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Determining Optimum Harvesting Date of 'Red Delicious' Apple at Jumla, Karnali Province of Nepal

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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 'Red 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 on weekly interval 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) was recorded in every sampling date. The study results revealed that fruit of 'Red Delicious' apple can be harvested from 2nd September and onwards since at that date TSS, TA, TSS/TA and SI were 12.00%, 0.30%, 40.10% and 4.00% respectively. Therefore, this study recommends the apple growers of Jumla and similar climatic tract to harvest 'Red Delicious' apple from 2nd September and onwards.
Keywords Total soluble solid; Titratable acidity; Starch index; Ripening ratio

Background

Apple is one of the most important temperate fruits of Nepal. Apple 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). In Karnali province, apple is cultivated in 9,591 ha areas of which 3,690 ha area is productive with 32,712 mt total production and 8.87 mt/ha productivity. Jumla ranks the first among the apple producing districts of Nepal in terms of productive area (1,454 ha), total production (13,958 mt) and productivity (9.60 mt/ha) (MOALD, 2023). 'Red Delicious', 'Golden Delicious', 'Royal Delicious', 'Rich-a-Red' and 'Jonathan' represent approximately 80% of the total apple production (Subedi, 2018).

As compared to the world productivity, Nepal's 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 harvesting 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; Rutkowskiet 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 'Red 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.

1 Material and Methods

1.1 Study site

This study was conducted at the fruit laboratory of Horticultural Research Station, Rajikot, Jumla. Samples were collected from 'Red Delicious' apple tree of 40 years old planted in Gairagaun farm which is located at 29.26° North latitude to 82.17° East longitude with 2,406 meter altitude above mean sea level. The mean pH, organic matter (%), nitrogen (%), 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 was given (Table 1).

Table 1 Mean monthly climatic data of the study site in 2016

Month	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Rainfall (mm)
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
July	24.33	16.76	81.85	177.30
August	23.88	16.17	81.74	252.60
September	25.05	14.72	77.10	102.70

Source: Meteorological field office, Jumla, 2016

1.2 Treatments and experimental design

Six dates of harvesting were studied in the experiment. Harvesting was started from 19th of August and continued till 23rd of September at weekly 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.

1.3 Plant materials

Samples were taken from 'Red Delicious' apple tree of 40 years old grafted onto crab apple (*Malus baccata* Borkh.) rootstocks receiving the optimum number of chemical fertilizers and manures. Cultural practices like mulching, weeding, control of insect pest and diseases were done as per the recommendations.

1.4 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 was harvested at weekly intervals started from 19th August and continued till 23rd September.

Fruit size was determined by weight, diameter and length. Individual fruit weight was recorded with digital weighing balance and the fruit diameter and length was measured with Vernier caliper. Fruit shape index was calculated by dividing the fruit length with fruit diameter. 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 'Red 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 was scored on a scale of 0~6 (Smith et al., 1979).

1.5 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).

2 Results and Analysis

2.1 Physical parameters

2.1.1 Fruit size

Fruit weight, fruit diameter and fruit length were statistically non-significant on different harvest dates (Table 2). Early or late harvest fruits during August-September did not show the significant differences in their weight, diameter and length.

Table 2 Effects of harvesting dates on fruit weight, fruit diameter and fruit length of 'Red Delicious' apple at HRS, Rajikot, Jumla during 2015 and 2016

Dates of harvest	Fruit weight (g)	Fruit diameter (cm)	Fruit length (cm)
19th August	106.50	6.23	5.34
26th August	109.80	5.82	5.04
2nd September	98.50	5.45	4.60
9th September	106.50	6.32	5.25
16th September	118.50	6.37	5.69
23rd September	110.80	6.18	5.45
GM	108.42	6.06	5.23
CV (%)	8.32	8.59	10.08
F test	NS	NS	NS
CD ($p \leq 0.05$)	-	-	-
SEm±	4.51	0.26	0.26

Note: GM=Grand mean; CV=Coefficient of variation; SEm±=Standard error of mean difference; CD($p \leq 0.05$)=Critical difference at probability value 0.05; NS=Non-significant

2.1.2 Fruit shape index

The fruit shape index was non-significantly varied from 0.82 to 0.89 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 'Red Delicious' fruit is oblong which is more or less round (Table 3).

2.1.3 Juice content

The juice content in the fruit was highly significant on different harvest dates. Significantly the highest juice content (53.87%) was observed on fruit harvested on 23rd of September followed by 16th September (48.45%). The lowest juice content (40.26%) was recorded on 26th August harvest (Table 4).

Table 3 Juice content (%) of 'Red Delicious' apple fruits harvested on different dates at HRS, Rajikot, Jumladuring 2015 and 2016

Dates of harvest	Juice content (%)
19th August	42.03
26th August	40.26
2nd September	48.42
9th September	47.74
16th September	48.45
23th September	53.87
GM	46.79
CV%	2.87
F test	**
CD (P≤0.05)	2.02
SEm±	0.67

Note: GM=Grand mean; CV=Coefficient of variation; SEm±=Standard error of mean difference; CD (p≤0.05)=Critical difference at probability value 0.05; **=Highly significant

Table 4 Fruit shape index of 'Red Delicious' apple harvested on different dates at HRS, Rajikot, Jumla during 2015 and 2016

Dates of harvest	Fruit shape index
19th August	0.85
26th August	0.86
2nd September	0.84
9th September	0.82
16th September	0.89
23th September	0.87
GM	0.86
CV%	4.92
F test	NS
CD (p≤0.05)	-
SEm±	0.02

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

2.2 Chemical parameters

2.2.1 Total soluble solids

The total soluble solid content of fruit was significantly affected by harvest date. Significantly the highest TSS (13.50%) was recorded on 23rd September harvesting whereas, the lowest value (8.00%) was observed on 19th August harvesting. Regarding TSS, it can be observed that during the ripening process, the TSS increased from 8.00% to 13.50% i.e. total increment was 5.50% during the study period (Figure 1).

2.2.2 Titratable acidity

Titratable acidity content of early harvested fruit was higher as compared to the late harvested fruit. Significantly the highest acidity (0.38%) was observed on the 19th August harvest which was statistically at par with 26th August harvest (0.37%). The lowest acidity (0.26%) was recorded on 23rd September harvesting (Figure 1).

2.2.3 Ripening ratio (TSS/TA)

Ripening ratio was statistically significant on different harvesting dates. Significantly the highest ratio (52.94) was recorded on 23rd September harvesting which was followed by 16th September harvesting (47.53). The 16th September harvesting was statistically at par with 9th September harvesting (45.87). The lowest ratio (21.38) was observed on 19th August harvesting. With the advancement of ripening, the ripening ratio showed ever increasing trend (Figure 1).

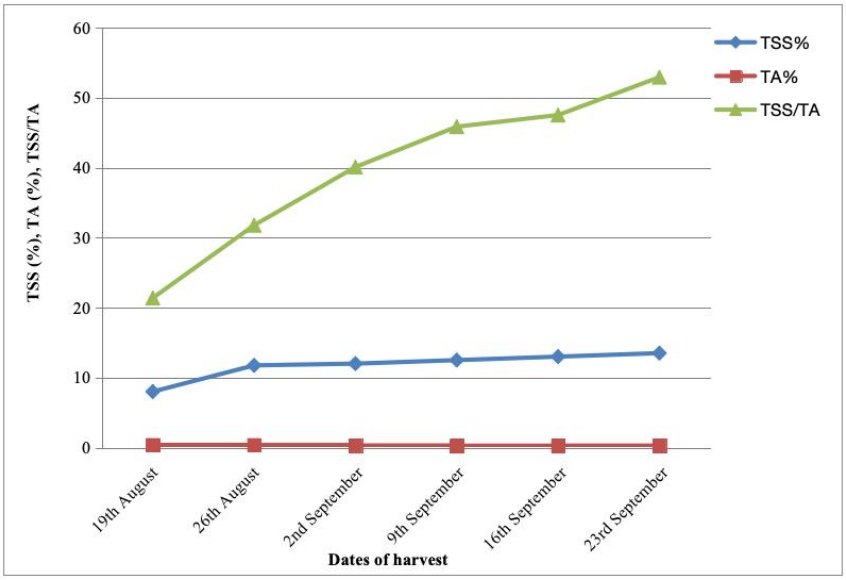

Figure 1 Total soluble solid, titratable acidity and ripening ratio of 'Red Delicious' apple harvested on different dates at HRS, Rajikot, Jumla during 2015 and 2016

2.2.4 Starch index

Starch index was highly significant in different dates of harvesting. Statistically, the highest starch index (5.50) was recorded on 23rd September harvesting which was statistically at par with 16th September harvesting (5.25). The lowest starch index (2.00) was observed on 19th August harvesting (Table 5).

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

Dates of harvest	Starch index
19th August	2.00^{e}
26th August	3.00^{d}
2nd September	4.00^{c}
9th September	5.00^{b}
16th September	5.25^{ab}
23th September	5.50^{a}
GM	4.12
CV%	7.24
F test	**
CD (P≤0.05)	0.45
SEm±	0.14

Note: GM=Grand mean; CV=Coefficient of variation;SEm±=Standard error of mean difference; CD (p≤0.05)=Critical difference at probability value 0.05; **=Highly significant

3 Discussion

The harvesting of 'Red Delicious' apple was started from 19th of August. By that time, it was assumed that fruit were at mature stage. Therefore, during 36 days period, the change in fruit size was not significant. However, 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 soluble solid content of juice from first observation (19th August) to the final observation (23rd September) was 11.84% (Table 4).

Preference of consumers for apples fruit is positively correlated with the soluble solid content, with rejection of apple fruits with its level below 12% (Harker et al., 2008).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).In a study made by Baumann (1994) reported that soluble solid showed little difference just before optimum harvesting date in 'Janagold' apple during 1989, 1990 and 1992, respectively. Rejection of early harvested fruit is due to the presence of sour taste (Chaudhari, 2005). However, in fruit harvest at optimum maturity, acidity in the combination with the total soluble solid imparts the pleasant taste to the fruit. Generally, the role of acid in fruit taste is hidden but incredible.

Argentaet al. (1995) observed that the TSS increased to a greater extent in apples as the picking time delayed. Study made by Kvikliene and Valiuskaite (2009) found increase in TSS could be attributed to the breakdown of starch into sugars. In Nepal, Chaudhari (2005) suggested that 'Red Delicious' and 'Royal Delicious' apple fruit can be harvested at 8.75% to 9.50% TSS reading. The TSS of apple and other fruits is an important quality parameter which determines the fruit taste (TSS/TA ratio) (Weibel et al., 2004). Icka and Damo (2014) reported that at the harvest time the ratio of TSS/TA should be between 15 and 20. However, in the present study the TSS/TA ratio was 21.38 on 19th August (1st date of harvest) and 31.78 on 26th August (2nd date of harvest). During that time TSS was lower (8.00% and 11.75% respectively) and the acidity was higher (0.38% and 0.37% respectively) indicating the inappropriate time of fruit harvesting.

During ripening the occurrence of starch in fruit diminishes gradually. Blanpied (1974) described about the presence of starch in the core of 'Red Delicious' apple fruit was 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. Chaudhari (2005) reported that apple fruit become mature when the starch index reading is 1 to 2. However, in the present study, the harvesting date of 'Red Delicious' apple was suitable on 2nd September since the starch index reading was 4.00 on that date which was attained after few days of maturity.

4 Conclusion

Jumla is the most important apple producing district of Karnali province of Nepal. Early harvesting of apple fruit is common in Jumla which results the shriveling and higher weight loss of fruit. 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 'Red Delicious' apple from 2nd September and onwards.

Authors' contributions

BC carried out trial designing, data recording, data analysis, literature review and manuscript preparation. RK carried out trial designing, conducted laboratory analysis of fruit sample and manuscript preparation. SK reviewed literatures and prepared manuscript. LB conducted laboratory analysis of fruit sample. All authors read and approved the final manuscript.

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