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Using Nano- Technology for Increasing " Washington " Navel Orange Production and Improving Fruit Character

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ABSTRACT

This study was carried out during 2019/2020 and 2020/2021 seasons on 40 years old 'Washington' Navel orange (*Citrus sinensis* L.), Osbeck grown in light clay soil at a private orchard in Gharbia, Governorate, Egypt. This work aims to evaluate the effect of foliar applications of nano-nitrogen and nano-potassium on vegetative growth, yield and fruit quality of 'Washington' Navel orange trees. The study consisted of nine treatments with three replicates of each treatment. The treatments were as follows: Full amount NPK (control), nitrogen nano 600 ppm, nitrogen nano 900 ppm, potassium nano 600 ppm, potassium nano 900, nitrogen nano 600 + potassium nano 600, nitrogen nano 900 ppm + potassium nano 900 ppm, nitrogen nano 600 ppm + potassium nano 900 ppm, nitrogen nano 900 ppm + potassium nano 600 ppm. Obtained results indicated that treatments with 900 ppm of nano nitrogen and 900 ppm of nano potassium induced an increase in tree canopy, number of fruits, fruit weight, total yield, fruit set (%), peel thickness, juice volume, TSS and Vitamin C. While the treatments with (N 900 + K900) and (N 0. + K 900) caused an increase in yield efficiency compared to the control treatment.

1. INTRODUCTION

The word citrus is derived from the Latin cedrus that comes from the Greek kedrus, which refers to the kedromelon or cedar-apples (citron) **(Jahoda, 1976)**. Citrus fruit are members of Rutaceae family, which include orange, grapefruit, lemon, lime, tangerine and mandarin, pummelo, and kumquat. It is generally accepted that pummelo, mandarin, and citron are the founding true species of all citrus varieties existing today **(Spiegel-Roy and Goldschmidt, 1996)**.

Which amounted to (541723 fed) in 2017 **(Abobatta and Khalifa, 2019)** or in terms of productivity, which amounted to (4098590 tons) with the average of (10.336 tons/fed) according to **Annual Report of the Egyptian Ministry of Agriculture (2017**). Fruit quantity and quality are affected by several factors including cultivar, rootstock, climate, soil, pests, irrigation, and nutrition **(Abobatta, 2018)**. Fruit in Egypt depending on the cultivated areas, the targeted cultivar of this study is 'Washington' Navel orange (*Citrus sinensis* L. Osbeck) **(Hodgson, 1967)**.

Citrus is commercially grown primarily in regions with mild winters located between 20^{o} and 40^{o} of latitude in both hemispheres **(McKnight and Hess, 2000)**. Citrus occupied the third position between fruit crops after grapes and apples worldwide **(FAO, 2016)**. Egypt ranking as the sixth producer after Brazil, China, USA, EU and Mexico in citrus production. Egypt ranked the third world producer in mandarin. Because the citrus fruits are the main. Therefore, supplying sufficient nutrition and water quantity should be high-priority practices for every grower for increasing yield and improving fruit quality. Furthermore, plant nutrition one of the main management practices and affect productivity and fruit quality, therefore, they nutrients has adverse effects of total yield and fruit quality **(Zekri *et al.*, 2003)**.

This work aims to evaluate the effect of foliar application of Nano Nitrogen and Nano Potassium on vegetative growth, yield, and fruit quality of 'Washington' Navel orange trees.

2. MATERIALS AND METHODS

This study was carried out during 2019/2020 and 2020/2021 seasons on 40 years old 'Washington' Navel orange (*Citrus sinensis* L. Osbeck) budded trees on Sour orange rootstock, (*Citrus aurantium* L., Osbek) and grown in a private orchard located at Meat lait Hashem in Al-Mahalla Al-Kubra, district Gharbia, Governorate, Egypt. Trees were planted at 5×5 m apart with a total number of 168 trees/fed in a light clay soil.

2.1 Common agricultural practices during both seasons

1- The irrigation method is the surface irrigation.

2- Three different types of fertilizers were used; NPK (ammonium nitrate [33.5% N], potassium sulphate [48.5% K_2O] and superphosphate [15.5% P_2O_5]) were added each season, as follows:

Both superphosphate (100 kg/fed) and sulfur (200 kg/fed) were scattered around the tree shade in late winter at 3rd of January. N fertilizer was added three times a year as follows:

During the first week of March (early spring) of both experimental seasons, trees received 200 kg ammonium nitrate/fed and 100 kg potassium sulfate/fed [48.5%].

Another 100 kg ammonium nitrate/fed were added in May after fruit set.

Fertilization was repeated again in July of both seasons by adding 200 kg ammonium nitrate/fed and 100 kg potassium sulfate/fed, throughout the year 167.5 kg.

3- Organic fertilizer as compost was added before irrigation by scattering around the tree trunk (15 kg/tree/season) during the first week of March (early spring).

4- The trees were sprayed using nano-nitrogen at a concentration of 600, 900 and nano-potassium at a concentration of 600, 900 in March, May and July in both seasons.

5- Weeds were mechanically removed in March, April, and May, and chemically controlled using 48.5% Herbozd herbicide in June, July and August.

6- The following micronutrients were sprayed in May and June; amino acids (7.42%), iron (1.2%), zinc (0.8%), manganese (1%), boron (0.1%), and molybdenum (0.1%).
7- Tree trunk was sprayed, in mid-September, for leaf whitefly (*Bemisia argentifolii*) control using a mixture of 10% Lambda pesticide (1.25 kg/600L water) and Malathion pesticide (one L/600L water).

2.2 Experiment

Fifty four trees were selected for this experiment and grouped in 9 treatments. Each treatment was represented by 6 trees in 3 replicates, with 2 trees each. Treatments can be summarized, as follows:
T1 = Full amount NPK (control).
T2 = Nitrogen nano 600ppm.
T3 = Nitrogen nano 900ppm.
T4 = Potassium nano 600ppm.
T5 = Potassium nano 900ppm.
T6 = Nitrogen nano 600 + potassium nano 600 ppm.
T7 = Nitrogen nano 900 + potassium nano 900 ppm.
T8 = Nitrogen nano 600 + potassium nano 900 ppm.
T9 = Nitrogen nano 900 + potassium nano 600 ppm.

2.3 Tree size (m^2): This was calculated according to the equation of **(Morse and Robertson, 1987)** as follows:

$$\text{Tree size} = 0.5236 \times HD^2$$

Where: H = tree height and D = tree diameter

2.4 Fruiting and fruit quality

2.4.1 Fruit set (%):

The percentage of remaining fruit was calculated after June drop using the following equation;

Final Fruit set (%) = Number of remaining fruit after June drop x 100 Total flowers number

2.4.2 Total yield:

Total yield (kg), average fruit weight (g), and fruit number per tree were calculated at harvest time (first week of May in both seasons).

2.4.3 Peel thickness:

The average thickness of the peel (mm) was measured according to **(Kwan, 2011)**.

2.4.4 Juice volume:

Four random fruits are taken from each treatment and then squeezed with a hand-squeezer. Juice was collected in a flask, and juice volume was record and then seeds were removed.

2.4.5 Total soluble solids (TSS):

It was measured using a refract meter, according to **(A.O.A.C. 1995)**.

2.4.6 Total acidity:

Juice samples was filtered and used to determine total acidity using the titration method against Na OH (0.1 N) in the presence of phenol phethalein, as an indicator, according to **(Chen and Mellenthin, 1981)** to calculate citric acid acidity percentage.

2.4.7 Ascorbic acid (vitamin C) content: This was determined in filtered juice samples and expressed as mg/100 ml juice, as described by **(A.O.A.C. 1995)** using 5ml juice sample and 5 ml of oxalic acid solution (2%). Then titrated against 2, 6-dichlorophenolendophenol indicator dye to the end point (the appearance of pink color) to calculate vitamin C.

2.5 Statistical analysis:

Data were analyzed using M-Stat program in a randomized complete block design (RCBD) as described by **(Snedecor and Cochran, 1980)** and means were compared using least significance difference (LSD) at $p \leq 0.05$ **(Little and Hills, 1972)**.

3. RESULTS AND DISCUSSION

3.1 Tree canopy (m^3) and yield efficiency

Results in Table 1 indicate that, the application of Nano-Nitrogen and Nano-Potassium at concentrations of N 900 ppm,

K 900 significantly affected both shoot number and length of 'Washington' Navel orange trees, as well as, tree canopy in comparison to the control during both seasons. Here as control recorded the lowest values of all three parameters compared to other treatments during the two seasons. Means in each column followed by the same letters are not significantly different at P≤0.05 level with new LSD. These results are in the same line with those found by **Mostafa and Saleh (2006) and Mostafa *et al*. (2005)** on Balady mandarin, who indicated that spraying potassium from several forms raised N, P and K. The data in Table 1 showed that yield efficiency increased using the foliar spray of Nano Nitrogen and Nano-Potassium at concentrations of N 900 ppm, K 900 and Nano-Potassium at concentration ppm, K 900 comparing with control, in the first season. In the second season, Nano-Nitrogen and Nano-Potassium at concentrations of N 900 ppm, K 600 ppm, and Nano-Potassium at concentration ppm, K 900 ppm treatment gave the highest values for the control values in the leaves.

3.2 No. of fruit/ tree and Fruit weight (g)

All tested treatments in Table 2 significantly increased fruit number and weight, compared to the control during both seasons. Whereas Nano-Nitrogen and Nano-Potassium at concentrations of N 900 ppm, K 900 ppm treatments have the highest values compared to control and the rest of the transactions. The results in Table2 show some increase in both No. and weight of fruits/tree. **Hafez, Omaima and El-Metwally (2007)** studied the influence of foliar spray of zinc 0.4%, potassium 1%. They indicated that, fruit length, diameter (L/D ratio) were significantly increased by treatment compared to control, application of Zn + K treatment recorded the highest values in this respect.

3.3 Total yield (kg/tree)

All treatments led to an increase in total yield compared to the control (Table 2), the most pronounced effect was recorded for the treatment of Nano-Nitrogen and Nano-Potassium at concentrations of N 900 ppm, K 900 ppm compared to the control and all other treatments. Similarly to the previously mentioned parameters, yield results are actually confirming the pronounced effect of spraying **K, N. (Achilea *et al*., 2000), Boman (2001)** they reported that foliar-applied of potassium nitrate was a potent tool to increase yields of various citrus species. In the yield of rice cultivar 'Bg 250' the highest yields was obtained in the treatment where 100% Nano N fertilizer was added compared to the control treatment which recorded the lowest yield **(Rathnayaka *et al.*, 2018)**.

3.4 Fruit set (%)

Application of Nano Nitrogen and Nano Potassium at concentrations of N 900 ppm, K 900 ppm significantly improved fruit set compared to all other treatments and control in which recorded the lowest fruit set percentage in both seasons (Table 3). Results are in line with previous reports that indicated a positive effect of spraying K+ 2% on fruit set (%) on Washington Navel orange **El-Shobaky and Mohamed (2000)**, also confirmed **Zalat (2008)** Navel orange sprayed by 5% KNO_3 at March and April increased fruit set. **El-Otmani *et al*. (2002)** found that, spraying 15% KNO_3 during flowering of Clementine mandarin increased fruit set. Spraying urea on navel orange trees led to an increase in fruit set, %, (**Siamal *et al*., 2008)**.

3.5 Peel thickness (mm)

Results in Table 3 of both seasons confirm the significant effect of Nano-Nitrogen and Nano-Potassium at concentrations of N 900 ppm, K 900 ppm, while, control treatment recorded the lowest fruit peel thickness.

Although, peel thickness may not be preferable for customers; however, it is considered an advantage for shipping. This may mean that control fruit are the best for quick consumption, unless some other treatments that insignificantly differ from the control may add some value to the fruit.

Previous findings stated that fruit peel thickness of Washington Navel orange

increased peel weight and thickness when spraying with potassium (2%) **El-Shobaky and Mohamed (2000), Zalat (2008)** recorded that, spraying Washington Navel orange by 5% KNO3 improved peel thickness.The application in Table 3 of Nano-Nitrogen and Nano-Potassium at concentrations of N 900 ppm, K 900 ppm significantly increased juice volume compared to the control during both seasons. However, Nano-Nitrogen and Nano-Potassium at concentrations of N 600 ppm, K 900 ppm recorded the highest juice content in comparison to the control and all other treatments during both seasons.

The foliar treatment that improved juice in both seasons in pomegranate fruit was the highest dose of nN fertilizer (nN2; by 7% to 9%), whereas the treatment U1 significantly increased aril juice (by 7%) only in the second season. **Sohrab *et al.* (2017) and Hamza *et al.* (2012)** found that foliar application of potassium has been reported to influence juice content of Clementine citrus fruits.

Table 1: Effect of applying Nano Nitrogen and Nano Potassium on growth and fruiting of 'Washington' Navel oranges during 2019/2020 and 2020/2021 seasons

Treatment		Total yield (kg/tree)		Tree canopy (m^3)		Yield efficiency	
N nano (ppm)	K nano (ppm)	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
0	0	55.58f	60.85f	12.65f	14.49c	4.394b	4.199d
0	600	70.89cde	85.76d	15.89cde	16.55bc	4.461b	5.182abc
0	900	86.20ab	95.72bc	14.302cde	16.47bc	6.027a	5.812a
Avr.		70.89	80.7767	14.93	15.8367	4.96	5.101
600	0	63.22ef	74.28e	13.74ef	17.93ab	4.601ab	4.143d
600	600	77.09bcd	86.90cd	16.82bcd	17.25abc	4.583ab	5.04abcd
600	900	84.53abc	103.1ab	18.76ab	18.80ab	4.506ab	5.484ab
Avr.		74.9467	88.0933	16.44	17.9933	4.559	4.896
900	0	69.17def	79.51 de	16.25bcde	16.47bc	4.257b	4.828abc
900	600	80.87abcd	99.86 b	18.32bc	17.06abc	4.414ab	5.853a
900	900	92.99a	111.8 a	19.64a	20.98 a	4.735ab	5.329ab
Avr.		81.01	97.0567	18.07	18.17	4.483	5.342
General avr.		75.61556	88.64222	16.48	17.3333	4.667	5.114

Table 2: Effect of applying Nano Nitrogen and Nano Potassium on growth and fruiting of 'Washington' Navel oranges during 2019/2020 and 2020/2021 seasons.

Treatment		No. of fruits/tree		Fruit weight (g)		Total yield (kg/tree)	
N nano (ppm)	K nano (ppm)	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
0	0	220.7e	231.7 e	251.7e	262.7f	55.58f	60.85f
0	600	242.3cd	270.0bc	292.5bcd	317.7de	70.89cde	85.76d
0	900	266.0ab	273.7bc	323.5abc	349.3bc	86.20ab	95.72bc
Avr.		243	258.4667	289.2333	309.9	70.89	80.7767
600	0	223.0e	248.3d	282.5de	298.7e	63.22ef	74.28 e
600	600	252.7bcd	265.3 c	304.8abcd	327.3cd	77.09bcd	86.90cd
600	900	258.3ab	281.0ab	327.4ab	367.0ab	84.53abc	103.1ab
Avr.		244.6667	264.8667	304.9	331	74.9467	88.0933
900	0	242.0d	263.3 c	285.8cde	302.0de	69.17 def	79.51de
900	600	257.3abc	279.3ab	314.3abcd	357.7ab	80.87abcd	99.86b
900	900	268.3a	292.3 a	345.3 a	382.3a	92.99 a	111.8 a
Avr.		255.8667	278.3	315.1333	347.3333	81.01	97.0567
General avr.		247.8444	267.2111	303.0889	329.4111	75.61556	88.64222

Table 3: Effect of applying Nano Nitrogen and Nano Potassium on growth and fruiting of 'Washington' Navel oranges during 2019/2020 and 2020/2021 seasons

Treatment		Peel thickness (mm)		Juice volume (ml^3)		Fruit set (%)	
N nano (ppm)	K nano (ppm)	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
0	0	0.454 c	0.4910d	221.7g	231.3e	8.391	6.868e
0	600	0.501bc	0.5567bcd	285.3d	289.0c	8.493ef	9.705cde
0	900	0.508bc	0.5703bc	299.3c	332.0ab	9.711c	9.448cde
Avr.		0.4877	0.5393	268.7667	284.1	8.865	8.6737
600	0	0.469 c	0.5237cd	271.3 e	281.3cd	8.066f	8.832de
600	600	0.476bc	0.5750bc	263.0f	280.7cd	9.240cd	10.51bcd
600	900	0.524b	0.6210b	311.3b	336.7a	10.51b	12.48abc
Avr.		0.4897	0.5732	281.8667	299.5667	9.272	10.6073
900	0	0.499bc	0.5563bcd	262.0f	273.0d	9.005de	8.901de
900	600	0.506bc	0.5940bc	310.0b	321.0b	9.705c	13.41ab
900	900	0.595a	0.6993a	321.0a	345.3a	11.51a	14.42a
Avr.		0.5333	0.6165	297.6667	313.1	10.07333333	12.2437
General avr.		0.5036	0.5767	282.7667	298.9222	9.403444	10.50822

Means in each column followed by the same letters are not significantly different at P≤0.05 level with new LS

Table 4: Effect of applying Nano Nitrogen and Nano Potassium on growth and fruiting of 'Washington' Navel oranges during 2019/2020 and 2020/2021 seasons

Treatment		TSS (%)		Acidity (%)		TSS/acid ratio		Vitamin C (mg/100 ml)	
N nano (ppm)	K nano (ppm)	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
0	0	11.47g	11.80f	1.115a	1.314a	10.29f	8.993f	45.35c	46.40e
0	600	12.10f	12.53e	0.991bc	1.062bc	12.26de	11.98de	50.03ab	53.41bc
0	900	12.47e	13.13cd	1.019bc	0.9653bc	12.26de	13.62cd	50.87ab	53.07bcd
Avr.		12.01333	12.4866	1.04167	1.1137	11.6033	11.531	48.75	50.96
600	0	12.70d	13.10cd	0.994bc	1.026bc	12.79cd	12.89cde	49.15bc	50.00d
600	600	13.03c	13.93b	0.959c	1.015bc	13.60bc	13.74bc	51.88ab	52.72bcd
600	900	14.13b	14.63a	0.992bc	0.9538c	14.25ab	15.34ab	51.91ab	55.36ab
Avr.		13.2867	13.8866	0.9816	0.9982	13.5467	13.99	50.98	52.6933
900	0	12.37e	12.93de	1.039ab	1.101b	11.92e	11.85e	48.82bc	50.71cd
900	600	12.76d	13.47c	1.016bc	0.9809bc	12.57de	13.74bc	51.88ab	54.37ab
900	900	14.47a	14.93a	0.993bc	0.9502c	14.58a	15.72a	53.66a	56.83a
Avr.		13.2	13.7766	1.016	1.0107	13.0233	13.77	51.4533	53.97
General avr.		12.8333	13.3833	1.0131	1.0409	12.7244	13.097	50.3944	52.541

Means in each column followed by the same letters are not significantly different at P≤0.05 level with new LSD.

3.6 Total soluble solids (TSS %)

Application in Table 4 of Nano-Nitrogen and Nano-Potassium at concentrations of N 900 ppm, K 900 ppm has significantly affected the percentage of fruit TSS in comparison to the control during both seasons. In addition, Nano-Nitrogen and Nano-Potassium at concentrations of N 600ppm, K 900 ppm showed significantly affected the percentage of fruit TSS in comparison to the control during the second season.

3.7 Acidity percentages

Similarly, Nano-Nitrogen and Nano-Potassium at concentrations of N 900 ppm, K 900 ppm recorded the minimum acidity percentage in fruit, and the difference was significant compared to all other treatments in Table 4. However, control treatment recorded the highest acidity percentage during both seasons. **Abd-Allah (2006)**

reported that, acidity percentage in the fruit juice was significantly increased by K_2HPO_4 treatment in Washington Navel orange. Vitamin C (mg/100 ml juice).

Trees treated with Nano-Nitrogen and Nano-Potassium at concentrations of N 900 ppm, K 900 ppm (Table 4) showed a significant improvement in vitamin C in comparison to the control, which recorded the lowest vitamin C, during both seasons. Same findings were reported by **Doaa, and Sefan (2020)** in case of total sugars, of 'King Ruby seedless' berries a significant increase in total sugars could be observed with the increase of Nano N concentration under 50% of the recommended dose of ammonium sulphate soil fertilizer compared to other treatments in the second season.

Mostafa and Saleh (2006), Mostafa *et al.* (2005) reported that spraying various citrus varieties with different potassium forms enhanced soluble solids content TSS/acid ratio. The results in Table 4 indicate that the application of Nano-Nitrogen and Nano-Potassium at concentrations of N 900 ppm, K 900 significantly affected in TSS/acid ratio in comparison to the control during both seasons. Whereas recorded control the lowest values of all parameters compared to other treatments during the two seasons. These results are in the same line with those found by **Doaa, and Sefan (2020)**, the highest SSC% and SSC/acid ratio of 'King Ruby seedless' berries were obtained in trees treated with 50% mineral plus 1000ppm Nano-N in both seasons.

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استخدام تقنية النانو لزيادة انتاجية برتقال الواشنجتن نفال وتحسين صفات الثمار

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مجلة العلوم الزراعية والبيئية المستدامة

الملخص

أجريت هذه الدراسة خلال موسمي ٢٠٢٠/٢٠١٩ و ٢٠٢١/٢٠٢٠ على أشجار برتقال أبو سرة 'واشنطن' (*Citrus sinensis* L. Osbeck) عمر ٤٠ عام مطعومة على أصل النارنج، نامية فى تربة خفيفة فى مزرعة خاصة فى محافظة الغربية، مصر. يهدف هذا البحث إلى تقييم تأثير رش نانو نيتروجين ونانو بوتاسيوم على محصول وجودة ثمار أشجار برتقال أبو سرة. حيث تم استخدام تسعة معاملات (كل معاملة ثلاث مكررات) على النحو التالى:

الجرعة السمادية الموصى بها طبقا لوزارة الزراعة NPK (الكنترول)، نيتروجين نانو ٦٠٠ جزء فى المليون، نيتروجين نانو ٩٠٠ جزء في المليون، نانو بوتاسيوم ٦٠٠ جزء في المليون، نانو بوتاسيوم ٩٠٠ جزء في المليون، نيتروجين نانو ٦٠٠ جزء في المليون + بوتاسيوم نانو ٦٠٠ جزء في المليون، نيتروجين نانو ٩٠٠ جزء في المليون + نانو بوتاسيوم ٩٠٠ جزء في المليون، نيتروجين نانو ٦٠٠ جزء في المليون + نانو بوتاسيوم ٩٠٠ جزء في المليون، نيتروجين نانو ٩٠٠ جزء في المليون + نانو بوتاسيوم ٦٠٠ جزء في المليون.

أشارت النتائج إلى أن معاملة نانو نيتروجين ونانو بوتاسيوم بتركيزات 900 جزء في المليون لكلاهما ادت لزيادة حجم المجموع الخضرى للأشجار، نسبة العقد، عدد الثمار، وزن الثمار، المحصول الكلي، سمك القشر، حجم العصير، المواد الصلبة الذائبة، وفيتامين ج. بينما أدت معاملة نانو نيتروجين ٩٠٠ جزء في المليون + نانو بوتاسيوم ٩٠٠ جزء في المليون ومعاملة بوتاسيوم ٩٠٠ جزء في المليون إلى زيادة الكفاءة المحصولية مقارنة بالاشجار غير المعاملة.

الكلمات المفتاحية
جوده الثمار، نانوتكنولوجي،البرتقال، النمو الخضري، المحصول