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Effect of Calcium Sources and Their Mode of Application on Growth and Plant Nutrient Uptake of Two Apple Varieties Grown under High Density Planting System

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Apples grown in Kashmir province are famous globally, but lack of post-harvest storage facilities deteriorate its quality and market acceptability. Calcium deficiency in acid soils deceives apple fruit quality. Calcium helps to reduce the occurrence of physiological disorders; it also plays essential role to improve growth and quality of produce. Modes of calcium application and its different doses on two apple varieties was tested in 3 factorial randomized block design to improve yield and quality at Ambri Apple Research Centre, Sher-e-Kashmir University of Agricultural Sciences and Technology, Kashmir, India in 2022. Foliar application of calcium to apple is most effective method for escalating fruit calcium content and quality. Among sources and their mode of application calcium nitrate foliar application at the rate of 3, 4 and 5 gram per litre of water performed better than foliar application of calcium chloride at the rate of 3, 4 and 5 gram per litre of water in improving fruit nutrients and yield of Golden Delicious than Red Chief Camspur, whereas soil application of calcium nitrate showed least response to improve fruit nutrient and yield in both varieties. Fruit length and fruit diameter improved with each enhanced calcium concentration in both varieties by different calcium sources and their mode of application. The partitioning of nutrients in plant leaves and fruits differed significantly, and in both varieties were dependent on applied calcium rates, calcium sources and their mode of application. Calcium nitrate foliar spray performed better than calcium chloride foliar spray or soil application of calcium nitrate in improving fruit growth and quality. Our study did not find any adversity of dosage in plants whether applied as foliar or to soil. The best results were observed in foliar application of calcium nitrate @ 5 g per lit water for all the parameters in both the varieties. Results of research evidenced that preharvest calcium sprays increase growth and improved fruit quality that led to reduce deterioration in post-harvest storage.

Keywords: High density apple; calcium chloride; calcium nitrate; mode of application; red chief campspur; golden delicious; slightly acidic soils.

1. INTRODUCTION

Union territory of Jammu and Kashmir is well known for its apple (*Malus domestica Rosaceae*) production, ranking first at national level and producing nearly 60 percent of total national production (Hanan, 2015). Apple grown in Kashmir valley is famous for taste and flavor. Apple occupies more than 48 percent of area under fruit crops in Jammu and Kashmir. Among major producing districts Baramulla, Kupwara, Shopian, Anantnag and Kulgam covers area of 25307, 19441, 21676, 18426 and 18144 hectares respectively and constitutes 62.5% of total area under apple cultivation in UT J&K. (Directorate of Horticulture 2019-20). Horticulture is vital driver of agricultural growth rate in Union territory of Jammu and Kashmir, accounting for almost 40 percent of total agricultural output (Malik, 2013). In relations to economy, this sector is progressing with annual export of more than 70 billion from the fruits alone grown in region (Naqash *et al*., 2019). Around 50% of area is covered under cultivation of apple and there is a 6 percent progression in yearly production of the crop (Government of Jammu and Kashmir, 2017a).

Traditional apple orchard plantation system not only provides poor yield because of low density plantations but also the poor-quality produce as productive canopy management remains limitation in it. Although in high density plantation (HDP) system maximum numbers of plants are established to achieve absolute output by best use of solar radiation, land, water, and nutrient from soil. HDP also have better adaptability to modern input saving technique such as drip irrigation, fertigation, mechanical harvesting and pruning etc. High density plantation system has potential to fill voids in apple production system and generate better economic returns as it starts fruit bearing in 2nd year of establishment whereas traditional orchards begin fruit bearing in the seventh or eighth year of planting (Wani *et al*., 2021).

Nutrients play an important function in fruit crops, nutrient deficiencies cause deprived fruit set, little productivity and mediocre fruit quality (Neilsen and Neilsen, 2006) that eventually get revealed by salient drop in economic security of farmers. Nutrient managing plays key role in fruit production and its quality as nutrient are needed for plant life existence (Marschner, 1995). Calcium deficiency usually occurs in very vigorously growing plants and its parts. Calcium plays pivotal role in adaption to cell membrane stabilization, environmental stresses and uptake of nutrients by roots (Schmitz Eiberger *et al*., 2002). It is crucial nutrient for growth and fruit quality; it acts as a messenger against environmental stresses (Hepler and Wayne, 1985). Reduced root expansion is caused by low calcium levels, necrosis of leaf, blossom end rot, curling, fruit cracking, bitter pit and deprived fruit storage strength (White and Broadley, 2003). Calcium is not freely mobile in plants, its deficiency, especially in acidic soil conditions, has a rapid impact on vigorously growing tissues (Mestre *et al*., 2012). Plant growth, chlorophyll content, membrane permeability and yield are all negatively influenced by calcium deficiency (Montanaro *et al*., 2015). Its necessity in avoiding numerous physiological disorders like bitter pit and water core in apple is quite evident (Amiri *et al.,* 2008). Calcium controls absorption of nutrients through the cell membranes and is significant in plant cell development and division, permeability and structure of the cell and carbohydrate metabolism (Conway *et al*., 2002). Although soil application is common method of fertilizer use in fruit trees, however, for rapid response, foliar spray is an ideal approach to combat nutrients deficiencies. Whereas considered an effective and economic method to use of fertilisers, furthermore plants occasionally grow at rates that are quicker than root support capability to absorb and translocate mineral to the critical leaf, flower and fruit tissues. Foliar sprays frequently help to overcome nutrient deficiency and preserve optimal nutrient levels to those critical tissues. Even if the prediction was only close to harvest time, it would have a significant impact on fruit storage management and economic losses. Virtually all pre-harvest features influencing the occurrence of apple bitter pit can be directly or indirectly linked to the fruits calcium nutrition and these disorders bound storage period to few months (Almeida *et al*., 2017).

2. MATERIALS AND METHODS

The current study was conducted in the year 2021-2022 at Ambri Apple Research Centre (AARC) Pahnoo, Shopian, Sher-e-Kashmir University of Agricultural Sciences and Technology, Kashmir. The investigational farm is located in a temperate region with cold winters and moderately hot summers (Fig. 1). The mean monthly meteorological data of district Shopian for the trial period collected by the Meteorological department is presented below in Fig. 2.

Composite soil sample in experimental plot was taken from 0-30 cm depth before initiation of experimental trial for understanding soil fertility status of soil to prepare action plan and its execution. The results of the collected sample revealed that the soil was slightly acidic in nature, medium in available nitrogen, high in potassium and phosphorus. The micronutrient content of the experimental soil is adequate as per requirement of crop. The soil of investigational farm is clay loam in texture with moderate cation exchange capacity (CEC) and organic carbon content.

A suitable 14 years old, well established apple orchard was selected. Nine healthy trees per treatment consisting three replications of apple variety Golden Delicious and Red Chief Camspur were selected on the basis of similar size, vigour and bearing capacity. The planting material of the selected orchard was grafted on clonal rootstock, M9. The established orchard had plant to plant spacing of 2.6 feet and line to line spacing of 10.4 feet. After demarcation, randomization of treatment combinations was done using R- software. RBD with 3 factors i.e., varieties, different fertilizer sources having different modes of application and concentration of fertilizer with three replications.

Foliar application of calcium at mid day time was done at (peanut stage, walnut stage and one month before expected harvesting) which were done on 2nd September in Red Chief Camspur and 14th September in Golden Delicious. Soil application of calcium nitrate as per treatments was carried at pea nut stage. The 12 treatment combinations for each variety constituting overall 24 treatments, having no Calcium, low dose (3g/lit $CaCl_2$ or $CaNO_3$ foliar application or 100g/plant $CaNO_3$ soil application), medium dose (4g/lit $CaCl_2$ or $CaNO_3$ foliar application or 200g/plant $CaNO_3$ soil application) and high dose (5g/lit $CaCl_2$ or $CaNO_3$ foliar application or 300g/plant $CaNO_3$ soil application). Other than different calcium treatment combinations all other essential nutrients were applied as per SKUAST-K recommendation.

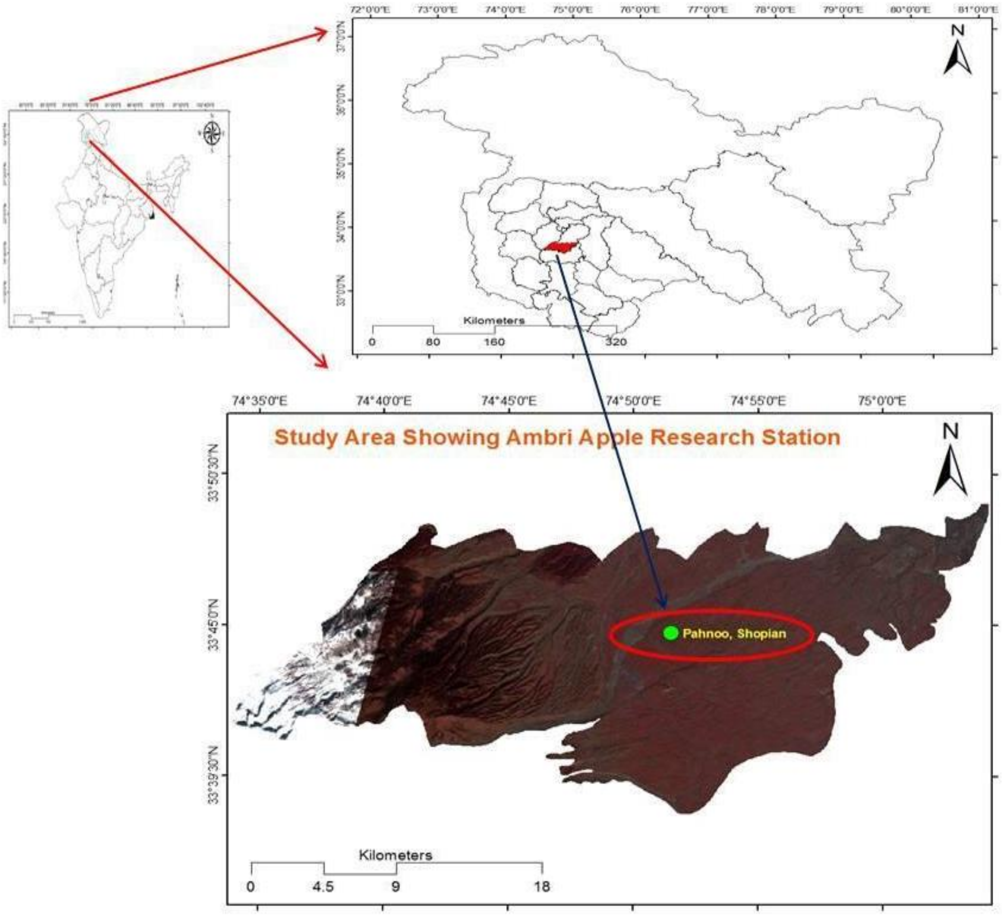

Fig. 1. Experimental location of research station

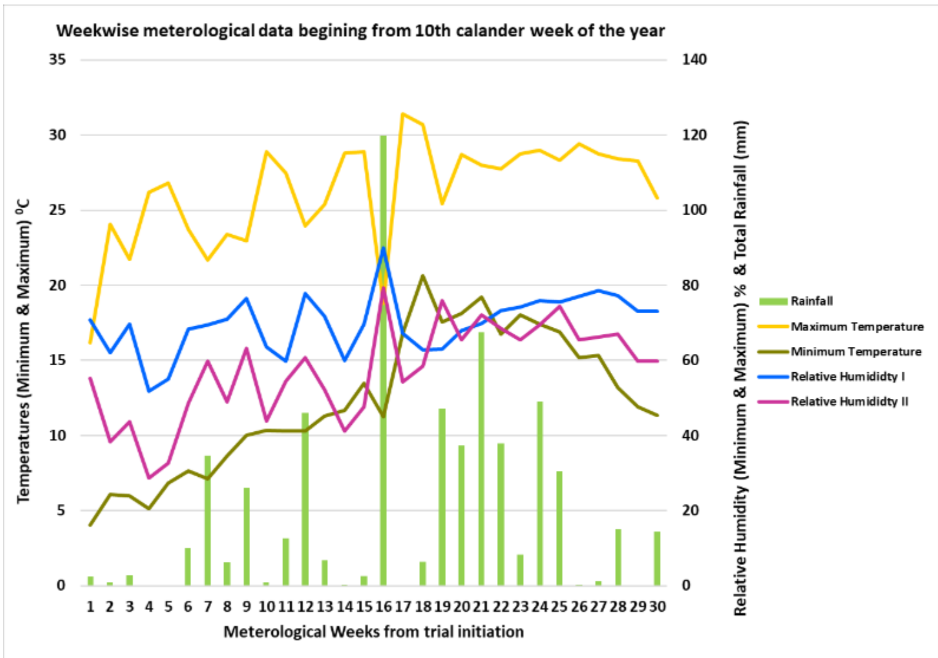

Fig. 2. Meteorological data of district during study period

Collection of leaf samples were carried nearby the periphery of plantation in mid of August. Samples were air dried on a quality filter paper in a shady area for 48 hours and finally dried in oven at 60°C till constant weight was attained. These samples were then crumpled in a stainless-steel whizzer to pass through 2mm mesh, meshed samples were then stored in poly bags for carrying out analysis. Collection of fruit samples was done following method recommended by Waller (1980). After collection, samples were washed with distilled water. Moisture was wiped by using filter paper and muslin cloth. Then slicing of fruits was done by a sharp knife and after every slicing knife was cleaned by distilled water prior initiating slicing apple of other treatment. The central core of apple fruit along with seeds was removed. The sliced samples were dried at room temperature on filter paper in a shady area for 48 hours and then oven dried at 60°C till constant weight was attained. Dried samples were crushed so that to get it pass through 2mm mesh and for carrying analysis were kept in polythene bags.

Length and diameter of arbitrarily selected three fruits in every treatment from each replication were measured by using Vernier calliper. The resulted values were averaged and stated in mm. Nitrogen (N) concentration in leaf and fruit samples was assessed by modified Kjeldhal's method (Jackson, 1973). Digestion of plant samples with diacid (HNO_3; $HClO_4$ in the ratio 9:4) was carried for determination of nutrients in plant samples. Phosphorous (P) content in leaf and fruit was estimated by Olsen method (Olsen *et, al.,*1954)**.** Potassium (K) content in leaf and fruit samples was determined by neutral normal ammonium acetate (Jackson, 1973). Calcium (Ca) and magnesium (Mg) in leaf and fruit samples were estimated by EDTA-Versenate method (Jackson, 1973). The data generated from investigation was analyzed and interpreted by using advanced standard statistical procedure.

3. RESULTS AND DISCUSSION

3.1 Fruit Length and Fruit Diameter of Apple (mm)

Applying calcium fertilizer markedly differs in fruit growth and yield parameters of apple. Compared to Red Chief Camspur, the fruit length and diameter of Golden Delicious apple was higher and varied significantly. The overall fruit length of Golden Delicious and Red Chief Camspur was 79.10 and 76.01 mm respectively, whereas fruit diameter was 77.79 and 75.63 mm respectively (Table 1 & Table 2). Calcium sources and their mode of application significantly improved fruit length and fruit diameter. Compared to control, the fruit length and diameter in foliar application of calcium chloride and calcium nitrate was comparatively higher than the soil application of calcium nitrate. Generally, fruit length and diameter increased by applying calcium chloride foliar application, calcium nitrate foliar application and calcium nitrate soil application. The apple trees sprayed with calcium nitrate foliar application showed higher average fruit length and diameter, followed by application of calcium chloride foliar application whereas least fruit length was observed in calcium nitrate soil application. The fruit length and diameter in calcium chloride foliar application, calcium nitrate foliar application and soil application of calcium nitrate were 79.24, 82.55, 70.88 mm and 78.86, 80.95 and 70.32 mm respectively. The fruit length and diameter showed an increasing trend with every enhanced level of calcium doses. Compared to control, applying calcium fertilizer as lower, medium and high dose showed significant variation in fruit length and diameter. In obtained data, fruit length and fruit diameter in apple varied significantly for no calcium application, low dose of calcium (3g/lit $CaCl_2$ or $CaNO_3$ foliar application or 100g/plant $CaNO_3$ soil application), medium dose (4g/lit $CaCl_2$ or $CaNO_3$ foliar application or 200g/plant $CaNO_3$ soil application) & high dose (5g/lit $CaCl_2$ or $CaNO_3$ foliar application or 300g/plant $CaNO_3$ soil application). The significant variation in fruit length and fruit diameter was 65.18, 78.49, 81.52 and 85.02 mm for fruit length and 66.03, 77.61, 80.19 and 83.00 mm for fruit diameter respectively. Among the significant interactions between sources x doses the fruit length varied from 65.17 to 90.94 mm; whereas fruit diameter varied from 65.99 to 88.94 mm. All other interactions and overall interaction were statistically non-significant.

Calcium plays vital role to enhance growth and yield attributing characters. Calcium immobility in the phloem infers that there is a very inadequate translocation of calcium from source to sink. Plants take up calcium as the divalent cation, Ca^{2+}. Soil factors such as inadequate calcium supply, very low pH and excess availability of other cations affect Ca^{2+} uptake and induce its deficiency. Kadir (2005), reported that application of calcium apple trees gave the largest fruit size and fruit weight. The fruit develops larger in size due to the enhanced cells, which are capable to attract more water, minerals and the carbohydrates that permit the fruit to get expanded and increase fruit size (Kano, 2003). The increase in fruit size by applying calcium sprays could be credited unswervingly to the fact that calcium is essential for the cell elongation and cell division (Erogul, 2014). Wojick (2012), also reported that logical improvement in terms of fruit size, weight and good appearance of apple fruits with foliar calcium chloride rise in fruit weight and size was attributed to a linear surge in calcium absorptions of fruits and leaves due to calcium application. Accumulation of calcium in leaves increases the calcium and other essential minerals content of leaves and might have contributed to improved cell division and promoting plant growth, which created cordial atmosphere to boost nutrient absorption (Moor *et al.* 2006). The application of calcium increases tree growth and potential of plant to produce more (Conway *et al.* 2002). Raese and Drake (2000) also reported that in different fruit crops that scarcity of calcium declines plant height by declining mitotic activity in the terminal. Accretion of calcium in leaves enhances calcium and other minerals content of leaves and may have contributed for better cell division and promoting root growth, which boosts nutrient (Sathya *et. al.* 2010). Golden Delicious performed better in regions temperate climatic conditions than Red Chief Camspur, and similar findings were earlier reported in different planning documents of state (Directorate of Horticulture Kashmir, Jammu and Kashmir, 2019-20).

3.2 Nutrient Concentration in Apple Leaves and Fruit

The partitioning of nutrients in the plant leaves and fruits differed highly (Table 3 to Table 12). Obtained data clearly revealed that the nutrient content in apple leaves and fruits was significantly dependent on the applied calcium rates, varietal response and calcium sources and their mode of application. In the experiment, the significantly lowest nitrogen, phosphorus, potassium, calcium and magnesium content was recorded in the leaves and fruits of apple trees with no calcium application, compared to trees fertilized with different rates of calcium, mode of application and their sources in both the varieties. In case of different interactions for nitrogen, phosphorous, potassium and magnesium we just found significant variation in sources x doses combination only, however calcium content vary significantly in all interactions other than variety x sources. Average nutrient content in the leaves and fruits of apple in calcium chloride foliar spray, calcium nitrate foliar spray and calcium nitrate soil application were 2.146, 2.248 and 2.153 % nitrogen in leaves and in case of apple fruit, nitrogen was 370.39, 400.33 and 376.79 ppm respectively (Table 3 & Table 4). Foliar calcium application resulted in an increase in P content of both leaves and fruits, whereas soil application of calcium nitrate as calcium source decreased apple leave and fruit phosphorus concentration, as it gets highly fixed with applied calcium in slightly acidic soils. Phosphorous in leaves was 0.170, 0.182 and 0.134 % and in fruits was 95.94, 98.15 and 91.36 ppm respectively for said combinations (Table 5 & Table 6). Average potassium content was 1.23, 1.30 and 1.10 % in leaves and 952.30, 996.20 and 710.94 ppm in apple fruits respectively for above mentioned different calcium sources (Table 7 & Table 8). The amount of calcium for respective treatments was 1.13, 1.30 and 0.94 % in leaves and 37.04, 44.02 and 31.95 ppm in fruit (Table 9 & Table 10), whereas magnesium for respective treatments was 0.387, 0.423 and 0.343 % in leaves and in fruit, it was 27.75, 29.17 and 25.38 ppm respectively (Table 11 & Table 12).

Substantially higher nutrient content in leaves and fruits was found in Golden Delicious compared to Red Chief Camspur, as earlier variety genetically adopted better to temperate climate. The nitrogen, phosphorous, potassium, calcium and magnesium values in leaf and fruit of Golden Delicious were 2.23, 0.17, 1.23, 1.16 and 0.387 % and 391.48, 98.18. 887.36, 38.46 and 28.36 ppm respectively, whereas above nutrient concentration in leaf and fruit of Red Chief Campsur were 2.14, 1.19, 1.09 and 0.38 % and 373.54, 92.11, 885.59, 36.88 and 26.52 ppm respectively.

Interestingly, the nutrient content in apple leaves and fruit was significantly dependent on the applied dosage. In obtained data, nutrient content in apple leaves and fruit varied significantly for no calcium application, low dose of calcium (3g/lit $CaCl_2$ or $CaNO_3$ foliar application or 100g/plant $CaNO_3$ soil application), medium dose (4g/lit $CaCl_2$ or $CaNO_3$ foliar application or 200g/plant $CaNO_3$ soil application) & high dose (5g/lit $CaCl_2$ or $CaNO_3$ foliar application or 300g/plant $CaNO_3$ soil application). In respective treatments significant variation in nitrogen content of leaves was 1.971, 2.179, 2.245 and 2.335 % and in fruits, it was 336.19, 387.52, 396.22 and 410.10 ppm respectively. Phosphorous content for respective treatments was 0.137, 0.165, 0.171 and 0.176 % in leaves and 92.67, 95.27, 95.77 and 96.89 ppm in fruit respectively. Potassium content for respective treatments was 1.07, 1.23, 1.25 and 1.28 % in leaves and 709.62, 923.33, 943.98 and 969.00 ppm in fruit respectively. The calcium content values in apple leaves for these combinations were 0.541, 1.065, 1.314 and 1.584% and in case of apple fruits calcium content was 26.13, 34.97, 41.53 and 48.06 ppm respectively. The significant variation for these combinations in magnesium content of leaves was 0.336, 0.392, 0.399 and 0.411 % and in case of fruits, magnesium content was 20.62, 25.47, 30.08 and 33.57 ppm respectively.

Nitrogen, phosphorous, potassium and magnesium content in leaf and fruit among interactions showed significant variation in sources and doses only, where as in all other interactions above nutrient content in apple leaves and fruits varied non-significantly. However, the calcium content in apple leaves and fruits in different interaction like variety x doses, sources x doses and variety x sources x doses had significant variation. The calcium content of leaves in these combinations ranged from 0.523 to 1.629, 0.537 to 1.840 and 0.517 to 1.88 % respectively whereas in fruit calcium content for these interactions ranged from 26.11 to 49.50, 25.92 to 57.58 and 26.00 to 57.83 ppm respectively.

Calcium application is highly involved to have certain synergistic and antagonistic effects on availability and translocation of other nutrients sprayed or applied to soil. A potential factor affecting efficacy of foliar Ca^{2+} applications may be the timing of application in relation to fruit development. The data for all nutrient content in leaf and fruit are presented in Tables which showed range of N, P, K, Ca and Mg (1.96 to 2.38 & 326.8 to 420.4, 0.131 to 0.179 & 89.67 to 100.18, 1.07 to 1.30 & 716.54 to 968.93, 0.558 to 1.629 & 26.14 to 49.50, 0.331 to 0.410 & 20.16 to 34.94) percent in leaves and ppm in fruits respectively.

The cracks are particularly prevalent in 'Golden Delicious' apple during early growing season and rise in width and number as the fruit enlarges and matures. At maturity, the cracks on the surface of the fruit become larger and form a network, number of cracks in cuticle enhanced as fruit developed. The expansion of cracks and other surface irregularities throughout the latter part of growing season may play a significant role in calcium penetration into apple fruit. (Chien Chang, 2004 and Peryea and Neilsen, 2005); studied that both calcium chloride and calcium nitrate were effective and there was no notable difference in the effectiveness of these two salts. Domagala-Swiatkiewicz (2009) reported that propensity of leaf calcium increases when fertilizers are applied, Ca content in apple leaves and fruits were larger by applying calcium through different mode of applications. Murtic *et, al* (2017) Calcium nutrition through soil is governed by chemistry of calcium with other nutrients and soil properties. Ca existing in soil as divalent cation (Ca^{2+}) easily enters the root apoplast along with mass flow of water and follows apoplastic or symplastic pathways to the xylem. The cause thereof is that calcium transport reliance on leaf transpiration intensity to uptake more Ca considerably, while fruit having lower transpiration intensity have frailer Ca uptake, which subsequently leads to greater differences in Ca accumulation between apple leaves and fruits.

Kadir (2005) stated that foliar application of $CaCl_2$ significantly raised the K concentration of the peel and flesh of 'Jonathan' apples. An antagonistic relationship between K and Ca has not been observed through foliar spraying treatments. Neilson and Edwards (1982) observed that magnesium content did change significantly in apple with calcium application compared to the control. Leonicheva *et al. (*2021) reported that fruit flesh of fruit sprayed with Calcium nitrate had high nitrogen content than untreated control. The concentrations of other mineral elements are known to increase in the flesh and skin of fruit in response to calcium sprays (Kadir, 2005). Foliar fertilizers significantly prejudiced fruit mineral content. Accumulation of N, K, Ca and Mg was lower for control in apple varieties than treated Motesharezadeh *et al. (*2021).

Table 1. Effect of calcium sources, doses and mode of application on fruit length (mm) of different apple varieties grown under high density plantation

Three Way Interaction							
Varieties	**Fertiliser Sources & Mode of Applications**		**Doses of Fertiliser***				***Sub Mean Variety x Source***
			No Calcium (D0)	**Low Dose (D1)**	**Medium Dose (D2)**	**High Dose (D3)**	
Red Chief Camspur (V1)	**Calcium Chloride Foliar (S1)**		63.93	78.03	81.43	86.53	*77.48*
	Calcium Nitrate Foliar (S2)		63.83	83.60	87.73	90.97	*81.53*
	Calcium Nitrate Soil (S3)		63.80	67.83	70.37	74.03	*69.01*
Sub Mean Variety x Dose			*63.85*	*76.49*	*79.84*	*83.84*	**76.01 (V1)**
Golden Delicious (V2)	**Calcium Chloride Foliar (S1)**		66.43	82.50	85.43	89.60	*80.99*
	Calcium Nitrate Foliar (S2)		66.50	87.27	89.57	90.90	*83.56*
	Calcium Nitrate Soil (S3)		66.60	71.73	74.60	78.10	*72.76*
Sub Mean Variety x Dose			*66.51*	*80.50*	*83.20*	*86.20*	**79.10(V2)**
Mean Doses of Fertiliser			**65.18 (D0)**	**78.49 (D1)**	**81.52 (D2)**	**85.02 (D3)**	
Two Way Interaction of Sources x Doses							
Sub Mean Source x Dose	**Calcium Chloride Foliar (S1)**		*65.18*	*80.27*	*83.43*	*88.07*	**79.24 (S1)**
	Calcium Nitrate Foliar (S2)		*65.17*	*85.44*	*88.65*	*90.94*	**82.55 (S2)**
	Calcium Nitrate Soil (S3)		*65.20*	*69.78*	*72.48*	*76.07*	**70.88 (S3)**
CD Value at (5%)	Varieties	Sources	Doses	Varieties x Sources	Varieties x Doses	Sources x Doses	Varieties x Sources x Doses
	1.11	1.36	1.57	NS	NS	2.72	NS

** D0= No Calcium (No Ca applied), D1= Low Dose (3g/lit $CaCl_2$ or $CaNO_3$ foliar application or 100g/plant $CaNO_3$ soil application), D2=Medium Dose (4g/lit $CaCl_2$ or $CaNO_3$ foliar application or 200g/plant $CaNO_3$ soil application) & D3= High Dose (5g/lit $CaCl_2$ or $CaNO_3$ foliar application or 300g/plant $CaNO_3$ soil application)*

Table 2. Effect of calcium sources, doses and mode of application on fruit diameter (mm) of different apple varieties grown under high density plantation

Three Way Interaction							
Varieties	**Fertiliser Sources & Mode of Applications**		**Doses of Fertiliser***				**Sub Mean Variety x Source**
			No Calcium (D0)	**Low Dose (D1)**	**Medium Dose (D2)**	**High Dose (D3)**	
Red Chief Camspur (V1)	**Calcium Chloride Foliar (S1)**		64.34	79.47	81.21	84.66	*77.42*
	Calcium Nitrate Foliar (S2)		64.38	82.42	84.76	88.45	*80.00*
	Calcium Nitrate Soil (S3)		64.52	67.49	71.70	74.19	*69.48*
Sub Mean Variety x Dose			*64.41*	*76.46*	*79.22*	*82.43*	**75.63 (V1)**
Golden Delicious (V2)	**Calcium Chloride Foliar (S1)**		67.74	82.47	85.03	86.00	*80.31*
	Calcium Nitrate Foliar (S2)		67.60	84.04	86.50	89.42	*81.89*
	Calcium Nitrate Soil (S3)		67.63	69.77	71.93	75.30	*71.16*
Sub Mean Variety x Dose			*67.66*	*78.76*	*81.15*	*83.57*	**77.79 (V2)**
Mean Doses of Fertiliser			**66.03 (D0)**	**77.61 (D1)**	**80.19 (D2)**	**83.00 (D3)**	
Two Way Interaction of Sources x Doses							
Sub Mean Source x Dose	**Calcium Chloride Foliar (S1)**		*66.04*	*80.97*	*83.12*	*85.33*	**78.86 (S1)**
	Calcium Nitrate Foliar (S2)		*65.99*	*83.23*	*85.63*	*88.94*	**80.95 (S2)**
	Calcium Nitrate Soil (S3)		*66.08*	*68.63*	*71.82*	*74.74*	**70.32 (S3)**
CD Value at (5%)	Varieties	Sources	Doses	Varieties x Sources	Varieties x Doses	Sources x Doses	Varieties x Sources x Doses
	1.23	1.50	1.74	NS	NS	3.01	NS

** D0= No Calcium (No Ca applied), D1= Low Dose (3g/lit $CaCl_2$ or $CaNO_3$ foliar application or 100g/plant $CaNO_3$ soil application), D2=Medium Dose (4g/lit $CaCl_2$ or $CaNO_3$ foliar application or 200g/plant $CaNO_3$ soil application) & D3= High Dose (5g/lit $CaCl_2$ or $CaNO_3$ foliar application or 300g/plant $CaNO_3$ soil application)*

Table 3. Effect of calcium sources, doses and mode of application on leaf nitrogen (%) in different apple varieties grown under high density plantation

Three Way Interaction						
Varieties	**Fertiliser Sources & Mode of Applications**	**Doses of Fertiliser***				***Sub Mean Variety x Source***
		No Calcium (D0)	**Low Dose (D1)**	**Medium Dose (D2)**	**High Dose (D3)**	
Red Chief Camspur (V1)	**Calcium Chloride Foliar (S1)**	1.967	2.203	2.140	2.263	*2.098*
	Calcium Nitrate Foliar (S2)	1.962	2.220	2.287	2.343	*2.204*
	Calcium Nitrate Soil (S3)	1.950	2.083	2.127	2.260	*2.105*
Sub Mean Variety x Dose		*1.961*	*2.109*	*2.185*	*2.289*	**2.136 (V1)**
Golden Delicious (V2)	**Calcium Chloride Foliar (S1)**	1.980	2.203	2.267	2.323	*2.193*
	Calcium Nitrate Foliar (S2)	1.973	2.350	2.400	2.447	*2.293*
	Calcium Nitrate Soil (S3)	1.990	2.193	2.250	2.373	*2.202*
Sub Mean Variety x Dose		*1.981*	*2.249*	*2.306*	*2.381*	**2.229 (V2)**
Mean Doses of Fertiliser		**1.971 (D0)**	**2.179 (D1)**	**2.245 (D2)**	**2.335 (D3)**	
Two Way Interaction of Sources x Doses						
Sub Mean Source x Dose	**Calcium Chloride Foliar (S1)**	*1.974*	*2.113*	*2.204*	*2.293*	**2.146 (S1)**
	Calcium Nitrate Foliar (S2)	*1.970*	*2.285*	*2.344*	*2.395*	**2.248 (S2)**
	Calcium Nitrate Soil (S3)	*1.970*	*2.138*	*2.189*	*2.317*	**2.153 (S3)**
CD Value at (5%)	Varieties / Sources	Doses	Varieties x Sources	Varieties x Doses	Sources x Doses	Varieties x Sources x Doses
	0.055 / 0.067	0.077	NS	NS	0.134	NS

** D0= No Calcium (No Ca applied), D1= Low Dose (3g/lit $CaCl_2$ or $CaNO_3$ foliar application or 100g/plant $CaNO_3$ soil application), D2=Medium Dose (4g/lit $CaCl_2$ or $CaNO_3$ foliar application or 200g/plant $CaNO_3$ soil application) & D3= High Dose (5g/lit $CaCl_2$ or $CaNO_3$ foliar application or 300g/plant $CaNO_3$ soil application)*

Table 4. Effect of calcium sources, doses and mode of application on fruit nitrogen (ppm) in different apple varieties grown under high density plantation

		Three Way Interaction				
Varieties	**Fertiliser Sources & Mode of Applications**	**Doses of Fertiliser***				***Sub Mean Variety x Source***
		No Calcium (D0)	**Low Dose (D1)**	**Medium Dose (D2)**	**High Dose (D3)**	
Red Chief Camspur (V1)	**Calcium Chloride Foliar (S1)**	326.90	367.57	374.90	389.67	*364.76*
	Calcium Nitrate Foliar (S2)	326.67	393.90	405.53	417.47	*385.89*
	Calcium Nitrate Soil (S3)	326.90	377.60	383.03	392.30	*369.96*
Sub Mean Variety x Dose		*326.82*	*379.69*	*387.82*	*399.81*	**373.54 (V1)**
Golden Delicious (V2)	**Calcium Chloride Foliar (S1)**	345.33	374.33	381.33	403.10	*376.03*
	Calcium Nitrate Foliar (S2)	346.17	429.93	438.93	444.07	*414.78*
	Calcium Nitrate Soil (S3)	345.17	381.77	393.60	413.97	*383.63*
Sub Mean Variety x Dose		*345.56*	*395.34*	*404.62*	*420.38*	**391.48 (V2)**
Mean Doses of Fertiliser		**336.19 (D0)**	**387.52 (D1)**	**396.22 (D2)**	**410.10 (D3)**	
		Two Way Interaction of Sources x Doses				
Sub Mean Source x Dose	**Calcium Chloride Foliar (S1)**	*336.12*	*370.95*	*378.12*	*396.38*	**370.39 (S1)**
	Calcium Nitrate Foliar (S2)	*336.42*	*411.92*	*422.23*	*430.77*	**400.33 (S2)**
	Calcium Nitrate Soil (S3)	*336.03*	*379.68*	*388.32*	*403.13*	**376.79 (S3)**
CD Value at (5%)	Varieties / Sources	Doses	Varieties x Sources	Varieties x Doses	Sources x Doses	Varieties x Sources x Doses
	7.416 / 9.082	10.487	NS	NS	18.164	NS

** D0= No Calcium (No Ca applied), D1= Low Dose (3g/lit $CaCl_2$ or $CaNO_3$ foliar application or 100g/plant $CaNO_3$ soil application), D2=Medium Dose (4g/lit $CaCl_2$ or $CaNO_3$ foliar application or 200g/plant $CaNO_3$ soil application) & D3= High Dose (5g/lit $CaCl_2$ or $CaNO_3$ foliar application or 300g/plant $CaNO_3$ soil application)*

Table 5. Effect of calcium sources, doses and mode of application on leaf phosphorous (%) in different apple varieties grown under high density plantation

Three Way Interaction							
Varieties	**Fertiliser Sources & Mode of Applications**		**Doses of Fertiliser***				***Sub Mean Variety x Source***
			No Calcium (D0)	**Low Dose (D1)**	**Medium Dose (D2)**	**High Dose (D3)**	
Red Chief Camspur (V1)	**Calcium Chloride Foliar (S1)**		0.133	0.167	0.180	0.200	*0.170*
	Calcium Nitrate Foliar (S2)		0.130	0.190	0.197	0.197	*0.179*
	Calcium Nitrate Soil (S3)		0.130	0.127	0.127	0.123	*0.127*
Sub Mean Variety x Dose			*0.131*	*0.161*	*0.168*	*0.173*	**0.158 (V1)**
Golden Delicious (V2)	**Calcium Chloride Foliar (S1)**		0.143	0.170	0.183	0.187	*0.171*
	Calcium Nitrate Foliar (S2)		0.143	0.187	0.200	0.213	*0.186*
	Calcium Nitrate Soil (S3)		0.140	0.147	0.140	0.137	*0.141*
Sub Mean Variety x Dose			*0.142*	*0.168*	*0.174*	*0.179*	**0.166 (V2)**
Mean Doses of Fertiliser			**0.137 (D0)**	**0.165 (D1)**	**0.171 (D2)**	**0.176 (D3)**	
Two Way Interaction of Sources x Doses							
Sub Mean Source x Dose	**Calcium Chloride Foliar (S1)**		*0.138*	*0.169*	*0.182*	*0.194*	**0.170 (S1)**
	Calcium Nitrate Foliar (S2)		*0.137*	*0.189*	*0.199*	*0.205*	**0.182 (S2)**
	Calcium Nitrate Soil (S3)		*0.135*	*0.137*	*0.134*	*0.130*	**0.134 (S3)**
CD Value at (5%)	Varieties	Sources	Doses	Varieties x Sources	Varieties x Doses	Sources x Doses	Varieties x Sources x Doses
	NS	0.011	0.011	NS	NS	0.020	NS

** D0= No Calcium (No Ca applied), D1= Low Dose (3g/lit $CaCl_2$ or $CaNO_3$ foliar application or 100g/plant $CaNO_3$ soil application), D2=Medium Dose (4g/lit $CaCl_2$ or $CaNO_3$ foliar application or 200g/plant $CaNO_3$ soil application) & D3= High Dose (5g/lit $CaCl_2$ or $CaNO_3$ foliar application or 300g/plant $CaNO_3$ soil application)*

Table 6. Effect of calcium sources, doses and mode of application on fruit phosphorous (ppm) in different apple varieties grown under high density plantation

Three Way Interaction							
Varieties	**Fertiliser Sources & Mode of Applications**		**Doses of Fertiliser***				***Sub Mean Variety x Source***
			No Calcium (D0)	**Low Dose (D1)**	**Medium Dose (D2)**	**High Dose (D3)**	
Red Chief Camspur (V1)	**Calcium Chloride Foliar (S1)**		90.83	91.67	92.50	94.83	*92.46*
	Calcium Nitrate Foliar (S2)		89.17	96.50	97.67	98.17	*95.38*
	Calcium Nitrate Soil (S3)		89.00	88.90	88.30	87.80	*88.50*
Sub Mean Variety x Dose			*89.67*	*92.36*	*92.82*	*93.60*	**92.11 (V1)**
Golden Delicious (V2)	**Calcium Chloride Foliar (S1)**		96.00	99.33	101.00	101.33	*99.42*
	Calcium Nitrate Foliar (S2)		95.17	100.83	101.50	106.17	*100.92*
	Calcium Nitrate Soil (S3)		95.83	94.37	93.63	93.03	*94.22*
Sub Mean Variety x Dose			*95.67*	*98.18*	*98.71*	*100.18*	**98.18 (V2)**
Mean Doses of Fertiliser			**92.67 (D0)**	**95.27 (D1)**	**95.77 (D2)**	**96.89 (D3)**	
Two Way Interaction of Sources x Doses							
Sub Mean Source x Dose	**Calcium Chloride Foliar (S1)**		*93.42*	*95.50*	*96.75*	*98.08*	**95.94 (S1)**
	Calcium Nitrate Foliar (S2)		*92.17*	*98.67*	*99.58*	*102.17*	**98.15 (S2)**
	Calcium Nitrate Soil (S3)		*92.42*	*91.63*	*90.97*	*90.41*	**91.36 (S3)**
CD Value at (5%)	Varieties	Sources	Doses	Varieties x Sources	Varieties x Doses	Sources x Doses	Varieties x Sources x Doses
	1.25	1.53	1.77	NS	NS	3.06	NS

** D0= No Calcium (No Ca applied), D1= Low Dose (3g/lit $CaCl_2$ or $CaNO_3$ foliar application or 100g/plant $CaNO_3$ soil application), D2=Medium Dose (4g/lit $CaCl_2$ or $CaNO_3$ foliar application or 200g/plant $CaNO_3$ soil application) & D3= High Dose (5g/lit $CaCl_2$ or $CaNO_3$ foliar application or 300g/plant $CaNO_3$ soil application)*

Table 7. Effect of calcium sources, doses and mode of application on leaf potassium (%) in different apple varieties grown under high density plantation

Three Way Interaction						
Varieties	**Fertiliser Sources & Mode of Applications**	**Doses of Fertiliser***				***Sub Mean Variety x Source***
		No Calcium (D0)	**Low Dose (D1)**	**Medium Dose (D2)**	**High Dose (D3)**	
Red Chief Camspur (V1)	**Calcium Chloride Foliar (S1)**	1.07	1.23	1.25	1.28	*1.21*
	Calcium Nitrate Foliar (S2)	1.05	1.34	1.35	1.39	*1.28*
	Calcium Nitrate Soil (S3)	1.05	1.09	1.09	1.10	*1.09*
Sub Mean Variety x Dose		*1.07*	*1.22*	*1.23*	*1.25*	**1.19 (V1)**
Golden Delicious (V2)	**Calcium Chloride Foliar (S1)**	1.07	1.27	1.31	1.35	*1.25*
	Calcium Nitrate Foliar (S2)	1.09	1.36	1.40	1.43	*1.32*
	Calcium Nitrate Soil (S3)	1.09	1.11	1.11	1.12	*1.11*
Sub Mean Variety x Dose		*1.08*	*1.25*	*1.27*	*1.30*	**1.23 (V2)**
Mean Doses of Fertiliser		**1.07 (D0)**	**1.23 (D1)**	**1.25 (D2)**	**1.28 (D3)**	
Two Way Interaction of Sources x Doses						
Sub Mean Source x Dose	**Calcium Chloride Foliar (S1)**	*1.07*	*1.25*	*1.28*	*1.32*	**1.23 (S1)**
	Calcium Nitrate Foliar (S2)	*1.07*	*1.35*	*1.38*	*1.41*	**1.30 (S2)**
	Calcium Nitrate Soil (S3)	*1.09*	*1.10*	*1.10*	*1.11*	**1.10 (S3)**
CD Value at (5%)	Varieties / Sources	Doses	Varieties x Sources	Varieties x Doses	Sources x Doses	Varieties x Sources x Doses
	0.022 / 0.027	0.031	NS	NS	0.054	NS

** D0= No Calcium (No Ca applied), D1= Low Dose (3g/lit $CaCl_2$ or $CaNO_3$ foliar application or 100g/plant $CaNO_3$ soil application), D2=Medium Dose (4g/lit $CaCl_2$ or $CaNO_3$ foliar application or 200g/plant $CaNO_3$ soil application) & D3= High Dose (5g/lit $CaCl_2$ or $CaNO_3$ foliar application or 300g/plant $CaNO_3$ soil application)*

Table 8. Effect of calcium sources, doses and mode of application on fruit potassium (ppm) in different apple varieties grown under high density plantation

Three Way Interaction						
Varieties	**Fertiliser Sources & Mode of Applications**	**Doses of Fertiliser***				***Sub Mean Variety x Source***
		No Calcium (D0)	**Low Dose (D1)**	**Medium Dose (D2)**	**High Dose (D3)**	
Red Chief Camspur (V1)	**Calcium Chloride Foliar (S1)**	714.80	987.33	1027.83	1070.67	*950.16*
	Calcium Nitrate Foliar (S2)	722.50	1045.33	1073.17	1114.67	*988.92*
	Calcium Nitrate Soil (S3)	712.33	716.83	719.83	721.83	*717.71*
Sub Mean Variety x Dose		*716.54*	*916.50*	*940.28*	*969.06*	**885.59 (V1)**
Golden Delicious (V2)	**Calcium Chloride Foliar (S1)**	703.60	1008.53	1034.23	1071.40	*954.44*
	Calcium Nitrate Foliar (S2)	702.63	1075.07	1108.50	1127.70	*1003.48*
	Calcium Nitrate Soil (S3)	701.83	706.87	700.30	707.70	*704.18*
Sub Mean Variety x Dose		*702.69*	*930.16*	*947.68*	*968.93*	**887.36 (V2)**
Mean Doses of Fertiliser		**709.62 (D0)**	**923.33 (D1)**	**943.98 (D2)**	**969.00 (D3)**	
Two Way Interaction of Sources x Doses						
Sub Mean Source x Dose	**Calcium Chloride Foliar (S1)**	*709.20*	*997.93*	*1031.03*	*1071.03*	**952.30 (S1)**
	Calcium Nitrate Foliar (S2)	*712.57*	*1060.20*	*1090.83*	*1121.18*	**996.20 (S2)**
	Calcium Nitrate Soil (S3)	*707.08*	*711.85*	*710.07*	*714.77*	**710.94 (S3)**
CD Value at (5%)	Varieties / Sources	Doses	Varieties x Sources	Varieties x Doses	Sources x Doses	Varieties x Sources x Doses
	NS / 13.48	15.57	NS	NS	26.97	NS

** D0= No Calcium (No Ca applied), D1= Low Dose (3g/lit $CaCl_2$ or $CaNO_3$ foliar application or 100g/plant $CaNO_3$ soil application), D2=Medium Dose (4g/lit $CaCl_2$ or $CaNO_3$ foliar application or 200g/plant $CaNO_3$ soil application) & D3= High Dose (5g/lit $CaCl_2$ or $CaNO_3$ foliar application or 300g/plant $CaNO_3$ soil application)*

Table 9. Effect of calcium sources, doses and mode of application on leaf calcium (%) in different apple varieties grown under high density plantation

Three Way Interaction							
Varieties	**Fertiliser Sources & Mode of Applications**		**Doses of Fertiliser***				***Sub Mean Variety x Source***
			No Calcium (D0)	**Low Dose (D1)**	**Medium Dose (D2)**	**High Dose (D3)**	
Red Chief Camspur (V1)	**Calcium Chloride Foliar (S1)**		0.557	1.030	1.310	1.550	*1.112*
	Calcium Nitrate Foliar (S2)		0.563	1.263	1.530	1.880	*1.289*
	Calcium Nitrate Soil (S3)		0.553	0.697	0.937	1.267	*0.864*
Sub Mean Variety x Dose			*0.558*	*0.997*	*1.259*	*1.539*	**1.088 (V1)**
Golden Delicious (V2)	**Calcium Chloride Foliar (S1)**		0.517	1.120	1.353	1.613	*1.151*
	Calcium Nitrate Foliar (S2)		0.533	1.290	1.567	1.880	*1.318*
	Calcium Nitrate Soil (S3)		0.520	0.987	1.187	1.393	*1.022*
Sub Mean Variety x Dose			*0.523*	*1.132*	*1.369*	*1.629*	**1.163 (V2)**
Mean Doses of Fertiliser			**0.541 (D0)**	**1.065 (D1)**	**1.314 (D2)**	**1.584 (D3)**	
Two Way Interaction of Sources x Doses							
Sub Mean Source x Dose	**Calcium Chloride Foliar (S1)**		*0.537*	*1.075*	*1.332*	*1.582*	**1.131 (S1)**
	Calcium Nitrate Foliar (S2)		*0.548*	*1.277*	*1.549*	*1.840*	**1.303 (S2)**
	Calcium Nitrate Soil (S3)		*0.537*	*0.842*	*1.062*	*1.330*	**0.943 (S3)**
CD Value at (5%)	Varieties	Sources	Doses	Varieties x Sources	Varieties x Doses	Sources x Doses	Varieties x Sources x Doses
	0.028	0.034	0.039	NS	0.056	0.068	0.098

** D0= No Calcium (No Ca applied), D1= Low Dose (3g/lit $CaCl_2$ or $CaNO_3$ foliar application or 100g/plant $CaNO_3$ soil application), D2=Medium Dose (4g/lit $CaCl_2$ or $CaNO_3$ foliar application or 200g/plant $CaNO_3$ soil application) & D3= High Dose (5g/lit $CaCl_2$ or $CaNO_3$ foliar application or 300g/plant $CaNO_3$ soil application)*

Table 10. Effect of calcium sources, doses and mode of application on fruit calcium (ppm) in different apple varieties grown under high density plantation

Three Way Interaction							
Varieties	**Fertiliser Sources & Mode of Applications**		**Doses of Fertiliser***				***Sub Mean Variety x Source***
			No Calcium (D0)	**Low Dose (D1)**	**Medium Dose (D2)**	**High Dose (D3)**	
Red Chief Camspur (V1)	**Calcium Chloride Foliar (S1)**		25.83	32.17	38.33	47.00	*35.83*
	Calcium Nitrate Foliar (S2)		25.97	40.67	49.00	57.33	*43.24*
	Calcium Nitrate Soil (S3)		26.63	31.00	33.17	35.50	*31.58*
Sub Mean Variety x Dose			*26.14*	*34.61*	*40.17*	*46.61*	**36.88 (V1)**
Golden Delicious (V2)	**Calcium Chloride Foliar (S1)**		26.00	32.50	43.50	51.00	*38.25*
	Calcium Nitrate Foliar (S2)		26.17	43.67	51.50	57.83	*44.79*
	Calcium Nitrate Soil (S3)		26.17	29.83	33.67	39.67	*32.33*
Sub Mean Variety x Dose			*26.11*	*35.33*	*42.89*	*49.50*	**38.46 (V2)**
Mean Doses of Fertiliser			**26.13 (D0)**	**34.97 (D1)**	**41.53 (D2)**	**48.06 (D3)**	
Two Way Interaction of Sources x Doses							
Sub Mean Source x Dose	**Calcium Chloride Foliar (S1)**		*25.92*	*32.33*	*40.92*	*49.00*	**37.04 (S1)**
	Calcium Nitrate Foliar (S2)		*26.07*	*42.17*	*50.25*	*57.58*	**44.02 (S2)**
	Calcium Nitrate Soil (S3)		*26.40*	*30.42*	*33.42*	*37.58*	**31.95 (S3)**
CD Value at (5%)	Varieties	Sources	Doses	Varieties x Sources	Varieties x Doses	Sources x Doses	Varieties x Sources x Doses
	0.743	0.910	1.050	NS	1.485	1.819	2.573

** D0= No Calcium (No Ca applied), D1= Low Dose (3g/lit $CaCl_2$ or $CaNO_3$ foliar application or 100g/plant $CaNO_3$ soil application), D2=Medium Dose (4g/lit $CaCl_2$ or $CaNO_3$ foliar application or 200g/plant $CaNO_3$ soil application) & D3= High Dose (5g/lit $CaCl_2$ or $CaNO_3$ foliar application or 300g/plant $CaNO_3$ soil application)*

Table 11. Effect of calcium sources, doses and mode of application on leaf magnesium (%) in different apple varieties grown under high density plantation

Three Way Interaction						
Varieties	**Fertiliser Sources & Mode of Applications**	**Doses of Fertiliser***				***Sub Mean Variety x Source***
		No Calcium (D0)	**Low Dose (D1)**	**Medium Dose (D2)**	**High Dose (D3)**	
Red Chief Camspur (V1)	**Calcium Chloride Foliar (S1)**	0.333	0.387	0.400	0.423	*0.386*
	Calcium Nitrate Foliar (S2)	0.327	0.443	0.453	0.467	*0.423*
	Calcium Nitrate Soil (S3)	0.333	0.337	0.340	0.343	*0.338*
Sub Mean Variety x Dose		***0.331***	*0.389*	*0.398*	*0.411*	**0.382 (V1)**
Golden Delicious (V2)	**Calcium Chloride Foliar (S1)**	0.343	0.390	0.400	0.423	*0.389*
	Calcium Nitrate Foliar (S2)	0.337	0.447	0.453	0.457	*0.424*
	Calcium Nitrate Soil (S3)	0.343	0.347	0.350	0.350	*0.348*
Sub Mean Variety x Dose		***0.341***	*0.395*	*0.401*	*0.410*	**0.387 (V2)**
Mean Doses of Fertiliser		**0.336 (D0)**	**0.392 (D1)**	**0.399 (D2)**	**0.411 (D3)**	
Two Way Interaction of Sources x Doses						
Sub Mean Source x Dose	**Calcium Chloride Foliar (S1)**	*0.338*	*0.389*	*0.400*	*0.423*	**0.387 (S1)**
	Calcium Nitrate Foliar (S2)	*0.332*	*0.445*	*0.453*	*0.462*	**0.423 (S2)**
	Calcium Nitrate Soil (S3)	0.338	0.342	0.345	0.347	**0.343 (S3)**
CD Value at (5%)	Varieties / Sources	Doses	Varieties x Sources	Varieties x Doses	Sources x Doses	Varieties x Sources x Doses
	NS / 0.007	0.008	NS	NS	0.013	NS

** D0= No Calcium (No Ca applied), D1= Low Dose (3g/lit $CaCl_2$ or $CaNO_3$ foliar application or 100g/plant $CaNO_3$ soil application), D2=Medium Dose (4g/lit $CaCl_2$ or $CaNO_3$ foliar application or 200g/plant $CaNO_3$ soil application) & D3= High Dose (5g/lit $CaCl_2$ or $CaNO_3$ foliar application or 300g/plant $CaNO_3$ soil application)*

Table 12. Effect of calcium sources, doses and mode of application on fruit magnesium (ppm) in different apple varieties grown under high density plantation

Three Way Interaction							
Varieties	**Fertiliser Sources & Mode of Applications**		**Doses of Fertiliser***				***Sub Mean Variety x Source***
			No Calcium (D0)	**Low Dose (D1)**	**Medium Dose (D2)**	**High Dose (D3)**	
Red Chief Camspur (V1)	**Calcium Chloride Foliar (S1)**		20.47	23.73	29.73	34.10	*27.09*
	Calcium Nitrate Foliar (S2)		19.83	25.43	30.73	34.90	*27.73*
	Calcium Nitrate Soil (S3)		20.17	25.00	26.59	27.60	*24.82*
Sub Mean Variety x Dose			*20.16*	*24.72*	*28.99*	*32.20*	**26.52 (V1)**
Golden Delicious (V2)	**Calcium Chloride Foliar (S1)**		21.00	26.00	31.00	36.00	*28.50*
	Calcium Nitrate Foliar (S2)		21.50	28.00	34.17	38.83	*30.63*
	Calcium Nitrate Soil (S3)		20.77	24.67	28.33	30.00	*25.94*
Sub Mean Variety x Dose			*21.09*	*26.22*	*31.17*	*34.94*	**28.36 (V2)**
Mean Doses of Fertiliser			**20.62 (D0)**	**25.47 (D1)**	**30.08 (D2)**	**33.57 (D3)**	
Two Way Interaction of Sources x Doses							
Sub Mean Source x Dose	**Calcium Chloride Foliar (S1)**		*20.73*	*24.87*	*30.37*	*35.05*	**27.75 (S1)**
	Calcium Nitrate Foliar (S2)		*20.67*	*26.72*	*32.45*	*36.87*	**29.17 (S2)**
	Calcium Nitrate Soil (S3)		*20.47*	*24.83*	*27.42*	*28.80*	**25.38 (S3)**
CD Value at (5%)	Varieties	Sources	Doses	Varieties x Sources	Varieties x Doses	Sources x Doses	Varieties x Sources x Doses
	0.645	0.790	0.912	NS	NS	1.579	NS

** D0= No Calcium (No Ca applied), D1= Low Dose (3g/lit $CaCl_2$ or $CaNO_3$ foliar application or 100g/plant $CaNO_3$ soil application), D2=Medium Dose (4g/lit $CaCl_2$ or $CaNO_3$ foliar application or 200g/plant $CaNO_3$ soil application) & D3= High Dose (5g/lit $CaCl_2$ or $CaNO_3$ foliar application or 300g/plant $CaNO_3$ soil application)*

Calcium in calcareous soil reacts with soil solution P to form a strong calcium phosphate and reduces its availability to plant. Calcium phosphate precipitation has low solubility value and thus availability of phosphorus is highly hindered to the plant. Murtic (2021), also found the fertigation treatment of calcium nitrate had the largest potential to enhance Ca content in apple. Increasing N supply enhances growth and consequently, increases leaf area and transpiration intensity. Calcium, magnesium and potassium ions are fairly similar in size and charge and hence, exchange sites cannot discriminate the difference between the ions. Often times, they comprehensively accept either ion irrespective of which ion is meant for that site. Generally, binding strengths of potassium and calcium are much sturdier than magnesium and they easily out-compete magnesium at exchange sites. ST Jakobsen (1993) the addition of Ca in the form of $Ca(N03)_2$ can displace Mg from the cation exchange complex and Mg will leach from the root zone. $Ca(N03)_2$ applications significant increase in residual soil nitrate nitrogen. Alkaline and calcareous soils, similar to this study, cause soluble phosphate ions to form little solubility calcium triphosphate or be absorbed on to solid calcium carbonate surfaces. Aggelopoulou *et al.,* 2011); alkaline or calcareous soils comprise large quantities of Ca^{2+} and Mg^{2+}, both of which compete directly with K for uptake. Thus, the availability of K^+ is somewhat more dependent on its concentration relative to that of Ca^{2+} and Mg^{2+} than on the total quantity of K^+ present in the soil. In the soil, Mg moves mainly by mass flow mediated by ionospheres down an electrochemical gradient. The engrossment of ionospheres may explain the effect cation competition from ammonium, K, Ca and Na on Mg uptake (Aggelopoulou *et al.,* 2011). This means that when other cations, especially K, ammonium and Ca are much more abundant in the soil, they compete directly with Mg for uptake into the plant.

4. CONCLUSION

Thus, it is concluded that the calcium application both as foliar or soil application had positive impact on growth and quality of apple in both the varieties. However, among the sources of calcium, calcium nitrate as foliar spray performed better than foliar spray of calcium chloride which in turn proved better than soil application of calcium nitrate. The most effective concentration of calcium nitrate was 5 g per liter water in both the varieties of Golden delicious and Red Chief Camspur for all the growth features and nutrient concentration. Our study did not find any adversity of dosage in plants whether applied to soil or directly to plant and we did observe better growth and quality at higher calcium doses. Among varieties Golden Delicious performed better than Red Chief Camspur. Results of research evidenced that preharvest calcium sprays increase growth, improved fruit quality and reduced its deterioration in post-harvest storage under ambient atmosphere.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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