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Effect of calcium chloride on growth, fruit quality and production of apple

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Abstract
Apples are particularly susceptible to calcium deficiency disorders. Many of these disorders only develop during storage and may not be apparent from an external examination of the fruit. There is a low tolerance in the market place for disorders such as bitter pit and internal breakdown. Rejection of fruit at this stage is particularly costly for the grower since the costs of grading, packaging and transport would have been incurred therefore, the present investigation was conducted with the aim of analyzing the response of apple plants to foliar application of calcium chloride at various concentrations applied during defined intervals at petal fall stage. The trees were sprayed with 0.25, 0.50 and 0.75g/liters during one, two and three weeks after petal fall applied in ten different treatment combinations along with control i.e. $CaCl_2$ 0.5% at 45 & 30 days before harvest. The different calcium treatments significantly ($p<0.05$) affected the annual shoot growth, yield, quality of apple and physiological weight loss of fruits.

Keywords: Apple, calcium chloride, growth, production, quality

Introduction
The cultivated apple (*Malus* × *domestica* Borkh.) is a member of family Rosaceae sub family Pomoideae. In India, apple is mainly grown in the North Western Himalayan region comprising states of Jammu & Kashmir, Himachal Pradesh and Uttrakhand. Its cultivation has now been extended to north eastern states like, Arunachal Pradesh, Sikkim, Nagaland and Meghalaya.

Apple cultivation in fact has revolutionized the socio-economic condition of the hill farmers where the land is considered less suitable for traditional agriculture due to its undulating topography and small holdings. It has grown to several hundred crore rupees industry sustaining the livelihood of about 1.50 lakh farmer families in the state beside other people engaged in its production as laborers, transporters, middleman etc. The area under apple in Himachal Pradesh increased from 3026 ha in 1960-61 to 109550 ha in 2015-16 with the corresponding increase in yield from 12000 tons in 1960-61 to 753350 MT in 2015-2016. Apple alone accounts for more than 75 per cent of the horticultural income generated in the state (NHB 2015) [13].

There has been a steady increase in the area and production of apple up to mid eighties but the productivity has not kept pace with the increase in area due to various biotic and abiotic factors. Of the various factors responsible for low productivity, nutrition is of significance importance determining fruit quality. A comprehensive study of 42 apple orchards in Himachal Pradesh have revealed wide spread deficiencies of N, P, K, Ca, Mn and B (Chadha & Awasthi, 2005) [4]. The key nutrients invariably used by the farmers/orchardists are N, P and K. The other macro and micro nutrients are generally over looked. Among the different nutrients Calcium plays an important role in quality fruit production. Availability of this nutrient in the soil may be limited because of soil related constraints like adverse soil pH, poor soil structure and due to its lesser mobility in soil etc. There are situations where the absorbed nutrient may be poorly translocated within the plant (Ca and B) under such situations addition of these nutrients to the soil will be inefficient and foliar feeding provides the best possibility to supplement the nutrient requirement.

The deficiency of certain elements like Ca, B and Zinc has been observed as a wide spread problem in all the apple growing areas of the state (Dev and Kapoor 1973, Sharma and Bhandari 1992) [5, 20]. The deficiency of these elements has been reported to cause many physiological disorders like development of cork spot, bitter pit and fruit russeting besides many vegetative disorders. Such fruits generally have lower consumer preference in the market resulting in great economic loss to the fruit growers. This probably indicates the existence of some nutritional imbalance that may be due to climate/moisture stress. This may also be attributed to low calcium and boron, beside other micro nutrients. Keeping in view the above problems (physiological disorders); it is proposed to study the effect of this nutrient on the quality fruit production with the following objectives:

i. To standardize the time and dose of foliar application of Calcium Chloride
ii. To study their effect on the incidence of physiological disorder

Material and Methods

The experiment was laid out at an elevation of 2169 m above mean sea level at 31° 33.483'N latitude and 78°16.512'E longitude in the Telangi Village of Kinnaur District. The experimental orchard lies under the High Hills and Cold Desert area of Himachal Pradesh where, summer is moderately hot and dry during May-June while, winter is quite severe experiencing and heavy snowfall during winter (December-February). The experiment was carried out on 12 year old trees of apple cultivar Starking Delicious raised on seedlings rootstocks. The trees had been planted at a spacing of 7×7 meters and trained as modified leader system. For the present study, three trees per treatment were selected on the basis of uniform vigour and were maintained under uniform cultural practices during the entire course of investigation. The experiment was laid out in Randomized Block Design (RBD) with three replications. The details are given as under:

T_1: Foliar application of $CaCl_2$ @ 0.5% at 45& 30 days before harvest (Control)
T_2: Foliar application of $CaCl_2$ @ 0.25g/litre one week after petal fall
T_3: Foliar application of $CaCl_2$ @ 0.25g/litre two weeks after petal fall
T_4: Foliar application of $CaCl_2$ @ 0.25g/litre three weeks after petal fall
T_5: Foliar application of $CaCl_2$ @ 0.50g/litre one week after petal fall
T_6: Foliar application of $CaCl_2$ @ 0.50g/litre two weeks after petal fall
T_7: Foliar application of $CaCl_2$ @ 0.50g/litre three weeks after petal fall
T_8: Foliar application of $CaCl_2$ @ 0.75g/litre one week after petal fall
T_9: Foliar application of $CaCl_2$ @ 0.75g/litre two weeks after petal fall
T_{10}: Foliar application of $CaCl_2$ @ 0.75g/litre three weeks after petal fall

Measurements

The data on tree growth, fruit set and crop yield to study the effect of different treatments were recorded. Observations regarding growth parameters, *viz*. annual shoot growth and leaf area were recorded as per standard procedures during the course of study. For taking fruit yield the crop load removed from the trees at the time of harvest season was recorded as kg tree^{-1}. The fruits were harvested carefully at full maturity and brought to the laboratory for analysis. After harvest fruit yield, fruit size, weight, fruit volume and fruit firmness were recorded with the standard procedure (A.O.A.C., 1980) to determine physical properties of fruits.

Statistical analysis

The data generated from these investigations were appropriately computed, tabulated and analyzed by applying Randomized Block Design (RBD). The level of significance was tested for different variables at 5 per cent level of significance.

Result and Discussion

Annual shoot growth

The perusal of data presented in Table 1 revealed that there were significant differences with respect to annual shoot growth during both the years of study. During the year 2015, the maximum annual shoot growth was recorded in T_9 (45.60 cm), which was statistically at par with T_8 (45.05 cm), T_1 (44.87 cm) and T_5 (44.63 cm) treatments. Minimum shoot growth was recorded in T_2 (38.60 cm) which was followed by T_3 (40.00 cm), T_6 (41.85 cm) and T_7 (41.97 cm) treatments. During the year 2016, maximum shoot growth was recorded in T_9 (42.23 cm) followed by T_{10} (41.37 cm) and the lowest was recorded in T_2 (34.83 cm) followed by T_3 (36.33 cm).

Leaf area

The data presented in Table 1 revealed that calcium chloride had a significant effect on the leaf area. During the year 2015, maximum leaf area was recorded in T_6 (35.53 cm^2) which was statistically at par with T_9 (35.13 cm^2) and T_{10} (35.06 cm^2) and the minimum leaf area was recorded in treatment T_2 (29.86 cm^2) which was significantly at par with T_3 (30.96 cm^2) and T_7 (31.13 cm^2). During the year 2016, maximum leaf area was recorded in T_6 (35.17 cm^2) and the lowest was recorded in T_2 (31.81 cm^2) which was statistically at par with T_3 (32.95 cm^2) and T_4 (33.51 cm^2).

Fruit yield

It is evident from the data presented in Table 2 that yield per tree was significantly affected by different concentration of $CaCl_2$ during both the years under study. During the year 2015, the highest fruit yield was recorded in T_7 (65.20 Kg/tree) which was statistically at par with T_5 (61.57 Kg/tree) T_2 (61.30 Kg/tree) and the lowest fruit yield of 50.77 Kg/tree was recorded in treatment T_8 followed by T_9 (52.37 Kg/tree) and T_{10} (54.23 Kg/tree) treatments. During the year 2016, the highest fruit yield was recorded in T_6 (61.48 Kg/tree) and the lowest fruit yield was recorded in T_8 (48.53 Kg/tree).

Fruit size

The data pertaining to the effect of $CaCl_2$ on fruit size is presented in Table 3.

Fruit length

Data pertaining to the effects of different concentration of calcium chloride treatment on fruit length are presented in Table 3. It is evident from data that fruit length was significantly affected by different concentration of $CaCl_2$ treatment during both the years of study. During the year 2015, the maximum fruit length was recorded in T_3 (71.52 mm) which was at par with T_1 (70.85 mm) and T_4 (69.14 mm),

T_2 (69.14 mm) and the minimum was recorded in T_9 (64.74 mm) followed by T_6 (66.03 mm). During the year 2016, maximum fruit length was recorded in T_2 (78.25 mm) followed by T_1 (75.51 mm), T_7 (73.67 mm) and T_3 (72.10 mm). The minimum was recorded in T_9 (69.09 mm) closely followed by T_8 (69.14 mm).

Fruit breadth

The data presented in Table 3 revealed that different concentration of $CaCl_2$ had a significant effect on fruit breadth during both the years. In the year 2015, the maximum fruit breadth was recorded in T_1 (76.52 mm) treatment, which was at par with treatment T_3 (74.01 mm), T_4 (73.48 mm) and T_2 (72.98 mm) The minimum was recorded in T_7 (68.46 mm) followed by T_5 (69.68 mm) and T_9 (69.75 mm). During the year 2016, the maximum fruit breadth was recorded in T_1 (76.44 mm) followed by T_{10} (76.41 mm) and T_2 (74.75 mm) and the minimum was recorded in T_3 (71.96 mm) followed by T_4 (72.12 mm).

Fruit weight

It is evident from the data presented in Table 3 that fruit weight was significantly affected by different concentration of $CaCl_2$ during both the years of study. During the year 2015, the highest fruit weight was recorded in T_3 (191.67 g) which was statistically at par with T_1 (187.67 g) and T_4 (174.57 g). The lowest was recorded in treatment T_9 (149.20 g) followed by T_7 (152.00 g) and T_6 (157.70 g) treatments. In the year 2016, highest fruit weight was recorded in T_1 (207.79 g) at par with T2 (207.53 g) and T6 (194.70 g). The lowest was recorded in T8 (165.99 g) followed by T9 (177.34 g) and T5 (182.71 g).

Fruit volume

The data on fruit volume presented in Table 3 revealed that fruit volume was significantly affected by CaCl2 treatments both the years of study. In the year 2015, the maximum fruit volume was recorded in T_3 (201.48 cc) followed by T_1 (197.87 cc) and the minimum was recorded in T_9 (159.75 cc) followed by T_7 (162.57 cc). During the year 2016, highest fruit volume was recorded in T_1 (217.52 cc) and lowest was recorded in T_8 (175.73 cc).

Fruit firmness

Foliar sprays of calcium chloride at different concentrations exhibited significant effect on fruit firmness (Table 3). During the year 2015, the highest fruit firmness was recorded in treatment T_1 (8.39 Kg/cm^2) which was statistically at par with T_8 (8.28 Kg/cm^2), T_6 (8.18 Kg/cm^2), T_9 (8.08 Kg/cm^2) and T_7 (8.04 Kg/cm^2) treatments. The lowest was recorded in treatment T_2 (7.59 Kg/cm^2) followed by T_3 (7.83 Kg/cm^2) and T_4 (7.86 Kg/cm^2). A similar trend was followed during 2016 being maximum in T_1 (8.88 Kg/cm^2) and lowest in T_2 (7.61 Kg/cm^2).

Physiological weight loss

The perusal of data revealed that different concentration of calcium chloride and storage intervals had a significant effect on physiological weight loss during both the years of study (Table 4). During the year 2015, minimum weight loss was recorded in T1 (4.03 %) and maximum weight loss was recorded in T2 (4.38 %). During the year 2016, minimum weight loss was recorded in T1 (4.02 %). However, maximum weight loss was recorded in T2 (4.35 %).

Different concentration of CaCl2 significantly influenced the physiological weight loss during both the years of study. An increasing trend in weight loss was observed with the increase in storage time. During the year 2015, minimum weight loss (1.87 %) was recorded after 15 days of storage interval which increased to (3.89 %) after 30 days of storage and registered a weight loss of 6.88 % after 45 days of storage. A similar trend in weight loss was observed during 2016 with a weight loss of 1.91 %, 3.86 % and 6.81 % after 15, 30 and 45 days respectively.

The interaction effect between CaCl2 treatment and storage intervals had a significant effect on physiological weight loss during both the years of study. During the year 2015, lowest physiological weight loss of 1.82 % was recorded in T1 and T8 treatments, after 15 days of storage interval. Similarly the weight loss after 30 days of storage was recorded to be minimum in T1 (3.68 %) and maximum in T3 (4.04 %). After 45 days of storage, treatment T1 registered the lowest weight loss of 6.59 % while maximum weight loss of 7.17 % was recorded in T2. During the year 2016, minimum weight loss was recorded in T1 (1.83 %) after 15 days of storage. Similarly the weight loss after 30 days of storage was recorded to be minimum in T1 (3.62 %) and maximum in T2 (4.03 %). After 45 days of storage, treatment T1 registered the lowest weight loss of 6.62 % while maximum weight loss of 7.01 % was recorded in T2.

Discussion

In the present study different concentration of $CaCl_2$ had a significant effect on annual extension growth and leaf area was observed when calcium chloride was applied at higher concentrations and sprayed more than once. Similar results have been reported by Raese and Drake (2002) [17] and Raese and Drake (1993) [16] in apple fruit crops. He *et al.,* (1998) [8] also reported that foliar sprays of calcium in apple trees increased initial growth of shoots, leaf dry weight and leaf N, K and Ca contents. Accumulation of calcium in leaves increases the Ca and other mineral contents of leaves which might have contributed for enhanced cell division, promoting root growth, which enhances nutrient absorption (Sathya *et al.,* 2010, Dole and Wilkins, 2005 and Rosen *et al.,* 2006) [19, 6, 18].

Calcium chloride had a beneficial effect on the improvement of fruit yield at lower concentrations but at higher concentrations with more number of sprays there was slight reduction in total yield of fruits. These results are in agreement with those reported by Asgharzade *et al.,* (2012) [2], Val *et al.,* (2008) [22], Wojcik (1999) [23] and Jafarpour and Poursakhi, (2011) [9], who claimed that foliar sprays of calcium at lower concentration and rates increased fruit yield in apple. Khalifa *et al.,* (2009) [11] reported that late applications with lower frequency showed a beneficial effect in terms of yield. However, higher frequency of spray beginning in early months of fruit development resulted in decreased yield. Wojcik, (1999) [23] reported that six to nine sprays of calcium in apple during the growing season tend to reduce the fruit size and subsequently the yield. The smaller size of fruits in higher concentrations of calcium chloride may have accounted for lower yield.

The results of the present study indicated that the foliar spray of $CaCL_2$ at different concentration significantly affected the fruit size, weight and volume. Fruit size was observed to be larger at lower concentration. At higher concentration, the fruit weight and volume was observed to be less in

comparison to the fruits sprayed with lower concentration. Several workers have reported significant improvement in the yield and quality of apple fruits following calcium sprays (Asgharzade *et al.*, 2012 and Khalifa *et al.*, 2009) [2, 11] Kadir, (2005) [10] also reported the improvement in fruit size, weight and appearance of apple fruits with foliar sprays of calcium chloride. They further reported that increase in fruit weight and size was attributed to a linear increase in calcium concentrations of fruits and leaves due to calcium applications. Mursec, (2004) [12] reported that foliar spray of Ca had a significant effect on the Ca content of the apple fruit, which in turn significantly affected fruit weight and size.

In the present study different concentration of $CaCl_2$ had a significant effect on fruit firmness. Higher concentration of $CaCl_2$ improved the fruit firmness. These results are in conformity with those of Tuckey, (1983) [21], Nijjer, (1985) [14], Ahmed *et al.*, (1998) [1] and Casero *et al.*, (2004) [3], who reported that foliar applications of calcium increased the firmness of apple fruits. The beneficial effects of calcium applications on fruit firmness could be attributed to the physiological role of calcium, which plays a binding role in the complex polysaccharides and proteins forming the cell wall (Tuckey, 1983 and Nijjer, 1985) [21, 14].

The maximum weight loss of fruits was recorded under low concentration of CaCl2 and minimum weight loss was recorded with increased concentration and more number of sprays. High concentration of CaCl2 consistently reduced the weight loss under storage condition. These observations are supported by the finding of Rabiei *et al.*, (2011) [15] who stated that calcium treatments influenced peroxidise and catalase enzyme in the apple fruits which delayed breakdown of cells and hence maintained the higher firmness and reduced weight loss percentage during storage. Farag and Nagy, 2012 also reported that the improvement of reduction in physiological weight loss during storage with application of calcium formulation might be attributed to their influence on maintaining the integrity of the plasma membrane.

Table 1: Effect of foliar application of calcium chloride on Annual shoot growth and leaf area of apple

Parameters\Treatments	Annual shoot growth (cm)		Leaf area (cm^2)	
	2015	2016	2015	2016
T_1- $CaCl_2$ @ 0.5% at 45& 30 days before harvest	44.87	41.30	31.88	34.44
T_2- $CaCl_2$ @ 0.25g/l one week after petal fall	38.60	34.83	29.86	31.81
T_3- $CaCl_2$ @ 0.25g/l two weeks after petal fall	40.00	36.33	30.96	32.95
T_4- $CaCl_2$ @ 0.25g/l three weeks after petal fall	43.47	36.80	33.16	33.51
T_5- $CaCl_2$ @ 0.50g/l one week after petal fall	44.63	37.50	32.20	33.85
T_6- $CaCl_2$ @ 0.50g/l two weeks after petal fall	41.85	37.70	35.53	35.17
T_7- $CaCl_2$ @ 0.50g/l three weeks after petal fall	41.97	38.00	31.13	33.56
T_8- $CaCl_2$ @ 0.75g/l one week after petal fall	45.05	39.00	33.95	34.88
T_9- $CaCl_2$ @ 0.75g/l two weeks after petal fall	45.60	42.23	35.13	34.74
T_{10}- $CaCl_2$ @ 0.75g/l three weeks after petal fall	43.63	41.37	35.06	34.78
$CD_{(0.05)}$	2.17	3.20	2.95	1.74

Table 2: Effect of foliar application of calcium chloride on fruit set, retention and yield

Parameters\Treatments	Yield (Kg/tree)	
	2015	2016
T_1- $CaCl_2$ @ 0.5% at 45& 30 days before harvest	60.50	59.00
T_2- $CaCl_2$ @ 0.25g/l one week after petal fall	61.30	56.17
T_3- $CaCl_2$ @ 0.25g/l two weeks after petal fall	58.17	60.15
T_4- $CaCl_2$ @ 0.25g/l three weeks after petal fall	55.67	57.73
T_5- $CaCl_2$ @ 0.50g/l one week after petal fall	61.57	55.58
T_6- $CaCl_2$ @ 0.50g/l two weeks after petal fall	57.50	61.48
T_7- $CaCl_2$ @ 0.50g/l three weeks after petal fall	65.20	59.75
T_8- $CaCl_2$ @ 0.75g/l one week after petal fall	50.77	48.53
T_9- $CaCl_2$ @ 0.75g/l two weeks after petal fall	52.37	50.83
T_{10}- $CaCl_2$ @ 0.75g/l three weeks after petal fall	54.23	52.98
$CD_{(0.05)}$	3.03	4.27

Table 3: Effect of foliar application of calcium chloride on physical fruit characters and firmness of apple

Parameters\Treatments	Fruit Length (mm)		Fruit Breadth (mm)		Fruit Weight (g)		Fruit Volume (cc)		Fruit Firmness (Kg/cm^2)	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
T_1- $CaCl_2$ @ 0.5% at 45& 30 days before harvest	70.85	75.51	76.52	76.44	187.67	207.79	197.87	217.52	8.39	8.88
T_2- $CaCl_2$ @ 0.25g/l one week after petal fall	67.76	78.25	72.98	74.75	172.77	207.53	183.07	217.27	7.59	7.61
T_3- $CaCl_2$ @ 0.25g/l two weeks after petal fall	71.52	72.10	74.01	71.96	191.67	182.98	201.48	192.78	7.83	7.76
T_4- $CaCl_2$ @ 0.25g/l three weeks after petal fall	69.14	71.78	73.48	72.12	174.57	183.46	185.02	193.45	7.86	7.63
T_5- $CaCl_2$ @ 0.50g/l one week after petal fall	66.79	71.77	69.68	73.58	165.70	182.71	176.03	192.32	7.91	8.45
T_6- $CaCl_2$ @ 0.50g/l two weeks after petal fall	66.03	71.68	70.37	73.33	157.70	194.70	168.02	204.60	8.18	8.51
T_7- $CaCl_2$ @ 0.50g/l three weeks after petal fall	66.87	73.67	68.46	73.53	152.00	184.79	162.57	194.66	8.04	8.37
T_8- $CaCl_2$ @ 0.75g/l one week after petal fall	67.70	69.14	71.19	72.70	160.43	165.99	170.83	175.73	8.28	8.43
T_9- $CaCl_2$ @ 0.75g/l two weeks after petal fall	64.74	69.09	69.75	74.56	149.20	177.34	159.75	187.10	8.08	8.22
T_{10}- $CaCl_2$ @ 0.75g/l three weeks after petal fall	67.74	71.25	71.78	76.41	162.00	193.62	172.53	203.58	7.91	8.58
$CD_{(0.05)}$	1.62	3.79	2.35	2.67	10.99	19.62	11.18	19.66	0.38	0.26

Table 4: Effect of foliar application of calcium chloride on physiological weight loss of apple at ambient storage

Treatments	Physiological weight loss (%)							
	2015				2016			
	15 Days	30 Days	45 Days	Mean	15 Days	30 Days	45 Days	Mean
T_1- $CaCl_2$ @ 0.5% at 45& 30 days before harvest	1.82	3.68	6.59	4.03	1.83	3.62	6.62	4.02
T_2- $CaCl_2$ @ 0.25g/l one week after petal fall	1.95	4.03	7.17	4.38	2.00	4.03	7.01	4.35
T_3- $CaCl_2$ @ 0.25g/l two weeks after petal fall	1.93	4.04	7.14	4.37	1.98	4.01	7.00	4.33
T_4- $CaCl_2$ @ 0.25g/l three weeks after petal fall	1.87	3.97	7.05	4.30	1.97	3.94	6.93	4.28
T_5- $CaCl_2$ @ 0.50g/l one week after petal fall	1.91	3.91	6.77	4.19	1.92	3.88	6.87	4.22
T_6- $CaCl_2$ @ 0.50g/l two weeks after petal fall	1.88	3.88	6.92	4.23	1.90	3.93	6.70	4.18
T_7- $CaCl_2$ @ 0.50g/l three weeks after petal fall	1.89	3.89	7.03	4.27	1.97	3.97	6.97	4.30
T_8- $CaCl_2$ @ 0.75g/l one week after petal fall	1.82	3.78	6.65	4.08	1.85	3.68	6.60	4.04
T_9- $CaCl_2$ @ 0.75g/l two weeks after petal fall	1.83	3.82	6.85	4.17	1.86	3.73	6.74	4.11
T_{10}- $CaCl_2$ @ 0.75g/l three weeks after petal fall	1.84	3.86	6.68	4.13	1.84	3.80	6.71	4.12
Mean	1.87	3.89	6.88		1.91	3.86	6.81	

$CD_{0.05}$	$CD_{0.05}$
Treatment (T)	0.06
Treatment (T)	0.03
Storage Interval (I)	0.03
Storage Interval (I)	0.02
T x I	0.10
T x I	0.05

Conclusion

Our results suggest that among the different concentration of $CaCl_2$ the foliar application @ 0.5% at 45 & 30 days before harvest resulted in increased shoot growth, leaf area, fruit size, weight, volume, fruit firmness, and decrease in physiological weight loss under storage. Organoleptic studies *viz*., appearance, texture, flavour and overall acceptability was also found to be the best. Whereas, foliar application of $CaCl_2$ @ 0.25g/l one week after petal fall was effective in increasing total soluble solids and sugars content.

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