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Comparison of Chelated and Non-Chelated Calcium in Silver Spur Apples under Temperate Conditions

Tajamul Farooq Wani[1], S.A. Simnani[1], Zahoor Ahmad Bhat[1], Nayar Afaq Kirmani[2], Sajad Mohd Wani[3], Nageena Nazir[4], Manzoor Ahmad Parray[5], Sheikh Amjid[2*], Shaila Din[1] and Shemoo Nisar[1]

[1]Division of Fruit Science, SKUAST- Kashmir (J&K), India.
[2]Division of Soil Science, SKUAST- Kashmir (J&K), India.
[3]Division of FST, SKUAST- Kashmir (J&K), India.
[4]Division of Agricultural Statistics, SKUAST- Kashmir (J&K), India.
[5]Division of Entomology, SKUAST- Kashmir (J&K), India.

(Corresponding author: Sheikh Amjid)*
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ABSTRACT: Chelated fertilizers are nutrient compounds in which essential minerals are bound to organic molecules, enhancing their stability and availability to plants. When used for foliar spray, they improve nutrient uptake efficiency by penetrating the leaf's waxy surface, ensuring optimal nutrient absorption and utilization, ultimately boosting plant growth and productivity. The research study, was conducted in the Experimental Block of the Division of Fruit Science, Faculty of Horticulture (FoH), SKUAST-Kashmir, Shalimar, Srinagar, during the years 2021 and 2022 focused on the apple cultivar Silver Spur within a high-density plantation grafted onto M-7 rootstock, each plant spaced 3.5 m × 3.5 m apart. The experiment comprises of five treatments replicated four times each, with a total of 20 plants organized into a Randomized Complete Block Design (RCBD). This comprehensive research aims to provide insights into optimizing nutrient management for enhancing apple orchard productivity under temperate conditions. Among the different chelated and non-chelated forms of CaT_4, Calcium 10% EDTA Chelated @ 300 mg/l recorded robust vegetative development in terms of annual shoot extension growth of 51.91 cm, incremental plant height of 41.95 cm and substantial plant girth of 28.74 cm in. The leaves exhibit a leaf area of 34.26 cm², reflecting the overall canopy efficiency. Fruit-related characteristics, such as a Fruit attributes include a length of 8.00 cm, diameter of 7.83 cm and a balanced L/D ratio of 1.022. The fruit weighs 233.58 g and yield of 18.96 kg/plant and a yield efficiency of 0.29 kg/cm², underscore the productive capacity of the cultivar and efficiency of treatment. It is concluded that among the chelated and non-chelated nutrients under foliar applications, chelated nutrients performed better than non-chelated nutrients in terms of growth, yield and quality of high density apple cv. Silver Spur. This knowledge can guide growers in making informed decisions to enhance both the nutritional quality and productivity of the Silver Spur cultivar.

Keywords: Apple cv. Silver Spur, High-density apple, Foliar nutrient application, Chelated nutrients, Orchard productivity, Temperate conditions.

INTRODUCTION

Apple (*Malus domestica* Borkh) cultivation is a vital component of the horticultural industry globally, especially in temperate regions where favourable climates support robust growth and yield. Globally it has an important economic impact and it has been estimated that almost 5 million hectares of apples is harvested worldwide. Approximately 17 million metric tons stem from European production, representing 20% of global production, which was approximately 90 million metric tons in 2019, becoming the fruit with the third-largest production, behind citrus and bananas (FAOSTAT, 2021). According to the data (statistical) presented in the World Apple Review (WAR. 2018), this fruit accounted for 12.26% of the world's total fruit production from 2012 to 2014, which was second only to bananas and citrus. Similarly, the global apple production exceeded 80 million tons in 2015 (FAO. 2015). In 2019, apples took third place in terms of popularity of fresh fruits (after bananas and watermelons) in the world and nearly 87.24 million metric tons of apples were produced worldwide (Gołębiewska *et al.,* 2022). In 2020, it was reported that China, with ~40.5 million tons (47%) (Fotiric *et al.,* 2022), was the leading producer of apples with 58% of total world production, followed by USA (6%), Turkey (3.61%), India (3%) and Iran (2%) (Wani *et al.,* 2021). It was estimated that average productivity of apple fruit in India was nearly 6–8 t/ha, much lower than that of other countries, *viz.* Belgium (46.22 t/ha), Denmark

(41.87 t/ha) and the Netherlands (40.40 t/ha) (FAO, 2018).

Indian apple exports are worth ~USD 10 million annually, of which ~USD 5 million comes from the apples of Jammu and Kashmir State, which provides jobs to 1.2 million people directly or indirectly. Jammu and Kashmir has the highest average yield and accounts for 67% of total fruit (apple) production and 50% of exports in the country, hence it is a substantial foreign exchange earner and important for economic growth (Parrey and Hakeem 2015). Kashmir is India's main apple producer, as almost 89% of the horticulture land in Kashmir is under apple cultivation. This is due to the suitable climate, awareness among the growers (Ahmad *et al.,* 2021), and strong adaptability to the growing environment. Nature has bestowed Kashmir valley with agro climatic conditions conducive for apple cultivation and a strong comparative advantage in its production and marketing. The fruit industry is the backbone of economy in Jammu and Kashmir. Jammu and Kashmir with the area of 1,64,742 hectares and production of 18, 82, 319 MT (NHB, 2017) is leading in both area and production. J&K has remained the leading apple producer accounting for more than 50% of area and 80% of the total production in the country. Around 7 lakh farming families (approx. 35 lakh souls) are directly or indirectly dependent on horticulture which contributes about 9 per cent to the Jammu and Kashmir's Gross Domestic product (GDP). The productivity of apple in J & K is 11.43 MT/ha which is higher than other apple producing states in the country yet it is far below the level achieved by the horticulturally advanced countries like New Zealand (56.72 MT/ha) and Chile (50.08 MT/ha) and also the proportion of A grade apple is very low (FAO. 2018). This low productivity is mainly due to senile orchards, non-availability of quality planting material, low density plantings and improper nutrient management. Within this context, the cultivar Silver Spur has gained prominence for its desirable characteristics, including high fruit quality and adaptability to intensive orchard management practices such as high-density planting systems. However, to ensure optimal growth and productivity, the availability of essential nutrients such as calcium plays a pivotal role. Calcium is indispensable for various physiological processes in apple trees, including cell wall structure, membrane integrity, enzyme activation and overall plant growth and development. Although naturally present in soil, its uptake by apple trees can be influenced by factors like soil pH, root activity and environmental conditions. Consequently, foliar application of calcium has emerged as a promising strategy to supplement tree nutrition, especially in high-density orchards where nutrient demand is intensified.

In recent years, chelated calcium formulations have garnered interest due to their enhanced stability and uptake compared to traditional non-chelated calcium sources. Chelated forms feature calcium ions bound to organic molecules, facilitating better absorption and utilization by apple trees. This enhanced bioavailability can lead to improved growth, fruit quality and overall productivity (Ahmed *et al.,* 2024). The benefits of growing apples in high-density orchards are manifold. Firstly, high-density planting allows for optimal space utilization, maximizing yield per unit area. Additionally, it promotes efficient resource utilization, including water and nutrients, leading to enhanced growth and productivity. Furthermore, high-density orchards facilitate easier management practices, such as pruning, pest control and harvesting, thereby reducing labour and operational costs. Comparing chelated and non-chelated forms of calcium, research indicates several advantages of chelated formulations. Chelated calcium exhibits greater stability in the soil, reducing the risk of leaching and runoff. Moreover, its enhanced uptake by apple trees ensures efficient utilization, resulting in improved growth, fruit quality and yield compared to non-chelated forms. However, despite the growing interest in foliar calcium application and chelated formulations, comprehensive research is essential to evaluate their efficacy under specific environmental conditions. By understanding the effects of different forms of calcium and concentrations on apple cultivars, particularly in high-density orchards, such insights are crucial for informing orchard management practices and guiding farmers towards sustainable and efficient approaches to maximize apple production in temperate regions like Kashmir.

MATERIAL AND METHODS

This study was conducted at the Experimental Block of the Division of Fruit Science, FoH at SKUAST-Kashmir, Shalimar campus, Srinagar, during 2021 and 2022, focused on the apple cultivar Silver Spur within a high-density plantation grafted onto M-7 rootstock, each plant spaced 3.5 m × 3.5 m apart. The experiment comprises of five treatments replicated four times each, with a total of 20 plants organized into a Randomized Complete Block Design (RCBD). The treatments included T1 - Water spray, T2 - Calcium 10% EDTA Chelated at 200 mg/l, T3 - Calcium 10% EDTA Chelated at 250 mg/l, T4 - Calcium 10% EDTA Chelated at 300 mg/l and T5 - Non-chelated Calcium at 1080 mg/l. These treatments were applied at specific stages: 21 days after petal fall, 21 days after the first spray and 30 days before harvest. The study aimed to assess their effects on Silver Spur apple growth and yield.

Various parameters were measured to evaluate growth and yield attributes. Annual shoot extension growth, incremental plant height and leaf area were measured using a measuring tape and Systronic Leaf Area Meter-211, respectively. Fruit length and diameter were measured using Mitutoyo 500-196-20 vernier calipers, from which the length-to-diameter (L/D) ratio was calculated. Fruit weight was determined using a pan balance, with the yield estimated by multiplying the total number of fruits per tree by the average weight of ten randomly selected fruits. Yield efficiency was calculated as kg cm^{-2} using a formula by Westwood (1993). By assessing these parameters, the study aimed to optimize nutrient management strategies to enhance apple orchard productivity in temperate climates. The

detailed profile of Silver Spur apple performance under the experimental conditions provides valuable insights for orchard management practices. Understanding the effects of different calcium treatments on growth and yield attributes contributes to more informed decision-making in apple cultivation, ultimately aiming for improved productivity and sustainability in apple orchards.

RESULTS AND DISCUSSION

As per the data given in Table 1-3 revealed the annual shoot extension growth, incremental plant height, plant girth, leaf area, fruit length, diameter, length/diameter ratio, fruit weight, yield and yield efficiency were calculated for both the consecutive year 2021 and 2022 separately as well as pooled data basis. The results obtained are discussed under different headings as:

Annual shoot extension growth (cm). The yearly increase in length of new shoots on apple trees, indicating their overall vigor and growth rate, crucial for assessing tree health and productivity in orchards. Among the different treatments T_4: Calcium 10% EDTA Chelated @ 300 mg/l recorded significantly highest annual shoot extension growth during 2021, 2022 and in pooled data (51.63 cm, 52.18 cm and 51.91 cm), followed by T_3: Calcium 10% EDTA Chelated @ 250 mg/l (51.37 cm, 51.92 cm and 51.65 cm)> T_2: Calcium 10% EDTA Chelated @ 200 mg/l (51.04 cm, 51.59 cm and 51.32 cm)> T_5: Non chelated Ca @ 1080 mg/l (50.84 cm, 51.39 cm and 51.12cm). The lowest values for annual shoot extension growth (50.52 cm, 50.73 cm and 50.63 cm) were recorded in T_1(Water spray). Accumulation of calcium in leaves increases the Ca and other minerals content of leaves and may have contributed for enhanced cell division and promoting root growth (Sathya *et al.,* 2010), which enhances nutrient absorption and finally the tree growth (Dole and Wilkins 2005).

Incremental plant height. The measured increase in height of apple trees over a specific time period, reflecting their vertical growth and development, an important indicator of tree vigor and potential yield. The results revealed that incremental plant height was significantly affected by treatments during 2018, 2019 and in pooled data. T4: Calcium 10% EDTA Chelated @ 300 mg/l recorded highest value for incremental plant height (41.48 cm, 42.41 cm and 41.95cm), (40.86 cm, 41.79 cm and 41.33 cm) in T_3: Calcium 10% EDTA Chelated @ 250 mg/l, (40.09 cm, 41.02 cm and 40.56 cm) in T_2: Calcium 10% EDTA Chelated @ 200 mg/l, (39.63 cm, 40.56 cm and 40.10 cm) in T_5: Non chelated Ca @ 1080 mg/l and (38.42 cm, 38.61 cm and 38.52 cm) in T_1(water spray). The highest to lowest order of treatments are as T4: Calcium 10% EDTA Chelated @ 300 mg/l >T3: Calcium 10% EDTA Chelated @ 250 mg/l > T2: Calcium 10% EDTA Chelated @ 200 mg/l > T5: Non chelated Ca @ 1080 mg/l> T1: Water spray. Increases N uptake by stimulating lateral root production through cell division and enlargement and shoot size increases, which can be attributed to the synergistic relationship between Ca and N Calcium aids in incremental plant height by promoting cell elongation and division, strengthening cell walls and facilitating upward growth. Adequate calcium availability supports the structural integrity and vigor of growing apple trees, leading to increased height (Bhat *et al.,* 2006; Ahad *et al.,* 2018; Tahir *et al.,* 2022).

Plant girth (cm). The circumference or girth measurement around the trunk of apple trees, indicating their thickness and overall size, important for assessing tree growth and maturity in orchards. Among the five treatments, the significantly highest plant girth (28.7cm, 28.78 cm and 28.74 cm) was observed in T_4: Calcium 10% EDTA Chelated @ 300 mg/l during 2018, 2019 and in pooled data followed by 28.37 cm, 28.45 cm and 28.41 cm in T_3: Calcium 10% EDTA Chelated @ 250 mg/l >27.78 cm, 27.86 cm and 27.82 cmin $_2$: Calcium 10% EDTA Chelated @ 200 mg/l >27.89 cm, 27.97 cm and 27.93 cm in T_5: Non chelated Ca @ 1080 mg/l. The lowest values for plant girth (27.45 cm, 27.48 cm and 27.47 cm), were recorded in T_1 (water spray).

Calcium spray can increase plant girth by promoting cell division and strengthening cell walls. Calcium is a vital nutrient for plant growth and development, playing a crucial role in cell division and expansion. When applied as a spray, calcium enhances cell wall formation, leading to thicker and stronger cell walls. This results in increased structural support for the plant, allowing it to grow thicker stems and branches, ultimately contributing to greater overall girth (Ahad *et al.,* 2018; Thor, 2019).

Leaf area. The total surface area covered by leaves on apple trees, crucial for photosynthesis, nutrient uptake and overall tree health, often measured to assess tree vigor and productivity. T_4: Calcium 10% EDTA Chelated @ 300 mg/l recorded significantly highest leaf area during 2021, 2022 and in pooled data (34.23cm^2, 34.29 cm^2 and 34.26 cm^2), followed by T_3: Calcium 10% EDTA Chelated @ 250 mg/l (33.58 cm^2, 33.64 cm^2 and 33.61 cm^2)> T_2: Calcium 10% EDTA Chelated @ 200 mg/l (32.87 cm^2, 32.93 cm^2 and 32.90 cm^2) > T_5: Non chelated Ca @ 1080 mg/l (32.90 cm^2, 32.96 cm^2 and 32.93 cm^2). The lowest values for leaf area (31.54 cm^2, 31.57 cm^2 and 31.56 cm^2) was recorded in T_1 (Water spray). Calcium plays a crucial role in leaf expansion and development by promoting cell wall structure and integrity. Adequate calcium levels facilitate the formation of strong cell walls, allowing cells to expand and elongate effectively during leaf growth. Additionally, calcium regulates cell division and differentiation processes, contributing to the development of healthy and robust leaf tissues. Consequently, sufficient calcium availability promotes optimal leaf area expansion, enhancing the overall photosynthetic capacity and vigor of apple trees. (Hocking *et al.,* 2016; Thor, 2019; Falcioni *et al.,* 2020).

Fruit length, fruit diameter and length/diameter ratio. The longitudinal measurement of apples, indicating their size and potential market value, crucial for determining consumer preference and fruit quality in orchards. The data revealed that treatment T_4: Calcium 10% EDTA Chelated @ 300 mg/l recorded

significantly highest fruit length during 2021, 2022 and in pooled data (7.99 cm, 8.00 cm and 8.00 cm), followed by T_3: Calcium 10% EDTA Chelated @ 250 mg/l (7.91 cm, 7.92 cm and 7.92 cm)> T_2: Calcium 10% EDTA Chelated @ 200 mg/l (7.83 cm, 7.84 cm and 7.84cm)> T_5: Non chelated Ca @ 1080 mg/l (7.72 cm, 7.73 cm and 7.73 cm). The lowest values for fruit length (7.60 cm, 7.61 cm and 7.61 cm) were recorded in T_1(Water spray).

The measurement across the widest part of apples, reflecting their overall size and shape, important for estimating yield and assessing fruit quality in orchards. The significantly highest fruit length was observed in T4: Calcium 10% EDTA Chelated @ 300 mg/l recorded highest value for fruit diameter (7.82 cm, 7.83 cm and 7.83 cm), (7.78 cm, 7.79 cm and 7.79 cm) in T_3: Calcium 10% EDTA Chelated @ 250 mg/l, (7.71 cm, 7.72 cm and 7.72 cm) in T_2: Calcium 10% EDTA Chelated @ 200 mg/l, (7.65 cm, 7.66 cm and 7.66 cm) in T_5: Non chelated Ca @ 1080 mg/l and (7.58 cm, 7.59 cm and 7.59 cm) in T_1(water spray). The highest to lowest order of treatments are as T4: Calcium 10% EDTA Chelated @ 300 mg/l >T3: Calcium 10% EDTA Chelated @ 250 mg/l > T2: Calcium 10% EDTA Chelated @ 200 mg/l > T5: Non chelated Ca @ 1080 mg/l> T1: Water spray

The ratio between the length and diameter of apples, indicating their elongation and symmetry, often used to assess fruit shape and marketability in orchards. Data pertaining to effect of foliar application of chelated Ca and non-chelated Ca on length/diameter ratio is presented in Table 2 during 2018, 2019 and in pooled data. Among all treatments, the significantly highest length/diameter ratio (1.022, 1.022 and 1.022) was observed in T_4: Calcium 10% EDTA Chelated @ 300 mg/l followed by 1.017, 1.017 and 1.017 in T_3: Calcium 10% EDTA Chelated @ 250 mg/l >1.016, 1.016 and 1.016 in T_2: Calcium 10% EDTA Chelated @ 200 mg/l >1.009, 1.009 and 1.009cmin T_5: Non chelated Ca @ 1080 mg/l. The lowest values for length/diameter ratio (1.003, 1.003 and 1.003), were recorded in T_1(water spray). Calcium plays a crucial role in cell wall development and integrity in apple fruits. Adequate calcium levels contribute to stronger cell walls, facilitating cell elongation and expansion. This results in increased fruit length and diameter. Moreover, balanced calcium levels can enhance fruit shape uniformity, leading to an optimal length-to-diameter ratio. Overall, calcium's influence on cell structure promotes desirable fruit size and shape characteristics in apple cultivation (Kowalik *et al.,* 2020). Mursec. 2004 noted that foliar sprays of Ca had a significant effect on the Ca content of the fruit, which in turn significantly affected fruit weight and size. Similar results were obtained by Bhat *et al.* (2009) due to $CaCl_2$ sprays in pear *cv.* Bartlett in Kashmir, in different fruit crops (Raese and Drake 2002; Hagag *et al*., 2011).

Fruit weight (g). The measured mass of individual apples, crucial for estimating yield and assessing fruit quality, often used to determine market value and consumer preference in orchards. The perusal of data in Table 2 revealed that treatment T_4: Calcium 10% EDTA Chelated @ 300 mg/l recorded significantly highest fruit weight during 2021, 2022 and in pooled data (233.33 g, 233.83 g and 233.58 g), followed by T_3: Calcium 10% EDTA Chelated @ 250 mg/l (228.25 g 228.75 g and 228.50 g)> T_2: Calcium 10% EDTA Chelated @ 200 mg/l (223.39 g, 223.89 g and 223.64 g)> T_5: Non chelated Ca @ 1080 mg/l (219.48 g, 219.98 g and 219.73 g). The lowest values for fruit weight (213.79 g, 214.29 g cm and 214.04 g) were recorded in T_1(Water spray). Calcium plays a crucial role in fruit development and weight gain by aiding in cell division, cell elongation and cell wall formation. Adequate calcium availability ensures proper fruit cell expansion, leading to larger and heavier fruits. Calcium also influences fruit texture and firmness, contributing to overall fruit quality. Through these mechanisms, calcium positively impacts fruit weight, resulting in the production of larger and more marketable fruits in apple orchards (Hocking *et al.,* 2016; Prashar *et al.,* 2022). Kadir (2005) also observed 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) noted that adding Ca (as foliar sprays) had a significant effect on the Ca content of the fruit, which in turn significantly affected fruit weight and size.

Yield and yield efficiency. The total quantity of harvested apples from trees in an orchard, indicating the productivity and economic value of apple cultivation, a key metric for assessing orchard performance and profitability. The results presented in Table 3 confirmed that yield was significantly affected by treatments during 2018, 2019 and in pooled data. T4: Calcium 10% EDTA Chelated @ 300 mg/l recorded highest value for yield (18.41 Kg/plant, 19.50 Kg/plant and 18.96 Kg/plant), (17.37 Kg/plant, 18.17 Kg/plant and 17.77 Kg/plant) in T_3: Calcium 10% EDTA Chelated @ 250 mg/l, (16.52 Kg/plant, 17.13 Kg/plant and 16.83 Kg/plant) in T_2: Calcium 10% EDTA Chelated @ 200 mg/l, (16.21 Kg/plant, 17.01 Kg/plant and 16.61 Kg/plant) in T_5: Non chelated Ca @ 1080 mg/l and (16.05 Kg/plant, 16.15 Kg/plant and 16.10 Kg/plant) in T_1(water spray). The highest to lowest order of treatments are as T4: Calcium 10% EDTA Chelated @ 300 mg/l >T3: Calcium 10% EDTA Chelated @ 250 mg/l > T2: Calcium 10% EDTA Chelated @ 200 mg/l > T5: Non chelated Ca @ 1080 mg/l> T1: Water spray. Calcium plays a crucial role in fruit yield by enhancing various physiological processes in plants. It strengthens cell walls, improving fruit firmness and reducing post-harvest losses. Calcium regulates enzyme activity, facilitating nutrient uptake and metabolism, which promotes overall plant growth and development. Additionally, calcium helps in fruit development and reduces disorders such as bitter pit, thereby increasing fruit yield. Ca increases plant height by increasing mitotic activity in the terminal meristem (Kadir, 2004; Mazumder *et al.,* 2021; Prashar *et al.,* 2022). Accumulation of Ca in leaves enhances the Ca and other minerals content of leaves and may have

contributed for improved cell division and promoting root growth, which boosts nutrient absorption (Sathya *et al.,* 2010). Thus, the application of calcium increases yield (Dole and Wilkins 2005).

The ratio of yield to a specific input or resource, such as land area or tree canopy, reflecting the efficiency of apple production in orchards, crucial for optimizing resource utilization and maximizing profitability. Data pertaining to effect of foliar application of chelated Ca and non-chelated Ca on yield efficiency is presented in Table 3 during 2018, 2019 and in pooled data. Among all treatments, the significantly highest yield efficiency (0.28 kg/cm^2, 0.29 kg/cm^{2}and 0.29 kg/cm^2) was observed in T_4: Calcium 10% EDTA Chelated @ 300 mg/l followed by 0.27 kg/cm^2, 0.28 kg/cm^2 and 0.28 kg/cm^2 in T_3: Calcium 10% EDTA Chelated @ 250 mg/l >0.26 kg/cm^2, 0.28 kg/cm^2 and 0.27 kg/cm^2 in T_2: Calcium 10% EDTA Chelated @ 200 mg/l >0.26 kg/cm^2, 0.27 kg/cm^2 and 0.27 kg/cm^2 in T_5: Non chelated Ca @ 1080 mg/l. The lowest values for yield efficiency (0.25 kg/cm^2, 0.24 kg/cm^2 and 0.25 kg/cm^2), were recorded in T_1(water spray). Calcium plays a pivotal role in improving yield efficiency by enhancing various physiological processes in apple trees, such as cell wall structure and enzyme activation. This leads to better fruit quality and increased resistance to physiological disorders, ultimately maximizing the productivity and economic value of apple cultivation (Prashar *et al.,* 2022).

Table 1: Influence of foliar application of chelated Ca and non-chelated Ca on Annual shoot extension growth, Incremental plant height, Plant girth and leaf area of high density apple cv. Silver Spur.

Treatments	Annual shoot extension growth (cm)			Incremental plant height (cm)			Plant girth (cm)			Leaf Area (cm^2)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1: Water spray	50.52	50.73	**50.63**	38.42	38.61	**38.52**	27.45	27.48	**27.47**	31.54	31.57	**31.56**
T_2: Calcium 10% EDTA Chelated @ 200 mg/l	51.04	51.59	**51.32**	40.09	41.02	**40.56**	27.78	27.86	**27.82**	32.87	32.93	**32.90**
T_3: Calcium 10% EDTA Chelated @ 250 mg/l	51.37	51.92	**51.65**	40.86	41.79	**41.33**	28.37	28.45	**28.41**	33.58	33.64	**33.61**
T_4: Calcium 10% EDTA Chelated @ 300 mg/l	51.63	52.18	**51.91**	41.48	42.41	**41.95**	28.7	28.78	**28.74**	34.23	34.29	**34.26**
T_5: Non chelated Ca @ 1080 mg/l	50.84	51.39	**51.12**	39.63	40.56	**40.10**	27.89	27.97	**27.93**	32.90	32.96	**32.93**
CD(p≤0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.534**	**0.561**	**0.546**

Table 2: Influence of foliar application of chelated Ca and non-chelated Ca on Fruit length, diameter, L/D ratio and Fruit weight of high density apple cv. Silver Spur.

Treatments	Fruit length (cm).			Fruit diameter (cm).			L/D ratio			Fruit weight (g).		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1: Water spray	7.60	7.61	**7.61**	7.58	7.59	**7.59**	1.003	1.003	**1.003**	213.79	214.29	**214.04**
T_2: Calcium 10% EDTA Chelated @ 200 mg/l	7.83	7.84	**7.84**	7.71	7.72	**7.72**	1.016	1.016	**1.016**	223.39	223.89	**223.64**
T_3: Calcium 10% EDTA Chelated @ 250 mg/l	7.91	7.92	**7.92**	7.78	7.79	**7.79**	1.017	1.017	**1.017**	228.25	228.75	**228.50**
T_4: Calcium 10% EDTA Chelated @ 300 mg/l	7.99	8.00	**8.00**	7.82	7.83	**7.83**	1.022	1.022	**1.022**	233.33	233.83	**233.58**
T_5: Non chelated Ca @ 1080 mg/l	7.72	7.73	**7.73**	7.65	7.66	**7.66**	1.009	1.009	**1.009**	219.48	219.98	**219.73**
CD (p≤0.05)	**0.673**	**0.681**	**0.677**	**0.683**	**0.689**	**0.686**	**NS**	**NS**	**NS**	**1.016**	**1.046**	**1.053**

Table 3:Influence of foliar application of chelated Ca and non-chelated Ca on Yield and Yield efficiency of high-density apple cv. Silver Spur.

Variant	Yield (kg/plant)			Yield efficiency (kg/cm^2)		
	2021	2022	Pooled	2021	2022	Pooled
T_1: Water spray	16.05	16.15	**16.10**	0.25	0.24	**0.25**
T_2: Calcium 10% EDTA Chelated @ 200 mg/l	16.52	17.13	**16.83**	0.26	0.28	**0.27**
T_3: Calcium 10% EDTA Chelated @ 250 mg/l	17.37	18.17	**17.77**	0.27	0.28	**0.28**
T_4: Calcium 10% EDTA Chelated @ 300 mg/l	18.41	19.5	**18.96**	0.28	0.29	**0.29**
T_5: Non chelated Ca @ 1080 mg/l	16.21	17.01	**16.61**	0.26	0.27	**0.27**
CD(P≤0.05)	**0.304**	**0.335**	**0.342**	**0.007**	**0.010**	**0.015**

CONCLUSIONS

This study confirms the superiority of chelated nutrients over non-chelated ones in stimulating the growth and yield of high-density Silver Spur apple cultivars in temperate climates. This underscores the efficacy of foliar nutrient sprays as a vital strategy for orchardists aiming to enhance orchard productivity. We advocate for the adoption of foliar nutrient applications using chelated formulations to improve both the nutritional quality and yield of Silver Spur apples. These findings provide valuable insights for growers, empowering

them to make informed decisions and optimize their orchard management practices effectively. By implementing these recommendations, growers can maximize the potential of their orchards and achieve sustainable success in apple cultivation.

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Conflict of Interest. None.

REFERENCES

Ahad, S., Mir, M., Ashraf, S., Mumtaz, S., & Hamid, M. (2018). Nutrient management in high density apple orchards–A Review. *Current Journal of Applied Science and Technology*, *29*(1), 1-16.

Ahmad, R., Hussain, B., & Ahmad, T. (2021). Fresh and dry fruit production in himalayan Kashmir, sub-Himalayan Jammu and trans-himalayan Ladakh, India. *Heliyon*, *7*(1).

Ahmed, N., Zhang, B., Chachar, Z., Li, J., Xiao, G., Wang, Q., & Tu, P. (2024). Micronutrients and their effects on horticultural crop quality, productivity and sustainability. *Scientia Horticulturae*, *323*, 112512.

Bhat, Z. A., Wani, M. S., & Wani, W. M. (2006). Evaluation of newly introduced apple cultivars for their vegetative characteristics. *Annals of Biology, 22*(1), 47-48.

Dole, J. M., & Wilkins, H. F. (1999). Floriculture: Principles and species, *Prentice-Hall Inc.*613.

Falcioni, R., Moriwaki, T., Perez-Llorca, M., Munné-Bosch, S., Gibin, M. S., Sato, F., & Antunes, W. C. (2020). Cell wall structure and composition is affected by light quality in tomato seedlings. *Journal of Photochemistry and Photobiology B: Biology*, *203*, 111745.

FAO; IFAD; WFP. The State of Food Insecurity in the World 2015. FAO: Rome, Italy, 6-15.

FAO-Food and Agriculture Organization of the United Nations (FAO). (2018). Production Year Book; FAO: Rome, Italy, 11-15

FAOSTAT (2021). Available online: http://www.fao.org/faostat/en/#data/QC

Fotiric Akšic, M., Dabic Zagorac, D., Gašic, U., Tosti, T., Natic, M., & Meland, M. (2022). Analysis of Apple Fruit (Malus× domestica Borkh.) Quality Attributes Obtained from Organic and Integrated Production Systems. *Sustainability, 14*, 5300.

Fruit: World Production by Type 2019 Statista. Available online:https://www.statista.com/statistics/264001/worldwideproductionof-fruit-by-variety/ (accessed on 22 March 2021).

Gołębiewska, E., Kalinowska, M., & Yildiz, G. (2022). Sustainable use of apple pomace (AP) in different industrial sectors. *Materials*, *15*(5), 1788.

Haggag, L., Shahin, M. F. M., Genaidy, E. A. E., & Fouad, A. A. (2013). Changes in fruit weight, dry matter, moisture content and oil percentage during fruit development stages of two olive cultivars. *Middle East Journal*, *2*, 21-27.

Hocking, B., Tyerman, S. D., Burton, R. A., & Gilliham, M. (2016). Fruit calcium: transport and physiology. *Frontiers in plant science*, *7*, 182808.

Kadir, S. A. (2005). Fruit quality at harvest of "Jonathan" apple treated with foliarly-applied calcium chloride. *Journal of plant nutrition*, *27*(11), 1991-2006.

Kowalik, P., Lipa, T., Michałojć, Z., & Chwil, M. (2020). Ultrastructure of cells and microanalysis in Malus domestica Borkh.'Szampion'fruit in relation to varied calcium foliar feeding. *Molecules*, *25*(20), 4622.

Mazumder, M. N. N., Misran, A., Ding, P., Wahab, P. E. M., & Mohamad, A. (2021). Effect of harvesting stages and calcium chloride application on postharvest quality of tomato fruits. *Coatings*, *11*(12), 1445.

Muršec, M. (2004). Influence of foliar feeding with calcium on fruit quality in apples. *Zbornik referatov 1. Slovenskega sadjarskega kongresa z mednarodno udeležbo, Krško, Slovenia, 24-26 marec 2004. Del 1*, 145-151.

National Horticulture Board (NHB) (2012). Indian Horticulture Database-2012, Ministry of Agriculture, Government of India.

Parrey, S. H., & Hakeem, I. A. (2015). Exploring marketing activities of apple growers: empirical evidence from Kashmir. *Pacific Business Review International*, *7*(12), 73-74.

Prashar, N., Bakshi, M., Shilpa, C., & Ughareja, A. (2022). Role of micro-nutrients in fruit production: A review.

Prashar, N., Bakshi, M., Shilpa, C., & Ughareja, A. (2022). Role of micro-nutrients in fruit production: A review.

Quality Attributes Obtained from Organic and Integrated Production Systems. Sustainability 2022, *14*, 5300. [CrossRef]

Raese, J. T., & Drake, S. R. (2006). Calcium foliar sprays for control of alfalfa greening, cork spot, and hard end in 'Anjou' pears. *Journal of Plant Nutrition, 29*, 543-552.

Sathya, S., Mani, S., Mahendran, P. P., & Arulmozhiselvan, K. (2010). Effect of application of boron on growth, quality and fruit yield of PKM 1 tomato. *Indian Journal of Agricultural Research*, *44*(4), 274-280.

Tahir, M. M., Mao, J., Li, S., Li, K., Liu, Y., Shao, Y., & Zhang, X. (2022). Insights into factors controlling adventitious root formation in apples. *Horticulturae*, *8*(4), 276.

Thor, K. (2019). Calcium-nutrient and messenger. *Frontiers in plant science*, *10*, 449564.

Wani, S. A., Kumar, S., Naqash, F., Shaheen, F. A., Wani, F. J., & Rehman, H. U. (2021). Potential of Apple Cultivation in Doubling Farmer's Income through Technological and Market Interventions: An Empirical Study in Jammu & Kashmir. *Indian Journal of Agricultural Economics*, *76*(2), 278-291.

WAR-World Apple Review; World fruit market analysts; Belrose, Inc.: Pullman, WA, USA, 2018; p. 20.

Westwood, M. N. (1993). Temperate-zone pomology: physiology and culture (Third Edition). Timber Press, Oregon.

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