



ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2026): 4.97
IJAFA 2026; 8(3): 12-18
www.agriculturaljournals.com
Received: 06-12-2025
Accepted: 20-01-2026

Mohammad Amaan Seh
Division of Food Science and
Technology, Sher-e-Kashmir
University of Agricultural Sciences
and Technology of Kashmir, Srinagar,
Jammu and Kashmir, India

Imtiyaz A Zargar
Division of Food Science and
Technology, Sher-e-Kashmir
University of Agricultural Sciences
and Technology of Kashmir, Srinagar,
Jammu and Kashmir, India

Syed Zameer Hussain
Division of Food Science and
Technology, Sher-e-Kashmir
University of Agricultural Sciences
and Technology of Kashmir, Srinagar,
Jammu and Kashmir, India

Sajad Mohd. Wani
Division of Food Science and
Technology, Sher-e-Kashmir
University of Agricultural Sciences
and Technology of Kashmir, Srinagar,
Jammu and Kashmir, India

Mushtaq Ah Beigh
Division of Food Science and
Technology, Sher-e-Kashmir
University of Agricultural Sciences
and Technology of Kashmir, Srinagar,
Jammu and Kashmir, India

Nageena Nazir
Division of Agricultural Statistics,
Sher-e-Kashmir University of
Agricultural Sciences and Technology
of Kashmir, Srinagar, Jammu and
Kashmir, India

Rizwan Rashid
Division of Vegetable Science, Sher-e-
Kashmir University of Agricultural
Sciences and Technology of Kashmir,
Srinagar, Jammu and Kashmir, India

Alamgir A Dar
RCRQA, Sher-e-Kashmir University
of Agricultural Sciences and
Technology of Kashmir, Srinagar,
Jammu and Kashmir, India

Riddheshwar Subhash Shinde
Division of Food Science and
Technology, Sher-e-Kashmir
University of Agricultural Sciences
and Technology of Kashmir, Srinagar,
Jammu and Kashmir, India

Corresponding Author:
Mohammad Amaan Seh
Division of Food Science and
Technology, Sher-e-Kashmir
University of Agricultural Sciences
and Technology of Kashmir, Srinagar,
Jammu and Kashmir, India

Effect of harvesting dates on physical characteristics of apple (Red delicious) across various locations of the Kashmir Valley

Mohammad Amaan Seh, Imtiyaz A Zargar, Syed Zameer Hussain, Sajad Mohd. Wani, Mushtaq Ah Beigh, Nageena Nazir, Rizwan Rashid, Alamgir A Dar and Riddheshwar Subhash Shinde

DOI: <https://www.doi.org/10.33545/2664844X.2026.v8.i3a.1227>

Abstract

The present research investigation, titled "Effect of harvesting dates on physical characteristics of Apple (Red Delicious) across various locations of Kashmir valley," was conducted in the Division of Food Science and Technology, SKUAST-Kashmir during the years 2023-2024. Apple fruits were gathered (Based on Days from Full Bloom) at three distinct dates separated by 10 days (H1, H2, and H3). Following harvest, the fruits were separated into three lots: one for fresh analysis, a second for ambient storage, and a third for refrigerated storage to monitor quality changes over time. Among physical parameters, average fruit weight, fruit length, fruit diameter, fruit thickness, arithmetic mean diameter, equivalent mean diameter, geometric mean diameter, fruit surface area, and volume increased while specific gravity, solid density, and bulk density decreased with each harvest. The sphericity and aspect ratio did not alter much between harvests. The fruit hardness decreased with each consecutive harvest. Optimal harvest date for apple CV. Red Delicious was discovered to be 161 for Srinagar, 163 for Budgam, 162 for Pattan, 152 for Kupwara, 162 for Anantnag, and Shopian 162 DFFB.

Keywords: Apple CV red delicious, harvesting, altitude, Kashmir Valley, physical parameters

Introduction

Apple (*Malus domestica* Borkh.) is a member of the *Rosaceae* family and subfamily *Pomoideae*, is one of the world's foremost tree fruits, valued both nutritionally and economically. The primary origin of cultivated apples traces to the Tian Shan mountains of Central Asia, where wild ancestors such as *Malus sieversii* continue to flourish. Genetic and archaeological findings pinpoint Kazakhstan, west of the Tian Shan, as the cradle of apple domestication, with the fruit's cultivation spreading westward along the Silk Road and reaching the Mediterranean and Europe by the Greek and Roman eras (Cornille *et al.* 2012) [9].

The apple is a pome, with the principal edible portion derived from the fleshy thalamus, and is renowned for its nutritional richness and health-promoting qualities. Apples are abundant in beneficial phytochemicals, including phenolic acids, flavonoids, and carotenoids, along with essential vitamins such as vitamin C and E. Comprehensive reviews highlight apples' antibacterial, anti-inflammatory, anti-diabetic, and anti-aging properties, and their consumption is associated with reduced risks of chronic ailments like cardiovascular disease, diabetes, and some cancers (Spengler, 2019; Cornille *et al.* 2012) [30, 9].

Nutritionally, apples comprise about 84-85% water, with carbohydrates, fibre, vitamins, and minerals making up the remaining components. They provide approximately 13.8 g of carbohydrates, 2.4 g of dietary fibre, and 4.6 mg of vitamin C per 100 g, making them a valuable addition to the human diet. The adage "an apple a day keeps the doctor away" is strongly supported by modern biomedical science for its preventive role against chronic diseases (Khan *et al.* 2020) [13].

China is the world's biggest apple producer, with an annual output of over 47 million tonnes, accounting for more than half of the worldwide supply. The United States follows with about 4.4 million tons, Turkey produces around 4.8 million tons, and India ranks fifth globally with approximately 2.6 million tons each year (Anonymous, 2024) [3].

Jammu and Kashmir, Himachal Pradesh, Uttarakhand, and Arunachal Pradesh are the top producers in India, with Jammu and Kashmir accounting for around 67-70% of total production. Productivity in Jammu and Kashmir is about 11.4 MT/ha over an area of around 165,000 hectares with annual production close to 1.88 million metric tons in 2020-2021. (Angamuthu, 2024; Shah, 2019) [2, 25].

Choosing the best harvesting date is critical for maintaining post-harvest quality and extending the storage life of apple fruits. Fruit quality cannot be enhanced after harvest because it is determined on the tree at the time of harvest. Harvesting time impacts crucial fruit features, including size and peel colour, which determine their commercial worth. Apples should be selected when mature but not completely ripe. Fruits harvested too early tend to be smaller, with less flavour and colour, and are more prone to disorders such as scald, bitter rot, and internal breakdown. Early harvested apples also experience greater mass loss due to water loss, as the cuticle is not yet fully developed at this stage. Proper timing helps maximise firmness, sugar content, and overall sensory acceptability, thereby ensuring quality and storability (Kus *et al.* 2023; Chalise and Giri, 2019) [17, 7].

In India, postharvest losses for apples range from 15% to 50%, depending on area, infrastructure, and season. According to the Food and Agriculture Organisation (2023), more than one-third of all apples are thrown after harvest each year. Global average apple losses range from 5% to 35% in most regions, but can reach 20%-50% in certain developing nations before reaching consumers (Li *et al.* 2025; Sweta *et al.* 2022) [18, 27]. Postharvest losses in apples are primarily attributed to mechanical damage, diseases and pathogens, physiological disorders, and water loss. Mechanical damage, including compression and bruising, is a significant issue due to the apple's thin peel and brittle texture, occurring during activities such as picking, handling, and transport (Yang *et al.* 2023; Amanullah *et al.* 2020) [32, 1]. Diseases and pathogens, notably over 90 fungal species like *Botrytis cinerea*, *Penicillium expansum* and *Mucor piriformis* cause storage rots and can proliferate even at reduced temperatures (Sweta *et al.* 2022) [27]. Physiological disorders, such as bitter pit, water core, and internal browning, stem from nutrient imbalances, particularly calcium deficiency, and inappropriate storage conditions, leading to considerable reductions in quality and yield. Furthermore, water loss results in undesirable outcomes like skin shrivelling, fruit softening, and diminished market acceptability (Hasan *et al.* 2024; Argenta *et al.* 2021) [11, 4].

The harvest date is a critical factor in determining apple fruit quality, shelf life, and postharvest losses. Early harvesting yields firmer fruit with greater storage potential but less developed flavour and colour. Conversely, late harvesting results in higher sugar content and better colour but diminished texture and an increased likelihood of physiological issues like water core and storage rots. Optimal harvest timing involves balancing biochemical characteristics such as sugar, acidity, and firmness to enhance consumer acceptance and reduce senescence and disease susceptibility. Therefore, meticulous evaluation of maturity indicators, including starch conversion, colour progression, and firmness, is crucial for synchronizing harvest timing with specific market or storage outcomes and ensuring minimal quality loss (Li *et al.* 2024; Atucha and

van Zoeren, 2018; Watkins *et al.* 2003; Skrzynski, 1993) [19, 6, 31, 29].

Studies show that harvesting Red Delicious apples at the commercial maturity stage, typically when internal ethylene concentration reaches about 1 $\mu\text{L L}^{-1}$, optimizes fruit quality traits such as firmness, sugar content, and peel colour. Properly timed harvesting reduces susceptibility to physiological disorders, enhances postharvest quality, and maximizes the market value of Red Delicious apples (Chalise *et al.* 2023) [8]. Most studies on apples compare their physical traits in only one location. No detailed research has been done on the main qualities of Red Delicious apples grown in different areas and orchard conditions in Kashmir, located in the north-western Himalayas. Because of this, there is little information on the physical features of Red Delicious apples in Kashmir. This study aims to provide detailed data on fruit quality, which is important for both market demand and orchard management in the region.

Materials and Methods

At the Division of Food Science and Technology, Sher-e-Kashmir University of Agriculture Sciences and Technology of Kashmir, Shalimar, a research was conducted with the goal of "Standardization of Harvesting dates of Apple (Red Delicious) from various locations across the valley of Kashmir". The methodologies adopted and the materials used throughout the investigation are detailed below: 3.1 Material Apple cv "Red Delicious" with uniform shape, size and firm texture was obtained from several locations of Kashmir. Apple fruits were harvested at three different dates with an interval of ten days.

After harvest, the fruits were separated into three lots: one for fresh analysis, a second lot held under ambient conditions ($21 \pm 2^\circ\text{C}$, RH 68%), and a third lot stored under refrigerated conditions (2°C , RH 95%) to monitor quality changes over storage periods. Samples from all three harvests were collected over a 60-day period with a 15-day storage interval (0, 15, 30, 45 and 60 days), and from refrigerated storage over a 180-day period with a 30-day storage interval (0, 30, 60, 90, 120, 150 and 180 days). Post cold storage studies for 25 days ($10 \pm 2^\circ\text{C}$, RH 67%) were also done for apples stored under refrigerated conditions with a storage interval of 05 days (0, 5, 10, 15, 20, and 25). The fruits were evaluated for the following parameters:

Physical parameters

1. Average fruit weight (g)

Ten randomly selected fruits were weighed on a digital electronic balance, and the average weight was calculated.

2. Fruit length (mm)

The length of ten randomly selected fruits from each treatment in each replication was measured using a digital vernier calliper. The fruit length was measured between the calyx and the style ends, and the average was expressed in millimetres (mm)

3. Fruit Width (mm)

The width of ten randomly selected fruits from each treatment in each replication was measured using a digital vernier calliper. The width was measured from side to side with the suture halfway between, and the average was expressed in millimetres (mm).

4. Fruit thickness (mm)

The thickness of ten randomly selected fruits from each treatment in each replication was measured using a digital vernier calliper. The thickness was measured diagonally from calyx to style end and the average was expressed in millimetres (mm).

5. Arithmetic mean diameter (mm): It is calculated by the following formula (Mohsenin, 1986) ^[20]

$$Da = \frac{L+W+T}{3}$$

Where, L= length (mm) was measured as a distance between calyx and style ends, W=width (mm) was measured from side to side with the suture halfway between and T=thickness (mm) was measured diagonally from calyx to style end.

6. Equivalent mean diameter (mm)

$$De = \sqrt[3]{L(W + T)^2}/4$$

Where, L=length (mm) was measured as a distance between calyx and style ends, W=width (mm) was measured from side to side with the suture halfway between and T=thickness (mm) was measured diagonally from calyx to style end.

7. Geometrical mean diameter (mm)

It is calculated by following formula (Arshad *et al.*, 2014) ^[5].

$$Dg = (L \times W \times T)^{1/3}$$

Where, L=length (mm) was measured as a distance between calyx and style ends, W=width (mm) was measured from side to side with the suture halfway between and T=thickness (mm) was measured diagonally from calyx to style end.

8. Sphericity

The sphericity, Sp (%), is determined by dividing the fruit's surface area by the surface area of sphere with the same volume. (Mohsenin, 1986) ^[20]

$$Sp = Dg/L$$

Where, Sp = Sphericity, Dg=geometric mean diameter (mm) and L = length (mm) was measured as a distance between calyx and style ends.

9. Fruit surface area

It is calculated by the following formula (Arshad *et al.* 2014) ^[5].

$$S = \Pi (Dg)^2$$

Where, S = Fruit surface area (mm²), Π = 3.14 and Dg = geometric mean diameter (mm)

10. Aspect ratio

It is calculated by the following formula (Arshad *et al.* 2014) ^[5].

$$Ra = \frac{L}{W}$$

Where, Ra=Aspect ratio, L=length (mm) was measured as a distance between calyx and style ends, W=width (mm) was measured from side to side with the suture halfway between.

11. Volume (cm³)

To determine the fruit volume, a container filled with water was put on the balance, one needle was inserted into the fruit, and one lever moved the needle, causing the fruit to float in water and calculating the mass of displaced water.

$$\text{Volume (cm}^3\text{)} = \frac{\text{Displaced water (g)}}{\text{Water specific mass (g/cm}^3\text{)}}$$

12. Bulk density (g/cm³)

Bulk density (BD) was measured by filling the apples in a glass flask of 1000 cm³ upto the brim, and the weight of the fruits was measured and calculated by using the following equation

$$BD = \frac{\text{Weight of fruits (g)}}{\text{Bulk volume (cm}^3\text{)}}$$

Where, Bulk volume=volume of glass flask

13. Solid density (g/cm³)

Solid density (SD) was measured by filling the apples in a glass flask of 1000 cm³ (V1) upto the brim, and the weight of fruits were measured (M). Toluene was used for the filling up the spaces in the glass flask (filled with apples) upto the brim (V2) and were calculated by following equation.

$$SD = \frac{M}{V1 - V2}$$

Where, SD is solid density (g/cm), M is fruit mass (g), and V1 (cm) is bulk volume, and V2 is the volume of toluene used for filling of glass flask

14. Specific gravity (g/cm³)

After recording the weight and volume of fruit samples, specific gravity was determined using the formula:

$$\text{Specific gravity} = \frac{\text{Mass (g)}}{\text{Volume cm}^3}$$

15. Fruit firmness (lbs/inch²)

Fruit flesh firmness was estimated by using a penetrometer (Effigi 327 using 11 mm probe) for ten fruits per treatment (Plochanski *et al.* 2000) ^[23].

Result and discussion

1. Average fruit weight (g), Fruit length (mm), Fruit width (mm) and fruit thickness (mm)

A significant variation was observed in average fruit weight, fruit length, fruit width, fruit thickness and arithmetic mean diameter (mm). The maximum average fruit weight (167.34 mm) was observed in late-harvested H3 (L6-SPN) fruits, while early harvested H1 (L1-SGR) fruits showed the minimum average fruit weight (142.10 mm). The increase in

average fruit weight may be due to the growth of the fruit during successive harvests. These results are in accordance with Papamihal (2013) [22], Ornelas-Paz *et al.* (2018) [21], Sarma *et al.* (2020) [24] and Kucuker and Aglar (2021) [15]. The maximum fruit length (70.82 mm), fruit width (71.84 mm) and fruit thickness (72.31 mm) were observed in late harvested H3 (L6-SPN) fruits, while early harvested H1 (L1-SGR) fruits showed minimum fruit length (63.72 mm), fruit width (65.42 mm) and fruit thickness (67.34 mm). The increase in fruit length, fruit width and fruit thickness in late harvests may be due to cell expansion during the development of the fruit. These results are in accordance with Ornelas-Paz *et al.* (2018) [21] and Sarma *et al.* (2020) [24].

2. Arithmetic mean diameter (mm), Equivalent mean diameter (mm) and Geometric mean diameter (mm)

Among different harvests studied, late harvested apples H3 (L6-SPN) showed maximum arithmetic mean diameter (71.83 mm), equivalent mean diameter (71.82 mm) and geometric mean diameter (71.84 mm) while as early harvested H1 (L1-SGR) fruits showed minimum arithmetic mean diameter (65.34 mm), equivalent mean diameter (65.34 mm) and geometric mean diameter (65.32 mm). Since the arithmetic mean diameter, equivalent mean diameter and geometric mean diameter are directly proportional to length, width and thickness. During the development of fruit, length, width and thickness increase and in turn would lead to an increase in the arithmetic mean diameter, equivalent mean diameter and geometric mean diameter. These results are in accordance with Ornelas-Paz *et al.* (2018) [21] and Kumar *et al.* (2018) [16].

3. Sphericity, Fruit surface Area (mm²×10³) and Aspect Ratio

The sphericity of 1.02 was recorded in all three harvests. The value of sphericity was greater than one, depicting an oblate fruit shape in all four harvests. These results are in line with Sharma *et al.* (2017) [26].

Among different harvests studied, late harvested apples H3 (L6-SPN) showed maximum fruit surface area (15.96×10³ mm²), while early harvested H3 (L1-SGR) showed minimum fruit surface area (12.00 ×10³ mm²). It may be due to cell expansion during development. The results are in

agreement with Sarma *et al.* (2020) [24]. The aspect ratio was recorded as the same (0.97) in all four harvests, which depicts that there was proportionate growth in length and breadth during the fruit development stage.

4. Volume (cm³), Bulk Density (g/cm³), Solid Density (g/cm³), Specific gravity (g/cm³) and Fruit Firmness (lbs/inch²)

The maximum volume (167.21 cm³) was recorded in late-harvested fruits, H3 (L6-SPN), while early harvested fruits, H1 (L1-SGR), showed the minimum volume (140.00 cm³). This may be due to cell expansion and shifts in airspace percentage during the development of the fruit. These results are in line with Sarma *et al.* (2020) [24].

The maximum bulk density (0.50 g/cm³), solid density (1.38 g/cm³) and specific gravity (1.03 g/cm³) were recorded in early harvested apples H1 (L6-SPN), while as late harvested H3 (L6-SPN) showed minimum bulk density (0.28 g/cm³), solid density (1.00 g/cm³) and specific gravity (0.90 g/cm³). The decrease in solid density, bulk density and specific gravity during the successive harvests may be due to an increase in intercellular air spaces during the growth of fruits. These results are in agreement with Dubey *et al.* (2003) [10], Singh *et al.* (2006) [28], Khoshnam *et al.* (2015) [14] and Sharma *et al.* (2017) [27].

The fruit firmness depends on the texture of the flesh and changes in the primary cell wall during ripening (Jan *et al.* 2012) [12]. Late-harvested H3 (L1-SGR) fruits showed lower firmness (16.60 lbs/inch²), and early harvested H1 (L6-SPN) fruits showed higher fruit firmness (19.03 lbs/inch²). This may be due to primary cell wall changes during the ripening of the fruit. The primary cell wall and middle lamella structures may be disassembled as a result of enzyme activity. These results are in line with Jan *et al.* (2012) [12]. Ornelas-Paz *et al.* (2018) [21] also reported that the softening of apples is associated with the modification of cell wall materials during ripening. The pectate. Moreover, the early-harvested fruits have low enzyme activity, due to which there is less degradation in the cell wall and hence more firmness.

Conflict of interest

The authors declared no conflicts of interest with respect to the research, authorship, and/or publication of this article.

Table 1: Effect of harvest dates on physical characteristics in apple cv. Red Delicious

Harvest Date	Locations	Parameters				
		Average Fruit weight (g)	Length (mm)	Width (mm)	Thickness (mm)	Arithmetic mean diameter (mm)
H1	L1-SGR	142.10	63.72	65.42	67.34	65.34
	L2-BDG	144.68	65.82	66.11	68.66	66.76
	L3-PTN	144.71	65.84	66.13	68.69	66.78
	L4-KUP	146.82	66.11	66.18	68.74	66.83
	L5-ANG	144.75	65.86	66.14	68.71	66.80
	L6-SPN	147.60	66.24	66.37	68.86	66.91
H2	L1-SGR	150.28	66.88	67.45	69.00	67.54
	L2-BDG	151.67	67.69	68.82	69.87	68.76
	L3-PTN	151.69	67.71	68.84	69.89	68.78
	L4-KUP	152.40	67.78	68.88	69.90	68.81
	L5-ANG	151.71	67.72	68.85	69.89	68.78
	L6-SPN	152.98	67.89	68.91	69.94	68.89
H3	L1-SGR	166.43	69.32	70.28	71.54	70.44
	L2-BDG	167.18	70.68	71.72	72.20	71.71
	L3-PTN	167.20	70.70	71.74	72.22	71.74
	L4-KUP	167.26	70.75	71.78	72.26	71.78
	L5-ANG	167.21	70.71	71.75	72.23	71.75
	L6-SPN	167.34	70.82	71.84	72.31	71.83
		0.615	0.298	0.406	0.284	0.051

H1=First harvest, H2=Second harvest, H3=Third harvest

Location	Full Bloom Date	1 st Harvest	2 nd Harvest	3 rd Harvest	DFFB
L1-SGR	07-April-2023	25 August 2023	04 September 2023	15 September 2023	161Days
L2-BDG	06-April-2023	26 August 2023	05 September 2023	16 September 2023	163 Days
L3-PTN	08-April-2023	27 August 2023	06 September 2023	17 September 2023	162 Days
L4-KUP	09-April-2023	28 August 2023	07 September 2023	18 September 2023	162 Days
L5-ANG	08-April-2023	27 August 2023	06 September 2023	17 September 2023	162 Days
L6-SPN	13-April-2023	01 September 2023	11 September 2023	22 September 2023	162 Days

Harvest Date	Locations	Parameters				
		Equivalent Mean Diameter (mm)	Geometric Mean Diameter (mm)	Specific gravity (g/cm ³)	Fruit surface Area (mm ² ×10 ³)	Aspect Ratio
H1	L1-SGR	65.34	65.32	1.00	12.00	0.97
	L2-BDG	66.76	66.76	1.00	13.33	0.97
	L3-PTN	66.78	66.78	1.00	13.36	0.97
	L4-KUP	66.83	66.81	1.00	13.39	0.97
	L5-ANG	66.80	66.79	1.00	13.37	0.97
	L6-SPN	66.91	66.89	1.00	13.45	0.97
H2	L1-SGR	68.43	68.38	1.00	14.00	0.97
	L2-BDG	69.16	69.18	1.00	14.86	0.97
	L3-PTN	69.19	69.20	1.00	14.87	0.97
	L4-KUP	69.23	69.24	1.00	14.89	0.97
	L5-ANG	69.20	69.20	1.00	14.87	0.97
	L6-SPN	69.34	69.35	1.00	14.94	0.97
H3	L1-SGR	70.41	70.65	1.00	15.80	0.97
	L2-BDG	71.70	71.72	1.00	15.84	0.97
	L3-PTN	71.73	71.74	1.00	15.86	0.97
	L4-KUP	71.76	71.78	1.00	15.90	0.97
	L5-ANG	71.73	71.75	1.00	15.87	0.97
	L6-SPN	71.82	71.84	1.00	15.96	0.97
	(CD<0.05)	0.039	0.069	N/S	0.05	N/S

H1=First harvest, H2=Second harvest, H3=Third harvest

Location	Full Bloom Date	1 st Harvest	2 nd Harvest	3 rd Harvest	DFFB
L1-SGR	07-April-2023	25 August 2023	04 September 2023	15 September 2023	161Days
L2-BDG	06-April-2023	26 August 2023	05 September 2023	16 September 2023	163 Days
L3-PTN	08-April-2023	17 August 2023	27 August 2023	07 September 2023	152 Days
L4-KUP	09-April-2023	28 August 2023	07 September 2023	18 September 2023	162 Days
L5-ANG	08-April-2023	27 August 2023	06 September 2023	17 September 2023	162 Days
L6-SPN	13-April-2023	01 September 2023	11 September 2023	22 September 2023	162 Days

Harvest Date	Locations	Parameters				
	-	Volume (cm ³)	Bulk Density (g/cm ³)	Solid Density (g/cm ³)	Specific gravity (g/cm ³)	Fruit Firmness (lbs/inch ²)
H1	L1-SGR	140.00	0.38	1.02	0.91	18.00
	L2-BDG	140.53	0.43	1.24	0.98	18.00
	L3-PTN	140.55	0.45	1.27	1.00	18.02
	L4-KUP	140.58	0.46	1.32	1.01	18.06
	L5-ANG	140.56	0.45	1.28	1.01	18.04
	L6-SPN	140.67	0.50	1.38	1.03	19.03
H2	L1-SGR	143.34	0.37	1.11	0.90	17.86
	L2-BDG	143.91	0.40	1.20	0.96	17.87
	L3-PTN	143.94	0.41	1.21	0.98	17.87
	L4-KUP	144.00	0.43	1.25	0.99	17.91
	L5-ANG	143.95	0.42	1.21	0.98	17.88
	L6-SPN	144.12	0.48	1.29	1.02	18.00
H3	L1-SGR	166.89	0.28	1.00	0.90	16.60
	L2-BDG	167.01	0.34	1.13	0.94	16.62
	L3-PTN	167.04	0.35	1.15	0.95	16.62
	L4-KUP	167.10	0.38	1.16	0.97	16.70
	L5-ANG	167.05	0.36	1.15	0.95	16.65
	L6-SPN	167.21	0.42	1.20	1.00	17.00
	(CD<0.05)	0.0016	0.0003	0.05	0.0003	0.0016

H1=First harvest, H2=Second harvest, H3=Third harvest

Location	Full Bloom Date	Ist Harvest	2 nd Harvest	3 rd Harvest	DFFB
L1-SGR	07-April-2023	25 August 2023	04 September 2023	15 September 2023	161Days
L2-BDG	06-April-2023	26 August 2023	05 September 2023	16 September 2023	163 Days
L3-PTN	08-April-2023	17 August 2023	27 August 2023	07 September 2023	152 Days
L4-KUP	09-April-2023	28 August 2023	07 September 2023	18 September 2023	162 Days
L5-ANG	08-April-2023	27 August 2023	06 September 2023	17 September 2023	162 Days
L6-SPN	13-April-2023	01 September 2023	11 September 2023	22 September 2023	162 Days

Conclusion

The study concludes that harvesting date significantly influences the physical characteristics of Red Delicious apples in Kashmir. Successive harvests improved fruit size, weight, and volume, while firmness, bulk density, solid density, and specific gravity decreased due to ripening and tissue softening. The optimum harvest dates were standardized as 161 DFFB for Srinagar, 163 DFFB for Budgam, 162 DFFB for Shopian, 152 DFFB for Pattan, and 162 DFFB for Kupwara, and Anantnag. These findings emphasize the importance of location-specific harvest timing to achieve maximum fruit quality, market acceptance, and better postharvest management of Red Delicious apples in the Kashmir valley.

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