Bull. Fac. Agric., Cairo Univ.,53 (2002): 275-288 .

EFFECT OF FOLIAR APPLICATION WITH CALCIUM ON YIELD AND FRUIT QUALITY OF VALENCIA ORANGE TREES

(Received:25.7.2001)

By

Y. H. El-Shafey , A.M. Abd El-Rahman* and A.M. El- Azaze*

Plant Physioogy Department, Faculty of Agriculture, Cairo University.
** Horticlture Research Institute, Agricultural Research Center, Giza*

ABSTRACT

This experiment was carried out during two successive seasons (1996-1997) and 1997-1998 on Valencia orange trees (20 year old) budded on sour orange rootstock in a private orchard at El-Sharkia Governonrate ; to study the effect of foliar application with calcium at (42, 84 and 126 ppm) at 3 spraying dates November or February and or two equal split doses at November and February . Yield and fruit quality parameters were recorded.

Calcium concentrations (84 and 126 ppm) at all application dates increased fruit pull force and fruit firmness proportionally , the best fruit pull force and firmness were obtained with spraying calcium at two equal split doses in November and February followed by calcium applied at February. The lowest fruit pull force and firmness were obtained from calcium applied at November for both seasons. There was no effect on fruit juice TSS or TAC and TSS / TAC ratio , except from calcium applied at 126 ppm in February which significantly decreased TSS.

Calcium treatments caused significant reduction in fruit respiration rate., Calcium treatments had no significant effect on fruit yield , except the high concentration (126 ppm) which caused a decrease in fruit weight .

Key words: *calcium, foliar application, fruit trees, valencia orange.*

1. INTRODUCTION

Valencia orange is Known in Egypt as summer fruit crop as it appears in markets during summer time as one of the most popular citrus cultivars for both local consumption and export . Calcium effect on abscission may be more related to deferral of senescence development than to the cementing effect of Ca on cell walls (Poovaiah and Leopold 1973). Calcium not only inhibited respiration but delayed the onset of climacteric and depressed the peak of ethylene production at the climacteric rise (Tingwa and Young 1974) . Calcium prevented the increase in the apparent free space of the tissues , usually associated with senescence , and maintained the protein synthesizing ability of the cells , so , Ca appeared to protect fruit cell membranes from disorganization , which delays but does not prevent senescence (Faust 1975) .

Ca plays a special role in maintaining the cell-wall structure in fruits and other storage organs by interacting with pectic acid in cell walls to form calcium pectate (Poovaiah 1986) . Also calcium maintains membrane function and this effect is due to a consequence of calcium binding to the outer surface of the plasma membrane where calcium can affect membrane fluidity (Ferguson and Drobak 1988) . Calcium treated fruits have lower membrane permeability and contain more chlorophylls and ascorbic acid than non- treated. Calcium treatment lowered respiratory CO_2 evolution and ethylene production (Poovaiah 1988) . Preharvest application of calcium and IAA on citrus fruits enhanced sugars accumulation and reduced acid concentration (Xie *et al.*, 1992) . A high positive correlation was reported between calcium concentrations and apple fruit firmness . Negative correlation between calcium and acidity was found and the K : Ca and N : Ca ratios were negatively correlated with fruit firmness The N : Ca ratio was additionally correlated with the dry matter content (Ben 1997) .

The aim of the present work was to study the effect of calcium foliage application on yield and fruit properties as pull force , firmness, abscission and some physiological and horticultural considerations .

2. MATERIAL AND METHODS

This study was conducted during the two successive seasons [(1996-1997) and (1997-1998)] on 20 year old Valencia orange trees

(*C. sinensis L.*) on sour orange rootstock in a private orchard at El-Sharkia Governorate. Thirty trees (3 trees per a treatment) were selected at random as uniform as possible in their growth vigour and yield. All the experimental trees were treated alike as far as cultural practices were concerned except for the purpose of this study , where, a foliar application of 10% sequestered calcium as Ca-EDTA was applied at the rates of 42 , 84 and 126 ppm using 8 liter solution volume per tree Table (1).

Table (1):Calcium concentration treatments and date of application.

Calcium concentration 0.0 (control)	Date November and February
42 PPm (Ca_1)	November 15 (N) February 15 (F) - Split dose 21 ppm at Nov. 15th + 21 ppm at Feb. 15th (NF)
84 PPm (Ca_2)	November 15 (N) February 15 (F) - Split dose 42 ppm at Nov. 15th + 42 ppm at Feb. 15th (NF)
126 PPm (Ca_3)	November 15 (N) February 15 (F) - Split dose 63 ppm at Nov. 15th + 63 ppm at Feb. th (NF)

Three fruit samples were taken in both seasons in December , February and March. Each sample was composed of 5 fruits (for each replicate) picked at random around the tree circumference. Physical and chemical properties were determined as follows :

1- **Pull force " fruit removal force"** was determined according to El-Zeftawi and Dimsey (1983) .

2- **Fruit firmness**, determined by means of Magness Taglor pressure tester.

3- **Fruit weight and yield,** at mid of April the average fruit weight was obtained in grams by weighting all the samples and calculating the average. Average yield per tree in kg was estimated by multiplying average fruit weight by the number of fruits per tree.

4- **Fruit shape,** height and diameter were measured in cm by Vernier caliper , height to diameter ratio was calculated.

5- **Peel thickness,** the thickness of fruit rind was measured by Vernier caliper .

6- **Total acidity** of the juice was obtained according to the method of **A.O.A.C (1960) .**

7- **Total soluble solids (TSS)** of juice expressed as ° Brix was determined by using Zeiss referactometer , and TSS to acid ratio was calculated .

Physiological properties as respiration rate were determined as described by Wali (1958) . and pre-harvest fruit drop was determined .

The obtained data were statistically analysed using analysis of variance for completely randomized design according to Averages were compared using L.S.D values at 5% level.

3. RESULTS AND DISCUSSION

3.1 Fruit pull force and firmness

From the data in Tables 2 and 3 as well as Figs. 1 and 2 it could be noticed that calcium treatments (42,84 and 126 ppm) resulted in significant increase in the pull force and firmness of fruit as compared to control . This increase in pull force was significant in the 2nd sampling date only in the 2nd season for the high calcium concentrations , (84 and 126 ppm) . Also , in the 3rd sampling date the highest pull force and firmness were recorded for calcium applied as two equal splits at November and February followed by calcium applied in February, while calcium . applied at November showed the lowest values . Similar results were obtained by Poovaiah (1986),

Table (2) : Effect of foliar application with calcium on the physical properties of Valencia orange fruits during the 1st and 2nd sampling date of seasons (1996-1997) and (1997-1998) .

Sample No.	Treatments	Fruit pull force in kgm		Fruit firmness in kgm	
		1st season	2nd season	1st season	2nd season
1st	Ca_1	5.96	5.73	8.42	8.59
	Ca_2	6.02	5.97	8.87	8.74
	Ca_3	6.32	6.13	9.04	9.12
	Cont. Ca_0	5.66	5.11	8.13	8.36
	L.S .D(0.05)	0.32	0.44	0.20	0.37
2nd	Ca_1	5.87	6.69	8.95	8.82
	Ca_2	6.61	6.97	9.01	9.11
	Ca_3	7.03	7.18	9.35	9.27
	Cont. Ca_0	6.27	6.15	8.62	8.79
	L.S.D(0.05)	0.27	0.59	0.17	0.22

Ca_1 : 42 ppm Ca_2 : 84 ppm Ca_3 : 126 ppm

Table (3) : Effect of foliar application with calcium on the physical properties of Valencia orange fruits during the 3rd sampling date of seasons (1996-1997) and (1997-1998) .

Treatments		Fruit pull force in kgm		Firmness in kgm	
		1st season	2nd season	1st season	2nd season
Ca_1	N	7.23	6.28	8.50	9.09
	F	8.30	7.01	10.98	9.42
	NF	9.40	8.44	10.99	10.28
Ca_2	N	7.36	7.78	8.03	9.43
	F	7.83	7.81	10.70	10.11
	NF	9.33	8.70	11.76	10.96
Ca_3	N	8.40	7.72	8.24	8.15
	F	7.40	8.15	10.60	10.91
	NF	9.52	8.99	12.00	11.50
Ca_0	cont.	5.52	3.90	8.43	8.51
L.S.D (0.05)		1.02	0.44	0.50	0.39

N : November F : February N F : Nov. and Feb. split close

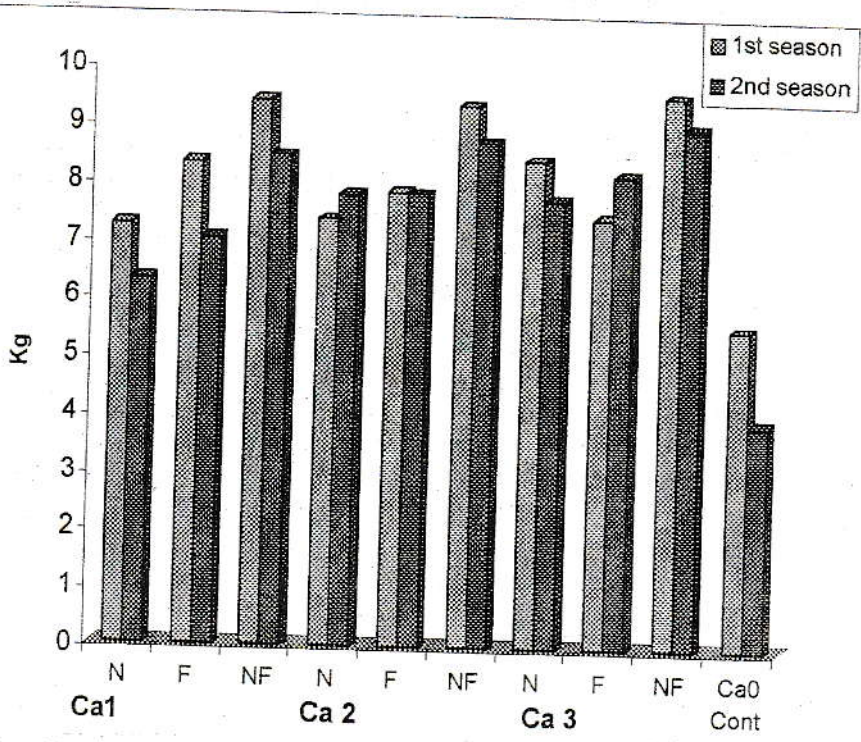

Fig. (1) Effect of foliar application with calcium on fruit pull force of Valencia orange during the 3rd sampling date

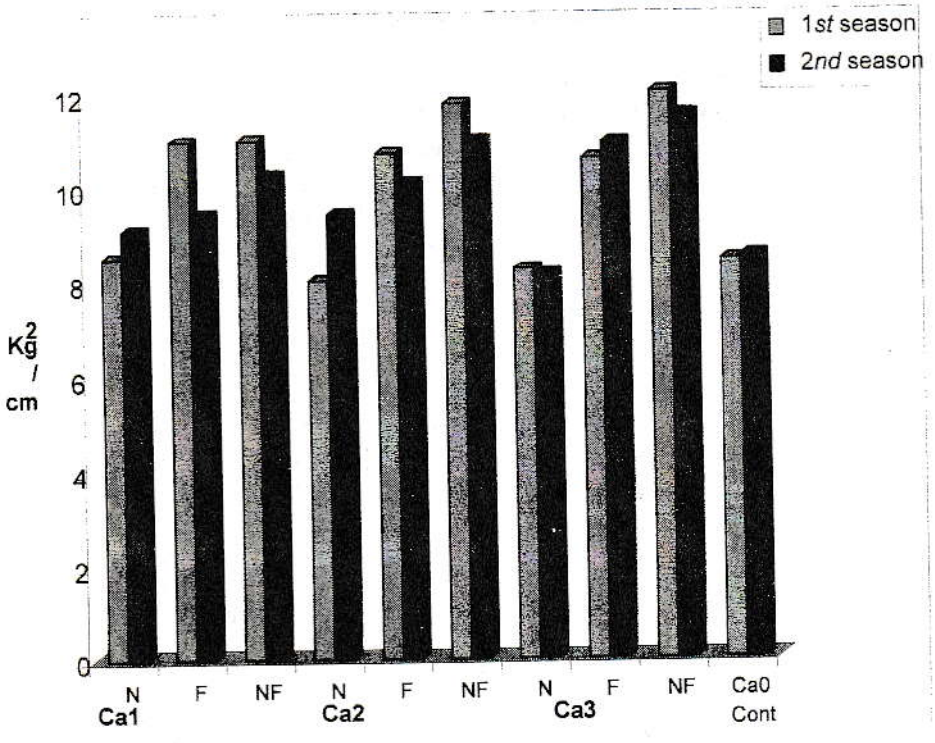

Fig. (2)Effect of foliar application with calcium on fruit firmness of Valencia orange during the 3rd sampling date

Ferguson and Drobak 1988 and Almela *et al.*, (1994). These workers pointed out that calcium has an important role in maintaining the cell wall structure and membrane integrity by the interaction of calcium with pectic acid in cell wall to form calcium pectate. Moreover, they added that calcium causes a reduction or delay in cell wall breakdown , and this effect causes a delay in fruit softening . In the present work , the timing of calcium application was critical. Application of calcium in

two split equal doses at November and February resulted in the highest fruit pull force and firmness .

*** Percentage and number of fruits dropped per tree**

Data presented in Table (4) show that all calcium treatments significantly decreased the number of fruits dropped as compared with control . The highest calcium concentrations (48 and 126 ppm) gave the best results for the percentage and number of fruits dropped per tree.

These results agree with Poovaiah and leopold (1973) who reported that the role of calcium in reducing fruit drop may be attributed to the inhibition of ethylene biosynthesis .

*** Fruit shape index**

Fruit shape index showed the relation of fruit height to diameter. It is well known that as this ratio increases , fruit shape tends to be oval while , when its equal (about one) the fruit shape is spherical , and when the ratio is less than one, then fruit is relatively flattened shape . From the results presented in Table (5) it could be noticed that all the treatments in the present study had no effect on fruit shape, and the fruits tend to be spherical through both seasons.

Table (4) : Effect of foliar application with calcium on the number of fruits dropped per tree and % of fruit drop during harvesting date.

Treatments		% of fruit drop		Number of fruit drop	
		1st season	2nd season	1st season	2nd season
Ca_1	N	1.75	1.77	6.67	7.00
	F	1.06	1.61	4.00	6.33
	NF	0.80	0.86	3.00	3.33
Ca_2	N	1.35	1.71	5.00	6.67
	F	0.00	0.43	0.00	1.67
	NF	0.88	0.76	3.33	3.00
Ca_3	N	0.36	0.87	1.33	3.33
	F	0.00	0.00	0.00	0.00
	NF	0.00	0.00	0.00	0.00
Ca 0	(cont.)	4.91	4.56	17.67	17.00
L.S .D	(0.05)	1.270	1.050	1.440	2.300

Ca_1 42 ppm Ca_2 84 ppm Ca_3 126 ppm
N: November F: February NF: Nov. and Feb.

*** Rind thickness**

All treatments in the present work had no effect on fruit peel-thickness for all sampling dates . Values recorded for all treatments in both seasons fluctuated in range between 0.63cm (the highest value recorded) – 0.53 cm. (the lowest value) which follow the same trend for control.

Table (5): Effect of foliar application with calcium on fruit shape in Valencia orange at harvest date during two seasons (1996 –1997) - (1997 –1998)

Treatments		Fruit shape index	
		1st season	2nd season
Ca_1	N	0.43	1.03
	F	1.03	1.17
	NF	1.05	0.47
Ca_2	N	0.99	1.01
	F	1.07	1.05
	NF	1.03	1.13
Ca_3	N	1.14	1.13
	F	1.27	1.05
	NF	1.10	1.09
Ca_0	cont.	0.98	1.00
	L.S.D	N. S	N. S

Ca_1: 42 ppm Ca_2 : 84 ppm Ca_3 : 126 ppm
N : November F : February N F : Nov. and Feb. split close

*** Total soluble solids**

The obtained results (Table 6) reveal that calcium concentrations 42 and 84 ppm had no significant effect on TSS of Valencia orange fruit . However , high calcium concentration 12 ppm significantly decreased TSS content. These results are in agreement with those obtained by Tripathi and Bhargava (1993) who indicated that pre harvest treatment of apple fruit with $CaCl_2$ (0.5%) decreased fruit total soluble solids content .

*** Titratable acidity**

Fruit juice acidity data presented in Table 4 disclosed that calcium treatments had no effect on fruit juice acidity except high Ca^{2+} concentration , where fruit juice acidity tended to be higher than control treatment .The obtained results are in accordance with those reported by Poovaiah (1988) who mentioned that calcium treatment resulted in an increase in fruit juice acidity of apple fruits .

***TSS / acid ratio**

Data concerning total soluble solids to acidity ratio are presented in Table (6) . It could be concluded that all treatments in the present study had no effect on fruit total soluble solids to acidity ratio in both seasons .

*** Fruit weight and yield**

Data in Table (7) showed that at harvest date ,calcium at (84 and 126 ppm) significantly reduced fruit weight in the 1st season , but, in the 2nd season this reduction was significant only with calcium at 126 ppm .The same trend had resulted for the yield which may be due to the strong relationship between fruit weight , fruit size and yield .These results confirm Muromtsev *et al.*, (1991) and Njoroge *et al.*, (1998 a , b) .

Table (6) : Effect of foliar application with calcium on TSS % , acidity % and TSS to acidity ratio of Valencia orange juice during two seasons (1996 –1997) - (1997 –1998)

Treatments	TSS		Acidity		TSS: acidity	
	Season$_1$	Season$_2$	Season$_1$	Season$_2$	Season$_1$	Season$_2$
Ca_1 N	10.43	10.81	1.11	1.20	9.40	9.01
F	11.23	10.88	1.12	1.17	10.03	9.30
NF	11.33	10.91	1.15	1.19	9.85	9.17
Ca_2 N	11.15	11.17	1.18	1.19	4.45	9.39
F	11.33	11.33	1.20	1.20	9.44	9.44
NF	10.53	11.00	1.21	1.19	8.70	9.24
Ca_3 N	11.17	11.06	1.21	1.19	9.23	9.29
F	11.00	11.63	1.19	1.17	9.24	9.94
NF	10.33	11.00	1.19	1.19	8.68	9.24
Ca_0 cont.	11.30	10.86	1.16	1.16	9.74	9.36
L.S.D	0.220	0.270	0.092	0.085	N.S	N.S

Ca_1 42 ppm Ca_2 84 ppm Ca_3 126 ppm

N : November F : February N F : Nov. and Feb. split close

Table (7) : Effect of foliar application with calcium on the number of fruits per tree, fruit weight. and fruit yield at harvest date of the two seasons (1996-1997) – (1997 –1998).

Treatments	No. of fruits per tree		Fruit weight gm		Fruit yield (Kg / tree)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
N	381.00	395.33	169.81	166.53	64.70	65.83
Ca_1 F	379.00	392.62	168.82	167.71	63.98	65.85
NF	377.00	389.00	168.41	168.51	63.49	65.55
N	369.33	390.00	168.41	167.11	62.20	65.17
Ca_2 F	379.33	388.67	170.84	166.25	64.80	64.62
NF	377.67	394.37	165.31	168.92	62.43	66.62
N	371.67	383.33	167.03	165.38	62.08	63.40
Ca_3 F	379.33	391.00	168.21	164.51	63.81	64.32
NF	376.00	392.67	165.21	165.81	62.12	65.11
Ca_0 cont.	360.00	373.00	173.11	169.35	62.32	63.17
L.S.D.	18.67	21.36	4.570	4.210	N. S	N. S

Ca_1 : 42 ppm Ca_2 : 84 ppm Ca_3 : 126 ppm Ca_0 :cont.
N: November F: February NF: Nov. and Feb.

Table (8): Effect of foliar application with calcium on the respiration rate (CO_2 / kg^{-1} h^{-i}) of Valencia orange fruits in the 2nd season (1997-1998) .

Treatments	Resp. rate
N	13.46
Ca_1 F	15.52
NF	12.94
N	13.42
Ca_2 F	11.75
NF	12.71
N	13.71
Ca_3 F	11.57
NF	12.51
Ca_0 cont.	15.83
L.S.D.	2.450

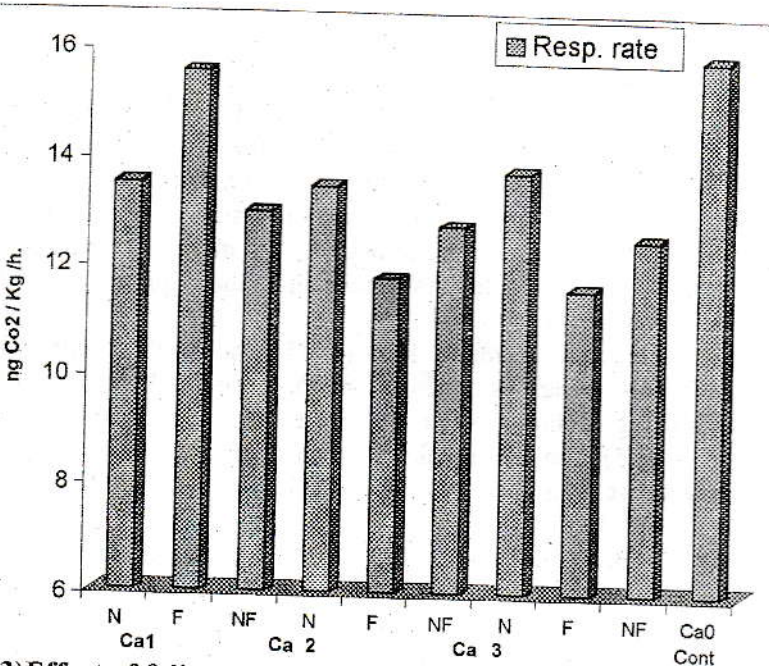

Fig. (3)Effect of foliar application with calcium rate (ng co_2 /Kg-1,h-1) of Valencia orange during harvest date in the 2nd season.

Physiological studies

Respiration rate

With regard to the effect of calcium foliar application on the fruit respiration rate, Table (8) and Fig 3 show that calcium treatments significantly reduced respiration rate. The reduction appears to be more with high calcium concentrations (84 and 126ppm) specially those applied at February. Low calcium concentration at November showed insignificant decrease in fruit respiration rate .These results are in agreement with those mentioned by Tingwa and Young 1974 and Poovaiah (1986). They reported that calcium depressed fruit respiration , delayed the onset of climacteric stage, and the increased calcium levels in fruit tissues altered various parameters of senescence such as respiration .

4. REFERENCES

Almela V., Zaragoza, S., Primo. Millo, E. and Agusti , M. (1994) : Hormonal control of splitting in " Nova" mandarin fruit . J. Hort. Sci., 69(6) : 969-973 .

A.O.A.C (1960). Official Methods of Analysis of the Association of Official Agricultural Chemists 8th Ed, 100 PP. Washington , D.C.

Ben J. (1997). Effect of the concentration of mineral constituents in apples on their post harvest quality and storage performance II. Relations between the concentration of mineral constituents in apples and some factors determining their quality . Folia – Horticulture , 9 (1) : 51-57 .

El-Zeftawi B.M. and Dimsey R.T. (1983).Evaluation of abscission chemicals in various combinations for loosening Valencia orange during regreening. J. Amer. Soc. Hort. Sci., 58(1) : 129-139 .

Faust M. (1975). The role of calcium in the respiratory mechanism and senescence of apples. Resh . Sci . 238 : 87 – 92 (C.F. Hort. Abst. 46 : 2911, 1976) .

Ferguson I. B. and Drobak B. K. (1988) . Calcium and the regulation of plant growth and senescence. Hort . Sci., 23(2) : 2312, 262-266 .

Muromtsev G. S, Krosms Kaya N.P., Letunora S.V. and Beresh I.G. (1991). Application of an ethylene producing preparation with soil activity on citrus crops. Doklady- vessoyuznoi. Ordena-Lenina –1- Ordena – Trudovogo – Krasnogoz- nomeni – Akadem Sel,skokhozya- istrenn ykh- Nauk – im v –I – Lenina 2 : 24 – 27 .

Njoroge C.K, Kerbel E.L., and Briskin D.P. (1998a). Effect of calcium and calcium and calmodulin antagonists on ethylene biosynthesis in tomato fruit. J. Sci. Food and Agric., 76 (2) : 209-214 (C.F. Hort. Abst. 68:5095 , 1998) .

Njoroge C.K, Kerbel E.L., and Briski D.P. (1998b). Effect of exogenous calnodulin and ATP on the activity of ethylene forming enzyme obtained from tomatoes and green pea pods . J. Sci. Food and Agric., 76(2) : 215- 220 (C.F. Hort. Abst., 68 : 5096, 1998) .

Poovaiah B.W. and Leoplod A.C. (1973) .Inhibition of abscission by calcium. Plant Physiol., 51 : 848- 851 .

Poovaiah B.W.(1986). Role of calcium in prolonging storage life of fruits and vegetables . Food Tech., 5 : 86 – 88 .

Poovaiah B.W. (1988). Molecular and cellular aspects of calcium action in plants. Hort. Sci., 23(2) : 267-270 .

Tingwa P.O. and Young R.E. (1974). The effect of calcium on the ripening of avocado (*Persea americana*) fruits . J. Amer. Soc. Hort. Sci., 99(6) : 540-542 .

Tripathi S.N., and Bhargava , J.N. (1993) . Effect of preharvest treatment of fungicides and chemicals on the post- harvest behaviors of red delicious apple in aircooled storage . Advances in Hort. forestry , 3 : 77-79 (C.F. Hort. Abst. 65 : 7717 , 1995).

Wali Y.A. (1958): Studies on the artificial ripening of pear fruits . Ph.D. Thesis , Fac., Agric. Cairo Univ., Egypt .

Xie Y. H., Ou, Y.; Cao, Zc. And Fa, Q.1992 : Effects of preharvest applications of calcium and IAA on the fruit quality of Jinchen (*Citrus sinensis*). J. South West Agric. Univ., 14 (6) : 543-545.

تأثير الرش الورقى بالكالسيوم على المحصول وجودة الثمار لأشجار البرتقال الصيفى

يحيى الشافعى ، عبد الرحمن محمد * ، أمجد محمد العزازى*

قسم فسيولوجى النبات–كلية الزراعة – جامعة القاهرة
* معهد بحوث البساتين – مركز البحوث الزراعية – الجيزة

ملخص

اجريت هذه الدراسة خلال موسمى ١٩٩٦/١٩٩٧ و ١٩٩٧/١٩٩٨ على اشجار برتقال صيفى عمر ٢٠ سنة مطعومة على اصل النارنج فى أحد البساتين الخاصة بمحافظة الشرقية وذلك لدراسة تاثير الرش بالكالسيوم المخلبى ١٠% مادة فعالة وبتركيزات (٤٢ ، ٨٤ ، ١٢٦ جزء فى المليون كالسيوم) فى ثلاث مواعيد اضافة مختلفة هى فبراير أو نوفمبر او على دفعتين متساويتين فى فبراير ونوفمبر وقد تم دراسة تاثير هذه المعاملات على المحصول والصفات الطبيعية والكيماوية للثمار وقد تم التوصل الى النتائج التالية :

ادى الرش بالكالسيوم بتركيزات ٨٤ و ١٢٦ جزء فى المليون فى جميع مواعيد الاضافة الى زيادة قوة شد وصلابة الثمار وكانت افضل نتيجة تم التوصل اليها عند رش الكالسيوم على دفعتين متساويتين فى نوفمبر وفبراير وفى نفس الوقت لم يلاحظ اى تأثير على هاتين الصفتين فى معاملة اضافة الكالسيوم فى نوفمبر فقط لكلا الموسمين .

لوحظ ايضا انه لا يوجد اى تاثير معنوى لاضافة الكالسيوم على نسبة المواد الصلبة الذائبة الكلية او الحموضة الكلية او النسبة بينهما ما عدا عند الرش

بالتركيز العالى للكالسيوم (١٢٦ جزء فى المليون) وفى شهر فبراير حيث ادى ذلك الى خفض معنوى فى نسبة المواد الصلبة الذائبة الكلية .

ادت جميع معاملات اضافة الكالسيوم رشاً على اشجار البرتقال الصيفى الى خفض معدل تنفس الثمار مما يعنى قدرتها على البقاء بحالة جيدة على الاشجار او ما بعد الحصاد عند التداول أو التخزين .

أخيراً لم يلاحظ اى تأثير للكالسيوم على تغير فى المحصول النهائى للاشجار الا مع الاضافة بتركيزات عالية ١٢٦ جزء فى المليون حيث ادت هذه المعاملة الى خفض متوسط وزن الثمرة .

يوصى من خلال النتائج التى تم التوصل اليها فى هذه الدراسة للحفاظ على الثمار بكامل حيويتها دون التأثير على صفات الجودة الطبيعية والكيماوية لاطول فترة ممكنة على الاشجار وكذلك لتقليل نسبة تساقط الثمار قبل الحصاد يوصى برش الكالسيوم المخلبى بتركيز ٨٤ جزء فى المليون على دفعتين متساويتين فى نوفمبر وفبراير على التوالى اثناء وجود الثمار على الاشجار مع مراعاة الحالة الغذائية للاشجار وميعاد الحصاد المناسب والغرض من التسويق .

المجلة العلمية لكلية الزراعة – جامعة القاهرة – المجلد (٥٣) العدد الثانى (إبريل ٢٠٠٢):٢٧٥-٢٨٨.