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Effect of Nitrogen and Potassium Fertilization on Vegetative Growth, Fruit Set and Quality of Washington Navel Orange Trees

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Abstract: Four doses of nitrogen were used i.e. 40, 60, 80 and 100 kg N/feddan annually in the form of ammonium. nitrate and three levels of potassium 100, 150 and 200 kg as potassium sulphate were tested as soil fertilization for I nvestigating their effects on vegetative growth, leaf nutrients content, fruitzet and fruit quality of Washington Navel orange trees. Data indicated that increasing N (100 kg/feddan/yr) and K (200 kg/feddan/yr) fertilization induced the largest increase in all growth parameters i.e. shoot length, shoot thickness, leaf number, leaf area and leaf dry weight in comparison with tested other treatments. Meanwhile, increasing applied nitrogen up to 100 kg / feddan and potassium sulphate up to 200 kg / feddan promoted all studied leaf nutrients. However, all doses of nitrogen and potassium treatments induced the highest increase of fruit and reduced fruit dropping. Nitrogen fertilizer treatments succeeded in maximizing total yield and improving fruit quality.

Kew words: Nabvel orange, nutrition, fruit set, leaf mineral content, yield.

INTRODUCTION

Citrus is one of the most important world fruit crops. However, citrus in Egypt is ranted as the first fruit crop and the cultivated area from is varieties and cultivars is increasing rapidly. Washington Navel orange occupies the largest orchard areas in the newly reclaimed sandy soil. Most of these orchards suffer from some adverse growth factors such as scarcity of water, salinity and poor soil fertility status. The control of fruit drop is very essential especially in the preharvest stage since most mature fruits which are potentially marketable, may be lost. The number of dropped fruit are highly positively correlated with air temperature during the period of physiological fruit drop.

Kouka *et al* [1] reported that the treatments which consistently indicated higher leaf K levels (1.5-1.8 %) of Washington Navel orange tree were obtained with N (500-1000 g/tree/yr) + K (500-1500 g/tree/yr) while the treatments which indicated consistently low leaf K (0.4-0.45 %) were the control and those treated with N (0-1000 g/tree/yr) + K (0-50 g/tree/yr) Nath and Mohan[2] they found that the highest values for peel thickness, peel percentage, TSS and acidity of Assam lemon fruits were obtained with high rates of N (900 g/tree/yr), whereas number of segments per fruit, pulp percentage, juice content and ascorbic acid concentration were lowest with high N rates.

The present work aimed mainly to assess the effect of nitrogen and potassium fertilization rates on tree growth, leaves constituents, as well as fruit set, fruit drop, yield and fruit quality.

MATERIALS AND METHODS

This study was carried out at El-Qalubia Governorate during seasons of 2004 and 2005. Healthy and nearly uniform washington navel orange trees (Citrus sinensis L. Osbeck) of 8 years old budded on sour orange rootstock grown in clay loam soil at 3.5 x 5.0 meters a part were devoted for this study.

The following treatments were used:

Nitrogen fertilization: Four doses of nitrogen were used i.e. 40, 60 and 80 (the dose normally applied in the orchard) and 100 kg N/feddan yearly in the form of ammonium nitrate. These doses of nitrogen fertilization were added as soil application. Each dose was divided in 7 equal amounts and added one monthly from early March to September.

Potassuim fertilization: Three levels of potassuim 100 (normal orchard application,) 150 and 200 kg as potassuim sulphate per feddan were added yearly to the soil and divided into three equal doses in March, June and August.

Measurements and determination:

Horticulture studies:

Vegetative growth: Four main branches nearly similar in diameter were chosen around each tree and tagged to measure the length of new shoots, which develop on these branches. These measurements were conducted in mid-March and repeated in December when growth ceased, then shoot length increase was calculated. Increment

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percentages for all previous measurements except leaf area were calculated and recorded as percentages.

Leaf samples: The previously measured leaves were used also for chemical analyses. Thus, the leaves were wiped with a damp cloth, washed with 0.1 N. hydrochloric acid then rinsed in distilled water and oven dried at 70 °C till constant weight. Leaf dry weight was calculated. Moreover, oven dried leaves were ground in a porcelain mortar and pestle and stored in small tight bags for the determination of N, P, K, Ca, Mg, Zn, Mn and Fe using the following procedures:

- Total nitrogen by semi-micro kjieldahl method as outlined by Pregl [3]
- Phosphorus using spekol spectrophotometer at 882.U.V. according to the method described by Murphy and Riely [4] .
- Potassuim photometrically using the method of Brown and Lilleland [5].
- Calcium and Magnesium by titration against versenate solution (Na-EDTA), method by Chapman and Pratt[6] .
- Iron, Zinc and Manganese spectraphotometrically using SP.1900 Atomic absorption spectrophotometer.
- Determined nutrients were expressed as percentages for N, P, K, Mg and Ca and ppm for Zn, Mn and Fe.

Measurements and determinations:

Fruiting:

Fruit set and fruit dropping: In late March of every season four branches were selected at random on each tree then tagged and their flowers during full bloom were counted and recorded. In early May, their fruit lets were counted and fruit set was calculated on the basis of the initial number of flowers as follow:

$$\text{Fruit set (\%)} = \frac{\text{No. of fruit lets}}{\text{No. of flowers}}$$

Fruits development was investigated in the three major stages as follows: June drop stage (i.e. 20th June – 1st July); fruit development stage (i.e. 20th Sept. – 20th October) and fruit harvest stage (i.e. 20th Nov. – 20th Dec.). for each of the previous fruit growth stages, periodicity of fruit drop and total fruit drop percentages were calculated based on the original number of fruit lets recorded at fruit set.

$$\text{Fruit drop (\%)} = \frac{\text{No. of dropped fruits}}{\text{No. of set fruit lets}}$$

Yield: In December (harvesting time) of both seasons, number of fruits per tree were counted and weighted in kg.

Fruit quality: Ten fruits from each tree were randomly sampled for determining both physical and chemical properties. On this concern, fruit weight (in gm) fruit size, peal thickness (cm), total soluble using hand refractometer, total acidity, total sugar, ascorbic acid content (milligrams per 100 ml juice according to the standard procedures in this respect (A.O.A.C., [7]. Meanwhile, the total soluble solids acid ratio for each sample was calculated and recorded.

Generally, all the previous treatments were arranged in a complete randomized block design with three replicates for each treatment and each replicate was represented by two trees. The obtained data were statistically analysed according to Snedecor and Cochran[8] . The means were differentiated using Duncan method at 5% level Duncan[9]

RESULTS AND DISCUSSIONS

Horticultural studies

a. Vegetative growth: It is clear from table (1) that in both seasons all vegetative growth increased as the level of applied nitrogen was raised to highest level. On the other hand, no significant difference was obtained between trees received 80 kg/fed N and 100 kg/fed as shoot length in the first season and leaf dry weight percentage on both seasons were concerned.

Generally, from the aforementioned results one can say that increasing N fertilization to a navel orange tree increased all parameters under studies. These result partially agree with the findings of Silm [10] on washington navel orange trees, noticed that vegetative growth increased N fertilization increased.

It was found that in both season shoot length, shoot thickness, leaf number, leaf area and leaf dry weight percentage increased with increasing the level of applied potassium to the trees.

These results generally agree with the finding of Androulakis *et al* [11] used K fertilizer in rates of (0.5 and 1.5 kg/tree) were applied on the grape fruit trees. They found that K had little effect on vegetative growth. On the other hand, Sleem[10] found that increasing K rate promoted Shoot length, Shoot thickness, leaf number, leaf area and leaf dry weight percentage of Washington navel orange tree.

Leaf nutrients content: The effect of different levels of nitrogen fertilization on leaf nutrients content is shown in Table (3). It is obvious that in both seasons leaf nutrients

Table 1: Effect of different nitrogen fertilization rates on some vegetative growth characteristics of Washington navel orange trees.

	Percentage increasment of									
	Shoot Length		Shoot thickness		Leaf Number		Leaf area Cm^3		Leaf dry Weight %	
Nitrogen Level Kg/fed	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
40	c 195.30	d 216.33	d 60.83	d 73.60	d 60.33	d 72.79	c 23.04	c 25.70	c 35.30	c 36.50
60	b 217.00	c 243.00	c 70.70	c 84.37	c 71.97	c 82.00	b 28.00	b 28.32	b 38.63	b 39.23
80	a 249.30	b 253.00	b 86.33	b 90.33	b 82.33	b 90.33	b 28.67	b 29.63	a 41.32	a 41.34
100	a 250.00	a 260.20	a 90.23	a 96.00	a 90.33	a 95.00	a 32.30	a 34.30	a 40.01	a 41.23

Table 2: Effect of different potassium fertilization rates on some vegetative growth characteristics of Washington navel orange trees

	Percentage increasment of									
	Shoot Length		Shoot thickness		Leaf Number		Leaf area Cm^3		Leaf dry Weight %	
Potassium Fertilizer K_2So_4 level Kg/fed	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
100	c 187.00	c 196.00	c 50.00	c 53.30	c 70.22	b 90.33	c 26.30	c 27.33	c 33.66	c 36.00
150	b 216.31	b 223.31	b 53.33	b 60.32	b 91.33	b 93.00	b 26.33	b 28.00	b 35.62	b 37.22
200	a 240.00	a 250.00	a 60.87	a 76.00	a 100.00	a 112.00	b 28.00	a 29.33	a 38.63	a 40.33

Table 3: Effect of different nitrogen fertilization rates of some leaf chemical constituents of Washington navel orange trees

	N (%)		P (%)		K (%)		Fe (ppm)		Zn (ppm)		Mn (ppm)	
Nitrogen Level Kg/fed	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
40	c 2.31	d 2.29	a 0.17	a 0.15	d 1.53	d 1.43	d 88.93	d 86.0	c 46.76	c 42.63	c 42.33	c 39.33
60	b 2.41	c 2.36	a 0.18	b 0.16	c 1.76	c 1.62	c 103.33	c 98.63	c 53.00	b 47.00	b 46.32	b 41.33
80	b 2.49	b 2.63	a 0.17	b 0.16	b 1.84	b 1.80	b 109.23	a 108.00	a 57.00	b 49.00	a 49.00	a 49.36
100	a 2.72	a 2.83	a 0.18	a 0.18	a 1.92	a 1.90	a 112.30	a 108.67	a 58.00	a 56.00	a 50.00	a 52.00

Table 4: Effect of different potassium fertilization rates of some leaf chemical constituents of Washington navel orange trees

	N (%)		P (%)		K (%)		Fe (ppm)		Zn (ppm)		Mn (ppm)	
Potassium Level Kg/fed	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
100	c 2.43	c 2.53	a 0.13	a 0.14	c 1.32	c 1.37	c 90	c 87	c 54.33	b 54.37	c 38.63	c 39.00
150	b 2.67	b 2.73	a 0.14	a 0.13	b 1.40	b 1.42	b 102	b 103	b 56.33	b 55.36	b 43.60	b 44.63
200	a 2.93	a 2.96	a 0.12	a 0.13	a 1.43	a 1.53	a 108	a 110	a 61.76	a 62.76	a 48.62	a 49.00

content i.e.N.P.K.Fe.Zn.and Mn increased as the level of applied nitrogen was raised to highest level. On the other hand, no significant difference was obtained between tree received 80 kg/fed N and 100 kg/fed as leaf Zn and Mn were concerned. Meanwhile, leaf P content data showed that significant difference was noticed between different levels of nitrogen fertilization in the first season.

Generally, one can conclude that increasing applied nitrogen up to 100 kg/feddan promoted all studied leaf nutrients which recorded the highest values followed by 80 kg/feddan treatment which occupied the second rank for N and K in both seasons and K and Zn in the second season. These results partially agree with the findings of Savooshi *et al* [12] on Valencia and Intrigliolo *et al* [13] on navel orange trees. They found that leaf nutrient content was closely related to the fruit yield and soil nutrient content, also nitrogen application significantly increased leaf N concentration.

It is clear from table (4) that in both seasons leaf nutrients content i.e.N.K.Fe.Zn and Mn increased with increasing applied K trees. On the other hand, no significant difference was noticed between 100,150 and 200 kg/K/feddan treatments when leaf P was concerned. Such effect was mostly significant in both seasons. This is in agreement with Cicala and Catara [14] on tarocco orange trees, reported that K treatments (0-1kg/tree, KNo_3) produced an increase in the level of leaf K. in addition Slim[10]reported on Washington navel orange who

Table 5: Effect of different nitrogen fertilization levels on fruit set and drop percentage of Washington navel orange trees

Nitrogen Level Kg/fed	Fruit set (%)		Fruit drop (%)	
	2004	2005	2004	2005
40	c 28.73	c 39.32	b 97.23	a 95.34
60	b 29.43	b 40.32	a 98.72	a 95.32
80	b 29.40	b 40.21	c 96.32	b 92.36
100	a 39.32	a 42.00	d 95.32	c 50.23

Table 6: Effect of different potassium fertilization levels on fruit set and drop percentage of Washington navel orange trees

Potassium Level Kg/fed	Fruit set (%)		Fruit drop (%)	
	2004	2005	2004	2005
100	c 39.23	c 40.32	a 99.20	a 96.21
150	b 42.27	b 43.34	b 95.23	b 92.32
200	a 43.23	a 45.32	c 93.20	c 50.00

mentioned that increasing K rate promoted N, Mn, Zn and Fe nutrient in leaves, while had in significant effect on leaf phosphorus content.

Fruiting

a. Fruit set and dropping: Data presented in table (5) showed that fruit indicated an obvious response to increasing nitrogen fertilization to trees in both seasons. Differences between studied nitrogen rates were always so high to reach the significant level. However, such significant effect between 60 and 80 kg N/feddan was not statistically noticed.

Mean while, fruit drop percentage decreased with increasing the level of applied N to trees. However, received 100 kg N/feddan treatment gave the lowest percentage of fruit drop in the both seasons.

On other hand, the difference between 40 and 60 kg nitrogen per feddan treatments was so small to be statistically significant. These results assured the findings of Slim [10] he found that increasing nitrogen fertilization to trees of Washington navel orange fruits (20 and 120 kg/fed/yr) resulted in the highest fruit set and the lowest fruit drop.

It is clear from table (6) that received 200 kg potassium/feddan/yr treatment gave the highest percentage of fruit set and the lowest percentage of fruit drop followed by using 150 Kg/potassium/feddan/yr as compared with 100 kg/feddan/yr in a descending order.

This is in agreement with sleem[10] found that fruit set percentage indicated an obvious response to increasing potassium fertilization. Upper most K rate (250 kg/fed/yr) obtained highest fruit set and the lowest fruit drop of Washington navel orange fruits.

Yield and fruit quality

3.a. Yield: Table (7) reflects that received 100 kg N/fed/yr gave significantly the highest number of fruits per tree and yield (kg) among all other used Nitrogen

Table 7: Effect of different nitrogen fertilization rates on fruit number and yield (kg) of Washington navel orange trees

Nitrogen Level Kg/fed	No. of fruits/tree		Yield(kg)/tree	
	2004	2005	2004	2005
40	d 92.33	c 39.32	c 25.63	c 24.67
60	c 98.36	c 100.63	b 27.33	b 28.26
80	b 110.67	a 126.77	b 28.67	a 39.33
100	a 116.32	a 126.33	a 37.28	a 38.67

Table 8: Effect of different potassium fertilization rates on fruit number and yield (kg) per tree of Washington navel orange trees

Potassium fertilizer K_2So_4Level Kg/fed	No. of fruits/tree		Yield(kg)/tree	
	2004	2005	2004	2005
100	b 112.98	b 114.00	c 28.32	c 30.23
150	a 132.63	a 139.32	b 30.67	b 33.34
200	a 134.82	a 134.32	a 33.43	a 36.32

level treatments in this study except in the second season, where using 80 kg N/fed/yr induced the same effect. On the other hand, no significant difference was observed between 80 and 100 kg N per feddan treatments in the second season.

Yield of Washington navel orange trees affected by different rates of potassium fertilization is expressed in table (8) either as number of fruit per tree or yield (kg). It is found that in both seasons total yield (kg) per tree increased with increasing the level of applied potassium to the trees. Nevertheless, no significant difference was obtained between 150 and 200 level of potassium sulphate per feddan.

Generally, increasing nitrogen fertilization rate from 40 to 100 kg/fed/yr. significantly increased number of fruits per tree.

These results agree with the findings of Intrigliolo, *et al* [13] on navel orange trees, mentioned that higher doses of N (1000 gm/tree) resulted in lower yield.

Androulakis *et al*[11] on grape fruit reported that N at higher rate (1.0 kg/tree) gave lower yields than (0.5 kg N/tree). Moreover, Nath and Mohan 2 on Assam lemon reported that application of 800 gm N/ tree resulted in the highest mean annual fruit yield and further increase in N rate caused a reduction in yield.

These results generally agree with the findings of Qinxuan *et al* [15]. They found that the role of potassium for Improving fruit yield and quality of lemon on 16 year old. Mean while, Kouka *et al* 1 they reported that the combination between the high rate of N and K increased fruit yield and fruit quality of Balady orange trees.

Fruit quality

a. Physical properties: Concerning fruit weight of Washington navel orange as affected by different rates of applied nitrogen, data presented in table (9) indicate that fruit weight increased toward the highest level of N (100 kg N per feddan) of both seasons.

Table 9: Effect of different nitrogen fertilization levels on fruit set and drop percentage of Washington navel orange trees

Nitrogen Level	Fruit weight (g)		Fruit size (cm)		Peel thickness (cm)	
Kg/fed	2004	2005	2004	2005	2004	2005
40	d 123.02	c 132.10	b 148.43	d 120.21	c 0.50	c 0.50
60	c 134.03	c 110.43	a 165.33	c 129.40	bc 0.53	b 0.70
80	b 154.93	b 130.63	a 168.87	a 169.00	b 0.64	b 0.70
100	a 183.73	a 142.16	a 169.13	b 155.13	a 0.86	a 0.92

Table 10: Effect of different potassium levels on fruit set and drop percentage of Washington navel orange trees

Potassium fertilizer	Fruit weight (g)		Fruit size (cm)		Peel thickness (cm)	
K_2So_4Level Kg/fed	2004	2005	2004	2005	2004	2005
100	c 120.00	b 13.23	c 126.30	b 132.63	b 0.53	c 0.50
150	b 123.02	ab 140.06	b 133.23	ab 143.23	a 0.64	b 0.62
200	a 133.06	a 142.03	a 146.23	a 148.20	a 0.67	a 0.69

Table 11: Effect of different nitrogen fertilization rates on fruit chemical properties of Washington navel orange trees

Nitrogen	T.S.S %		Acidity %		T.S.S/acid ratio		Ascorbic acid mg/100ml	
Level Kg/fed	2004	2005	2004	2005	2004	2005	2004	2005
40	c 9.7	c 9.6	a 0.18	a 0.80	c 11.97	c 12.00	c 33.60	d 26.32
60	b 10.5	bc 10.2	b 0.73	a 0.81	b 14.38	c 12.59	c 32.36	c 28.67
80	b 10.6	b 10.8	b 0.72	b 0.77	b 14.72	b 14.02	b 39.37	b 32.41
100	a 11.5	a 11.7	c 0.65	c 0.69	a 17.69	a 16.96	a 42.65	a 41.39

Table 12: Effect of different potassium fertilization rates on fruit chemical properties of Washington navel orange trees

potassium	T.S.S %		Acidity %		T.S.S/acid ratio		Ascorbic acid mg/100ml	
Level Kg/fed	2004	2005	2004	2005	2004	2005	2004	2005
100	b 9.37	c 11.20	a 1.05	a 0.92	c 8.92	c 12.17	c 31.93	c 30.30
150	a 12.40	b 12.42	b 0.62	b 0.80	a 20.00	b 15.52	b 33.32	b 34.67
200	a 12.27	a 13.40	b 0.63	c 0.68	b 19.48	a 19.71	a 34.80	a 38.83

On the contrary, in the second season no significant difference was noticed between 40 and 60 kg N per feddan treatments. Meanwhile, fruit size increased with increasing the level of applied nitrogen (80 and 100 kg/ feddan/ yr) in the second season.

On the other hand, no significant difference was noticed between 60, 80 and 100 kg N per feddan treatments in the first season. However, fruit peel thickness increased with increasing the applied N to trees. That was true in both seasons of study. Moreover, no significant difference was observed between 60 and 80 kg N per feddan treatments.

Generally, nitrogen rates exerted an obvious effect on some fruit physical properties. Increasing N rates significantly increased fruit weight, fruit size and peel thickness compared with lower N rates. These results partially agree with the findings of Nath and Mohan[2] on Assam lemon mentioned that high with higher level of nitrogen application caused thicker fruit peel.

It is clear from table (10) that in both seasons fruit weight and fruit size increased with increasing the level of applied potassium of Navel orange trees. However, the significant difference between the first and second level was so small to be noticed in the second season. Meanwhile, fruit peel thickness increased with increasing the amount of applied potassium to trees of the second season,

On the other hand, no significant difference was noticed between 150 and 200 kg K per feddan treatments in the first season of study.

The present results are in a general harmony with Okada *et al* [16] on Satsuma mandarin they mentioned that fruit size increased as K fertilization increased, Cicala and Catara [14] on tarocco orange trees, noticed that there was a significant correlation between leaf K content and fruit number, fruit weight and rind thickness.

chemical properties: It is clear from table(11) that in both seasons, increasing N fertilization significantly increased juice T.S.S, T.S.S/acid ratio and ascorbic acid content and decreased juice acidity. However, no significant difference was obtained between 60and 80 kg N treatments when T.S.S was concerned in both seasons a well a juice acidity and T.S.S in the first season. On the other hand, fruits of the second season were more rich in ascorbic acid as compared with the corresponding ones of the first season.

Generally, from the aforementioned results one can say that increasing N fertilization to navel orange trees increased juice T.S.S, T.S.S: acid ratio and ascorbic acid content and decreased juice acidity simultaneously. The obtained results are in harmony with the findings of Nath and Mohan[2] studied the effect of N fertilizer at 0, 300, 400, 500, 600, 700, 800 and 900 g N/tree of Assam lemon.

They found that the highest values for T.S.S and acidity of fruits were obtained with high rates of N, whereas Juice content and ascorbic acid concentration were lowest with high N rates. Meanwhile, Sleem[10] found the applied Nitrogen rate of Washington navel orange trees induced clear effect on some fruit chemical constituents. The least values of T.S.S, T.S.S/acid ratio and ascorbic acid content developed from 30 kg N rate.

However, increasing N dosage significantly increased these contents. On the other contrary, fruit acidity content showed opposite trend.

Table(12) involved total soluble solids, acidity, T.S.S/acid ratio and ascorbic acid content in fruit juice of Navel orange trees as affected by different rates of potassium.

It was found that juice T.S.S, T.S.S/ acid ratio and ascorbic acid content increased significantly with increasing applied potassium of trees of both seasons.

Meanwhile, juice acidity decreased with increasing the level of applied potassium. On the other hand, no significant difference was obtained between 150 and 200 kg K/ feddan/yr when juice T.S.S and acidity were concerned in the first season.

Conclusively, total soluble solids, T.S.S: acid ratio and ascorbic acid content generally increased as potassium fertilization rates increased.

The present results are in a general harmony with Qinxuan *et al* [1]who noticed the role of potassium for improving fruit yield and quality of lemon on 16 years old Eureka lemon trees sprayed 4 times with Kcl (1%). The treatment increased T.S.S content, ascorbic acid and total acidity contents. Meanwhile, Dass and Srivastava [17]found that the interaction with other nutrients and crop demand for K increases in juice color and high T.S.S/acid ratio of citrus trees.

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