



# PHYSICO-CHEMICAL EVALUATION OF TEN APPLE (*MALUS DOMESTICA* BORKH.) CULTIVARS GROWN IN UTTARAKHAND HILLS OF INDIA

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## Abstract

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

**Key words :** Apple, cultivars, physico-chemical evaluation, brix.

## Introduction

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 24.97 million metric tonnes from an area of 0.33 million ha (NHB, 2014). The maximum proportion of apple is contributed by Jammu & Kashmir State of India, having an annual production of about 16.47 million metric tonnes followed by Himachal Pradesh and Uttarakhand hills having an annual production of 0.74 million metric tonnes and 77500 metric tonnes, respectively (NHB, 2014). Kheiralipour *et al.* (2008) observed fruit size of 75.28 mm × 84.12 mm for Redspar and 58.31 mm × 67.17 mm for Delbarstival cultivars of apple. Harvesting of apple depends on the maturation of the fruit. Apple maturation can be divided into two stages; physiological and horticultural. Physiological maturity is the stage of standard development when fruits continue ontogeny even if detached. Horticultural maturity is the

stage of development when fruits possess the prerequisites for utilization by consumers for a particular purpose (Kader, 1999). Seth *et al.* (1983), while studying the biological changes during fruit development, maturity and post harvest storage in Early Shanburry and Chaubattia Anupam found increasing trend in T.S.S., ascorbic acid and total sugars up to maturity; however acidity of the fruit decreased throughout the storage. 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 g 100g<sup>-1</sup> (Red Boskoop), 0.41 g 100g<sup>-1</sup> (Lobo) and 0.42 g 100g<sup>-1</sup> (Jonagold) in various apple cultivars.

New Zealand has been regarded as one of the best apple producing region in the world. Recently, some exotic apple cultivars were introduced from New Zealand and other European countries. These cultivars are prolific bearer and show better colour development, where colour development specially in the Delicious group is a major

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problem (Jindal *et al.*, 1992). New Zealand introduced some very popular varieties *viz.*, Braeburn, Gala, Royal Gala, Azetec and Galaxy, 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 in 1968 by a cross between 'Jonathan Golden Delicious' (Anonymous, 2016). The introduction of these exotic apple cultivars under mid hill conditions of Uttarakhand has shown promising future. These cultivars differ with respect to their fruit growth and quality attributes, depending upon the prevailing climatic conditions.

## Materials and Methods

### Source of material

The experiment was conducted on 9 exotic apple cultivars *viz.*, Aurora ( $T_1$ ), Brookfield ( $T_2$ ), Braeburn ( $T_3$ ), Galaxy ( $T_4$ ), Azetec ( $T_5$ ), Scarlet Gala ( $T_6$ ), Marini Red ( $T_7$ ), Jonagold ( $T_8$ ) and Royal Gala ( $T_9$ ) and commercial apple cultivar Royal Delicious ( $T_{10}$ ) as check. Uniform age trees of about 5 year old were selected and similar orchard management practices were employed. The experiment was carried out in Randomized Block Design 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 & Technology, Hill Campus Ranichauri, Sub Research Station Kanatal, Distt. Tehri Garhwal, Uttarakhand State, India.

### Fruit size (cm)

Length and diameter of fruits were measured by digital vernier calipers and average fruit size of 10 fruits was than calculated.

### Fruit weight (g) and volume (ml)

Fruit weight was recorded by weighing it on 'Electronic Balance' and mean weight of ten fruits was thus computed. Fruit volume 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 ten fruits was measured.

### Total soluble solids (T.S.S.)

Total soluble solids present in fruit pulp was recorded at room temperature by using hand refractometer and expressed in terms of degree brix ( $^{\circ}B$ ). Three observations were taken from each sample and their mean values were computed.

### Titrateable acidity (%)

The acidity of fruit was estimated by titrating the

fruit pulp extract with 0.5 N NaOH using phenolphthaleine as indicator (Ranganna, 1986) and expressed in terms of percentage malic acid.

### Total sugar

Total sugars in the fruit pulp were estimated by Lane and Eyon method (Ranganna, 1986). Titre value obtained after inversion of sugar.

### Ascorbic acid (mg/100g)

Ascorbic acid content was measured by using 2, 6-Dichlorophenol indophenols (DCPIP) visual titration method as described by Ranganna (1986).

### Statistical analysis

The experiment data were analyzed statistically using the method given by Cochran and Cox (1992) for Randomized Block Design. The significance of variation among the treatments were observed by applying 'F' test 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

### Fruit length and diameter

Data presented in table 1 showed that all the apple cultivars varied significantly in their fruit length and measured the maximum in Braeburn (55.40 mm), thereafter, Royal Delicious (53.87mm) and Galaxy (51.31mm), while the minimum fruit length was noted in Azetec (40.52mm) and Jonagold (42.59mm) 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 set was perceived in Azetec *i.e.*, 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 first and second years, respectively recorded the significant 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 *i.e.*, 50.53 mm and subsequently in Scarlet Gala (52.59 mm) and Azetec (53.03 mm). 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 flesh.

These findings related to varied fruit size are in accordance with the result of Shukla and Pant (1983) who observed the fruit of 7.10 cm in Red Delicious at harvest after 134 days of the full bloom. Sharma et al. (1997) stated 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 upto 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 Redspars and 58.31 mm for Delburstival cultivar of apple was also recorded (Kheiralipour *et al.*, 2008).

In a study conducted by Tabatabaeefar and Rajabipour (2005) confirmed 73, 70, and 67 mm as the mean fruit length, width and thickness for apple varieties Red Delicious and Golden Delicious, with means of 71.83 and 71.57 mm, respectively. Whereas, the mean fruit diameter was 84.12 mm for Redspars and 67.17 mm for Delbarstival cultivars of apple (Kheiralipour *et al.*, 2008).

Similar to our findings, Yosef and Belal (2014) reported that among two cultivar Golden Delicious (5.23cm and 6.33cm) was high than Royal Starking (4.90cm and 5.73cm) in fruit length and width, respectively. Whereas, Atashi *et al.* (2015) observed among two cultivar, Golden Delicious (77.74mm and 82.24mm) was higher than Red Delicious (69.16mm and 78.29mm) in fruit length and diameter, respectively.

### Fruit weight and volume

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 first year. In the second year the fruit weight was the highest recorded in Royal Delicious (168.48 g) followed by Galaxy (164.88 g), Royal Gala (142.61 g) and Brookfield (135.25 g). In this year, 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 Aurora followed by Azetec (111.02 g) and Marini Red (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 1<sup>st</sup> year 2010. In the 2<sup>nd</sup> year, 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 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) in their experiment with quality evaluation of apple fruits at different elevation ranges registered 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). In another study, the mean fruit weight for eight apple cultivars namely; Ruby Gala, Buckeye, Royal Beaut, Obrogala, Brookfield, Schniga, Galaxy and Mondial Gala was recorded as 198.00, 223.60, 215.20, 188.90, 214.60, 198.20, 194.90 and 187.00 g, respectively (Iglesias *et al.*, 2008).

The work of Adhikari *et al.* (1985) on physico-chemical changes in apple variety Red Delicious also revealed a gradual increase in fruit volume 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 cvs., Red Delicious, Royal Delicious and Golden Delicious recorded the fruit volume as 193.00, 202.00 and 182.46 ml, respectively (Kumar, 2002). Yosef and Belal (2014) also reported that among two cultivar Golden Delicious (112.10g) was high than Royal Starking (87.53g) in fruit weight. Singh *et al.* (2015) confirmed the maximum fruit weight in Scarlet Spur (254.44g) and minimum in Golden Spur (116.44g) while maximum fruit volume was 333.00cc

in Scarlet Spur. Atashi *et al.* (2015) reported that among two cultivar, Golden Delicious (240.8g and 330.63mm<sup>3</sup>) was higher than Red Delicious (215.22g and 262.13mm<sup>3</sup>) in fruit weight and volume, respectively.

#### Total soluble solids

The observations on total soluble solids (<sup>o</sup>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<sup>o</sup>B, 14.27<sup>o</sup>B) followed by Royal Gala (14.13<sup>o</sup>B, 14.13<sup>o</sup>B), Galaxy (13.57<sup>o</sup>B, 13.57<sup>o</sup>B) and Aurora (13.27<sup>o</sup>B, 13.20<sup>o</sup>B), while the minimum T.S.S. was recorded in Marini Red (11.20<sup>o</sup>B, 11.20<sup>o</sup>B) and Azetec (12.06<sup>o</sup>B, 12.07<sup>o</sup>B) in both the years. The average of two years estimation recorded the maximum value of total soluble solid in Scarlet Gala (14.27 <sup>o</sup>B) followed by Royal Gala (14.13 <sup>o</sup>B) and Galaxy (13.57 <sup>o</sup>B), while the minimum was observed in Marini Red (11.20 <sup>o</sup>B) and Azetec (12.06 <sup>o</sup>B). The T.S.S. in rest of cultivars ranged between 12.40 <sup>o</sup>B (Jonagold) to 13.24 <sup>o</sup>B (Aurora). The levels of total soluble solids 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<sup>o</sup>B (Golden Delicious), 12.80<sup>o</sup>B (Red Delicious) and 14.60<sup>o</sup>B (Royal Delicious). 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 highest T.S.S. (15.24 <sup>o</sup>B) for cultivar Red Fuji followed by Scarlet Gala (14.50 <sup>o</sup>B) as compared to the lowest total soluble solids of 11.66 <sup>o</sup>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 <sup>o</sup>B), Scarlet O'Hara (16.10 <sup>o</sup>B), Rubinstar Jonagold (16.70 <sup>o</sup>B) and Gold Rush (16.60 <sup>o</sup>B). In contrast, Campeanu *et al.* (2009) noticed a low value of T.S.S. of Jonathan and Delicious *i.e.*, 11.50 and 11.00 <sup>o</sup>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 <sup>o</sup>B (Fred Hough) to 14.00 <sup>o</sup>B (Daiane). Solomankhin and Blanke (2010) noticed the T.S.S. content for the apple cultivars, Fuji (14.90 g/100g) and Pinova (10.20 g/100g). Whereas, the TSS were 10.36%, 10.19%,

9.22%, and 7.3% respectively for four apple cultivars *viz.*: Atitli, Kapak, Kowse and Paiez (Jalali *et al.*, 2013). In another study, Yosef and Belal (2014) reported that among two cultivar, Royal Starking (19.2%) was higher than Golden Delicious (18.4%) in Fruit TSS. Atashi *et al.* (2015) also reported that among two cultivar, the TSS of Red Delicious (15.75%) was higher than Golden Delicious (14.98%).

#### Titrateable acidity

Data recorded on titrateable 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 titrateable acidity shown in table 2 estimated the highest acidity 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 intermediate range between 0.237% (Brookfield) to 0.450% (Jonagold). 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 titrateable acidity from 0.80 to 0.26% (1978) and 1.06 to 0.44% (1979) during the 2<sup>nd</sup> week of June to 1<sup>st</sup> 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 per cent and Lod, which varies between 0.60 to 0.70 per cent, 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 g 100g<sup>-1</sup> (Red Boskoop), 0.41 g 100g<sup>-1</sup> (Lobo) and 0.42 g 100g<sup>-1</sup> (Jonagold), whereas it was 0.24, 0.35 and 0.17 per cent for Mutzu, Jonathan and Delicious, respectively. Similarly, Yosef and Belal (2014) reported that among two cultivar, Golden Delicious (0.39%) was higher than Royal Starking (0.26%) in total acidity.

#### Ascorbic acid

The ascorbic acid content presented in table 2 indicates that Marini Red (9.90 mg/100g, 9.81 mg/100g) possessed the highest amount of ascorbic acid closely

**Table 1 :** Fruit weight, volume, diameter and length of various exotic apple cultivars compared to Royal Delicious.

Cultivar	Character											
	Fruit weight (g)			Fruit volume (ml)			Fruit diameter (mm)			Fruit length (mm)		
	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
Aurora	110.10	111.84	110.97	129.63	121.87	125.75	48.39	52.67	50.53	43.89	44.59	44.24
Brookfield	169.41	135.25	152.33	191.29	174.67	182.98	61.03	61.58	61.31	47.98	47.41	47.70
Braeburn	147.67	115.59	131.63	172.81	131.30	152.06	63.15	67.45	65.30	58.16	52.64	55.40
Galaxy	167.17	164.88	166.03	190.75	199.71	195.23	63.22	69.49	66.34	53.04	49.58	51.31
Azetec	110.61	111.42	111.02	140.88	129.67	135.28	52.09	53.96	53.03	41.97	39.06	40.52
Scarlet Gala	160.85	133.56	147.21	175.03	142.14	158.59	51.41	53.77	52.59	44.33	45.18	44.76
Marini Red	120.77	114.08	117.43	141.86	125.32	133.59	61.69	65.53	63.61	50.55	47.92	49.24
Jonagold	149.93	113.15	131.54	172.90	141.81	157.36	52.14	56.86	54.50	43.63	41.54	42.59
Royal Gala	160.28	142.61	151.45	178.70	152.74	165.72	52.59	61.58	57.09	46.23	46.07	46.15
Royal Delicious (Commercial Check)	171.75	168.48	170.12	199.58	192.79	196.19	73.84	75.61	74.73	57.08	50.66	53.87
CD(0.05)	14.67	18.18	–	16.48	15.11	–	5.89	4.94	–	4.36	3.50	–
SEm±	4.94	6.12	–	5.55	5.09	–	1.98	1.66	–	1.47	1.18	–

following by Braeburn (9.53 mg/100g, 9.77 mg/100g) and Jonagold (9.35 mg/100g, 9.53 mg/100g) 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/100g, 5.94 mg/100g) and Scarlet Gala (6.57 mg/100g, 6.57 mg/100g). All the cultivars observed significant differences over Royal Gala except Scarlet Gala in 1<sup>st</sup> year.

The maximum two years mean value of ascorbic acid was recorded in Marini Red (9.86 mg/100g) followed by Braeburn (9.65 mg/100g) and Jonagold (9.44 mg/100g), while minimum in Royal Gala (6.07 mg/100g) and Scarlet Gala (6.57 mg/100g). Other cultivar lies between 7.16 mg/100g (Galaxy) to 8.68 mg/100g (Azetec). The decline in ascorbic acid (Vitamin-C) 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 55.35 µg/g fresh tissue at the harvesting stage of 'Esopus-Spitzenburg' apple, while it was in maximum amount (67.52 µg/g fresh tissue) at 10 or 20 days before harvesting. Joshi and Seth (1985) informed that the fruit had the maximum Vitamin-C content at fruit set (80.00 µg/g fresh tissue) and minimum at harvesting (30.92 µg/g). Mandal (2000), while working on comparative study of apple cvs. Red Fuji and Scarlet Gala showed declining trend of ascorbic acid (mg/100g) from 12.26 to 2.99 in Red Fuji after 143 days and 12.17 to 3.26 in Scarlet Gala, after 123 days of full bloom. Sedov and Makarkina (2008) noticed that the clone 'Papirovkva Tetraploidnaya' contain

maximum ascorbic acid *i.e.*, 21.20 mg/100g while; minimum was estimated in McIntosh *i.e.*, 4.80 mg/100g. 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/100g, respectively.

### Sugar

The critical examination of the data indicates that total sugar content varied significantly among all the apple cultivars (table 2). The cultivar Royal Gala have the highest percentage of total sugar (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 prove 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%).

In apple fruits, the 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)

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

Cultivar	Character											
	T.S.S. (°B)			Titratable acidity (%)			Ascorbic acid (mg/100g)			Total sugar (%)		
	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
Aurora	13.27	13.20	13.24	0.698	0.654	0.676	8.14	8.41	8.28	7.10	7.11	7.11
Brookfield	13.20	13.14	13.17	0.291	0.245	0.268	7.36	7.29	7.33	9.60	9.36	9.48
Braeburn	13.14	12.93	13.04	0.651	0.645	0.648	9.53	9.77	9.65	8.11	8.11	8.11
Galaxy	13.57	13.57	13.57	0.238	0.235	0.237	7.13	7.18	7.16	9.90	9.77	9.84
Azetec	12.06	12.06	12.06	0.191	0.186	0.189	8.69	8.66	8.68	7.36	7.55	7.46
Scarlet Gala	14.27	14.27	14.27	0.426	0.420	0.423	6.57	6.57	6.57	10.11	10.36	10.24
Marini Red	11.20	11.20	11.20	0.721	0.712	0.717	9.90	9.81	9.86	7.70	7.62	7.66
Jonagold	12.40	12.40	12.40	0.469	0.430	0.450	9.35	9.53	9.44	7.03	7.09	7.06
Royal Gala	14.13	14.13	14.13	0.301	0.291	0.296	6.20	5.94	6.07	11.37	11.35	11.36
Royal Delicious (Commercial Check)	13.20	13.20	13.20	0.403	0.386	0.395	7.55	7.44	7.50	8.55	8.21	8.38
CD(0.05)	0.27	0.17	–	0.10	0.14	–	0.41	0.24	–	0.21	0.14	–
SEm±	0.92	0.56	–	0.34	0.46	–	0.14	0.81	–	0.72	0.47	–

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 of 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, 11.20 g 100g<sup>-1</sup>, respectively. Vieira *et al.* (2009) estimated the total sugar contain for 6 apple cultivars *viz.*, Imperatriz, Daiane, Fred Hough, Fuji Superema, Galaxy and Baronessa which ranged from 11.54 g 100g<sup>-1</sup> (Imperatriz) to 14.78 g 100g<sup>-1</sup> (Fuji Superema). However, Atashi *et al.* (2015) reported that among two cultivar, Red Delicious (227.8 mg/100g) was higher than Golden Delicious (161.46 mg/100g) in Total Sugar of fruit.

## 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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