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Research Paper

Effect of crop load on leaf and fruit nutrient status in apple cv. Gala Redlum

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ABSTRACT

The present investigation on effect of crop load on leaf and fruit nutrient status in apple cv. Gala Redlum was carried out at experimental field of Division of Fruit Science, SKUAST-Kashmir during the year 2021-2022. The experiment was carried out in RCBD with three replications on 4-year-old "Gala Redlum" plants grafted on M9 rootstock in a high density orcharding system, which were hand thinned to C2:4; C3: 6; C4: 8; C5:10 fruits per cm^2 of TCSA and no thinning as C1: control. The results obtained revealed that the maximum leaf N (2.492 %), leaf P (0.277 %), leaf K (1.605 %), leaf Ca (15466.60 ppm) and fruit N (0.322 %), fruit P (0.192 %), fruit K (0.945 %) was obtained from C_2 (4 fruits per cm^2 of TCSA). On the basis of TCSA, maximum leaf N (2.236 %), leaf P (0.232 %), leaf K (1.395 %), leaf Ca (13933.33ppm), fruit N (0.288 %), fruit P (0.144 %), fruit K (0.883 %) was recorded under S_2 (10-12 cm^2 TCSA). Moreover, maximum leaf N (2.507 %), leaf P (0.287 %), leaf K (1.610 %) leaf Ca (15866.66 ppm), fruit N (0.327 %), fruit P (0.197 %), fruit K (0.950 %) were recorded under C_2S_2 followed by C_3S_2 treatment combination. Maximum fruit Ca (10866.66ppm) was recorded under C_1S_1 treatment combination. Results of the present study revealed that thinning of Gala Redlum apples is very important not only for ensuring the optimum nutritional status of the plant but also for a good quality yield in the current year and subsequently a good return bloom in the next year. Furthermore, the data from the present study suggests that a threshold for optimal fruit quality and consistent bloom was obtained around 6 fruits/ cm^2 of TCSA.

Key words: Apple, calcium, fruit, gala redlum, leaf, nitrogen, phosphorus, thinning

The premier table fruit of the world is the cultivated apple *(Malus x domestica* Borkh.*)* and is known as "King of temperate fruits". Apple is one of the most important temperate fruit of north western Himalayan region. It belongs to the Rosaceae family and is believed to have originated in temperate region of western Asia between Black Sea and Caspian Sea. The cultivated apple, is an interspecific hybrid complex of allopolyploid origin (Korban and Skirvin, 1984). Apple is produced by more than 90 countries of the world. Globally apple is grown over an area of 4,717,384 ha with annual production of 79,139,368 MT (FAOSTAT, 2019). In India it is grown over an area of 309,000 ha with total production of 27,83,000 MT predominantly grown in Jammu and Kashmir, Himachal Pradesh, Uttaranchal, Arunachal Pradesh and Nagaland (Anonymous, 2020a). The leading producer is Jammu and Kashmir with an area of 164,742 ha and production of 18,82,319 MT (Anonymous, 2020b). Commercially apple is the most important fruit of Kashmir valley. The productivity of apple in Jammu and Kashmir is around 11MT/ha though it appears to be highest among the apple producing states in the country yet it is far below the level achieved by the horticulturally advanced countries and also the proportion of A-grade apple is low.

In high density orcharding system under good management practices most of the varieties result in heavy bloom and fruit set. Excessive crop load on fruit trees leads to biennial bearing. This can result in economic losses both in "on" year when excessive cropping leads to reduced fruit size and in "off" year when yields can be light or non- existent. There is a strong market for graded high quality apples. Export markets primarily exist for high quality fruit in large count size. In recent years growers have relied primarily on chemical thinning to adjust crop load with a lesser reliance on hand thinning to reduce labour requirement. But in India hand thinning is still the primary means of adjusting crop load. The standard industry practice for crop load management in many countries is based on chemical thinning (CT), with thinning chemicals applied during the bloom and post-bloom periods, followed up with hand thinning. However, the response to chemical thinning is weather-dependent and there is considerable variation between cultivars in sensitivity to thinning chemicals (Bound and Wilson, 2007).

Several different methods of crop manipulation have been described by Costa *et al*. (2013) including mechanical thinning, flower thinning by hand and bud extinction during the dormant winter period. The thinning programs therefore are intended to maintain a uniform crop load through the years with enhanced quality and marketable size of fruits. Keeping in view the importance and economic value of thinning the investigation therefore was carried out to study the effect of crop load on leaf and fruit nutrient status in apple cv. Gala Redlum.

MATERIALS AND METHODS

The experiment was conducted on four year old apple trees cv. Gala Redlum on M-9 rootstock at the Experimental Farm of the Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar campus during the year 2021-22. The recommended package of practices were followed with regard to fertilizer, irrigation and other cultural requirements. The treatments were allocated in a Randomized Complete Block Design (RCBD) with three replications in a factorial experiment, with two factors i.e., hand thinning (at 10-12mm fruit size) and trunk cross-sectional area (TCSA). The experimental details are as under:

Crop	Apple (*Malus x domestica* Borkh.)
Variety	Gala Redlum
Total number of treatments	10
Replications	03
Total number of trees	30
Design	RCBD (Randomized Complete Block Design- Factorial)
Factor 1	Trunk Cross- Sectional Area (TCSA)
Levels	Two
	S1: 8-10 cm^2
	S2: 10-12 cm^2
Factor 2	Crop load
Levels	Five
	C1: control (No thinning)
	C2: 4 fruits per cm^2 of TCSA
	C3: 6 fruits per cm^2 of TCSA
	C4:8 fruits per cm^2 of TCSA
	C5: 10 fruits per cm^2 of TCSA

Observations recorded: The various observations recorded are described as under:

Leaf nutrient status: Leaf samples were collected at medium height from four sides of the tree consisting of middle portion of current season's terminal shoot growth. A composite sample of 30 to 40 leaves per tree were taken for analysis. Leaf samples were decontaminated with water and 0.2% liquid detergent to remove dirt and other extraneous stuff. Leaves were again washed meticulously with N/10 HCl and distilled water to eliminate metallic adulteration. Additional moisture was removed and samples were kept in paper bags and dehydrated in a hot air oven at 65ºC. Dried leaves were crushed in an electrical grinder and packed in aluminum coated paper bags for further analysis.

Fruit nutrient status: Fruit samples of about 15 fruits per treatment were collected randomly at the time of harvest and taken for analysis. Fruit samples were cleaned meticulously under tap water and with 0.2% liquid detergent after that fruits were again washed thoroughly with N/10 HCl and distilled water to eliminate metallic impurities. Samples were sliced and dehydrated in hot air oven at 65ºC. Dried samples were ground in an electrical grinder and preserved in polythene bags for further analysis.

Nitrogen: Leaf and fruit nitrogen contents were estimated by digesting the samples in concentrated sulphuric acid in presence of digestion mixture containing potassium sulphate, ferrous sulphate and copper sulphate in the ratio of 10:1:0.5. Then 0.5gram of powdered sample was taken in digestion tube to which a pinch of digestion mixture and 10 ml of H_2SO_4 was added to the tube placed in a digestion block at 420ºC till the solution turned out to be whitish green. Content of nitrogen in apple leaves was assessed by micro Kjeldahl's method recommended by Jackson (1973). 20ml of digested sample was taken in a digested tube and fit in to the Nitrogen Analyser. 10 ml of 4% boric acid solution comprising of bromocresol green and methyl red indicator was taken in a conical flask. The flask was kept so that condenser orifice of distillation apparatus was immersed into boric acid solution. NaOH (40%) was transferred to the micro- Kjeldahl assembly distillation continued for about 5 minutes till the nitrogen Analyser stopped and boric acid changed into green color. After the process of digestion was over, boric acid was titrated against N/50 H_2SO_4. A blank was also run to a similar end point as that of sample.

Fruit nitrogen content was estimated by Kjeldahl's method proposed by Jackson (1973). 0.5g of ground fruit sample was digested in concentrated sulphuric acid (H_2SO_4) and distilled with sodium hydroxide (NaOH-40%). Ammonium N was fixed in H_3BO_3 (4%) and is titrated with 0.1N H_2SO_4 following the method suggested by Jackson (1973). Also, a blank was run to a similar end point as that of sample. Nitrogen per cent was calculated by the formula given below:

$$N(\%) = \frac{Samples\ reading - Blank\ reading\ x\ 0.014}{weight\ of\ sample\ (g)}\ x\ 100$$

P, K, and Ca analysis: Samples each of leaf and fruit were digested individually in a di-acid mixture of Nitric acid and Perchloric acid in proportion of 9:4 for estimation of phosphorus, potassium and calcium. Powdered sample one gram each of leaf and fruit were placed in a conical flask measuring 100ml to which 20 ml of di-acid (HNO_3 + perchloric acid) was added. Sample was kept under a hot flame till it changed to a clear solution and filtrate was diluted to 50 ml using deionized water.

Phosphorous: Phosphorus was measured by Vandate-molybdate colorimetric method suggested by Jackson (1973). 5ml of potassium extract was taken in a flask and 20ml of double distilled water was added to it to make volume up to 25ml. The samples were read on a flame photometer at 548nm wavelength as described by Jackson (1973). Calcium was assessed by means of atomic absorption spectrophotometer (AAS 4141) as per the method suggested by Jackson (1973) and results were expressed in percentage.

RESULTS AND DISCUSSION

Leaf nitrogen (%) was significantly affected by crop load and trunk cross sectional area (TCSA). Maximum nitrogen content (2.492%) was observed in C_2 (4 fruits per cm^2 of TCSA). Minimum (1.960 %) was recorded in control (no thinning). There was also a significant difference between leaf nitrogen content of different trunk cross-sectional area (TCSA). Significantly maximum nitrogen (2.236 %) was recorded in S_2 (10-12 cm^2 TCSA) and minimum nitrogen (2.202 %) was recorded in S1 (8-10 cm^2 TCSA).

The interaction effect of crop load and trunk cross - sectional area (TCSA) on leaf nitrogen was also significant. Maximum leaf nitrogen (2.507 %) was recorded in C_2S_2 treatment combination followed by 2.477 % in C_2S_1 treatment combination. Minimum nitrogen content (1.943%) was recorded in C_1S_1 treatment combination. The nutrient content of leaves at later growth stage showed that the total nitrogen content in the leaves with the medium and low-crop load treatments were significantly higher than that of high- crop load treatment, which also indicates that thinning fruit could significantly improve the nitrogen content of leaves, and thereby increasing the chlorophyll content of leaves. The high amount of crop load did not promote the absorption and utilization of nitrogen, which was mainly caused by the decrease of carbohydrate in roots provided by the shoot, affecting the activity of plant root and limiting the absorption and utilization of nitrogen (Ding *et al*., 2017).

Table 1: Effect of crop load on leaf nitrogen content (%) in apple cv. Gala Redlum

Crop load	TCSA		Mean
	S_1 (8-10 cm^2 TCSA)	S_2 (10-12 cm^2 TCSA)	
C_1 (No thinning)	1.943	1.977	**1.960**
C_2 (4 fruits per cm^2 of TCSA)	2.477	2.507	**2.492**
C_3 (6 fruits per cm^2 of TCSA)	2.317	2.363	**2.340**
C_4 (8 fruits per cm^2 of TCSA)	2.210	2.237	**2.223**
C_5 (10 fruits per cm^2 of TCSA)	2.063	2.097	**2.080**
Mean	**2.202**	**2.236**	
C.D ($p \leq 0.05$); Trunk cross sectional area (S) = 0.0040 ; Crop load (C) = 0.0063 ; (S×C) = 0.009			

Maximum phosphorus content (0.277 %) was observed in C_2 (4 fruits per cm^2 of TCSA) while minimum (0.170 %) was recorded under control (no thinning). There was also a significant difference between leaf phosphorus content of different trunk cross – sectional area (TCSA). Significantly maximum phosphorus (0.232 %) was recorded in S_2 (10-12 cm^2 TCSA) and minimum phosphorus (0.215 %) was recorded in S_1 (8-10 cm^2 TCSA). Differences for this particular nutrient due to Crop loads and TCSA interactions were also observed to be significant. Maximum phosphorus (0.287 %) was recorded in C_2S_2 treatment combination followed by phosphorus content of (0.267 %) in C_2S_1 treatment combination. Minimum nitrogen content (0.163 %) was recorded in C_1S_1 treatment combination. Data presented in Table-2 indicates that the phosphorus content of leaves was affected by thinning and TCSA. Increased crop load consistently decreased leaf phosphorus (Neilsen and Neilsen, 2015). This is similar to the results of Zarei *et al.* (2014) who reported that leaf mineral concentration increased in response to fruit thinning.

Table 2: Effect of crop load on leaf phosphorus content (%) in apple cv. Gala Redlum

Crop load	TCSA		Mean
	S_1 (8-10 cm^2 TCSA)	S_2 (10-12 cm^2 TCSA)	
C_1 (No thinning)	0.163	0.177	**0.170**
C_2 (4 fruits per cm^2 of TCSA)	0.267	0.287	**0.277**
C_3 (6 fruits per cm^2 of TCSA)	0.247	0.253	**0.250**
C_4 (8 fruits per cm^2 of TCSA)	0.213	0.237	**0.225**
C_5 (10 fruits per cm^2 of TCSA)	0.183	0.207	**0.195**
Mean	**0.215**	**0.232**	
C.D ($p \leq 0.05$); Trunk cross sectional area (S) = 0.0023 ; Crop load (C) = 0.0036 ; (S×C) = 0.005			

Leaf potassium (%) was significantly affected by crop load and TCSA. Maximum potassium content (1.605%) was observed in C_2 (4 fruits per cm^2 of TCSA) while minimum (1.167 %) was recorded under control (no thinning). Leaf potassium content also differed significantly with different TCSA. Maximum potassium (1.395 %) was recorded in S_2 (10-12 cm^2 TCSA) and minimum potassium (1.379 %) was recorded in S_1 (8-10 cm^2 TCSA). Leaf K was significantly reduced with increasing crop load. Atay (2016) obtained similar results when adjusting trees to crop loads of 3.5, 3.9 and 5.1 fruits/cm^2; leaf K decreased linearly as fruit load was increased. This was attributed to the large sink strength of fruit for potassium. Leaf NPK was significantly influenced by trunk cross – sectional area (TCSA). Maximum NPK was recorded under S2 (10-12 cm^2 of TCSA), while minimum was recorded under S1 (8-10 cm^2 of TCSA). Increase in NPK by increasing trunk cross-sectional area (TCSA) may be due to the fact that TCSA of the tree is directly related to transport of nutrients from root to different parts of the plant and the distribution of food materials from site of production to site of utilization Hartmann and Kester (2002).

Table 3: Effect of crop load on leaf potassium content (%) in apple cv. Gala Redlum

Crop load	TCSA		Mean
	S_1 (8-10 cm^2 TCSA)	S_2 (10-12 cm^2 TCSA)	
C_1 (No thinning)	1.163	1.170	**1.167**
C_2 (4 fruits per cm^2 of TCSA)	1.600	1.610	**1.605**
C_3 (6 fruits per cm^2 of TCSA)	1.480	1.500	**1.490**
C_4 (8 fruits per cm^2 of TCSA)	1.380	1.410	**1.395**
C_5 (10 fruits per cm^2 of TCSA)	1.273	1.287	**1.280**
Mean	**1.379**	**1.395**	
C.D ($p \leq 0.05$) ; Trunk cross sectional area (S) = 0.0080 ; Crop load (C) = 0.0126 ; (S×C) = N.S			

It was observed that crop load and trunk cross-sectional area (TCSA) significantly affected calcium content of the leaves. Maximum calcium content (15466.60 ppm) was observed in C_2 (4 fruits per cm^2 of TCSA) while minimum (12216.60ppm) was recorded under control (no thinning). There was also a significant difference between leaf calcium content of different trunk cross-sectional area (TCSA). Significantly maximum calcium content (13933.33 ppm) was recorded in S_2 (10-12 cm^2 TCSA) and minimum calcium content (13460.00 ppm) was recorded in S_1 (8-10 cm^2 TCSA). Interaction effect was found to be significant between different crop loads and TCSA for leaf calcium content. Maximum calcium (15866.66 ppm) was recorded in C_2S_2 treatment combination followed by calcium content (15066.66 ppm) in C_2S_1 treatment combination. Minimum calcium content (12066.66 ppm) was recorded in C_1S_1 treatment combination. Increased Ca by increasing trunk cross - sectional area (TCSA) may be due to the fact that TCSA of the tree is directly related to transport of nutrients from root to different parts of the plant and the distribution of food materials from site of production to site of utilization (Hartmann and Kester, 2002).

Table 4: Effect of crop load on leaf calcium content (ppm) in apple cv. Gala Redlum

Crop load	TCSA		Mean
	S_1 (8-10 cm^2 TCSA)	S_2 (10-12 cm^2 TCSA)	
C_1 (No thinning)	12066.66	12366.66	**12216.60**
C_2 (4 fruits per cm^2 of TCSA)	15066.66	15866.66	**15466.60**
C_3 (6 fruits per cm^2 of TCSA)	14066.66	14633.33	**14350.00**
C_4 (8 fruits per cm^2 of TCSA)	13266.66	13735.33	**13500.00**
C_5 (10 fruits per cm^2 of TCSA)	12833.33	13066.66	**12950.00**
Mean	**13460.00**	**13933.33**	
C.D ($p \leq 0.05$) ; Trunk cross sectional area (S) =32.35; Crop load (C) = 51.15 ; (S×C) = 72.34			

Naturally, plant mineral nutrient demand is met by supply from the roots and mineral nutrient uptake is then distributed aboveground. Low crop load and high vegetative vigor can exacerbate Ca related disorders by altering the balance in Ca distribution between the leaves and fruits (de Freitas and Mitcham, 2012). Because leaves transpire at greater rates than developing fruit, increased leaf area or decreased number of fruits can negatively affect Ca levels in fruit and cause a higher amount of Ca to be distributed to leaves. Although vegetative growth may be stimulated by crop removal which has led to the hypothesis that active shoot growth may compete with developing fruits for calcium during the season in cox's orange pippin apple (Volz *et al.*, 1993). Crop load and trunk cross-sectional area (TCSA) significantly affected nitrogen content of the fruits (Table-5). Maximum nitrogen content (0.322%) was observed in C_2 (4 fruits per cm^2 of TCSA) while minimum

(0.245 %) was recorded under control (no thinning). There was also a significant difference between fruit nitrogen content of different trunk cross-sectional area (TCSA). Significantly maximum nitrogen (0.288 %) was recorded in S_2 (10-12 cm^2 TCSA) and minimum nitrogen (0.281 %) was recorded in S_1 (8-10 cm^2 TCSA). Data pertaining to interaction studies of different crop loads and TCSA with respect to fruit nitrogen was perceived to be significant. Maximum nitrogen (0.327 %) was recorded in C_2S_2 treatment combination followed by nitrogen content (0.317 %) in C_2S_1 treatment combination. Minimum nitrogen content (0.243 %) was recorded in C_1S_1 treatment combination.

Table 5: Effect of crop load on fruit nitrogen content (%) in apple cv. Gala Redlum

Crop load	TCSA		Mean
	S_1 (8-10 cm^2 TCSA)	S_2 (10-12 cm^2 TCSA)	
C_1 (No thinning)	0.243	0.247	**0.245**
C_2 (4 fruits per cm^2 of TCSA)	0.317	0.327	**0.322**
C_3 (6 fruits per cm^2 of TCSA)	0.297	0.313	**0.305**
C_4 (8 fruits per cm^2 of TCSA)	0.283	0.287	**0.285**
C_5 (10 fruits per cm^2 of TCSA)	0.263	0.267	**0.265**
Mean	**0.281**	**0.288**	
C.D ($p \leq 0.05$) ; Trunk cross sectional area (S) = 0.0023 ; Crop load (C) = 0.0036 ; (S×C) = 0.005			

Maximum phosphorus content (0.277 %) was observed in C_2 (4 fruits per cm^2 of TCSA) and minimum (0.170%) was recorded under control (no thinning). There was also a significant difference between fruit nitrogen content of different trunk cross-sectional area (TCSA). Significantly maximum phosphorus (0.232 %) was recorded in S_2 (10-12 cm^2 TCSA) and minimum phosphorus (0.215 %) was recorded in S_1 (8-10 cm^2 TCSA). Significant effect was observed for fruit phosphorus with respect to crop load and TCSA. Maximum phosphorus (0.287%) was recorded in C_2S_2 treatment combination followed by phosphorus content (0.267 %) in C_2S_1 treatment combination. Minimum phosphorus content (0.163 %) was recorded in C_1S_1 treatment combination. Potassium content of fruits as influenced by crop load and trunk cross-sectional area differs significantly. Maximum potassium content (0.945 %) was observed in C_2 (4 fruits per cm^2 of TCSA) whereas, minimum (0.810 %) was recorded under control (no thinning).There was also a significant difference between fruit potassium content of different trunk cross-sectional area (TCSA). Significantly maximum potassium (0.883 %) was recorded in S_2 (10-12 cm^2 TCSA) and minimum potassium (0.869 %) was recorded in S_1 (8-10 cm^2 TCSA).

Table 6: Effect of crop load on fruit phosphorus content (%) in apple cv. Gala Redlum

Crop load	TCSA		Mean
	S_1 (8-10 cm^2 TCSA)	S_2 (10-12 cm^2 TCSA)	
C_1 (No thinning)	0.063	0.087	**0.075**
C_2 (4 fruits per cm^2 of TCSA)	0.187	0.197	**0.192**
C_3 (6 fruits per cm^2 of TCSA)	0.157	0.173	**0.165**
C_4 (8 fruits per cm^2 of TCSA)	0.133	0.147	**0.140**
C_5 (10 fruits per cm^2 of TCSA)	0.103	0.117	**0.110**
Mean	0.129	0.144	
C.D ($p \leq 0.05$); Trunk cross sectional area (S) = 0.0023; Crop load (C) = 0.0036; (S×C) = 0.005			

Maximum calcium content (9966.66 ppm) was observed in control (no thinning) whereas minimum (1966.66 ppm) was recorded under C_2 (4 fruits per cm^2 of TCSA). A significant effect was chronicled between fruit calcium levels and different TCSA. Maximum calcium (6453.33 ppm) was recorded in S_1 (8-10 cm^2 TCSA) and minimum calcium (5180.00 ppm) was recorded in S_2 (10-12 cm2 TCSA). Interaction effect was found to be significant between different crop load and TCSA for fruit calcium content. Maximum calcium (10866.66 ppm) was recorded in C_1S_1 treatment combination followed by calcium content (9066.66 ppm) in C_1S_2 treatment combination and minimum calcium content (1766.66 ppm) was recorded in C_2S_2 treatment combination.

Table 7: Effect of crop load on fruit potassium content (%) in apple cv. Gala Redlum

Crop load	TCSA		Mean
	S_1 (8-10 cm^2 TCSA)	**S_2 (10-12 cm^2 TCSA)**	
C_1 (No thinning)	0.807	0.813	**0.810**
C_2 (4 fruits per cm^2 of TCSA)	0.940	0.950	**0.945**
C_3 (6 fruits per cm^2 of TCSA)	0.900	0.917	**0.908**
C_4 (8 fruits per cm^2 of TCSA)	0.867	0.883	**0.875**
C_5 (10 fruits per cm^2 of TCSA)	0.830	0.850	**0.840**
Mean	**0.869**	**0.883**	
C.D ($p \leq 0.05$); trunk cross sectional area (S) = 0.0092 ; crop load (C) =0.0146 ; (S×C) = N.S			

Fruit NPK (%) was significantly influenced by thinning treatment and TCSA. Maximum NPK was obtained in C_2 (4 fruits per cm^2 of TCSA) while as minimum was recorded in control (no thinning). Increase in NPK content might be due to the fact that crop load affects mineral contents particularly in fruit of light cropping trees in which higher contents of N, P and K were observed due to the larger size of fruit (Fallahi *et al*., 1984). Fruit K also decreased with increased fruit load. This may be due to a dilution effect, as there is a limited amount of K and a higher amount of fruit to disperse the K across in higher cropped trees. Fruits on heavily thinned trees or the larger fruits have the higher concentrations of potassium (Sharples, 1964). These results are also in line with the finding of Wunsche and Ferguson (2005) who reported that fruit from light cropping trees, attributed to the greater fruit size and higher concentrations of phosphorus and nitrogen in the fruit. Neilsen and Neilsen (2015) in their study determined that fruit K and P concentrations decreased at high crop load. Bound (2010) reported that the effect of thinning was generally to increase phosphorus and potassium concentration in the fruit at harvest, the greatest effect being associated with the early period of thinning (5 to 20 days after full bloom).

Table 8: Effect of crop load on fruit calcium content (%) in apple cv. Gala Redlum

Crop load	TCSA		Mean
	S_1 (8-10 cm^2 TCSA)	**S_2 (10-12 cm^2 TCSA)**	
C_1 (No thinning)	10866.66	9066.66	**9966.66**
C_2 (4 fruits per cm^2 of TCSA)	2166.66	1766.66	**1966.66**
C_3 (6 fruits per cm^2 of TCSA)	4266.66	3133.33	**3700.00**
C_4 (8 fruits per cm^2 of TCSA)	6533.33	4966.66	**5750.00**
C_5 (10 fruits per cm^2 of TCSA)	8433.33	6966.66	**7700.00**
Mean	**6453.33**	**5180.00**	
C.D ($p \leq 0.05$); Trunk cross sectional area (S) = 32.35 ;Crop load (C) = 51.15 (S×C) = 72.34			

Fruit Ca was significantly influenced by thinning treatment. High vegetative vigor can lead to transpiration imbalances and less Ca being allocated to the developing fruit as Ca is immobile in the phloem, Calcium that is absorbed by other plant organs cannot be translocated to the fruit (Wunsche and Ferguson, 2005). The amount of affected fruit can increase dramatically in situations of excessive vigor and/or low crop loads. Wunsche and Ferguson (2005) reported that larger fruit have lower Ca concentrations suggesting that high fruit growth rates in late stages of fruit development can lead to fruit Ca deficiencies. Fruit from heavily cropped trees has been shown to have higher calcium and lower potassium content than fruit from light cropped trees (Volz *et al*., 1993).

CONCLUSION

The present investigation on the effect of crop load on the nutrient status of leaves and fruits in apple cv. Gala Redlum reveals that optimal thinning significantly enhances nutrient content and fruit quality. The maximum leaf and fruit nutrient levels were observed in trees thinned to 4 fruits per cm² of TCSA, with the combination of 10-12 cm² TCSA yielding the highest nutrient concentrations. These results underscore the importance of thinning for maintaining optimal nutritional status and achieving high-quality yield. The study suggests that maintaining around 4-6 fruits per cm² of TCSA is crucial for optimal fruit quality and consistent return bloom, highlighting the critical role of crop load management in high-density orcharding systems.

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