ascorbic acid/100 ml fresh juice)	
	2014	2015	2014	2015
T_1	9.97 a	9.36 a	36.72 d	35.81 d
T_2	10.04 a	9.03 a	40.23 c	40.96 bc
T_3	9.25 a	9.17 a	42.48 bc	37.37 cd
T_4	8.97 a	8.59 a	42.65 bc	41.52 bc
T_5	10.03 a	8.47 a	41.97 c	38.50 cd
T_6	9.41 a	8.43 a	41.37 c	44.30 ab
T_7	8.96 a	9.31 a	43.67abc	46.65 a
T_8	9.30 a	7.18 a	41.92 c	43.60 ab
T_9	9.23 a	7.41 a	42.30 c	45.51 ab
T_{10}	9.30 a	8.09 a	45.72 ab	47.79 a
T_{11}	9.31 a	7.05 a	46.57 a	47.65 a

Any values on the same vertical line for the same character having the same letter are not statistically different according to DMRT.

T_1= Control (Untreated trees). T_2= Mycorrhizae fungi at 15 g/tree/ year.

T_3= T_2+ Sulphur at 1 kg/tree/ year. T_4= T_2+ Nile fertile at 750 g/tree/year.

T_5= T_2+ 2cm Bio-tol /lL water was sprayed at Feb. up to May. T_6= T_2 + Sulphur + 30 ppm GA_3 was sprayed at full bloom stage.

T_7= T_2 + Nile fertile + 30 ppm GA3. T_8= T_2 + Bio-tol + 30 ppm GA_3.

T_9= Phosphorine (Bio-fertal) at 11 g/tree/ year + Nile fertile. T_{10}= Phosphorine (Bio-fertal) + Bio-tol + 30 ppm GA_3.

T_{11}=Phosphorine (Bio-fertal) + Sulphur + 30 ppm GA_3.

The above mentioned results are in accordance with those reported by El-khawega and Maklad (2013) on Valencia orange trees, El- khayat and Abd El-Rehiem (2013) on Balady mandarin trees, Dutta et al. (2014), Vadak et al. (2014) on Sweet oranges and El-Zawily (2016) on Washington Navel orange trees. They found that treated trees with bio-fertilizers and Mycorrhizal fungi increased TSS, total acidity %, SSC / acid ratio and vitamin C content compared with non- treated trees. While, Ashour et al. (2009) on Balady orange trees and Ahmed et al. (2013) on Valencia orange trees. They showed that SSC%, SSC/acid ratio, vitamin C content were increased while total acidity % was decreased when the trees treated with Nile fertile + citric acid + Dynamic compared with untreated trees. However, Ibrahim (2007) on Valencia orange trees and Saleem et al. (2008) on Balady sweet orange trees, they showed that, spraying the trees with GA_3 improved chemical fruit quality (SSC, vitamin C and acidity) compared to unsprayed trees.

Soil properties

Soil pH and salinity(EC)

Data obtained in Table 7 show that values of soil pH were slightly decreased with applying T_{11}, T_{10}, T_9, T_8, T_7, T_6 and T_5 comparing with other treatments and control (T_1). Moreover, EC values were decreased with all soil amendments treatments compared with control. These results are in harmony with those obtained by Miller et al. (1990) showed that the beneficial effects of sulphur on fruiting of Valencia orange trees might be attributed to its favorable effects on decreasing soil pH and soil salinity as well as increasing uptake of all nutrients. Also, Idso et al. (1995), Zeerban et al (2000), Atom (2013), and Soliman and Aaid (2016) found that soil pH and EC slightly decreased with applied sulphur and bio-fertilizers as soil application compared with control.

Available soil macronutrients and its organic matter

Data presented in Table 7 show that the soil available macronutrients (N, P and K) and organic matter% tended to increase with all soil amendments treatments compared to untreated trees. These results in confirmed with those obtained by Zeerban et al (2000), Mir et al. (2014), Soliman and Aaid (2016) and Zayan et al. (2016). They found that soil amendment treatments including sulfur and bio-fertilizers significantly increased available soil N, P, k and soil organic matter content compared with control.

TABLE 7. Effect of some soil amendments and GA_3 foliar application on some physical and chemical properties at the end of experiment

Characters / Treatments	pH	EC (dS m^{-1})	Available macronutrients (ppm)			O.M. (%)
			N	P	K	
T_1	8.30	2.43	25.65	7.02	372.90	1.07
T_2	8.10	1.64	24.47	7.17	381.13	1.22
T_3	8.00	1.62	23.50	7.13	382.83	1.24
T_4	8.03	1.65	24.44	7.17	380.20	1.32
T_5	7.92	1.59	25.43	7.17	381.13	1.29
T_6	7.96	1.60	24.37	7.18	381.83	1.32
T_7	7.93	1.57	25.40	5.16	381.33	1.32
T_8	7.85	1.72	25.10	7.15	380.83	1.33
T_9	7.93	1.70	25.80	7.21	381.83	1.26
T_{10}	7.83	1.88	26.13	7.23	380.80	1.23
T_{11}	7.88	1.89	25.1	7.39	382.17	1.28

Any values on the same vertical line for the same character having the same letter are not statistically different according to DMRT.
T_1= Control (Untreated trees). T_2= Mycorrhizae fungi at 15 g/tree/ year.
T_3= T_2+ Sulphur at 1 kg/tree/ year. T_4= T_2+ Nile fertile at 750 g/tree/year.
T_5= T_2+ 2cm Bio-tol /lL water was sprayed at Feb. up to May.
T_6= T_2 + Sulphur + 30 ppm GA_3 was sprayed at full bloom stage.
T_7= T_2 + Nile fertile + 30 ppm GA3. T_8= T_2 + Bio-tol + 30 ppm GA_3.
T_9= Phosphorine (Bio-fertal) at 11 g/tree/ year + Nile fertile. T_{10}= Phosphorine (Bio-fertal) + Bio-tol + 30 ppm GA_3.
T_{11}=Phosphorine (Bio-fertal) + Sulphur + 30 ppm GA_3.

Soil microbial counts and dehydrogenase activity

Data in Figs. 1 and 2 illustrate that there were significant differences among all treatments. Microbial counts (colonies number of fungi, bacteria and yeast) and dehydrogenase activity were increased under T_7 and T_8 followed in decreasing order T_{10}, T_{11}, T_3, T_4, T_9 and T_6 in both seasons. This increasing may due to the essential roles of organic and bio-fertilization on enhancing soil fertility, micro-flora activity, natural hormones, antioxidants, vitamins B and antibiotics which resulted in enhancing dehydrogenase activity (Dahama, 1999 and Kannaiyan, 2002). The obtained results are in agreement with those reported by Rizk-Alla and Tolba (2010), Allam *et al.* (2012), Mir *et al.* (2014) and Zayan *et al.* (2016). They reported that application of bio-fertilizers, arbuscular mycorrhizae (AM) fungi and Nile fertile gave the highest soil microorganisms (fungi, bacteria and yeast) content and the dehydrogenase activity compared with control.

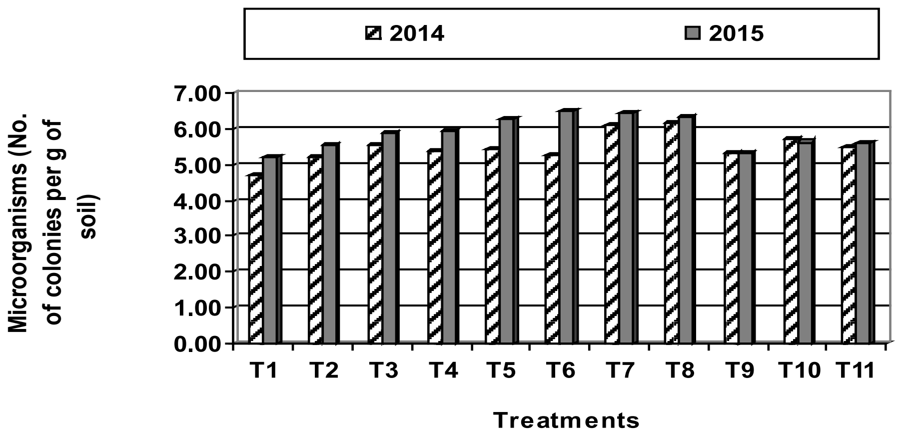

Fig. 1. Effect of some soil amendments and GA_3 foliar application on soil microbial counts in 2014 and 2015 seasons

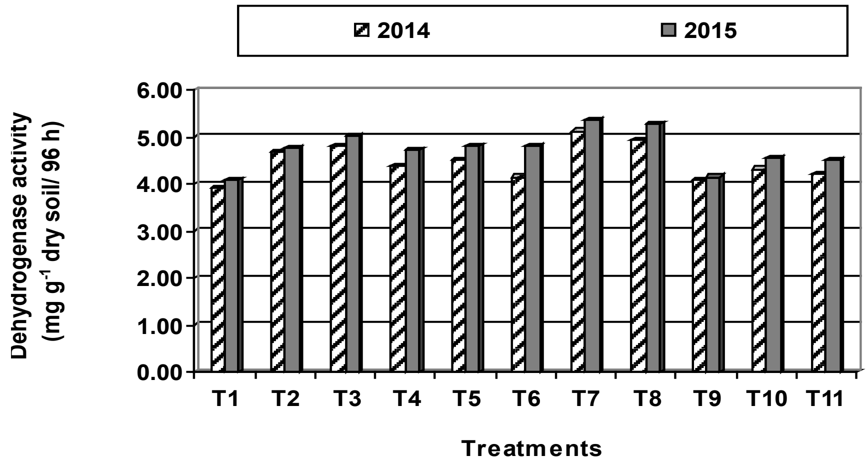

Fig. 2. Effect of some soil amendments and GA_3 foliar application on soil dehydrogenase activity in 2014 and 2015 seasons

Conclusion

From the obtained results, it could be recommended Washington Navel orange growers on clay soil to add T_{11} or T_{10} followed by T_9 and T_7 treatments for its positive effects on most soil properties and stimulating vegetative growth and improving nutritional status, yield and fruit quality of Washington Navel orange trees under conditions of this experiment at Kafrelsheikh governorate.

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إستجابة أشجار البرتقال بسره لبعض مُحسنات التربة والرش بالجبريلين تحت ظروف الأراضي الطينية

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أجريت هذه الدراسة خلال موسمي 2014 و 2015م على أشجار البرتقال بسره عمر 8 سنوات مطعومه على أصل النارنج ومنزرعة بقرية شنو-محافظة كفر الشيخ- مصر بهدف دراسة تأثير بعض محسنات التربة والرش بالجبريلين على النمو الخضري والحالة الغذائية والمحصول وجودة الثمار وكذلك خواص التربة. وتم ترتيب التجربة في تصميم القطاعات الكاملة العشوائية وتضمنت الدراسة (11) معاملة مركبة كالأتى:-1 الكنترول (أشجار غير معاملة), -2الميكروهيزا 15جم/شجرة/السنة, -3الميكروهيزا 15جم/شجرة/السنة + الكبريت 1كجم/شجرة/السنة -4الميكروهيزا 15جم/شجرة/السنة + نايل فرتيل 750جم/شجرة/السنة, -5الميكروهيزا 15جم/شجرة/السنة + البيوتول 2سم/1لتر رشاً من شهر فبراير حتى مايو, -6الميكروهيزا + الكبريت + 30جزء في المليون جبريلين (GA_3) رشاً في مرحلة الإزهار الكامل, -7الميكروهيزا + نايل فرتيل + 30جزء في المليون جبريلين (GA_3), 8- الميكروهيزا + البيوتول+ 30جزء في المليون جبريلين (GA_3), 9- الفوسفورين (البيوفيرتال) 11جم/شجرة/السنة + نايل فرتيل,-10الفوسفورين (البيوفيرتال) 11جم/شجرة/السنة + البيوتول + 30جزء في المليون جبريلين (GA_3), 11- الفوسفورين (البيوفيرتال) + الكبريت + 30جزء في المليون جبريلين (GA_3). بالإعتماد على النتائج المتحصل عليها من هذه الدراسة فإن الأشجار التي عوملت بالمعاملة 11 [الفوسفورين (البيوفيرتال) 11جم/شجرة/السنة + الكبريت 1كجم/شجرة/السنة + 30جزء في المليون جبريلين (GA_3)] تليها المعاملة 7 كانت أكثر تأثير إيجابياً في قياسات النمو الخضري (حجم مظلة الشجرة ومساحة الورقة والوزن الجاف للورقة وكذلك الوزن النوعي لنموات دورة الربيع) وزيادة محتوى الأوراق من الكلورفيل والعناصر الغذائية في كلا موسمي الدراسة. المعاملة 11 تليها العاملة 10 و9 و8 و7 أعطت أحسن محصول وصفات جودة للثمار مقارنة للأشجار الغير معاملة (المعاملة 1) . بالنسبة pH و ECالتربة كان هناك أنخفاض واضح بينما كان هناك زيادة في قيم محتوي التربة من النيتروجين والفوسفور والبوتاسيوم الميسر ونشاط الكائنات الحية الدقيقة وكذا نشاط انزيم الديهيدروجينيز للاشجار المعاملة بالمعاملات 11 و10 و9 و7 مقارنة بالكنترول.

لذلك توصي هذه الدراسة مزارعي أشجار البرتقال بسره بإضافة المعاملة 11 أو المعاملة 7 أو إضافة المعاملة 10 أو 9 وذلك لتحسين النمو الخضري والحالة الغذائية والمحصول وجودة الثمار وكذلك خواص التربة للحصول علي أعلى عائد لأشجار البرتقال بسره في الأرض الطينية تحت ظروف محافظة كفر الشيخ.