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ENHANCING TOMATO FRUITS YIELD AND QUALITY USING FOLIAR SPRAY WITH CALCIUM.

Kamal, A. M. and M. A. Abd Al-Gaid
Veget. Res. Dept., Hort. Res. Inst., Agric. Res. Center, Giza, Egypt.

ABSTRACT

Two field experiments were performed during the two successive seasons of 2003 and 2004 at Mansoura Vegetable Research station at El-Baramon, Dakahlia Governorate, Egypt, to study the effects of some calcium sources and levels as a foliar spray applications to reduce the disordered fruits; *i.e.,* cracking and blossom end rot as well as improving fruit yield and quality of tomato cv. GS 12.

The main findings obtained from this investigation showed that:

- Sprayed tomato plants with Ca-nitrate at 1.5 or 2 g Ca /L gave the lowest values of the percentage of cracked fruit types; radial, longitudinal, ring, transversals and total cracked fruits as well as fruits infected with blossom end rot.
- Total marketable yield per feddan was significantly increased and reaches its maximum values by foliar application with Ca-nitrate at 1, 1.5 or 2 g Ca /L.
- Fruit dry matter content was significantly affected by foliar spray of 1.5 g Ca /L of Ca-nitrate compared with all other treatments and control.
- The most effective treatment affected on fruit total soluble solids was that of using 1.5 g Ca /L of Ca-chloride or Ca-nitrate.
- Ascorbic acid content and titratable acidity of tomato fruit did not significantly influenced with all used calcium treatments.
- Foliar application of 2 g Ca /L of Ca-chloride or Ca-nitrate showed a significant enhancing effect on Ca content of tomato fruits.
- Tomato plants which sprayed with 2 g Ca /L of Ca-chloride or 1, 1.5 or 2 g Ca /L of Ca-nitrate were reached the highest total carbohydrate of tomato fruits.
- Nitrate content in tomato fruit was significantly decreased with foliar application of Ca-chloride at 1.5 or 2 g Ca /L followed by using Ca-nitrate at 1.5 or 2 g Ca /L.

It can be recommended that foliar spray tomato plants with Ca-nitrate at 1.5 g Ca /L at the beginning of flowering and repeating every 15 days produce good tomato yield with less percentage from disorders fruits.

In conclusion, this study demonstrated that it is possible to minimize disorders fruits and produce highest yield and quality of tomato by foliar spraying with Ca-nitrate at 1.5 g Ca /L at the beginning of flowering 4 times each 15 day intervals.

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) is the first vegetable crop in Egypt for local consumption and export. Fruit cracking and Blossom end rot are serious problems in tomato cause a significant economic degradation of fresh market yield and fruits quality, Calcium plays a very important role in the structure of the cell wall and occurs in plant as calcium pectate, which is a component of every plant cell wall (Bennett, 1994 and Burns and Pressey, 1987), also calcium involved in plant tolerance to heat stress by regulating antioxidant metabolism (Jiang and Huang, 2001). Calcium deficiency usually induced in plants because calcium is not a highly mobile element (Mengel and Kirkby, 1978). Moreover, favourable calcium nutrition is important for preventation of cracking in tomatoes (Peet, 1992). Fruit cracking is a common physiological disorder that occurs in tomato summer crop production, it is proposed that not a single factor are involved in fruit cracking but a sequence of two equally important factors, variety, un-regular water irrigation, high temperature (Table 1) or nutrition (Sanders, 2006). Moreover, the susceptibility of tomato fruit cracking has been correlated with a range of environmental and physiological factors as well as Ultrastructural and anatomical features (Thompson, 2001). There are many types of tomato fruit cracking; *e.g*. longitudinal or burst cracking, ring or concentric cracking, grazing or russeting cracking, star or radial cracking (Peet, 1992). Several researchers have attributed the occurrence of fruit cracking and blossom-end rot (BER) in tomato to Ca deficiency. Spraying application of Ca compounds was reported to reduce fruit cracking under field and laboratory conditions (Callan, 1986; Christensen, 1996; Glenn and Poovaiah, 1989; Lang and Flore, 1999 and Weichert *et al*., 2004). Blossom end rot (BER) was reduced by application of Ca (Al-Dolimy and Al-Any, 1987, and Lin *et al.,* 2000). Blossom end rot (BER) is caused by many factors but the underlying cause of this disorder is an inadequate amount of Ca^{2+} in the blossom-end of the fruit (Ohta *et al*., 1994; Ho *et al*., 1999; Kitano *et al*., 1999 and Saure, 2001).

Considering the above factors, an experiment was performed to study the combined effects of some calcium sources and levels as foliar spray applications to reduce the disordered fruits; *i.e.,* cracking and blossom end rot as well as to improve tomato fruit yield and its quality.

MATERIALS AND METHODS

The present experiment was performed during the two successive seasons of 2003 and 2004 at Mansoura Vegetable Research station at El-Baramon, Dakahlia Governorate, Egypt to determine the effects of foliar spraying with some Ca sources at deferent concentrations to reduce the disordered fruits; *i.e.,* cracking and blossom end rot as well as to improve fruit yield and quality of tomato. The experiment included 16 treatments as follow:

1- Control
2- Ca-citrate at 1 g Ca /L
3- Ca-citrate at 1.5 g Ca /L
4- Ca-citrate at 2 g Ca /L
5- Ca-chloride at 1 g Ca /L
6- Ca-chloride at 1.5 g Ca /L
7- Ca-chloride at 2 g Ca /L
8- Ca- nitrate at 1 g Ca /L
9- Ca- nitrate at 1.5 g Ca /L
10- Ca- nitrate at 2 g Ca /L
11- Ca-sulfate at 1 g/L Ca
12- Ca-sulfate at 1.5 g/L Ca
13- Ca-sulfate at 2 g Ca /L
14- Ca-oxide at 1 g Ca /L
15- Ca-oxide at 1.5 g Ca /L
16- Ca-oxide at 2 g Ca /L

Deferent Ca sources were used as foliar treatments, *i.e.,* Ca citrate (25% Ca), Ca chloride (26% Ca), Ca nitrate (19% Ca), Ca- sulfate (22% Ca) and Ca-oxide (35% Ca). Tomato, cv. GS 12 hybrid, transplants were planted in the open field on 1st of May during the two summer seasons, using randomized complete block design with three replicates. Each plot consisted of four ridges each of 3.5 m long and 1 m wide, tomato seedlings were transplanted into one side ridges at spacing of 50 cm. Tomato plants were received N, P and K fertilizers at the rates of 150 Kg N, 75 Kg P_2O_5 and 150 Kg K_2O / fed. Fertilizers were applied in the form of ammonium nitrate (33.5 % N), calcium superphosphate (15 % P_2O_5) and potassium sulfate (48 % K_2O). Normal cultural practices for tomato were followed according to the instruction laid down by Egyptian Ministry of Agriculture.

Calcium sources were applied as foliar spray 4 times, at the beginning of flowering (25% flowering from plants) and each 15 days intervals using spreading agent (Super film 1 ml/ Liter). The untreated plants (control) were sprayed with tap water using the same spreading agent.

All harvested fruits from each plot at full maturity stage all over the season, were used to determine the percentage of disordered tomato fruits *i.e.* cracked fruits (radial cracking, longitudinal cracking, ring cracking, transversals cracking and total cracked fruits), blossom end rot fruits (BER) and total marketable tomato yield were calculated from all harvested marketable fruits /plot and then as tons / fed.

A representative sample of 5 fruits from each experimental plot at the marketable ripe stage were taken from the 3rd harvest for determination of fruit dry matter %, total soluble solids (TSS %), ascorbic acid (mg/100g fresh fruit weight) and titratable acidity according to the methods of A.O.A.C. (1990). Calcium percentage was determined in fruits dry matter according to methods described by Barrows and Simpson (1962). Total carbohydrate mg/g in dried fruit according to Snell and Snell (1953). Nitrate content (mg/kg fresh fruit weight) was determined in fruit dry weight and calculated as fresh weight basis depending on fruit water content according to Sen and Donaldson (1978). The average weekly temperature during seasonal growth of 2003 and 2004 summer seasons, were recorded by Shawa weather station, are shown in Table 1.

The obtained data were subjected to statistical analysis as a combined for the two seasons according to Gomez and Gomez (1984). The treatment means were compared using New Least Significant Difference at 5% level of probability as mentioned by Waller and Duncan (1969).

RESULTS AND DISCUSSION

1. Effect of foliar spraying with some Ca sources at deferent concentrations on disorder fruits and marketable yield of tomato:

Data in Table 2 show the effect of Ca foliar treatments on disorder fruits and marketable yield of tomato, it is clear from such data that all used calcium treatments had a significant effect on all of studied characters, combined analysis of 2003 and 2004 seasons. These results clear obviously that tomato plants which sprayed with Ca-nitrate at 1.5 or 2 g Ca /L gave the

Table 1: The average weekly temperature during seasonal growth of 2003 and 2004 summer seasons at Dakahlia area, Egypt.

Month	2003		2004	
	Min.	Max.	Max.	Min.
May	19.6	28.6	17.4	29.5
	19.7	28.1	18.1	28.4
	19.1	28.4	17.8	29.5
	18.8	27.9	16.2	29.4
June	23.5	31.7	20.1	32.3
	23.4	30.4	19.7	32.7
	24.6	30.8	21.6	30.4
	24.4	32.3	21.4	33.4
July	23.7	32.2	19.3	32.9
	22.9	31.1	19.1	31.4
	22.6	32.7	20.2	33.0
	24.4	33.6	19.0	33.4
August	22.1	34.5	24.1	33.0
	23.4	33.8	25.4	34.1
	22.5	34.4	24.2	32.8
	22.2	33.7	24.0	33.4

lowest values of the percentage of cracked fruit types; radial, longitudinal, ring, transversals and total cracked fruits as well as fruit with blossom end rot disorder. This means that tomato plants which unsprayed (control) gave the highest values in this respect, it is also clear that radial cracking recorded the highest values of cracking, followed by transversal and longitudinal cracking, respectively. Date indicates also that total marketable yield per feddan was significantly increased and reaches its maximum values (15.21, 15.15 and 14.96 ton/fed) with foliar application of Ca-nitrate at 1, 1.5 or 2 g Ca /L, respectively. These results were conformity with those obtained by Lin *et al.* (2000) and Hao and Papadopoulos (2004) on tomato they found that the incidence of blossom end rot of tomato fruit decreased with increasing calcium fertilization level. Also Ho *et al*. (1999) and Saure (2001) reported that low supply of calcium to tomato fruit leads to more fruit with blossom end rot. Moreover, El-Mansi *et al.* (2005) induced that percentage of cracked fruit, blossom end rot and total number of disordered fruits was decreased with increasing calcium chloride concentration up to 2 % concentration. Moreover, spraying tomato plants with calcium chloride at 1% or 2% concentrations increased percentage of number of ideal fruits. Wooldridge *et al.* (1998); Crisosto *et al.* (2000) and Carlos *et al*., (2003) they reported that sprayed calcium nitrate offers better results than calcium chloride. On the other hand, Taylor *et al. (*2004) used Ca $(NO_3)_2$; Ca thiosulfate; $CaCl_2$ and $CaSO_4$ as a deferent calcium sources, they found that marketable yield of tomato were higher with Ca $(NO_3)_2$ or $CaCl_2$, whereas, number and weight of BER fruits were lower with Ca $(NO_3)_2$.

The pronounced promotional effect of foliar applications of Ca on decreasing fruit disorders and increasing yield of tomato may be due to their effect on optimizing Ca content in tomato fruit tissue. However, many authors emphasis the role of the Cuticular membrane (Jeffree, 1996) and the extent to which it develops in epidermal and subepidermal walls (Wattendorf and Holloway, 1980; Emmons and Scott, 1998 and Antonio, 2004). Calcium, also, plays an essential role in processes that preserve the structural and functional integrity of plant membranes, stabilize cell wall structures, regulate ion transport and selectivity and control ion-exchange behaviour as well as cell wall enzyme activities (Rengel, 1992 and Marschner, 1995). Maximum relative growth rate of tomato fruit occurs at 12 to 15 days after anthesis during this period of rapid cell expansion deficiency of Ca is most disastrous during this period of rapid cell expansion in the fruit (Willumsen *et al*., 1996). Moreover Wein (1997) reported that immobile nature of calcium in plant and the difficulty translocation of this element from one part of the plant to other increases blossom end rot. On the other hand, Saure (2001) reported that an increase in physiologically active gibberellins (GAs) and a resulting decrease in Ca^{2+}, causing the enhanced permeability of cell membranes at the beginning of cell enlargement, at this stage, usually the highest amount of physiologically active GAs and the lowest amount of Ca^{2+} are found. It could be suggested that, foliar applied of Ca meet the requirements and the deficiency of this element during this period of fruit rapid cells expansion and consequently deceased tomato fruits disorders.

2. Effect of foliar spraying with some Ca sources at deferent concentrations on fruits quality of tomato:

Data presented in Table 3 show the effect of Ca foliar treatments on fruits quality of tomato. It is clear that fruit dry matter content was significantly affected by foliar spray of 1.5 g Ca /L of Ca-nitrate compared with all other treatments and control, meanwhile, the most effective calcium treatment affected fruit total soluble solids was that of using 1.5 g Ca /L of Ca-chloride or Ca-nitrate. On the other hand, ascorbic acid content and titratable acidity of tomato fruit did not significantly influenced with all used Ca foliar treatments. The same data showed a significant enhancing effect of foliar application of 2 g Ca /L of Ca-chloride or Ca-nitrate on Ca content of tomato fruits. However, tomato plants which sprayed with 2 g Ca /L of Ca-chloride or 1, 1.5 or 2 g Ca /L of Ca-nitrate were reached the highest total carbohydrate of tomato fruits. Regarding nitrate content of tomato fruits it is obviously clear that nitrate contents was significantly decreased and reaches its minimum values (32.4 and 30.1 mg /kg fresh weight) with foliar application of Ca-chloride at 1.5 or 2 g Ca /L followed by using Ca-nitrate at 1.5 or 2 g Ca /L. In contrast, control plants were greatly reached the maximum values of nitrate in tomato fruit (57.8 mg /kg fresh weight). These results are coinciding with Garcia *et al*. (1995), who found that foliar treatment with $CaCl_2$, gave higher TSS content than the non treated tomato plants. Moreover, Taylor *et al. (*2004) indicated that fruit Ca concentrations were generally higher with $Ca(NO_3)_2$ compared to all other foliar application Ca sources, *i.e.*, Ca thiosulfate, $CaCl_2$ or $CaSO_4$. Meanwhile, El-Mansi *et al.* (2005) mentioned that ascorbic acid in juice of tomato fruits decreased with increasing calcium chloride up to 2 %, while titratable acidity increased with increasing calcium chloride treatment; meanwhile, increasing calcium chloride treatment had no significant effect on fruit mineral composition and nitrate content.

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The role of calcium in enhancing fruit dry matter content , total soluble solids and Ca content of tomato fruits may be related to the osmotic potential of the Ca solution, which will tend to limit water uptake by the fruit, or to the enhancement of epidermal calcium nutrition on tomato fruit (Huang and Snapp, 2004).

In general, from the previous mentioned results and discussion, it could be concluded that foliar application of tomato plants with Ca-nitrate at 1.5 g Ca /L as foliar spray 4 times, from the beginning of flowering reduced the disordered fruits; *i.e.*, cracking and blossom end rot as well as improve tomato fruit yield and quality.

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تحسين محصول و جوده ثمار الطماطم بالرش الورقي بالكالسيوم.

أحمد مصطفى كمال و محسن عبد الوهاب عبد الجيد.
قسم بحوث الخضر – معهد بحوث البساتين – مركز البحوث الزراعية – مصر

أجريت تجربتان حقليتان في العروة الصيفية خلال الموسمين المتعاقبين ٢٠٠٣ و٢٠٠٤ و ذلك بالمحطة البحثية بالبرامون- محافظه الدقهلية- مصر وذلك لدراسة تأثير الرش الورقي ببعض مصادر و مستويات الكالسيوم لخفض نسبه الثمار المعابه وخاصة الثمار المصابة بالتشقق وكذلك المصابة بتعفن الطرف الزهري بالإضافة إلي تحسين المحصول و الجودة لثمار الطماطم وكانت أهم النتائج ما يلي :

- أدي الرش الورقي بنترات الكالسيوم بتركيز ١,٥ أو٢ جرام كالسيوم/لتر إلي الحصول علي اقل نسبه من الثمار المصابة بالتشقق و خاصة التشقق الشعاعي و التشقق الطولي و التشقق العرضي و التشقق الحلقي وكذلك المصابة بتعفن الطرف الزهري.
- أعطي الرش الورقي بنترات الكالسيوم بتركيز ١ أو ١,٥ أو٢ جرام كالسيوم/لتر أفضل محصول تسويقي كلي للفدان.
- أدي الرش الورقي بنترات الكالسيوم بتركيز ١,٥ جرام كالسيوم/لتر إلي زيادة معنوية في محتوي الثمار من المادة الصلبة.
- أدي الرش الورقي بكلوريد الكالسيوم أو بنترات الكالسيوم بتركيز ١,٥ جرام كالسيوم/لتر إلي الحصول علي أعلي نسبه مواد صلبه ذائبة بالثمار بينما لم يتأثر كلا من فيتامين ج أو الحموضة لثمار الطماطم بجميع معاملات الكالسيوم.
- اظهر الرش الورقي بكلوريد الكالسيوم أو بنترات الكالسيوم بتركيز ٢ جرام كالسيوم/لتر أفضل تأثير علي محتوي الثمار من الكالسيوم بينما أدي الرش الورقي بنترات الكالسيوم بتركيز ١,٥ كالسيوم/لتر إلي الحصول علي أعلي محتوي من الكربوهيدرات بالثمار.
- أدت معامله نباتات الطماطم بالرش الورقي بكلوريد الكالسيوم بتركيز ١,٥ أو ٢ جرام كالسيوم/لتر يليه معاملة الرش بنترات الكالسيوم بمعدل ١,٥ أو ٢ جرام كالسيوم/لتر إلي الحصول علي اقل محتوي من النترات.

و عليه فإنه يمكن التوصية بالرش الورقي لنباتات الطماطم بنترات الكالسيوم بتركيز ١,٥ جرام كالسيوم/لتر أربع مرات مع بداية الإزهار و تكرار ذلك كل ١٥ يوم لإنتاج محصول جيد من الطماطم مع اقل نسبه من الثمار المعابه و خاصة المصابة بالتشقق وكذلك المصابة بتعفن الطرف الزهري.

Table 2: Effect of foliar spraying with some Ca sources at deferent concentrations on disorder fruits and marketable yield of tomato, combined analysis of 2003 and 2004 seasons.

Ca- treatments	Disorder fruits (%) *fed*							Total marketable yield ton/fed
	radial cracking	Longitud-inal cracking	Ring cracking	Transve-rsals cracking	Total cracked fruits (%)	Blossom end rot (BER)%	Total Disorders fruits (%)	
Control	7.79	1.34	0.14	1.94	11.23	0.65	11.88	13.50
Ca-citrate 1 g Ca /L	4.47	1.01	0.09	1.79	7.36	0.66	8.02	14.48
Ca-citrate 1.5 g Ca /L	5.04	0.91	0.10	1.54	7.59	0.57	8.16	14.73
Ca-citrate 2 g Ca /L	5.71	0.93	0.08	1.32	8.04	0.49	8.53	14.24
Ca-chloride 1 g Ca /L	4.12	0.84	0.10	1.01	6.07	0.51	6.58	14.07
Ca-chloride 1.5 g Ca /L	3.74	0.91	0. 11	0.95	5.71	0.54	6.25	14.37
Ca-chloride 2 g Ca /L	4.11	0.80	0.05	0.91	5.87	0.47	6.34	15.01
Ca- nitrate 1 g Ca /L	2.45	0.71	0.05	0.97	4.18	0.41	4.59	15.21
Ca- nitrate 1.5 g Ca /L	2.32	0.51	0.08	0.81	3.72	0.52	4.24	15.15
Ca- nitrate 2 g Ca /L	2.41	0.57	0.07	0.78	3.83	0.54	4.37	14.96
Ca-sulfate 1 g Ca /L	6.11	1.24	0.07	1.92	9.34	0.62	9.96	14.02
Ca-sulfate 1.5 g Ca /L	4.54	1.04	0.11	1.25	6.85	0.54	7.39	14.39
Ca-sulfate 2 g Ca /L	4.62	0.94	0.08	1.17	6.81	0.57	7.38	14.49
Ca-oxide 1 g Ca /L	5.22	1.04	0.12	1.27	7.65	0.61	8.26	14.62
Ca-oxide 1.5 g Ca /L	4.98	0.88	0.08	1.33	7.27	0.58	7.85	14.41
Ca-oxide 2 g Ca /L	3.45	0.67	0.09	1.24	5.45	0.47	5.92	14.64
New L.S.D.	**0.223**	**0.085**	**0.021**	**0.116**	**0.372**	**0.143**	**0.203**	**0.240**

Table 3: Effect of foliar spraying with some Ca sources at deferent concentrations on fruits quality of tomato, combined analysis of 2003 and 2004 seasons.

Ca- treatments	Dry matter content (%)	T.S.S. (%)	Ascorbic acid mg /100 gm FW	Titratable acidity mg/100ml juice	Ca %	Total carbohydrate mg/g DM	Nitrate content mg/kg (F.W.)
Control	5.16	4.31	112.5	1.21	0.51	304.3	53.1
Ca-citrate 1 g Ca /L	5.04	4.83	106.7	1.08	0.67	308.5	43.1
Ca-citrate 1.5 g Ca /L	5.23	4.50	110.1	1.11	0.75	334.0	41.3
Ca-citrate 2 g Ca /L	5.37	4.76	112.0	1.07	0.78	424.4	39.8
Ca-chloride 1 g Ca /L	5.27	4.63	112.5	1.10	0.77	379.7	40.2
Ca-chloride 1.5 g Ca /L	5.30	5.19	96.3	1.16	0.70	471.0	32.4
Ca-chloride 2 g Ca /L	5.48	5.01	91.4	1.13	0.81	484.4	30.1
Ca- nitrate 1 g Ca /L	5.35	4.51	113.4	1.19	0.67	490.0	42.4
Ca- nitrate 1.5 g Ca /L	5.83	5.32	131.4	1.11	0.75	500.1	38.5
Ca- nitrate 2 g Ca /L	5.44	5.11	122.0	1.09	0.89	495.3	35.4
Ca-sulfate 1 g Ca /L	5.09	4.24	105.3	1.24	0.57	413.1	48.4
Ca-sulfate 1.5 g Ca /L	5.02	4.98	91.7	1.34	0.65	395.0	41.0
Ca-sulfate 2 g Ca /L	5.13	5.08	100.3	1.16	0.71	405.4	44.2
Ca-oxide 1 g Ca /L	5.37	4.42	118.6	1.23	0.61	337.1	49.4
Ca-oxide 1.5 g Ca /L	5.29	4.82	105.9	1.14	0.65	386.4	55.2
Ca-oxide 2 g Ca /L	5.41	4.31	110.1	1.30	0.68	410.1	45.7
New L.S.D.	**0.219**	**0.182**	**N.S.**	**N.S.**	**0.073**	**29.40**	**2.45**