



Effect of calcium sprays on fruit quality and shelf-life of apple (*Malus × domestica*)

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Apple (*Malus × domestica* Borkh.) is a most important temperate fruit crop of the north western Indian Himalayan region. It is mainly cultivated in the states of Jammu and Kashmir, Himachal Pradesh and Uttarakhand, which account for 99% of total production. A comprehensive study of apple orchards in Himachal Pradesh has reported widespread deficiencies of nutrients particularly Ca, Zn and B in trees (Chadha and Awasthi 2005). Calcium is considered as one of the most important minerals determining the quality of fruit since it is required for cell elongation and cell division (Rizzi and Abruzzese 1990). The storage disorders in fruits appear closely related to low calcium content in tissues (Shear 1975). Although, higher amounts of calcium in soils of apple growing regions of Himachal Pradesh have been reported due to calcareous nature of parent material and precipitation of lime in lower depths (Negi 1976), yet their availability to the plant is limited due steep gradient of soils, low pH, drought condition and nutrient interaction. Therefore, foliar feeding provides best possibility to supplement the calcium requirement. In recent years, widespread deficiency of calcium has been observed in apple orchards and orchardists go for only one spray of calcium about 45 days before the harvest, which seems to be insufficient to control the storage disorders occurred due to deficiency of calcium in the fruits. Therefore, the present investigations were undertaken by using different concentrations of calcium chloride and calcium nitrate sprayed at different stages of fruit growth and development in apple to assess its effect on growth, yield, fruit quality, and shelf-life of fruits during storage.

The present investigation was carried out during 2011 in an apple orchard situated 1935 m above mean sea level at 31° 15' N latitude and 77° 23' E longitudes in Shimla, Himachal Pradesh. Sixteen-years-old 'Starking Delicious' apple trees of uniform size and vigour raised on seedling

rootstocks spaced at 7 m × 7 m and trained to modified central leader system were selected for the present study. Two commercial grade calcium formulations, viz. CaCl₂ at 0.4, 0.5, 0.6% and Ca(NO₃)₂ at 0.2, 0.4 and 0.6% were sprayed once (75 days after full bloom) and repeated thrice (45, 60 and 75 days after full bloom) and five times (15, 30, 45, 60 and 75 days after full bloom). The experiment was laid out in randomized block design with 19 treatments and each treatment was replicated thrice. Twenty shoots of current season's growth per experimental tree were randomly selected in all the directions and length of these shoots was measured in the month of December with the help of measuring tape. Fifty fully developed leaves were randomly collected during mid July from all around the periphery of the tree and leaf area was measured with the help of Automatic Leaf Area Meter (Licor Model 3100). The total yield was recorded by weighing the total number of fruits on a tree at the time of harvest and expressed as kg per tree. Ten fruits from each replication were randomly selected at harvest and length and breadth of each fruit was measured with digital vernier caliper. The weight of ten fruits taken for the measurement of fruit size was recorded on electric top balance. The values so obtained were averaged and expressed in grams per fruit.

Fruit quality parameters, viz. fruit firmness, total soluble solids, acidity and sugars were determined as per standard procedures of AOAC (1995). The fruits were stored for 100 days in cold storage, viz. temperature (1–4°C) and Relative Humidity (90–95%) and after that observations on physiological weight loss, fruit firmness, total soluble solids and sugars were recorded with the standard procedure of AOAC (1995). The data were subjected to pooled analysis and statistically analyzed (Gomez and Gomez 1984).

The data showed significant variation in annual shoot growth and leaf area with the foliar sprays of calcium during both the years (Table 1). Pooled data reveals that the highest annual shoot growth (34.93 cm) and leaf area (37.47 cm²) was recorded with five sprays of 0.6% Ca(NO₃)₂. These results are in conformity with those of He *et al.* (1998), who reported that foliar spray of calcium nitrate increased tree growth; leaf area and leaf dry weight. Among the two

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Table 1 Effect of foliar applications of calcium chloride and calcium nitrate on growth, yield and fruit quality of apple cv. Starking Delicious

Treatment	Annual shoot growth (cm)	Leaf area (cm ²)	Yield (Kg/tree)	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (g)	Fruit firmness (kg/cm ²)	TSS (°Brix)	Titrateable acidity (%)	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)
	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
T1 [0.4% CaCl ₂ {× 1}]	27.95	30.02	116.61	74.98	78.40	190.70	7.90	12.20	0.47	10.70	8.95	1.66
T2 [0.4% CaCl ₂ {× 3}]	29.69	33.47	109.52	74.63	77.47	184.58	8.03	11.88	0.46	10.31	8.46	1.83
T3 [0.4% CaCl ₂ {× 5}]	32.25	34.71	106.01	73.06	77.51	180.14	8.26	11.21	0.48	9.64	7.95	1.86
T4 [0.5% CaCl ₂ {× 1}]	31.81	32.01	115.10	74.89	78.29	189.79	7.96	12.28	0.47	10.83	9.17	1.66
T5 [0.5% CaCl ₂ {× 3}]	32.90	34.49	115.65	74.21	77.97	189.45	8.15	11.64	0.47	10.16	8.39	1.76
T6 [0.5% CaCl ₂ {× 5}]	34.11	34.83	112.40	73.49	77.15	188.59	8.27	11.09	0.52	9.39	7.42	1.96
T7 [0.6% CaCl ₂ {× 1}]	27.06	29.52	110.63	74.80	77.82	186.58	8.06	11.99	0.47	10.53	8.79	1.74
T8 [0.6% CaCl ₂ {× 3}]	30.78	34.02	108.23	73.29	76.88	183.58	8.16	11.76	0.49	10.22	8.36	1.85
T9 [0.6% CaCl ₂ {× 5}]	33.57	35.03	95.19	71.84	76.37	175.72	8.45	11.06	0.52	9.12	6.98	2.14
T10 [0.2% Ca (NO ₃) ₂ {× 1}]	30.44	32.78	119.42	76.39	79.36	193.23	7.56	12.62	0.41	11.23	9.89	1.33
T11 [0.2% Ca (NO ₃) ₂ {× 3}]	32.08	33.58	109.70	75.40	78.59	187.49	7.91	12.38	0.44	10.92	9.37	1.55
T12 [0.2% Ca (NO ₃) ₂ {× 5}]	33.04	34.35	104.58	74.12	78.17	185.37	7.64	12.23	0.47	10.80	9.01	2.31
T13 [0.4% Ca (NO ₃) ₂ {× 1}]	31.75	33.54	113.16	76.33	79.30	191.89	7.86	12.46	0.44	10.91	9.38	1.56
T14 [0.4% Ca (NO ₃) ₂ {× 3}]	33.15	35.14	106.71	74.78	78.12	190.16	7.98	12.10	0.46	10.74	8.91	1.82
T15 [0.4% Ca (NO ₃) ₂ {× 5}]	34.27	35.26	99.08	74.14	77.11	187.61	8.15	11.70	0.50	10.23	8.20	2.03
T16 [0.6% Ca (NO ₃) ₂ {× 1}]	32.69	33.46	111.01	76.03	78.92	189.68	7.87	12.21	0.45	10.88	9.29	1.58
T17 [0.6% Ca (NO ₃) ₂ {× 3}]	33.14	35.92	100.89	74.32	77.98	187.42	8.10	12.01	0.47	10.64	8.77	1.76
T18 [0.6% Ca (NO ₃) ₂ {× 5}]	34.93	37.47	85.49	72.99	77.60	183.29	8.25	11.50	0.50	10.43	8.19	1.95
Control (Water spray)	31.09	32.78	89.93	72.77	76.39	177.20	7.49	13.12	0.42	11.79	10.15	1.55
CD (P=0.05)	3.41	3.35	10.43	1.61	1.65	5.27	0.54	1.18	0.02	1.56	1.47	0.17

Where, × 1, single spray; × 3, three spray; × 5, five spray

sources of calcium, Ca(NO₃)₂ was found better in improving the vegetative growth parameters than CaCl₂. Ca(NO₃)₂ contain 15% nitrogen, which is necessary part of all proteins, enzymes, chlorophyll and metabolic processes involved in the photosynthesis, and transfer of energy (Barker and Bryson 2006), may accounted for better growth of plants.

The fruit yield was significantly affected by the

concentration and number of the sprays of calcium during both the years. The highest yield (119.42 kg/tree) was recorded with single spray of Ca(NO₃)₂ at 0.2%, closely followed by single spray of 0.4% CaCl₂ (116.61 kg/tree) and 0.5% CaCl₂ (115.10 kg/tree). Results also indicate that fruit yield was found to decrease with the increase in concentration and number of sprays (Table 1). These results

are in agreement with those of Asgharzade *et al.* (2012), who reported that foliar spray of calcium at lower concentration and rates increased yield of apple. Khalifa *et al.* (2009) reported that late application with lower frequency shows a beneficial effect in term of yield; however, higher frequency of spray beginning in early months of fruit development resulted in decreased yield.

Fruit size was reduced with the higher concentration of both the sources of calcium and more number of sprays; however, fruit weight was not affected much with calcium sprays. Khalifa *et al.* (2009) also observed improvement of size and weight of apple fruits with the lower concentration of calcium. Foliar sprays of higher concentration of calcium during early stages of fruit development reduced fruit size, however, its effect is not pronounced at later stages of fruit development. These results are in conformity with those of Wojcik (1999), who reported that 6 to 9 sprays of Ca during the growing season tended to reduce the fruit size and weight of apple.

Fruit quality parameters were significantly enhanced by foliar application of calcium at different concentrations (Table 1). Fruit firmness showed an increasing trend with the increase in concentration and number of sprays of CaCl_2 and $\text{Ca}(\text{NO}_3)_2$ during both the years. The highest fruit firmness (8.45 kg/cm^2) was recorded in fruits harvested from trees

sprayed 5 times with 0.6% CaCl_2 , followed by treatment of 5 sprays of 0.5% CaCl_2 . These treatments were statistically at par with each other but significantly superior to control and single spray of lower concentration both CaCl_2 and $\text{Ca}(\text{NO}_3)_2$. This could be attributed to the binding role of calcium in the complex polysaccharides and proteins forming cell wall (Tuckey 1983). However, the TSS and total sugars decreased significantly with the increase in concentration and number of sprays of CaCl_2 and $\text{Ca}(\text{NO}_3)_2$. Minimum TSS content (11.06°B), total sugar (9.12%) and reducing sugars (6.98%) was found in fruits harvested from trees sprayed 5 times with 0.6% CaCl_2 . However, titratable acidity was highest in this treatment. The lowest fruit firmness and highest TSS and sugars were recorded in control. Foliar sprays of calcium increase fruit calcium content which helps in restraining the activity of polyphenol oxidase and prevent early ripening thereby accounted for lower sugars content in the fruits (Zhao *et al.* 2011).

Treatment consisting of 5 sprays of 0.6% CaCl_2 registered the minimum weight loss (3.08%) of fruits and retains highest fruit firmness (5.85 kg/cm^2) during storage (Table 2). Similarly, the loss in fruit weight along with more fruit firmness was also recorded in 5 sprays of 0.5% CaCl_2 sprays, which was significantly better than control. Foliar sprays of both the formulation of calcium significantly

Table 2 Effect of foliar applications of calcium chloride and calcium nitrate on physiological fruit weight loss and fruit quality of apple during storage

Treatment	Physiological weight loss (%)	Fruit firmness (kg/ cm^2)	TSS ($^\circ\text{Brix}$)	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)
	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
T1 [0.4% CaCl_2 { $\times 1$ }]	6.70	4.58	12.65	12.25	10.89	1.29
T2 [0.4% CaCl_2 { $\times 3$ }]	6.04	5.01	13.58	12.76	11.53	1.17
T3 [0.4% CaCl_2 { $\times 5$ }]	3.75	5.65	14.30	12.47	11.61	1.67
T4 [0.5% CaCl_2 { $\times 1$ }]	6.19	4.66	13.16	12.38	11.08	1.14
T5 [0.5% CaCl_2 { $\times 3$ }]	5.22	5.22	13.71	12.86	11.48	1.22
T6 [0.5% CaCl_2 { $\times 5$ }]	3.21	5.71	14.55	13.38	11.70	1.58
T7 [0.6% CaCl_2 { $\times 1$ }]	6.34	4.70	13.29	12.67	11.27	1.18
T8 [0.6% CaCl_2 { $\times 3$ }]	4.53	5.23	13.71	12.90	11.60	1.30
T9 [0.6% CaCl_2 { $\times 5$ }]	3.08	5.85	14.77	13.39	11.83	1.47
T10 [0.2% $\text{Ca}(\text{NO}_3)_2$ { $\times 1$ }]	7.14	4.22	12.47	11.95	10.85	0.98
T11 [0.2% $\text{Ca}(\text{NO}_3)_2$ { $\times 3$ }]	6.48	4.49	13.44	12.74	11.53	1.13
T12 [0.2% $\text{Ca}(\text{NO}_3)_2$ { $\times 5$ }]	5.19	4.75	13.80	12.96	11.63	1.28
T13 [0.4% $\text{Ca}(\text{NO}_3)_2$ { $\times 1$ }]	6.61	4.27	12.59	12.02	10.94	1.05
T14 [0.4% $\text{Ca}(\text{NO}_3)_2$ { $\times 3$ }]	5.38	4.71	13.53	12.71	11.41	1.22
T15 [0.4% $\text{Ca}(\text{NO}_3)_2$ { $\times 5$ }]	4.15	5.12	14.22	13.18	11.64	1.45
T16 [0.6% $\text{Ca}(\text{NO}_3)_2$ { $\times 1$ }]	6.36	4.52	12.70	12.12	10.98	1.10
T17 [0.6% $\text{Ca}(\text{NO}_3)_2$ { $\times 3$ }]	4.17	4.92	13.69	12.68	11.39	1.19
T18 [0.6% $\text{Ca}(\text{NO}_3)_2$ { $\times 5$ }]	3.51	5.44	14.45	13.17	11.72	1.38
Control (Water spray)	7.44	4.22	12.18	11.77	11.69	1.03
CD (P=0.05)	0.67	0.24	1.18	0.43	0.51	0.09

Where, $\times 1$, single spray; $\times 3$, three spray; $\times 5$, five spray

improved TSS, total sugars and also retained higher amounts of non-reducing sugars as compared to control during storage periods. Increase in concentration and number of sprays of both the sources of calcium increased TSS, and sugar contents and the highest TSS, total sugar and non reducing sugar contents was found in the treatment comprising 0.6-% CaCl_2 sprayed 5 times. The reduced weight loss and higher fruit firmness during storage has also been reported by Conway *et al.* (2002). Rabiei *et al.* (2011) stated that calcium treatment influenced peroxides and catalyses enzyme activity in the fruits and delayed breakdown of cells thus maintained the high firmness, TSS and sugars and reduced weight loss during storage in apple.

Based on the results of the experiment, it may be concluded that five sprays of 0.5 or 0.6% CaCl_2 was found beneficial in improving fruit quality and shelf-life of fruits in storage.

SUMMARY

The present investigation was carried out during 2011-2012 in an apple orchard situated 1935 m amsl in Shimla, district in Himachal Pradesh in order to assess the effect of foliar nutrition of calcium on growth, yield, fruit quality and shelf-life of apple. Two commercial grade calcium formulation, viz. CaCl_2 at 0.4, 0.5 and 0.6% and $\text{Ca}(\text{NO}_3)_2$ at 0.2, 0.4 and 0.6 % were sprayed once (75 days after full bloom), thrice (45, 60 and 75 days after full bloom) and five times (15, 30, 45, 60 and 75 days after full bloom). The experiment was laid out in randomized block design with 19 treatments (replicated thrice). Two years pooled data revealed that five sprays of 0.6% $\text{Ca}(\text{NO}_3)_2$ significantly increased annual shoot growth and leaf area, but reduced the total yield, fruit size and weight. However, results of storage studies revealed that five sprays of 0.5 and 0.6% CaCl_2 significantly reduced the physiological fruit weight loss, retain higher fruit firmness, TSS and sugar contents and improve the shelf-life of fruits in ambient storage conditions.

REFERENCES

- A O A C. 1995. Association of Official Analytical Chemists. *Official Methods of Analysis*. Benjamin Franklin Station, Washington D C.
- Asgharzade A, Ali V G and Mahdi B. 2012. Effect of Calcium Chloride (CaCl_2) on some quality characteristic of apple fruits in Shirvan region. *African Journal of Microbiology Research* 6(9): 2000–03.
- Barker A V and Bryson G M. 2006. Nitrogen, pp. 22 -43. *Handbook of Plant Nutrition*. (Eds) Barker A V and Pilbeam D J. CRC Press, USA.
- Chadha K L and Awasthi R P. 2005. *The Apple: Improvement, Production and Post-harvest Management*. Malhotra Publishing house. New Delhi. pp 238–39.
- Conway W S, Sams C E and Hickey K D. 2002. Pre and postharvest calcium treatment of apple fruit and its effect on quality. *Acta Horticulturae* 594: 413–19.
- Gomez K A and Gomez A A. 1984. *Statistical Procedures for Agricultural Research*. 2nd Edn., John Wiley and Sons Inc., New York. pp 187–240.
- He WeiHua, Huang XianGan, Wang RuiYun, ShanHu Li, Huang ChunXia and Yang WenFang. 1998. Studies on the effect of application of calcium nitrate on apple trees. *Journal of Fruit Science* 15(1): 20–25.
- Khalifa R Kh M, Omaira M H and H Abd-el-Khair. 2009. Influence of Foliar Spraying with Boron and Calcium on Productivity, Fruit Quality, Nutritional Status and Controlling of Blossom end rot Disease of Anna Apple Trees *World Journal of Agricultural Sciences* 5(2): 237–43.
- Negi A S. 1976. 'Soil fertility evaluation of the districts of Kinnaur in Himachal Pradesh'. PhD thesis, IARI, New Delhi.
- Rabiei V, Shirzadeh E, Sharafi Y and Mortazavi N. 2011. Effects of postharvest applications of calcium nitrate and acetate on quality and shelf-life improvement of "Jonagold" apple fruit. *Journal of Medicinal Plants Research* 5(19): 4912–17.
- Rizzi E and Abruzzese A. 1990. Effects of calcium treatment on some biochemical indexes during the developing of apple fruit. *Horticultural Science Abstract* 60(7): 4966–73.
- Shear C B. 1975. Calcium related disorders of fruits and vegetables. *Horticultural Science* 10: 361– 65.
- Tuckey R B. 1983. Calcium spray for sweet cherries. (In) 'Proceedings of Washington State Horticulture Association' 79: 194–98.
- Wojcik P. 1999. Gloster apple yield and fruit quality as influenced by frequency of calcium chloride spray. *Journal of Fruit Ornamental Plant Research* 7(4): 181–94.
- Zhao XiaoMei, Kai Ye, WenHui Li, JunFeng G, YuPeng Wu, ShuPing Z, Meng Yi Na and JianWen Ni. 2011. Preliminary report of the effect of preharvest calcium spray on *Pyrus bretschneideri* rehd (Korla fragrant pear) in storage. *Xinjiang Agricultural Sciences* 48(6): 1021–27.