Asian Journal of Advances in Agricultural Research

4(3): 1-13, 2017; Article no.AJAAR.37900
ISSN: 2456-8864

Impact of Citric Acid, Ascorbic Acid and Some Nutrients (Folifert, Potaqueen) on Fruit Yield and Quality of Washington Navel Orange Trees

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Authors' contributions

This work was carried out in collaboration between all authors. Authors HEMEB, SFEG and MHMB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript and managed the analyses of the study. Author AAEK managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJAAR/2017/37900
Editor(s):
(1) Muhammad Azam, Professor, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan.
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(3) Ashraf Ezzat Hamdy, Al-Azhar University, Egypt.
Complete Peer review History: http://prh.sdiarticle3.com/review-history/22578

Original Research Article

Received 1st November 2017
Accepted 1st January 2018
Published 3rd January 2018

ABSTRACT

The present study was conducted on 11-year-old Washington navel orange trees budded on sour orange rootstock grown in loamy sand soil under surface irrigation system at a private orchard at Manzala village, Toukh region, Qalubia Governorate, Egypt during 2015 &2016 seasons. to investigate the influence of foliar application with citric acid (CA) 1 g/L, ascorbic acid (AA) 1 g/L, Folifert 1.5 g/L and Potaqueen 3 g/L on fruiting aspects and fruit quality. However, the beneficial effect varied greatly from one investigated treatment to another. Anyhow, the treatment T_{12} (Ascorbic acid at 1 g/L+ Folifert at 1.5 g/L + Potaqueen at 3 g/L) was statistically the superior for Washington navel orange trees during two experimental seasons. Also T_{11} (Citric acid at 1 g/L+ Folifert at 1.5 g/L+ Potaqueen at 3 g/L) came second. The reverse was true with the water sprayed treatment (control) which ranked statistically the last rank during the two experimental seasons the trend was true almost with all the investigated measurements, fruiting aspects (fruit set, fruit

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retention and yield as No. or weight of harvested fruits per trees besides yield per one tree, and fruit quality: a- physical properties (average fruit weight, fruit dimension s, shape index, peel thickness and fruit juice volume), b- chemical properties (TSS%, total acidity %, TSS/Acid ratio, total sugars and vitamin C contents). On the other hand, nine other investigated treatments were in-between the aforesaid two extremes, in spite of the statistically varied as compared to the abovementioned superior (T_{12}) and inferior (T_1) treatments during two experimental seasons.

Keywords: Washington navel orange; citric acid; ascorbic acid; fruiting aspects; fruit quality; Folifert and Potaqueen.

1. INTRODUCTION

(Citrus is considered to be one of the world's most common popular and favorite fruit. In Egypt, [420333.6 faddans = one faddan = 0.42ha) (more than 39% from total fruit area) are planted with citrus trees. The production of citrus in Egypt was increased to 3980151 tonnes in 2012 [1]. Thus, Egypt is considered to be one of the ten largest producers of citrus in the world. Thereby, strenuous efforts have always been exerted for increasing production of citrus through a better understanding of its reaction to environment and mineral nutrition.

The small antioxidant molecule vitamin C (L-ascorbic acid, AA) fulfills essential metabolic functions in the life of animals and plants. Some fungi can synthesize erythro-ascorbic acid, a vitamin C analogue with similar metabolic functions. Among prokaryotes, only cyanobacteria have been reported to have a small AA amount [2].

Ascorbic acid is a regulator of plant growth and development owing to its effects on cell division and differentiation and it involves in wide range of important functions such as antioxidants defense, photo protection and regulation of photosynthesis and growth regulation. [3] Reported that ascorbic acid gave the best yield and bunch quality on Flame seedless grapevine.

Citric acid plays an essential role in signal transduction system, membrane stability and functions, activating transporter enzymes, metabolism and translocation of carbohydrates [4]. Also, citric acid as antioxidant is suggested mainly for improving yield and fruit in terms of increasing fruit weight, total soluble solids%, and total reducing sugar Introduction and in decreasing pear fruit firmness and total acidity as compared with unsprayed one [5].

Many investigations studied the effect of spraying macro and micronutrients on growth, yield and fruit quality. Such as nitrogen, phosphorus, potassium, magnesium zinc, manganese and boron [6-14] were highly effective in improving, nutritional status, yield and quality of different fruit trees.

Thus, this study aimed to investigate the influence of foliar application with citric acid (CA), ascorbic acid (AA), Folifert and Potaqueen on yield aspects and fruit quality of Washington navel orange trees.

2. MATERIALS AND METHODS

This study was carried out during 2015 & 2016 seasons on 11-year-old Washington navel orange trees budded on sour orange rootstock grown at 5.0 meters a parts in loamy sand soil under surface irrigation of a private orchard at Manzala village, Toukh region, Qaloubia Governorate, Egypt. All trees were subjected to the same horticultural practices [irrigation, fertilization, weeds & pest control] adopted in the region according to the recommendation of the Ministry of Agriculture (250 kg nitrogen fertilizers, 200 kg phosphorus fertilizers and 100kg potassium fertilizers). It was devoted to investigate the influence of foliar application with citric acid (CA), ascorbic acid (AA), Folifert (Folifert content: Zn 7.06%, Mn 4.20, Fe 2.80%, Cu 2% and B 0.6%) and Potaqueen (Potaqueen content: N 5%, P 5% and K 36.5%) in addition to tap water as control treatment.

The treatments used in this study as follow:

- T_1 - Tap water (control).
- T_2 - Citric acid (CA) at 1g/L.
- T_3 - Ascorbic acid (AA) at 1g/L.
- T_4 - Folifert at 1.5g/L.
- T_5 - Potaqueen at 3g/L.
- T_6 - (CA) at 1g/L+ Folifert at 1.5g/L.
- T_7 - (CA) at 1g/L+ Potaqueen at 3g/L.
- T_8 - (AA) at 1g/L+ Folifert at 1.5g/L.
- T_9 - (AA) at 1g/L+ Potaqueen at 3g/L.
- T_{10}- Folifert at 1.5g/L+ Potaqueen at 3g/L.

T_{11}- (CA) at 1 g/L+ Folifert at 1.5 g/L+ Potaqueen at 3 g/L.
T_{12}- (AA) at 1 g/L+ Folifert at 1.5 g/L+ Potaqueen at 3 g/L.

2.1 Experiment Layout

The complete randomized block design with three replications was employed for arranging the twelve investigated treatments, whereas each replicate was represented by a single tree. Consequently, 36 healthy fruitful Washington navel orange trees were carefully selected, as being healthy, disease free and in the on-year state. Chosen trees were divided according to their growth vigor into three categories [blocks] each included 12 similar trees for receiving the 12 investigated treatments [a single tree was randomly subjected to one treatment].

Taking into consideration that spray treatments were applied covering the whole foliage of each tree canopy, whereas 5 liters found to be sufficient in this concern. Periodically applied 6 times/season at one-month interval [in 1st week of February, March, April, May, June and July].

Methodology as has been reported in this study in order to evaluate the response to various investigated treatments was carried out through determining changes in different measurements of the following examined characteristics:

> On late March 2015 and early April 2016 four main branches [limbs/scaffolds] well distributed around each tree periphery were carefully selected and tagged during 1st and 2nd seasons, respectively. Moreover, 20 newly spring developed shoots were also labeled.

2.2 Fruiting Measurements

2.2.1 Fruit set percentage

At full bloom during each experimental season number of perfect flowers per each tagged limb was counted. After 75% of petal fall fruit set as value of perfect flowers were estimated according the following equation used by [15].

Fruit set % = (Number of set fruitlets/limb/ No. of opened flowers/limb) x 100

2.2.2 Fruits retention and drop %

Percentage of both retained and dropped fruits, were periodically determined on August 1st according to the following equations:

Fruits retention (%) per tree = (Number of presented (remained) fruits at a given date/ Number of set fruitlets) x 100

Fruits drop % = (Number of dropped fruits at a given date/ Number of set fruitlets) x 100

2.2.3 Yield

On mid December 2015 and 2016 fruits of each individual tree were separately harvested, then counted and weighed. Tree productivity (yield) was estimated either as a number or weight (kg) of harvested fruits per each tree. Besides, yield per each tree.

2.3 Fruit Quality

2.3.1 Fruit physical properties

In this regard average fruit weight (g) [using ten fruit]; dimensions (polar and equatorial diameters i.e., length and width in cm.); fruit shape index (length: width); juice volume (cm^3) and peel/rind thickness (mm) were the fruit physical characteristics investigated in this regard.

2.3.2 Fruit chemical properties

Fruit juice volume, total soluble solids percentage (TSS%) was determined using a Carl Zeiss hand refract meter. Total acidity as grams of citric acid per 100 ml fruit juice was determined after [16]. Total soluble solids/ acid ratio were also estimated. Ascorbic acid (Vitamin C) content was determined using 2, 6 dichlorophenol indophenol indicator for titration after [16]. Moreover, total sugars values were determined according to the method described by [17].

2.4 Statistical Analysis

All data obtained during both seasons for experiments included in this investigation were subjected to analysis of variance according to [18]. In addition, significant differences among means were differentiated according to the Duncan, multiple test range [19] where capital letters were used for distinguishing means of different treatments for each investigated characteristic.

3. RESULTS AND DISCUSSION

3.1 Some Fruiting Aspects of Washington Navel Orange Trees

3.1.1 Fruit set percentage (%)

Table 1 displays obviously that eleven investigated treatments with citric acid, ascorbic acid, Folifert and Potaqueen solely or if combined together will increased significantly the fruit set value over control (T_1) however T_{12} (Ascorbic acid at 1 g/L+ Folifert at 1.5 g/L.+ Potaqueen at 3 g/L) was statistically the superior. Whereas, the greatest fruit set % in Washington navel orange trees i.e. 23.99 and 23.89% were exhibited during 2015 and 2016 experimental seasons, respectively. However, T_{11} (Citric acid at 1 g/L+ Folifert at 1.5 g/L.+ Potaqueen at 3 g/L) ranked statistically second. Descending values are followed by T_{10}, T_7, T_9, T_8 and T_5 during both 2015 and 2016 experimental seasons. In addition, T_2 (Citric acid 1 g/L) and T_3 (Ascorbic acid 1 g/L) were the least effective as both came last just prior the control (T_1) during both 2015 and 2016 experimental seasons.

3.1.2 Fruit retention %

It is quite evident as shown from tabulated data in Table 2 that fruit retention followed similar trend previously which detect with fruit set value. The greatest fruit retention which was significantly coupled with Washington navel orange trees subjected to T_{11} (Citric acid at 1g/L+ Folifert at 1.5 g/L.+ Potaqueen at 3 g/L) and T_{12} (Ascorbic acid at 1g/L+ Folifert at 1.5g/L.+ Potaqueen at 3 g/L) during two experimental seasons, respectively. Moreover, T_{10} (Folifert at 1.5 g/L+ Potaqueen at 3 g/L) ranked statistically second regarding its efficiency to increase fruit retention score i.e., showed 15.86 & 16.34% during 2015 and 2016 experimental seasons, respectively. On the contrary, the lowest fruit retention value was significantly induced by water spray Washington navel orange trees (control) i.e., 9.24 and 9.60 during 2015 and 2016 experimental seasons, respectively. In addition, other investigated treatments were in-between the aforesaid two extremes.

3.1.3 Fruit drop percentage (%)

It is quite clear that as shown from tabulated data in Table (1) that an opposite trend to the previously found with retained fruit value was obviously detected in this respect. On other side, all investigated fertilizers treatments resulted significantly in reducing fruit drop percentage as compared to T_1 (control). The most effective treatments for reducing fruit drop% in closed relationship to the Washington navel orange trees subjected to T_{11} (Citric acid at 1 g/L+ Folifert at 1.5 g/L.+ Potaqueen at 3 g/L) and T_{12} (Ascorbic acid at 1 g/L+ Folifert at 1.5 g/L.+ Potaqueen at 3 g/L) during both 2015&2016 experimental seasons.

Table 1. Effect of some antioxidants, Folifert and Potaqueen on fruit set (%), fruit retained (%) and fruit drop (%) of Washington navel orange trees during 2015 and 2016 experimental seasons

Parameters	Fruit set (%)		Fruit retained (%)		Fruit drop (%)	
Treatments / Seasons	1st	2nd	1st	2nd	1st	2nd
T_1: Control (Water spray)	14.40h	14.12 i	9.24 i	9.60 h	90.76 a	90.40 a
T_2: Citric acid at 1g/L	15.00 g	15.06h	9.87 h	10.17 g	90.13 b	89.83 b
T_3: Ascorbic acid at 1g/L	15.34 g	15.18h	10.14 g	10.39 f	89.86 c	89.61 c
T_4: Folifert at 1.5g/L	18.10 f	18.14 g	12.81 f	13.48 d	87.19 d	86.52 e
T_5: Potaqueen at 3g/L	18.73 e	18.76 f	13.8 e	14.14 c	86.20 e	85.86 f
T_6: Citric at 1g/L+ Folifert at 1.5 g/L	18.72 e	18.62 f	1293 f	13.00 e	87.07 d	87.00 d
T_7: Citric at 1g/L+ Potaqueen at 3g/L	19.94d	20.48d	14.07 d	14.16 c	85.93 f	85.84 f
T_8: Ascorbic at 1g/L+ Folifert at 1.5g/L	18.91 e	18.64 f	12.9 f	13.01 e	87.10 d	86.99 d
T_9: Ascorbic at 1g/L+ Potaqueen at 3g/L	19.88d	20.05 e	14.82 c	15.23 b	85.18 g	84.77 g
T_{10}: Potaqueen at 3g/L + Folifert at 1.5g/L	22.06 c	21.81 c	15.86 b	16.34 a	84.14 h	83.66 h
T_{11}: Citric at 1g/L + Folifert at 1.5g/L + Potaqueen at 3g/L	23.21b	22.88b	16.17 a	16.30 a	83.83 i	83.70 h
T_{12}:Ascorbic at 1g/L+ Folifert at 1.5g/L+ Potaqueen at 3g/L	23.99 a	23.89 a	16.12 a	16.40 a	83.84 i	83.60 h

Values within each column followed by the same letter/s are not significantly different at 5% level

The obtained results concerning the positive effect of foliar sprays with citric and ascorbic acid on some fruiting aspects of Washington navel orange trees go in line with the findings of [20] on "Anna" apple trees, [21] on "Kinnow", [22] on Swelling peach trees and [23] on Washington navel orange.

The obtained results of foliar sprays with the Folifert on some fruiting aspects of Washington navel orange trees are in harmony with earlier reports of [24] and [25] on Washington navel orange trees. They noticed that spraying Fe, Mn and Zn alone or in combination increased total yield as well as fruit weight and fruit number of Washington navel orange trees.

Obtained results regarding the positive influence of fertilizers treatments by the Potaqueen (N, P and K) on increasing some fruiting aspects of Washington navel orange cultivar are in agreement with the findings of [26] and [27] on orange. Also, [23] on Washington navel orange trees.

3.2 Average Fruit Weight (g), Number of Fruits/Tree and Yield/Tree (kg) of Washington Navel Orange Trees

Yield of the Washington navel orange trees, expressed either as average weight, number and yield of harvested fruit per tree were investigated three productivity parameters regarding the response to differential investigated treatments. Data obtained during both 2015 and 2016 experimental seasons are presented in Table 2.

All measurement of tree productivity i.e. average fruit weight, number of fruit per tree and yield per tree of harvested Washington navel orange fruits responded positivity and significantly to the various investigated treatments. Herein, three measurements were increased by all investigated treatments compared to control (T_1). Meanwhile, three cropping parameters of tree productivity followed the same trend. Whereas, T_{12} (Ascorbic acid at1g/L+ Folifert at 1.5g/L.+ Potaqueen at 3g/L) surpassed statistically all other investigated treatments during 2015 and 2016 experimental seasons. However, T_{11} (Citric acid at 1g/L+ Folifert at 1.5g/L+ Potaqueen at 3g/L) particularly in the second season ranked statistically second after the superior (T_{12}). In addition, treatments (fromT_{10} to T_4) were significantly more effective than T_1, T_2, and T_3. Such trend was true during 2015 and 2016 experimental seasons. However, the variance in response between three measurements of tree productivity was in positive relationship to increase exhibited over control (T_1) by giving nutritive treatment.

The obtained results concerning the positive effect of foliar sprays with citric and ascorbic acid on some fruiting aspects of Washington navel orange trees go in line with the findings of [28] on"Manfalouty" pomegranate trees, [29] on "Banaty" grapevines, [30] on

Table 2. Effect of some antioxidants, Folifert and Potaqueen on average fruit weight (g), number of fruits/tree and yield/tree (Kg) of Washington navel orange trees during 2015 and 2016 experimental seasons

Parameters	Average fruit weigh (g)		No. of fruits/tree		Yield/tree (Kg)	
Treatments / Seasons	1st	2nd	1st	2nd	1st	2nd
T_1: Control (Water spray)	220.00k	219.73j	97.00 g	95.67h	21.35 j	21.03 i
T_2: Citric acid at 1g/L	230.33 j	234.67i	102.67 f	101.33g	23.65 i	23.79 h
T_3: Ascorbic acid at 1g/L	236.67 i	238.00h	104.00 f	102.33g	24.62 i	24.36 h
T_4: Folifert at 1.5g/L	252.33h	255.67g	132.67 e	130.33f	33.49 h	33.34 g
T_5: Potaqueen at 3g/L	263.33 f	266.67f	141.30 d	139d	37.23 f	37.08 e
T_6: Citric at 1g/L+ Folifert at 1.5 g/L	253.60h	256.67g	135.67 e	133.67e	34.43 h	34.32 g
T_7: Citric at 1g/L+ Potaqueen at 3g/L	265.67e	269.33e	149.33 c	146.67c	39.69 e	39.51 d
T_8: Ascorbic at 1g/L+ Folifert at 1.5g/L	256.33g	256.67g	141.00 d	140.33d	36.15 g	36.03 f
T_9: Ascorbic at 1g/L+ Potaqueen at 3g/L	272.33d	273.33d	151.67 c	148.67c	41.31 d	40.64 c
T_{10}: Potaqueen at 3g/L + Folifert at 1.5g/L	285.00c	286.00c	163.00 b	159.67b	46.48 c	45.68 b
T_{11}: Citric at 1g/L + Folifert at 1.5g/L + Potaqueen at 3g/L	291.00b	293.66b	166.67 a	164.33a	48.51 b	48.27 a
T_{12}:Ascorbic at 1g/L+ Folifert at 1.5g/L+ Potaqueen at 3g/L	294.33a	296.66a	168.33 a	165.67a	49.56 a	49.16 a

Values within each column followed by the same letter/s are not significantly different at 5% level

"Thompson seedless" grapevines, [31] on " Kelsey" plum trees, [5] on "Le-Conte" pear trees, [32] on mango cultivars (Zebda, Awase, Alphonso and Taimour), [20] on “Anna" apple trees, [21] on "Kinnow", [22] on Swelling peach trees and [23] on Washington navel orange.

The obtained results of foliar sprays with Folifert on some fruiting aspects of Washington navel orange trees are in harmony with earlier reports of [33], [34], [24] and [25] on Washington navel orange trees. They noticed that spraying Fe, Mn and Zn alone or in combination increased total yield as well as fruit weight and fruit number of Washington navel orange trees.

Obtained results regarding the positive influence of fertilizers treatments by the Potaqueen (N, P and K) on increasing some fruiting aspects of Washington navel orange cultivar are in agreement with the findings of [35-40] on mango, [41] on mandarin, [26] and [27] on orange. They mentioned that spraying the aforementioned fruit crop species with N, P, and K alone or in combinations gave the best results with regard yield expressed in weight and number of fruits per tree. Also, [23] demonstrated that the highest potassium silicate (0.20%) in combination with two salicylic acid concentrations (100 & 200 ppm) particularly higher one were the most effective for most measurements of fruiting aspects (fruit set, fruit retention and yield as No. or weight of harvested fruits per trees of Washington navel orange trees.

3.3 Fruit Quality Measurements of Washington Navel Orange Trees

3.3.1 Fruit physical properties

In this regard average fruit weight (g.); dimensions (polar and equatorial diameters i.e., length and width in cm.); fruit shape index (length: width); juice volume (cm^3) and peel/rind thickness (mm) were the fruit physical characteristics investigated in this regard.

3.3.2 Fruit dimensions

The polar and equatorial fruit diameters of Washington navel orange fruits were the investigated two fruit dimensions regarding their response to differential treatments. Table 3 shows obviously that both parameters responded significantly to some treatments. However, T_{12} (Ascorbic acid at 1 g/L+ **Folifert** at 1.5 g/L+ Potaqueen at 3 g/L) was the superior and resulted significantly in the tallest polar and equatorial diameters.

Statically followed by T_{11} (Citric acid at 1 g/L+ Folifert at 1.5 g/L.+ Potaqueen at 3 g/L) which followed by T_{10} (Folifert at 1.5 g/L.+ Potaqueen at 3 g/L). On the contrary, T_1 (control), T_2 (Citric acid at 1 g/L) and T_3 (Ascorbic acid at 1 g/L) which induced significantly the poorest fruits in their dimensions during 2015 and 2016 experimental seasons. In addition, other investigated treatments were in-between the aforesaid extremes either noticeable degree of efficiency linked with T_7 (Citric acid at 1 g/L+ Potaqueen at 3 g/L) and T_6 (Citric acid at 1 g/L+ Folifert at 1.5 g/L) compared to the analogous members of such intermediate treatments. Such trend was true during 2015 and 2016 experimental seasons.

3.3.3 Fruit shape index

Concerning the fruit shape index (polar diameter: equatorial diameter) of Washington navel orange cv. In response to differential investigated treatments, Table 3 shows clearly that the variances were relatively too few to be taking into consideration from the statistical point of few. Such trend was during 2015 and 2016 experimental seasons. Variations in fruit shape index indices due to the differential investigated treatment could be logically explained on the unparalleled response of two fruit dimension to a given treatment. Since, in most cases the increase in fruit polar diameter was relatively higher than those resulted in fruit equatorial diameter as the response to each treatment was individually taking into consideration.

3.3.4 Fruit peel thickness (mm)

Concerning the response of fruit peel thickness to the differential investigated treatments. Table 4 display obviously that Washington navel orange fruits of subjected trees to T_{12} (Ascorbic acid at 1 g/L+ Folifert at 1.5 g/L+ Potaqueen at 3 g/L) had significantly the thickest fruit peel thickness i.e., 3.25 and 3.33 mm during 2015 and 2016 experimental seasons, respectively statistically in the thickest fruit peel thickness followed by T_{11} (Citric acid at 1 g/L+ Folifert at 1.5 g/L+ Potaqueen at 3 g/L). Moreover, other treatments could be arranged into the following descending order. T_{10} (Folifert at 1.5 g/L.+ Potaqueen at 3 g/L), T_9 (Ascorbic acid at 1 g/L.+ Potaqueen at 3 g/L), T_7 (Citric acid at 1 g/L+ Potaqueen at 3 g/L) and T_5 (Potaqueen at 3 g/L) which ranked 3rd , 4th, 5th and 6th after aforesaid two superior treatments. Such trend was during both experimental seasons, the reverse was true with ware sprayed (T_1) Washington navel orange trees where the thinnest peel thickness (2.54 and 2.57 mm) were resulted during 2015 and 2016 experimental seasons, respectively.

3.4 Fruit Chemical Properties

3.4.1 Juice volume (cm^3)

The response of fruit juice volume of various investigated treatments as shown from Table 4 declared that investigated treatments increased it significantly over control during both experimental seasons of study. Generally, it could be noticed the superiority of T_{12} (Ascorbic acid at 1 g/L+ Folifert at 1.5 g/L+ Potaqueen at 3 g/L) followed by T_{11} (Citric acid at 1g/L+ Folifert at 1.5 g/L+ Potaqueen at 3 g/L) and T_{10} (Folifert at 1.5 g/L.+ Potaqueen at 3g/L) in both experimental seasons. However, T_1 (control) ranked statistically last rank during both seasons of study.

Table 3. Effect of some antioxidants, Folifert and Potaqueen on fruit dimensions (cm) and fruit shape index of Washington navel orange trees during 2015 and 2016 experimental seasons

Parameters	Fruit dimensions (cm)				Fruit shape index	
	Polar diameter		Equatorial diameter			
Treatments / Seasons	1st	2nd	1st	2nd	1st	2nd
T_1: Control (Water spray)	7.74 f	7.76 f	7.76 f	7.79 f	0.998 a	0.997 a
T_2: Citric acid at 1g/L	7.76 f	7.78 f	7.78 f	7.80 f	0.998 a	0.998 a
T_3: Ascorbic acid at 1g/L	7.78 f	7.79 f	7.80 f	7.81 f	0.997 a	0.998 a
T_4: Folifert at 1.5g/L	7.89 e	7.91 e	7.90 e	7.93 e	0.999 a	0.998 a
T_5: Potaqueen at 3g/L	7.98 d	7.99 d	8.01 d	8.01 d	0.997 a	0.998 a
T_6: Citric at 1g/L+ Folifert at 1.5 g/L	8.00 d	8.01 d	8.03 d	8.03 d	0.996 a	0.998 a
T_7: Citric at 1g/L+ Potaqueen at 3g/L	8.08 c	8.10 c	8.11 c	8.12 c	0.996 a	0.997 a
T_8: Ascorbic at 1g/L+ Folifert at 1.5g/L	8.00 d	8.01 d	8.03 d	8.03 d	0.996 a	0.997 a
T_9: Ascorbic at 1g/L+ Potaqueen at 3g/L	8.08 c	8.08 c	8.11 c	8.10 c	0.996 a	0.998 a
T_{10}: Potaqueen at 3g/L + Folifert at 1.5g/L	8.41 b	8.52 b	8.44 b	8.55 b	0.996 a	0.997 a
T_{11}: Citric at 1g/L + Folifert at 1.5g/L + Potaqueen at 3g/L	8.47 a	8.52 b	8.49 b	8.55 b	0.998 a	0.997 a
T_{12}:Ascorbic at 1g/L+ Folifert at 1.5g/L+ Potaqueen at 3g/L	8.51 a	8.58 a	8.56 a	8.60 a	0.995 a	0.997 a

Values within each column followed by the same letter/s are not significantly different at 5% level

Table 4. Effect of some antioxidants, Folifert and Potaqueen on peel thickness (mm) and juice volume (cm^3) of Washington navel orange trees during 2015 and 2016 experimental seasons

Parameters	Peel thickness (mm)		Juice volume (cm^3)	
Treatments / Seasons	1st	2nd	1st	2nd
T_1: Control (Water spray)	2.54 j	2.57 l	71.55 i	71.68 g
T_2: Citric acid at 1g/L	2.62 i	2.64 k	74.43 h	75.2 f
T_3: Ascorbic acid at 1g/L	2.66 h	2.69 j	78.29 g	78.43 e
T_4: Folifert at 1.5g/L	2.73 g	2.75 i	81.50 f	81.63 d
T_5: Potaqueen at 3g/L	2.86 e	2.93 f	86.11 e	86.74 c
T_6: Citric at 1g/L+ Folifert at 1.5 g/L	2.73 g	2.80 h	81.26 f	81.65 d
T_7: Citric at 1g/L+ Potaqueen at 3g/L	2.97 d	2.99 e	86.51 e	86.67 c
T_8: Ascorbic at 1g/L+ Folifert at 1.5g/L	2.84 f	2.89 g	81.51 f	81.88 d
T_9: Ascorbic at 1g/L+ Potaqueen at 3g/L	2.98 d	3.02 d	87.9 d	88.18 c
T_{10}: Potaqueen at 3g/L + Folifert at 1.5g/L	3.07 c	3.12 c	90.78 c	91.11 b
T_{11}: Citric at 1g/L + Folifert at 1.5g/L + Potaqueen at 3g/L	3.16 b	3.22 b	92.55 b	94.59 a
T_{12}:Ascorbic at 1g/L+ Folifert at 1.5g/L+ Potaqueen at 3g/L	3.25 a	3.33 a	94.45 a	95.81 a

Values within each column followed by the same letter/s are not significantly different at 5% level

3.4.2 Fruit juice TSS (Total soluble solids %)

Table 5 display obviously that all investigated treatments increase the fruit juice TSS (%) of Washington navel orange cultivar. During both 2015 and 2016 experimental seasons. However, the highest fruit juice TSS (%) was markedly coupled with T_{12} (Ascorbic acid at 1g/L+ Folifert at 1.5 g/L+ Potaqueen at 3 g/L), T_{11} (Citric acid at 1 g/L+ Folifert at 1.5 g/L+ Potaqueen at 3g/L) and whereas the richest TSS (%) i.e., 12.05,12.01,12.00 and 11.97% were resulted from T_{12} and T11duyring 2015 and 2016 experimental seasons, respectively. Moreover, T_{10} (Folifert at 1.5 g/L+ Potaqueen at 3 g/L) ranked statistically second as the influence on fruit juice TSS % was concerned. The reverse was true with the fruit juice TSS% of water sprayed trees (control) which induced significantly the poorest fruits in their TSS % content during experimental seasons of study. In addition, other investigated treatments were in-between the abovementioned two extremes. Such trend was true during 2015 and 2016 experimental seasons.

3.4.3 Fruit juice acidity percentage (%)

With regard to the fruit juice acidity strength of Washington navel orange trees as influenced by the differential fertilizers treatments, data obtained during both 2015 and 2016 experimental seasons are presented in Table 5. It is quite clear that an opposite trend to that previously found with TSS % was obviously detected in this respect. Hence, fruit juice acidity percentage was increased significantly by T_1 (control) during both 2015 and 2016 experimental season. The reverse was true with T_{12} (Ascorbic acid at 1 g/L+ Folifert at 1.5 g/L+ Potaqueen at 3 g/L) and T_{11} (Citric acid at 1 g/L+ Folifert at 1.5 g/L+ Potaqueen at 3 g/L) which induced significantly the poorest fruits in their total acidity percentage during both experimental seasons.

3.4.4 Fruit juice total soluble solids/Total acidity ratio

It is quite clear as shown from tabulated data in Table 5 that TSS/acid ratio was slightly influenced by the differential investigated treatments. However, the highest TSS/acid ratio was marked coupled with T_{12} (Ascorbic acid at 1 g/L+ Folifert at 1.5 g/L+ Potaqueen at 3 g/L), whereas, the richest TSS/acid ratio i.e., 13.70 and 13.75 was resulted by T_{12} during 2015 and 2106 experimental seasons, respectively. Moreover, T_{11} (Citric acid at 1 g/L+ Folifert at 1.5 g/L+ Potaqueen at 3 g/L) ranked statistically second as the influenced on TSS/acid ratio was concerned during both experimental seasons, the reverse was true with TSS/acid ratio of water sprayed trees (control) whish induced significantly the lowest fruits in their TSS/acid ratio during 2015 and 2016 experimental seasons. In addition, other investigated treatments were in-between the aforesaid extremes i.e., T_{12} (superior) during both experimental seasons.

3.4.5 Fruit juice total sugars percentage (%)

Data obtained during both experimental seasons as shown from Table (6) display clearly that all investigated treatments increase fruit juice total sugars value than control (T_1) during both experimental seasons. However, the increase varied from one treatment to another, whereas, the greatest increase was statistically in concomitant to T_{12} (Ascorbic acid at 1g/L+ Folifert at 1.5 g/L+ Potaqueen at 3 g/L). Moreover, T_{11} (Citric acid at 1g/L+ Folifert at 1.5 g/L+ Potaqueen at 3 g/L) ranked statistically second rank and exhibited fruit juice total sugars estimated value of (8.53 and 8.51) % during both 2015 and 2016 experimental seasons, respectively. Descending followed by T_{10} (Folifert 1.5 g/L+ Potaqueen 3 g/L), T_9 (Ascorbic acid 1g/L+ Potaqueen 3 g/L) and T_8 (Ascorbic acid 1g/L+ Folifert 1.5 g/L). Hence, such four effective treatments i.e., T_7, T_5, T_6, and T_4 not only exceeded control but also surpassed the two other treatments i.e., T_2 and T_3 during 2015 and 2016 experimental seasons.

3.4.6 Fruit juice ascorbic acid (V.C.) content

Data obtained during both 2015 and 2016 experimental seasons shown from Table 6 displayed that all investigated compounds treatments increased fruit juice vitamin C content over control. The increase was significantly during both experimental seasons**.** However, T_{12} (Ascorbic acid at 1 g/L+ Folifert at 1.5 g/L+ Potaqueen at 3 g/L) was statistically the superior and showed the greatest juice (VC) content i.e., 63.69 and 66.14 VC /100 ml fruit juice during 2015 and 2016 experimental seasons, respectively. Moreover, T_{11} (Citric acid at 1 g/L+ Folifert at 1.5 g/L+ Potaqueen at 3 g/L) ranged statistically second rank after the aforesaid superior treatment during both experimental seasons. In addition, other investigated treatments were in-between the aforesaid extremes i.e., T_{12} the superior and (T_1) the inferior during both 2015 and 2016 experimental seasons.

The present results concerning the effects of foliar sprays with citric and ascorbic acid on fruit quality traits of Washington navel orange go partially in line with that pointed out by several investigators regarding the beneficial effect of investigated treatment on increasing fruit quality measurements by [42,43],30] and [44] some grapevine cultivars, [45] on "Sewy" dates, [31] suggested on "Kelsey" plums, [5] and [46] on "Le-Cont" pears, [47] on “Picaul” olives, [32] on four mango cultivars namely Zebda, Awase, Alphonso and Taimour, [20] on "Anna" apples, [48] and [49] on “Florda Prince” and "Swelling" peaches, respectively, [50] on ‘Salimi’ pomegranates, [51] on Canino apricots. They reported that foliar sprays with antioxidant induced higher positive effect on fruit quality parameters of the previously mentioned fruit crop species.The obtained results regarding the of foliar sprays with the mixture of micronutrients on fruit quality parameters of Washington navel orange trees are in agreement with the findings of [33,24,25] on Washington navel

Table 5. Effect of some antioxidants, Folifert and Potaqueen on fruit juice T.S.S (%), total acidity and TSS/Acid ratio of Washington navel orange trees during 2015 and 2016 experimental seasons

Parameters	Fruit juice T.S.S (%)		Total acidity (%)		TSS/Acid ratio	
Treatments / Seasons	1st	2nd	1st	2nd	1st	2nd
T_1: Control (Water spray)	9.97 j	10.00k	1.074 a	1.051 a	9.29 j	9.52 j
T_2: Citric acid at 1g/L	10.11 i	10.10j	0.999 b	0.994 b	10.13 i	10.16 i
T_3: Ascorbic acid at 1g/L	10.23 h	10.24i	0.986 bc	0.982 b	10.37 h	10.42 h
T_4: Folifert at 1.5g/L	10.62 g	10.66h	0.978 cd	0.965 c	10.86 g	11.05 g
T_5: Potaqueen at 3g/L	11.24 d	11.21e	0.963 de	0.955 cd	11.68 e	11.74 e
T_6: Citric at 1g/L+ Folifert at 1.5 g/L	10.75 f	10.74g	0.974 cd	0.962 cd	11.03 fg	11.17 fg
T_7: Citric at 1g/L+ Potaqueen at 3g/L	11.26 d	11.28d	0.954 ef	0.948 d	11.80 e	11.90 e
T_8: Ascorbic at 1g/L+ Folifert at 1.5g/L	10.84 e	10.92f	0.969 de	0.965 c	11.14 f	11.31 e
T_9: Ascorbic at 1g/L+ Potaqueen at 3g/L	11.40 c	11.46c	0.940 f	0.930 e	12.13 d	12.32 d
T_{10}: Potaqueen at 3g/L + Folifert at 1.5g/L	11.79 b	11.82b	0.905 g	0.897 f	13.03 c	13.18 c
T_{11}: Citric at 1g/L + Folifert at 1.5g/L + Potaqueen at 3g/L	11.97 a	12.00a	0.890 gh	0.886 fg	13.45 b	13.55 b
T_{12}:Ascorbic at 1g/L+ Folifert at 1.5g/L+ Potaqueen at 3g/L	12.01 a	12.05a	0.877 h	0.877 g	13.70 a	13.75 a

Values within each column followed by the same letter/s are not significantly different at 5% level

Table 6. Effect of some antioxidants, Folifert and Potaqueen on total sugars and vitamin C of Washington navel orange trees during 2015 and 2016 experimental seasons

Parameters	Total sugars (%)		Vitamin C (mg/100ml)	
Treatments / Seasons	1st	2nd	1st	2nd
T_1: Control (Water spray)	7.51 l	7.53 k	51.00 j	51.59 j
T_2: Citric acid at 1g/L	7.60 k	7.63 j	51.29 ij	52.53 i
T_3: Ascorbic acid at 1g/L	7.75 j	7.75 i	51.6 hi	53.44 fg
T_4: Folifert at 1.5g/L	7.94 i	7.99 h	52.04 g	53.16 gh
T_5: Potaqueen at 3g/L	8.23 f	8.26 f	52.085 f	54.13 e
T_6: Citric at 1g/L+ Folifert at 1.5 g/L	7.97 h	8.00 h	51.75 gh	52.74 hi
T_7: Citric at 1g/L+ Potaqueen at 3g/L	8.25 e	8.28 e	53.42 e	54.36 e
T_8: Ascorbic at 1g/L+ Folifert at 1.5g/L	8.05 g	8.04 g	52.97 f	53.84 ef
T_9: Ascorbic at 1g/L+ Potaqueen at 3g/L	8.34 d	8.36 d	55.25 d	57.24 d
T_{10}: Potaqueen at 3g/L + Folifert at 1.5g/L	8.44 c	8.46 c	60.36 c	63.31 c
T_{11}: Citric at 1g/L + Folifert at 1.5g/L + Potaqueen at 3g/L	8.51 b	8.53 b	61.71 b	65.22 b
T_{12}:Ascorbic at 1g/L+ Folifert at 1.5g/L+ Potaqueen at 3g/L	8.53 a	8.59 a	63.69 a	66.14 a

Values within each column followed by the same letter/s are not significantly different at 5% level

orange trees, [52-55] on different citrus species and varieties. They mentioned that foliar sprays with Fe, Mn and Zn alone or in combinations enhanced the studied fruit quality traits of the aforementioned citrus fruit species and varieties.

The prospective effects of potassium on fruit quality may be attributed to it's an important role in plant physiological activities including the activation of enzymes and plant protein synthesis, photosynthesis and osmotic adjustment. In plants with potassium deficiency, soluble nitrogen compounds and sugars will be accumulated and also starch will be reduced [56]. Also, [57] mentioned that potassium is necessary for basic physiological functions, such as the formation of sugars and starch, the synthesis of proteins, cell division and growth, fruit formation and could improve fruit size, flavor and color.

The obtained results concerning the positive effect of foliar sprays with mixture of N, P and K on some fruit quality parameters of Washington navel orange trees go in line with the findings of [26], [27] and [23]. They mentioned that spraying orange trees with N, P and K alone or in combinations improving most fruit quality parameters.

4. CONCLUSION

It can be recommended from the results of this study that T_{11} which is the mixture of ascorbic acid, folifert and potaqueen at a certain percentage, are able to increases the productivity and fruit quality of Washington Navel Orange Tree (Ascorbic acid at 1g/L +Folifert at 1.5g/L + Potaqueen at 3 g/L). So above formed mixture can be used for further cultivation of Washington Navel orange tree.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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