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EFFECT OF FAST AND SLOW RELEASE FERTILIZATION ON YIELD AND FRUIT QUALITY OF NAVEL ORANGE (*Citrus sinensis*)

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ABSTRACT: This study aimed to assess the impact of different sources, concentrations, and application methods of nitrogen on fruit set, yield, and the physical and chemical characteristics of Navel orange fruits. A field experiment was conducted during the 2020/2021 and 2021/2022 seasons on Navel orange trees onto sour orange rootstock at the Orchard of the Faculty of Agriculture, Menoufia University. The soil's texture is clay loam. The experiment followed a completely randomized block design. The results showed that the best N sources were the slow-release N fertilizer Enciabene, liquid ammonium nitrate, ammonium sulfate, and urea, in descending order. The combined application of Enciabene plus liquid ammonium nitrate gave satisfactory yield and fruit quality. Raising levels of Enciabene from 1.25 to 2.5 kg/tree had a slight effect on all the characters studied. Optimal yield and superior physical and chemical properties of Navel orange fruits were achieved by fertilizing the trees with 0.500 kg/tree of Enciabene in conjunction with 2 L/tree of liquid ammonium nitrate.

Keywords: Navel orange, yield, quality, Enciabene.

INTRODUCTION

Citrus is suggested to be one of the most important fruit crops all over the world. It ranks third position between fruit crops and is only preceded by grapes and apples. The domesticated citrus species are thought to originate from the tropical and subtropical areas of Southeast Asia, where they have been cultivated since ancient times. Most of the commercial production is now in subtropical regions with a Mediterranean climate (according to Zang, 2024).

Citrus is Egypt's most important fruit crop in terms of acreage, production, and exports. The economic significance of citrus fruits positions them among the foremost agricultural products in Egypt, alongside other vital crops. In Menoufia Governorate where the present study was carried out, the total citrus cultivated area reached 21117 feddans presented 199050 metric ton fruits. The navel orange area reached 12680 feddans and produced 120118 metric tons of fruits (according to the Bulletin of Agricultural Statistics, 2022).

Nitrogen plays a key role in the nutrition of citrus trees. It is responsible for the biosynthesis of protein, organic nutrients, enhancing cell division and chlorophylls, building cellulose and lignin which play an important role in farming plant structure. It is also beneficial in the synthesis of enzymes. Fruit trees did not produce fruit without this essential macro-element (Chapman, 1968).

This study aimed to clarify the effects of various sources, concentrations, and application methods of nitrogen on fruit set, yield, and the physical and chemical properties of Navel orange fruits. Selecting optimum sources, levels, and methods of N applications is considered an important target. The results obtained will be of utmost importance, potentially assisting navel orange cultivators in the Menoufia Governorate in optimizing nitrogen management for their orchards.

MATERIALS AND METHODS

This investigation was conducted during the 2020/2021 and 2021/2022 seasons on twenty-seven uniform-in-vigor Navel orange trees budded on sour orange rootstock at the Orchard

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of the Horticultural Experimental Station, Faculty of Agriculture, Shebin El-Kom, Menoufia Governorate. The trees were planted 5 × 5 meters apart. The soil orchard is a well-drained clay loam with a water table at least two meters deep. The objective of this experiment was to study the effect of different sources, levels, and methods of nitrogen applications on fruit set, yield as well as physical and chemical properties of Navel orange fruits.

The experiment included the following nine treatments:

1- Application of ammonium sulfate at 5 kg/tree. (Traditional treatment).
2- Application of liquid ammonium nitrate at 2.5L / tree.
3- Application of urea at 2.2 kg/tree.
4- Application of Enciabene at 1.25 kg/tree.
5- Application of Enciabene at 1.875 kg/tree.
6- Application of Enciabene at 2.5 kg/tree.
7- Application of Enciabene at 0.500 kg + urea at 1.75 kg/tree.
8- Application of Enciabene at 0.500 kg + ammonium nitrate at 2 L/tree.
9- Application of Enciabene at 0.500 kg + ammonium sulfate at 4 kg/tree.

The slow-release nitrogen fertilizer, namely Enciabene (40% N) at the previous amount was added once at the beginning of spring growth flush. The three fast-release nitrogen fertilizers namely urea (46.5% N), liquid ammonium nitrate (41.2 % N), and ammonium sulfate (20.6%) were added in five equal batches at the start of the spring growth cycle, one month later, just after fruit setting and two-month intervals.

The chosen trees received the P and K soil fertilization program as recommended by the Egyptian Ministry of Agriculture including 20 m^3 F.Y.M (0.3% N, 1.2% K_2O, and 0.54% P_2O_5), 200 kg calcium superphosphate (15.5% P_2O_5), and 250 kg Potassium sulfate (48% K_2O) per feddan. Other agricultural practices such as irrigation, hoeing, pruning as well and pest and fungi management were done as usual.

The experiment was set as a completely randomized block design with three replicates, one tree/each.

The following data were recorded

1- Measurements of fruit setting

Initial fruit setting percentages were estimated by counting the number of flowers on the labeled shoots periodically at five-day intervals starting in the second week of March in both seasons till setting was completed (first week of April) then the number of fruit lattes was counted, and the percentage of initial fruit setting was calculated by total number of flowers and multiplying the product × 100. The final fruit setting was calculated by dividing the number of fruits just before harvesting by the total number of flowers and multiplying the product × 100.

2- Measurements of yield and fruit quality

Harvesting was achieved during the regular commercial harvesting time prevailing under Menoufia Governorate conditions (mid of December in both seasons) when TSS/acid reached 8/1. Yield expressed in weight (kg) was recorded.

To study the physical and chemical properties of the fruits, ten fruits at harvesting date were picked at random from constant height and from all treatments of each tree. All fruit samples were tested for:

1- Average fruit weight (gm).
2- Average fruit volume (cc).
3- Fruit dimensions height and width, in cm.
4- Fruit shape index values by dividing the height by the width of the fruit.
5- Percentage of juice.
6- Fruit peel thickness (cm).
7- Percentage of total soluble solids by a handy refractometer.
8- Percentage of total acidity (as g citric acid / 100 ml juice) by titration with 0.1N sodium hydroxide using phenolphthalein as an indicator (A.O.A.C., 1995).

9- The ratio between total soluble solids and acid.
10- Ascorbic acid content (as mg / 100 ml juice) was determined by using 2,6 dichlorophenol indophenols dye (A.O.A.C., 1995).
11- The percentage of total and reducing sugars was determined according to the volumetric method of Lane and Eynon (1965).

3- Statistical analysis

All the obtained data during the study in both seasons were tabulated and statistically analyzed, and the differences between treatment means were compared using the L.S.D. test according to Snedecor and Cochran (1967).

RESULTS AND DISCUSSIONS

1- Effect of different sources, levels and methods of N applications on the percentages of initial and final fruit setting

Data in Table (1) shows the effect of different sources, levels, and methods of N applications on the percentages of initial and final fruit setting of Navel orange trees in 2020/2021 and 2021/2022 seasons.

It is clear from the obtained data that percentages of initial and final fruit setting of Navel orange trees were significantly varied among different sources, levels, and methods of N applications. The maximum values were detected on the trees fertilized with Enciabene at 2.5 kg/tree, liquid ammonium nitrate at 2.5 liter/tree, ammonium sulfate at 5 kg/tree, and urea at 2.2 kg/tree, in descending order. The combined application of Enciabene at 0.5 kg/tree with urea, liquid ammonium nitrate, and ammonium sulfate improved percentages of initial and final fruit setting more than each fertilizer alone. The best combination treatment included the application of 0.5 kg/tree Enciabene with 2 L/tree liquid ammonium nitrate.

Data concerning the effect of N levels clearly shows that there was a slight promotion in the percentages of initial and final fruit setting with increasing levels of Enciabene from 1.25 to 2.5 kg/tree particularly when applied without any soluble N fertilizers.

Table 1: Effect of different sources, levels, and methods of N applications on the percentage of initial, final fruit set and yield/tree (kg) of Navel orange trees in 2020/2021 and 2021/2022 seasons.

Treatments	First season			Second season		
	Initial fruit set (%)	Final fruit set (%)	Yield/ tree (kg)	Initial fruit set (%)	Final fruit set (%)	Yield/ tree (kg)
Ammonium sulfate at 5 kg/tree	33.10	2.12	50.00	38.66	2.80	54.60
Liquid ammonium nitrate at 2.5 L/tree	36.11	2.36	52.00	41.00	2.96	57.10
Urea at 2.2 kg/tree	26.11	1.42	43.00	35.00	2.11	47.00
Enciabene at 1.25 kg/tree	39.11	2.60	54.00	44.00	3.11	60.00
Enciabene at 1.875 kg/tree	39.27	2.62	54.2	44.25	3.18	60.20
Enciabene at 2.5 kg/tree	39.33	2.65	54.3	44.55	3.22	60.4
Enciabene at 0.500 kg + urea at 1.75 kg/ tree	40.96	2.91	55.1	44.11	3.71	63.1
Enciabene at 0.500 kg +ammonium nitrate at 2L/tree	44.00	4.10	61.0	50.00	4.67	68.3
Enciabene at 0.500 kg +ammonium sulphate at 4kg/tree	42.21	3.51	59.0	47.00	4.37	66.9
L.S.D. at 0.05	2.05	0.22	2.0	2.11	0.15	2.3

The best overall treatment regarding the percentages of initial and final fruit setting included the application of 0.5 Enciabene + liquid ammonium nitrate at 2.0 L/tree. Under such promising treatment, the final fruit set percentage reached 4.10 and 4.67% in both seasons, respectively. The minimum percentage of the final fruit set percentage was recorded on the tree fertilized via soil with urea at 2.2 kg/tree. Similar results were recorded in both seasons.

These results agree with those obtained by Ruiz *et al.*, (2017) and Li *et al.*, (2020) who worked on the effect of fast-release N fertilizers on Navel orange trees.

2- Effect of different sources, levels and methods of N applications on the yield per tree

Data in Table (1) shows the effect of different sources, levels, and methods of N applications on the yield kg/tree of Navel orange trees in the 2020/2021 and 2021/2022 seasons.

There was a remarkable and significant difference on the yield of Navel orange trees among various sources, levels and methods of N applications.

Data regarding N sources reveal the fertilizing the trees via soil with Enciabene at 2.5 kg/tree, liquid ammonium nitrate at 2.5 L/tree, ammonium sulfate at 5 kg/tree or urea at 2.2 kg/tree, in descending order was favorable in improving the yield per tree. Trees fertilized with Enciabene at 2.5 kg/tree produced 54.3 and 60.4 kg/tree in both seasons, respectively. Yield per tree reached 43.0 and 47.0 kg in the trees received 2.2 kg urea in the 2020/2021 and 2021/2022 seasons, respectively. The best fast-release N fertilizer used with Enciabene was liquid ammonium nitrate, ammonium sulfate, and urea, in descending order. The best-combined application of fertilizers included fertilization with Enciabene at 0.5 kg/tree plus liquid ammonium nitrate at 2 L/tree. Under such promising treatment, yield reached 61.0 and 68.3 kg/tree, in both seasons, respectively.

There was a slight and gradual promotion on the yield per tree due to raising Enciabene levels from 1.25 to 2.5 kg/tree when applied alone. However, Enciabene at 0.5 kg/tree especially when applied with three fast-release N fertilizers was significantly accompanied by increasing the yield per tree. These results were the same in both seasons.

These results are in harmony with those obtained by Li *et al.*, (2020) who worked on the effect of fast-release N fertilizers on Navel orange trees. The effect of slow-release N fertilizers on the yield was supported by the results of Lopez-Gomez *et al.* (2017) and Navarro *et al.* (2020) on Navel orange trees.

3. Effect of different sources, levels, and methods of N applications on some characteristics of the fruits

Data in Tables (2 and 3) show the effect of different sources, levels, and methods of N applications on the weight, volume, and dimensions of fruit (height and width), fruit shape value, juice percentage as well and fruit peel thickness of Navel orange trees in 2020/2021 and 2021/2022 seasons.

Except for fruit shape value, physical characteristics varied across N applications based on source, level, and method.

Data regarding the effect of N sources, obviously reveal that the application of Enciabene at 2.5 kg/tree significantly improved fruit weight, volume, and dimensions as well as juice percentage while reduced fruit peel thickness compared to using 2.2 kg urea, 2.5 L liquid ammonium nitrate and 5 kg ammonium sulfate per tree. Slight variations in such physical traits were detected among the three fast-release N fertilizers namely urea, ammonium nitrate, and ammonium sulfate.

The best fast-release N fertilizers in this respect were liquid ammonium nitrate, ammonium sulfate, and urea in descending order.

Combined application of Enciabene at 0.5 kg/tree with liquid ammonium nitrate, ammonium sulfate, and urea was beneficial for improving the physical character of fruits in terms of increasing weight, volume, height, and width of fruit as well as juice percentage and in decreasing fruit peel thickness compared to using each fertilizer alone. The best results concerning physical characters were detected on the trees that received Enciabene at 0.5 kg/tree plus 2 L liquid ammonium nitrate. Fertilizing the trees via soil with 2.2 kg of urea only resulted in unfavorable effects on the physical quality of the fruits.

There was a slight and insignificant promotion in the physical quality of the fruits in response to raising the Enciabene level from 1.25 to 2.5 kg/tree when applied alone.

Varying sources, levels, and methods of N application did not affect the fruit shape value of Navel orange fruits. Similar results were obtained in both seasons regarding the influence of fast-release N fertilizers on physical characters.

These results agree with those obtained by Habsay (2017) and Li *et al.* (2020) on Navel oranges, and Silber *et al.* (2019) on Valencia oranges.

The results of Ruiz *et al.* (2017) on Navel oranges and Navarro *et al.* (2020) on Valencia orange trees supported the beneficial effects of using slow-release N fertilizers on the physical quality of the fruits.

Table (2): Effect of different sources, levels, and methods of N applications on the average fruit weight (g), fruit volume (cc), fruit height (cm), and fruit width (cm) of Navel oranges in 2020/2021 and 2021/2022 seasons.

Treatments	First season				Second season			
	fruit weight (g)	fruit volume (cc)	fruit height (cm)	fruit width (cm)	fruit weight (g)	fruit volume (cc)	fruit height (cm)	fruit width (cm)
Ammonium sulfate at 5 kg/ tree	196.00	202.30	8.13	8.06	202.30	208.92	8.26	8.16
Liquid ammonium nitrate at 2.5 L/tree	197.00	203.35	8.19	8.11	203.35	210.02	8.32	8.20
Urea at 2.2 kg/tree	195.00	201.25	8.05	7.98	201.25	207.81	8.14	8.02
Enciabene at 1.25 kg/tree	204.61	211.34	8.21	8.12	211.34	218.41	8.34	8.21
Enciabene at 1.875 kg/tree	204.91	211.66	8.28	8.13	211.66	218.74	8.40	8.22
Enciabene at 2.5 kg/tree	205.00	211.75	8.30	8.15	211.75	218.91	8.43	8.24
Enciabene at 0.500 kg + urea at 1.75 kg/ tree	205.91	212.71	8.35	8.22	212.71	219.85	8.47	8.29
Enciabene at 0.500 kg +ammonium nitrate at 2L/tree	205.00	222.25	8.60	8.36	222.25	229.86	8.69	8.41
Enciabene at 0.500 kg +ammonium sulfate at 4kg/tree	207.00	213.85	8.45	8.30	213.85	221.20	8.57	8.36
L.S.D. at 0.05	7.55	7.00	0.06	0.05	7.11	6.95	0.05	0.04

Table (3): Effect of different sources, levels, and methods of N applications on the fruit shape, juice percentage, and fruit peel thickness (cm) of Navel orange fruits in 2020/2021 and 2021/2022 seasons.

Treatments	First season			Second season		
	Fruit shape	Juice percentage	Fruit peel thickness (cm)	Fruit shape	Juice percentage	Fruit peel thickness (cm)
Ammonium sulfate at 5 kg/ tree	1.01	40.50	0.34	1.01	42.48	0.36
Liquid ammonium nitrate at 2.5 L/tree	1.01	42.00	0.32	1.01	44.05	0.35
Urea at 2.2 kg/tree	1.01	40.00	0.35	1.01	41.95	0.36
Enciabene at 1.25 kg/tree	1.01	41.71	0.33	1.02	43.75	0.34
Enciabene at 1.875 kg/tree	1.02	41.90	0.32	1.02	44.95	0.33
Enciabene at 2.5 kg/tree	1.02	42.09	0.31	1.02	44.15	0.33
Enciabene at 0.500 kg + urea at 1.75 kg/ tree	1.02	42.95	0.31	1.02	45.05	0.34
Enciabene at 0.500 kg +ammonium nitrate at 2L/tree	1.03	47.00	0.27	1.03	49.30	0.28
Enciabene at 0.500 kg +ammonium sulphate at 4kg/tree	1.02	45.00	0.29	1.03	47.20	0.30
L.S.D. at 0.05	N.S.	1.55	0.02	N.S.	1.42	0.03

2. Effect of different sources, levels, and methods of N applications on some chemical characteristics of fruits

Percentages of total soluble solids, total acidity, total and reducing sugars, total soluble solids/acid, and ascorbic acid content of Navel oranges fruits in 2020/2021 and 2021/2022 seasons in response to various sources, levels, and methods of N applications are shown in Tables (4 and 5).

It is evident from the obtained data that varying sources, levels, and methods of N applications were followed by great differences in the chemical quality of the fruits.

Data concerning the effect of sources reveal that fertilizing Navel orange trees with Enciabene at 2.5 kg/tree was very effective in enhancing chemical fruit quality in terms of increasing total soluble solids, total soluble solids/acid and ascorbic acid content and in decreasing the total acidity compared to using the other three fertilizers namely liquid ammonium nitrate, ammonium sulfate, and urea. Fertilizing the trees with urea at 2.2 kg/tree resulted in the lowest promotion of chemical fruit quality. Combined application of the slow-release N fertilizer, namely Enciabene at 0.5 kg/tree with any fast-release N fertilizers was favorable in improving the chemical quality of the fruits compared to using each N source only. The best overall treatment concerns the chemical quality of the fruits including the application of 0.5 kg/tree Enciabene plus 2 L/tree liquid ammonium nitrate. The chemical quality of the fruits gradually tended to promote with increasing Enciabene levels from 1.25 to 2.5 kg/tree when applied alone.

Similar results regarding fast-release N fertilizers were obtained by Li *et al.*, (2020) on Navel orange fruits and Silbre *et al.*, (2019) on Valencia oranges. The results of slow-release N fertilizers were supported by Navarro *et al.*, (2020) on Valencia orange fruits and Ruiz *et al.*, (2017) on Navel orange fruits.

Table (4): Effect of different sources, levels, and methods of N applications on the percentage of total soluble solids, total acidity, and total soluble solids/acid ratio of Navel orange fruits in the 2020/2021 and 2021/2022 seasons.

Treatments	First season			Second season		
	TSS (%)	Acidity (%)	TSS/acid ratio	TSS (%)	Acidity (%)	TSS/acid ratio
Ammonium sulfate at 5 kg/ tree	14.00	1.286	10.9	13.80	1.291	10.7
Liquid ammonium nitrate at 2.5 L/tree	14.05	1.253	11.2	13.86	1.259	11.0
Urea at 2.2 kg/tree	14.00	1.260	11.1	13.79	1.266	10.9
Enciabene at 1.25 kg/tree	14.04	1.241	11.3	13.90	1.249	11.1
Enciabene at 1.875 kg/tree	14.05	1.233	11.4	13.96	1.246	11.2
Enciabene at 2.5 kg/tree	14.06	1.229	11.5	14.00	1.244	11.3
Enciabene at 0.500 kg + urea at 1.75 kg/ tree	14.11	1.225	11.5	14.08	1.230	11.4
Enciabene at 0.500 kg +ammonium nitrate at 2L/tree	14.45	1.145	12.6	14.31	1.151	12.4
Enciabene at 0.500 kg +ammonium sulfate at 4kg/tree	14.35	1.181	12.2	14.27	1.186	12.0
L.S.D. at 0.05	0.03	0.033	0.2	0.04	0.039	0.2

Table (5): Effect of different sources, levels, and methods of N applications on the percentage of total sugars, reducing sugars, and ascorbic acid content (mg/100 ml juice) of Navel orange fruits in 2020/2021 and 2021/2022 seasons.

Treatments	First season			Second season		
	Total sugars (%)	Reducing sugar (%)	Ascorbic acid content	Total sugars (%)	Reducing sugar (%)	Ascorbic acid content
Ammonium sulfate at 5 kg/ tree	10.00	4.00	40.0	9.96	3.98	47.0
Liquid ammonium nitrate at 2.5 L/tree	10.05	4.38	41.0	10.01	4.05	48.0
Urea at 2.2 kg/tree	9.86	3.94	40.8	9.82	3.95	46.0
Enciabene at 1.25 kg/tree	10.21	4.00	42.9	10.15	4.11	49.6
Enciabene at 1.875 kg/tree	10.22	4.02	43.0	10.16	4.12	49.7
Enciabene at 2.5 kg/tree	10.23	4.03	43.5	10.18	4.13	50.0
Enciabene at 0.500 kg + urea at 1.75 kg/ tree	10.22	4.09	45.0	10.22	4.22	50.8
Enciabene at 0.500 kg +ammonium nitrate at 2L/tree	10.39	4.20	50.0	10.36	4.30	53.8
Enciabene at 0.500 kg +ammonium sulphate at 4kg/tree	10.32	4.02	47.3	10.29	4.32	52.5
L.S.D. at 0.05	0.04	0.03	1.2	0.03	0.05	1.1

Conclusions

The best N sources for Navel orange trees grown under clay loam soil included the application of the slow-release N fertilizer Enciabene, liquid ammonium nitrate, ammonium sulfate, or urea, in descending order. The combined application of Enciabene plus liquid ammonium nitrate gave satisfactory promotion on growth, yield, and fruit quality. Raising levels of Enciabene from 1.25 to 2.5 kg/tree had a slight effect on all the characters studied.

The best results about yield as well as physical and chemical properties of Navel orange fruits were obtained due to fertilizing the trees with Enciabene at 0.500 kg/tree plus 2 L/tree liquid ammonium nitrate. Enciabene was applied once at the start of growth while liquid ammonium nitrate was added in five equal batches. This recommendation was true under experimental and resembling conditions.

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تأثير التسميد سريع وبطيء الذوبان علي محصول وخواص الجودة للبرتقال بسرة (*Citrus sinensis*)

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الملخص العربي

أجريت هذه الدراسة خلال موسمي (٢٠٢١/٢٠٢٠) و (٢٠٢٢/٢٠٢١) علي سبعة وعشرون شجرة برتقال بسرة مطعمة علي أصل النارنج في مزرعة كلية الزراعة – بشبين الكوم – جامعة المنوفية وكان قوام التربة طينية طميية.

كان هدف التجربة إلقاء المزيد من الضوء علي تأثير المصادر والجرعات والطرق المختلفة لاستخدام النيتروجين علي النمو والمحصول والخصائص الطبيعية والكيميائية نسبة للثمار وتحديد أفضل المصدر والجرعات وطريقة استخدام النيتروجين في مزارع البرتقال بسرة. وكان التصميم الاحصائي المستخدم في التجربة هو القطاعات كاملة العشوائية. وذلك لتقييم تأثير المصادر والجرعات والطرق المختلفة لاستخدام النيتروجين علي الإثمار في أشجار البرتقال بسرة. وقد أوضحت النتائج المتحصل عليها أن أفضل مصادر التسميد الآزوتي لأشجار البرتقال بسرة تتضمن استخدام السماد الآزوتي بطيء التحلل (الانسيابين)، نترات الأمونيوم السائل، كبريتات الأمونيوم، اليوريا مرتبة ترتيباً تنازلياً. وكان الاستخدام المشترك بسمادي الانسيانين ونترات الأمونيوم السائلة مفضلاً ومثالياً في تحسين النمو والمحصول والخصائص الطبيعية والكيميائية للثمار. وكان هناك تأثير طفيف علي جميع الصفات تحت الدراسة عند رفع الجرعة المستخدمة من الانسيابين من ١,٢٥ إلي ٢,٥ كجم/شجرة. كما أمكن الحصول علي أفضل النتائج بخصوص المحصول والخصائص الطبيعية والكيميائية للثمار البرتقال بسرة عند تسميد الأشجار بسماد الانسيانين بمعدل ٠,٥٠٠ كجم للشجرة بالإضافة إلي استخدام نترات الأمونيوم بمعدل ٢ لتر للشجرة.

الكلمات المفتاحية: برتقال بسرة – العائد – الجودة – إنسيابين.