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Enhancing Productivity, Fruit Quality and Nutritional Status of 'Washington' Navel Orange Trees by Foliar Applications with GA_3 and Amino Acids

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Abstract: This investigation was carried out on 12-years old 'Washington' navel orange trees budded on sour orange rootstock during two successive seasons (2016 and 2017). The trees grew in a loamy sand soil under surface irrigation system at a private orchard, Qalubia Governorate, Egypt. The objective of the study was to examine the effect of individual foliar applications of gibberellic acid (GA_3) at (0, 25 or 50 ppm) as well as individual foliar applications of a commercial compound Bioflow™ containing 27.3% amino acids at (0, 1 cm^3/L, 2 cm^3/L or 3 cm^3/L) on enhancing leaf nutritional status and increasing yield in terms of quantity and quality. Foliar applications of combinations between the two materials at the different concentrations were also examined. Applications were applied for five times at one-month intervals starting at full-bloom time during both seasons. The results of the current investigation revealed that, in both seasons, recorded yield parameters (fruit set %, fruit retention %, number of fruits/tree, yield (kg) /tree and average fruit weight (gm)/ tree) were all favorably influenced by the different GA_3 and amino acid treatments. The highest values for the different parameters were recorded when the highest level of GA_3 was combined with the highest rate of amino acids. Fruit size and juice % content also followed the same trend. Most of the recorded Juice quality parameters (TSS%, TSS/Acid ratio, Vitamin C content and Total sugars%) showed desirable responses to increasing application rates of GA_3 and amino acids. On the other hand, juice acidity % showed a steady decrease with the increase of applications rates of the two tested substances. Total Chlorophyll content of fresh leaves was significantly increased in response to the different GA_3 and amino acid treatments. Furthermore, the recorded values increased steadily with increasing the application rates of the two applied substances. The highest Chlorophyll content was obtained when the highest GA_3 was applied in combination with the highest amino acids rate. The results also revealed that for most of the determined leaf nutrient contents (viz., N, P, K, Ca, Mg, Fe, Mn and Zn), in general raising the application rates of GA_3 and/or amino acids resulted in steady significant increases in the recorded values.

Key words: 'Washington' navel orange · GA_3 · Amino acids · Foliar sprays · Leaf mineral contents · Yield · Fruit quality

INTRODUCTION

In Egypt, citrus occupies the first position among fruit crops grown in country both for cultivated area (533, 835 feddans) and production (4, 646, 579 tons annually). 'Washington' navel orange holds the first rank among the species of Citrus. It occupies about 34 % of the total cultivated area of Citrus with total production of 1, 697, 222 tons annually [1].

The use of growth regulators to increase fruit yield has become important in agriculture today with the purpose of enhancing vegetative growth, fruit set, yield and quality attributes. Gibberellic acid has been utilized in citriculture with several purposes including fruit set improvement, increasing fruit yield and enhancing fruit physical and chemical properties [2-4]. 'Washington' navel orange is a parthenocarpic cultivar where young fruits tend to be more vulnerable to drop compared to young fruits from pollinated flowers resulting in decreasing fruit yield [5]. Gibberellic acid encourages cell division and elongation, increase stalk length and enhance flowering and fruit volume [6].

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'Washington' navel orange trees sprayed with GA_3 at 10 or 20 ppm one week after fruit set had higher final fruit set percentage and fruit yield (kg per tree) as compared to untreated trees [7]. Additionally, it was also reported that the values of fruit TSS/acid ratio and vitamin C (V. C) when sprayed with GA_3 as a pre-harvest treatment, yet the fruit total acidity was decreased when compared with the control [8].

Amino acids are considered as precursors and the build blocks of protein synthesis, which could be enzymes important for metabolic activities to stimulate cell growth [9]. Amino acids contained both acid and basic groups and act as buffers, that help to maintain favorable pH value within the plant cell. Amino acids can impact directly and indirectly the physiological activities in plant growth and development [10]. Promoting effect of amino acids on protecting plant cells from oxidation and all stresses as well as enhancing the biosynthesis of proteins, plant pigments, natural hormones such as IAA, gibberellin and cytokinine and cell division is reflected on stimulating nutritional status and fruiting [10-12].

Exogenous application of amino acids not only increased growth but also enhanced fruit yield and quantity of different fruit species, i.e. apples, grapes and pears [13-16].

Thereupon, this work was designed to examine the results of foliar spraying 'Washington' navel orange trees with GA_3 and amino acids on enhancing nutritional status and increasing fruit set, yield and quality.

MATERIALS AND METHODS

This study was carried out during 2016 & 2017 seasons on 12-year-old 'Washington' navel orange (*Citrus sinensis* (L.) Osbeck) trees budded on sour orange (*Citrus aurantium*, L.) rootstock grown at 5.0 meters apart in loamy sand soil under surface irrigation of a private orchard at Manzala village, Tough region, Qalubia 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. It was devoted to investigating the influence of individual foliar applications of Gibberellic Acid (GA_3) at 0, 25 or 50 ppm as well as individual foliar applications of a commercial compound "*Bioflow*" containing 27.3% amino acids at 0, 1 cm^3/L, 2 cm^3/L or 3 cm^3/L in addition to tap water as a control treatment. Foliar applications of combinations between the two materials at the different concentrations were also examined. The treatments used in this study as follow:

- Tap water (control).
- GA_3 25 ppm
- GA_3 50 ppm
- Amino acids 1 cm^3/L
- Amino acids 2 cm^3/L
- Amino acids 3 cm^3/L
- GA_3 25ppm + amino acids 1 cm^3/L
- GA_3 25 ppm + amino acids 2 cm^3/L
- GA_3 25 ppm + amino acids 3 cm^3/L
- GA_3 50 ppm + amino acids 1 cm^3/L
- GA_3 50 ppm + amino acids 2 cm^3/L
- GA_3 50 ppm + amino acids 3 cm^3/L

The experiment was laid out in a randomized complete block design in a factorial experiment (3 levels of GA_3 * 4 levels of amino acids = 12 treatments) with three replications (single tree per each replicate) was employed for arranging these treatments. Devoted trees for each treatment were sprayed five times with the corresponding solution five times at one-month interval starting from full-bloom during each season. The following characters were measured:

Productivity Aspects: Fruit set%, fruit retention % and yield expressed as either number of fruit /tree, average of fruit weight and yield kg/tree.

Fruit Quality Fruit Physical Properties: Average fruit weight (g), fruit dimensions (length & diameter), fruit shape index (length : diameter), fruit juice weight (g) and juice (%).

Fruit Chemical Characteristics: Were determined according to A.O.A.C. [17] for fruit juice TSS% using hand refractometer, fruit juice total acidity as citric acid by titration against NaOH (0.1N), TSS/Acid ratio, total sugars % were determined after the method described by Smith *et al.* [18] and fruit juice Vitamin C (ascorbic acid) content (mg/100ml juice) by titration with 2-6 dichlorophenol indophenol pigment.

Photosynthetic Pigments: Total chlorophyll contents in fresh leaves were determined by using Minolta meter SPAD-502.

Macro and Micronutrients Contents in Leaves: Total leaf (N) was determined by the modified micro Kjeldahl method mentioned by Pregl [19]. Total leaf (P) was determined by wet digestion of plant materials after the methods described by Piper [20]. Total leaf (K) was

determined photometrically according to the method described by Brown [21]. Calcium and Magnesium percentages as well as Iron, Manganese and Zinc were determined using the Atomic absorption spectrophotometer "Perkin Elmer -3300" according to Chapman [22].

Statistical Analysis: All data obtained during both seasons were subjected to analysis of variance and significant differences among means were determined according to Snedecor [23]. Capital and small letters were used for distinguishing between means of specific effect of two investigated factors i.e. gibberellic acid and amino Acids' concentrations and interaction between them, respectively, according to Duncan [24].

RESULTS AND DISCUSSIONS

Yield Parameters: Table (1) clearly shows that, in both seasons, the recorded yield parameters (fruit set %, fruit retention %, number of fruits/tree, yield /tree and average fruit weight / tree) were all favorably influenced by the different GA_3 and amino acid treatments. Moreover, the values recorded for the different parameters showed steady significant increases by raising the application rates of GA_3 and/or amino acids. Accordingly, the highest values for the different parameters were recorded when the highest level of GA_3 was combined with the highest rate of amino acids.

The improved effect of GA_3 treatment on fruit set and fruit retention may be due to the role of GA_3 through cell division and cell enlargement in the meristem cells of flowers, which induced a positive effect on decreased fruit drop and increasing fruit set and retention percentages.

Moreover, there are three important apparent actions, the first that GA_3 intensifies an organ ability to function as a nutrient sink. The second one the ability of GA_3 to increase the synthesis of IAA in plant tissues. Whereas, the third action includes improving the synthesis of hydrolytic enzymes such as amylase in aleurone cells [25].

The use of GA_3 by many researchers have shown reduced flower drop, increased flower retention and yield in citrus and other fruit species such as, mango and apple [26, 3, 27]. Moreover, Hifny *et al.* [2] studied the effect foliar spray with GA_3 at 10 & 20 ppm and NAA at 20 & 25ppm alone and their combinations at one week after full bloom on 'Washington' navel orange trees. They stated that foliar spray with GA_3 at 20 ppm + NAA at 25ppm decreased fruit drop percentage and significantly increased the fruits yield (kg/ tree).

Furthermore, amino acids play a very important role in plant, it represents the building blocks of proteins and have a vital role in nitrogen metabolism provide shuttle molecules organic nitrogen through the plant. Additionally, amino acids restore specific enzymes for protein synthesis and play principals roles during metabolic processes, it has been cited that some amino acids act as signal molecules and others are precursors for the synthesis of phytohormones or other secondary metabolites with signal function [8, 28].

The obtained results of amino acids in this concern are in accordance with previously reported studies on different fruit varieties i.e., Valencia oranges, Fagry Kelan Mango, different apple cultivars, Flame Seedless Grapevines and "Le Conte" Pear [29-33, 14]. They all concluded that foliar sprays of amino acids significantly improved fruit set, fruit weight and total yield of fruits. The general positive effects of amino acid foliar spray applications could be attributed to the enhancement of pollen tube ovule penetration and delay ovule senescence, which increases fruit set and yield [13]. In a study on the effect of foliar application with tryptophan at 25 & 50 ppm, amino calcium at 1% and potassium nitrate at 0.5% on fruit set % and fruit yield of 'Washington' navel orange. It was reported that, tryptophan at 25 and 50ppm scored the highest records of fruit set and yield (kg/ tree) [34].

Fruit Quality

Fruit Physical Properties

Fruit Size: The results recorded on fruit characteristics of navel orange fruits in the two seasons (Table 2) generally illustrated that the GA_3 and amino acid applications either individually or in combination induced an increase in fruit size in terms of polar as well as equatorial dimeters whereas the fruit shape index, in most cases, remained unchanged.

Juice Production: The results presented in Table (2) show that juice weight/fruit was significantly affected by the different GA_3 and amino acid treatments. In both seasons, raising the application rate of either one of these two substances resulted in steady significant increases in the mean values recorded for juice weight/fruit, with the highest levels of GA_3 (50 ppm) or amino acids (3 cm^3/L) giving the highest mean values. Such favorable effects of GA_3 and amino acids on juice weight/fruit can be attributed to the increase in fruit size and weight due to the treatments. It is also clear from the data in Table 2 that the effect of each of the two substances on juice

Table 1: Yield Parameters [fruit set %, fruit retention%, number of fruits/tree, average fruit weight (g) and yield/tree (Kg)] of 'Washington' navel orange cv. as influenced by specific and interaction effects of gibberellic acid (GA_3) & amino acids' concentrations during 2016 & 2017 seasons.

	First season (2016)				Second season (2017)			
	GA_3 (ppm)				GA_3 (ppm)			
	Control	25	50	Mean*	Control	25	50	Mean*
Amino acids (cm^3/L)				Fruit set (%)				
Control	11.75k	13.13h	13.64g	12.84D	11.98l	13.65i	14.06h	13.23D
1	12.95j	14.59f	16.12c	14.55C	13.05k	16.02f	17.08c	15.38C
2	12.97ij	15.71e	16.67b	15.12B	13.39j	16.60e	17.24b	15.74B
3	13.03i	15.81d	16.95a	15.26A	15.74g	16.95d	17.43a	16.71A
Mean**	12.68C	14.81B	15.85A	----	13.54C	15.81B	16.45A	----
				Fruit retention (%)				
Control	9.28i	10.94f	11.09f	10.44D	9.04i	11.21f	11.73e	10.66D
1	10.21h	12.02e	13.01bc	11.75C	10.41h	12.74d	13.62b	12.26C
2	10.71g	12.37d	13.22ab	12.10B	10.92g	12.96c	13.92a	12.60B
3	10.87fg	12.81c	13.42a	12.37A	11.07fg	13.09c	14.09a	12.75A
Mean**	12.27C	12.04B	12.69A	----	10.36C	12.50B	13.34A	----
				Number of fruits / tree				
Control	104.7k	125.0h	131.7g	120.5D	104.7l	130.7h	137.3g	124.2D
1	114.3j	137.3f	151.3c	134.3C	118.7k	139.3f	150.7c	136.2C
2	118.3i	141.3e	158.3b	139.3B	123.3j	143.3e	159.7b	142.1B
3	124.0h	145.0d	161.7a	143.6A	128.0i	148.7d	161.3a	146.0A
Mean**	115.3C	137.2B	150.8A	----	118.7C	140.5B	152.3A	----
				Average fruit weight (g)				
Control	218.3l	231.3k	236.3j	228.7D	221.7l	231.7k	235.5j	229.6D
1	241.7i	254.0f	264.0c	253.2C	237.7i	255.3f	266.2c	253.1C
2	244.7h	257.0e	269.7b	257.1B	245.3h	259.7e	271.0b	258.7B
3	248.0g	261.7d	272.0a	260.6A	249.7g	261.7d	273.3a	261.6A
Mean**	238.2C	251.0B	260.5A	----	238.6C	252.1B	261.5A	----
				Yield / tree (kg)				
Control	22.86j	28.93h	31.13g	27.64D	23.21j	30.28h	32.35g	28.61D
1	27.64i	34.89f	39.96c	34.16C	28.21i	35.58f	40.11c	34.63C
2	28.97h	36.33e	42.70b	36.00B	30.26h	37.22e	43.27b	36.92B
3	30.76g	37.95d	43.98a	37.56A	31.96g	38.90d	44.11a	38.32A
Mean**	27.56C	34.52B	39.44A	----	28.41C	35.50B	39.96A	----

*&** refer to specific effect of GA_3 & amino acids' concentrations, respectively. Means of specific and interaction effects followed by the same capital and small letters, respectively didn't significantly differ at 5% level

weight/fruit was independent from the effect of the other, i.e. the effect of the GA_3 treatments on juice weight/fruit followed the same general trend regardless of the level of amino acids that was applied (and vise-versa). As a result, the highest juice weight/fruit was recorded in trees that were sprayed with the highest levels of GA_3 and amino acids (50 ppm and 3 cm^3/L, respectively).

Regarding the effect of the treatments on the juice content (%), it can be seen from the data in Table (2) that the effect of amino acids on fruit content was generally similar to its effect on all the other recorded fruiting and yield parameters, i.e. the mean juice content (%) was steadily increased by raising the amino acids concentration from 0 to 1, 2 or 3 cm^3/L. The GA_3 treatments also caused significant increases in the juice content, compared to that of control fruits (which had the lowest mean juice content in both seasons). However, it is clear that in this respect, GA_3 was more effective when applied at the low level (25 ppm) than at the prominent level (50 ppm). In both seasons, fruits of trees sprayed with GA_3 at 25 ppm had the highest mean juice content. Moreover, the higher effectiveness of the low GA_3 level (25 ppm) was evident when this GA_3 level was applied with no amino acids treatment, or with amino acids at 1 or 2 cm^3/L, but with the highest amino acids concentration (3 cm^3/L), GA_3 was most effective when applied at 50 ppm in the first season (giving an insignificantly higher value than GA_3 at 25 ppm), whereas in the second season, the highest value was obtained when no GA_3 was applied.

Table 2: Fruit physical properties fruit dimensions, shape index, juice weight (g) and juice content % of 'Washington' navel orange cv. as influenced by specific and interaction effects of gibberellic acid (GA_3) & amino acids' concentrations during 2016 & 2017 seasons.

	First season (2016)				Second season (2017)			
	GA_3 (ppm)				GA_3 (ppm)			
Amino acids (cm^3/L)	Control	25	50	Mean*	Control	25	50	Mean*
				Polar diameter (cm)				
Control	7.86k	8.24h	8.32g	8.14D	8.26f	8.29ef	8.32e	8.29D
1	7.97j	8.41f	8.46c	8.28C	8.02i	8.47d	8.62b	8.37C
2	8.11i	8.43e	8.50b	8.35B	8.13h	8.51cd	8.70a	8.45B
3	8.13i	8.44d	8.54a	8.37A	8.21g	8.56c	7.73a	8.50A
Mean**	8.02C	8.38B	8.46A	----	8.16C	8.46B	8.59A	----
				Equatorial diameter (cm)				
Control	7.91h	8.09f	8.20e	8.06D	7.96k	8.16h	8.19g	8.10D
1	7.98g	8.45d	8.50b	8.31C	8.00j	8.52f	8.65c	8.39C
2	8.10f	8.48c	8.52b	8.36B	8.10i	8.56e	8.71b	8.46B
3	8.10f	8.51b	8.56a	8.39A	8.16h	8.60d	8.75a	8.50A
Mean**	8.02C	8.38B	8.44A	----	8.06C	8.46B	8.57A	----
				Fruit shape index				
Control	0.994c	1.018a	1.015ab	1.009A	1.038a	1.016b	1.016b	1.023A
1	0.999a-c	0.995bc	0.995bc	0.996B	1.002bc	0.993c	0.996c	0.997B
2	1.002a-c	0.994bc	0.998a-c	0.998B	1.004bc	0.994c	1.000bc	0.999B
3	1.003a-c	0.993c	0.998a-c	0.998B	1.006bc	0.995c	1.000bc	1.000B
Mean**	1.000A	1.000A	1.002A	----	1.012A	1.000B	1.003B	----
				Juice weight (g)/fruit				
Control	88.90k	99.23j	100.1i	96.08D	90.56j	100.8i	102.0h	97.76D
1	103.2h	116.1e	119.0c	112.8C	104.3g	114.8e	118.7c	112.6C
2	106.3g	116.6e	120.6b	114.5B	104.7g	115.5e	120.2b	113.4B
3	111.0f	117.9d	122.8a	117.2A	113.3f	116.3d	123.2a	117.6A
Mean	102.4C	112.4B	115.6A	----	103.2C	111.8B	116.0A	----
				Juice content (%)				
Control	40.72h	42.89f	42.36g	41.99C	40.85g	43.49e	43.30e	42.55D
1	42.69f	45.70a	45.09b	44.49B	43.90d	44.94b	44.60c	44.48B
2	43.46e	45.36b	44.72d	44.52B	42.67f	44.48c	44.34c	43.83C
3	44.75cd	45.06b	45.15b	44.99A	45.39a	44.45c	45.08b	44.97A
Mean**	42.91C	44.75A	44.33B	----	43.20B	44.34A	44.33A	----

*&** refer to specific effect of GA_3 & amino acids' concentrations, respectively. Means of specific and interaction effects followed by the same capital and small letters, respectively didn't significantly differ at 5% level.

It can also be seen that the different amino acid treatments caused significant increases in the juice content, regardless of the GA_3 level that was applied (in both seasons). However, the relative effectiveness of the amino acid treatments, compared to each other, depended on the GA_3 level that was used and differed from one season to the other. In general, it can be stated that when no GA_3 was applied, or when GA_3 was applied at the high level (50 ppm), the amino acids was most effective when applied at the highest concentration (3 cm^3/L), but when GA_3 was sprayed at the low level (25 ppm), the amino acids gave the best results when applied at the lowest concentration (1 cm^3/L).

The data recorded in the two seasons (Table 2) also show that the various combinations of GA_3 and amino acid treatments gave results that differed from one season to the other. In the first season, the highest juice content was obtained in fruits of trees sprayed with GA_3 at 25 ppm + amino acids at 1 cm^3/L, whereas in the second season, the highest juice content was obtained due to spraying the trees with amino acids at 3 cm^3/L, with no GA_3 treatment.

Fruit Chemical Properties: Most of the recorded juice quality parameters (TSS%, total acidity, TSS/Acid ratio, V. C content and Total sugars%) showed desirable responses to increasing application rates of GA_3 and amino acids as shown in Table (3). In both seasons the highest values for these characteristics were obtained with the highest application levels of the two substances. On the other hand, juice acidity % showed a steady decrease with the increase of applications rates of the two tested substances. Accordingly, the highest acidity %

Table 3: Fruit chemical properties (fruit juice TSS %, total acidity %, TSS/Acid ratio, Vitamin C content (mg/100 ml) and total sugars %) of 'Washington' navel orange cv. as influenced by specific and interaction effects of gibberellic acid (GA_3) & amino acids' concentrations during 2016 & 2017 seasons.

	First season (2016)				Second season (2017)			
	GA_3 (ppm)				GA_3 (ppm)			
Amino acid (cm^3/L)	Control	25	50	Mean*	Control	25	50	Mean*
				TSS (%)				
Control	10.08l	11.02k	11.09j	10.73D	10.09k	11.05j	11.07j	10.74D
1	11.25i	12.05f	13.13c	12.14C	11.21i	11.95f	13.01c	12.06C
2	11.41h	12.11e	13.56b	12.36B	11.42h	12.05e	13.39b	12.29B
3	11.56g	12.63d	13.70a	12.63A	11.59g	12.55d	13.57a	12.57A
Mean**	11.08C	11.95B	12.87A	----	11.08C	11.90B	12.76A	----
				Total Acidity (%)				
Control	1.014a	1.007a	1.004ab	1.008A	1.019a	1.011a	1.007a	1.012A
1	0.988b	0.950cd	0.918e	0.952B	0.978b	0.943cd	0.915e	0.945B
2	0.966c	0.942d	0.913e	0.940C	0.967bc	0.942cd	0.901e	0.937BC
3	0.961c	0.941d	0.904e	0.935C	0.953cd	0.940d	0.895e	0.929C
Mean**	0.982A	0.960B	0.935C	----	0.979A	0.959B	0.930C	----
				TSS/Acid ratio				
Control	9.94l	10.94k	11.05j	10.64D	9.90l	10.93k	10.99j	10.61D
1	11.39i	12.68f	14.30c	12.79C	11.46i	12.67f	14.22c	12.78C
2	11.81h	12.86e	14.85b	13.17B	11.81h	12.79e	14.86b	13.15B
3	12.03g	13.42d	15.15a	13.54A	12.16g	13.35d	15.16a	13.56A
Mean**	11.29C	12.48B	13.84A	----	11.33C	12.44B	13.81A	----
				Vitamin C (mg/100 ml)				
0	51.87k	52.84j	56.34i	53.68D	52.52i	53.25i	55.61h	53.80D
1	59.19h	64.91f	70.99c	65.03C	58.37g	66.41e	71.47c	65.42C
2	62.34g	66.82e	72.13b	67.10B	63.71f	68.43d	72.47b	68.20B
3	62.76g	68.15d	73.62a	68.18A	64.34f	68.93d	74.86a	69.37A
Mean**	59.04C	63.18B	68.27A	----	59.74C	64.25B	68.60A	----
				Total sugars (%)				
Control	7.35l	8.15k	8.26j	7.92D	7.45l	8.15k	8.31j	7.97D
1	8.39i	9.00f	9.69c	9.02C	8.36i	9.07f	9.71c	9.05C
2	8.46h	9.25e	9.88b	9.19B	8.46h	9.29e	9.76b	9.17B
3	8.67g	9.40d	9.94a	9.34A	8.71g	9.47d	9.97a	9.39A
Mean**	8.22C	8.95B	9.44A	----	8.25C	8.99B	9.44A	----

*&** refer to specific effect of GA_3 & amino acids' concentrations, respectively. Means of specific and interaction effects followed by the same capital and small letters, respectively didn't significantly differ at 5% level.

was recorded in the fruits juice of control trees (receiving no GA_3 or amino acid treatments). Whereas, the lowest values were recorded with the highest levels of GA_3 and amino acids applied separately or in combination.

The effects of GA_3 on fruit physical and chemical properties go in line with earlier studies where foliar application of GA_3 enhanced orange fruit quality [35, 3]. Additionally, Abd El-Rahman *et al.* [36] mentioned that foliar application of 'Washington' naval orange with 50 ppm GA_3 at full bloom stage increased fruit diameter and fruit length. While, Kassem *et al.* [37] showed that foliar sprays of 'Washington' navel oranges by GA_3 as a pre-harvest treatment increased fruit juice content, V. C content, TSS% and total acidity % as compared with the control. Moreover, Hifny *et al.* [2] mentioned that fruit weight, fruit size, fruit length, fruit diameter and fruit juice and TSS%, total acidity%, TSS/acid ratio and V.C content positively affected by using GA_3 treatment.

The recorded results of amino acids dealing with their prospective affect on enhancing fruit quality are in harmony with earlier studies on Pears, grapevines and apples [16, 33, 31]. Also, El-Shazly and Mustafa [38] on 'Washington' navel orange pointed out that amino green II (amino acids mixture) as foliar application at 0.25 and 0.50% increased fruit juice %, total soluble solids (TSS), total sugars and V.C contents in comparison with control.

Table 4: Leaf total chlorophyll (SPAD 502), N %, P%, K% and Ca% contents of 'Washington' navel orange cv. as influenced by specific and interaction effects of gibberellic acid (GA_3) & amino acids' concentrations during 2016 & 2017 seasons

	First season (2016)				Second season (2017)			
	GA_3 (ppm)				GA_3 (ppm)			
Amino acids (cm^3/L)	Control	25	50	Mean*	Control	25	50	Mean*
				Total chlorophyll (mg/g FW)				
Control	8.79l	9.28k	9.38j	9.15D	8.90k	9.29j	9.37i	9.19D
1	10.19i	10.64f	10.90c	10.58C	10.13h	10.70e	10.84c	10.56C
2	10.26h	10.71e	11.02b	10.66B	10.36g	10.76d	10.90b	10.67B
3	10.45g	10.79d	11.07a	10.77A	10.51f	10.82c	10.99a	10.78A
Mean**	9.93C	10.35B	10.59A	----	9.98C	10.39B	10.53A	----
				Nitrogen (%)				
Control	2.13k	2.20j	2.21h	2.18D	2.18j	2.21i	2.24i	2.21D
1	2.26i	2.41f	2.56c	2.41C	2.36h	2.46f	2.57c	2.46C
2	2.32h	2.46e	2.60b	2.46B	2.41g	2.50e	2.60b	2.50B
3	2.37g	2.50d	2.67a	2.52A	2.44fg	2.53d	2.63a	2.53A
Mean**	2.27C	2.39B	2.51A	----	2.35C	2.42B	2.51A	----
				Phosphorus (%)				
Control	0.120e	0.123e	0.128de	0.124B	0.123e	0.125de	0.129de	0.126B
1	0.132c-e	0.146a-d	0.157a	0.145A	0.135c-e	0.143b-d	0.156ab	0.144A
2	0.137b-e	0.150a-c	0.161a	0.149A	0.138b-e	0.148a-c	0.162a	0.149A
3	0.139b-e	0.152ab	0.164a	0.151A	0.140b-e	0.152a-c	0.166a	0.153A
Mean**	0.132C	0.143B	0.153A	----	0.134B	0.142B	0.153A	----
				Potassium (%)				
Control	1.32i	1.37h	1.40h	1.36D	1.34h	1.39g	1.41g	1.38D
1	1.49g	1.52f	1.59cd	1.53C	1.45f	1.52e	1.60c	1.52C
2	1.52f	1.57de	1.63b	1.57B	1.51e	1.58c	1.62b	1.57B
3	1.55e	1.60c	1.67a	1.61A	1.56d	1.62b	1.65a	1.61A
Mean**	1.47C	1.52B	1.57A	----	1.47C	1.53B	1.57A	----
				Calcium (%)				
Control	4.05j	4.11i	4.15h	4.10D	4.15j	4.18i	4.24h	4.19D
1	4.29g	4.38f	4.56c	4.41C	4.34g	4.50f	4.69c	4.51C
2	4.36f	4.52d	4.69b	4.53B	4.51f	4.59e	4.74b	4.61B
3	4.41e	4.67b	4.84a	4.64A	4.70c	4.64d	4.88a	4.74A
Mean**	4.28C	4.42B	4.56A	----	4.42C	4.48B	4.64A	----

*&** refer to specific effect of GA_3 & amino acids' concentrations, respectively. Means of specific and interaction effects followed by the same capital and small letters, respectively didn't significantly differ at 5% level

Leaf Chemical Composition

Leaf Chlorophyll Content: Chemical analysis of fresh navel orange leaves (Table 4) showed that in both seasons, their total Chlorophyll content was significantly increased in response to the different GA_3 and amino acid treatments. Furthermore, the recorded values increased steadily with increasing the application rates of the two applied substances. Accordingly, the highest chlorophyll content was obtained when the highest GA_3 was applied in combination with the highest amino acids rate.

Leaf Nutrient Contents: The results recorded in the two seasons (Tables 4 & 5) showed that for most of the determined leaf nutrient contents (viz., N, K, Ca, Mg, Fe and Mn), raising the application rates of GA_3 and/or amino acids resulted in steady significant increases in the recorded values. The effect of GA_3 on leaf P% contact was generally similar to its effect on the above-mentioned nutrient (especially in the first season, whereas in the second season GA_3 at 25 ppm did not significantly increase the mean leaf P % compared to the control). The amino acid treatments also increased the leaf P% content significantly compared to the control. However, the values recorded for the three amino acid application levels were insignificantly different from each other.

Leaf Zn contents showed steady significant increases, in both seasons, as a result of increasing the application rate of amino acids (Table 5). On the other hand, the leaf Zn content was significantly decreased by applying GA_3 at 25ppm (compared to the control) but was significantly increased by GA_3 at 50 ppm.

Table 5: Leaf Mg %, Fe (ppm), Mn (ppm) and Zn (ppm) of 'Washington' navel orange cv. as influenced by specific and interaction effects of gibberellic acids (GA_3) & amino acids' concentrations during 2016 & 2017 seasons

	First season (2016)				Second season (2017)			
	GA_3 (ppm)				GA_3 (ppm)			
Amino acid (cm^3/L)	Control	25	50	Mean*	Control	25	50	Mean*
				Magnesium (%)				
Control	0.365f	0.381ef	0.389e	0.378D	0.361h	0.385g	0.391g	0.379D
1	0.395e	0.435c	0.464b	0.431C	0.401g	0.439ef	0.467bc	0.436C
2	0.415d	0.446c	0.470b	0.443B	0.425f	0.462cd	0.491a	0.459B
3	0.339c	0.475b	0.495a	0.470A	0.445de	0.484ab	0.500a	0.477A
Mean**	0.403C	0.434B	0.454A	----	0.408C	0.443B	0.462A	----
				Iron (Fe) ppm				
Control	66.25l	68.68k	71.39j	68.77D	67.23l	70.08k	71.59j	69.63D
1	75.68h	73.40i	81.62d	76.90C	78.24f	74.37i	82.30d	78.31C
2	77.37g	78.06f	83.30b	79.58B	77.56h	77.91g	84.49b	79.99B
3	80.08e	82.62c	84.92a	82.54A	80.27e	83.39c	86.32a	83.32A
Mean**	74.84C	75.69B	80.31A	----	75.83C	76.44B	81.17A	----
				Manganese (Mn) ppm				
Control	28.91l	31.37k	34.49j	31.59D	29.45j	32.05i	35.20h	32.23D
1	39.31i	40.04h	43.61d	40.99C	40.36g	41.18e	43.53c	41.69C
2	40.55g	42.20f	44.56c	42.44B	40.65f	43.31d	45.07b	43.01B
3	42.71e	45.02b	49.41a	45.71A	43.29d	45.09b	50.10a	46.16A
Mean**	37.87C	39.66B	73.01A	----	38.44C	40.41B	43.47A	----
				Zinc (Zn) ppm				
Control	21.75i	24.45h	26.10g	24.10D	21.99i	25.22h	26.23g	24.48D
1	28.11e	27.69f	30.45c	28.75C	28.24f	28.21f	30.39d	28.95C
2	30.55c	29.59d	32.64b	30.93B	31.15c	29.71e	33.15b	31.33B
3	32.48b	29.80d	35.03a	32.44A	33.29b	30.22d	36.10a	33.20A
Mean**	28.22B	27.88C	31.06A	----	28.67B	28.34C	31.47A	----

*&** refer to specific effect of GA_3 & amino acids' concentrations, respectively. Means of specific and interaction effects followed by the same capital and small letters, respectively didn't significantly differ at 5% level.

The recorded results of GA_3 in terms of nutritional status go in line with the analogous cited earlier on 'Washington' navel oranges as well as on different orange cultivars concluding that treatments of GA_3 were mostly effective in enhancing leaf mineral contents [39, 40, 37, 41, 42].

The obtained results of amino acids in this concern are in agreement with previously reported the findings on 'Washington' navel orange [37] where foliar sprays with amino green II as a source of amino acids mixture enhanced leaf chlorophyll content and leaf mineral contents (N, P, K, Ca and Mg). Comparable results were also reported on pears [14] where amino acid treatments enhanced the nutritional status of fruit trees.

In conclusion, it can be recommended to spray navel orange trees with GA_3 at 50 ppm in combination with amino acids at 3 cm^3/L on monthly basis five times during the period from full bloom (March) to July. This treatment combinedly provided the best results for most of the yield and fruit quality parameters.

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