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Effect of Source and Rate of Nitrogen Fertilization on Yield, Fruit Quality and Leaf Mineral Composition of Valencia Orange Trees Grown in Riyadh, Saudi Arabia

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Abstract. This investigation was carried out during 1992 and 1993 seasons to study the influence of ammonium sulfate and urea at different rates (0, 250, 500, 750, and 1000 g N/tree) on the yield, fruit quality and leaf mineral composition of Valencia orange trees growing in Riyadh. The results revealed that there were no significant differences in the yield, physical and chemical properties of the fruits due to sources of nitrogen applied. Whereas, rates of nitrogen markedly affected the yield and most of fruit properties in both seasons. In addition, yield and fruit properties were responded positively to increasing the rates of nitrogen up to 750 and 1000 g N/tree as compared with the control and the lowest rate of nitrogen. However, the nitrogen fertilization was more effective and pronounced in the second season than in the first one. Concerning leaf analysis, data showed that the application of ammonium sulfate as a nitrogen source produced a significant increase in the leaf nitrogen content as compared with applying urea. Furthermore, increasing nitrogen rates resulted in a significant increase in leaf nitrogen content than that of the control. No obvious effect was found in leaf macro or micronutrient contents between both sources of nitrogen applications. On the other hand, increasing rates of nitrogen caused marked increase in leaf Mg and Cu contents, slight increase in leaf Fe and Mn contents, and marked decrease in leaf K and Na contents as compared with the control. However, leaf P, Ca, and Zn contents were unaffected by the different rates of nitrogen application.

Introduction

Soils of the Kingdom of Saudi Arabia, being a part of arid and semi-arid regions, are subjected to the problem of inherently low nitrogen content. Thus, heavy nitrogen fertilizer applications are often necessary to obtain high yields for most plants grown on these soils [1].

Nitrogen is the key fertilizer element affecting yield. It has a pronounced effect on the growth and appearance of the tree and fruit quality. It is estimated that about 33% of the nitrogen applied to citrus on Florida's well-drained sandy soil is lost by leaching and volatilization [2]. In addition, many sources of nitrogen are satisfactory for citrus, provided pH control is practiced and no harmful contaminants (such as biuret and perchlorate) are present in the nitrogen material [3]. Moreover, optimum rates of nitrogen application have not been clearly established for different orange cultivars. Chapman [4] reported that the source, rate, and method of nitrogen application must be tailored to soil, plant species, plant age, and climatic situations. Previous work have been conducted on the effect of nitrogen fertilization on growth, flowering, and fruiting of local orange in Riyadh by Youssef *et al.* [5].

Recently, much interest has been developed in utilization of a certain source of nitrogen with an optimum rate that resulted in enhancing citrus productivity in Saudi Arabia. Accordingly, the aim of this experiment was to investigate the response of Valencia orange trees growing in Riyadh region to nitrogen sources and rates. In addition, leaf mineral content, yield and fruit quality of the treated trees were also determined.

Materials and Methods

The present study was carried out during 1992 and 1993 seasons on 13-year-old Valencia orange trees (*Citrus sinensis,* Osbeck) budded on sour orange rootstock and growing at Dirab Experimental and Research Station, College of Agriculture, King Saud University. The soil of the experimental orchard classified as sandy loam calcareous. Data presented in Table 1 show some physical and chemical properties of the soil surface of the experimental orchard, which is low in organic matter, native N and P [1].

Table 1. Some physical and chemical properties of the soil of the experimental orchard

Texture	pH	E.C. dS/m	$CaCO_3$ %	Organic matter %	Available-N* ppm	Sodium bicarbonate soluble-P ppm	Available-K NH_4OAC ppm
Sandy loam	7.5	7.1	33.3	0.2	54.9	1.0	192.0

*Available-N was determined as NO_3 and NH_4^+ using Microkjeldahl method described by Chapman and Pratt [6].

All trees were almost uniform in size, spacd at 10 × 10 meters apart and were grown under date palm trees. All management practices were the same as those usually followed in the commercial orchards. Forty Valencia orange trees were arranged in a split plot design involving 2 sources of nitrogen (as the main plot) and 5 rates of nitrogen (as sub-plot) for a total of 10 treatments. Nitrogen sources used were ammonium sulfate (21% N) and urea (46% N). Each source of nitrogen applied at rates of : 0 (control), 250, 500, 750, and 1000 g of actual N/tree/year. Four replications were used with one tree per each replicate. Each nitrogen fertilizer rate was divided into three equal doses and applied at first before bloom in mid-March, second after fruit set in mid-May, and third in mid-July in both seasons.

Yield was recorded (as number and weight of fruits per tree) at harvest time on October 15 in both seasons. For determination of fruit properties, 10 fruits were taken from each tree. Fruit volume, diameter, length, peel thickness, peel weight, and volume of juice per fruit were measured. In juice, total soluble solids were determined using a hand refractometer, percentage of acidity (as citric acid) by titration with 0.1 N sodium hydroxide and vitamin-C (as ascorbic acid) by titration with 2,6-dichlorophenol indophenol blue dye, according to A.O.A.C. [7].

In order to determine the leaf mineral composition, leaf samples were collected from each tree during the last week of July in both seasons. Each sample was composed of 50 leaves taken at random from non-fruiting shoots of spring flush. The leaves were washed several times with tap water, distilled water and then oven dried at 70°C. The dried leaves were ground and digested with hydrogen peroxide and sulfuric acid and kept for nutrient elements determinations [8]. Total nitrogen was determined colorimetrically according to Evanhuis [9]. Phosphorus was determined colorimetrically by the ascorbic acid method [10]. Potassium and sodium were measured against a standard using air propane flame photometer [6]. Calcium, magnesium, iron, zinc, manganese, and copper were measured using Perkin-Elmer atomic absorption spectrophotometer Model 2380.

The data obtained were subjected to the analysis of variance proposed for split-plot design presented by Steel and Torrie [11, 377-387].

Results and Discussion

Effect of source and rate of nitrogen fertilization on

I) Yield

Data concerning the effect of ammonium sulfate and urea as two sources of nitrogen on the yield of Valencia orange trees presented in Table 2. Data revealed that

Table 2. Effect of source and rate of nitrogen fertilization on the yield of Valencia orange trees in 1992 and 1993 seasons

Treatments	Number of fruit per tree	Fruit weight (g)	Yield per tree (kg)
Source			
Ammonium sulfate	172.60 a	158.30 a	27.50 a
Urea	165.30 a	150.60 a	25.20 a
Rate			
Control	148.37 b	135.30 c	20.01 c
250 g N/tree	159.69 ab	157.98 ab	25.54 b
500 g N/tree	166.06 ab	153.31 b	25.88 ab
750 g N/tree	184.50 a	168.66 a	30.94 a
1000 g N/tree	185.87 a	157.00 ab	29.29 ab
Season			
1992	115.80 a	150.51 a	17.37 a
1993	222.00 b	158.39 b	35.29 b

Means not sharing the same letter with columns are significantly different ($P < 0.05$) according to Duncan's multiple range test.

there were no significant differences in the number, weight of fruits and the yield per tree due to sources of nitrogen used. On the other hand, rates of nitrogen significantly affected the number, weight of fruits and the yield per tree. It was also noticed that the yield per tree was increased with increasing the rates of nitrogen up to 750 and 1000 g N/tree as compared with the control and the lowest rate of nitrogen. The increase in fruit yield was related to both large fruit weight and greater number of fruits. Figure 1 shows that higher rates of nitrogen gave not only increase in fruit yield but also higher leaf nitrogen content. This suggests that the yield influence with increasing fertilizer rates is a response to additional nitrogen. Furthermore, number weight of fruits and the yield per tree responded more positively to the different nitrogen applications in the second season than in the first one.

These results were generally in agreement with those obtained by Tsanava *et al.* [12], Hume *et al.* [13,14] and Marshaniya and Mikeladze [15] working on Valencia, Washington navel oranges and mandarins, and Ahmed *et al.* [16] working on Egyptian Balady lime trees. They all reported that the yield of trees was responded positively to nitrogen sources. Some of them also found that ammonium sulfate tended to be the best nitrogen source for citrus trees. However, Reese and Koo [17,18], Koo

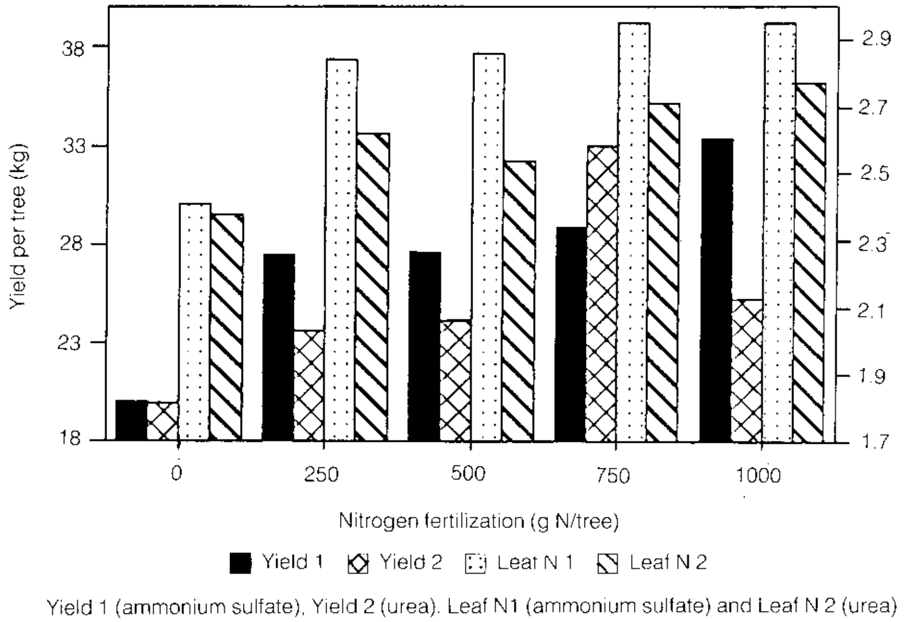

Fig. 1. Effect of source and rate of nitrogen fertilization on yield and leaf nitrogen content of valencia orange trees

[19], and Plessis and Koen [20] working on different orange cultivars and Romero and Torres [21] on lime, revealed that increased rates of nitrogen application increased fruit production.

II. Fruit quality

a) Physical properties

The data presented in Table 3 indicate that all the studied physical properties of Valencia orange fruits were significantly influenced by the rates of nitrogen applications than by the nitrogen sources. All nitrogen treatments caused better effects on the volume, length, diameter, and juice volume of fruits as compared with the control. The best results were, generally, obtained by additing 750 g N/tree. It was also noted that increasing nitrogen rates increased peel thickness and peel weight of fruit as compared with the control.

These findings were, generally, in line with those obtained by Damigella and Tribulato [22], Reese and Koo [17], and Plessis and Koen [20] on oranges and Koo *et al.* [23] on lemon. They found that increasing nitrogen rates produced beneficial effects on the most physical properties of the fruits.

Table 3. Effect of source and rate of nitrogen fertilization on the physical properties of Valencia orange fruits in 1992 and 1993 seasons

Treatments	Fruit volume (ml)	Juice volume per fruit (ml)	Fruit length (cm)	Fruit diameter (cm)	Peel thickness (mm)	Peel weight per fruit (g)
Source						
Ammonium sulfate	185.0 a	84.5 a	6.9 a	6.9 a	55 a	44.7 a
Urea	172.8 a	82.4 a	6.8 a	6.8 a	54 a	41.2 a
Rate						
Control	154.8 c	68.8 b	6.4 b	6.3 c	50 c	36.6 b
250 g N/tree	182.8 ab	81.8 a	7.0 a	6.9 b	57 ab	44.5 a
500 g N/tree	173.9 b	91.6 a	6.9 a	6.9 b	53 bc	43.2 a
750 g N/tree	200.0 a	85.5 a	7.1 a	7.2 a	59 a	47.2 a
1000 g N/tree	182.9 ab	89.4 a	7.0 a	7.0 ab	55 abc	43.3 a
Season						
1992	180.3 a	88.9 a	6.8 b	6.9 a	57 a	40.9 b
1993	177.4 a	77.9 b	7.0 a	6.8 b	52 b	45.1 a

Means not sharing the same letter within columns are significantly different ($P < 0.05$) according to Duncan's multiple range test.

b) Chemical properties

Data presented in Table 4 show that nitrogen source did not affected the chemical properties of the fruits. Meanwhile, increasing rates of nitrogen up to 1000 g N/tree caused an increase in the total soluble solids (TSS) and TSS/Acid ratio and a marked decrease in the percentage of acidity. Whereas, vitamin-C content of the fruits was unaffected by nitrogen levels as compared with the control.

These findings were, somewhat, in agreement with those obtained by Calvert [24] who found that increasing nitrogen levels decreased soluble solids and acid content of Temple orange juice. Also, Koo *et al.* [23] found that increasing rates of nitrogen application decreased acid content of lemon juice. However, Reese and Koo [17] working on Hamlin, Pineapple, and Valencia oranges, found that increasing nitrogen rates increased soluble solids and acid percent. Likewise, Ahmed *et al.* [16] found that TSS and total acidity in the lime juice were increased by high nitrogen fertilization.

Table 4. Effect of source and rate of nitrogen fertilization on the chemical properties of Valencia orange fruits in 1992 and 1993 seasons

Treatments	Total soluble solids (%)	Acidity (%)	TSS/ Acid ratio	Vitamin-C (mg/100 ml juice)
Source				
Ammonium sulfate	12.84 a	1.53 a	8.39 a	41.00 a
Urea	12.83 a	1.53 a	8.39 a	40.36 a
Rate				
Control	12.26 b	1.64 a	7.48 b	41.50 a
250 g N/tree	12.69 ab	1.54 b	8.24 ab	41.40 a
500 g N/tree	13.06 ab	1.51 b	8.65 ab	39.90 a
750 g N/tree	13.01 ab	1.50 b	8.67 ab	41.20 a
1000 g N/tree	13.15 a	1.45 b	9.07 a	39.40 a
Season				
1992	13.07 a	1.52 a	8.60 a	40.70 a
1993	12.60 a	1.54 a	8.18 a	40.70 a

Means not sharing the same letter with columns are significantly different ($P < 0.05$) according to Duncan's multiple range test.

III. Leaf mineral composition

a) Macronutrients

Data presented in Table 5 and Fig. 1 show that the application of ammonium sulfate as a source of nitrogen produced a significant increase in leaf nitrogen content as compared with urea. In addition, increasing nitrogen rates resulted in a significant increase in leaf nitrogen content as compared with the control. Moreover, leaf nitrogen content was significantly higher in samples collected during the second season than that of the first one. These results are in general agreement with those obtained by many investigators such as Calvert [24], Koo *et al.* [23], Reese and Koo [18], Hume *et al.* [13,14] and Ahmed *et al.* [16]. They reported that the leaf nitrogen content of citrus trees was positively corrected with increasing rates of nitrogen applications.

In the present study, leaf nitrogen content ranged from 2.41 to 2.86%, being suggested for optimum fruit yield in Valencia orange trees. Similarly, Chapman [4] working on some citrus species (especially grapefruit, oranges and mandarins), suggested that leaf nitrogen of 2.25 to 2.40% being ample. Also, Koo *et al.* [23]

Table 5. Effect of source and rate of nitrogen fertilization on the leaf mineral composition of Valencia orange trees in 1992 and 1993 seasons

Treatment	% on dry weight basis						ppm on dry weight basis			
	N	P	K	Ca	Mg	Na	Fe	Zn	Mn	Cu
Source										
Ammonium sulfate	2.80 a	0.16 a	1.00 a	6.48 a	0.34 a	0.167 a	125.50 a	17.30 a	26.50 a	11.20 a
Urea	2.61 b	0.15 a	1.01 a	6.26 a	0.32 a	0.136 b	113.90 a	16.40 a	30.00 a	12.40 a
Rate										
Control	2.41 b	0.15 a	1.05 a	6.18 a	0.29 b	0.164 a	114.80 b	15.50 a	28.10 ab	8.30 b
250 g N/tree	2.73 a	0.16 a	1.00 ab	6.55 a	0.37 a	0.159 a	130.90 a	16.60 a	26.40 b	10.30 b
500 g N/tree	2.70 a	0.16 a	0.97 b	6.60 a	0.36 a	0.155 ab	118.00 ab	17.40 a	30.30 a	10.60 b
750 g N/tree	2.83 a	0.16 a	0.98 b	6.43 a	0.33 ab	0.143 bc	117.40 ab	17.40 a	27.10 ab	14.30 a
1000 g N/tree	2.84 a	0.16 a	1.02 ab	6.11 a	0.31 b	0.136 c	117.30 ab	17.30 a	29.20 ab	1550 a
Season										
1992	2.37 b	0.14 b	1.19 a	6.68 a	0.34 a	0.162 a	104.90 b	13.30 b	28.30 a	12.10 a
1993	3.04 a	0.17 a	0.82 b	6.06 b	0.33 a	0.140 b	134.40 a	20.40 a	28.20 a	11.60 a

Means not sharing the same letter within columns are significantly different ($P < 0.05$), according to Duncan's multiple range test.

reported that a leaf nitrogen content of 2.20 to 2.60% is suggested for optimum fruit production for 'Bearss' lemon trees.

Data of the present study also showed that there was no significant effect of nitrogen fertilization source on leaf phosphorus, potassium, calcium, and magnesium. Whereas, increasing rates of nitrogen produced marked changes in the leaf mineral composition of some elements. For example, leaf magnesium increased, while potassium and sodium tended to decrease with increasing nitrogen rates. However, leaf phosphorus and clacium contents were unaffected by the different treatments (Table 5). These results my be considered a dilution effect caused by the vigorous growth induced by nitrogen applications. Similar results were obtained on citrus trees by Labanauskas *et al.* [25], Reese and Koo [18], Hernandez [26] and Koo [3].

b) Micronutrients

Data presented in Table 5 show that there were no significant differences in the leaf iron, zinc, manganese, and copper contents due to sources of nitrogen fertilization. Whereas, increasing rates of nitrogen application resulted in a significant increase in leaf copper content, and slight increase in leaf iron and manganese contents as compared with the control. However, leaf zinc content was unaffected by increasing rates of nitrogen applications.

These findings were, somewhat, in agreement with those obtained by Labanauskas *et al.* [25,27] who found that soil application of nitrogen fertilizers to citrus trees increased the concentrations of Mn and Fe, and decreased Zn, and Cu in the leaves as compared to untreated analogous leaves. Likewise, Sahota and Arora [28] found that increasing rates of nitrogen application to Hamlin sweet orange, reduced Zn content. Regarding to marked increase in the leaf copper content with adding high rate of nitrogen as compared with the control (Table 5), Chapman [4] suggested that the high rate of nitrogen fertilizer might have solubilized enough copper to toxic.

Conclusion

Regular nitrogen application was necessary to obtain high yield with the best quality of Valencia orange fruits. There were no significant differences in the yield, physical and chemical properties of the fruits can be attributed to nitrogen sources (ammonium sulfate or urea) applied in this investigation. Increasing rates of nitrogen applications, markedly increased the yield and the most of fruit properties. The best results were obtained by adding 750 and 1000 g N/tree/year. The application of ammonium sulfate as a nitrogen source caused a marked increase in leaf nitrogen content as compared with applying urea. Increasing rates of nitrogen fertilization resulted in significant increase in leaf N, Mg, and Cu contents, a slight increase in leaf Fe and Mn contents, and a marked decrease in leaf K and Na contents. However, leaf P, Ca, and Zn contents were unaffected.

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تأثير مصدر ومعدّل السماد النيتروجيني المضاف على المحصول وجودة الثمار والمحتوى المعدني للأوراق في أشجار برتقال فالنشيا نامية في الرياض

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ملخص البحث. أجري هذا البحث خلال عامي ١٩٩٩٢ و ١٩٩٣م بغرض دراسة تأثير معدلات التسميد الأزوتي (صفر، ٢٥٠، ٥٠٠، ٧٥٠، ١٠٠٠جم نيتروجين/شجرة) باستخدام مصدرين (كبريتات الأمونيوم واليوريا) على المحصول وجودة الثمار والمحتوى المعدني للأوراق في أشجار برتقال فالنشيا نامية في محطة الأبحاث والتجارب الزراعية بمزرعة كلية الزراعة، جامعة الملك سعود بالرياض.

وقد أظهرت النتائج أنه لا توجد هناك اختلافات جوهرية بين سمادي كبريتات الأمونيوم واليوريا في تأثيرهما على المحصول أو الصفات الفيزيائية أو الكيميائية للثمار، بينما وجد أن هناك اختلافات معنوية مؤكدة بين معدلات التسميد الآزوتي على المحصول ومعظم صفات جودة الثمار. كما وجد أن هناك استجابة موجبة للمحصول وصفات الجودة بزيادة معدل التسميد الأزوتي حتى ٧٥٠، ١٠٠٠جم ن/شجرة وذلك بالمقارنة بالكنترول وبالمعدل المنخفض من الأزوت. وكان تأثير التسميد الأزوتي أكثر وضوحًا في العام الثاني بمقارنته بالعام الأول.

وفيما يختص بتحليل الأوراق، فقد أظهرت النتائج أن استخدام كبريتات الأمونيوم كمصدر نيتروجيني أدى إلى احتواء الأوراق على نسبة أعلى من النيتروجين مقارنة باستخدام اليوريا في تسميد الأشجار. كما أن زيادة معدل التسميد قد أدى إلى زيادة محتوى الأوراق من النيتروجين في الموسم الثاني مقارنة بالموسم الأول. وبالرغم من أنه لم يكن هناك فرق واضح بين استخدام مصدري النيتروجين في تأثيرهما على محتوى الأوراق من العناصر الكبرى والصغرى والتي تم تقديرها، إلا أن زيادة معدل التسميد النيتروجيني المضاف للأشجار قد أدى إلى زيادة محتوى الأوراق من عناصر المغنيسيوم والحديد والمنجنيز والنحاس. وإلى نقص محتواها من عناصر البوتاسيوم والصوديوم مقارنة بالكنترول. ولم يتأثر محتوى الأوراق من عناصر الفسفور والكالسيوم بزيادة معدل التسميد الآزوتي.