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EFFECT OF TRYPTOPHAN, SALICYLIC AND ASCORBIC ACIDS ON PRODUCTIVITY AND FRUIT QUALITY OF NAVEL ORANGE TREES

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ABSTRACT: A field experiment was carried out during the 2019 and 2020 seasons on 12-year-old Navel orange trees grown in El Bustan district, El Behera Governorate, Egypt. Three concentrations (25, 50 and 75 ppm) of tryptophan, (100, 200 and 300 ppm) of salicylic, and (500, 750 and 1000 ppm) of ascorbic as well as the control (tape water) were foliar application three times a year, i.e., at full bloom stage and the second one was performed just after fruit setting and the third was sprayed four weeks later. The results showed that, tryptophan treatment at 75 ppm improved shoot length, tree height, tree canopy volume, fruit weight, fruit length, fruit diameter, and fruit volume. Moreover, salicylic as foliar application at 300 ppm increased fruit set percentage, fruit retention percentage, numbers of fruits/ tree, yield, yield efficiency, peel thickness, juice weight, fruit juice percentage, TSS, ascorbic acid content, and total sugars content.

Key words: Navel orange; Tryptophan; Salicylic; Ascorbic; Fruit retention; Yield; Fruit quality

INTRODUCTION

Orange occupies the first rank among all fruits cultivated in Egypt**.** The navel orange (*Citrus sinensis* L. Osbeck) cultivar is one of Egypt's most popular citrus fruits because it is tasty and high in nutrients and vitamin C (**Aly *et al.*, 2015**). It is grown on a large scale in newly reclaimed lands, but the anomalous environmental factors harm the yield.

Navel orange production in the hot season is difficult due to high temperatures and excessive radiation **(Saied *et al.*, 2020)**. The flowers, fruits, and fruit quality are sensitive to adverse climatic and soil conditions. Thus, the yield of navel orange trees grown in sandy soil conditions is typically reduced by heavy flower and fruitlet shedding and poor fruit quality **(Mohamed and Hamdy, 2019)**. High percent fruits of navel orange can be lost if heat occurs early in development **(Abd El-Naby *et al.*, 2020)**

Several horticultural practices could be used to enhance tree productivity by reducing the harmful effects of high temperatures during the flowering and fruit set periods. Chemicals could be used in one of these horticultural practices. Tryptophan amino acid has been shown to accumulate in plant tissues under various conditions **(Yang *et al.*, 1999** and **Mansour, 2000)**. On the other hand, (**Carol, 2001)** has approved the use of tryptophan and analogs as a plant growth regulator, and he reported that leaves, flowers, and fruits of Washington navel orange take up, translocate, and convert tryptophan to IAA. In addition, the application of tryptophan to Frost navel orange and Fina Clementine trees at the end of the fruit cell division stage significantly increased the cumulative total yield with no negative effect on fruit quality (**Pillitteri *et al.*, 2010).** In the same concern, (**Khuong *et al.*, 2010)** on navel orange, Clementine mandarin, (**Hanafy *et al.*, 2012)** on Valencia orange, and (**Omima *et al.*, 2014)** on the Manfalouty pomegranate variety. They mentioned that foliar sprays of tryptophan amino acid improved tree growth, yield, and fruit quality parameters of the aforementioned fruit species.

Salicylic acid (SA) classified as a plant hormone-like substance, has been reported to play an important role in the regulation of plant growth and development. It stimulates flowering and tuberization in a range of some angiosperm species, increasing flower life and improving flowering number or density and fruit set percentages **(Kazemi, 2013** and **Mohammadi *et al.*, 2015).** The mechanism of salicylic acid was reported by **(Oata, 1975** and **Pieterse** and **Muller (1977)**, who concluded that

salicylic acid-induced flowering by acting as a chelating agent. This view was supported by **(Raskin *et al.*, 1987** and **Ngullie *et al.*, 2014)** who confirmed that salicylic acid functioned as an endogenous growth regulator of flowering and florigenic activity. In addition, (**Masoud and Osama, 2012)** found that the application of salicylic acid at 25 to 100 ppm was very effective in enhancing leaf area as well as the physical and chemical characteristics of Washington navel orange trees compared with check treatment. Furthermore, spraying salicylic acid at 100 to 400 ppm once or twice improved all growth characteristics; initial fruit set (%), fruit retention (%), yield; and fruit quality over the control treatment **(Habasy, 2015)**. On the other hand, the effect of salicylic acid foliar spray at 200 mg/l improved leaf area index, fruit retention, fruit yield, and fruit quality (chemicals and physical properties) and decreased total acidity content in fruit orange juice **(Mohamed and Hamdy, 2019)**. Ascorbic acid is an essential nutrient for growth and development owing to its effects on cell division and differentiation, and it is involved in a wide range of important functions such as antioxidant defense, photoprotection and regulation of photosynthesis, and growth regulation. (**El-Sayed *et al.*, 2000)** reported that ascorbic acid gave the best yield and bunch quality on Flame seedless grapevine.

Great efforts should be exerted constantly to increase the cultivated area, and production, and improve the fruit quality of Navel oranges to satisfy local consumption and increase demand for Egyptian oranges in international markets.

With the foregoing background, the scope of the present research was to evaluate the effects of spraying with tryptophan, salicylic, and ascorbic acids on vegetative growth, fruit set, fruit retention, productivity, and fruit quality of navel orange trees.

MATERIALS AND METHODS

This investigation was carried out during two successive seasons in 2019 and 2020 at a private orchard which was located in El Bustan district, El Behera Governorate, Egypt. 12-year-old navel orange trees grafted on Volkamer lemon (*Citrus volkameriana* Ten & Pasq rootstock), grown in sandy soil, and spaced 6 x 4m apart (175 trees/fed.) under a well-fed drip irrigation system. Physical and chemical analysis of the experimental soil is shown in Table (1). Meanwhile, an analysis of used water from irrigation is recorded in the Table (2).

Table 1. Analysis of experimental soil

Soil Depth (cm)	Texture Class	pH Soil past	E.Ce (dSm^{-1})	Organic matter %	Soluble cations (meq/l)				soluble anions (meq/l)			
					Ca^{++}	K^{+}	Na^{+}	Mg^{+}_{+}	Cl^{-}	$SO_4^{=}$	HCO_3^{-}	$CO_3^{=}$
0-30	Sand	7.6	1.38	0.17	4.9	0.74	6.04	2.16	6.46	5.03	2.35	-
30-60	Sand	8.3	0.55	0.16	1.4	0.29	3.17	0.64	1.82	1.77	1.91	-

Table 2. Chemical analysis of irrigation water

PH	EC	EC ppm	Soluble cations mg/L				Soluble anions mg/L			
			Ca^{++}	Mg^{++}	K^{+}	Na^{+}	HCO_3^{-}	CO_3^{-}	SO_4^{-}	Cl^{-}
7.84	0.55	352	1.80	1.83	0.21	1.71	1.70	0.00	2.10	1.70

Sixty healthy, nearly uniform in shape and size, and productivity plants that received the same horticultural practices, were subjected to ten treatments:

1- control (tape water)

2- Tryptophan as a foliar spray at 25 ppm (TR 25 ppm).

3- Tryptophan as a foliar spray at 50 ppm (TR 50 ppm).

4- Tryptophan as a foliar spray at 75 ppm (TR 75 ppm).

5- Salicylic as a foliar spray at 100 ppm (SA 100 ppm).

6- Salicylic as a foliar spray at 200 ppm (SA 200 ppm).

7- Salicylic as a foliar spray at 300 ppm (SA 300 ppm).

8- Ascorbic as a foliar spray at 500 ppm (ASA 500 ppm).

9- Ascorbic as a foliar spray at 750 ppm (ASA 750 ppm).

10- Ascorbic as a foliar spray at 1000 ppm (ASA 1000 ppm).

The experiment was designed as a randomized complete block design with three blocks (replicates), and each block (replicate) was represented by ten treatments and every treatment contain two trees thus, the total numbers of trees for this experiment equal 60 trees (3 blocks X 10 treatments X 2 trees). Foliar application of Tryptophan, Salicylic and Ascorbic treatments were carried out three times, the first foliar was done at the full bloom stage (1st week of April) and the second one was performed just after fruit setting (1st week of May) and the third was sprayed one month later (1st week of June). Meanwhile, the control trees were sprayed with tap water at the previously mentioned times.

The response of Navel orange trees to the tested Tryptophan, Salicylic and Ascorbic treatments was evaluated through the following determinations.

Vegetative growth

Shoot length was measured in the spring of each season. Twenty non-fruiting shoots from the spring cycle were tagged in all directions of each tree. At the end of October, the tagged shoots were measured by the ruler as (cm). While the area of leaves was determined by using a portable area planimeter, Mod Li3100 Ali (Li-Cor). The plant height (m) of each tree was measured from the soil surface to the top of canopy as well as canopy circumference was measured.

Each tree was measured for crown radius (m) in eight directions (every 45°), beginning with magnetic north, around the entire tree circumference. Thus, heavy flower and fruitlet shedding and poor fruit quality typically reduce the yield of navel orange trees grown in sandy soil conditions **(Mohamed and Hamdy, 2019).**

Four branches of three years of age, having similarities in vigor and size, were chosen and labeled per tree in the early spring of both seasons, and the following parameters were studied.

Fruiting measurements

Fruit set (%)

The flowers on twenty-five shoots per tree (the fourth leaf/shoot) were counted, and the percentage of fruit set was calculated using the following equation **(Westwood, 1978)** based on the number of flowers that emerged per shoot and the number of developed fruitlets after about two weeks of full bloom**.**

Fruit set (%) = (total number of set fruitlets/total number of flowers) x 100.

Fruits retention and drop (%)

At a given date during each experimental season, the percentage of retained fruits was estimated according to the formula of **(Ashraf *et al.*, 2013):**

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

Fruit drop (%) = 100 – Fruit retention (%).

Yield (Kg/ tree)

At harvest time, the number of fruits per each treated tree was counted and reported. Then the yield (kg) per tree was weighed and recorded. Yield efficiency was calculated by dividing the fruit yield weight by the canopy volume according to (**Whitney *et al.*, 1995).**

Fruit quality

Fruit physical properties

Ten fruits were randomly sampled per tree to estimate fruit weight (g), fruit dimensions (length (cm) and diameter (cm)), fruit volume (cm^3), peel thickness (mm) and fruit juice weight (g).

Fruit chemical properties

The juice was extracted and total soluble solids percentage (TSS) were determined by using a hand refractometer (**Chen and Mellenthin, 1981).** Total acidity percentage was determined as the percentage of citric acid by titration with sodium hydroxide and using phenolphthalein 1(%) as an indicator according to the official methods of analysis **(Chen and Mellenthin, 1981)**. Titration with 2, 6 dichloro phenol-indo-phenol was used to determine the ascorbic acid content of the juice, which was calculated as milligrams per 100 ml of juice as well as vitamin C content **(A.O.A.C., 1985)**. Sugars in total (%) determined in a fresh fruit sample based on (**Malik and Singh, 1980).**

Statistical analysis

The obtained data in the 2019 and 2020 seasons were subjected to analysis by (**Clarke and Kempson, 1997).** Means were differentiated using the Range test at the 0.05 level **(Duncan, 1955)**.

RESULTS AND DISCUSSION

Some vegetative growth parameters

It is clear from Table (3) that all tested treatments succeeded in increasing shoot length, leaf area, tree height, canopy circumference as compared with the control in both seasons of the study. However, tryptophan treatments surpassed the corresponding ones of salicylic and ascorbic in enhancing the shoot

length of navel orange trees in both seasons, thus tryptophan at 75 ppm proved to be the superior treatment in this respect. The tree height takes the same trend to shoot length in both seasons. In addition, leaf area recorded the highest significant value with salicylic at 300 ppm treatment. Other treatments produced a slight enhancing effect in this concern from the statistical standpoint. Moreover, in the first season of 2019 tryptophan at 75 ppm and salicylic at 300 ppm treatments produced a similar and high positive effect on tree canopy circumference as compared with the control treatment. Generally, 75 ppm tryptophan treatment gave a high positive effect on canopy circumference. In the second season, of 2020 tryptophan at 75 ppm gave the highest values of tree canopy circumference compared with the control treatment.

The observed results are consistent with **Hanafy *et al.* (2012)**. who found that a gradual increase in most of growth characteristics of Valencia orange plants with increasing rate of tryptophan amino acid as a foliar spray at (25, 50 and 100 ppm). In their study of the Manfalouty pomegranate variety, **Omima *et al.* (2014)** noted that tryptophan treatment at 100 ppm was the most effective treatment for enhancing vegetative growth. Additionally, according to **(El-Khayat, 2018)**, spraying trees three times with gibberellic acid, ascorbic acid, citric acid, and salicylic acid increased tree vegetative growth. According to **(Russell, 1982; Taiz and Zeiger, 2002)**, tryptophan is the precursor of the indole acetic acid (auxin), which is crucial for controlling plant growth and development. Additionally, tryptophan creates the building blocks of protein required for metabolic activities **(Davies, 1982).**

Table 3. Effect of tryptophan amino acid and some antioxidants on some vegetative growth parameters of Navel orange trees in 2019 and 2020 seasons

Treatments	Shoot length (cm)	Leaf area (cm^2)	Tree height (m)	Canopy circumference (m)
		2019		
Control	11.11 f	17.04 g	2.49 ef	8.77 f
TR 25 ppm	14.60 de	19.06 ef	2.96 cd	9.92 cde
TR 50 ppm	15.77 cd	19.85 d	3.41 b	10.55 bcd
TR 75 ppm	19.58 a	21.72 c	3.89 a	12.31 a
SA 100 ppm	13.55 e	21.47 c	2.72 def	10.27 cde
SA 200 ppm	16.83 bc	22.68 b	2.84 de	11.54 ab
SA 300 ppm	17.22 bc	24.81 a	3.32 bc	11.69 a
ASA 500 ppm	14.32 de	18.79 f	2.42 f	9.45 ef
ASA 750 ppm	15.51 cd	19.57 de	2.69 def	9.63 def
ASA 1000 ppm	17.74 b	20.05 d	2.71 def	10.63 bc
		2020		
Control	10.59 e	17.22 e	2.29 f	9.02 g
TR 25 ppm	13.24 cd	18.47 de	2.49 e	12.09 bc
TR 50 ppm	14.31 bcd	18.33 de	2.84 b	13.07 ab
TR 75 ppm	17.57 a	22.66 bc	3.32 a	13.44 a
SA 100 ppm	12.86 cde	21.94 c	2.69 bcd	10.26 f
SA 200 ppm	13.61 cd	24.72 ab	2.70 bc	11.55cde
SA 300 ppm	15.39 abc	26.06 a	2.78 b	11.73 cd
ASA 500 ppm	12.61 de	17.88 e	2.57 cde	9.86 fg
ASA 750 ppm	15.05 a-d	19.51 de	2.54 de	10.43 ef
ASA 1000 ppm	16.58 ab	20.51 cd	2.81 b	10.88 def

Control = water tap, TR= Tryptophan, SA= Salicylic acid and ASA= Ascorbic acid.
Mean within each column followed by the same letter(s) are not significantly different at 5% level.

Fruiting measurements

Table (4) shows that tryptophan, salicylic and ascorbic succeeded in enhancing fruit set percentage as compared with check treatment in both seasons. Generally, 300 ppm salicylic sprayed trees showed to be the highest fruit set percentage exerted (9.77 and 8.28%) against (6.52 and 5.18%) for tap water control treatment in both seasons, respectively. Moreover, tabulated data illustrated that all tested tryptophan, salicylic and ascorbic treatments produced a pronounced effect on fruit retention percentage (after June drop, August, October and December) as compared with the control treatment in 2019 and 2020 seasons. Anyhow, salicylic treatments, particularly in the high concentration (300 ppm), increased fruit retention percentage (after June drop, August, October and December) in both seasons.

Table 4. Effect of tryptophan amino acid and some antioxidants on fruit set (%) and changes in fruit retention (%) of Navel orange trees in 2019 and 2020 seasons

Treatments	Fruit set (%)	Fruit retention (%) (After June drop)	Fruit retention (%) (August)	Fruit retention (%) (October)	Fruit retention (%) (December)
			2019		
Control	6.52 d	16.84 d	15.95 d	15.92 d	9.09 d
TR 25 ppm	7.76 c	20.44 c	18.81 c	18.18 c	11.02 c
TR 50 ppm	8.48 bc	22.52 bc	20.46 bc	19.51 bc	12.13 bc
TR 75 ppm	8.94 ab	23.85 ab	21.51 ab	20.35 ab	12.84 ab
SA 100 ppm	7.83 c	20.63 c	18.95 c	18.29 c	11.11 c
SA 200 ppm	8.58 bc	22.82 bc	20.69 bc	19.69 bc	12.28 bc
SA 300 ppm	9.77 a	26.27 a	23.42 a	21.85 a	14.12 a
ASA 500 ppm	7.77 c	20.47 c	18.83 c	18.19 c	11.03 c
ASA 750 ppm	8.10 c	21.41 c	19.57 c	18.81 c	11.53 c
ASA 1000 ppm	8.13 bc	21.51 bc	19.66 bc	18.85 bc	11.59 bc
			2020		
Control	5.18 h	14.02 h	13.65 h	14.69 h	8.32 g
TR 25 ppm	6.13 fg	16.76 fg	15.95 fg	16.65 fg	9.38 ef
TR 50 ppm	7.28 bc	20.08 bc	18.75 bc	18.97 bc	11.28 bc
TR 75 ppm	7.41 bc	20.47 bc	19.07 bc	19.25 bc	11.50 b
SA 100 ppm	6.98 cd	19.20 cd	18.00 cd	18.35 cd	10.76 bcd
SA 200 ppm	7.48 b	20.67 b	19.23 b	19.43 b	11.66 b
SA 300 ppm	8.28 a	22.97 a	21.18 a	21.05 a	12.98 a
ASA 500 ppm	5.91 g	16.13 g	15.42 g	16.19 g	9.00 fg
ASA 750 ppm	6.51 ef	17.85 ef	16.87 ef	17.39 ef	9.97 de
ASA 1000 ppm	6.78 de	18.62 de	17.52 de	17.96 de	10.45 cd

Control = water tap, TR= Tryptophan, SA= Salicylic acid and ASA= Ascorbic acid.
Mean within each column followed by the same letter(s) are not significantly different at 5% level.

Fruit drop percentage

Table (5) demonstrates that all tested tryptophan, salicylic and ascorbic treatments produced a pronounced negative effect on fruit drop percentage (after June drop, August, October and December) of navel orange trees as compared with the control treatment. Generally, salicylic treatments recorded comparatively lower values of fruit drop percentage (after June drop, August, October and December) than other treatments. In this respect, 300 ppm salicylic treatment scored the lowest values of fruit drop percentage (after June drop, August, October and December) for the control treatment in the 2019 and 2020 seasons, respectively.

Yield parameters

It is clear from Table (6) that tryptophan, salicylic and ascorbic sprayed trees produced a higher number of fruits than those sprayed with tap water control in both seasons of the study. Anyhow, 300 ppm salicylic treatment shows superiority in this respect. In addition, tryptophan, salicylic and ascorbic treatments succeeded in improving tree yield as compared with the control in both seasons. Generally, 300 ppm salicylic sprayed trees showed to be the highest production trees gave (41.40 and 40.18 kg/tree) against (25.06 and 22.31 kg/tree) for tap water control sprayed trees in the 2019 and 2020 seasons, respectively. Moreover, the yield per feddan (ton) takes the same trend to tree yield in both seasons. Also, the tested salicylic treatments caused a significant increase in yield efficiency than the control treatment. In addition to, salicylic at 200 and/or 300 ppm treatments produced a statistically similar and higher positive effect on yield efficiency as compared with other treatments including the control in first season. Meanwhile, in the second season salicylic at 300 ppm treatment shows superiority in this respect compared with the control treatment.

Table 5. Effect of tryptophan amino acid and some antioxidants on seasonal changes in fruit drop* (%) of Navel orange trees in 2019 and 2020 seasons

Treatments	Fruit drop (%) (After June drop)	Fruit drop (%) (August)	Fruit drop (%) (October)	Fruit drop (%) (December)
		2019		
Control	83.16 a	84.05 a	84.08 a	90.98 a
TR 25 ppm	79.56 b	81.19 b	81.82 b	89.22 bc
TR 50 ppm	77.48 bc	79.55 bc	80.49 bc	87.80 ef
TR 75 ppm	76.15 cd	78.49 cd	79.65 cd	87.46 fg
SA 100 ppm	79.37 b	81.05 b	81.78 b	88.60 cd
SA 200 ppm	77.18 bc	79.31 bc	80.31 bc	87.00 g
SA 300 ppm	73.74 d	76.58 d	78.16 d	85.48 h
ASA 500 ppm	79.53 b	81.17 b	81.81 b	89.30 b
ASA 750 ppm	78.49 bc	80.35 bc	81.15 bc	88.70 bcd
ASA 1000 ppm	78.59 b	80.43 b	81.19 b	88.23 de
		2020		
Control	85.98 a	86.36 a	85.32 a	91.68 a
TR 25 ppm	83.25 bc	84.05 bc	83.35 bc	90.62 bc
TR 50 ppm	79.92 fg	81.25 fg	81.03 fg	88.72 ef
TR 75 ppm	79.53 fg	80.93 fg	80.76 fg	88.50 f
SA 100 ppm	80.79 ef	81.99 ef	81.65 ef	89.24 def
SA 200 ppm	79.34 g	80.77 g	80.57 g	88.34 f
SA 300 ppm	77.03 h	78.82 h	78.95 h	87.03 g
ASA 500 ppm	83.87 b	84.58 b	83.81 b	91.00 ab
ASA 750 ppm	82.15 cd	83.13 cd	82.62 cd	90.03 cd
ASA 1000 ppm	81.38 de	82.48 de	82.04 de	89.55 de

Control = water tap, TR= Tryptophan, SA= Salicylic acid and ASA= Ascorbic acid.
Mean within each column followed by the same letter(s) are not significantly different at 5% level.
*Refer to drop % at different measurement data was estimated as accumulated values.

Table 6. Effect of tryptophan amino acid and some antioxidants on fruit No. / tree, yield / tree (kg), Yield (ton/fed.) and yield efficiency of Navel orange trees in 2019 and 2020 seasons

Treatments	Fruit No. / tree	Yield / tree (kg)	Yield (ton/fed.)	Yield efficiency
		2019		
Control	105 g	25.06 f	4.39f	2.87 d
TR 25 ppm	113 f	28.78 e	5.04e	2.90 cd
TR 50 ppm	118 e	31.37 d	5.49d	2.97 cd
TR 75 ppm	134 bc	37.98 b	6.65b	3.10 bcd
SA 100 ppm	126 d	31.08 d	5.44d	3.29 b
SA 200 ppm	138 b	35.32 c	6.18c	3.70 a
SA 300 ppm	154 a	41.40 a	7.25a	3.90 a
ASA 500 ppm	130 cd	31.79 d	5.56d	3.09 bcd
ASA 750 ppm	134 be	34.42 c	6.02c	2.99 bcd
ASA 1000 ppm	137 b	37.08 b	6.49b	3.17 bc
		2020		
Control	101 e	22.31 h	3.90h	2.49 fg
TR 25 ppm	109 e	27.14 g	4.75g	2.25 g
TR 50 ppm	128 cd	33.19 cd	5.81cd	2.55 efg
TR 75 ppm	134 bc	37.13 b	6.50b	2.76 c-f
SA 100 ppm	130 cd	30.68 ef	5.40ef	3.11 bc
SA 200 ppm	140 b	34.86 bc	6.10bc	3.34 b
SA 300 ppm	152 a	40.18 a	7.03a	3.70 a
ASA 500 ppm	122 d	29.05 fg	5.08fg	2.85 cde
ASA 750 ppm	127 cd	31.69 de	5.55de	2.75 def
ASA 1000 ppm	130 cd	34.14 c	5.97c	2.90 cd

Control = water tap, TR= Tryptophan, SA= Salicylic acid and ASA= Ascorbic acid.
Mean within each column followed by the same letter(s) are not significantly different at 5% level.

All treatment increased fruit yield in a positive way through several processes. Due to salicylic acid's influence on boosting plant metabolism and biosynthesis during fruit development, foliar sprays SA on navel orange trees greatly enhanced yield, fruit weight, and reduced drop percentage **(Habasy, 2015)**. Salicylic acid has positive impacts on plant metabolism, nutrient absorption, and translocation, which may enhance plant pigments and other nutrients **(Ding *et al.*, 2001)**. Its benefits on improving early fruit set and fruit retention could be explained by salicylic acid's remarkable beneficial effects on improving C/N in favour of enhancing flowering as well as the tolerance of plants to all stimuli as well as its effects on minimizing June drop **(Ding and Wang, 2003)**. Salicylic acid's good impact on the yield may be interpreted as boosting initial fruit set, fruit retention, and minimizing June drop. Salicylic acid may improve the production and transport of plant pigments and Mg, which could account for its beneficial effects on fruit quality. These results are in agreement with those obtained by **Ahmed (2011)** on Sakkoti date palms; **Abd El-Rahman** and **El- Masry (2012)** on Valencia trees; **Ahmed *et al.* (2014)** on Keitte mango trees; **Omar (2015)** on Saidy date palms and **Abd El-Mageed (2015)** on Sakkoti date palms. The abovementioned investigators indicated that Salicylic acid foliar spray had a positive effect on tree yield.

Fruit quality

Table (7) demonstrates that all tested tryptophan, salicylic and ascorbic succeeded in improving the fruit weight of navel orange trees in both seasons as compared with the control treatment. Generally, 75 ppm tryptophan treatment gave the highest fruit weight exerted (282 and 257 g) against (238 and 219 g) for the control treatment in both seasons, respectively. Other treatments produced a slight enhancing effect with respect to the standpoint. Also, the statistical analysis illustrates that all tested concentrations of tryptophan, salicylic and ascorbic exerted a positive enhancing effect on the fruit length of navel orange trees as compared with the control in both seasons. Shortly, 75 ppm tryptophan treatment showed a constant trend and higher values of fruit length throughout the two seasons of study. Other salicylic and ascorbic treatments scored less than an intermediate value in this concern. In addition, the data indicates that tryptophan, salicylic and ascorbic sprayed trees produced a higher value of fruit diameter than those sprayed with tap water control in both seasons of the study. Anyhow, 75 ppm tryptophan treatment showed superiority in this respect.

Table 7. Effect of tryptophan amino acid and some antioxidants on Fruit Weight (g), Fruit length (cm), Fruit diameter (cm) and Fruit volume of Navel orange trees in 2019 and 2020 seasons

Treatments	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit volume (cm^3)
		2019		
Control	238 g	7.86 h	7.45 g	227 f
TR 25 ppm	254 d	8.24 f	7.90 e	243 d
TR 50 ppm	264 c	8.31 d	7.98 c	253 c
TR 75 ppm	282 a	8.46 a	8.12 a	270 a
SA 100 ppm	246 e	8.14 g	7.81 f	236 e
SA 200 ppm	254 d	8.28 e	7.93 d	244 d
SA 300 ppm	267 b	8.36 c	8.00 c	256 c
ASA 500 ppm	243 f	8.22 f	7.89 e	234 e
ASA 750 ppm	255 d	8.30 d	7.95 d	245 d
ASA 1000 ppm	270 b	8.41 b	8.04 b	260 b
		2020		
Control	219 f	7.72 i	7.48 g	210 f
TR 25 ppm	247 d	8.32 e	8.04 d	237 d
TR 50 ppm	258 c	8.45 b	8.19 b	146 c
TR 75 ppm	257 a	8.58 a	8.30 a	164 a
SA 100 ppm	236 e	8.21 g	7.95 e	226 e
SA 200 ppm	248 d	8.29 f	8.03 d	238 d
SA 300 ppm	264 b	8.41 c	8.15 bc	253 b
ASA 500 ppm	238 e	8.16 h	7.89 f	229 e
ASA 750 ppm	248 d	8.29 f	8.03 d	238 d
ASA 1000 ppm	262 b	8.37 d	8.11 c	252 b

Control = water tap, TR= Tryptophan, SA= Salicylic acid and ASA= Ascorbic acid.
Mean within each column followed by the same letter(s) are not significantly different at 5% level.

Moreover, table (7) indicates that all tested tryptophan, salicylic and ascorbic treatments enhanced fruit volume of navel orange trees as compared with the control treatment in both seasons. Generally, 75 ppm tryptophan treatment was the alone treatment that induced a positive significant effect in this respect. Other treatments produced a slight enhancing effect in this concern from the statistical standpoint.

Table (8) demonstrates that in the first season 75 ppm tryptophan and (200 and 300 ppm) salicylic treatment scored statistically similar and had higher positive effects on peel thickness as compared with other treatments including the control. Meanwhile, in the second season 300 ppm salicylic treatment gave a high positive effect on peel thickness as compared with the control treatment in this study. In addition, Table (8) indicates that all tested treatments scored statistically higher values of juice weight as compared with the control treatment in both seasons. Generally, 300 ppm salicylic treatment induced the highest juice weight exerted (187.0 and 168.7 g) against (108.3 and 92.3 g) for the control treatment in both seasons of the study. Moreover, Table (8) shows that all tested tryptophan, salicylic and ascorbic treatments produced a pronounced effect on fruit juice percentage as compared with the control treatment in both seasons of the study. Generally, salicylic treatments, practically a high concentration of 300 ppm showed superiority in increasing fruit juice percentage as compared with control treatment in both seasons of study.

Table 8. Effect of tryptophan amino acid and some antioxidants on Peel thickness (mm), Juice weight (g) and Fruit juice % of Navel orange trees in 2019 and 2020 seasons

Treatments	Peel thickness (mm)	Juice weight (g)	Fruit juice %
2019			
Control	0.36 d	108.33 d	43.26 bc
TR 25 PPM	0.38 cd	134.33 c	43.73 bc
TR 50 PPM	0.44 bc	153.67 bc	47.45 bc
TR 75 PPM	0.51 a	161.33 b	47.35 bc
SA 100 PPM	0.48 ab	149.67 bc	59.61 a
SA 200 PPM	0.55 a	157.67 bc	53.23 ab
SA 300 PPM	0.51 a	187.00 a	60.52 a
ASA 500 PPM	0.41 cd	137.67 c	47.33 bc
ASA 750 PPM	0.48 ab	146.33 bc	45.58 bc
ASA 1000 PPM	0.49 ab	146.67 bc	42.34 c
2020			
Control	0.35 d	92.33 c	40.79 d
TR 25 ppm	0.36 d	135.67 b	41.66 d
TR 50 ppm	0.44 c	146.67 ab	43.49 d
TR 75 ppm	0.45 c	162.67 ab	46.42 bcd
SA 100 ppm	0.49 bc	137.33 b	54.93 ab
SA 200 ppm	0.53 ab	146.00 ab	55.53 a
SA 300 ppm	0.56 a	168.67 a	60.02 a
ASA 500 ppm	0.45 c	144.00 ab	52.61 abc
ASA 750 ppm	0.49 bc	149.67 ab	45.99 cd
ASA 1000 ppm	0.49 bc	151.67 ab	41.09 d

Control = water tap, TR= Tryptophan, SA= Salicylic acid and ASA= Ascorbic acid.
Mean within each column followed by the same letter(s) are not significantly different at 5% level.

Juice quality

The tested concentration of tryptophan, salicylic and ascorbic treatments effect on fruit TSS content more than the control treatment in both seasons of the study. Moreover, 300 ppm salicylic treatment proved to be the most efficient treatment in this concern. Other treatments showed more or less an intermediate value in this respect. In addition, the tryptophan, salicylic and ascorbic treatments have a pronounced reductive effect on fruit total acidity content as compared with the control. Briefly, 300 ppm salicylic treatment proved to be the most efficient treatment in reducing fruit total acidity content. Other tested treatments showed nearly similar values from a statistical standpoint. Moreover, the tryptophan, salicylic and ascorbic treatments have a pronounced reductive effect on fruit total acidity content as compared with the control. Shortly, 300 ppm salicylic treatment proved to be the most efficient treatment in reducing fruit total acidity content. Other tested treatments showed nearly similar values from a statistical standpoint.

Also, all the tested treatments recorded statistically higher values of fruit ascorbic acid content as compared with the control treatment in the 2019 and 2020 seasons. Generally, 300 ppm salicylic treatment induced the highest fruit ascorbic acid content as compared with the control treatment in both seasons of the study.

In addition, all the tested tryptophan, salicylic and ascorbic treatments succeeded in improving fruit total sugar content of navel orange trees in both seasons as compared with the control treatment. Generally, 300 ppm salicylic treatment recorded the highest values of fruit total sugars content as compared with the control treatment in both seasons.

Table 9. Effect of tryptophan amino acid and some antioxidants on total soluble solids, total acidity %, vitamin C % and total sugar (%) of Navel orange trees in 2019 and 2020 seasons

Treatments	Total soluble solids (TSS)%	Total acidity %	Vitamin C %	Total sugar (%)
		2019		
Control	10.70 g	0.807 a	39.72 cd	7.43 e
TR 25 ppm	11.03 fg	0.723 ab	40.81 abc	7.63 e
TR 50 ppm	12.07 abc	0.710 bc	41.16 ab	8.49 c
TR 75 ppm	12.13 abc	0.710 bc	41.26 ab	9.24 b
SA 100 ppm	11.19 efg	0.707 bc	39.41 d	8.16 d
SA 200 ppm	12.19 ab	0.670 bcd	40.86 abc	8.53 c
SA 300 ppm	12.32 a	0.633 cde	41.79 a	9.68 a
ASA 500 ppm	11.44 def	0.743 ab	39.47 d	7.54 e
ASA 750 ppm	11.65 cde	0.607 de	40.45 bcd	8.41 c
ASA 1000 ppm	11.73 bcd	0.560 e	40.80 abc	9.24 b
		2020		
Control	9.96 e	0.847 a	40.72 h	7.65 g
TR 25 ppm	9.99 e	0.810 ab	42.47 gh	7.82 f
TR 50 ppm	10.71 c	0.790 abc	42.54 fgh	8.16 e
TR 75 ppm	11.14 b	0.720 de	45.40 bcd	8.33 bc
SA 100 ppm	10.46 cd	0.773 bcd	44.41 def	7.72 g
SA 200 ppm	11.38 b	0.710 de	46.41 bc	8.40 b
SA 300 ppm	11.98 a	0.660 e	50.33 a	8.64 a
ASA 500 ppm	10.34 d	0.807 ab	43.09 efg	8.22 de
ASA 750 ppm	10.42 d	0.733 cd	44.56 cde	8.29 cd
ASA 1000 ppm	11.24 b	0.730 cd	46.52 b	8.35 bc

Control = water tap, TR= Tryptophan, SA= Salicylic acid and ASA= Ascorbic acid.
Mean within each column followed by the same letter(s) are not significantly different at 5% level.

In this regard, the results were consistent with those of **Khuong *et al.* (2010)** on citrus, **Pillitteri *et al.* (2010)** on Clementine mandarin, **Habasy (2015)** on Navel orange trees, and **El-Khayat (2018)** on Washington navel orange in terms of the effects of tryptophan, salicylic, and ascorbic on fruit quality. They said that the fruit quality of the aforementioned fruit species was improved by foliar spraying tryptophan, salicylic, and/or ascorbic acid.

CONCLUSION

Consequently, the present results approved that using salicylic acid at 300 ppm treatment on Navel orange trees enhanced fruit set, fruit retention, productivity, juice weight, fruit juice weight percentage, and chemical properties by increasing TSS, ascorbic acid and total sugar content and decreasing total acidity content. Moreover, tryptophan treatment at 75 ppm improved shoot length, tree height, tree canopy volume, and physical properties by increasing fruit weight, fruit length, fruit diameter and fruit volume.

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RESEARCH ARTICLE

Effect of tryptophan, salicylic and ascorbic acids on productivity and fruit quality of Navel orange trees

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