EFFECTS OF CALCIUM NITRATE ON SOME FRUIT QUALITY PARAMETERS IN STRAWBERRY VARIETIES

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Abstract

Effects of the calcium nitrate doses were investigated in five strawberry cultivars on fruit quality parameter such as yield, firmness, average fruit weight, individual marketable fruit weight and individual unmarketable fruit weight. Cultivar 'Osmanlı' has soft fruit firmness, 'Camarosa' has hard strong fruit firmness and 'Sevgi', 'Ebru', 'Kaşka' cultivars have medium fruit firmness. Different Calcium Nitrate ($Ca(NO_3)_2$) doses(0 ml 100 L^{-1}(control), 150 ml 100 L^{-1}, 300 ml 100 L^{-1} and 450 ml 100 L^{-1}) were sprayed on the leaves with one week intervals. Examined quality parameter weren't affected calcium nitrate doses except fruit firmness at April and beginning of May. The highest fruit firmness was detected at third dose (450 ml 100 L-1) in 10 May. All these parameters were affected from different strawberry cultivar which has different fruit firmness. Calcium nitrate was inadequate for improving fruit quality such as firmness, yield and marketable fruit size.

Key words: *calcium, firmness, fruit quality, marketable fruit, strawberry*

1. INTRODUCTION

Strawberries, grown in many agricultural areas of the world though they mainly cultivated northern hemisphere of the world. Cultivated strawberries (*Fragaria* × *ananassa* Duch.), appeared by natural cross breeding between octoploid *F. chiloensis* (L.) Duch. and *F. virginiana* Duch. species during middle of 18th century (Staudt 1989). These strawberries are being successfully grown in the temperate areas (Hancock 1999). Turkey is an important country at strawberry production with 372.498 tonnes in 2013. Main production is occurred in Mediterranean region (59 %) with 221.347 tonnes (FAO 2016). Strawberry consumption is increased over the past few decades with determining benefit effects on human health. Many epidemiological studies have indicated the association between the consumption of diets rich in fruits and vegetables and lower risk of chronic pathologies, including cancer, cardiovascular and neurodegenerative diseases, obesity, and inflammation (Chu et al. 2002; Johnsen et al. 2003). Strawberry, belong to berries, take an important position among the fruits due to their high natural antioxidant compounds, including phenolic, minerals, vitamin C which contributed to the high nutritional quality of the fruit. Besides, strawberry is very valuable at human diet with their high minerals, vitamins and dietary fibre, as well as to their relevant contents of fat-soluble vitamins (i.e. vitamin A and tocopherol) and carotenoids (i.e. lutein and zeaxanthin). Also strawberry which has sweet flavor could be a delicious alternative snack with their low total calories (32 kcal/100g fresh fruit) (Giampieri et al. 2013).

Turkey has a unique position like a bridge between Asia and Europe. However, commerce of strawberry is inadequate level with 19.553 tonnes (5%) due to lack of transportation and sensitive structure of strawberry (FAO 2016). Improving the transportation and post-harvest circumstances can increase the commerce of this crop. Calcium application is most used method for increasing fruit firmness and decreasing the decay of strawberry fruits (Lara, Garcia & Vendrell 2004; Vicente et al. 2007).

Application of Ca and B increased these elements concentration in foliage of strawberry cultivar 'Elsanta' however, these elements had no effect on total and marketable fruit yield, average fruit weight, total soluble solids and titratable acidity (Wojcik & Lewandowski 2003). In another study, reported by Singh, Sharma & Tyagi (2007) the same applications significantly affect fruit quality by increasing fruit color (6.5-6.7%) and reduce grey mould (1.2-1.3%) which has negative effect on fruit appearance. Palencia et al. (2010), studied interactions between plant nutrition elements and occurrence of tip burn and found no relationship between tip burn and calcium levels. However it was reported that K:Ca and

K:Mg ratios were important for the appearance of tip burn symptoms. If these ratios exceed 1.77 for K:Ca and 3.40 for K:Mg, risk of tip burn occurrence would increase 50% percent.

The aim of this study was to determine the effect of calcium nitrate ($Ca(NO_3)_2$) doses on quality parameters such as marketable fruit percentage (%), yield (g $plant^{-1}$), firmness (Newton), yield per plant at each month (g $plant^{-1}$), weight of fruit (g), marketable fruit weight at each month (g) and unmarketable fruit weight at each month (g) in strawberry varieties having different fruit firmness.

2. MATERIALS AND METHODS

2.1. Plant material

This study was carried out in a glasshouse at Cukurova University, Adana, during 2012-2013 growing period. Five strawberry cultivars used as plant material. Cultivar 'Osmanlı' has soft fruit firmness, 'Camarosa' has hard strong fruit firmness and 'Sevgi', 'Ebru', 'Kaşka' cultivars have medium fruit firmness. Calcium nitrate used as a calcium source in the study.

2.2. Experiment design and treatments

Fresh pot plants were planted in fall in a glasshouse. Study was set up as randomly split plot experimental design with three replications and each replication contained 20 plants. Soil was analyzed before planting. Soil was fumigated with Metam sodium and then plants were planted to the fumigated soil within raised beds covered with black polyethylene mulch. Plug plants were planted double row system and designed by triangle method. The distance between the double rows was 1.2 m while the distance between nearby plants in the double row was 0.25 m. Plants irrigated with drip irrigation system common fertilization program were carried out with drip irrigation. Foliar calcium nitrate fertilization started 15th January (first blooming time) and continued until 15th May (end of the active vegetative growth period) in 2013. Different Calcium Nitrate ($Ca(NO_3)_2$) doses (0 ml 100 L^{-1} (control), 150 ml 100 L^{-1}, 300 ml 100 L^{-1} and 450 ml 100 L^{-1}) were sprayed on the leaves with one week intervals.

2.3. Measurement and observation

Fruits were harvested during the growing period and calculated by 0.1 sensitive scale. Then, monthly and total yield were measured at each plant as a gram. Average fruit weight was obtained by divided to total fruit weight to total fruit number at each harvested fruits during to the harvesting period. All harvested fruits are divided to two class as a marketable or unmarketable fruit at each harvest time. Fruit belong to the 'Osmanlı' is sorted as unmarketable fruit which below to the 2 grams and malformed fruits, the rest fruits were supposed marketable. The other cultivars are sorted as unmarketable fruit which below to the 5 grams and malformed fruits, the rest fruits were supposed marketable. Texture analysis of fruits was occurred with TA×T plus Analysis equipment at three times (30th April, 10th May and 23rd May) during the growing period. The measurements were done on 10 fruit at two cross equatorial sides for each replication by using 2 mm probe with constant speed 2.5 mm s^{-1} until 5 mm inside of fruits.

2.4. Statistical analysis

The experiment was arranged as a completely randomized split plot design with three replications, while the main factor was established from doses of calcium nitrate. The sub-plot occurred strawberry varieties that have different fruit firmness. Each replication consisted of 20 plants. The obtained data were analyzed with the statistical program JMP, 5.0.1. standard version (SAS Institute Inc., Cary, NC). We performed analysis of variance to determine the effects of calcium nitrate applications on the strawberry varieties for some quality parameters of fruits. A least significant difference test was performed to examine differences among the different groups. Comparisons that yielded $P \leq 0.001$, $P \leq 0.01$ and $P \leq 0.05$ were considered to be statistically significant.

3. RESULT AND DISCUSSION

The yield was not affected as statistical significant by application of calcium nitrate doses and interaction of calcium nitrate doses by cultivar. However, among the cultivars, were found significantly differences (Table 1). The yield of 'Camarosa' cultivar was significantly higher than all the other cultivars, whereas the others take a same statistical group at range of 78.84 – 93.94 g plant $^{-1}$. Calcium application was used in strawberry fruits for improving the fruit quality at pre-harvest stage (Singh, Sharma & Tyagi 2007) delaying of decay and weight loss at the post-harvest stage (Shafiee, Taghavi & Babalar 2010; Chen et al. 2011). Our result agrees with Singh et al. (2007), who reported that no remarkable effect on total yield by calcium application at the pre-harvest stage. Flower initiating is first step of fruit formation by determining mainly photoperiod and temperature, also is affected some application like nitrogen fertilization (Sonsteby et al. 2009; Durner 2016). Our experiment was consisted of short-day (SD) plants that initiate flowers under SD conditions at temperatures changing from about 15ºC to 25ºC (Guttridge 1985, Taylor 2002). While, there were not significant differences at interaction between cultivars and doses. It was found important differences interaction cultivar and application, even in same cultivar. Especially, the yield obtained from the third dose of application was lower than second dose at 'Ebru' and 'Kaşka' cultivars. Beside of these, 'Camarosa' were shown different behavior with increasing at third dose from 119.61 to 162.48 g plant $^{-1}$. The different behavior of cultivars was derived from genetically structure of cultivars which affected different level at nitrogen application.

Table 1. Effect of the calcium nitrate doses at strawberry cultivars on total fruit yield (g plant $^{-1}$)

	Cultivars					
Doses	**Osmanlı**	**Sevgi**	**Ebru**	**Kaşka**	**Camarosa**	**Dose av.**
0	68.22	85.71	95.81	92.59	141.98	96.86
1	92.50	105.02	80.93	103.52	145.77	105.55
2	73.27	94.97	95.06	97.25	119.61	96.03
3	81.36	90.04	77.02	77.30	162.48	97.64
Cultivar av.	78.84 b	93.94 b	87.21 b	92.66 b	142.46 a	
$LSD_{cultivar}$***= 19.458			LSD_{dose} = NS		$LSD_{culxdos}$= NS	

(1): Differences between the means were showed with different letters

(2): N.S.: Not Significant, ***: p<0.001; **: p<0.01; * : p<0.05

The result about with effect of calcium nitrate doses at strawberry cultivars on average fruit weight during the growing period were shown the Table 2. There were not a significant application and cultivar by calcium nitrate dose interaction for average fruit weight. However, cultivars were found statically difference in term of average fruit weight. The highest fruit weight was obtained at 'Camarosa' cultivar with 7.36 g, 'Kaşka' was followed this cultivar with 7.10 g fruit weight. 'Ebru' and 'Sevgi' were taken different statistical group with 6.55 and 6.51 g fruit weight, respectively. The lowest fruit weight was determined at 'Osmanlı' cultivar due to genetically property. Singh, Sharma & Tyagi (2007), reported that any statically differences pre-harvest application of calcium and boron with calcium on the individual berry weight.

Table 2. Effect of the calcium nitrate doses at strawberry cultivars on average fruit weight (g) during the growing period

	Cultivars					
Doses	**Osmanlı**	**Sevgi**	**Ebru**	**Kaşka**	**Camarosa**	**Dose av.**
0	2.64	6.60	6.64	6.93	7.31	6.02
1	2.67	6.62	6.26	6.91	7.46	5.99
2	2.63	6.35	6.17	7.63	6.45	5.85
3	2.65	6.48	7.12	6.91	8.22	6.28
Cultivar av	2.65 c	6.51 b	6.55 b	7.10 a	7.36 a	
$LSD_{cultivar}$***= 0.458			LSD_{dose}= NS		$LSD_{cultxdos}$= NS	

(1): Differences of between the means were showed with different letters

(2): NS: Not Significant, ***: p<0.001; **: p<0.01; * : p<0.05

Effect of the application doses on the individual marketable fruit weight of the different cultivars is shown Table 3. There were not sorted any marketable fruit on March due to insufficient pollination by lower bee activity. The highest marketable fruit weight was obtained on May, while the lowest was in June due to high temperature and decreasing of the plant vigor. The interaction of cultivars by application dose and application were not found statistical significant expect of April. Calcium nitrate application were affected the negatively of marketable fruit weight at all doses. The highest fruit weight was found to the control. Marketable fruit weight was significantly different among the cultivars at each examined month. The lowest weight was obtained 'Osmanlı' cultivar due to genetic structure, whereas 'Camarosa' had higher fruit weight expect June. Santos and Chandler (2009), reported that linearly improve of total marketable fruit with increasing N dose from 0.5 to 0.9 kg/ha per day depending to the cultivar at the first setting study. They could not found any statistical differences on the total marketable fruit weight and number at the second setting study. Effect of the calcium fertilization was found different on the marketable fruit weight among researchers. While Wojcik & Lewandowski (2003), were not found to the effect of the calcium application on total and marketable fruit yield, average fruit weight of strawberry cultivar 'Elsanta'. Contrast of this founding, Singh, Sharma & Tyagi (2007), were determined significantly positively effect on the marketable fruit yield at the 'Chandler' cultivar. The different results may arise from application time, cultivar which has different genetic background and climate condition. Marketable fruit weight was mainly affected by cultivar. Also, increasing temperature and decreasing plant vigor were lowered the marketable fruit weight in June.

Table 3. Effect of the calcium nitrate doses at strawberry cultivars on individual marketable fruit weight (g) at each month during the harvesting period

		Cultivars					
Month	**Dose**	**Osmanlı**	**Sevgi**	**Ebru**	**Kaşka**	**Camarosa**	**Dose av.**
	0	4.33 f	16.66 a	7.00 def	11.20 bc	10.82 bc	**10.00 *a***
April	**1**	4.05 f	6.83 def	6.62 ef	9.39 cde	9.28 cde	**7.23 *b***
7.65 ab	**2**	0.00 g	7.78 de	0.00 g	0.00 g	9.72 bcd	**5.67 *c***
	3	4.34 f	12.66 b	9.68 cd	10.86 bc	11.75 bc	**7.69 *b***
Cultivar av.		3.18 D	10.98 A	5.82 C	7.86 B	10.39 A	
		$LSD_{cultivar}$***=1.484	LSD_{dose}*** =1.327		$LSD_{culxdos}$***=2.968		
	0	3.52	10.14	8.42	11.24	11.01	**8.87**
May	**1**	3.59	10.00	9.07	9.69	11.11	**8.69**
8.75 a	**2**	3.68	9.30	9.39	10.52	11.11	**8.80**
	3	3.72	8.66	10.38	10.63	9.83	**8.64**
Cultivar av.		3.63 C	9.52 B	9.32 B	10.52 A	10.76 A	
		$LSD_{cultivar}$**=0.751	LSD_{dose} = N. S.		$LSD_{culxdos}$=N. S.		
	0	2.66	8.41	7.98	8.64	8.50	**7.24**
June	**1**	2.82	7.94	7.84	8.86	8.07	**7.11**
7.22 b	**2**	2.66	8.11	7.95	9.46	7.94	**7.22**
	3	2.67	8.09	8.34	8.98	8.43	**7.30**
Cultivar av.		2.70 C	8.14 B	8.03 B	8.98 A	8.23 B	
LSD_{month}=1.228		$LSD_{cultivar}$***=0.446		LSD_{dose} = N. S.		$LSD_{culxdos}$=N.S.	

(1): Differences of between the means were showed with different letters

(2): N.S.: Not Significant, ***: p<0.001; **: p<0.01; * : p<0.05

Effect of the application doses on the individual unmarketable fruit weight of the different cultivars is shown in Table 4. There were not determined the unmarketable fruit in June at all examined plot. This result was arisen from suitable growing conditions and good bee activity during the May-June months. The highest fruit weight was obtained at March due to high level of malformed fruit which rooted lack of the pollination. While the application of calcium nitrate doses was not influenced on individual unmarketable fruit weight. Interaction of cultivars by applications were statistical significant only at May. There were significantly (p<0.001) differences among the cultivars during harvesting period. The lowest unmarketable fruit weight of cultivar was similar our previous founding, 'Osmanlı' cultivar had smallest fruit among the cultivars due to genetic structure at each examined month. We could not found enough literature about effect of the pre-harvest application on unmarketable fruit weight in the strawberry. Singh, Sharma & Tyagi (2007), reported that effect of the pre-harvest applications on percentage of malformed fruit. According their results, Calcium alone was not any amelioration on malformed fruit (10.9%). However, combination with boron was great impact on malformed fruit (3.1 %). The other pre-harvest applications were conducted by Singh et al. (2010), found the significantly decreased in the malformed fruit with applying of different vermicompost leachates compared to control.

Table 4. Effect of the calcium nitrate doses at strawberry cultivars on individual unmarketable fruit weight (g) at each month during the harvesting period

		Cultivars					
Month	**Doses**	**Osmanlı**	**Sevgi**	**Ebru**	**Kaşka**	**Camarosa**	**Dose av.**
	0	2.50	9.42	7.88	6.18	7.81	**6.76**
March	**1**	2.43	7.45	9.51	7.09	8.57	**7.01**
6.68 a	**2**	3.03	8.41	6.83	6.14	7.74	**6.43**
	3	2.75	7.12	8.16	7.30	7.21	**6.51**
Cultivar av.		2.68 B	8.10 A	8.10 A	6.68 A	7.83 A	
		$LSD_{cultivar}$***= 1.732		LSD_{dose} =N. S.		$LSD_{culxdos}$=N. S.	
	0	1.97	4.65	5.16	5.65	4.85	**4.46**
April	**1**	2.07	4.62	5.05	5.63	4.90	**4.45**
4.48 b	**2**	2.13	5.25	4.95	5.28	5.20	**4.56**
	3	2.12	4.66	5.55	4.80	5.21	**4.47**
Cultivar av.		2.07 C	4.79 B	5.18 AB	5.34 A	5.04 AB	
		$LSD_{cultivar}$***= 0.435		LSD_{dose} = N. S.		$LSD_{culxdos}$= N. S.	
	0	1.65 f	4.49 cde	4.78 abc	4.47 cde	4.91 abc	**4.06**
May	1	1.58 f	4.01 e	4.64 a-d	5.05 abc	5.12 ab	**4.08**
4.05 b	2	1.67 f	4.15 de	4.57 b-e	5.02 abc	4.52 cde	**3.98**
	3	1.78 f	4.78 abc	4.76 abc	3.99 e	5.17 a	**4.10**
Cultivar av.		1.67 D	4.36 C	4.69 AB	4.63 BC	4.93 A	
LSD_{month}***=0.688		$LSD_{cultivar}$***= 0.293		LSD_{dose} = N.S.		$LSD_{culxdose}$**= 0.586	

(1): Differences of between the means were showed with different letters

(2): N.S.: Not Significant, ***: p<0.001; **: p<0.01; * : p<0.05

Effect of the calcium nitrate doses on the fruit firmness were measured at strawberry cultivars which has different flesh firmness at the three certain times (Table 5). Examined times did not show significant different in term of fruit firmness. There were not obtained clearly impact of application doses on fruit firmness expect 10th May. At this time, highest dose of calcium nitrate was significantly improved fruit firmness compared to the others. Cultivars were showed great differences in term of fruit firmness as our expected. The highest fruit firmness was determined 'Camarosa' cultivar at all examined time. However, value of firmness showed great differences among the times for 'Camarosa'. All the others were slightly changed according to examined time and treatments. The lowest firmness value was found 'Osmanlı' as expected. However, it wasn't influenced from examined time as like 'Camarosa'. Our national cultivars ('Sevgi', 'Ebru' and 'Kaşka') which has good flavor and size were taken medium position in term of fruit firmness during the experiment.

Many researchers (Wojcik & Lewandowski 2003; Singh, Sharma &Tyagi 2007) have found positive relationship between fruit firmness and Ca content, while in contrast, Chen et al. (2011), reported that $CaCl_2$ treatment did not affect the fruit firmness at strawberry during storage. Also, 4% $CaCl_2$ treated fruit had the highest decay rate, which was possibly due to phytotoxicity by the high concentration calcium treatment. Fruit size an important parameter shows the large variability in term of firmness which can be reduced by large fruit size (Doving & Mage 2002). In our study, genetically structure was

more efficient than application of calcium nitrate among the cultivars in term of determining the fruit firmness during the experiment. Doses could not show any phytotoxic effect on fruit during experiment.

Table 5. Effect of the calcium nitrate doses at strawberry cultivars on fruit firmness (Newton) at certain examined date. (Newton)

		Cultivars					
Dates	**Doses**	**Osmanlı**	**Sevgi**	**Ebru**	**Kaşka**	**Camar.**	**Dose av.**
30th April 0.406	**0**	0.193	0.289	0.280	0.290	0.978	**0.406 *ab***
	1	0.216	0.314	0.272	0.282	0.632	**0.343 *b***
	2	0.263	0.396	0.379	0.425	0.900	**0.473 *a***
	3	0.239	0.391	0.314	0.307	0.767	**0.404 *ab***
Cultivar av.		0.228 C	0.347 B	0.326 B	0.312 BC	0.819 A	
		$LSD_{cultivar}$***= 0.093		LSD_{dose}* = 0.083		LSDculxdos= N. S.	
10th May 0.373	0	0.241	0.318	0.355	0.380	0.475	**0.354 *b***
	1	0.242	0.378	0.377	0.404	0.399	**0.360 *b***
	2	0.233	0.296	0.390	0.412	0.457	**0.357 *b***
	3	0.286	0.367	0.415	0.391	0.638	**0.420 *a***
Cultivar av.		0.250 D	0.339 C	0.384 BC	0.397 B	0.492 A	
		$LSD_{cultivar}$***= 0.053		LSD_{dose}* = 0.023		$LSD_{culxdos}$= N. S.	
23rd May 0.390	0	0.276 gh	0.343 d-h	0.355 d-g	0.335 e-h	0.738 a	**0.410**
	1	0.242 h	0.332 e-h	0.354 d-g	0.344 d-h	0.535 b	**0.361**
	2	0.279 gh	0.362 d-g	0.375 d-g	0.393 c-f	0.540 b	**0.390**
	3	0.289 fgh	0.351 d-h	0.402 cde	0.449 bcd	0.495 bc	**0.397**
Cultivar av.		0.272 C	0.347 B	0.372 B	0.380 B	0.577 A	
LSD_{date}= N. S.		$LSD_{cultivar}$***= 0.055		LSD_{dose} = N. S.		$LSD_{culxdos}$*= 0.110	

(1): Differences of between the means were showed with different letters

(2): NS: Not Significant, ***: p<0.001; **: p<0.01; * : p<0.05

4. CONCLUSION

Examined quality parameter were not affected calcium nitrate doses except fruit firmness at April and beginning of May. The highest fruit firmness was detected at third dose (450 ml 100 L^{-1}) in 10th May. All these parameters were affected from different strawberry cultivar which has different fruit firmness. Calcium nitrate was inadequate for improving fruit quality such as firmness, yield and marketable fruit size. In our study, fruit quality parameters were mainly determined by genetically structure of strawberry which came from different genetic background. According to our founding, researchers may try new calcium forms or other pre-harvest application for improving fruit quality in strawberry.

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