Research article
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Influence of Fruit Thinning Intensity on Yield and Fruit Quality of Apple Cultivars

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Abstract

The influence of fruit thinning intensity on the yield and fruit quality of Apple cultivars was conducted at Kalam Summer Station (KSS), Swat, during the year 2023-24. The experiment was laid out in a Randomized Complete Block Design (RCBD) with split-plot arrangements, replicated three times. Apple cultivars (Royal Gala, Gala Must, and Jonica) were assigned to the main plot, and fruit thinning intensity (control, 10%, 20%, 30%, and 40%) was restricted to the subplots. The experimental results clarified that fruit thinning at 40% significantly increased the total soluble solids (11.74° Brix), ascorbic acid (10.48 mg/100 mL), reducing sugar (7.54%), and non-reducing sugar (4.29%) in apple fruits compared to the control. In contrast, it significantly decreased the titrable acidity (0.51%) and yield per plant (44.33 kg) compared with the control. Despite apple cultivars, there is a significant effect on all the parameters except non-reducing sugar. The cultivar Royal Gala had maximum TSS (10.41 °Brix), reducing sugar (7.49%), non-reducing sugar (4.35%), and yield plant^{-1} (95.6 kg) with minimum ascorbic acid contents (9.67%). The maximum titrable acidity (0.65%) and ascorbic acid content (11.24 mg/100mL) were observed in cultivar Jonica, which had a minimum TSS (10.96° Brix), reducing sugar (5.97%), and yield per plant (72.86 kg). Among the cultivars, the Gala Must had no maximum values in any attribute while having minimum titrable acidity (0.58%). The interaction between thinning intensity and cultivars significantly affected all parameters except titrable acidity and the levels of reducing and non-reducing sugars in apple fruits. The experiment concluded that thinning at a rate of 40% significantly increased TSS, ascorbic acid, reducing and non-reducing sugars, while decreasing titrable acidity and yield per plant. It is recommended that thinning intensity at the rate of 40% in cultivars Royal Gala and Jonica could be applied to obtain quality fruit production of the apple.

Keywords: Apple, Thinning intensity, TSS, Ascorbic acid, Titrable acidity, Reducing and non-reducing sugars.

Highlights

- The influence of fruit thinning intensity on the yield and fruit quality of the Apple was monitored
- Apple cultivars (Royal Gala, Gala Must, and Jonica) were investigated
- 40% significantly increased TSS, ascorbic acid, reducing and non-reducing sugars

1. Introduction

Apple (*Malus domestica* L.) is a pomaceous fruit of the rose family, called "Rosaceae". It is one of the well-known fruits of the genus Malus, used by humans and widely cultivated worldwide. The cultivation of apples appears to have originated among the Greeks and Romans, gradually spreading through their invasions and travels to Europe and Asia (Morgan and Richards, 1993). In Pakistan, apple growing is primarily limited to the northern hilly areas of Punjab, Khyber Pakhtunkhwa, and Balochistan (Chuadhry and Malik, 1994). In 2010, approximately 69 million tons of apples were grown worldwide. In which China's contribution was approximately 50% and the United States' contribution was 6% of the total production. China, U.S.A, Italy, France, Chile, and Poland were the leading exporters of apple fruit, while the major importers were the U.K., Russia, the Netherlands, and Germany (Desmond and Andrew, 1994).In Pakistan, apples are readily available during the peak harvesting season in fruit markets (Ali *et al*., 2011). The total area under apple cultivation during 2011-12 was 110.411 thousand hectares, with a production of 598.804 thousand tons. From the earliest times, it has been used as a food due to its curative characteristics, which is clear from the proverb, "an apple a day keeps the doctor away." To improve the quality of apple fruits, thinning of flowers and fruits is practiced, which may increase blooming and decrease the biennial cropping (Link, 2000). To achieve a regular yield and optimal quality, fruit thinning is regularly applied to apple trees. A heavy crop load reduces flower bud initiation, resulting in low yields the following year. The thinning of flowers and young fruits has many positive effects on regular bearing and fruit quality. An advantage of early thinning, when carried out during the flowering period, is the possibility of additionally thinning fruits later by using plant growth regulators and adjusting the crop load to the optimum level (Milic *et al.,* 2011).

Thinning may be classified as chemical or manual, using hands. Chemical thinning is proficient only in the case of flowers, while hand thinning is practiced for both flowers and fruits (Link, 2000*).* In chemical thinning, concentrations, application time, and environmental factors may influence the ultimate thinning response (Greene *et al*., 2002). H*and* thinning is more beneficial because it increases the size of remaining fruits, produces uniform and high-quality fruits, decreases competition for nutrients/space between the fruits, reduces the risk of biennial bearing (off-year), and helps achieve regular yields each year. It also increases the exposure of fruits to the sun, which is necessary for color development, maturation, and ripening (Hoying *et al.,* 2011). In contrast the chemical thinning of fruits may occasionally causes adverse effects such as reduces fruit growth (Jones *et al*., 1983.), fruit deformation (Rogers and Williams,1977), fruit russeting (Pavieia and Paulia, 1989; Byers and Carbaugh, 1991; Bound *et al*., 1993), poor fruit color (Byers and Carbaugh, 1991; Link, 1991), reduces yield (Byers and Carbaugh, 1991; Elfving and Cline, 1993a; McArtney *et al*., 1995; Marini, 1996; Link, 1998) and minimizes calcium concentration in fruit (Elfving and Cline, 1993b). It also has some positive effects on fruit weight (Pavieia and Paulia, 1989; Bound et al., 1993) and reduces biennial bearing (Vercamen, 1997; Link, 1998). For the commercial production of apples, annual thinning is beneficial to ensure uniform yield and high-quality fruits for the market. Therefore, the influence of chemical thinners may lack the necessary crop load reduction, resulting in unacceptable results (Stadler and Widmer, 2003*).* Considering the importance of fruit thinning in achieving high-quality apple production, the present experiment was designed with the objectives of optimizing thinning intensity for quality fruit production of apple cultivars and identifying the most suitable and productive cultivars for the agroclimatic conditions of Swat.

2. Materials and Methods

The influence of fruit thinning intensity on yield and fruit quality of Apple cultivars was conducted at Kalam Summer Station (KSS), Swat, located at an elevation of 7800 feet above Sea level during the year 2023-24. The experiment was laid out in a Randomized Complete Block Design (RCBD) with split-plot arrangements, involving two factors and replicated three times. The apple cultivars (Royal Gala, Gala Must, and Jonica) were assigned to the main plot, and fruit thinning intensity (control, 10%, 20%, 30%, and 40%) was restricted to the subplots. The whole tree was divided into four portions, and then the fruits of a single branch from a single portion were counted and then averaged for the entire tree. When the apple fruits reached the size of a berry, thinning was done with intensities of 0%, 10%, 20%, 30%, and 40%. Random selections were made to record the various parameters related to the chemical attributes of apple fruit.

2.1. Total soluble solids (TSS) (°Brix)

Tota soluble solids for all treatment replicates were measured using a Brix refractometer. A drop of each sample solution was placed on the clean prism surface of the refractometer, which was calibrated with a percent sugar scale, and the corresponding Brix value was recorded.

2.2. Titrable acidity (%)

Titrable acidity of the fruit was determined by the standard titration method prescribed in A.O.A.C. (1980) of randomly selected fruits for all treatments in each replication, with the help of the following formula.

$$\%\ \text{Acidity} = \frac{\text{N x T x 0.0067 x 100 x 100}}{\text{S x D}}$$

Where,
N = Normality of NaOH
T = mL of 0.1 N NaOH used
D = mL of sample taken for dilution
S = mL of diluted sample taken for titration (0.0067 is a constant factor)

2.3. Ascorbic acid (mg. 100mL^{-1})

Ascorbic acid content in the fruit was quantified using the dye titration method recommended by A.O.A.C. (1980), applied to randomly selected samples from each treatment group in every replication, using the following formula

$$\text{Ascorbic acid (mg 100 ml}^{-1}) = \frac{\text{F x T x 100 x 100}}{\text{D x S}}$$

Where,
F=Factor for standardization $= \frac{\text{mL of ascorbic acid}}{\text{mL of dye}}$
T = mL of dye used for the sample
D = mL of sample taken for titration
S = mL of dilute apple juice taken for titration

2.4. Reducing sugar (%)

The reducing sugar content was quantified using Benedict's reagent, following the protocol described initially by Benedict (1908). The preparation involved the following components:

Fehling's Solution A: 34.65 g of copper(II) sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$) was dissolved in 500 mL of distilled water.
Fehling's Solution B: 173 g of sodium potassium tartrate (Rochelle salt) and 50 g of sodium hydroxide (NaOH) were dissolved in 500 mL of distilled water.
Indicator Solution: 0.2 g of methylene blue was dissolved in 100 mL of distilled water.
All solutions were prepared by thorough stirring to ensure complete dissolution of the reagents. The final mixture was transferred to a 500 mL volumetric flask and diluted to the mark with distilled water to obtain the working reagent.

2.5. Non-reducing sugar:

It was determined by using the Benedict reagent (Benedict, 1908). The following reagents were used to determine the non-reducing sugar content of the apple fruit.
Fehling's Solution A: Dissolve 34.65 g of $CuSO_4$. 5 H_2O in 500 mL of distilled water.
Fehling's Solution B: Dissolve 173 g of sodium Potassium titrate and 50 g of NaOH in 500 mL of distilled water.
Indicator: Methylene blue.

2.6. Yield Plant^{-1} (kg)

The yield of Plant^{-1} of each treatment was recorded in kilograms by weighing the fruits from randomly taken thinned trees in each replication.

2.7. Statistical analysis:

The data obtained were analyzed using the analysis of variance (ANOVA) technique, which is appropriate for RCBD with split-plot arrangements, in a two-factor factorial experiment. For this reason, a statistical package, Statistix 8.1, was used with the least significant difference (LSD) at a 5% probability level (Jan *et al.,* 2009).

3. Results and Discussion

3.1. Total soluble solids (Brix)

The statistical analysis revealed that cultivars, fruit thinning intensity, and their interaction significantly influenced the total soluble solids (TSS) of apple fruit (Fig. 1). Mean data (Table 1) showed that fruit thinning intensity had a significant influence on the TSS of apple fruit.

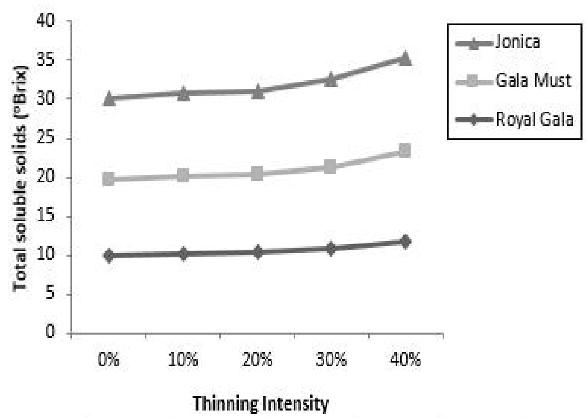

Figure 1: A relation between Total Soluble Solids and Thinning intensity of three apple cultivars

The highest TSS (11.74 °Brix) was noted in apple trees that are thinned at 40%, followed by TSS (10.85 and 10.37 °Brix) in fruit thinning intensity of 30 and 20% respectively. The lowest TSS (10.03 °Brix) was noted in un-thinned apple plants. Regarding fruit thinning intensity, apple cultivars also exhibited significant variation among the different cultivars. The maximum TSS (10.96 °Brix) was recorded in cultivar Jonica, followed by TSS (10.58 and 10.41 °Brix) in cultivars Gala Must and Royal Gala, respectively. The interaction between thinning intensity and cultivars indicated that as the levels of thinning intensity increased, a linear increase was noted in the TSS of apple fruits which was similar to the observation of Link, (2000) and Carlos *et al*., (2006) that total soluble solids of the fruit increased ultimately due to fruit thinning, which improves the supply of carbohydrates (Glucose, Sucrose and Fructose) to remaining fruits. The results are in parallel with the findings of Rab *et al*.(2012), who observed the maximum total soluble solids in the apricot fruit trees treated with 40% thinning in relation to control thinning, in which minimum TSS was observed. A similar result about thinning intensity was also observed by Tahir and Hamid (2002) in guava fruits. Weibel *et al*. (2004) and Peck et al. (2006) confirmed that the total soluble sugars (TSS) of fruits are a vital quality attribute, in combination with composition and texture.

3.2. Titrable acidity (%):

Statistical analysis of the data regarding titrable acidity reveals that both apple cultivars and fruit thinning intensity significantly impact the titrable acidity of apple fruits. In contrast, the interaction between them showed a non-significant effect (Fig. 2).

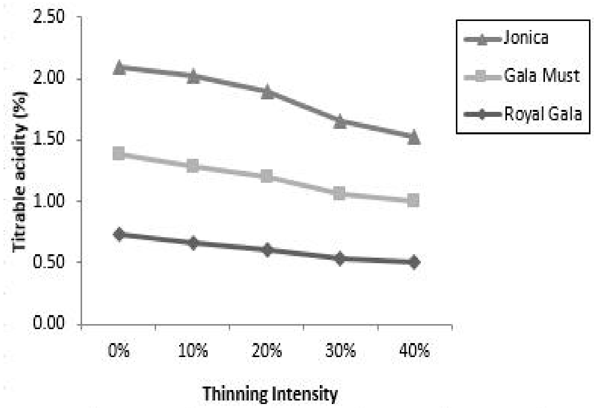

Figure 2: A relation between Titrable acidity (%) and Thinning intensity of three apple cultivars

Results reports in Table 1 indicate that fruit thinning intensity had a significant impact on titratable acidity in apple trees. The highest titratable acidity (0.70%) was observed in trees that were not subjected to thinning, whereas the lowest acidity (0.55%) was recorded at a thinning intensity of 30%, followed by an acidity level of 0.51%, which was statistically similar to the 30% treatment. Significant differences in titratable acidity were noted regarding apple cultivars, in which cultivar 'Jonica' exhibited the highest acidity (0.65%), followed by 'Royal Gala' (0.60%). In contrast, the lowest acidity was observed in the remaining cultivars (Table 1). The current results are similar to those of Rab et al. (2012), who reported the highest acidity levels in control (non-thinned) treatments and the lowest acidity in apricot fruits thinned to 40%. Similarly, Tahir and Hamid (2002) suggested that fruit thinning delays the maturation process, thereby reducing the acidity levels in apricot fruits.

3.3. Ascorbic acid (mg 100 g^{-1}):

The analysis of variance showed that apple cultivars, fruit thinning intensity, and interaction between them significantly affected the ascorbic acid of apple fruit (Fig-3).

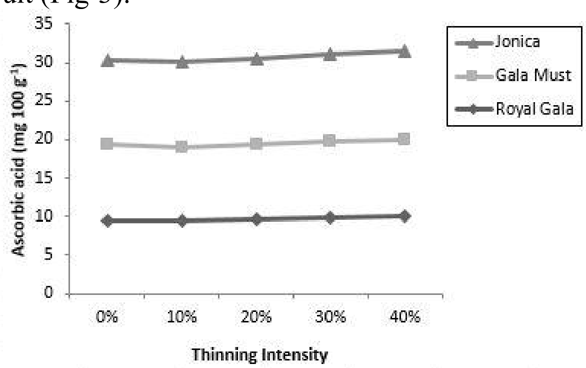

Figure 3: A relation between Ascorbic acid (mg 100 g^{-1}) and Thinning intensity of three apple cultivars

Table 1 demonstrated that thinning intensity significantly enhanced ascorbic acid levels in apple fruits. The maximum ascorbic acid (10.48 mg 100 g^{-1}) was recorded in apple trees that were thinned 40%, followed by ascorbic acid (10.36, 10.19, and 10.04 mg 100 g^{-1}) in the plants that were thinned 30, 20 and 10% respectively. The minimum ascorbic acid (9.93 mg 100 g^{-1}) was noted in the apple trees that were un-thinned. Regarding apple cultivars, a significant variation was found among the different cultivars of apple. The maximum ascorbic acid (11.24 mg 100 g^{-1}) was recorded in cultivar Jonica. In comparison, the minimum ascorbic acid content (9.67mg 100 g^{-1}) was noted in cultivar Royal Gala, which was statistically equivalent to the ascorbic acid content (9.68 mg 100 g^{-1}) in cultivar Gala Must. Interaction between fruit thinning intensity and cultivars showed a significant difference in ascorbic acid of apple fruits (Fig.3). Maximum ascorbic acid (11.43 mg 100 g^{-1}) was recorded in cultivar Jonica, which was thinned at 40%. At the same time, the minimum ascorbic acid (9.37 mg 100 g^{-1}) was recorded in cultivar Royal Gala, where fruit thinning was not performed.

Ascorbic acid is one of the major nutritional components of fruits, which also enhances protection against various diseases associated with oxidative stress (Mark et al., 2002). Due to thinning, the improvement in ascorbic acid content of fruits further enhances the quality of thinned fruits (Rab et al., 2012). The results are in line with the findings of Ouma (2012), who concluded that the ascorbic acid content of citrus fruits increased when they were thinned. Reports by Sharma and

Awasthi (1990), Downtown et al. (1987), and Rab et al. (2012) supported the same results, namely the availability of sugar and increased photosynthesis.

Table 1: Total soluble solids (°Brix), Titrable acidity (%), and Ascorbic acid (mg 100 g^{-1}) of apple cultivars as affected by fruit thinning intensity

Apple Cultivars	Total soluble solids (°Brix)	Titrable acidity (%)	Ascorbic acid (mg 100 g^{-1})
Royal Gala	10.58 b	0.60 ab	9.67 b
Gala Must	10.41 c	0.58 b	9.68 b
Jonica	10.96 a	0.65 a	11.24 a
LSD α 0.05	0.08	0.05	0.04
Thinning intensity (%)			
0 % (Un-thinned)	10.03 c	0.70 a	9.93 e
10 %	10.24 d	0.67 a	10.04 d
20 %	10.37 c	0.63 a	10.19 c
30 %	10.85 b	0.55 b	10.36 b
40 %	10.74 a	0.51 b	10.48 a
LSD α 0.05	0.50	0.08	0.04
Interaction (CxT)	0.08	N-S	0.07

Means followed by similar letter(s) in a column do not differ significantly. N-S = Non-significant. C x T = Interaction between Cultivars and Thinning intensity.

3.4. Reducing sugar (%):

Analysis and interpretation of the data revealed that cultivars and fruit thinning intensity had a significant effect on reducing sugar in apple fruits, while the interaction between them did not significantly affect the reducing sugar of apple fruits (Fig. 4).

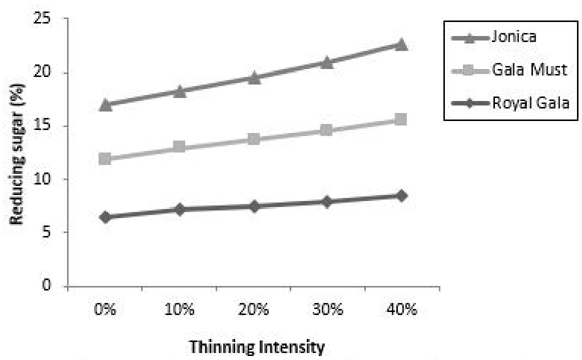

Figure 4: A relation between Reducing Sugars (%) and Thinning intensity of three apple cultivars

The results presented in Table 2 indicate a statistically significant effect of fruit thinning intensity on reducing sugar content in apples. The highest concentration of reducing sugars (7.54%) was observed in trees subjected to 40% fruit thinning, followed by 6.98% in the 30% thinning treatment. In contrast, the lowest reducing sugar content (5.68%) was recorded in un-thinned trees. Apple cultivar also had a significant influence on reducing sugar levels. The cultivar 'Royal Gala' exhibited the highest reducing sugar content (7.49%), whereas the lowest value (5.97%) was found in 'Jonica', which was statistically comparable to 'Gala Must' (6.21%). The elevated reducing sugar levels in 'Royal Gala' may be attributed to enhanced nutrient uptake, which likely promotes carbohydrate accumulation due to its vigorous sink activity. These findings are consistent with those reported by Meland (2009), suggesting that genetic differences among cultivars may contribute to variations in sugar accumulation. Furthermore, fruit thinning has been shown to increase total soluble solids, including both reducing and non-reducing sugars (Tahir & Hamid, 2002). Similar trends were observed by Rab et al. (2012), who reported that thinning practices improved sweetness in apricot fruits.

3.5. Non-reducing sugars (%):

Analysis of the observed data revealed that fruit thinning intensity had a significant effect on the non-reducing sugar content of apple fruits, whereas cultivar type and the interaction between thinning intensity and cultivar showed no significant influence (Fig. 5). The mean values presented in Table 2 further confirmed that thinning intensity significantly affected non-reducing sugar levels. The highest concentration of non-reducing sugars (4.29%) was recorded in plants subjected to 40% fruit thinning, followed by 3.96% and 3.77% in plants thinned at 30% and 20%, respectively. In contrast, the lowest concentration (3.31%) was observed in unthinned plants. Similar findings were reported by Rab et al. (2012) in apricots and Meland (2009) in apples. They suggested that the increase in non-reducing sugars may be attributed to enhanced nutrient uptake, which promotes carbohydrate accumulation and leads to elevated levels of both reducing and non-reducing sugars.

3.6. Yield plant^{-1}(kg):

The analysis of variance showed that fruit thinning intensity, apple cultivars, and the interaction between them had a significant effect on the yield of apple fruits per plant (Fig. 6). Mean values (Table-2) clarified that the highest yield plant^{-1} (126.11 kg) was observed in un-thinned apple trees, followed by yield plant^{-1} (108.67 and 84.11 kg) in fruit thinning intensity of 10 and 20% respectively. The lowest yield was noted in Plant^{-1} (44.33 kg) after 40% fruit thinning in apple trees.

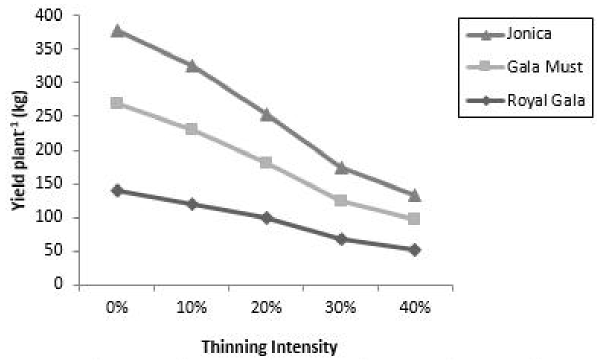

Figure 4: A relation between the Yield of Plant^{-1} and the Thinning intensity of three apple cultivars

Among cultivars, the highest yield plant^{-1} (95.60 kg) was recorded in cultivar Royal Gala, which was statistically different from the rest of the cultivars, followed by yield plant^{-1} (84.33 kg) in Gala Must. In comparison, the lowest yield plant^{-1} (72.86 kg) was recorded in cultivar Jonica. A significant variation was recorded in fruit thinning intensity and apple cultivars. Increasing the fruit thinning intensity from 0 to 40%, a gradual decline in fruit yield was observed. Similar results were reported by Jemric et al. (2004) in apples and by Cittadini et al. (2012) in sweet cherries, regarding the yield reduction due to thinning. Other scientists, such as Valenzuela (1992), Blanco (1987), Nielsen and Dennis (1983), Gambrell et al. (1983), and Hull et al. (1995), have reported similar results regarding fruit thinning in apples.

Table 2: Reducing sugar (%), Non-reducing sugar (%) and Yield plant^{-1} (kg) of apple cultivars as affected by fruit thinning intensity

Apple Cultivars	Reducing sugar (%)	Non-reducing sugar (%)	Yield plant^{-1} (kg)
Royal Gala	7.49 a	4.35 a	95.60 a
Gala Must	6.21 b	3.52 a	84.33 b
Jonica	5.97 b	3.40 a	72.86 c
LSD α 0.05	0.95	N-S	1.04
Thinning intensity (%)			
0 % (Un-thinned)	5.68 d	3.31 c	126.11 a
10 %	6.08 cd	3.46 c	108.67 b
20 %	6.51 bc	3.77 b	84.11 c
30 %	6.98 b	3.96 b	58.11 d
40 %	7.54 a	4.29 a	44.33 e
LSD α 0.05	0.51	0.28	1.83
Interaction (C x T)	N-S	N-S	3.18

4. Conclusion

The experimental results indicated that fruit thinning at a rate of 40% significantly increased TSS, ascorbic acid, reducing and non-reducing sugars, while decreasing yield and titrable acidity. Among the cultivars, the highest yield, TSS, reducing sugar, and non-reducing sugar were noted in cultivar Royal Gala, while Jonica performed better regarding titrable acidity and ascorbic acid, but produced a low yield, TSS, and reducing sugar. The apple cultivars Royal Gala and Jonica are recommended for high yield and quality fruit production under the agroclimatic conditions of the Swat Valley.

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Conflict of Interest.

It is declared that there is no conflict of interest among Authors

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