Physico-chemical evaluation of Apple (*Malus domestica* Borkh.) cultivars grown in mid hills of North India

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**ABSTRACT**

The objective of this study was to compare the physico-chemical properties of 10 apple cultivars grown in mid hills of India. Fruit weight, volume, size, total soluble solids (T.S.S.), total sugars, titratable acidity and ascorbic acid content were measured in the cultivars Aurora, Brookfield, Braeburn, Galaxy, Azetec, Scarlet Gala, Marini Red, Jonagold, Royal Gala and Royal Delicious. The results showed significant differences in physico-chemical attributes of apple cultivars. Among all the cultivars the maximum fruit size (50.66 mm length, 74.73 mm diameter) and fruit weight (170.12 g) were observed in cv. Royal Delicious, while the minimum fruit size (40.52 mm length, 53.03 mm diameter) and weight (110.97 g) were measured in Azetec and Aurora, respectively. The highest volume (196.79 ml) of fruit was registered in Royal Delicious in comparison to the minimum (125.75 ml) in Aurora. The maximum T.S.S. (14.27 °B) and acidity (0.717%) was noticed in Scarlet Gala and Marini Red, respectively. While the minimum T.S.S. and acidity was observed in Marini Red (11.20 °B) and Azetec (0.186%). The ascorbic acid varied from 6.07 mg/100 g in Royal Gala to 9.86 mg/100 g in Braeburn, whereas the total sugar ranged 11.36% in Royal Gala to 7.06% in Jonagold.

**KEYWORDS**


Presently, apple occupies prime position in area as well as in production among temperate fruits grown in Uttarakhand hills. The production of apples in India is estimated 2.4 MT from an area of 0.31 million ha (NHB, 2014). The maximum proportion of apple is contributed by Jammu and Kashmir state of India, having an annual production of about 1.64 MT followed by Himachal Pradesh (0.738 MT) and Uttarakhand hills (0.07 MT) (NHB, 2014). Kheiralipour *et al.* (2008) observed fruit size of 75.28 mm × 84.12 mm for Redsp and 58.31 mm × 67.17 mm for Delbarstival cultivars of Apple.

Vieira *et al.* (2009) reported the cultivars of apple *viz.*, Imperatriz, Daiane, Fred Hough, Fuji Suprema, Galaxy and Baronesa having T.S.S. between 11.80 °B (Fred Hough) to 14.00 °B (Daiane). Adamczyk *et al.* (2009) reported the acidity of 0.71% (Red Boskoop), 0.41% (Lobo) and 0.42% (Jonagold) in various apple cultivars. Braeburn, Gala, Royal Gala, Azetec and Galaxy varieties were introduced by New Zealand, while the cultivar Aurora originated from a cross between ‘Splendour × Gala’ made at the Pacific Agri-food Research Center.
The cultivar Jonagold originated from New York by a cross between ‘Jonathan × Golden Delicious’. The introduction of these exotic apple cultivars under mid hill conditions of Uttarakhand has shown promising future. These cultivars differ with respect to their flowering, fruit-set and yield, fruit growth and quality attributes, depending upon the prevailing climatic conditions. In the present experiment these exotic varieties were evaluated for their performance and physico-chemical properties.

Materials and Methods

The experimental site, Sub Research Station Kanatal (Tehri Garhwal) is about 20 km away from Chamba on Chamba-Mussoorie main road. It falls in the mid hills of Garhwal region of Uttarakhand at an altitude of 2100 m above mean sea level. The region represents a humid temperate climate with an annual rainfall of 1278.40 mm. The meteorological data collected by Meteorological Section of College of Forestry and Hill Agriculture at Hill Campus Ranichauri (G. B. Pant University of Agriculture and Technology) showed that during 2010 the maximum and minimum temperature were 26.20 °C and 3.00 °C in the months of June and February, while in the year 2011 it was 24.90 °C and 3.00 °C in the month of May and February, respectively. The relative humidity varied between 36.5% to 93.5% and 52.50% to 93.50% with the rainfall of 1219.20 mm and 571.70 mm in the year 2010 and 2011, respectively. On an average, in both the years the wind speed was around 3.00 km/ha.

The experiment was conducted on 9 exotic apple cultivars as 9 treatments viz., Aurora (T1), Brookfield (T2), Braeburn (T3), Galaxy (T4), Azetec (T5), Scarlet Gala (T6), Marini Red (T7), Jonagold (T8) and Royal Gala (T9) and commercial apple cultivar Royal Delicious (T10) as check. Uniform age trees of about 5 year old were selected and similar orchard management practices were employed. The experiment was carried out with three replications and two trees under each replication were selected as a treatment unit. The experiment was carried out during February, 2010 to August, 2011 in the orchard of the G.B. Pant University of Agriculture and Technology, Hill Campus Ranichauri, Sub Research Station Kanatal, Distt. Tehri Garhwal, Uttarakhand state, India. Length (mm) and diameter (mm) of 10 fruits were measured by digital vernier calipers and mean values were given. Fruit weight was recorded by weighing it on ‘Electronic Balance’ and mean weight of ten fruits was thus computed. Fruit volume (ml) was recorded by using water displacement method. Fruits were submerged in graduated cylinder, containing water and both initial and final volume of water was recorded. The total fruit volume was thus obtained by subtracting initial volume from final volume of water and finally the mean volume of 10 fruits was measured. Total soluble solids (T.S.S.) present in fruit pulp was recorded at room temperature by using hand refractometer and expressed in terms of degree Brix (°B). Three observations were taken from each sample and their mean values were computed. The acidity of fruits was estimated by titrating the fruit pulp extract with 0.5 N NaOH using phenolphthalein as indicator (Ranganna, 1986) and expressed in terms of percent malic acid.

Total sugars in the fruit pulp were estimated by Lane and Eyon method (Ranganna, 1986). Ascorbic acid content was measured by using 2, 6-Dichlorophenol indophenols (DCPIP) visual titration method as described by (Ranganna, 1986). The experimental data were analyzed statistically using the method given by (Cochran and Cox, 1992) for completely randomized block design. The significance of variation among the treatments were observed by applying Fisher’s least significance difference test (Fisher, 1935) and critical differences (CD) at 5% level of probability was calculated to compare the mean values of the treatment for all the characters.

Results and Discussion

Data presented in table 1 showed that all the apple cultivars varied significantly in their fruit length and measured maximum in Braeburn (58.16 mm, 52.64 mm), thereafter, Royal Delicious (57.08 mm, 50.66 mm) and Galaxy (53.04 mm, 49.58 mm), while the minimum fruit length was noted in Azetec (41.97 mm, 39.06 mm) and Jonagold (43.63 mm, 42.59 mm) in the year 2010 and 2011, respectively. The two years average values of fruit size recorded the highest mean fruit length in Braeburn (55.40 mm) and subsequently in Royal Delicious (53.87 mm) and Galaxy (51.31 mm) whereas, the lowest fruit size was perceived in Azetec (40.52 mm) followed by Jonagold (42.59 mm) and Aurora (44.24 mm).
A close perusal of observation on fruit diameter also revealed the significant variation among the different apple cultivars (Table 1). The cultivars; Royal Delicious (73.84 mm, 75.61 mm), Braeburn (63.15 mm, 67.45 mm), Galaxy (63.22 mm, 69.49 mm), Marini Red (61.69 mm, 65.53 mm) and Brookfield (61.03 mm, 61.58 mm) in the year 2010 and 2011, respectively recorded the significance over Aurora (48.39 mm, 52.67 mm) in both the years while, Royal Gala (61.58 mm) was found significant in the year 2011 only. The maximum mean values of fruit diameter was recorded in Royal Delicious (74.73 mm) followed by Galaxy (66.34 mm) and Braeburn (65.30 mm). However, the minimum fruit diameter was noticed in Aurora (50.53 mm) and subsequently in Scarlet Gala (52.59 mm) and Azetec (53.03 mm). It is apparent from the data presented in Table 1 that all the cultivars significantly differed in their fruit weight and the maximum weight was recorded in Royal Delicious (171.75 g) followed by Brookfield (169.41 g), Galaxy (167.17 g) and Scarlet Gala (160.85) while, the minimum in Aurora (110.00 g), Azetec (110.61 g) and Marini Red (120.77 g) in the year 2010. In the year 2011 the fruit weight was recorded highest in Royal Delicious (168.48 g) followed by Galaxy (164.88 g), Royal Gala (142.61 g) and Brookfield (135.25 g).

In the year 2011, the minimum fruit weight was recorded in Azetec (111.42 g), Aurora (111.84 g) and Jonagold (113.15 g). The maximum mean value of fruit weight was observed in Royal Delicious (170.12 g) followed by Galaxy (166.03 g) and Brookfield (152.33 g) whereas, the minimum value of fruit weight was observed as 110.97 g in Royal Delicious (117.43 g). A significant variation was also noticed on fruit volume among the different apple cultivars (Table 1). Out of the 10 apple cultivars investigated, the maximum volume was confirmed in Royal Delicious (199.58 ml) followed by Brookfield (191.29 ml), Galaxy (190.75 ml) and Royal Gala (178.70 ml) whereas, the minimum volume is shown in the cultivars, Aurora (129.63 ml), Azetec (140.88 ml) and Marini Red (141.86 ml) in the year 2010. In the year 2011, it was the maximum in Galaxy (199.71 ml), Royal Delicious (192.79 ml), Brookfield (174.67 ml) and Royal Gala (152.74 ml) while the minimum volume is observed in Aurora (129.63 ml), Marini Red (125.32 ml) and Azetec (129.67 ml).

Table 1 depicts the highest mean value of fruit volume observed in Royal Delicious (196.19 ml) followed by Galaxy (195.23 ml) and Brookfield (182.98 ml), however the minimum was observed in Aurora (125.75 ml) Marini Red (133.59 ml) and Azetec (135.28 ml). The observations on total soluble solids (°Brix) revealed that in general, a significant variation exists among the apple cultivars (Table 2). The highest respective values of T.S.S. in the year 2010 and 2011 was noted in Scarlet Gala (14.27 °B, 14.27 °B) followed by Royal Gala (14.13 °B, 14.13 °B), Galaxy (13.57 °B, 13.57 °B) and Aurora (13.27 °B, 13.20 °B), while the minimum T.S.S. was recorded in Marini Red (11.20 °B, 11.20 °B) and Azetec (12.06 °B, 12.07 °B) in both the years. The average of two years estimation recorded the maximum value of total soluble solid in Scarlet Gala (14.27 °B) followed by Royal Gala (14.13 °B) and Galaxy (13.57 °B), while the minimum was observed in Marini Red (11.20 °B) and Azetec (12.06 °B). The T.S.S. in rest of cultivars ranged between 12.40 °B (Jonagold) to 13.24 °B (Aurora). Data recorded on titratable acidity at harvesting stage represented significant variation among all the cultivars (Table 2). In both the years 2010 and 2011, maximum acidity values were obtained in Marini Red (0.721%, 0.711%) followed by Aurora (0.698%, 0.654%) and Braeburn (0.651%, 0.645%) while, minimum was observed in Azetec (0.191%, 0.186%), Galaxy (0.238%, 0.235%) and Brookfield (0.291%, 0.241%).

The mean values of titratable acidity (table 2) was highest in Marini Red (0.717%) followed by Aurora (0.676%) and Braeburn (0.648%) while, Azetec (0.189%) and Galaxy (0.237%) were the lowest in acidity values. The other cultivars noticed range between 0.237% (Brookfield) to 0.450% (Jonagold). The ascorbic acid content presented in Table 2 indicates that Marini Red (9.90 mg/100 g, 9.81 mg/100 g) possessed the highest amount of ascorbic acid closely following by Braeburn (9.53 mg/100 g, 9.77 mg/100 g) and Jonagold (9.35 mg/100 g, 9.53 mg/100 g) in the year 2010 and 2011, respectively. The estimate of the lowest amount of ascorbic acid in first and second year was found in Royal Gala (6.20 mg/100 g, 5.94 mg/100 g) and Scarlet Gala (6.57 mg/100 g, 6.57 mg/100 g). All the cultivars observed significant differences over Royal Gala except Scarlet Gala in 1st year.
The maximum two years mean value of ascorbic acid was recorded in Marini Red (9.86 mg/100 g) followed by Braeburn (9.65 mg/100 g) and Jonagold (9.44 mg/100 g), while minimum in Royal Gala (6.07 mg/100 g) and Scarlet Gala (6.57 mg/100 g). Other cultivar lies between 7.16 mg/100 g (Galaxy) to 8.68 mg/100 g (Azetec). Total sugar content varied significantly among all the apple cultivars (Table 2). The cultivar Royal Gala have the highest total sugar per cent (11.37%, 11.35%) followed by Scarlet Gala (10.11%, 10.36%), Galaxy (9.90%, 9.77%) and Brookfield (9.60%, 9.36%), while minimum estimate of sugar content was found in Jonagold (7.03%, 7.09%), Aurora (7.10%, 7.11%) and Azetec (7.36%, 7.55%). All cultivar were proven to be significantly superior over Jonagold and Aurora in both the year i.e., 2010 and 2011. The maximum mean value of total sugar was obtained in Royal Gala (11.36%) followed by Scarlet Gala (10.24%) and Braeburn (9.84%), while minimum in Jonagold (7.06%) and subsequently in Aurora (7.11%) and Azetec (7.46%).

The variation in fruit size in different apple cultivars is featured to be the inter-varietal differences associated with the genetic makeup of the cultivars and governed by the cell size and inter-cellular spaces of the fruit flesh. These findings related to varied fruit size are in accordance with the result of (Sharma et al., 1997) who reported that fruit length continuously increases from 4.87 cm to 6.22 cm (Golden Delicious) and 5.12 cm to 5.55 cm (Red Gold) after fruit set up to harvest stage. Tripathi et al. (2002) while studying on two apple strain Ambri and Lod in Uttarakhand hills found the fruit length of 5.08 cm and 5.66 cm, respectively. The mean fruit length of 75.28 mm for Redspar and 58.31 mm for Delburstival cultivar of apple was also recorded (Kheiralipour et al., 2008). Similar to our findings, Divakar et al. (1984) mentioned the fruit diameter of 7.10 cm in apple variety ‘Bukingham’.

In a study conducted by (Farooqui et al., 1986) confirmed the diameter of 6.22 cm (Ambri), 7.62 cm (Golden Delicious) and 8.24 cm (Red Delicious) at harvesting stage. Maini et al. (1997) stated that fruit diameter greatly varied in cultivar Golden Delicious and Red Gold from 5.94 to 6.96 cm and 6.06 to 6.83 cm, respectively. Whereas, the mean fruit diameter was 84.12 mm for Redspar and 67.17 mm for Delbarstival cultivars of apple (Kheiralipour et al., 2008).

The variation of fruit weight and volume in different apple cultivars is attributed to the inter-varietal differences associated with the genetic makeup of the cultivars and governed by the cell size and inter-cellular spaces of the fruit flesh. The results on the fruit weight and volume are supported from the observations made by (Westwood et al., 1967), who also registered the fruit weight of small, medium and large fruits of Golden Delicious apples as 134.00 g, 214.00 g, 294.00 g and 386.00 g, respectively. Sharma et al. (1997) reported that at various elevation ranges the respective values of fruit weight in cultivars Golden Delicious and Red Gold as; 97.20 g and 94.60 g (mid hills), 107.83 g and 127.80 g (high hills) and 175.30 g and 116.25 g (dry temperate). Iglesias et al., 2008 reported the mean fruit weight for eight apple cultivars namely; Ruby Gala, Buckeye, Royal Beaut, Obrogala, Brookfield, Schniga, Galaxy and Mondial Gala was as 198.00, 223.60, 215.20, 188.90, 214.60, 198.20, 194.90 and 187.00 g, respectively.

Adhikari et al. (1985) reported gradual increased in fruit volume of Red Delicious from the time of fruit set, which reached to its maximum limit of 243.87 ml. Physico-chemical changes were also observed during fruit development and maturity by (Farooqui et al., 1986) and recorded the cv. ‘Red Delicious’ having the maximum fruit volume (250.00 ml) and Ambri the minimum (120.00 ml), during the harvesting stage. Singh (2001) also reported the fruit volume for Royal Delicious (200.33 ml), Scarlet Gala (176.24 ml) and Golden Delicious (180.00 ml). Furthermore, the cultivars; Red Delicious, Royal Delicious and Golden Delicious recorded the fruit volume as 193.00, 202.00 and 182.46 ml, respectively (Kumar, 2002).

The levels of T.S.S. keep on increasing as the fruit matures and are considered as one of the most important component for assessing the fruit quality. The appreciable differences with respect to T.S.S. in different apple cultivars may be explained on the basis of leaf: fruit ratio and subsequently on the synthesis of more photosynthesis and their further breakdown into simple metabolites. Ghosh and Govind (1981), while working on yield performance and quality of different apple varieties noticed the T.S.S. percentage as 14.30 °B (Golden Delicious), 12.80 °B (Red Delicious) and 14.60 °B (Royal Delicious).
Table 1. Fruit weight, volume, diameter and length of various exotic apple cultivars compared to Royal Delicious

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Fruit Weight (g)</th>
<th>Fruit Weight (g)</th>
<th>Fruit Weight (g)</th>
<th>Fruit Weight (g)</th>
<th>Fruit Weight (g)</th>
<th>Fruit Weight (g)</th>
<th>Fruit Weight (g)</th>
<th>Fruit Weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aurora</td>
<td>110.10</td>
<td>111.84</td>
<td>110.97</td>
<td>129.63</td>
<td>121.87</td>
<td>125.75</td>
<td>48.39</td>
<td>52.67</td>
</tr>
<tr>
<td>Brookfield</td>
<td>169.41</td>
<td>135.25</td>
<td>152.33</td>
<td>191.29</td>
<td>174.67</td>
<td>182.98</td>
<td>61.03</td>
<td>61.58</td>
</tr>
<tr>
<td>Braeburn</td>
<td>147.67</td>
<td>115.59</td>
<td>131.63</td>
<td>172.81</td>
<td>131.30</td>
<td>152.06</td>
<td>63.15</td>
<td>67.45</td>
</tr>
<tr>
<td>Galaxy</td>
<td>167.17</td>
<td>164.88</td>
<td>166.03</td>
<td>190.75</td>
<td>199.71</td>
<td>195.23</td>
<td>63.22</td>
<td>69.49</td>
</tr>
<tr>
<td>Aztec</td>
<td>110.61</td>
<td>111.42</td>
<td>111.02</td>
<td>140.88</td>
<td>129.67</td>
<td>135.28</td>
<td>52.09</td>
<td>53.96</td>
</tr>
<tr>
<td>Scarlet Gala</td>
<td>160.85</td>
<td>133.56</td>
<td>147.21</td>
<td>175.03</td>
<td>142.14</td>
<td>158.59</td>
<td>51.41</td>
<td>53.77</td>
</tr>
<tr>
<td>Marini Red</td>
<td>120.77</td>
<td>114.08</td>
<td>117.43</td>
<td>141.86</td>
<td>125.32</td>
<td>133.59</td>
<td>61.69</td>
<td>65.53</td>
</tr>
<tr>
<td>Jonagold</td>
<td>149.93</td>
<td>113.15</td>
<td>131.54</td>
<td>172.90</td>
<td>141.81</td>
<td>157.36</td>
<td>52.14</td>
<td>56.86</td>
</tr>
<tr>
<td>Royal Gala</td>
<td>160.28</td>
<td>142.61</td>
<td>151.45</td>
<td>178.70</td>
<td>152.74</td>
<td>165.72</td>
<td>52.59</td>
<td>61.58</td>
</tr>
<tr>
<td>Royal Delicious</td>
<td>171.75</td>
<td>168.48</td>
<td>170.12</td>
<td>199.58</td>
<td>192.79</td>
<td>196.19</td>
<td>73.84</td>
<td>75.61</td>
</tr>
<tr>
<td>(Commercial Check)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CD (0.05)</td>
<td>14.67</td>
<td>18.18</td>
<td>-</td>
<td>16.48</td>
<td>15.11</td>
<td>-</td>
<td>5.89</td>
<td>4.94</td>
</tr>
<tr>
<td>SEM±</td>
<td>4.94</td>
<td>6.12</td>
<td>-</td>
<td>5.55</td>
<td>5.09</td>
<td>-</td>
<td>1.98</td>
<td>1.66</td>
</tr>
</tbody>
</table>

Table 2. T.S.S., titratable acidity, ascorbic acid and total sugar of various exotic apple cultivars compared to Royal Delicious

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>T.S.S. (°B)</th>
<th>Titratable acidity (%)</th>
<th>Ascorbic acid (mg/100 g)</th>
<th>Total Sugar (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aurora</td>
<td>13.27</td>
<td>13.20</td>
<td>13.24</td>
<td>0.698</td>
</tr>
<tr>
<td>Brookfield</td>
<td>13.20</td>
<td>13.14</td>
<td>13.17</td>
<td>0.291</td>
</tr>
<tr>
<td>Braeburn</td>
<td>13.14</td>
<td>12.93</td>
<td>13.04</td>
<td>0.651</td>
</tr>
<tr>
<td>Galaxy</td>
<td>13.57</td>
<td>13.57</td>
<td>13.57</td>
<td>0.238</td>
</tr>
<tr>
<td>Aztec</td>
<td>12.06</td>
<td>12.06</td>
<td>12.06</td>
<td>0.191</td>
</tr>
<tr>
<td>Scarlet Gala</td>
<td>14.27</td>
<td>14.27</td>
<td>14.27</td>
<td>0.426</td>
</tr>
<tr>
<td>Marini Red</td>
<td>11.20</td>
<td>11.20</td>
<td>11.20</td>
<td>0.721</td>
</tr>
<tr>
<td>Jonagold</td>
<td>12.40</td>
<td>12.40</td>
<td>12.40</td>
<td>0.469</td>
</tr>
<tr>
<td>Royal Gala</td>
<td>14.13</td>
<td>14.13</td>
<td>14.13</td>
<td>0.301</td>
</tr>
<tr>
<td>Royal Delicious (Commercial Check)</td>
<td>13.20</td>
<td>13.20</td>
<td>13.20</td>
<td>0.403</td>
</tr>
<tr>
<td>CD (0.05)</td>
<td>0.27</td>
<td>0.17</td>
<td>-</td>
<td>0.10</td>
</tr>
<tr>
<td>SEM±</td>
<td>0.92</td>
<td>0.56</td>
<td>-</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Granger (1994) stated that the apple cultivars viz., Empire, Spartan, McIntosh and Liberty exhibited the soluble solid (%) of 12.60, 11.20, 11.00 and 11.90, respectively, at harvesting stage. In respect to our present investigation (Singh, 2001) also recorded the heighest T.S.S. (15.24 °B) for cultivar Red Fuji followed by Scarlet Gala (14.50 °B) as compared to the lowest T.S.S. of 11.66 °B in Amb-Starking and Lord Lambourne. However, (Masabni and Wolfe, 2007) reported high T.S.S. containing apple cultivars viz., Rezista Gala (16.60 °B), Scarlet O'Hara (16.10 °B), Rubinstar Jonagold (16.70 °B) and Gold Rush (16.60 °B). In contrast (Campeanu et al., 2009) noticed a low value of T.S.S. of Jonathan and Delicious i.e., 11.50 °B and 11.00 °B, respectively.

Vieira et al. (2009) reported the cultivars of apple Imperatriz, Daiane, Fred Hough, Fuji Suprema, Galaxy and Baronesa having T.S.S. between 11.80 °B (Fred Hough) to 14.00 °B (Daiane). Solomakhin and Blanke (2010) noticed the T.S.S. content for the apple cultivars, Fuji (14.90 g/100g) and Pinova (10.20 g/100g). The inter-varietal differences in the acidity of fruit are attributed to the presence of varying amount of organic acids. In close confirmity to our present findings (Pruthi et al., 1961) observed the acidity of 0.73% (Golden Delicious) and 0.58% (Red Delicious). Adhikari et al. (1985) studied on apple variety Fanny and estimated the ranging amount of titratable acidity from 0.80 to 0.26% (year 1978) and 1.06 to 0.44% (year 1979) during the 2nd week of June to 1st week of August.
Kumar (2002) while comparing the standard and spur type of apple cultivars found Tydeman’s Early Worcester having maximum acidity (0.45%), whereas minimum acidity was found in Top Red (0.21%). Tripathi et al. (2002) reported the acidity of two strains of Ambri apple which varies between 0.10 to 0.12% and Lod which varies between 0.60 to 0.70%, in the hilly region of Uttarakhand. While studying three apple cultivars namely; Red Boskoop, Lobo and Jonagold. Adamczyk et al. (2009) reported the acidity of 0.71% (Red Boskoop), 0.41% (Lobo) and 0.42% (Jonagold), whereas it was 0.24, 0.35 and 0.17% for Mutzu, Jonathan and Delicious, respectively.

The decline in ascorbic acid content in some varieties might be on account of decrease in acidity, which ultimately indicated to oxidation of ascorbic acid content. Joshi and Divakar (1985) also found an ascorbic acid content of 5.54 mg/100 g fresh tissue at the harvesting stage of ‘Esopus-Spitzenburg’ apple, while it was in maximum amount (6.75 mg/100 g fresh tissue) at 10 or 20 days before harvesting. Joshi and Seth (1985) informed that the fruit had the maximum ascorbic acid content at fruit set (8.0 mg/100 g fresh tissue) and minimum at harvesting (3.09 mg/100 g). Mandal (2000), while working on comparative study of apple cvs. Red Fuji and Scarlet Gala showed declining trend of ascorbic acid from 12.26 mg/100 g to 2.99 mg/100 g in Red Fuji after 143 days and 12.17 mg/100 g to 3.26 mg/100 g in Scarlet Gala, after 123 days of full bloom. Sedov and Makarkina (2008) noticed that the clone ‘Papirovka Tetraploidnaya’ contain maximum ascorbic acid i.e., 21.20 mg/100 g while; minimum was estimated in McIntosh i.e., 4.80 mg/100 g.

In close conformity to our findings Compeanu et al. (2009) reported the ascorbic acid content for the cultivars; Mutzu, Jonathan and Delicious, as 7.51, 7.66 and 7.89 mg/100 g, respectively. In apple fruits, starch accumulate at very early stages of fruit development and with the advancement of maturity, the accumulated starch is hydrolyzed into sugars. The extent of variation in sugars in different apple cultivars obviously is due to leaf: fruit ratio, abundance of chloroplast and variable amount of starch in young fruits.

In conformity to these results (Ghosh and Govind, 1981) conducted work on different apple varieties and estimated the total sugar percentage of 11.00% (Sunset), 9.00% (Golden Delicious) and 7.00% (Red Stony). Seth et al. (1983) observed that the apple hybrid ‘Chaubattia Anupam’ showed the maximum total sugars (8.40%) during the harvest time and reported that the sugar content decreased with the time of storage. In another study the highest total sugar of 8.06% during 140 days of fruit growth, while the lowest was found at 110 days (Joshi and Divakar, 1985). Jindal et al. (1992) showed the Maximum total sugar in cultivar Top Red (9.00%) followed by ‘Stark Spur Golden’ (8.09%) and Red Spur (7.66%), whereas the minimum values was found in cultivar Starking Delicious (6.05%).

Kumar (2002) noted the higher sugars (9.23%) in Top Red compared to 8.21% in Stark Spur Gold. Wu et al. (2006) noticed that the apple cultivars viz., Fuji, Ralls, Qin Guan and Golden Delicious contain more sugar than Jonagold, Orin, Granny Smith and Delicious. Adamczyk et al. (2009) reported the total sugar content for the apple cultivars; Red Boskoop, Lobo and Jonagold as 11.06, 9.68 and 11.20%, respectively. Vieira et al. (2009) estimated the total sugar contain for 6 apple cultivars viz., Imperatriz, Daiane, Fred Hough, Fuji Superema, Galaxy and Baronesa which ranged from 11.54% (Imperatriz) to 14.78% (Fuji Superema).

**Conclusion**

Hence, it can be concluded that the maximum fruit size, weight and volume were attained by Royal Delicious, whereas the smallest fruit was obtained from Azetec and fruit weight and volume in Aurora. The cultivar Scarlet Gala estimated appreciably a high T.S.S., low acidity and fairly good total sugar content. The highest amount of sugar and ascorbic acid were however, recorded in cv. Royal Gala and Marini Red, respectively.

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Conflict of Interest

All authors of this manuscript have consented positive contribution and have no conflict of interest.

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