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Determination of Optimum Harvesting Date for 'Royal Delicious' Apple (*Malus domestica* Borkh.) at Jumla, Nepal

B. Chalise*[1], R.K. Giri[2]
[1]Mountain Agricultural Research Institute, Guthichaur, Jumla
[2]Horticultural Research Station, Rajikot, Jumla
*Corresponding author e-mail: *basantchalise@gmail.com*

Abstract

Study was conducted during two consecutive years 2015 and 2016 at the fruit laboratory of Horticultural Research Station, Rajikot, Jumla to determine the optimum harvesting date of 'Royal Delicious' apple grafted on crab apple (*Malus baccata* Borkh.). Fruit samples were collected from 40 years old trees planted in Gairagaun farm at 2,406 meter above mean sea level altitude. Samples were taken from four trees as a replication and a total of eight fruits per tree per picking were collected from the branches located at east, west, north and south directions (two fruits per branch). Fruits sample were harvested at weekly intervals started from 19th August and continued till 23rd September. Fruit weight, fruit diameter, fruit length, fruit shape index, total soluble solid (TSS), titratable acidity (TA), TSS/TA ratio, starch index (SI) were recorded in every sampling date. The study results revealed that fruit of 'Royal Delicious' apple can be harvested from 2nd September and onwards since at that date TSS, TA, TSS/TA and SI were 11.50%, 0.27%, 42.97 and 4.50 respectively. Therefore, this study recommends the apple growers of Jumla and similar climatic tract to harvest 'Royal Delicious' apple from first week of September.

Keywords: Total soluble solid, titratable acidity, starch index, ripening ratio, optimum harvest date

Introduction

Apple (*Malus domestica* Borkh.) is one of the most important temperate fruits of Nepal. Trees have been planted in 54 districts out of 75 in Nepal; however, there are only 12 important apple producing districts stretched in high mountainous regions (FDD, 2015). Out of these, five districts of the Karnali are major apple growing districts with a production of 7,603 mt from the productive area 1,881 ha. Jumla ranks the first among the apple producing districts of Nepal in terms of productive area (850 ha) and production 3,500 mt (MOAD, 2017). 'Red Delicious', 'Golden Delicious', 'Royal Delicious', 'Rich-a-Red' and 'Jonathan' constitute about 80% of the total apple production (Subedi, 2018).

As compared to the world productivity, Nepals productivity seemed to be very poor due to the lack of quality planting material, lack of proper nutrition and poor management of orchard (HRS, 2016). Additionally, the postharvest loss during transportation and storage is also very high in apple (Subedi, 2018). It has been reported that 25-50% of fruit and vegetables produced are lost after harvest in Mississippi of United States (Vielma et al., 2008). The main reason behind the high postharvest loss is due to the untimely harvest of fruit, fault harvesting, packaging and transportation techniques. The disadvantages of early apple harvesting include reduced yield due to smaller fruit size, greater susceptibility to post-harvest water loss and

even the inability to produce sensory trait required by the consumer, especially due to the low sugar content and low production of aromatic compounds (De Castro et al., 2007). The harvest of fruits after the optimum maturity stage also favors the occurrence of low sensorial quality due to the loss of crispness and juiciness and excessively high sugar/ acidity ratio (Watkins et al., 2005).

Determining the optimum harvesting date plays a pivotal role in maintaining the postharvest quality as well as prolonging the storage period of apple fruits. The quality of fruits cannot be improved after the harvest since it is determined at the harvesting time in the tree. In addition, the harvesting time also influences important characteristics that define the commercial value of fruits such as size and peel color (Plotto et al., 1995). The quality of fruits depends on the optimum harvesting time and appropriate storage condition during the postharvest period (Streif, 1996; Vielma et al., 2008). To ensure the highest quality at the end of long-term storage, apples fruits must be harvested when mature but not yet fully ripe stage (De Long et al., 1999; Rutkowski et al., 2008). When immature apples are harvested, they do not develop their full ripeness after storage, which leads to a small size, poor fruit color, sour and starchy flavor and a weak aroma. They are also more susceptible to scald, bitter-pit and internal breakdown. Mass reduction by water loss is also greater in apples picked earlier because the cuticle is not completely formed at this moment (Juan et al., 1999; Zerbini et al., 2003). Unlike this, apples harvested when over-mature are vulnerable to mechanical injury and disease, and sensitive to low temperature breakdown or watercore (Haribar et al., 1996). All these physiological processes take place even under optimum conditions, which complicates storage (Braun et al., 1995; Ingle et al., 2000).

This study was carried out with an objective of assessing the quality of 'Royal Delicious' apple fruit picked at different dates. This study aims to develop decision support system in favor of apple growers to pick the fruits at optimum date and store them for further use. It is hoped that finding of this study will be highly supportive to the apple growers of Jumla as well as other areas having the similar climatic tract of Nepal.

Materials and Methods

Study site

The study was conducted at the fruit laboratory of Horticultural Research Station, Rajikot, Jumla. Samples were collected from 'Royal Delicious' apple tree of 40 years old planted in Gairagaun farm which is located at 29.26^0 North latitude to 82.17^0 East longitude with 2,406 meter altitude above mean sea level (HRS, 2016). The mean pH, organic matter (%), nitrogen (%, N), phosphorous (mg/kg soil, P_2O_5) and potassium (mg/kg soil, K_2O) content of the soil was 5.64, 5.0, 0.18, 28.93, and 195 respectively (HRS, 2016). The climatic data of the study site is given in Annex 1.

Annex 1. Mean monthly climatic data of the study site in 2015/2016

Year	Month	Maximum Temperature (^{0}C)	Minimum Temperature (^{0}C)	Relative Humidity (%)	Total Rainfall (mm)
2015	July	24.01	15.08	75.29	111.00
	August	24.68	15.56	78.32	117.70
	September	27.18	11.98	67.59	29.60
	October	23.07	4.64	62.96	34.30
	November	20.19	-0.20	55.91	6.80
	December	16.25	-4.23	56.16	0.00
2016	January	13.11	-4.51	58.76	26.90
	February	17.79	-1.40	54.55	30.80
	March	20.05	3.24	57.09	40.10
	April	24.96	5.93	52.98	11.10
	May	24.80	9.75	63.18	55.80
	June	27.66	15.44	64.75	48.30
Average		21.98	5.94	62.29	42.70

Source: Meteorological field office, Jumla, 2016

Treatments and experimental design

There were six harvesting dates namely, D1 for 19th August harvest, D2 for 26th August harvest, D3 for 2nd September harvest, D4 for 9th September harvest, D5 for 16th September harvest and D6 for 23rd September harvest. This study was designed on the basis of the farmers' experience on harvesting time of 'Royal Delicious' apple which was about one week before and continued for 36 days at one week intervals. Treatments were arranged in randomized complete block design (RCBD) where four trees were considered as four replications (single tree as a single replication). In each replication each date of harvest was considered as single plot. The total number of plots i.e. date of harvest in each replication (single tree) was six.

Plant materials

The color of ripe fruit is red. Fruit is sweeter like 'Red Delicious' apple. Fruit samples were taken from 40 years old 'Royal Delicious' apple grafted onto crab apple (*Malus baccata* Borkh,) which were introduced from India (HRS, 2016). Trees were supplied with the optimum amount of chemical fertilizers and manures. Cultural practices like mulching, weeding, control of insect pest and diseases were done as per the recommendations.

Sampling and fruit analysis

During 2015 and 2016, fruit samples were taken from four trees as a replication and a total of eight fruit per tree were picked from the branches located at east, west, north and south directions (two fruits per branch). Fruit were harvested at weekly intervals started from 19th August and continued till 23rd September.

Fruit juice was extracted with apple juicer. After extracting and straining the juice, TSS was observed by placing a single drop of juice in prism of the analog hand refractometer. Similarly, titratable acidity was determined by titrating 10 ml juice of 'Royal Delicious' apple fruit with standard solution of sodium hydroxide (0.1 N). TSS/TA (ripening ratio) was calculated with the formula TSS/TA (Sadler and Murphy, 2010).

$$TA\% = \frac{N \times V_1 \times 67 \times 100}{V_2 \times 1000}$$

Where:

N= Normality of titrant, usually NaOH (mEq/ml)
V_1= Volume of titrant (ml)
67 = Equivalent weight of malic acid (mg/mEq)
V_2 = Volume of sample (ml)
1000 = Factor relating milligrams to grams (mg/g) (1/10 = 100/1000)

Starch patterns were prepared by dipping half part of the fruit for 30 seconds into a solution of 1 g potassium iodide plus 0.25 g iodine in 100 ml distilled water (Beattie and Wild, 1973). The starch patterns which indicated the relative amount of starch and sugar scored on a scale of 0-6 (Smith et al., 1979).

Data collection and statistical analysis

Data on fruit weight, fruit diameter, fruit length, fruit shape index, total soluble solid (TSS), titratable acidity (TA), TSS/TA and starch index (SI) was recorded during the laboratory analysis on different dates. Observed data were analyzed using MS-Excel (Microsoft Excel.2010) and MSTAT-C package (Version 1.3). Means were separated with Duncan's Multiple Range Test (DMRT) at 5% level of significance (Gomez and Gomez, 1984).

Results and Discussion

A. Physical parameters

Fruit size

'Royal Delicious' apple fruits were analyzed for fruit size in each picking dates from 19th August to 23rd September at each 7 days intervals. Fruit weight, fruit diameter and fruit length were statistically non-significant on different harvest dates. The fruit weight harvested on different dates was non-significantly varied from 99.75 g on 9th September to 128.80 g on 26th August harvesting with 112.17 g mean value. Similarly, fruit diameter was also non-significantly ranged from 5.86 cm on 9th September to 6.50 cm on 26th August harvesting with 6.15 cm mean diameter. The length of fruit also non-significantly differed from 5.00 cm harvested on 9th September to 5.47 cm on 16th September harvesting where the mean fruit length was 5.26 cm (Table 1).

Table 1. Effects of harvesting dates on fruit weight, fruit diameter and fruit length of 'Royal Delicious' apple at HRS, Rajikot, Jumla during 2015 and 2016

Harvest dates	Fruit weight (g)	Fruit diameter (cm)	Fruit length (cm)
19th August	102.00	6.06	5.29
26th August	128.80	6.50	5.46
2nd September	111.30	6.10	5.12
9th September	99.75	5.86	5.00
16th September	124.50	6.42	5.47
23rd September	106.80	5.92	5.20
GM	112.17	6.15	5.26
CV%	13.34	7.12	5.70
F test	NS	NS	NS
CD (P≤0.05)	22.55	0.66	0.45
SEm±	7.48	0.22	0.15

SEm± = Standard error of mean difference, CV = Coefficient of variation, CD (P≤0.05) = Critical difference at probability value 0.05, GM = Grand mean, NS = Non-significant

The size of the 'Royal Delicious' apple harvested on different dates showed non-significant difference. Minor differences in the size could be due to the number of fruits retained in the trees. Higher the number of fruits retained in the tree, lower will be the size of fruit. Moreover, better soil nutrition of orchard tree can also affects the size of fruits. Tree supplied with optimum soil nutrient can produce good sized fruits.

Fruit shape index

Fruit shape index is the ratio of fruit length to the diameter which implies the shape of the fruit. The fruit shape index was non-significantly varied from 0.84 to 0.88 with the mean index 0.86. In every harvesting date, fruit have slightly higher diameter as compared to the length. Thus it can be concluded that the shape of fruit of 'Royal Delicious' fruit is oblong which is more or less round (Table 2).

Table 2. Fruit shape index of 'Royal Delicious' apple harvested on different dates at HRS, Rajikot, Jumla during 2015 and 2016

Harvest dates	Fruit shape index
19th August	0.88
26th August	0.84
2nd September	0.84
9th September	0.85
16th September	0.85
23th September	0.88
GM	0.86
CV%	5.61
F test	NS
CD (P≤0.05)	0.07
SEm±	0.02

SEm± = Standard error of mean difference, CV = Coefficient of variation, CD (P≤0.05) = Critical difference at probability value 0.05, GM = Grand mean, NS = Non-significant

Juice content

Fruits were analyzed for juice content in each picking dates from 19th August to 23rd September at each 7 days intervals. The juice content in the fruit was non-significant on different harvest dates. Non-significantly the highest juice content (54.86%) was observed on fruit harvested on 23rd of September followed by 16th September (53.00%) whereas the lowest juice content (45.31%) was recorded on 19th August harvest (Table 3).

Table 3. Juice content (%) of 'Royal Delicious' apple fruits harvested on different dates at HRS, Rajikot, Jumla during 2015 and 2016

Harvest dates	Juice %
19th August	45.31
26th August	50.97
2nd September	51.00
9th September	52.00
16th September	53.00
23th September	54.86
GM	51.19
CV%	7.46
F test	NS
CD (P≤0.05)	5.76
SEm±	1.91

SEm± = Standard error of mean difference, CV = Coefficient of variation, CD (P≤0.05) = Critical difference at probability value 0.05, GM = Grand mean, NS = Non-significant

The trend of juice content in fruits was increasing with advancement of fruit maturity due to the breakdown of insoluble polysaccharides into a more soluble form by the enzymatic activity (Ng et al., 2013). In the present study, the juice content was lower in initial observation as compared to the later dates. Total increment in the juice content of fruit from first observation (19th August) to the final observation (23rd September) was 9.25% (Table 3).

B. Chemical parameters

'Royal Delicious' apple fruits were analyzed for TSS, TA and TSS/TA ratio from 19th August to 23rd September at each 7 days interval. Results showed highly significant difference on these parameters. The increase in TSS could be attributed to the breakdown of starch into sugars (Kvikliene and Valiuskaite, 2009). Since, TSS percentage was a function of total dissolved solids and moisture content of the fruit, the increase in TSS could be due to the concentration of soluble solids in moisture loss (Farooq and Khan, 2012).

Total soluble solids

The TSS of apples and other fruits is an important quality factor which determines the fruit taste (TSS/TA ratio) (Weibel et al., 2004). TSS content of 'Royal Delicious' apple fruit showed the increasing trend. The TSS content of fruit was significantly affected by harvest date. Significantly the highest TSS (13.02%) was recorded on 23rd September harvesting whereas, the lowest value (8.52%) was observed on 19th August harvesting (Table 4). During the 36 days period, the TSS increased from 8.52% to 13.02% i.e. total increment was 4.52%. This increase in TSS is due to the breakdown of insoluble polysaccharides into a more soluble form by the enzymatic activity (Ng et al., 2013).

In a study made by Baumann (1994) reported that soluble solid showed little difference just before optimum harvesting date in 'Janagold' apple. Similar results have been reported by Argenta et al. (1995). He observed that at optimum harvesting date, there were variations in the internal indices among orchards and seasons and found that the TSS increased to a greater extent in apples as the picking time delayed. The preference of consumers for apples positively correlated with the soluble solid content, with rejection of apple fruits with its level below 12% (Harker et al., 2008).

Titratable acidity

Unlike sugars, the concentrations of organic acids decrease with the advancement of ripening resulting decreased TA in ripe fruit. TA content of late harvested fruit was lower than those harvested at an earlier date. Significantly the highest acidity (0.30%) was observed on the 19th August harvesting followed by 26th August (0.29%), 2nd September (0.27%), 9th September (0.23%) and 16th September (0.22%) respectively. The lowest acidity (0.21%) was recorded on 23rd September harvesting (Table 4).

TSS/TA (Ripening ratio)

With the advancement of ripening, the ripening ratio showed ever increasing trend. Ripening ratio was statistically significant on different harvesting dates. Significantly the highest ratio (61.81) was recorded on 23rd September harvesting which was followed by 16th September harvesting (56.85), 9th September (51.83), 2nd September (42.97) and 26th August (37.64). The lowest ratio (28.17) was observed on 19th August harvesting (Table 4).

Ripening involves structural and chemical modifications of fruit composition, resulting from processes like transformation of chloroplasts into chromoplasts, loss of chlorophyll and accumulation of carotenoids, softening of the tissue and changes in acids and sugars metabolism (Goldschmidt, 1980; Brady, 1987). Wilcke, (2002) and Quartin, (2004) as cited by Icka and Damo (2014) reported that in the harvest time the ratio of TSS/TA should be between 15 and 20. In the present study the TSS/TA ratio was 28.17 on 19th August (1st date of harvest) and 61.81 on 23rd September (final date of harvest). During that time the total increment in TSS/TA ratio was 33.64.

Table 4. Total soluble solid, titratable acidity and ripening ratio of 'Royal Delicious' apple harvested on different dates at HRS, Rajikot, Jumla during 2015 and 2016

Harvest dates	TSS%	TA%	Ripening ratio
19th August	8.52^{e}	0.30^{a}	28.17^{f}
26th August	11.00^{d}	0.29^{b}	37.64^{e}
2nd September	11.50^{cd}	0.27^{c}	42.97^{d}
9th September	12.00^{bc}	0.23^{d}	51.83^{c}
16th September	12.60^{ab}	0.22^{e}	56.85^{b}
23th September	13.02^{a}	0.21^{f}	61.81^{a}
GM	11.44	0.25	46.54
CV%	4.51	5.23	7.07
F test	**	**	**
CD (P≤0.05)	0.78	0.001	4.96
SEm±	0.26	0.001	1.64

SEm± = Standard error of mean difference, CV = Coefficient of variation, CD (P≤0.05) = Critical difference at probability value 0.05, Treatment means followed by common letter (s) within a column are not significantly different at 5% by DMRT, GM = Grand mean

Starch index

Fruits were analyzed for starch index on each picking dates from 19th August to 23rd September at each 7 days intervals. The study done for two years revealed that the starch index was highly significant in different dates of harvesting. Statistically, the highest starch index (5.75) was recorded on 23rd September harvesting which was statistically at par with 16th September harvesting (5.50). The lowest starch index (2.52) was observed on 19th August harvesting (Table 5).

According to Blanpied (1974), presence of starch in the core of 'Red Delicious' apple fruit was a useful indicator of immaturity of the fruit. Smith et al. (1979) noted uniformity of starch index readings at the pre-climacteric minimum for three apple varieties is the good indicator of the maturity of the fruit. Thus, there is evidence that a relationship exists between starch hydrolysis and the physiological age of the fruit. According to Luton (1994) the starch iodine test is used for classifying local orchards in order of their probable maturity time.

Table 5. Starch index of 'Royal Delicious' apple harvested on different dates at HRS, Rajikot, Jumla during 2015 and 2016

Harvest dates	Starch index
19th August	2.52e
26th August	4.00d
2nd September	4.50cd
9th September	5.01bc
16th September	5.50ab
23th September	5.75a
GM	4.55
CV%	7.77
F test	**
CD (P≤0.05)	0.53
SEm±	0.18

SEm± = Standard error of mean difference, CV = Coefficient of variation, CD (P≤0.05) = Critical difference at probability value 0.05, Treatment means followed by common letter (s) within a column are not significantly different at 5% by DMRT, GM = Grand mean

Conclusion

Jumla is the most important apple producing district of Karnali province of Nepal. Early harvest period of apple coincided with important festival of Nepal like Teej, Dashain and Deepawali that increases the market price of apple. Growers are also willing to harvest apple as earliest as possible due to the problem of theft. This study suggested the apple growers to harvest 'Royal Delicious' apple from first week of September for storage and a week delayed harvesting of apple for fresh consumption. It is also recommended that harvesting date should be adjusted in warmer or cooler growing year depending upon the prevailing climatic condition.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

Authors' contribution

B. Chalise: Designed and performed experiment, analyze data and wrote the paper.
R.K. Giri: Performed experiment, data recorded.

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