Original Research Article

Effect of crop load on Yield and QualityParameters in apple cv. Gala Redlum

ABSTRACT

The present study was conducted at the experimental field of the Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir during the year 2021-2022. The primary objective of this study was to assess the impact of varying crop loads on the growth, yield, quality, and return bloom of Gala Redlum apples, with specific emphasis on trunk cross-sectional area (TCSA). The experimental design involved a Randomized Complete Block Design (RCBD) with three replications, utilizing 4-year-old Gala Redlum plants. The trees were subjected to manual thinning, resulting in crop loads of 4, 6, 8, 10 fruits per cm² of TCSA, with a non-thinned control group. Notably, the maximum fruit yield (18.52 kg/tree) was observed in the control group (no thinning), while the minimum yield (7.57 kg/tree) was recorded in the C_2 group (4 fruits per cm² of TCSA), followed by C_3 (11.03 kg/tree). Furthermore, the impact of different TCSA ranges on fruit yield was statistically significant. The maximum fruit yield (14.45 kg/tree) was observed in the S_2 group (10-12 cm² TCSA), while the minimum yield (12.16 kg/tree) was noted in the S_1 group (8-10 cm² TCSA). Yield efficiency, measured as yield per unit of TCSA, reached its highest (1.838 kg/cm²) in the control group and is lowest (0.766 kg/cm²) in the C_2 group (4 fruits per cm² of TCSA).The results further revealed that the C_2 group (4 fruits per cm² of TCSA) exhibited the maximum Total Soluble Solids (TSS) content (14.73 °Brix), total sugars (11.62%), and TSS: Acid ratio (61.45). Similarly, the C_3 group (6 fruits per cm² of TCSA) demonstrated elevated TSS (14.20 °Brix), total sugars (10.99%), and TSS: Acid ratio (54.66). Additionally, the S_2 group (10-12 cm² TCSA) recorded the highest TSS (13.75 °Brix), total sugars (10.51%), and TSS: Acid ratio (50.53).The combination of C_2S_2 and C_3S_2 treatments exhibited superior results, with the highest TSS (14.82 °Brix), total sugars (11.77%), and TSS: Acid ratio (62.64). Fruit firmness (8.81 kg/cm²) and fruit acidity (0.327%) were maximized in the C_1S_1 treatment combination.

***Keywords*:** Hand thinning, TCSA, TSS, fruit firmness, Acidity.

INTRODUCTION

The apple (*Malus x domestica*Borkh), belonging to the family Rosaceae, is a robust and widely cultivated temperate fruit across the globe. In India, it thrives in the Himalayan region, spanning from Jammu and Kashmir to Arunachal Pradesh, with a concentration in the North-Western region between latitudes 28^o and 30^oN. Globally, apple cultivation covers 4,717,384 hectares, yielding approximately 79,139,368 metric tons (FAOSTAT, 2019).In India, it occupies 309,000 hectares, with a total production of 27,83,000 metric tons, primarily in Jammu and Kashmir, Himachal Pradesh, Uttaranchal, Arunachal Pradesh, and Nagaland (Anonymous, 2020a).

Jammu and Kashmir lead in apple production, with 164,742 hectares and 18,82,319 metric tons (Anonymous, 2020b).Despite its significance in the Kashmir Valley, the apple productivity in Jammu and Kashmir is around 11 metric tons per hectare, lagging behind horticulturally advanced countries. The proportion of A-grade apples is also relatively low. Transitioning from low-density to high-density orcharding with exotic varieties aims to boost productivity. However, challenges arise in achieving desired size and quality due to heavy bloom and fruit set, leading to biennial bearing and economic losses.

Excessive crop load results in small, poorly colored and low quality fruits, diminishing orchard longevity. Large and high-quality apples have a strong market demand, particularly for export. Growers traditionally rely on chemical thinning for crop load adjustment, but in countries like India, where land holding is small and fragmented, hand thinning remains the primary method. Precision crop load management involves precise pruning, chemical or hand thinning, and adjusting the number of fruits per tree. Chemical thinning is standard in many countries, but its unpredictability and environmental impact necessitate exploring alternative methods, such as mechanical thinning, flower thinning by hand, and bud extinction during the dormant winter period (Costa et al., 2013).These crop manipulation methods aim to enhance fruit quality and marketable size while mitigating severe alternate bearing in the following season. The study underscores the need for environmentally acceptable approaches to manage crop load, considering the variability in weather conditions and cultivar sensitivity to thinning chemicals (Bound, 2001, 2010). Therefore, this study aims at to ascertain the impact of various crop loads on yield and quality attributes of Gala apples planted under High Density Orchard~~ing~~.

MATERIALS AND METHODS

The experiment was conducted on four-year-old Gala Redlum apple trees grafted onto 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 agricultural year 2021-2022. Adhering to recommended package practices, including fertilizer application, fertigation, and irrigation, the trial aimed to assess the impact of two key factors: hand thinning and trunk cross-sectional area (TCSA).A Randomized Complete Block Design (RCBD) with three replications was employed for the factorial experiment. The factorial design incorporated various combinations of hand thinning and TCSA as distinct treatment factors. This approach enhances the experimental robustness by systematically varying these factors and considering their individual and interactive effects on the growth, yield and quality parameters of Gala Redlum apple trees. The meticulous application of recommended horticultural practices ensured the experiment's precision and reliability. The experiment involved crop loads of 4, 6, 8, 10 fruits per cm² of TCSA, labeled as C_2,C_3,C_4 and C_5 respectively, with a non-thinned control group as C_1.The orchard trees were categorized into two groups labeled as S_1 (8-10 cm^2 TCSA) and S_2 (10-12 cm^2 TCSA) based on trunk cross-sectional area measurements. The Trunk Cross-sectional Area was determined as per W~~w~~estwood (1993):

Trunk Cross sectional Area (T.T.S.C.A) in cm^2=[Trunk girth of scion (cm)]^2/3.14.

The Yield efficiency was calculated as:

Yield Efficiency = Fruit Yield (kg/tree) / T.T.C.S.A (cm²).

The methods employed here adhere to established protocols, ensuring precision and consistency in fruit quality assessment.

RESULTS AND DISCUSSION

The data in Table 1 demonstrates a significant impact of crop load and trunk cross-sectional area (TCSA) on fruit yield. The highest yield (18.52 kg/tree) was observed in the control group (no thinning), while the lowest yield (7.57 kg/tree) occurred in C_2 (4 fruits per cm^2 of TCSA), followed by C_3 (11.03 kg/tree). TCSA also significantly affected fruit yield, with S_2 (10-12 cm^2 TCSA) recording the maximum yield (14.45 kg/tree) and S_1 (8-10 cm^2 TCSA) recording the minimum (12.16kg/tree). Interaction studies indicated significant variations, with the C_1S_2 treatment combination yielding the maximum (19.34 kg/tree) and C_2S_1 combination yielding the minimum (6.72 kg/tree).

The yield efficiency was significantly influenced by crop load (Tab.2), with all thinning treatments reducing efficiency compared to the control. The control group exhibited the maximum efficiency (1.838 kg/cm^2), while C_2 (4 fruits per cm^2 of TCSA) showed the minimum efficiency (0.766 kg/cm^2). TCSA and the interaction effect of crop load and TCSA did not significantly affect yield efficiency.Increased crop load led to higher partitioning of photo-assimilates in fruits, resulting in increased total fruit yield per tree and decreased mean fruit size. Thinning treatments decreased yield by reducing the number of fruits. Total fruit yield in apple trees is more affected by the number of fruits than by mean fruit weight. Thinning treatments generally reduced yield efficiency but increased average fruit weight.The positive correlation between TCSA and yield in apple trees is attributed to TCSA's role in nutrient transport, influencing fruit yield. Thinning treatments reduced yield efficiency, but TCSA positively correlated with yield efficiency. These findings align with previous studies emphasizing the importance of TCSA in fruit yield and efficiency in apple trees.

Increased crop load leads to higher photo-assimilates being partitioned in fruits than in vegetative organs, although the amount of nutrients and dry matter allocated to each individual fruit decreases (Marcelis, 1996). This fact accounts for both the increase in the total fruit yield per tree and the decrease in the mean fruit size with increases in crop load. Thus, higher total fruit yield under increased crop load is due to an increase in fruit number and to the greater sink capacity of fruits compared to roots, trunk and vegetative shoots (Ho, 1992; Inglese *et al*., 2002). Fruit yield gets decreased by thinning as yield is a result of fruit number on tree (Yildirim *et al.*, 2014). In addition total fruit yield of apple trees is affected more by the number of fruits than by mean fruit weight (Forshey and Elfving, 1989; Elfving and Schechter, 1993). These results are in line with the finding of Serra (2016) who observed that highest crop load in apple recorded the heaviest production and lowest crop load recorded the lowest production. Henriod *et al.* (2008) reported that the drawbacks from reduced crop load, however, were a substantial reduction in mean yield per tree. Anthony *et al.* (2019) reported that yield and production increased with increased crop load, with significant differences across each crop load category. Castro *et al.* (2015) reported that total yield gets decreased by increasing crop load. Yield was significantly influenced by trunk cross-sectional Area (TCSA).

Maximum yield was recorded under S_2 (10-12 cm^2 of TCSA), while minimum was recorded under S_1 (8-10 cm^2 of TCSA). Increase in fruit yield 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), which ultimately influences the fruit yield. These results are in line with the finding of Srivastava *et al*. (2019 a) reported that TCSA has positive correlation with yield kg/ tree in apple. Srivastava *et al.* (2019 b) also recorded positive correlation between TCSA and yield kg/ tree in apple. Westwood and Roberts (1970) reported that the trees with maximum TCSA recorded significantly higher yield in apple.

The thinning treatments tended to reduce the yield efficiency in comparison to control. But average fruit weight was significantly increased. This can be attributed to the fact that the percentage of fruits retained at the time of maturity was low compared to control and therefore, there was no appreciable increase in fruit yield. These findings are in accordance with those of Marini (2004). Our results are also in agreement with the findings of Fruk*et al.* (2017) who reported that the untreated trees yielded highest total number of fruits with maximum total yield efficiency. Thinning treatments lead to a decrease in fruit yield as it is predominantly influenced by the number of fruits on the tree (Yildirim et al., 2014). The total fruit yield of apple trees is more affected by the number of fruits than by mean fruit weight (Forshey and Elfving, 1989; Elfving and Schechter, 1993). Consistent with these findings, Serra (2016) observed that the highest crop load in apples resulted in the heaviest production, while the lowest crop load led to the lowest production. Reduced crop load, however, comes with drawbacks, including a substantial reduction in mean yield per tree (Henriod et al., 2008). Anthony et al. (2019) reported an increase in yield and production with an increase in crop load, showing significant differences across each crop load category. On the contrary, Castro et al. (2015) reported a decrease in total yield with an increase in crop load.Trunk cross-sectional area (TCSA) significantly influences yield, with maximum yield recorded under S_2 (10-12 cm^2 of TCSA) and minimum under S_1 (8-10 cm^2 of TCSA).

Yield efficiency was significantly influenced by trunk cross-sectional area (TCSA). Maximum yield efficiency was recorded under S_2 (10-12 cm^2 of TCSA), while minimum was recorded under S_1 (8-10 cm^2 of TCSA). Increase in fruit yield 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. These results are in line with the finding of Srivastava *et al.* (2019a) as they reported that TCSA of apple plant has positive correlation with yield efficiency.

Srivastava *et al.* (2019 b) also recorded positive correlation between TCSA of apple plant and yield efficiency.Increased crop load results in a higher allocation of photo-assimilates to fruits over vegetative organs, despite a decrease in the nutrients and dry matter allocated to each individual fruit (Marcelis, 1996). This phenomenon contributes to both the rise in total fruit yield per tree and the reduction in mean fruit size with an increase in crop load. The elevated total fruit yield under increased crop load is attributed to greater fruit numbers and the enhanced sink capacity of fruits compared to roots, trunk and vegetative shoots (Ho, 1992; Inglese *et al*., 2002).

The increase in fruit yield with an increase in TCSA may be attributed to its direct relation to nutrient transport from root to various plant parts and the distribution of food materials, ultimately influencing fruit yield. This aligns with Srivastava et al.'s (2019a, 2019b) findings of a positive correlation between TCSA and yield in apple trees.Thinning treatments tend to reduce yield efficiency compared to the control, although average fruit weight significantly increases. This increase in average fruit weight can be attributed to the lower percentage of fruits retained at maturity compared to the control, resulting in no appreciable increase in overall fruit yield. These findings are consistent with Marini (2004) and Fruk et al. (2017), who reported that untreated trees yielded the highest total number of fruits with maximum total yield efficiency.Yield efficiency is significantly influenced by TCSA, with maximum efficiency recorded under S_2 (10-12 cm^2 of TCSA) and minimum under S_1 (8-10 cm^2 of TCSA). The positive correlation between TCSA and yield efficiency in apple plants is in line with the findings of Srivastava et al. (2019a, 2019b). Westwood and Roberts (1970) also reported that trees with maximum TCSA recorded significantly higher yields in apples.

Fruit Firmness (kg/cm^2):

Table 3 analysis reveals a significant influence of crop load and trunk cross-sectional area (TCSA) on fruit firmness. Control fruits displayed notably higher firmness (8.73 kg/cm²) compared to thinned ones, with C_2 (4 fruits per cm² of TCSA) recording the minimum firmness (7.19 kg/cm²). Varied TCSA also affected firmness, with S_1 (8-10 cm² TCSA) reaching maximum firmness (8.05 kg/cm^{2}), and S_2 (10-12 cm^{2} TCSA) recording the minimum (7.92 kg/cm^{2}). Interaction analysis showed significant variation, with the maximum firmness (8.81 kg/cm^{2}) in C_1S_1 treatment and the minimum (7.14 kg/cm^{2}) in C_2S_2 treatment. Thinning treatments, particularly C_2, led to decreased firmness, attributed to accelerated maturation and ripening, in accordance with Forshey (1970), Bana *et al*. (1976), McCartney and Wells (1995), Von Mollendorff*et al*. (1992), Stopar *et al*. (2007), Trevisan *et al*. (2000), and Jemric*et al.* (2003).

Total Soluble Solids/TSS (^{0} Brix):

Data in Table 4 reveals significant differences in TSS content among crop loads and TCSA. Maximum TSS (14.73 ^{o}Brix) was in C_2, followed by 14.20 ^{o}Brix in C_3, while the control had the minimum (12.59 ^{o}Brix). TCSA significantly affected TSS, with S_2 (10-12 cm^{2} TCSA) at maximum (13.75 ^{o}Brix) and S_1 (8-10 cm^{2} TCSA) at the minimum (13.60 ^{o}Brix). Interaction effects were notable, with maximum TSS (14.82 ^{o}Brix) in C_2S_2 treatment and the minimum (12.51 ^{o}Brix) in C_1S_1 treatment.

Acidity (%):

Table 5 highlights significant influences of crop load and TCSA on fruit acidity. Maximum acidity (0.322 %) was in control, while C_2 (4 fruits per cm^{2} of TCSA) had the minimum (0.240 %). TCSA also significantly affected acidity, with S_1 (8-10 cm^{2} TCSA) at maximum (0.285 %) and S_2 (10-12 cm^{2} TCSA) at the minimum (0.277 %). Interaction effects between crop load and TCSA on acidity were non-significant.

Total Sugar Content (%):

Table 6 demonstrates significant impacts of crop load and TCSA on total sugar content. Maximum (11.62 %) was in C_2, while the control recorded the minimum (9.13 %). TCSA variations also affected total sugar content, with S_2 (10-12 cm^{2} TCSA) at maximum (10.51%) and S_1 (8-10 cm^{2} TCSA) at the minimum (10.24 %). Interaction effects were significant, with maximum total sugar content (11.77 %) in C_2S_2 treatment and the minimum (8.99 %) in C_1S_1 treatment.

TSS: Acid Ratio:

Table 7 illustrates significant effects of different crop loads and TCSA on TSS: Acid ratio. Maximum ratio (61.45) was in C_2, followed by C_3 (54.66), while the control had the minimum (39.16). Different TCSA significantly affected the ratio, with S_2 (50.53) at maximum and S_1 (48.60) at the minimum. Interaction effects between crop load and TCSA on TSS: Acid ratio were non-significant.

Thinning treatments especially C_2 led to decreased firmness, increased TSS, total sugar content and TSS: Acid ratio and decreased acidity. TCSA played a crucial role in influencing these parameters. Findings align with literature (Greene and Autio, 1989; Link, 2000; Bound and Wilson, 2007; Serra, 2016; Henriod *et al.,* 2008; Anthony *et al.,* 2019; Jemric*et al.,* 2003; Meland, 2009). The observed reduction in acidity under thinning treatments may be attributed to the conversion of organic acids into sugar, in line with Keserovic *et al*. (2016). TCSA influenced TSS and TSS: Acid ratio, consistent with Kumar *et al*. (2014, 2019).Thinning treatments, especially C_2, led to decreased firmness, increased TSS, total sugar content, and TSS: Acid ratio, and decreased acidity. TCSA played a crucial role in influencing these parameters. Findings align with literature (Greene and Autio, 1989; Link, 2000; Bound and Wilson, 2007; Serra, 2016; Henriod *et al.,* 2008; Anthony *et al.,* 2019; Jemric*et al*., 2003; Meland, 2009). The observed reduction in acidity under thinning treatments may be attributed to the conversion of organic acids into sugar, in line with Keserovic *et al*. (2016). TCSA influenced TSS and TSS: Acid ratio, consistent with Kumar *et al*. (2014, 2019).

CONCLUSION:

In conclusion, the findings underscore the critical importance of thinning Gala Redlum apple trees to ensure a high-quality yield is achieved and thereby returns. Moreover, the data suggests that maintaining an optimal fruit quality and consistent bloom is achievable at a crop load threshold of around 6 fruits per cm^2 of TCSA.

REFERENCES

Anonymous.(2020a). Area and production of horticultural crops 2019-20.Ministry of Agriculture and Farmers Welfare.(Government of India).

Anonymous.(2020b). District-wise area and production of major horticultural crops in Jammu and Kashmir state for the year 2018-19.Department of Horticulture, Jammu and Kashmir.

Anthony, B., Serra, S., &Musacchi, S. (2019).Optimizing crop load for new apple cultivar "WA38". *Agronomy***9**(2), 107-127.

Bana, D. S., Srivastava, R. P., &HariOm.(1976). Studies on the thinning of the fruits by hand and with plant growth substances and their effects on the final retention and quality of apple cv. 'Red Delicious'. *Indian Journal of Horticulture***33**(3-4): 227-232.

Bound, S. A. (2001).Managing crop load. **In:** Crop Management and Postharvest Handling of Horticultural Products (Eds. R. Dris, R. Niskanen, and M. Jain) Oxford & IBH Publishing Co., Pvt. Ltd.: New Delhi, India, 89-109.

Bound, S. A. (2010). Alternate thinning chemicals for apples. *ActaHorticulturae*, 884: 229–236.

Bound, S. A., & Wilson, S. J. (2007). Ammonium thiosulphate and 6-benzyladenine improve the Crop load and fruit quality of 'Delicious' apple. *Australian Journal of Experimental Agriculture*, **47**, *635-644.*

Costa, G. D., Blanke, M. M., &Widmer, A. (2013). Principles of thinning in fruit tree crops Needs and novelties. *ActaHorticulturae*,**998**, 17–26.

Castro, D. C., Alvarez, N., Gabriel, P., Micheloud, N., Buyatti, M., &Gariglio, N. (2015). Crop loading studies on 'Caricia' and 'Eva' apples grown in a mild winter area. *Scientia Agricola*, **727(**3), 237-244.

Greene, D. W., &Autio, W. R. (1989).Evaluation of BA as a chemical thinner in 'McIntosh' apples.*Journal of the American Society for Horticultural Science*, **114**, 68-73.

FAOSTAT.(2019). Agricultural Statistical database, available online at http://faostat.fao.org.

Fruk, M., Vukovic, M., Jatoi, M. A., Fruk, G., Josip, B., &Jemric, T. (2017).Timing and rates of NAA as blossom and fruitlet chemical thinner of apple cv. Braeburn. *Emirates Journal of Food and Agriculture*,**29**(2), 156-162.

Henriod, R. E., Tustin, D. S., Breen, K. C., Oliver, M., Dayatilake, G. A., Palmer, J. W., Seymour, S., Diack, R., & Johnston, J. (2008). Thinning effects on "Scifresh" apple fruit quality at harvest and after storage.In IX International Symposium on Integrating Canopy, Rootstock, and Environmental Physiology in Orchard Systems, 903, 783-788.

Ho, L.C. (1992). Fruit growth and sink strength. In: Marshall, C.; Grace, J., eds. Fruit and seed production: aspects of development, environmental physiology, and ecology. Cambridge University Press, Cambridge, UK. p. 101-124.

Inglese, P., Caruso, T., Gugliuzza, G., & Pace, L. S. (2002). Crop load and rootstock influence on dry matter partitioning in trees of early and late ripening peach cultivars. Journal of the American Society of Horticultural Science, **127**, 825-830.

Jemric, T., Pavicic, N., Blaskovic, D., Krapac, M., &Pavicic, D. (2003).The effect of hand and chemical fruit thinning on ‘Golden Delicious Cl. B’ apple fruit quality. Current Studies of Biotechnology, **3**(25), 193-198.

Kumar, D., Ahmed, N., Srivastava, K. K., & Dar, T. A. (2014).Effect of trunk cross-sectional area of rootstock on growth, yield, quality, and leaf nutrient status in Apricot (Prunusarmeniaca) cv. CITH-Apricot-2.*Indian Journal of Agricultural Sciences*, **84**(2), 236-40.

Kumar, D., Srivastava, K. K., & Singh, S. R. (2019).Correlation of trunk cross-sectional area with fruit yield, quality, and leaf nutrient status in plum under North West Himalayan region of India.*Journal of Horticultural Sciences*, **14**(1), 26-32.

Marcelis, L. F. M. (1996). Sink strength as a determinant of dry matter partitioning in the whole plant. *Journal of Experimental Botany*, **47**, 1281-1291.

Marini, R. P. (2004). Combinations of ethephon and accel for thinning ‘Delicious’ apple trees. *Journal of the American Society of Horticultural Science*, **120**, 802-807.

Mcartney, S. J., & Wells, G. H. (1995).Chemical thinning of ‘Asian’ and ‘European’ pear with ethephon and NAA. *New Zealand Journal of Crop and Horticultural Science*, **23**, 73-84.

Meland, M. (2009). Effects of different crop loads and thinning times on yield, fruit quality, and return bloom in Malus × domesticaBorkh. ‘Elstar’. *Journal of Horticultural Science and Biotechnology*, **6**, 117-121.

Ho, L.C. (1992). Fruit growth and sink strength. In: Marshall, C.; Grace, J., eds. Fruit and seed production: aspects of development, environmental physiology, and ecology. Cambridge University Press, Cambridge, UK. p. 101-124.

Inglese, P., Caruso, T., Gugliuzza, G., & Pace, L. S. (2002). Crop load and rootstock influence on dry matter partitioning in trees of early and late ripening peach cultivars. *Journal of the American Society of Horticultural Science,* **127**, 825-830.

Elfving, D. C., & Schechter, I. (1993). Fruit count, fruit weight, and yield relationships in 'Delicious' apple trees on nine rootstocks. *Hort Science*, **28**, 793-795.

Forshey, C. G., &Elfving, D. C. (1989).The relationship between vegetative growth and fruiting in apple trees.*Horticultural Review,* **11**, 229-287.

Link, H. (2000).Significance of flower and fruit thinning on fruit quality.*Plant Growth Regulators,* **31**(1), 17-26.

Greene, D. W., &Autio, W. R. (1989).Evaluation of BA as a chemical thinner in 'McIntosh' apples.*Journal of the American Society for Horticultural Science,* **114**, 68-73.

Serra, S. (2016). Crop load influences fruit quality, nutritional balance, and return bloom in 'Honeycrisp' apple. *Hort Science*, **51**(3), 236-244.

Srivastava, K. K., Kumar, D., Singh, S. R., Chand, O., &Pandey, S. (2019a). Effect of tree architecture and variety on growth and yield attributes of apple under UHDP. *Journal of Crop and Weed*,**15**(1), 50-55.

Srivastava, K. K., Kumar, D., Singh, S. R., & Sharma, O. C. (2019b). Effect of cultivars on tree growth, yield, and quality attributes of apple on espalier architecture under high-density planting system. *Journal of Horticultural Sciences*, **14**(1), 20-25.

Stopar, M., Tojnko, S., & Turk, B. A. (2007). Fruit thinning of 'Gala' apple trees using ethephon, NAA, BA and their combinations. *PomologiaCroatica*, 13:3.

Trevisan, R., Faria, J. L. C., Fachinelo, J. C., & Silva, J. G. C. (2000). Chemical thinning of peach (Prunuspersica L. Batsch) cv. BR-2 trees.*RevistaCientifica Rural*, **5**, 49-55.

Von-Mollendorff, L. J., Jacobs, G., & De Villiers, O. T. (1992). The effects of storage temperature and fruit size on firmness, extractable juice, wolliness and browning in two nectarines cultivars. *Journal of horticultural science*, **67**(5), 647-654.

Westwood, M. N. 1993. Temperate Zone Pomology. Timber Press, Portland, Oregon. Revised Edition pp. 223.

Westwood, M. N., & Roberts, A. N. (1970).The relationship between trunk cross-sectional area and weight of Apple trees.*Journal of the American Society for Horticultural Science*, **95**(1), 28-30.

Yildirim, F. A., Kepenek, G., Şan, B., Yildirim, A. N., &Kacal, E. (2014).Effects of BA+GA4+ 7 treatments on fruit quality in 'Fuji' apple variety.*Turkish Journal of Agricultural and Natural Sciences*, **2**, 1387-1390.

Table 1: Effect of crop load on yield per tree (kg) 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)	17.69	19.34	**18.52**

C_2 (4 fruits per cm^2 of TCSA)	6.72	8.42	**7.57**
C_3 (6 fruits per cm^2 of TCSA)	10.02	12.04	**11.03**
C_4 (8 fruits per cm^2 of TCSA)	12.67	15.09	**13.88**
C_5 (10 fruits per cm^2 of TCSA)	13.68	17.36	**15.52**
Mean	12.16	14.45	
C.D ($p \leq 0.05$) Trunk cross sectional area (S) = 0.40 Crop load (C) = 0.63 (S×C) = 0.90			

Table 2: Effect of crop load on yield efficiency (kg/cm^2 TCSA) 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)	1.830	1.845	**1.838**
C_2 (4 fruits per cm^2 of TCSA)	0.761	0.770	**0.766**
C_3 (6 fruits per cm^2 of TCSA)	1.075	1.087	**1.081**
C_4 (8 fruits per cm^2 of TCSA)	1.371	1.377	**1.374**
C_5 (10 fruits per cm^2 of TCSA)	1.520	1.550	**1.53**
Mean	1.312	1.326	
C.D ($p \leq 0.05$) Trunk cross sectional area (S) = NS Crop load (C) = 0.036 (S×C) = NS			

Table 3: Effect of crop load on fruit firmness (Kg/cm^2) 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)	8.81	8.66	**8.73**
C_2 (4 fruits per cm^2 of TCSA)	7.25	7.14	**7.19**
C_3 (6 fruits per cm^2 of TCSA)	7.68	7.55	**7.61**
C_4 (8 fruits per cm^2 of TCSA)	8.09	7.98	**8.03**
C_5 (10 fruits per cm^2 of TCSA)	8.43	8.31	**8.37**
Mean	8.05	7.92	
C.D ($p \leq 0.05$) **Trunk cross sectional area (S) = 0.0061** **Crop load (C) = 0.0097 (S×C) = 0.014**			

Table 4: Effect of crop load on fruitTSS (^{0}Brix)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)	12.51	12.67	**12.59**
C_2 (4 fruits per cm^2 of TCSA)	14.65	14.82	**14.73**
C_3 (6 fruits per cm^2 of TCSA)	14.14	14.27	**14.20**
C_4 (8 fruits per cm^2 of TCSA)	13.65	13.76	**13.70**
C_5 (10 fruits per cm^2 of TCSA)	13.08	13.24	**13.16**
Mean	13.60	13.75	
C.D ($p \leq 0.05$) **Trunk cross sectional area (S) = 0.0078** **Crop load (C) = 0.012 (S×C) = 0.018**			

Table 5: Effect of crop load on fruit acidity (%)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)	0.327	0.317	**0.322**
C_2 (4 fruits per cm^2 of TCSA)	0.243	0.237	**0.240**
C_3 (6 fruits per cm^2 of TCSA)	0.263	0.257	**0.260**
C_4 (8 fruits per cm^2 of TCSA)	0.287	0.277	**0.282**
C_5 (10 fruits per cm^2 of TCSA)	0.303	0.297	**0.300**
Mean	0.285	0.277	
C.D ($p \leq 0.05$) **Trunk cross sectional area (S) = 0.0032 Crop load (C) = 0.0051 (S×C) = NS**			

Table 6: Effect of crop load on total sugars (%) 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)	8.99	9.28	**9.13**
C_2 (4 fruits per cm^2 of TCSA)	11.47	11.77	**11.62**
C_3 (6 fruits per cm^2 of TCSA)	10.87	11.12	**10.99**
C_4 (8 fruits per cm^2 of TCSA)	10.26	10.52	**10.39**
C_5 (10 fruits per cm^2 of TCSA)	9.61	9.88	**9.74**
Mean	10.24	10.51	
C.D ($p \leq 0.05$) **Trunk cross sectional area (S) = 0.0091 Crop load (C) = 0.0143 (S×C) = 0.020**			

Table 7: Effect of crop load onTSS: Acid ratio in apple cv. Gala Redlum

Crop load	**TCSA**		**Mean**
	S_1(8-10 cm^2	**S_2(10-12 cm^2**	

	TCSA)	**TCSA)**	
C_1 (No thinning)	38.31	40.01	**39.16**
C_2 (4 fruits per cm^2 of TCSA)	60.25	62.64	**61.45**
C_3 (6 fruits per cm^2 of TCSA)	53.71	55.61	**54.66**
C_4 (8 fruits per cm^2 of TCSA)	47.63	49.77	**48.70**
C_5 (10 fruits per cm^2 of TCSA)	43.13	44.64	**43.88**
Mean	48.60	50.53	
C.D ($p \leq 0.05$) **Trunk cross sectional area (S) = 0.58 Crop load (C) = 0.92 (S×C) = N.S**			